A CASE STUDY ON SOLID WASTE MANAGEMENT IN DHAKA CITY

MOHAMMAD WASIUZZAMAN SHOHAN

DEPARTMENT OF INDUSTRIAL & PRODUCTION ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
BUET
DHAKA-1000, BANGLADESH

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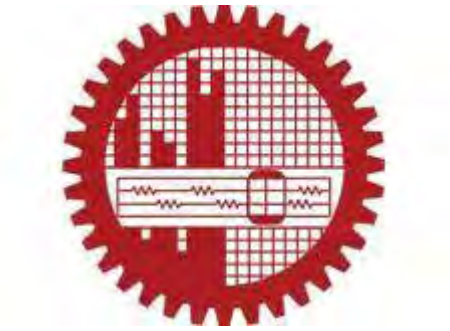
BY

MOHAMMAD WASIUZZAMAN SHOHAN

The thesis submitted to Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, in partial fulfillment of the requirements for the degree of Master of Advanced Engineering Management.



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CERTIFICATE OF APPROVAL

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Mohammad Wasiuzzaman Shohan

Dedicated to:

My Parents

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

DCC	Dhaka City Corporation
SWM	Solid Waste Management
MSW	Municipal Solid Waste
NGO	Non Government Organizations
MSWM	Municipal Solid Waste Management
WHO	World Health Organization
SW	Solid Waste
UNEP	United Nations Environmental Program
GHG	Green House Gas
JICA	Japan International Cooperation Agency
CBO	Congressional Budget Office
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Center for Advanced Studies

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ABSTRACT

Solid waste management is considered as one of the most immediate and serious environmental problems confronting municipal authorities in developing Asian Countries. Rapid growth of population and industrialization degrades the urban environment and places serious stress on natural resources, which undermines equitable and sustainable development. Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most cities like Dhaka. Although Dhaka City Corporation (DCC) acknowledges the importance of adequate solid waste collection and disposal as well as resource recovery and recycling, it is mostly beyond their resource to deal effectively with the growing amount of solid waste generated by the expanding cities. Consequently solid waste is indiscriminate by dumped on roads and into open drains thus leading to serious health risk and degradation of living environment for millions of urban people. In the last decade, however, importance of community involvement in solid waste management and use of adapted technologies were recognized for improving the solid waste management system.

There exist a few studies that deal with the estimation of solid waste generation in Dhaka city. However, these studies, which are mostly based on the naive forecasting approaches, cannot predict the amount of waste correctly as evident from a considerable mismatch between predicted and actual waste generation reported by DCC. In the present study, regression analysis is employed to estimate the generation of waste in Dhaka city that shows considerable agreement between the predicted and actual amounts of waste generation. In this study primary data was obtained from interviews with 100 families in Dhaka City and secondary data were collected from various sources (internet, publications, etc.) to estimate total quantity of household waste generated in Dhaka. Waste generation with respect to various factors (such as population growth, new consumer product in market, income level, and education) is also analyzed.

The present study develops a forecast for future waste generation that can assist in managing the waste in an effective way so that the adverse effect of generated waste on environment can be minimized.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Waste is an unavoidable byproduct of human activities Economic development, urbanization and improving living standards in cities, have led to an increase in the quantity and complexity of generated waste. Rapid growth of population and industrialization degrades the urban environment and places serious stress on natural resources, which undermines equitable and sustainable development [1]. Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most cities of the world.

Dhaka, the Capital City of Bangladesh, is expanding rapidly turning it into a mega city with an enormous growth of population at a rate of around 6 percent a year [1]. Dhaka City Corporation (DCC) has an area of 131 km^2 and population of 120 million and population density exceeds 92,000 per km^2 [2]. Rapid growth of industries, lack of financial resources, inadequate trained manpower, inappropriate technology and lack of awareness of the community are the major constraints of solid waste management for the fast growing metropolis of Dhaka [1].

Solid waste disposal poses a greater problem because it leads to land pollution if openly dumped, water pollution if dumped in low lands and air pollution if burnt. Dhaka city is facing serious environmental degradation and public-health risk due to uncollected disposal of waste on streets and other public areas, clogged drainage system by indiscriminately dumped wastes and by contamination of water resources near uncontrolled dumping sites [3].

The Dhaka City Corporation (DCC) is responsible for solid waste management. DCC is facing serious problems in providing a satisfactory service to the city dwellers with its limited resources and a poor management plan. An inadequate information base (regarding quantity, type and characteristics of wastes), poor operation and maintenance of service facilities and above all lack of civic awareness on the part of a section of the population are adding up to the deteriorating environmental situation [3].

Municipal corporations of the developing countries are not able to handle increasing quantities of waste and a significant portion of wastes are not properly stored, collected or disposed in the proper places for ultimate disposal due to lack of enthusiasm, consciousness, loyalty, as well as money. There is a need to work towards a sustainable waste management system, which requires environmental, institutional, financial, economic and social sustainability.

In less developed Asian countries integrated management and safe disposal of solid waste can be found in reference. Most appropriate systems for collection, storage and transportation and choice of a suitable method for disposal, sustainable management programs and proper planning is entirely depends on the characteristics of municipal solid waste .

The approach for SWM varies and should be compatible with the nature of a given society. Many studies on SWM management in developing countries have revealed that waste quantities and composition vary according to the characteristics of a place, and the management must be adapted to certain limitations common to these settings. Some of these limitations are attributed to the immaturity of SWM management discipline in developing countries on the one hand and new laws to regulate solid waste not systematically enforced because of a lack of clarity in the duties and liabilities of the parties involved. On the other hand, indigenes depend on the capability of municipal authorities for municipal solid waste collection and disposal [4]

The fundamental environmental issue in industrial and developing countries throughout the world is how to best identify and manage waste streams [5]. As urbanization continues to take place, the management of solid waste poses major public health and environmental problems in urban areas of many developing countries. Thus development must be sustainable such that it is based on an integrated approach and interaction between social, cultural, economic and ecological. Sustainability therefore means reducing the ecological footprint while simultaneously improving the quality of life – for ours and future generations – within the capacity limits of the globe [6]. SWM has been an integral part of every human society and policies vary both within and between developing countries. The characteristics and

quantity of SWM arising from domestic, commercial, and industrial activities in a region is not only the result of growing population, rising standards of living and technology development, but also due to the abundance and type of the region‟s natural resources [7].

Waste generation dates back as far as man started roaming the earth. The abandonment of the nomadic life in later years led to the creation of permanent communities. Until recently, waste was given a low priority in most municipalities, conference rooms and government offices responsible for public health and safety. [8]. It was only way into the 19th century that the idea of collecting and disposing of garbage in a systematic fashion became part of the general drive to improve public health [9]. In today‟s cities solid waste is removed and is either sent to disposal or is reprocessed for subsequent use.

1.2 PROBLEMS RELATED TO INEFFICIET WASTE MANAGEMENT

Many developing urban areas are characterized by piles of rubbish in every open space. The cause of the large scale litter problem is that there is no effective and appropriate way for residents to dispose of their solid waste. The dense population of these areas makes it impossible for people to bury wastes on their own land and many communities have no collection system to remove wastes, either from individual households or from convenient collection point. When there is a collection system, it is often insufficient. Some common problems are [10]:

- Too few collections per week,
- Inadequate on-site storage
- Irregular services.

Garbage becomes a breeding ground for mosquitoes and other flies when left uncovered. It serves as a harbor for disease victors. Typhoid Fever in many places was likely caused by flies that bred in the local dump [10]. Open dump disposal also threatens surface and groundwater resources.

According to [11] report**,** developing countries face several major problems as a result

of solid waste such as;

- Health hazards from uncollected waste
- Health hazards from collected but poorly disposed of waste
- Economic burden of waste disposal on towns and cities.

The limitation of data on the composition of MSW in developing countries and wide variability of available figures from country to country is a setback to waste management. Thus towns find it difficult in providing infrastructure and service that can keep pace with the fast growing urban population which poses serious challenges to policy makers in the local government to make necessary adjustments in their service programmers. One of the most pressing problems facing municipalities is the inefficient and long-term disposal of solid waste. The degree of human risk associated with solid waste handling and disposal varies in all countries although some problems are more severe and widespread in developing countries. Based on Cointreau (1996) [12], these problems are classified into four main categories:

1) The presence of human fecal matter,
2) The presence of potential hazardous industrial waste,
3) The decomposition of solids into constituent chemical which contaminate air and water systems and
4) The air pollution caused by consistently burning dumps and methane release.

This study is intended to determine solid waste generation by considering population data as well as other influential factors (such as: population growth, new consumer product in market, income level, education) that can affect waste generation. And prepare solid waste management program across the whole country depending on waste generation amount and population on different area.

1.3 OBJECTIVES OF THE PRESENT STUDY

Objective is to increase efficiency and effectiveness of waste collection and management system with the developed study which will help in decision making regarding country wise waste collection and management.

This study looks in brief at the current waste- generation, characteristics and

management scenario in Dhaka City, along with the associated environmental impacts. The main objectives of this study are:

- Estimation of the total quantity of household waste generated in Dhaka
- Estimation of density of the waste generated in different areas;
- Develop method to reduce the adverse effect of wastes on environment

1.4 RESEARCH QUESTIONS & METHODOLOGY

1.4.1 Research Questions

- ✓ What is the present waste generation amount per family?
- ✓ How much do the family pay and are the satisfied?
- ✓ What is the cost of collection and dumping of solid waste generated?

The research goal and objectives have been achieved through:

- Review of available literature, data and relevant information on waste management projects and policies both national and international.
- Formal and informal interviews with community leaders, family members.
- Formal and informal interviews with solid waste management officials and discussion with local NGOs
- Administration of questionnaires to households and institutions to assess public participation in programmes, policies and various waste management practices.

1.5 JUSTIFICATION OF THE STUDY AND LIMITATION

1.5.1 Justification

It is expected that the findings of this study will enable policy makers make wise decisions regarding waste management that will benefit local communities. The study will raise an awareness that will enhance initiatives to reduce the problem, highlighting the role of different stakeholders and extent to which they can be active in addressing it. This dissertation is also relevant to international agencies with strong

financial and technical background, not leaving out national, small and medium enterprises interested in waste management. This information will help locals identify specific income generating activities thus making waste contributes to poverty reduction.

CHAPTER 2: LITERATURE REVIEW AND CASE STUDY

2.1 SOLID WASTE DEFINITIONS

The term solid waste may be used to refer to municipal waste and falls under seven categories: residential (household or domestic waste), commercial, institutional, street sweeping, construction and demolition, sanitation and industrial [13]. Likewise, municipal solid waste refers to solid wastes from houses, streets and public places, shops, offices, and hospitals, which are very often the responsibility of municipal or other governmental authorities. Solid waste from industrial processes is generally not considered as municipal. However, because this waste finally ends up in the municipal waste stream, it should be taken into account when dealing with solid waste. Synonymous to solid waste are terms such as “garbage”, “trash”, “refuse” and “rubbish” [14] especially in some literature in North America.

Table 1: Definition of waste relating to their types [10]

Waste Type	Definition
Construction debris	Detritus minerals from construction and demolition
Organic waste	Biodegradable component of municipal waste (e.g. food and yard waste)
Household	Waste from private households
Household-commercial waste	Waste from commercial establishments, businesses, the service sector, public institutions, and industries that possess similar characteristics than household waste
Commercial Waste	Waste with characteristics similar to household waste.

Municipal solid waste(MSW)	Household, bulky, household-like commercial, yard, open market, and construction and demolition waste; street sweepings; etc.

Types of Solid waste: [10]

Solid wastes are usually one of three types,

- municipal wastes,
- industrial wastes and
- Hazardous wastes.

Municipal waste:

The definitions of terms and the classifications used to describe the components of solid wastes vary greatly in practice as well as in the literature. The definitions presented in (Table: 1) are intended to serve as guide for municipal solid wastes.

Industrial wastes

Industrial wastes are waste arising from industrial activities. They include rubbish (associated with the support personnel), process wastes, ashes, demolition and construction wastes, special wastes and hazardous wastes.

Hazardous wastes

Hazardous waste are classified as wastes that pose a substantial danger, either immediately or over a period of time, to human, plant or animal life. A waste is classified hazardous based on the fact that it exhibits any of the following characteristics: ignitability, corrosively, reactivity or toxicity.

2.2 FUNCTIONAL ELEMENTS OF SWM SYSTEM

The activities associated with management of SWM from the point of generation to final disposal are grouped into the following functional elements [10] :

- waste generation;

- Waste handling and sorting, storage, and processing at the source;
- collection;
- sorting, processing and transformation;
- transfer and transport; and
- Disposal.

Functional elements are closely interconnected but they are not necessarily presented in every municipal solid waste management system.

In most low and middle income countries, the system is limited to

- waste generation,
- handling at the source,
- collection and
- Disposal at landfills.

In most developed countries, every functional element is found within the system.

2.3 GLOBAL SIGNIFICANCE OF WASTE MANAGEMENT

Internationally, the focus on waste management has been on innovative recycling technologies, disposal options such as incineration, and the controversies surrounding disposal site selection (landfills & Incineration) in first world communities. However, cost reduction and environmental products are the primary issues [15].

Increasing population, urbanization, industrialization, faced by developing countries in Africa, Asia, South America, are all pointing out to further increases of refuse. Urbanization induces a consumer based society whereby an increase in concentration of people and industrial/commercial development implies an accumulation of waste which needs to be properly managed and safely disposed of. [10, 16]

The genesis of the problem with the disposal of waste dates back to the time when humans first began to congregate in tribes, villages and communities and the accumulation of waste became a consequence of life. Thus the littering of food and

other solid wastes in medieval towns led to the breeding of rats and the outbreak of the plague epidemic which killed half of the Europeans in the 14th century and caused many subsequent epidemics and high death tolls.

Solid waste management is one of the main responsibilities of both urban and rural communities and the fundamental objective of solid waste management programmes is to minimize the pollution of the environment as well as utilizing the waste as a resource. Even though per capita waste generation rates in developing countries is less than in higher-income countries, the capacity of the responsible local authorities to manage waste from collection, to recycling or reuse and disposal, is limited [17]. Targets can be achieved using methods that can be afforded by the community over the long term and with less risk to the persons involved. An input of universally valid skills or techniques, or a set of similar culture- neutral attitudes defines management itself, while management of waste requires particular kind of intellectual insight, which would be expected to yield value specific solutions to local problems (18).

Table 2: Percentage of worldwide used waste disposal methods [19]

Continent	**Percentage of waste disposed by**					
	Recycling	**Sanitary landfill**	**Open Dum**	**Incineration**	**Open Burning**	Others
Africa	3.9	29.3	47	1.4	9.2	8.4
Asia	8.5	30.9	50.9	4.7	1.7	4.5
Europe	10.7	27.6	33	13.8	11.8	4.4
N. America	8.1	91.1	0	0	0	0
Latin A.	3.2	60.5	34	2	5.5	2

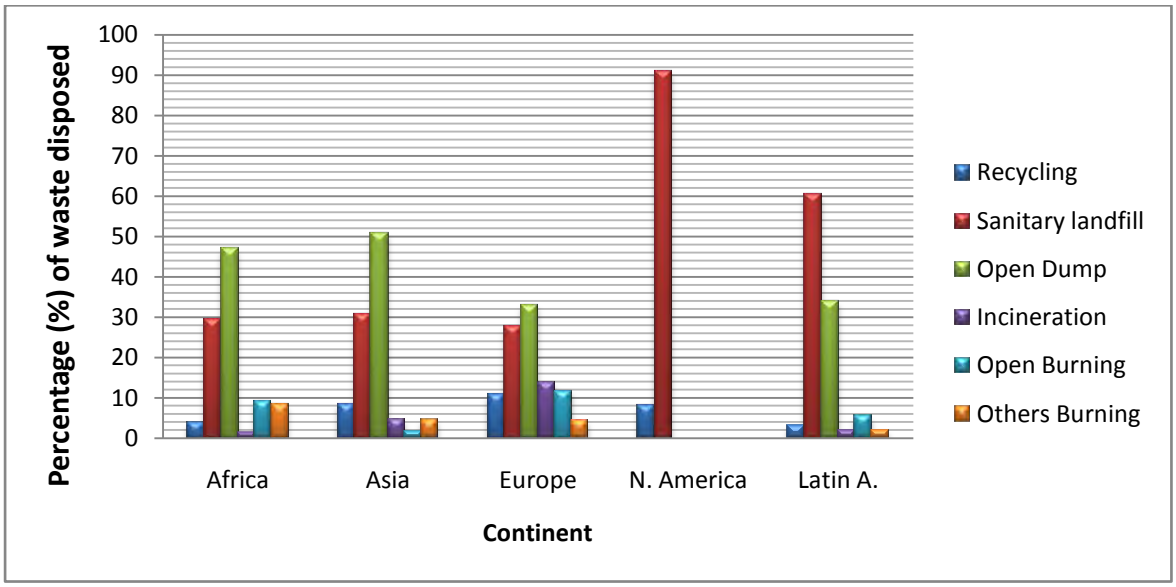

Figure 1: Percentage of worldwide used waste disposal methods [10, 19]

Waste can be classified based on the source or industry that generates the waste stream. Municipal solid waste (MSW) has grown in volume as the world's population has grown and become more urbanized [20]

Table 3: Global perspective on solid waste quantities [21]

	Generation Rates Kg / Capita / Day		
	Low-income Country	**Middle-income country**	**High-income country**
Mixed Urban waste – large city	0.5-0.75	0.55-1.00	0.75-2.2
Mixed Urban waste – small to medium city	0.35-0.65	0.45-0.75	0.65-1.5
Residential waste Only	0.25-0.45	0.35-0.65	0.55-1.0

The composition of MSW depends on a number of factors such as the lifestyles of the population, their relative standards of living, general consumer patterns, and the level

of technological advancement of a particular country [20]. It is a common knowledge that waste is nothing but useful material at wrong place and there is no material in the world which is not useful in one-way or the other.

Waste management has now become a pressing concern for industrial societies because they produce large volumes of waste as a result of economic growth and lifestyle choices. Waste management technologies like land filling and incineration do not offer a complete solution to this problem. The attitude of people towards waste changes as types of wastes are changing [10]. This has brought awareness to people that the solution lies in using waste as a resource rather than to be destroyed. Public awareness and attitudes to waste can affect the population"s willingness to cooperate and participate in proper waste management practices. Information on health risks as a result of deficient solid waste management are important issues which have to be continually communicated to all sectors of the society. Solid waste management is concerned with the generation, on-site storage, collection, transfer, transportation, processing and recovery, and ultimate disposal of solid wastes.

Per capita waste generation for developing countries is lower than average. However, the high rates of urbanization and increasing poverty may have a considerable influence on inter country per capita waste generation. According to report [22], per capita waste generation from urban areas of Egypt is 0.8kg per day while in rural areas it is 0.3 kg per capita per day.

Table 4: SWM in Low and Medium Income Countries [23]

	Low-income Countries	**Middle-income countries**
Waste generation(Kg/person/day)	0.3 to approx. 0.6	0.7 approx.1.1
Collection coverage	Less than 70%	80 to 90%
Disposal costs(US$/person/year)	Less than 1	1-3

SWM expenditure in total municipal budget (%)	15.4 to approx. 38	6 approx. 23,2
Recycling	Informal(metal, glass, plastic, composting)	Formal + Informal(metal, glass, plastic, composting)
Recycling	Informal(metal, glass, plastic, composting)	Formal + Informal(metal, glass, plastic, composting)

The purpose of recent EU policies has been to promote more recycling and energy extraction of products and materials thereby decreasing landfilling and organic fraction not ending up in landfills at all. This comes as a result of negative environmental effects of landfills such as emissions (CO2 and methane) to the air that affects climatic conditions and risk of water pollutant transport. EU Council Directives 1999/31/EC of April 1999 [24] stipulates that waste materials should be separated at source, where recyclable and combustible materials are recovered for recycling and hazardous waste is phased out from production system. The significance of different options in some developed countries is shown in table 5. It is clearly seen that U.S.A is after China regarding sanitary landfill and Japan after Switzerland in incineration.

Table 5: Different Treatment Options of MSW (%) in Some EU Countries [24]

Countries	**Incineration**	**Biological Treatment**	**Sanitary landfill**
U.S.A	20	5	75
Japan	72.8	4.2	23
Switzerland	80	-	20
Germany	28	10	62
France	40	22	38
Denmark	70	12	18

Sweden	50	10	40
China	6.9	7.5	85.6

In Mexico, most of the treatment sites have stopped operating for lack of market, the high operational cost (incineration & recycling) and the bad quality of finish product resulting from composting. The outcome of this is that most of the collected waste is not treated at all and its final destiny lies in the few landfills which comply with the required technological characteristics and disposal sites that are open air dumps. In developed countries, it is worth noting that in spite of having progressed in the creation of waste recycling infrastructure, composting with or without energy generation, the disposal of solid waste in landfills is still very significant. In countries like the Netherlands, waste incineration is a method of final disposal which has been increasing. On the other hand, landfills have decreased considerably from 1,000 active sanitary landfills in the 70s to 47 in 1996 [25]. These changes were as a result of the prohibition in 1996 for landfilling combustible waste and higher tariffs for landfilling institute since 1999.

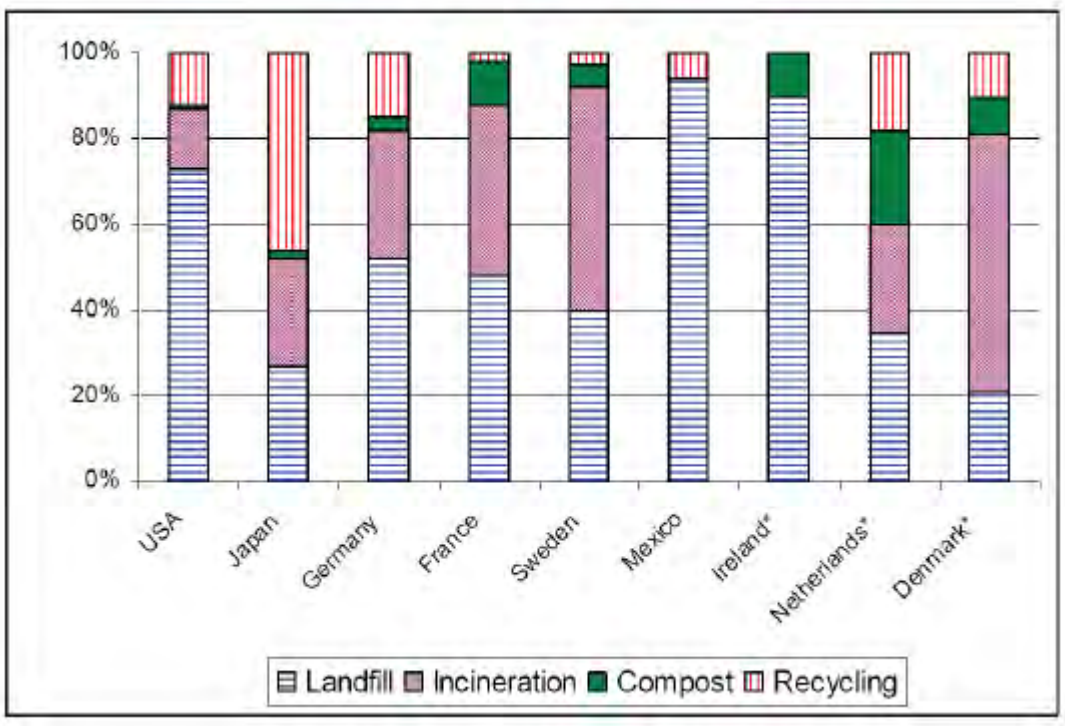

Figure 2: Municipal solid waste treatment in various countries [26]

In the continent of Asia, the average generation in low income countries varies from

Figure 3: Generation of Waste (kg/Person/Year) in Different Countries [27]

0.4-0.9 kg/person/day, in middle-income countries, 0.5-1.1 kg/person/day; in high income countries it is 1.1-2.0 kg/person/ day or even more as in Hong Kong: 5.1 kg/person/day [28]. In European waste management hierarchy, land filing is the last option. In some European countries and continents, this is not yet a reality. About 95% handling of waste in the world is land filled or dumped into holes in land or directly on the banks of rivers or into the sea [29]

Solid waste has traditionally been a local concern in most countries. Urban solid waste has become a national and international issue because of the growth in waste volumes, the environmental consequences of past disposal practices, and the potential impacts of measures adopted to address the problem of waste disposal [30]. When considering the advancements in solid waste processing and resource recovery since four decades ago, this leads to both encouraging and disturbing trends.

Until the advent of environmental awareness in the late 60s, landfilling (dumping) and incineration of solid waste were the two principal means of disposal in North America [31]. This saw the closure of many incinerators because of air pollution, dumps were closed or upgraded to sanitary landfillings, and landfilling became a more widely utilized method of disposal. The effects of improper landfilling because of incinerator air pollution and ground water contamination became an impetus of

waste volume reduction and materials recovery in efforts to conserve landfill space and reclaim nonrenewable resources.

Although using the same methodologies, solid waste management practices still differ widely throughout the world. Japan burns more than 70% of its waste, while more than 84% of American waste goes into landfills [20]

The need for landfills has been reduced significantly in Germany in the last decade. Main reasons being that the increasing amount of waste has been channeled for recycling and recovery. The remaining solid waste goes to waste incineration, for co-incineration in coal- fired power-stations, cement kilns and for mechanical and biological treatment. In the 1970s, Germany had 50,000 landfills, while in 2000 the number of landfills had reduced dramatically to 333 [32, 33], Simultaneously, Germany has seen an increase in the number of waste incineration plants i.e. from seven incinerators with capacity of 718,000 tonnes/year in 1965 to incinerators with capacity of 17,800,000 tonnes/year in 2007 [34] and also mechanical-biological plants for municipal waste disposal. The three landfills in Singapore are outside the city limits and for close to four decades, there has been a 2.09 million tones increase in the amount of solid waste generated [35] and thus a significant demand on the waste management and disposal. On this note, landfilling is the last option in the MSW management decision in Singapore. Landfill is reserved for the waste that cannot be treated or disposed of in any way and about 91% of waste collected is incinerated and about 9% along with the as generated from incineration are disposed of at Semakau landfill [35]

In low income countries, solid waste generation rates average only 0.4 to 0.6 Kg/person/day, as opposed to 0.7 to 1.8 Kg/person/day in fully industrialized countries. A report by Blight and Mbende [36] and Arlosoroff [37] noted several common differences in the composition of solid waste in developing countries:

- Moisture content is 2-3 times greater than developed countries,
- Waste density 2-3 times greater
- Large quantities of dust, dirt (street sweepings, etc)
- Large amount of organic waste (vegetable matter, etc.)

- Smaller particle size on average than in industrialized nations.

It is worth noting that because of increase population countries in Africa, Latin America and Asia account for nearly 40 percent of annual methane emissions from landfills, which is equal to 37 million metric tons of carbon dioxide equivalent or the amount of air emissions from more than 102 million automobiles [38] China is now experiencing a fast increase in solid waste quantities. According to a report by Delvoie [39] China surpassed the United States as the World‟s largest waste generator in 2004. By 2030, China‟s annual solid waste quantities will increase by another 150% - growing from 190 million tons in 2004 to over 480 million tons in 2030. This growing waste stream possesses significant impact on the society, environment and economic development. Waste categorization in China is not always consistent or comprehensive from city to city and this seriously affects the utilization of the database.

2.4 SOLID WASTE MANAGEMENT IN DEVELOPED COUNTRIES

The problem of solid waste especially MSW in the industrialized countries has been the cause of growing concern in recent years, becoming one of the main areas of the environmental policy debate. But now, because of the growth in waste volumes, the environmental consequences of past disposal practices, there is raised concerns about the economic viability and environmental acceptability of the current waste-disposal methodologies. In Europe and also the Baltic states, waste is one of the main environmental concerns [40]. The volume of household waste generated will likely be on the increase over the coming years as a result of the increase of amount of packaging used on products.

Comparing the management of urban solid waste in the late 1970s to that of today, it is clear that there is a revolution in waste management underway in most of the industrialized countries. This revolution can be seen in four aspects;

(i) revolution in the management method, away from landfill and toward material recycling and energy recovery. There is a change away from landfill, toward material recycling and energy recovery.

(ii) Strengthening of the environmental standards applied to waste

management facilities which have led to the closing or upgrading of many existing facilities.

(iii) Change in public attitude toward waste in virtually all industrialized countries. The public has come to view all methods of disposal as posing unacceptable risks.

(iv) A profound change in attitudes toward the proper role of producer industries. This can be seen in the implementation of polluters‟ pays principle and companies being asked by governments to accept increasing levels of responsibility for the waste resulting from consumption of their products. [30]

In Europe, the growth has been in recycling more than in energy recovery, but in the United States, both have grown at the expense of landfill. The U.S. EPA projects that material recovery was more than double again in the 1990s, accounting for 30% of total waste management in the 2000. Energy recovery grow to 21%, leaving only 49% of municipal waste for land disposal [41]. The approach to waste management in North America has evolved over the years from disposal in open dumps until the 60‟s, the emergence of sanitary landfills as the preferred method of waste management in the 70‟s to integrated waste management. This waste management philosophy is to ensure the treatment of all wastes as resource material, some suitable for recycling, others for conversion to compost [42]

In Japan, only 10% of the land is suitable for residential purposes. The shortage of land in accessible areas limiting the availability of suitable landfill sites is the driving force behind Japan‟s waste management policy3.Some 52 million tones of municipal waste is generated each year in Japan, 77.4% of which is incinerated, 5.9% land filled and 16.7% recycled [43]. Source separation of waste by households is well established with separation into either combustible or non-combustible material or recyclable materials such as glass, metal cans, newspapers etc.

2.5 SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

MSWM is a major responsibility of local governments. The requirement of appropriate organizational capacity and cooperation between numerous stakeholders

in the private and public sectors make the task complex. With the importance of waste management to public health and environmental protection, solid waste management in most cities of developing countries is highly unsatisfactory [44]. African countries were given the opportunity by the WHO to prioritize their environment health concerns, the results revealed that while solid waste was identified as the second most important problem(after water quality), but less than 30% of urban populations have access to " proper and regular garbage removal [45].

Table 6: Capacity Development in Solid Waste [10]

Economic levels of countries	Low-income countries	Middle-income countries
Waste minimization	No organized programs, but reuse and low per capita waste generation rates are common	Some discussions on waste minimization, but rarely incorporated into any organized program
Collection	Service is limited to high visibility areas, the wealthy, and businesses willing to pay	Expanded collection areas. Trucks are used for Collection
Recycling	Recycling activities are performed by the informal sector (scrap dealers and waste pickers). Localized markets for recycling are common	While the informal sector is still involved, relatively large machinery is sometimes used for sorting and recycling. Materials are often hauled out of the city as recyclables.
Composting	No organized programs. Wastes including organic matter are not put to good use	Efforts toward composting are made at many parts of the city. Large composting plants are generally unsuccessful. Small-scale composting projects tend

		to become more successful
Incineration	Not common or successful because of high capital operation cost. High percentage of moisture and inorganic matter call for supplement fuel and have a smaller impact on volume reduction	Incinerators are sometimes used but not common due to economic reasons
Land filling	Usually open dumping with virtually no environmental controls	Some controlled and sanitary landfills with some environmental controls. Open dumping is still common
Costs	Collection costs represent 80- 90% of the SWM budget. Collection fees are regulated by some municipalities, but the quality of collection service is low	Collection costs represent 50-80% of the SWM budget. Some municipalities regulate collection and disposal fees. Innovative arrangement are in place for fee collection

2.6 SOLID WASTE MANAGEMENT IN ASIAN DEVELOPING COUNTRIES

Asian developing countries have increased their population, urbanization and industrialization which contribute to solid waste (SW) generation. For example, in India it was between 0.2 kg/capita/day and 0.5 kg/capita/day with 217 million people [46, 47]. Asian developing countries are experiencing in increasing population, income and urban growth. This situation contributes to the increase of SW volume and type. Most of municipal solid waste comes from residential areas, commerce and other sources [48] Description of sources and types of SW in Southeast Asian countries is shown in Table 7

Table 7: Sources and types of municipal waste in Southeast Asia UNEP [49, 50]

Sources	Typical Waste generators	Types of solid waste
Domestics	Single houses and apartments	Food scraps, paper, corrugated boxes, plastics, clothing, glass, metals, ashes, and domestic hazardous waste
Shopping and commercial areas	Shopping centers, hotels, restaurants, markets, offices	Paper, corrugated boxes, plastics, wood, food scraps, glass, metals, special wastes, hazardous waste
Institutional	School, governments offices, medical care centers, prisons	As mentioned above in shopping and commercial areas
Public facilities	Street cleaning, landscaping, parks, beaches, recreation areas	Street cleaning, landscape and yard trimming, general waste from recreation areas

SW generation and its composition in some Asian developing countries are shown in Table 8. The main component of SW is decomposable organic waste which has a range of 42% to 80.2%. Other SW components, which appear in less portion, are paper, plastic, cloth, metals, glass, ash and others [46]

In Pondicherry, India [51], Kuala Lumpur, Malaysia [52] and Dhaka, Bangladesh [48] the second component of waste is paper, followed by plastic. The remains are textile, glass, metal, rubber and leather, and others

Table 8: SW generation and composition in cities of Asian developing countries [46]

Country	Waste generation		Composition									
	Ton/day	Kg/cap/day	Decomposable	Paper	Plastic	Textile	Glass	Metal	Rubber	Wood	Ash	others
Surabaya (Indonesia)	2160	.8	72.41	7.26	10.09	2.68	1.7	1.41	.46	2.39	1.48	.12
Jakarta (Indonesia)	6000	.65	68.12	10.11	11.08	2.45	1.63	1.90	.55	NA	NA	4.12
Allahabad (India)	500	.4	45.3	3.6	2.86	2.22	.73	2.54	41.66	-	-	-
Pondicherry (India	370	.59	42	30	10.4	4.5	5	4.1	2.5	1.5	NA	NA
Kathmandu (Nepal)	523.8	.66	71	7.5	12	.9	1.3	.5	.3	NA	NA	6.7
Bangkok (Thailand)	8778	1.54	42.68	12.09	10.88	4.68	6.63	3.54	2.57	6.9	NA	10.04
Phuket (Thailand	364	2.17	49.39	14.74	15.08	2.07	9.67	3.44	2.28	NA	NA	3.33
Yala (Thailand	80	1.049	49.3	14.5	19.9	-	10.08	.4	-	5.1	NA	NA
K. Lumpur (Malaysia	3798	1.62	61.5	16.5	15.3	1.3	1.2	.25	.6	.4	.7	NA
Rasht (Iran	420	.8	80.2	8.7	9	.4	.2	.7	-	.4	NA	.4
Dhaka, Bangladesh	5340	.485	68.3	10.7	4.3	2.2	.7	2	1.4	-	NA	10.4

2.6.1 COLLECTION AND TRANSPORTATION OF SW

In Asian developing countries, SW cycles through collection, transport and final disposal. In Jakarta only 70% waste was collected [53, 54] The collection service in developing countries was conducted door-to door, such as in Jakarta [54], in metro cities in India [55], and in Bangalore[56]. The other difficulty in transportation of SW are the aging of waste transport vehicles and the condition of streets in Sri Lanka [57], and weakness in organization structures, and collection method in Yangon, Myanmar [58].

2.6.2 FINAL DISPOSAL AND TREATMENT

UNEP [49] stated that methods for final SW treatment and disposal in developing Southeast Asian countries were commonly open dumping, landfill and others. These

proportions were open dumping (more than 50%), landfill (10-30%), incineration (2-5%), and composting (less than 15%). The final disposal method is generally open dumped landfill. In Malaysia the amount of SW collected for final disposal, was about 70%, whereas 20-30% was dumped or thrown into river [59]. In Bandung, the collected municipal SW was 60%, and the rest was dumped on the roadside, drainage and river [60]. Almost similar conditions were found in Malaysia, landfill was the only method for disposal [61]. In Indonesia, the transported SW to landfill was 69%, buried 9.6%, composted7.15%, burnt 4.8%, and disposed to river 2.9% and others 6.55% [62]. The Southern Province of Sri Lanka also conducted the final disposal in open dump 22 sites, and composting only 1 site of the 57 sites [60]

Composting is one of the treatments for solid waste, which more suitable than other treatment in Asian developing countries such as incinerator [63]. The most composition of SW in those countries is decomposable organic, which has high moisture content. The constraints of composting in Asian developing countries included high cost in operation and maintenance, and weak in maintenance and operation of facilities, incomplete separation of non-compostable materials. Besides, as well as higher cost of compost compare to commercial fertilizers, also affect the implementation of composting UNEP [49]. On the contrary, SWM in Asian developing countries is less financial resource, and low enforcement of environmental regulation [64]. As the problem of composting, composting is applied in India only 10-12%, and other countries like Nepal, Pakistan, Bangladesh and Sri Lanka less than 10% [65]. Methods for final SW treatment and disposal in developing Southeast Asian countries were commonly open dumping, landfill and others. These proportions were open dumping (more than 50%), landfill (10-30%), incineration (2-5%), and composting (less than 15%). The final disposal method is generally open dumped landfill. In Malaysia the amount of SW collected for final disposal, was about 70%, whereas 20-30% was dumped or thrown into river [59]. In Indonesia, the transported SW to landfill was 69%, buried 9.6%, composted 7.15%, burnt 4.8%, disposed to river 2.9% and others 6.55% [62]. The Southern Province of Sri Lanka also conducted the final disposal in open dump 22 sites, and composting only 1 site of the 57 sites [57].

2.6.3 ALTERNATIVE SOLUTIONS IN SWM

SW generation in Asian developing countries shows an increase in plastic components. Another problem is the dominance of biodegradable organic waste (more than 40% of total weight), which is potential to emit greenhouse gases (GHGs). Therefore, appropriate strategies should be determined for solving these problems [46].

2.6.4 CHANGING OF THE PUBLIC BEHAVIOR

The improvement in living standards has changed life style and SW composition. In high-income residential areas in some developing countries recyclable material (i.e. plastics, metal, glass and others) tend to increase, because of the consumption of more packaged products. Following are some alternative solutions which have been successfully implemented in Surabaya and Medan, Indonesia. In these cities public awareness was improved after receiving guidance concerning environmental issues. The trainers were from local leaders and facilitators with the assistance of Non Government Organizations (NGOs). This program was performed as community based SWM [66]. The program successfully applied 3R (reduce, reuse, recycling), which included waste separation at the source and composting. In Yala, Thailand, the poor communities in reducing SW was triggered by exchanged the trash for nutrition food. They empower themselves in environmental awareness [67]

Most of Asian developing countries face SW generation problems. The main constraints are weak organization and limited budget allocation for SWM. Therefore, in most Asian developing countries SW reduction is conducted from the source up to the landfill sites [46]

2.7 CASE STUDIES (BANGLADESH)

CASE STUDY 01: THE STUDY ON THE SOLID WASTE MANAGEMENT IN DHAKA CITY BY JICA (MARCH 2005)

In March 2005 JICA developed a case study on solid waste management of Dhaka city. The objective of that study were to formulate master plan concerning solid waste management in Dhaka City with the target year of 2015 [68] and to develop capabilities and management skills of the DCC personnel through the technology transfer during the course of the Study [23]

The population was projected 7.7 million for 2015 and 6.7 million for 2010 respectively. The area of DCC was assumed fixed at 131 km. Quantity of solid waste to be generated was estimated based on the population growth and waste generation rate. The waste generation was projected at 3,909 t/d and 4,624 t/d for the years 2010 and 2015, respectively. They made disposal plan for 3 dump site. Those were Matuail, Berri Band and Uttara [69]

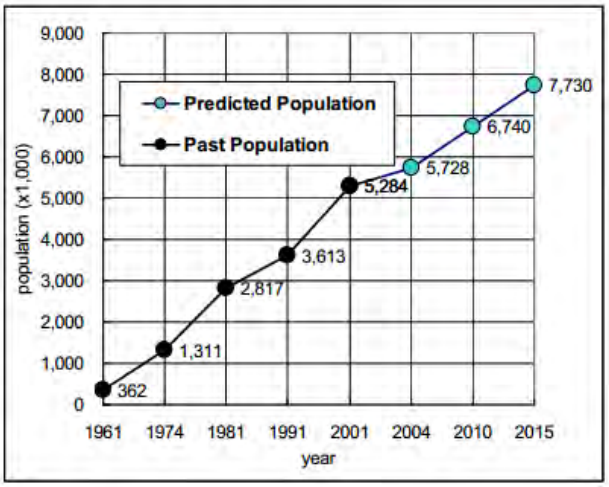

Figure 4: Population Prediction for 90 wards in DCC (2002-2015)[23]

Household Awareness survey was conducted by JICA study team in February 2004. The survey was composed of Household Questionnaire Survey and focus group discussion. [39]

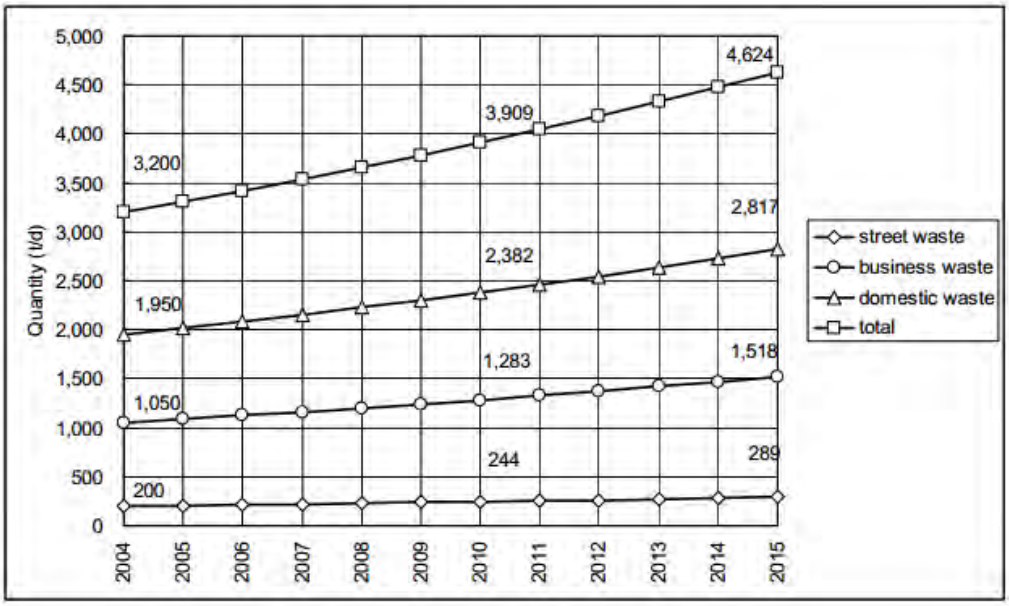

Figure 5: Forecast of solid waste generation amount [23]

WASTE DISCHARGE AND PRIMARY COLLECTION [68]

Below there are some answers those were tried to find by the study team during this study. Summary is discussed below:

During the study it was found that Servants/maids were in charge of waste discharge among 96 % of upper group and 79 % of middle group, while members of the households, mostly wives and daughters, are in charge among 95 % of lower group,.

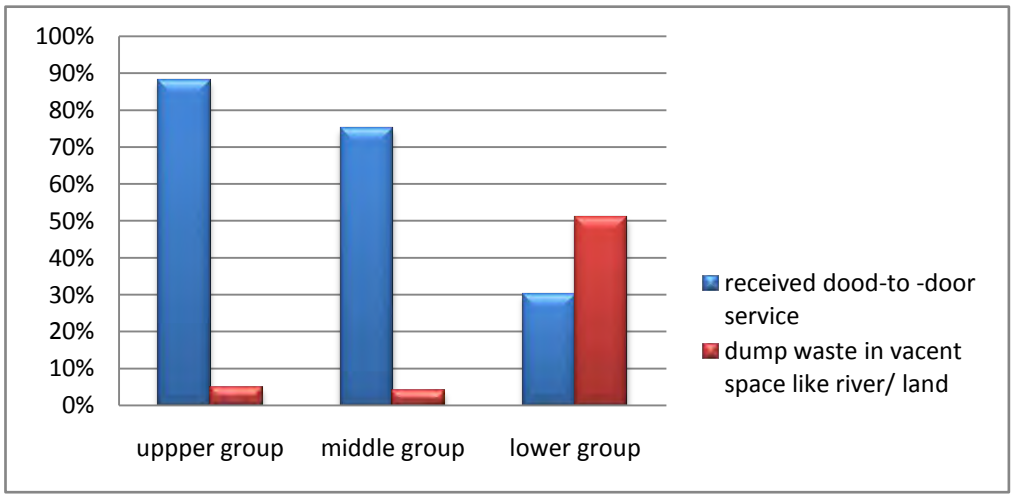

Figure 6: Door-to-door service and waste dumping percentages

The study got some data [Figure 6] that shows 88 % of upper group households and 75 % of middle group receive door-to-door collection service, while only 30 % of lower group receive such service. 51 % of lower group households dumped their waste in vacant lands/river/marsh, while only 5% of upper group and 4% of middle group do that.

During study it was observed that 80 % in new urban areas received the service from CBO and 14 % from private companies. In old urban areas, 64 % of households receive the service from CBO and 19 % from DCC cleaners. In Old Dhaka, 78 % replied DCC cleaners were providing the service. 85% were satisfied with the door-to-door collection service.

Waste Collection Charge: 88% were paying door-to-door waste collection charges. Upper group paid from Tk. 11 to more than Tk. 100 per month. 77 % of middle group paid Tk. 11 to Tk. 20 per month. 82 % of lower group paid Tk. 1 to Tk. 10 per month.

DCC Services and Secondary Collection: 21 % of the respondents (household heads), did not know the locations of nearest dustbins/containers. 58 % in new urban areas and 52 % in older urban areas replied that dustbins/containers lie farther than 300 ft from house. On the other hand, 32 % in Old Dhaka replied that dustbins/containers are located nearer than 70 ft and 28 % nearer than 150 ft.

72 % of middle group and 75 % of lower group households were not satisfied with the services, while more than half of upper group households were satisfied with the services.

Of those who were not satisfied with the waste collection service, 69 % replied that wastes were scattered around bins/containers and 34 % replied that bins/containers were too far or there were no bins in their areas; 21 % replied that time schedule of collection was not suitable.

60 % was not satisfied with the street sweeping provided by DCC (or private companies in privatized zones); 34 % of respondents in new urban areas replied that street sweeping was not provided in their areas.

Waste Segregation, Recycling and Composting: 91 % of upper group and 88 % of middle group give or sell recyclable waste, while only 29 % of lower group do that.

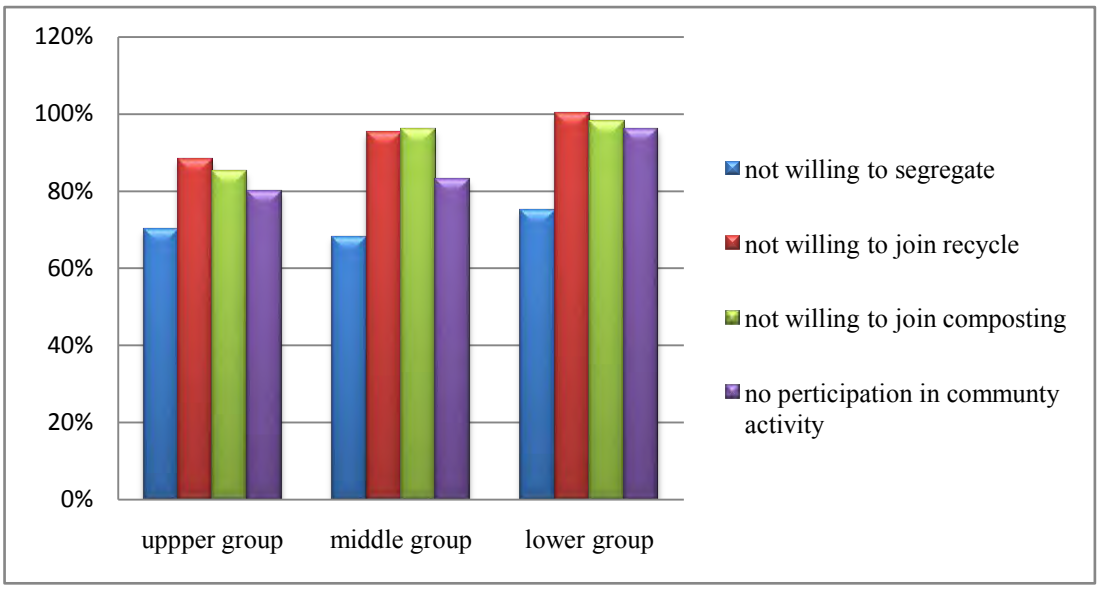

Figure 07: Waste Segregation, recycling composting status of different group of people [23]

70% of upper group, 68 % of middle group and 75 % of lower group were not willing to participate in waste segregation activities. 88 % of upper group, 95 % of middle group and 100 % of lower group were not willing to participate in recycling activities. 85% of upper group, 96 % of middle group and 98% of lower group were not willing to participate in composting activities. 80% of upper group, 83 % of middle group and 96 % of lower group were not participating in any community activities.

77 % of all respondents replied that they were willing to participate in activities on solid waste management in their communities.

POPULATION AND GENERATION OF WASTE FORCASTE

In their case study JICA forecasted total (street + business + domestic) solid waste generation of 3909 t/d and 4624 t/d for the year 2010 and 2015 respectively. And forecasted population was 6.74 million and 7.7 million respectively. Forecasted

domestic or household waste generation was 2382 t/d and 2817 t/d for the year 2010 and 2015 respectively [68]

Recommendations of JICA study:

- Open dumping should be stopped immediately and be replaced with new safe options like control dumping.
- Waste picking practice should be improved
- Encourage NGOs and private companies to establish community based segregation at source
- Capable and practical personnel have to assign.
- Waste collection, disposal and treatment may be privatized.

Limitations of JICA study:

- In JICA report no specific Forecasting method was mentioned.
- Forecasting error was not calculated.
- Population projection was 7.7 million for 2015 which is much less than year 2011 (1,20,43,977); (Community Report, Dhaka Zila, June 2012, BBS) (2)

CASE STUDY 02: MUNICIPAL SOLID WASTE MANAGEMENT IN DHAKA CITY

In this study 36 and 41 no ward of Dhaka City were selected as study area. By data collection it had been observed that only 70% to 80% of the total generated waste was collected and disposed of per day by Dhaka City Corporation (DCC). The rest of the wastes remain on the roadside bins and curbside creating unhealthy environment. In addition, based on the experimental results it was found that the waste generation varies from 0.110 to 0.142 kg/capita/day [70]

General information of ward no 36 and 41:

Ward No. 36 under Zone- 4 of the DCC area, and covering the area of North Shajahanpur, South Shajahanpur and Shajahanpur railway colony. As per DCC (2005), - there were 16,550 households, 70,781 total population with 38,930 male and 31,851 female in this ward. The municipal solid wastes (MSW) were disposed in

the designated concrete dustbin and container provided by the City Corporation.

Ward no 41, under Zone-6 of the DCC area, and covering the area of Agargaon, Taltola Govt. Colony, Shamoli Road 1& 2 and Amlertak. As per this study, there were 20,750 households, 87,240 total populations with 46,249 male and 40,991 female, in this ward. The municipal solid wastes (MSW) are disposed in the designated concrete dustbin and container provided by the city corporation.

The total daily wastes generated in DCC areas were calculated about 5400 tons, in which residential, commercial and institutional wastes were about 4048, 1178 and 62 tons, respectively. Residential waste is the main portion of solid wastes streams which was about 76% of total wastes [25]

To determine the total generation of solid waste of the 36 & 41 no wards from the households, three houses were selected from each ward from which solid waste was measured regularly. Four buckets were supplied to household to store their waste in the bucket. Bucket for:

- Bio degradable waste
- Reusable waste
- Non reusable waste
- Other waste

The details are in appendix D.

FINDING IN THE STUDIES:

a) Solid Waste Generation Rate and Physical Composition in the Study Area

Average total per capita waste generation rate of households in ward no 36 was 0.142kg/capita/day**.** Average total per capita waste generation rate of households in ward no 41 was 0.110kg/capita/day**.** It was seen that a major portion (80% - 90%) of solid waste in residential, commercial and market areas of Dhaka City was organic. This indicated the potentials of recycling of organic waste for resource recovery. Domestic waste generation rate which was proportional to the income rate.

b) Contribution of NGO's

In 36 no ward Samannito Shishu Shastha Songstha (Integrated Child Health Organization) and in 41 no ward Environmental Cleaning Illiteracy and Anti Drag Organization had been working. They mainly collect waste from house to house in different para/mahalla by small van (manually driven) and store the waste in road side bins. From the storage bins DCC truck collect the waste and dump it in ultimate disposal site. By giving this service the NGO"s take about 10 to 20 Tk per house.

RECOMMENDATIONS:

Various recommendations were proposed to improve waste management system thorough study. According to the study only 70% to 80% of the total generated waste was collected and disposed per day by DCC. The rest of the wastes remain on the road side bins or curbside creating unhealthy environment all around such as bad odor, soiled street and aesthetically problem. To solve the problem DCC need to find a proper solid waste management system in the Dhaka City. More over NGO"s may play a certain role by involving the community in the waste management system. The collection time and frequency should be such that maximum amount of waste is collected from the source. Different area may be covered by different collection time and frequency. If possible a waste recycling plant may be established for better resource recovery from solid waste because a major portion (80% - 90%) of solid waste is organic.

LIMITATIONS:

In this study no specific technique or method was mentioned to measure the total waste generation and for forecasting. Probable error was not also calculated in this case study. Only 3-6 houses were sampled from each ward which is very low comparing the whole population.

CASE STUDY 03: A STUDY ON SOLID WASTE MANAGEMENT SYSTEM OF DHAKA CITY CORPORATION: EFFECT OF COMPOSTING AND LANDFILL LOCATION (2004-2005)

According to this study in 2004-2005 an estimate of generation rate indicated that the

generation rate of 3500 tons/day may exceed 30 thousand tons/day by the year 2020. The mixed waste dumped at dumping sites was characterized with high organic content and high moisture content (about 80% and 50-70% by weight, respectively). According to required land filling areas, projected assuming 50% collection efficiency, on the year 2020, land requirements with composting of 40-80% of the organic wastes range from 167.11 acres/yr. to 96.97 acres/yr., while that without any composting stands at 206.31 acres/yr. Results from this study shows that the imminent selection of dumping sites away from the city center due to unavailability of land and/or higher land price will induce three times as high daily waste transportation cost as compared to that at present.

PER CAPITA WASTE GENERATION

DCC conducted a survey and estimated an average waste generation of 2.326 kg/family/day for high-income group, 1.260 kg/family/day for medium income group and 0.461 kg/family/day for the low-income groups [71] However, these values may not be very representative because the survey was very limited in extent covering only 11 high income, 8 middle income and 7 low- income families. For a city of 7 million such a small sample size is quite inadequate [71]

On the basis of the 1981 and 1991 census data, BCAS (1998) [72] calculated a compound growth rate of 2.74% for the DCC population during this period, and estimated a population of 4.64 million for the year 1998 using the growth rate [71, 72]. With estimated daily generation of 2398 tons, this gives a per capita generation of 0.52 kg/capita/day. DCC on the other hand, reported a population of 7 million for the DCC area [71], almost 1.5 times higher than that estimated by BCAS (1998) [72] However, since the waste generation estimate of DCC (1999) (71)is also much higher (3500 tons/day), per capita generation calculated from DCC (1999) data (0.50 kg/capita/day) was very close to the value reported by the BCAS (1998) [71, 72]

PROJECTION OF FUTURE WASTE GENERATION

To make predictions about future waste generation from estimates of population requires prediction of future per capita waste generation. BCAS used a simple procedure for predicting future waste generation [72]. The annual compound growth

rate of population, on the basis of the 1981 and 1991 census data, was estimated to be 2.74%. Assuming an annual GAP (Gross Annual Product) growth rate of 4%, and that 70% of the additional income going into consumption, waste generation growth factor based on GAP growth was taken as 4 X 0.070 = 2.8%. Based on this growth rate and a 1998 per capita generation of 0.52 kg/capita/day, BCAS predicted waste generations for the future years up to 2021. Using the same procedure as followed by BCAS [72], another estimate for future waste generation is made based on the population of 1991 (census) and population of 1999 (DCC 1999) [71]. The estimated population growth rate is 7.79%. Assuming the same waste generation growth factor of 2.8%, an estimate of waste generation for future years is provided.

Comparing above two estimates it is observed that according to the predictions of BCAS (1998) [72], the generation of solid waste would be around 8,478 tons/day by the year 2020 where as the second estimate predicts that the waste generation will reach over 30,195 tons/day by 2020. The wide variation in the two predicted values is due to the fact that the population considered in two estimates differs considerably. With so much variation and uncertainty in the present estimates of solid waste generation and population, one would have little confidence in any prediction.

CHARACTERISTICS OF SOLID WASTE

Food wastes constituting a major part of the wastes from the Motijheel area where a large number of hotels and restaurants were operating, or, cloths/rags dominating the wastes from New Market area. Paper and plastic also constitute major fraction of solid waste in the commercial areas. As observed for the residential solid waste, food wastes constituted the major part of the mixed wastes (about 70% by weight on an average), probably indicating the predominance of residential source in the overall solid waste. Important constituents included polythene/plastic, paper, cloth, garden wastes, and brick/stone/metal/glass/ceramic.

PRIMARY COLLECTION SYSTEM OF SOLID WASTE

In some areas of Dhaka city demountable containers were used for onsite storage of

municipal solid waste. All parts of the city were not provided with these bins and there were no specific rules and criteria of placing the dustbins. In cases where there were no bins, waste was simply dumped on the ground.

In some residential areas like Kalabagan, Dhanmondi, Banani, Gulshan, Baridhara and Uttara, *„house to house"* waste collection service had been organized by some private initiatives. Rickshaw vans were used for collection of waste from houses and conveying to municipal containers.

FINAL DISPOSAL OF SOLID WASTE

According to this study DCC had disposes solid wastes adopting crude dumping methods, and thereby, creates environmental hazards and health risks. The dumped solid wastes were dressed irregularly by pay loaders, excavator, tire dozer, chain dozer etc.

According to DCC [71] six dumping sites were been abandoned after filling to their capacities. These sites were: (1) Kulsi, (2) Chalkbari-Mirpur, (3) Gabtoli-Mirpur, (4) Lalbagh ShosanGhat, (5) Mugdapara and (6) Jatrabari. In 1999, major portion of solid wastes (88%) were dumped at Matuail site. Wastes disposed at the other two- Lalbagh site (11%) and Mirpur site (1%) were insignificant. During this study almost all the wastes were being dumped to Matuail, and others were used when Matuail site is inaccessible due to rain or damage of driveways, repairing and maintenance of unloading platforms.

Matuail landfill was covered about 52 acres of low-lying agricultural land acquired by DCC in 1986 [73]. Out of this, 13 acres had been developed for parking/platform and the rest 39 acres was used for land filling. It was being used for dumping of solid waste since 1993. Earth dyke for isolation encloses the dumpsite.

ENVIRONMENTAL IMPACT OF IMPROPER LAND FILLING

The open air dumping of solid wastes at the dumping locations, besides were causing aesthetic problems and nuisance due to nauseating pungent odor, also promotes

spreading of disease by the disease vectors such as flies, mosquitoes, rats etc. The situation was further aggravated by the indiscriminate disposal of hazardous hospital and clinical wastes in the roadside bins and dumpsters.

LIMITATIONS OF THE CALCULATION:

Data provided on the same item by DCC and BCAS tend to differ as observed. Due to lack of the related data from a single source, author had to use the „amount of waste transportation" data from BCAS with the „cost of transportation" data from DCC [74]. This was very likely to create inconsistency. Moreover much accuracy cannot be claimed in the conversion of previous data of waste transportation to fit the present situation.

CASE STUDY 04:
URBAN SOLID WASTE MANAGEMENT SCENARIO OF BANGLADESH: PROBLEM AND PROSPECT", WASTE CONCERN TECHNICAL DOCUMENTATION, JUNE 2005.

One of the directly related consequences of population growth is the increase in waste generation. With the conventional system of collection, transportation and crude dumping of solid waste, municipal areas of Bangladesh are generally faced with rapid deterioration of environmental and sanitation condition. As such, urban solid waste management has become a major concern for the cities and towns of Bangladesh.

According to this study in 1951, the percentage of urban population was only 4.33% of the total population. Since then the rising trend has continued reaching around 24% by the year 2001. Growth of urban population due to large influx of rural-urban migration was triggered by the migrants" poverty at home [75].

Table 9: Urbanization in Bangladesh [75]

Year	Total urban population	Percent of urban population	Average annual growth
1951	181977	4.33	1.69
1961	264072	5.19	3.75
1974	627360	8.78	6.62
1981	13535963	15.54	10.63
1991	20872204	20.15	5.43
2001	28808477	23.39	3.27

FINDINGS OF THE STUDY:

Total Waste Generation: From Table 10 it was found that total waste generated in the urban areas of Bangladesh per day was 13,332.89 tons. Based on the total estimated urban population of the year 2005, per capita waste generation rate was computed as 0.41 kg /capita/day.

Food &Vegetable, Paper Products, Plastic, Leather, Rubber, Metals, Glass and ceramic, Wood/ Grass/ Leaves, Rags, Textile, Jute, Medicine/ Chemical, Rocks, Dirt &Misc were the major waste portion found during this study.

Among different components the total percentage of compostable (including food, vegetable, rags, jute, wood, grass, leaves etc.) waste was found to be comparatively higher. This study also showed that a substantial portion (69% to 77%) of solid waste in the urban areas was compostable. Average compostable content of the waste was 74% with the remaining 26% being non-compostable. The large quantity of organic contents present in urban solid waste composition indicates the necessity for frequent collection and removal. The average density of urban solid waste at collection point was estimated at 288 kg/m. This density may vary depending on the season. Based on the survey it was also estimated that the average on-truck density as 576kg/m and average landfill density without any compaction as 1152 kg/m [75]

Table 10: Total Waste generation in urban areas of Bangladesh [75]

City/Town	WGR (kg/cap/da	No.of City/Tow	Estimated Populatio	Total Population (2005)	TWG (Ton/day)		Average TWG (Ton/day
					Dry season	Wet season	
Dhaka	0.56	1	6,116,731	6,728,404	3,767.91	5,501.14	4,634.52
Chittagong	0.48	1	2,383,725	2,622,098	1,258.61	1,837.57	1,548.09
Rajshahi	0.3	1	425,798	468,378	140.51	205.15	172.83
Khulna	0.27	1	879,422	967,365	261.19	381.34	321.26
Barisal	0.25	1	397,281	437,009	109.25	159.51	134.38
Sylhet	0.3	1	351,724	386,896	116.07	169.46	142.76
Pourashavas	0.25	298	13,831,187	15,214,306	3,803.58	5,553.22	4,678.40
OtherUrban Centers[8]	0.15	210	8,379,647	9,217,612	1,382.64	2,018.66	1,700.65
Total	0.41(Avg.)	514	32,765,516	36,042,067	10,839.7	15,826.0	13,332.89

The collection cost varies from Tk. 235 to Tk. 1932 per ton of waste. The number of cleaners also falls quite short behind the standard in almost all the cities/towns. While the number of cleaners for satisfactory manual cleansing is 2 -5 per 1000 population, in most urban areas it varies from 0.55 to 1.2 per 1000 population

RECYCLING OF WASTE

According to this study informal sector was playing an important role in Bangladesh in recycling of solid wastes. The existence of waste, mainly inorganic, has opened quite an extensive scope for various groups of the community to utilize it profitably. Informal sector was also playing a prominent role in collection of recyclable materials. All the buyers of the recyclable items belong to the informal sector and only a few formal manufacturers were involved in using recyclable items as raw material. Although recycling of solid waste was not included in the national environmental policy, waste had become the main source of income for several groups of the informal sector [75]. The informal sector was responsible for recycling from 4% to 15 % of the total solid waste generated in different cities and urban centers. It was estimated that informal sector has been able to save Tk 10,705.5 million annually through recycling of 4% to 15% of the total generated waste.

LAND REQUIREMENT

Generally, density of waste at landfill sites in this sub-continent had been found as 1.1

ton/ m without any compaction [76]. In this study it was also found that 4 meters height the total area required per year to dispose the total generated urban waste was 273.21 acre. Based on the rate of waste collection the total landfill area required for waste disposal for 4 meters depth of filling per year works out as 137.24acres. Without composting the total land area required was 273 acre whereas with 50% composting it was reduced to 157 acres and with 74% composting it was further reduced to only 99 acres per year. In this study it was also found that the area required for composting plant for the diverted 50% and 74% of compostable waste work out around 159 acres and 235 acres respectively [75] it may be seen that by the year 2050 the landfill requirement without composting will exceed 1000 acres. On the other hand, in the same year with 75% composting landfill requirement will be only around 400 acres –a substantial reduction of over 60 percent [75].

CHAPTER 3: RESEARCH DESIGN & METHODOLOGY

3.1 STUDY AREA

Ashkona under Dakshin Khan Thana the map shown in Fig. 07 is expanding rapidly with an enormous growth of population. Solid waste is being generated at a faster pace, posing a serious management threat. The rapid growth of population, lack of financial resources, inadequate trained manpower, inappropriate technology and lack of awareness of the community are the major constraints of solid waste management for the fast growing area like this in Dhaka.

Figure 8: Study Area (Ashkona)

3.2 METHODOLOGY

The methodology of this survey consists of practical field observation and field based data collection of solid waste generation, collection, transportation of solid waste management situation through structured and non-structured questionnaire and formal and non-formal interviews. The relevant secondary data for this study was collected from published sources. During the survey some influential factors were also considered such as: population growth, new consumer product in market, income level, education which can affect waste generation. The overall work to be done is described schematically by the flow chart showing in the Figure. 9

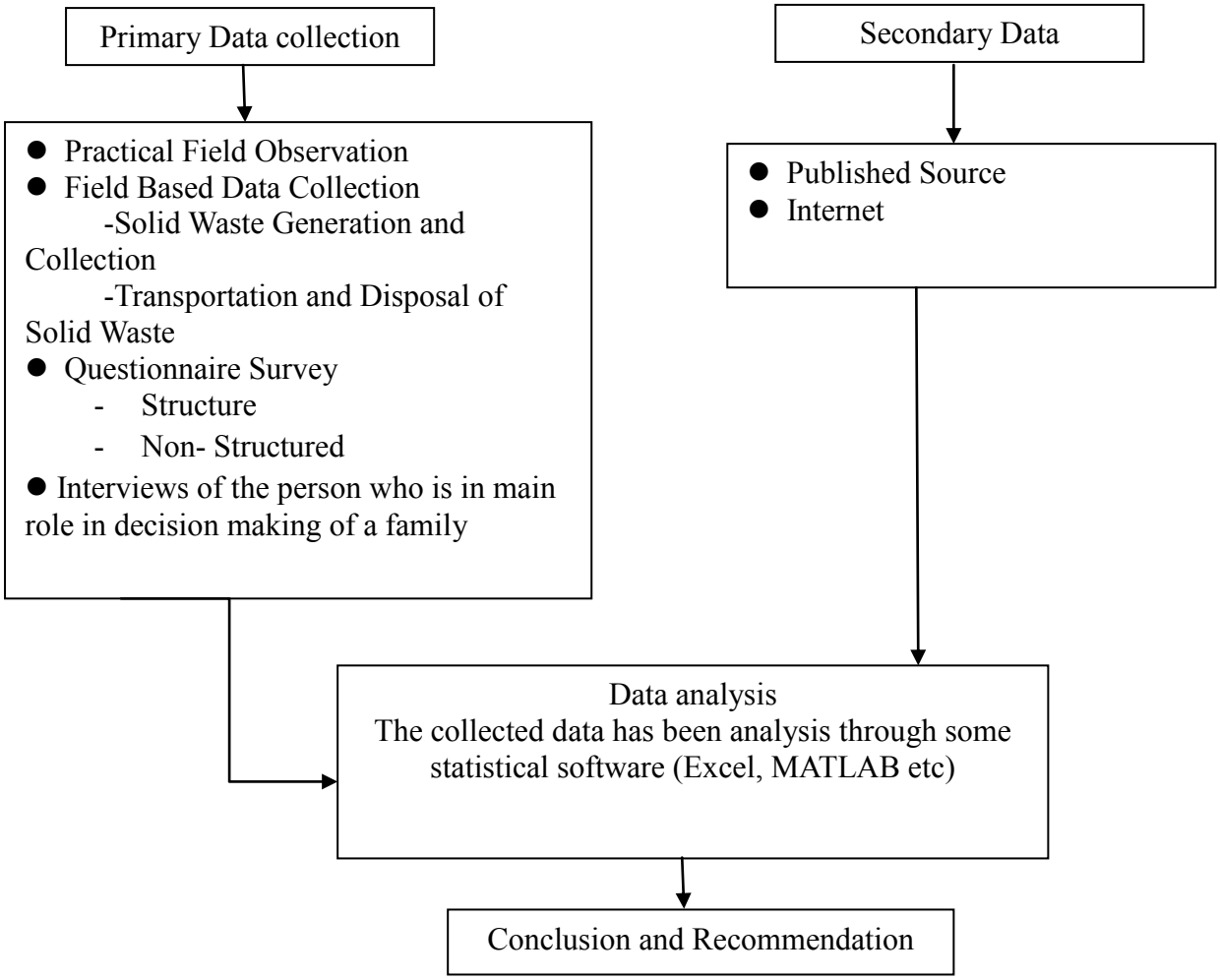

Figure 9: Flow Chart of Research Methodology

This study was undertaken to assess the environmental conditions, solid waste generation, collection, transportation solid waste management etc of Dhaka City Corporation , and to identify the deficiencies for the improvement of existing situation. In order to achieve the objectives a comprehensive literature review, household surveys and field visits, and a questionnaire survey was conducted. „Household head" means the person who plays the main role in the decision-making process of a family. In the absence of the household head, the second important adult member of the family was interviewed. A questionnaire survey was also conducted upon 100 respondents of Ashkona Dakkinkhan area (Dhaka City Corporation).

3.3 SURVEY FORM

It is observed from the surveys that solid waste management situation in the study

areas are not satisfactory. Moreover, the waste disposal is not adequate and needs improvement in those areas. However, the questionnaire survey forms has the information about occupation, income level (monthly), family members, house ownership, per capita waste generation classified according to the income level, type of solid waste generation etc. In Appendix E survey form is attached.

CHAPTER 4: DATA COLLECTION

4.1 PRIMARY DATA COLLECTION

The study consists of solid waste produced by household sector and managed by the local community. It is based on primary data survey in 2013 and 100 households were interviewed with the help of questionnaires. Questionnaire is attached in appendix E Questionnaire measured household existing solid waste practices as well as individual knowledge, attitudes, concerns, willingness to participate and regarding general issues on solid waste. Interviews were conducted among adults aged face to face at respondents own homes throughout the Area. Interviews took place between 8:00am and 12:00pm in two days.

The research at the 100 households was obtained by a stratified random sampling technique. The sample distribution was selected such that it reflected both a representative sample size due to different socio-economic circumstances (High income, Middle income & low income). A descriptive survey across the section of the population involving personal interviews was used to collect data. The rationale for the selection of households was based on the following reasons [10]:

- Household is one of the most important institutions in a society and within which the gender norms are expressed, reinforced and reflected in large institutions of society.
- Household is a basic unit of society where individuals both cooperate and compete for resources

Table 11: Primary Data Collection Method

Study Object	**Method**
Household Structure: Employment, education, property ownership	- Household Survey questionnaire - Observation
Household SWM practices: Storage, resource recovery, collection and disposal	- Questionnaire - Interviews - Observation

4.2 SECONDARY DATA COLLECTION

The review of secondary data has been very useful for this research. Firstly, studies which involved the consultation of official reports, articles, legal documents, published literatures and Case studies.

CHAPTER 5: DATA ANALYSIS AND DISCUSSION

Collection of solid waste in an urban area is difficult and complex because the generation of residential and commercial-industrial solid waste takes place in every home, every apartment building, and every commercial and industrial facility as well as on the streets, parks, event vacant areas.

Generally in the study are „door to door waste collection" facilities is being provided by "Small Local Association". Waste collection generally starts from 08.00am to 02.00 pm. After collection collected waste are dumped into open space.

In almost every home in Ashkona, storage of waste is done in one way or the other. Storage containers like plastic buckets are kept in the kitchen and in some cases; plastic bags are keep at the back yard in order to store waste. Primary waste collection and transportation to communal bins is regular that is, at least every one or two days. Waste disposal is largely based on the availability of space. Most waste is dumped in nearby open empty space.

Figure 10: Open dumping of Waste after collection

Figure 11: Waste dumped in open space from household

Open dumping still remains the cheapest and most effective solution to get rid of rising heaps of garbage. The present disposal site is distantly located from source of waste generation. This has led to increase transfer costs due to longer collection and hauling time. When a place filled up then local authority try to find new place for dumping the waste.

RECYCLING

With increasing urbanization, lack of space and cultural shift toward disposable plastics, there is decrease in household segregation. The burning of combustible waste such as plastics, cardboard and paper at designated areas is widely practiced. With these methods typically used for final disposal, the overall condition of dumpsite (uncontrolled landfill) is still unsatisfactory.

Figure 12: Primary collection of solid waste from house

PRIMARY COLLECTION:

There is planning of collection waste every day from every house. But some time it is not collected every day and it is also found that from few houses wastes were not collected for 2 or 3 days. After collection of waste from household the waste was dumped into local open

LEVEL OF EDUCATION IN SURVEY AREA:

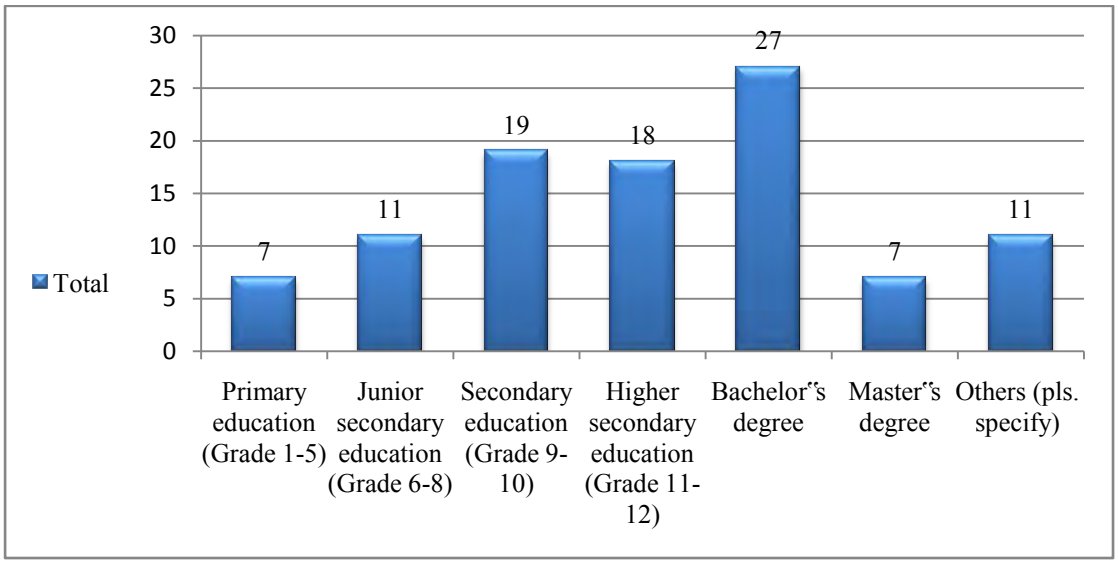

Figure 13: Level of education of the most educated member of household

7% of sampled population did only Primary education (Grade 1-5), 11% ended education at the level of Junior secondary education (Grade 6-8), 19% attended Secondary education (Grade 9-10), 18% did Higher secondary education (Grade 11-12), 34% have been to the University and 11% have diploma or others degree. The overwhelming majority of 56% is an indication that people"s in Ashkona can get environmental ideas thorough little awareness and print media.

SOLID WASTE GENERATION

Per capita solid waste generation is significantly depends on the different income level with different living standard of cities. Figure 14 shows that the monthly income level of the people living in Ashkona Dakkinkhan area. 29% people in the study area which have monthly income greater than BDT 30000, on the other hand a major

group of people (43%) having monthly income between BDT 11000-30000. Fig 13 shows the variation of the per capita solid waste generation in residential areas in study area with respect to different income level.

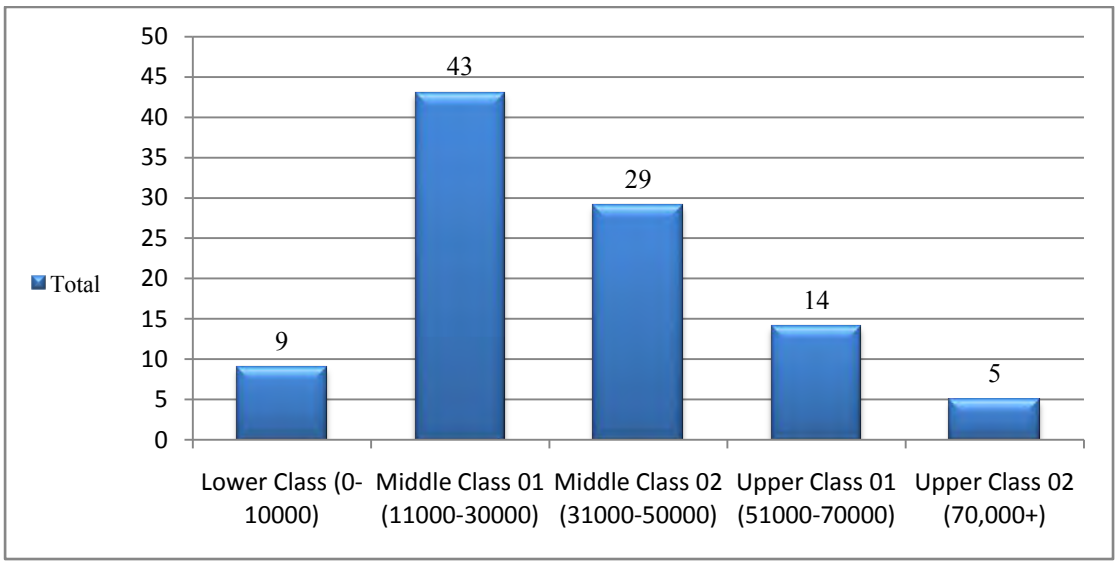

Figure 14: Monthly Income level of the people in survey area

WASTE GENERATION (PER FAMILY/DAY):

higher income level family produces higher amounts of waste (1.18 Kg/day) whereas the lower income level family produces 0..78 Kg solid waste per day.

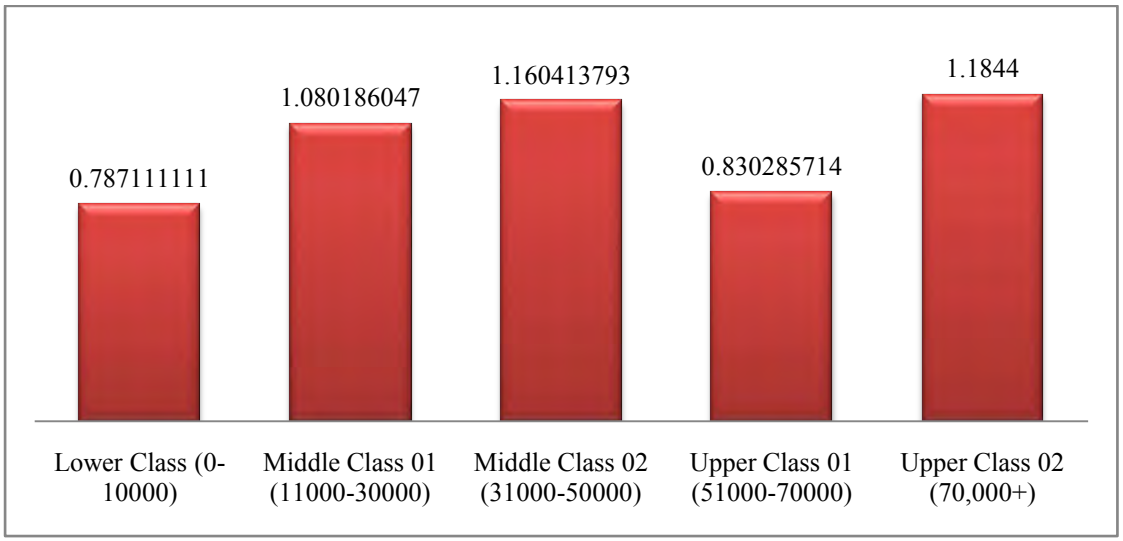

Figure 15: Waste Generation with respect to Income level (kg/family/day)

On basis of education level from figure 16 it can say that family having less education are producing more waste than others. 1.52 kg waste generated by family having primary education level where a university attended family is producing waste of around .96 kg per day. During study it was also noted that people with higher educational qualification spend most of the day time in office or outside of home that's how generated waste by the concern the family waste in day time.

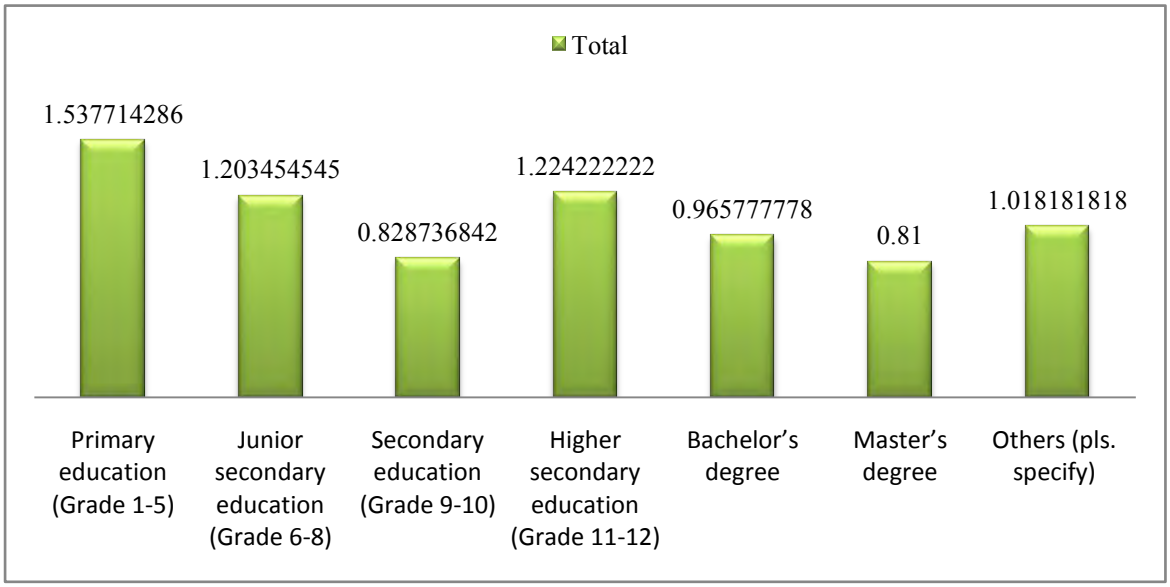

Figure 16: Waste Generation with respect to Educational level (kg/family/day)

From the figure 17 it is found that in people from rented house generate more waste that the owner himself. Average amount generated are 0.80 kg & 0.89 kg to the owned pucca and semi pucca house respectively. Whether in rented houses waste produces 1.1 kg & 1.05 kg respectively to the rented pucca and semi pucca houses.

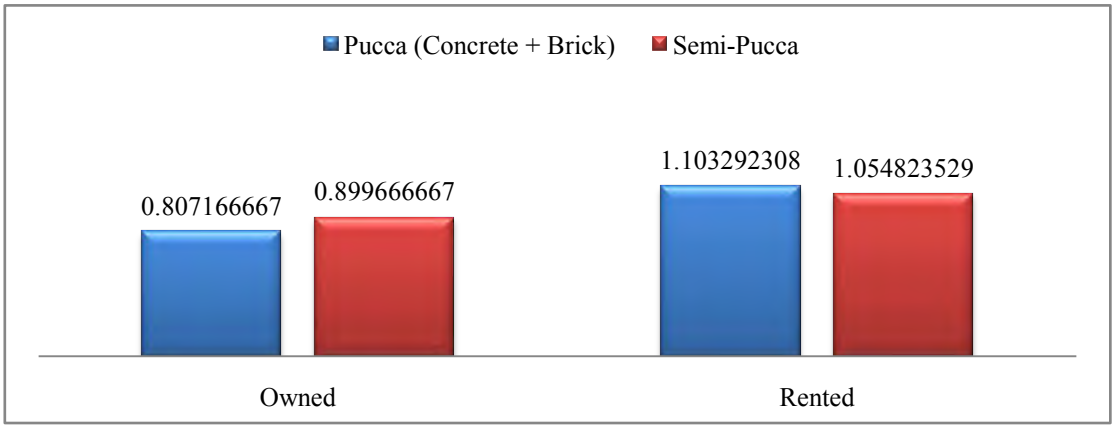

Figure 17: Waste generation (KG) based on house type & ownership

PRESENT COST OF COLLECTION:

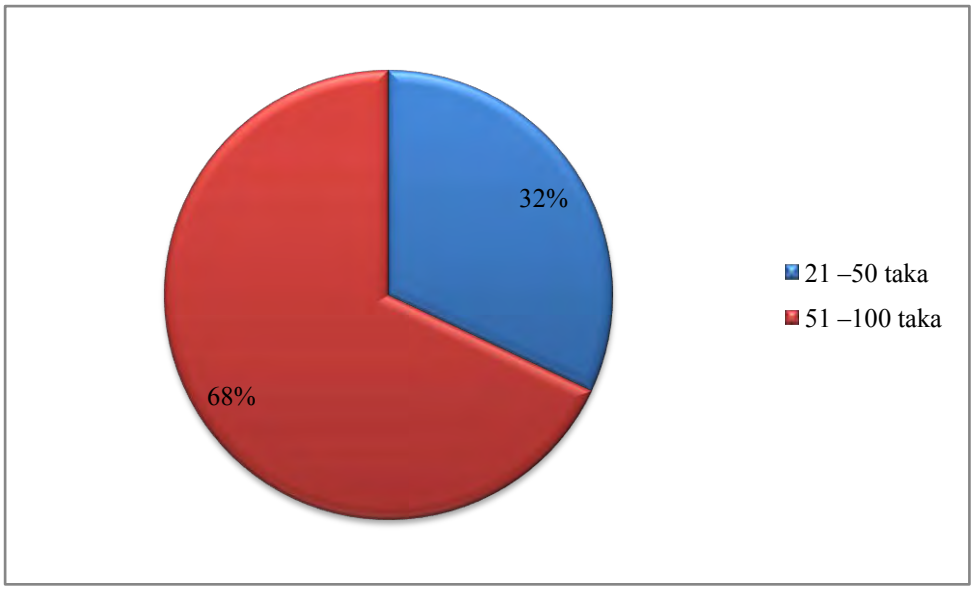

Figure 18: Monthly cost/Family

In the survey area 68% family paid between 51-100 taka per month and 32% family paid between 21-50 Taka. Generally the cost of collection varies on type of house. Generally from pucca house waste collection rate is higher.

Monthly salary of the persons working for collecting the waste is varies between 6000- 15000 TK depending on the experience. In Ashkona the local community has 8 van and 3 persons for each van to collect the waste from houses and the collection starts from 08:00 am to 03:00 pm.

Segregation of waste:

During the study it was also found that no house has any segregation system. All the wastes are dumped into one drum or bucket and waste picker collect the waste from that common space.

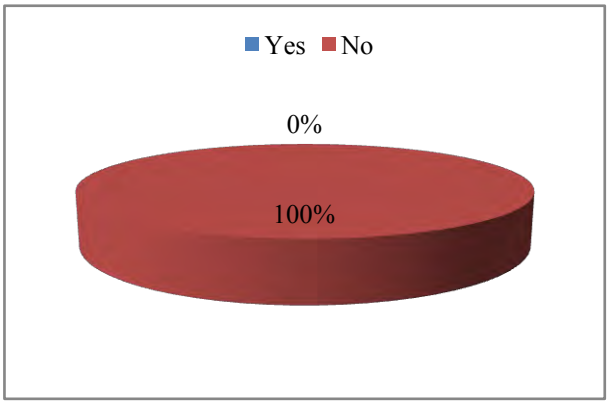

Figure 19: Waste Segregation Percentages

FORECASTED WASTE GENERATION:

From the calculation in Appendix C is it found that in 2030 forecasted waste generation (only household) is near about 4020 ton/day.

Equation for population forecast: $Y = -4641653.71 + 236064.3 * X$

Here, $a = -4641653.71$ $X = Year\ (1999, 2000, ...)$

$b = 236064.3$ $Y = population$

$r = 0.94773$

$r^2 = 0.89820$

Then Multiplying Y by 0.242430556 kg value calculated from Appendix A the forecasted waste was calculated in Appendix C for different year.

Here consumption habit, income range, education range was considered as same as present time. With the variation of these things the amount of waste generation forecasted has certainly changed. According to the forecasting waste generation will 1.33 times in year 2030 in comparison with 2014 waste generation of 3011 ton.

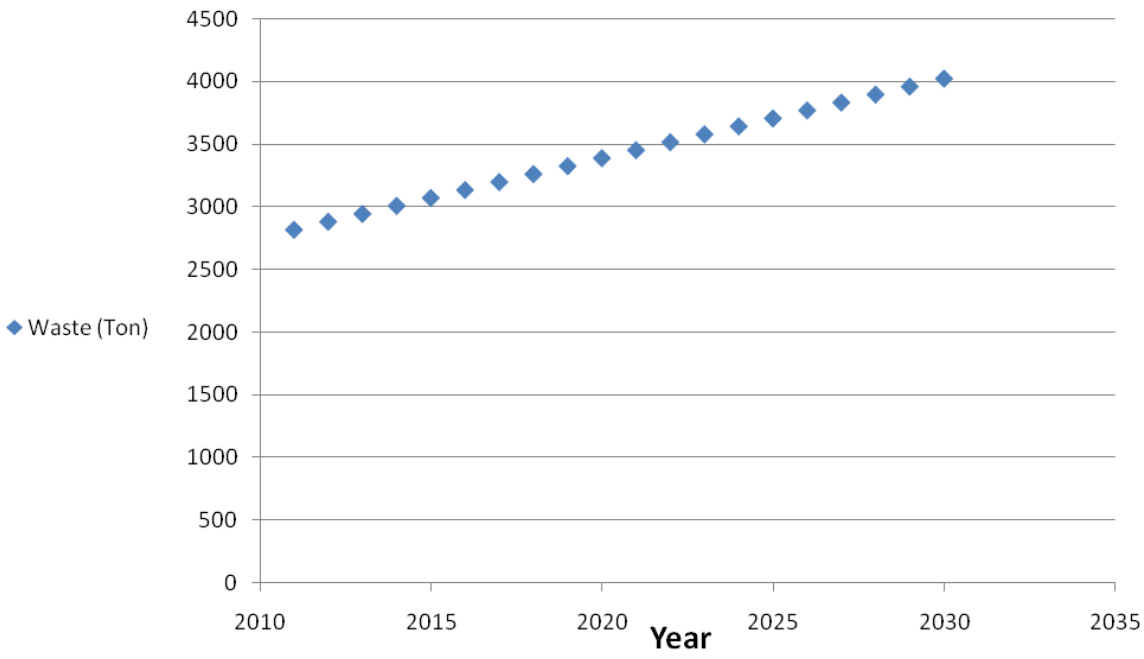

Figure 20: Forecasted waste amount for different year

CHARTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSIONS

Population in Dhaka city as well in Bangladesh is increasing rapidly and waste generation is also increasing. Depending on the education level, income level, house type, waste generation varies. Waste generation types are changing due to the adaption and availability of various packaging product (e.g., food etc.). It is found that none of the families has segregation practice at the initial level of waste management in houses and also waste pickers do not have any different designated place to dump different waste in separate space. Source-segregated waste is essential for better management, so households should be motivated accordingly. Segregation practice at initial level in houses can increase the effectiveness of waste management and can make it easy to waste picker to manage the wastes and waste collection for recycling can be easier.

It is also not possible for the waste picker to collect all the waste from the houses because some portion of household waste (e.g., bottle, packet, food leftover etc.) is been regularly dumped into open nearby space (e.g., like road side or in pond or lake etc.). Those decrease the effectiveness of waste management. General practice of waste management in the study area is open dumping [Figures 8, 9, 18]. Segregation of different types of waste is not practiced during open dumping of the waste by the waste picker. For this reason non degradable (which are mostly plastic-based) waste remains for a longer period and causes more environmental pollution.

All the waste collection, waste dumping, man power management in study area are controlled by “Small Local Association”. DCC needs to accommodate the inclusion of NGOs, micro enterprises into the main stream of Solid Waste Management. Capable and practical personnel have to assign. Waste collection, disposal and

Figure 21: Plastic bag in open dumping

treatment may be privatized.

6.2 RECOMMENDATIONS

Open dumping should be stopped and be replaced with new safe options like control dumping. Waste picking practice should be improved. DCC needs to encourage NGOs and private companies to establish community based segregation at source. Public awareness of waste segregation, recycling and reuse should be raised through public campaigns and media demonstrations through NGOs to encourage the personnel in all rural and urban area to use separate container to dump non-biodegradable (mainly plastic based) based product waste which can be collected easily and used for recycling.

Only by using minimum two waste containers (one for plastic, rubber, metal etc. & one for compostable waste e.g., food, paper etc.) waste segregation can be easier at initial level.

Figure 22: Example of Bin for non bio degradable and recyclable product

With the increasing concern of waste management DCC need to give focus on waste composting and recycling. Composting is due to the high percentage of organic material in the waste composition found in previous studies [68, JICA 2005]. For the plastic, rubber, metal based waste recycling would be a better choice to reduce environmental pollution.

6.3 LIMITATIONS

There was a lack of availability of information from the internet and municipal offices. Comparing to the large population only 100 families were studies in two stages in 2 different days. In this thesis, simple linear regression is used to estimate the population in Dhaka city. However, multiple linear regression analysis with other significant variables (e.g., economic growth of population, no of members in family etc.) could bring more accurate forecast of waste generation.

6.4 FUTURE RESEARCH

Further research based on source-based waste segregation and its impact can bring result for better and effective waste management. Study on waste recycling and composting can also be carried out. Effects of economic growth of low economic level population on waste generation can be a challenging study and can help to find more accurate results.

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APPENDIX: A

Family No	Educational Level	Economic Class	Family Member	Total Waste	House Type	What is the house made of?	how much do you pay monthly?
1	Master´s degree	Middle Class 02 (31000-50000)	4	0.50	Rented	Pucca (Concrete + Brick)	21 –50 taka
2	Secondary education (Grade 9-10)	Middle Class 02 (31000-50000)	3	1.314	Rented	Pucca (Concrete + Brick)	21 –50 taka
3	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	5	0.614	Rented	Pucca (Concrete + Brick)	51 –100 taka
4	Others (pls. specify)	Middle Class 02 (31000-50000)	6	1.31	Rented	Pucca (Concrete + Brick)	51 –100 taka
5	Master´s degree	Upper Class 02 (70,000+)	2	2.2	Rented	Pucca (Concrete + Brick)	51 –100 taka
6	Secondary education (Grade 9-10)	Upper Class 01 (51000-70000)	5	0.7	Owned	Pucca (Concrete + Brick)	51 –100 taka
7	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	3	1.1	Rented	Pucca (Concrete + Brick)	51 –100 taka
8	Higher secondary education (Grade 11-12)	Middle Class 02 (31000-50000)	4	0.9	Rented	Pucca (Concrete + Brick)	51 –100 taka
9	Higher secondary education (Grade 11-12)	Middle Class 02 (31000-50000)	4	0.986	Rented	Pucca (Concrete + Brick)	51 –100 taka
10	Others (pls. specify)	Middle Class 02 (31000-50000)	3	1.43	Rented	Pucca (Concrete + Brick)	51 –100 taka
11	Junior secondary education (Grade 6-8)	Middle Class 01 (11000-30000)	6	1.6	Rented	Pucca (Concrete + Brick)	21 –50 taka
12	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	4	0.542	Rented	Pucca (Concrete + Brick)	51 –100 taka
13	Higher secondary education (Grade	Middle Class 01 (11000-	2	1.42	Rented	Pucca (Concrete +	51 –100 taka

	11-12)	30000)				Brick)	
14	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	3	1.01	Rented	Pucca (Concrete + Brick)	51 –100 taka
15	Primary education (Grade 1-5)	Middle Class 01 (11000-30000)	5	1.85	Rented	Pucca (Concrete + Brick)	21 –50 taka
16	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	4	3.3	Rented	Pucca (Concrete + Brick)	51 –100 taka
17	Primary education (Grade 1-5)	Middle Class 01 (11000-30000)	4	0.504	Rented	Pucca (Concrete + Brick)	51 –100 taka
18	Primary education (Grade 1-5)	Lower Class (0-10000)	3	1.1	Rented	Pucca (Concrete + Brick)	51 –100 taka
19	Primary education (Grade 1-5)	Middle Class 01 (11000-30000)	5	3.11	Rented	Pucca (Concrete + Brick)	51 –100 taka
20	Primary education (Grade 1-5)	Middle Class 01 (11000-30000)	5	1.1	Rented	Pucca (Concrete + Brick)	51 –100 taka
21	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	5	0.35	Rented	Semi-Pucca	21 –50 taka
22	Primary education (Grade 1-5)	Middle Class 01 (11000-30000)	5	0.3	Rented	Semi-Pucca	21 –50 taka
23	Junior secondary education (Grade 6-8)	Middle Class 01 (11000-30000)	6	1.204	Rented	Semi-Pucca	21 –50 taka
24	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	3	0.3	Rented	Semi-Pucca	51 –100 taka
25	Junior secondary education (Grade 6-8)	Middle Class 01 (11000-30000)	4	2.23	Rented	Semi-Pucca	21 –50 taka
26	Junior secondary education (Grade 6-8)	Middle Class 02 (31000-50000)	3	0.91	Rented	Semi-Pucca	51 –100 taka
27	Junior secondary education (Grade 6-8)	Middle Class 02 (31000-50000)	6	2.56	Rented	Semi-Pucca	21 –50 taka
28	Primary education	Middle Class	13	2.8	Rented	Semi-Pucca	21 –50 taka

	(Grade 1-5)	01 (11000-30000)					
29	Others (pls. specify)	Upper Class 01 (51000-70000)	15	0.508	Owned	Pucca (Concrete + Brick)	51 –100 taka
30	Higher secondary education (Grade 11-12)	Upper Class 01 (51000-70000)	4	2.17	Rented	Pucca (Concrete + Brick)	51 –100 taka
31	Secondary education (Grade 9-10)	Upper Class 01 (51000-70000)	5	0.5	Owned	Pucca (Concrete + Brick)	51 –100 taka
32	Others (pls. specify)	Middle Class 02 (31000-50000)	5	1.22	Rented	Pucca (Concrete + Brick)	51 –100 taka
33	Others (pls. specify)	Upper Class 02 (70,000+)	3	0.842	Rented	Pucca (Concrete + Brick)	51 –100 taka
34	Bachelor‟s degree	Upper Class 01 (51000-70000)	3	0.92	Rented	Pucca (Concrete + Brick)	51 –100 taka
35	Master‟s degree	Middle Class 01 (11000-30000)	3	0.384	Rented	Pucca (Concrete + Brick)	51 –100 taka
36	Secondary education (Grade 9-10)	Middle Class 02 (31000-50000)	4	1	Rented	Pucca (Concrete + Brick)	51 –100 taka
37	Secondary education (Grade 9-10)	Upper Class 01 (51000-70000)	5	0.512	Owned	Pucca (Concrete + Brick)	51 –100 taka
38	Others (pls. specify)	Upper Class 01 (51000-70000)	5	0.606	Rented	Pucca (Concrete + Brick)	51 –100 taka
39	Bachelor‟s degree	Upper Class 01 (51000-70000)	1	0.466	Rented	Pucca (Concrete + Brick)	51 –100 taka
40	Bachelor‟s degree	Middle Class 02 (31000-50000)	4	2.13	Rented	Pucca (Concrete + Brick)	51 –100 taka
41	Secondary education (Grade 9-10)	Upper Class 01 (51000-70000)	3	0.446	Rented	Pucca (Concrete + Brick)	51 –100 taka
42	Others (pls. specify)	Upper Class 01 (51000-70000)	7	0.83	Rented	Pucca (Concrete + Brick)	51 –100 taka

43	Others (pls. specify)	Middle Class 02 (31000-50000)	6	0.622	Rented	Pucca (Concrete + Brick)	51 –100 taka
44	Others (pls. specify)	Upper Class 02 (70,000+)	5	1.74	Rented	Pucca (Concrete + Brick)	51 –100 taka
45	Others (pls. specify)	Middle Class 02 (31000-50000)	5	1.052	Rented	Pucca (Concrete + Brick)	51 –100 taka
46	Higher secondary education (Grade 11-12)	Upper Class 01 (51000-70000)	4	1.548	Owned	Pucca (Concrete + Brick)	51 –100 taka
47	Bachelor‟s degree	Middle Class 02 (31000-50000)	3	2.362	Rented	Pucca (Concrete + Brick)	51 –100 taka
48	Higher secondary education (Grade 11-12)	Middle Class 02 (31000-50000)	4	0.954	Rented	Pucca (Concrete + Brick)	51 –100 taka
49	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	3	1.42	Rented	Pucca (Concrete + Brick)	51 –100 taka
50	Higher secondary education (Grade 11-12)	Middle Class 02 (31000-50000)	3	0.9	Rented	Semi-Pucca	51 –100 taka
51	Secondary education (Grade 9-10)	Lower Class (0-10000)	2	1.25	Rented	Pucca (Concrete + Brick)	21 –50 taka
52	Higher secondary education (Grade 11-12)	Upper Class 01 (51000-70000)	4	1	Owned	Pucca (Concrete + Brick)	21 –50 taka
53	Bachelor‟s degree	Middle Class 01 (11000-30000)	6	0.804	Rented	Semi-Pucca	51 –100 taka
54	Bachelor‟s degree	Middle Class 01 (11000-30000)	5	1.262	Rented	Pucca (Concrete + Brick)	51 –100 taka
55	Junior secondary education (Grade 6-8)	Lower Class (0-10000)	5	1.266	Rented	Pucca (Concrete + Brick)	51 –100 taka
56	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	5	1.264	Owned	Semi-Pucca	21 –50 taka
57	Bachelor‟s degree	Middle Class 01 (11000-	4	0.624	Rented	Pucca (Concrete +	51 –100 taka

		30000)				Brick)	
58	Others (pls. specify)	Middle Class 01 (11000-30000)	4	1.04	Rented	Pucca (Concrete + Brick)	51 –100 taka
59	Junior secondary education (Grade 6-8)	Middle Class 01 (11000-30000)	3	0.45	Rented	Semi-Pucca	21 –50 taka
60	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	6	1.422	Rented	Semi-Pucca	21 –50 taka
61	Junior secondary education (Grade 6-8)	Middle Class 01 (11000-30000)	3	0.224	Rented	Semi-Pucca	21 –50 taka
62	Secondary education (Grade 9-10)	Lower Class (0-10000)	8	0.764	Rented	Semi-Pucca	21 –50 taka
63	Junior secondary education (Grade 6-8)	Lower Class (0-10000)	3	0.714	Rented	Semi-Pucca	21 –50 taka
64	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	4	0.53	Rented	Pucca (Concrete + Brick)	21 –50 taka
65	Bachelor‟s degree	Middle Class 01 (11000-30000)	7	0.82	Rented	Pucca (Concrete + Brick)	51 –100 taka
66	Bachelor‟s degree	Upper Class 02 (70,000+)	3	0.52	Owned	Pucca (Concrete + Brick)	51 –100 taka
67	Bachelor‟s degree	Middle Class 02 (31000-50000)	4	0.416	Rented	Pucca (Concrete + Brick)	21 –50 taka
68	Bachelor‟s degree	Middle Class 02 (31000-50000)	3	2.93	Rented	Pucca (Concrete + Brick)	51 –100 taka
69	Master‟s degree	Middle Class 01 (11000-30000)	2	0.456	Rented	Pucca (Concrete + Brick)	51 –100 taka
70	Secondary education (Grade 9-10)	Middle Class 02 (31000-50000)	5	0.94	Owned	Pucca (Concrete + Brick)	51 –100 taka
71	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	3	0.372	Rented	Pucca (Concrete + Brick)	51 –100 taka
72	Bachelor‟s degree	Middle Class	2	0.432	Rented	Pucca	51 –100

		01 (11000-30000)				(Concrete + Brick)	taka
73	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	4	0.256	Rented	Pucca (Concrete + Brick)	51 –100 taka
74	Master‟s degree	Upper Class 01 (51000-70000)	3	0.66	Rented	Pucca (Concrete + Brick)	51 –100 taka
75	Higher secondary education (Grade 11-12)	Middle Class 01 (11000-30000)	6	2.346	Rented	Pucca (Concrete + Brick)	51 –100 taka
76	Bachelor‟s degree	Middle Class 02 (31000-50000)	5	0.806	Owned	Pucca (Concrete + Brick)	51 –100 taka
77	Secondary education (Grade 9-10)	Middle Class 02 (31000-50000)	4	0.798	Rented	Pucca (Concrete + Brick)	51 –100 taka
78	Junior secondary education (Grade 6-8)	Middle Class 02 (31000-50000)	3	1.8	Rented	Pucca (Concrete + Brick)	51 –100 taka
79	Bachelor‟s degree	Middle Class 02 (31000-50000)	4	0.698	Rented	Pucca (Concrete + Brick)	51 –100 taka
80	Bachelor‟s degree	Upper Class 02 (70,000+)	2	0.62	Rented	Pucca (Concrete + Brick)	51 –100 taka
81	Higher secondary education (Grade 11-12)	Middle Class 02 (31000-50000)	4	0.42	Rented	Pucca (Concrete + Brick)	51 –100 taka
82	Bachelor‟s degree	Middle Class 01 (11000-30000)	3	0.858	Rented	Pucca (Concrete + Brick)	51 –100 taka
83	Bachelor‟s degree	Middle Class 02 (31000-50000)	4	0.772	Rented	Pucca (Concrete + Brick)	21 –50 taka
84	Bachelor‟s degree	Middle Class 02 (31000-50000)	3	1.422	Rented	Pucca (Concrete + Brick)	21 –50 taka
85	Bachelor‟s degree	Upper Class 01 (51000-70000)	4	0.758	Rented	Pucca (Concrete + Brick)	21 –50 taka
86	Bachelor‟s degree	Middle Class 01 (11000-30000)	5	0.46	Owned	Pucca (Concrete + Brick)	51 –100 taka

87	Bachelor˝s degree	Lower Class (0-10000)	4	0.62	Owned	Semi-Pucca	21 –50 taka
88	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	3	1.1	Rented	Pucca (Concrete + Brick)	21 –50 taka
89	Bachelor˝s degree	Middle Class 01 (11000-30000)	5	0.892	Owned	Pucca (Concrete + Brick)	21 –50 taka
90	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	4	0.634	Rented	Pucca (Concrete + Brick)	21 –50 taka
91	Bachelor˝s degree	Lower Class (0-10000)	3	0.446	Rented	Pucca (Concrete + Brick)	21 –50 taka
92	Bachelor˝s degree	Middle Class 01 (11000-30000)	3	1.394	Rented	Pucca (Concrete + Brick)	21 –50 taka
93	Bachelor˝s degree	Lower Class (0-10000)	5	0.644	Owned	Semi-Pucca	21 –50 taka
94	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	7	1.3	Rented	Semi-Pucca	21 –50 taka
95	Bachelor˝s degree	Middle Class 02 (31000-50000)	4	0.7	Rented	Semi-Pucca	21 –50 taka
96	Junior secondary education (Grade 6-8)	Lower Class (0-10000)	4	0.28	Rented	Pucca (Concrete + Brick)	51 –100 taka
97	Master˝s degree	Middle Class 02 (31000-50000)	2	0.5	Owned	Semi-Pucca	51 –100 taka
98	Bachelor˝s degree	Middle Class 02 (31000-50000)	5	1.3	Owned	Pucca (Concrete + Brick)	51 –100 taka
99	Master˝s degree	Middle Class 01 (11000-30000)	4	0.97	Owned	Semi-Pucca	51 –100 taka
100	Secondary education (Grade 9-10)	Middle Class 01 (11000-30000)	9	1.4	Owned	Semi-Pucca	51 –100 taka
			432	104.73			
			Avg waste/ person 0.242430556 kgs				

APPENDIX: B

X	Y	X^2	XY				
year	population			References			
1961	362000	3845521	709882000	JICA		b=	236064.3073
1974	1311000	3896676	2587914000	JICA			
1981	2817000	3924361	5580477000	JICA		a=	-464165375.7
1991	3613000	3964081	7193483000	JICA			
2001	8511228	4004001	17030967228	CENSUS 2011			
2011	12043997	4044121	24220477967	CENSUS 2011			
X BAR	Y BAR		SUM X^2				r
1986.5	4776370.833		23678761				0.94773
SUM X	SUM Y		SUM XY	N			r^2
11919	28658225		57323201195	6			0.898
	X BAR ^2						
	3946182						

APPENDIX: C

		WASTE GENERATION			
YEAR [X]	POPULATION (Forecasted) [Y]	**[Y * 0.242430556]** Forecasted (kg)	Waste (Ton)		
2011	10559946.36	2560053.663	2821.975301		
2012	10796010.67	2617282.865	2885.059679		
2013	11032074.98	2674512.066	2948.144056		
2014	11268139.29	2731741.267	3011.228434		
2015	11504203.59	2788970.468	3074.312812	2817	257.3128
2016	11740267.9	2846199.669	3137.39719	1ton= 907.185 kg	
2017	11976332.21	2903428.871	3200.481567		
2018	12212396.51	2960658.072	3263.565945		
2019	12448460.82	3017887.273	3326.650323		
2020	12684525.13	3075116.474	3389.7347		
2021	12920589.44	3132345.675	3452.819078		
2022	13156653.74	3189574.876	3515.903456		
2023	13392718.05	3246804.078	3578.987833		
2024	13628782.36	3304033.279	3642.072211		
2025	13864846.67	3361262.48	3705.156589		
2026	14100910.97	3418491.681	3768.240966		
2027	14336975.28	3475720.882	3831.325344		
2028	14573039.59	3532950.084	3894.409722		
2029	14809103.9	3590179.285	3957.4941		
2030	15045168.2	3647408.486	4020.578477		

APPENDIX: D

- *Biodegradable waste:* Biodegradable wastes are the wastes which are biologically degradable and mainly produced in the kitchen. e.g. vegetables, food waste, fish scales, meat etc.
- *Reusable waste:* These are the wastes, which can be used again after its original use is ended for the same purpose or other use. e.g. reusable bottles, ash from kitchen and reusable bags .
- *Non-reusable waste:* These are the waste, which cannot be used again for the same purpose or other use. e.g. paper, cosmetic bottle etc.
- *Other waste:* These are mainly metals, glass, plastic, can etc

APPENDIX: E

QUESTIONNAIRE FOR SOLID WASTE MANAGEMENT SERVICE SURVEY

Name of Area: _____ Ward No:_____Zone No. _____

Name of HH head (interviewee)	
Home Address	

Educational Level	
1. Never studied in any educational institution 2. Primary education (Grade 1-5) 3. Junior secondary education (Grade 6-8) 4. Secondary education (Grade 9-10)	5. Higher secondary education (Grade 11-12) 6. Bachelor"s degree 7. Master"s degree 8. Ph. D. 9. Others (pls. specify)_____

Type of Area	Type of Development:	Economic Class
1. Newer Urban Area 2. Older Urban Area 3. Old Dhaka 4. Slum Area	1. Planned Developed Area 2. Spontaneously Developed Area	1. Upper Class 02 (70,000+) 2. Upper Class 01 (51000-70000) 3. Middle Class 02 (31000-50000) 4.Middle Class 01 (11000-30000) 5.Lower Class (0-10000)

NOTE: THE INTERVIEWEE MUST BE THE HOUSEHOLD (HH) HEAD.

Data on waste characteristics are available, please complete the following table:

Age limit	Family Member	Total waste (weight)	Component	weight	% By Weight
0-9			Paper		
10-14			Plastic and rubber		
15-24			Organic or vegetables		
24-34			Glass and ceramic		
35-44			Ferrous metal		
45-54			Aluminum		
55-64			Wood		
65+			Textile		
			Garden waste		
			Others		
			Total		

LIVING ENVIRONMENT

Do you own or rent the house you live in?	1. Owned 2. Rented 3. Occupied, rent free 4. Others (pls. specify)_____

What is the house made of?	1. Pucca (Concrete + Brick) 2. Semi-Pucca 3. Kacha (CGI sheet and bamboo) 4. Kacha (Bamboo and straw) 5. Others (pls. specify)_____

WASTE STORAGE AND PRIMARY COLLECTION

Do you have any space to store waste in your house?	1. Yes 2. No
If yes, a. Where do you store the waste?	1. in the house 2. in the garden 3. others (pls. specify)
b. What is the capacity of the waste storage at your house? How many days can you store your waste?	1. sufficient for one day 2. sufficient for two days 3. sufficient for three day 4. sufficient for four days to one week 5. sufficient for more than one week
c. Do you have any problems on waste storage at your house? (multiple answers acceptable)	1. Yes, bad smell 2. Yes, insects such as flies 3. Yes, dirtiness in look 4. Yes, (pls. specify) 5. No problem
Do you segregate your waste?	1. Yes 2.No
If yes, how do you segregate your waste?	
Member of household (Relation with HH head:) _____	2. Servant/maid 3. Others (pls. specify) _____
How does your household dispose of wastes it generates?	
1. Door-to-door collection 2. Dispose to waste bin/container 3. Dumped in vacant land/ river/ marsh	4. Others (pls. specify) _____
If your answer to the above is 1, who collects waste?	
1. NGO 2. Small Local Association /Organized Community 3. Youth Club 4. Private Company 5. Government Staff Association	6. DCC Sweeper 7. Individual person 8. Other (pls. specify) 9. I don"t know
Are you satisfied with the waste collection?	1. Yes 2. No
If you are not satisfied, what are the reasons? (multiple answers acceptable)	
1. Does not collect everyday 2. Collection time is not fixed 3. No door-to-door collection service	4. Other (pls. specify) _____
Do you pay any waste collection fee?	1. Yes 2. No
If yes, how much do you pay monthly?	
1. 1 – 10 taka 2. 11 –20 taka 3. 21 –50 taka 4. 51 –100 taka	5. 100+ taka 6. Other gift (pls. specify) _____
If no, are you willing to pay a waste collection fee?	1. Yes 2. No
a. If your answer to the above is yes, how much are you willing to pay?	

1. 1 – 10 taka 2. 11 -20 taka 3. 21 -50 taka 4. 51 -100 taka	5. 100+ taka 6. Others gift (pls. specify) _____
b. If your answer to the above is no, why?	
1. Time schedule of garbage collection is not good 2. Not satisfied with their work	3. Already paid tax to DCC for these works 4. Others (pls. specify) _____

Year when the data was collected:
Data collected by: ☐ actual survey; ☐ by estimation

Collected by:
Date: