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MUNICIPAL SOLID WASTE AND RECOVERY POTENTIAL: BANGLADESH PERSPECTIVE

[*1]M. Alamgir, [2]A. Ahsan

[1]Department of Civil Engineering, Khulna University of Engineering and Technology, Khulna 920300, Bangladesh

[2]Department of Architecture and Civil Engineering, University of Fukui, 3-9-1 Bunkyo, Fukui 910-8507, Japan

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ABSTRACT

A total of 7690 tons of municipal solid waste generated daily at the six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet, as estimated in 2005. Sampling was done at different waste generation sources such as residential, commercial, institutional and open areas, in different seasons. The composition of the entire waste stream was about 74.4% organic matter, 9.1% paper, 3.5% plastic, 1.9% textile and wood, 0.8% leather and rubber, 1.5% metal, 0.8% glass and 8% other waste. The per capita generation of municipal solid waste was ranged from 0.325 to 0.485 kg/cap/day while the average rate was 0.387 kg/cap/day as measured in the six major cities. The potential for waste recovery and reduction based on the waste characteristics are evaluated and it is predicted that 21.64 million US$/yr can be earned from recycling and composting of municipal solid waste.

Key words: Municipal solid waste, generation, composition, characterization, recovery potential, reduction

INTRODUCTION

Rapid urbanization and population growth are largely responsible for very high increasing rate of MSW generation in the urban areas of Bangladesh, one of the densely populated Least Developed Asian Countries (LDACs). These scenario posses a social, environmental and professional threat for city dwellers, urban planners, development authorities and other concerned stakeholders. In Bangladesh, a major portion of population does not have access to waste collection services and only an insignificant fraction of the generated wastes are actually collected by door-to-door collection system introduced by non-governmental organizations (NGOs) and community based organizations (CBOs) in late 90's against tiny payment. Moreover, due to lack of motivation, awareness, commitment, expertise as well as money a considerable portion of wastes, 40-60%, are not properly stored, collected or disposed in the designated places for ultimate disposal (Ahsan *et al*., 2005). As a result, the unmanageable increasing quantity of MSW creates enormous environmental problems. A feasibility study on the various aspects of integrated management and safe disposal of MSW in LDACs can be found in Alamgir *et al*., (2005). The MSW industry has four components: recycling, composting, land filling and waste to energy (WTE) via incineration (Tchobanoglous *et al*., 1993). Information on the characteristics of MSW is an essen-tial part for the selection of most appropriate system for storage and transport, evaluating equipment needs, determination of the potential for resource recovery, choice of a suitable method for disposal, sustainable management programs and proper planning. Characterization is also important to determine its possible environmental impacts on nature as well as on society. The per capita waste generation and percent composition of various waste components are the two most important types of data for decision makers. This information is necessary in order to identify waste components to target for source reduction and recycling programs, and to

*Corresponding author-Email: *alamgir@ce.kuet.ac.bd*
Tel: +880 41 769468, Fax: +880 41 774780

programs, and to allow technical professionals to design any waste facility such as material recovery facilities (MRF), WTE projects, sanitary landfills, composting facilities, etc.

This paper aims to evaluate the per capita generation, total daily generation, percent composition and reduction in Bangladesh. To meet this demand, sampling was done in different waste generation sources such as residential, commercial, institutional and open areas at six major cities, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet as shown in Fig. 1 in the map

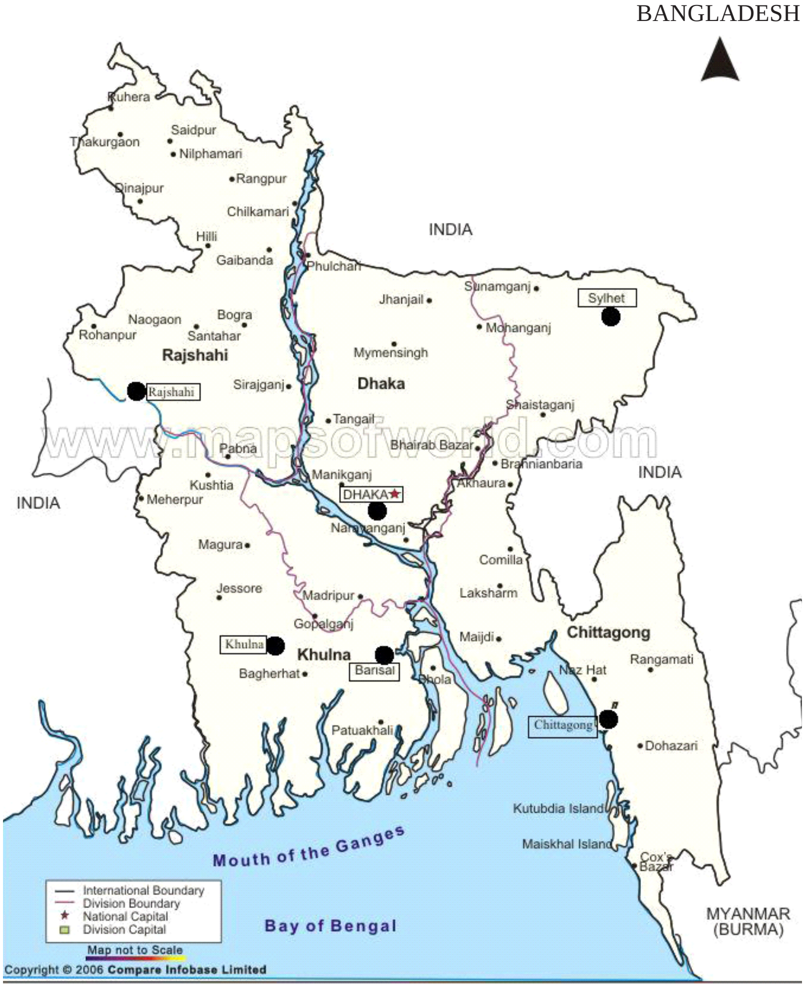

Fig. 1: The location of study cities in the map of Bangladesh

MATERIALS AND METHODS

In conducting a study at local conditions, a variety of waste characterization methods can be used, reported in USEPA (1996). A simple method is sampling for the characterization of MSW. Two approaches or sampling points are generally being used, one is sampling directly from waste generation sources, which is applied for this study and another is sampling from trucks at the disposal sites. Sampling was designed to be three-way stratified for this study because of seasonal and geographical variation can have an impact on waste characteristics. The first level is stratification by geographical regions i.e. by city, while the second is stratification by waste generation sources such as residential, commercial, institutional and open areas (as street sweeping). The third is seasonal stratification. Bangladesh has three main seasons: summer, monsoon and winter. Sampling was designed to take place during these seasons and for simplicity the year is sub-divided into the three seasons. Data were collected from 21 May to 30 June 2004 of season 1, from 1 July to 29 August 2004 of season 2 and from 3 November 2004 to 5 January 2005 of season 3. A total of three hundred and twenty samples were collected during the year of 2004 and 2005 from each city of Bangladesh.

Sample weight

Klee (1980) indicated that the smaller the sample weight the greater the variance of the waste sample composition. He stated that as the sample weight is decreased from approximately 91 kg, the sample variance is increased rapidly, but above that for the weight of approximately 140 kg, the variance decreased much more slowly. He thus recommended a sample weight between 91 and 140 kg. In Bangladesh, about 80% waste components passing through the 100 mm sieve opening (Ahsan, 2005). Because the size of the waste components in the study areas is relatively smaller than the developed countries, it is expected that the smaller amount could adequately represent the characteristics of MSW. Considering this reality of the study areas, the target sample weight for this research was set at 100 kg.

Field protocol

The preliminary survey was conducted to find out 5 representative wards in each city so that the different waste generation sources such as residential, commercial and institutional areas were exist in each ward. Then 5 different income level households were selected in residential areas depending on different socio-economic status and number of household members. A total of 25 households waste generation rates were investigated in each city by supplying 2 different colour bins in each household. One bin for rapidly biodegradable waste and another for slowly biodegradable and non-biodegradable waste. A list of waste separation was pasted on outer surface of each bin and also requested to store the waste separately. Householders accumulate the aside materials also that they would normally give away or sell to itinerant buyers of recyclables, or recycle shops. The daily average generation rate in each household with per capita generation was evaluated. Then estimate the total amount of MSW generation from residential areas by knowing total population in each city. The commercial establishments were categorized as wet market, shopping complex, hotel, restaurant and others. Five wet markets and five shopping complexes were selected in each city and the daily average generation per shop/stall for wet market and shopping complex were evaluated individually. The waste generation rates for hotels and restaurants were also surveyed. Total numbers of wet markets and shopping complexes with number of shops/ stalls, hotels and restaurants within the city areas were collected from city corporation authorities and trade license section. Then estimate the amount of MSW generation from commercial establishments in each city.

In institutional areas, five educational institutions (college/school) and five health care centers (hospital/clinic) were selected in each city. The daily average waste generation per student (for educational institutions) and per bed (for health care centers) were evaluated. Then the total amount of MSW generated in institutional areas by knowing the total numbers of educational institutions with students and health care centers with beds within the city areas were estimated. The waste generation per 100 m of road length for sweeping was determined by selecting five-paved roads (1 km each) in each city. All paved roads were not swept daily. Only certain important paved roads were swept daily, many others were swept on alternate days or twice in a week, and some were swept occasionally or not at all. Total length of daily sweeping paved road (average) was collected from the respective city authority and then estimate the total generation for sweepings in each city. Finally the total MSW generation from residential, commercial, institutional areas and for street sweepings was determined for each city. Table 1 shows the solid waste sampling sources and frequency in each city.

Laboratory protocol

The weight of collected waste samples were measured in laboratory and then transported to the designated shed for sorting. Twenty-two targeted sorting categories were selected for the collected samples. The composition was then categorized into eight major categories: organic matter, paper, plastic, textile and wood, leather and rubber, metal, glass and other (After AIT, 1991) as shown in Table 2. Portions of the waste were placed on a sorting table and sorted manually, then placed into the identified containers. An estimation of wetness of the sample was made and each container was weighed after the completion of sorting. Standard personnel safety procedures were followed during the sorting process such as wearing gloves, apron, safety glasses and boots, etc.

Table 1: Solid waste sampling sources and frequency in each city

Generation sources	Sampling sources	Sampling frequency	Total number of samples per source
Residential:			
High socio-economic (A)	5	7	35
Middle upper socio- economic (B)	5	7	35
Middle socio- economic (C)	5	7	35
Middle lower socio- economic (D)	5	7	35
Low socio- economic (E)	5	7	35
Commercial:			
Wet market	5	7	35
Shopping complex	5	7	35
Institutional:			
College/school	5	5	25
Hospital/clinic	5	5	25
Street sweeping	5	5	25
Total			320

Table 2: Waste composition category (after AIT, 1991)

Waste category	Waste components
Organic matter	Waste from foodstuff such as food and vegetable refuse, fruit skin, stem of green, corncob, leaves, grass and manure.
Paper	Paper, paper bags, cardboard, corrugated board, box board, newsprint, magazines, tissue, office paper and mixed paper (all paper that does not fit into other category).
Plastic	Any material and products made of plastics such as wrapping film, plastic bag, polythene, plastic bottle, plastic hose and plastic string.
Textile and wood	Has its origin from yarn, wood and bamboo such as cotton, wool, nylon, cloth, desk, chair, bed board, toy and coconut shell.
Leather and rubber	Any material and products made of rubber or leather such as ball, shoes, purse, rubber band and sponge.
Metal	Ferrous and non-ferrous metal such as tin can, wire, fence, knife, bottle cover, aluminium can and other aluminium, foil, ware and bi-metal.
Glass	Any material and products made of glass such as bottles, glassware, light bulb and ceramics.
Other	Yard waste, tyres, batteries, large appliances, nappies/sanitary products, medical waste, miscellaneous*.

*Dust, ash, shell, bone, straw, rope, brick, stone pottery and fines (pass through 63-mm opening sieve).

RESULTS

MSW generation

Table 3 shows the income level based per capita generation at residential areas in six major cities of Bangladesh. The average highest generation rate was found to be 0.368 kg/capita/day at residential areas in Dhaka whereas the lowest was 0.259 kg/capita/day in Barisal. The mean generation rate in residential areas as obtained as 0.309 kg/capita/day for six cities of different income level with different living standard.

As shown in Table 4, a total of 7690 t of waste generated daily in the six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet as estimated in the year of 2005. The Dhaka city contributed the major portion (69%) to the total waste stream, which amounted as 5340 t. The Dhaka and Chittagong city contributed approximately 87% (6655 t) of the waste stream. The overall socio-economic condition of the country is also very much responsible for the very high percentage of organic matter. The generation rate was ranged from 0.325 to 0.485 kg/cap/day, while highest generation rate was 0.485 kg/cap/day in Dhaka city, lowest generation rate was 0.325 kg/cap/day in Barisal city and the weighted average was 0.387 kg/capita/day for six major cities. Table 5 presents the contribution of different sources in total generation of MSW, where nearly 78% of generated waste came from the residential sector, 20% came from the commercial sector, 1% from the institutional sector and rest from other sectors.

Table 3: Per capita generation at residential areas in six major cities of Bangladesh

Income level	Per capita generation (kg/day)						
	DCC	CCC	KCC	RCC	BCC	SCC	Average
A	0.504	0.378	0.368	0.343	0.327	0.429	0.392
B	0.389	0.343	0.333	0.320	0.278	0.395	0.343
C	0.371	0.350	0.319	0.242	0.247	0.340	0.312
D	0.305	0.253	0.264	0.309	0.269	0.248	0.275
E	0.270	0.189	0.203	0.239	0.172	0.260	0.222
Average	0.368	0.303	0.297	0.291	0.259	0.334	0.309
SD	0.090	0.079	0.065	0.047	0.057	0.080	0.070

DCC-Dhaka City Corporation. CCC-Chittagong City Corporation. KCC-Khulna City Corporation. RCC-Rajshahi City Corporation. BCC-Barisal City Corporation. SCC-Sylhet City Corporation. SD-Standard deviation.

Table 4: Component weight of MSW generated in six major cities of Bangladesh

Waste category	MSW generation (ton/day)						All waste stream
	DCC	CCC	KCC	RCC	BCC	SCC	
Organic matter	3647	968	410	121	105	158	5409
Paper	571	130	49	15	9	18	792
Plastic	230	37	16	7	5	8	303
Textile & wood	118	28	7	3	2	5	163
Leather & rubber	75	13	3	2	1	1	95
Metal	107	29	6	2	2	2	148
Glass	37	13	3	2	1	2	58
Other	555	97	26	18	5	21	722
Total	5340	1315	520	170	130	215	7690
Population (million)	11.00	3.65	1.50	0.45	0.40	0.50	-
Per capita (kg/day)	0.485	0.360	0.347	0.378	0.325	0.430	0.387*

*Weighted average

Table 5: Contribution of different sources in total generation

Sources	MSW generated daily from different sources (%)						Weighted average
	DCC	CCC	KCC	RCC	BCC	SCC	
Residential	75.9	83.8	85.9	77.2	79.6	78.0	78.1
Commercial	22.1	13.9	11.6	18.6	15.5	18.5	19.7
Institutional	1.2	1.1	1.0	1.2	1.5	1.3	1.2
Street sweeping	0.5	0.5	0.6	1.2	1.2	0.8	0.6
Other	0.4	0.6	1.0	1.8	2.3	1.4	0.5
Total	100	100	100	100	100	100	100

MSW composition

The waste composition for the entire waste stream of six major cities in the year of 2005 is shown in Table 6. The percentage composition of waste combined from all locations was about 74.4% organic matter, 9.1% paper, 3.5% plastic, 1.9% textile and wood, 0.8% leather and rubber, 1.5% metal, 0.8% glass and 8% other waste. The biodegradable fraction (organic matter) is normally very high as compared to other fractions, essentially due to the use of fresh vegetables and foods, which is common in each city. There is a little variation in percent composition for different cities. Organic matter ranges from 68 to 81% for the six cities, while paper and plastic are about 7 to 11% and 3 to 4%, respectively. Glass, leather and rubber were the smallest composition for all locations.

Table 6: Composition of MSW generated

Waste category	MSW composition (% by wet wt.)						All waste stream
	DCC	CCC	KCC	RCC	BCC	SCC	
Organic matter	68.3	73.6	78.9	71.1	81.1	73.5	74.4
Paper	10.7	9.9	9.5	8.9	7.2	8.6	9.1
Plastic	4.3	2.8	3.1	4.0	3.5	3.5	3.5
Textile & wood	2.2	2.1	1.3	1.9	1.9	2.1	1.9
Leather & rubber	1.4	1.0	0.5	1.1	0.1	0.6	0.8
Metal	2.0	2.2	1.1	1.1	1.2	1.1	1.5
Glass	0.7	1.0	0.5	1.1	0.5	0.7	0.8
Other	10.4	7.4	5.1	10.8	4.5	9.9	8.0
Total	100	100	100	100	100	100	100

Comparison between seasons

Table 7 presents a summary of the annual mean weight fractions, which sorted into the eight waste categories for each of the three seasons. Season 1 to be related to summer, hot weather and fruits season (when jackfruit, mangoes and other summer fruits are available) also the organic fraction is relatively high than winter season. Season 2 is the monsoon season and the end of the fruit season, when heavy rains were occurred. All waste components are in wet state hence the bulk density is increased. The last season is winter designated here as season 3 could be related to special winter events, holiday activities and good weather. One might expect that seasonally sorted mean weight fractions would vary; however, the influence of seasonal variation on MSW composition is insignificant, as some factors influence the increase of wastes generation, while the other factors tend to reduce.

Table 7: Mean weight fractions of the various components of MSW in different seasons

Seasons	Mean weight fraction							
	Organic matter	Paper	Plastic	Textile and wood	Leather and rubber	Metal	Glass	Other
Summer	0.761	0.086	0.031	0.017	0.008	0.018	0.007	0.072
Monsoon	0.779	0.077	0.037	0.016	0.009	0.010	0.008	0.064
Winter	0.693	0.111	0.036	0.023	0.006	0.017	0.009	0.105
Annual mean	0.744	0.091	0.035	0.019	0.008	0.015	0.008	0.080

Comparison with other studies

Composition: Several studies have been conducted in Dhaka city to determine the composition of generated MSW. A comparison of the present study with other studies is presented in Table 8. There was no reporting about number of samples taken, the selection criteria, sampling design and data analysis method, etc. in previous studies. Since MSW from different sources is typically dumped into the same container/truck, the waste obviously gets mixed. The waste components analyzed in each study were different and regrouped to match the components. Organic matters were varied over a wide margin ranging from about 62 to 88% during the period of 1993-2003 in Dhaka city, whereas paper and plastic vary from about 1 to 10% and 1 to 7%, respectively, as reported in the previous studies.

Table 8: Comparison of composition with other studies in Dhaka city

Data sources	Composition (% by wet wt.)							
	Organic matter	Paper	Plastic	Textile and wood	Rubber and leather	Metal	Glass	Other
Rahman, 1993	65-88	1-7	1-2	1-2				7-15[a]
BCSIR, 1998[1]	70.0	9.2	5.0	0.2	1.1	0.1	0.25	14.2
BCSIR, 1998[2]	65.8	4.1	6.8	6.4	0.7	6.0[b]		10.2
BCSIR, 1998[3]	62.3	4.7	5.4	7.4	0.2	1.2[b]		18.8
BCSIR, 1998[4]	73.7	3.4	3.5	3.6	1.2	6.8[b]		7.8
BCSIR, 1998[5]	67.2	9.6	5.1	4.7	0.8	2.9[b]		9.7
Moqsud, 2003	80.0	8.0	6.0	0.5	0.5	2.0[b]		3.0
Present study, 2005	68.3	10.7	4.3	2.2	1.4	2.0	0.7	10.4

[a]Includes glass, metal and other [b]Includes metal, glass and woods [1]Mirpur areas [2]South Kamlapur areas [3]Mugda fish wholesale market areas [4]Matuail areas [5]Kachukhet bazaar areas.

Per capita waste generation:

In order to determine per capita generation from an estimated of total generation of waste, one would require a good estimation of the population. Conversely, if reasonable estimations (present and future) of per capita generation are available, one could estimate present and future generation of wastes from reliable estimation of present and future population. However, there appears to be considerable differences among researchers on the estimation of city population. Reported per capita waste generation was varied over a high range from 0.26 to 0.83 kg/capita/day during the period of 1990-2004 for Dhaka city as presented in Table 9. There is a wide variation in the estimation of waste generation as well as of population in all previous studies. Based on the 1981 and 1991 census data, BCSIR (1998) calculated a compound growth rate of 2.8% for Dhaka city and estimated a population of 4.64 million for the year of 1998. With an estimated daily generation of 2398 tons, this gives a per capita generation of 0.52 kg/day. In addition, the per capita generation reported in 1990 (by DIFPP-Dhaka Integrated Flood Protection Project) and 1997 (by PASL-Pan Asia Services Ltd.) is very high than recent studies due to the inclusion of industrial and constructional waste streams with MSW.

DCC (1999), on the other hand, reported a population of 7 million for Dhaka city, which is almost 1.5 times higher than that of the estimated value of BCSIR (1998). However, DCC estimated the waste generation is 3500 ton/day where per capita generation rate is 0.50 kg/day, which is very close to the value reported by the BCSIR (1998). However in the year of 2000, JICA reported a population of 9.5 million for Dhaka city and per capita generation is 0.50 kg/day, which is very close to the present study. Assuming an annual GAP (gross area product) of 4% and assuming that 70% of the additional income would go into consumption, a waste generation growth factor of 2.8% (= 0.70 × 4) was estimated by BCSIR (1998). Based on this growth rate, waste generation rate was estimated as 0.52 kg/capita/day in the year of 1998.

Potential for recovery and reduction

Hereafter, the potential for waste recovery and reduction is discussed from the view of market value. Table 10 presents the market values for recoverable materials in the waste stream of Bangladesh. Recycling is the reprocessing of wastes, either into the same material (closed loop recycling) or a different material (open loop recycling). Another form of recycling is composting. Controlled biological decomposition process of organic waste into humus, a soil-like material is known as composting. The prices were obtained from national associated recycler, compost producer and retailer of Bangladesh.

The total weight of recyclable and compostable materials was 2,488,185 t (6817 t/d) in the six major cities of Bangladesh in 2005. The average recovery rate is 70%, experienced of national associated recycler. Then the recovered materials are 4772 t/d (= 6817 × 70%) and the revenue is 213,097 $/d or 77,780,430 $/yr as shown in Table 10. The cost of recycling is the sum of the capital and operating cost (O&M) of the material recovery centre (MRF). Although detailed costs vary by community, the configuration of the MRF and many other factors, one can make preliminary estimation from the general average cost data. The typical unit capital cost for a low-tech MRF is $10,000 per ton of daily capacity (Tchobanoglous and Kreith, 2002). The waste generated from the six major cities of Bangladesh is 7690 t/d (2,806,850 t/yr) as shown in Table 4. Thus, the capital cost for an MRF is approximately $76,900,000 (= 7690 × 10,000). The typical O&M cost for a low-tech MRF is 20 $/t. Thus, the O&M cost for an MRF would be 153,800 $/d (= 7690 × 20). Revenues thus exceed costs by 59,297 $/d (= 213,097 – 153,800) or 21,643,430 $/yr (not considering the time value of money within the year). The revenues from one year of operation would pay for the construction of the MRF.

The long-term implications of recycling can be seen from considering the present worth of the value of revenue minus O&M cost. One can convert an annual value to a present worth value using standard economic tables if the life of a facility and an interest rate are specified (Grant *et al.*, 1982). Present worth values for the revenues over cost are shown in Table 11 for various facility lives and interest rates. The present worth of the

Table 9: Comparison of per capita generation with other studies in Dhaka city

Data sources	Population (million)	MSW amount (ton/day)	Per capita generation (kg/day)
DCC, 1985[a]	-	1776	-
HDP, 1986	-	1040	-
DIFPP, 1990	3.0	2500	0.83
WHO, 1990[a]	3.0	2210	0.73
MML, 1991	3.4	1300	0.38
JICA, 1991[a]	3.4	1540	0.45
BCAS, 1991[a]	3.4	1590	0.47
PASL, 1997	4.2	3000-5000	0.71 - 1.19
RSWC, 1998	4.6	1200-1600	0.26 - 0.34
BCSIR, 1998	4.6	2398	0.52
DCC, 1999	7.0	3500	0.50
JICA, 2000	9.5	4750	0.50
JICA, 2004[b]	10.0	5000	0.50
Bhorerkagoj, 2004	10.0	4000-5000	0.4 - 0.5
Present study, 2005	11.0	5340	0.48

HDP-Housing Development Project. DCC-Dhaka City Corporation. DIFPP-Dhaka Integrated Flood Protection Project. WHO-World Health Organization. MML-Mott Macdonald Ltd. JICA-Japan International Cooperation Agency. BCAS-Bangladesh Centre for Advanced Studies. PASL-Pan Asia Services Ltd. RSWC-ROTEB Solid Waste Consultancy. BCSIR-Bangladesh Council of Scientific and Industrial Research.
[a]As quoted in Ali, 2001
[b]Forecasting value of JICA (2000) for 2004

Table 10: Recoverable materials in MSW of Bangladesh

Recyclable items	2006 price (US$/t)	Weight (t)	Recovered weight[b] (t)	Market value (US$)
Recyclable materials[a]				
Paper				
Newspaper loose	80	135,800	95,060	7,604,800
Book loose	40	57,800	40,460	1,618,400
Office mixed loose	50	69,300	48,510	2,425,500
Magazine loose	100	26,000	18,200	1,820,000
Plastic				
Hard plastic	30	66,300	46,410	1,392,300
Soft plastic	100	33,100	23,170	2,317,000
Pet bottles	40	11,000	7,700	308,000
Metal				
Ferrous metal	70	34,000	23,800	1,666,000
Aluminium items	150	10,800	7,560	1,134,000
Steel items	80	9,100	6,370	509,600
Leather & rubber				
Leather	50	19,700	13,790	689,500
Sponge/Rubber	60	14,900	10,430	625,800
Glass				
Broken glass	15	13,100	9,170	137,550
Bottle glass	20	8,000	5,600	112,000
Bone	40	5,000	3,500	140,000
Sub-total		513,900	359,730	22,500,450
Compostable materials[c]				
Organic matter	80	1,974,285	1,382,000	55,279,980[d]
Total		2,488,185	1,741,730	77,780,430

[a]Price is obtained from associated recyclers: Shahin & Sons Recycling Industry (SSRI), Khulna, Bangladesh.
[b]70% of the weight is recoverable, experienced of SSRI.
[c]Price is obtained from associated compost producer and retailer: Prodipan (NGO), Khulna, Bangladesh.
[d]50% of the recovered organic matter can be converted into compost product (80 × 1,382,000 × 50% = 55,279,980), experienced of Prodipan.

revenues minus O&M cost far exceeds the capital cost, even considering short facility lives and high interest rates. Present worth value mainly changes with present worth factor, which also closely related to interest rates and facility life. For facility life of 20 years, present worth value may be increased about three times, when present worth factor increased as four times. In the same way,

Table 11: Present worth values for excess of revenues over O&M costs

Facility life (years)	Interest rate (%)	Present worth factor	Excess of revenues (million US$/yr)	Present worth[a] (million US$)
20	20	4.870	21.643	105.404
	10	8.514		184.272
	5	12.462		269.720
	2	16.351		353.892
10	20	4.192	21.643	90.729
	10	6.144		132.977
	5	7.722		167.131
	2	8.983		194.423

[a]Present worth = present worth factor × excess of revenues (US$/yr)

present worth value for facility life of 10 years may be increased about two times, when present worth factor is increased by two times. Such present worth would still show the value of recycling even if revenues were less than calculated above or if excess costs associated with bags or bins for recyclable collection were considered.

DISCUSSION

In high socio-economic family, daily waste generation rates were generally higher than the other lower socio-economic families. The per capita generation rate was ranged from 0.325 to 0.485 kg/cap/day, while the average rate was 0.387 kg/cap/day for the six major cities. A total of 7690 t of MSW generated daily in the six major, while the Dhaka city contributed the most (69%, 5340 t) to the total waste stream. In six major cities, it is observed that the organic matters are usually the predominant component in the waste stream, which ranged from 68 to 81% due to the common habit of fresh food consumption, while paper and plastic are about 7 to 11% and 3 to 4%, respectively. The glass, leather and rubber were the smallest composition in each city. Statistical analysis indicates that the waste characteristics are slightly different with respect to geographical regions and the influence of seasonal variation is insignificant.

There is a little variation of other waste characterization studies with compared to the present study due to different local conditions, methodologies, scope and waste component definitions. Composition of MSW is also positively related to other several influencing factors which are changed with time. The important factors are public attitude, population density, habits and custom of living, life styles, economic conditions, fruit seasons, climate, recycling and waste management program, all have a great impact on the waste composition. In addition, there was also a lack of a standard definition for waste sorting categories. Thus, each study defines some of their waste categories differently from other study. There was no reliable study conducted in other major cities of Bangladesh except Dhaka, so comparison could not be possible for other cities. However, recycling and composting are the great prospective sectors and have immense possibilities to earn revenue for integrated and sustainable waste management as well as environmental benefits. It is also evaluated that the revenue can be earn 21.64 million US$/yr from MSW for six major cities of Bangladesh. Nevertheless, this is just estimation, many factors are community specific. The cost of waste collection is not included because it would be incurred whether the waste is recycled or landfilled. But the collection cost should be included for the remaining uncollected waste, which are improperly disposed on roadside ditches or other vacant places. The waste that used to be discarded need to be recovered and managed in a sustainable way. It would be more appropriate, if the cost data of low-tech MRF and O&M of developing countries can be used for estimating the revenues. The USEPA (1996) recommends that recycling be the top priority option used in an integrated solid waste management system. Economical feasibility is not the only factor that drives the waste management system. A sustainable waste management system also needs to be environmentally sound and socially acceptable.

In low-income countries like Bangladesh, much inorganic waste (such as plastic, metal, glass, etc.) is partially recycled by mainly informal sectors, while NGOs take the lead in composting of organic portion in limited scale and the recycling sector is not touched yet. Nonetheless, much of the organic portion as well as other, value-less waste remains a major problem. This often constitutes more than half by weight of the total MSW generated and requires costly removal and disposal (Ali, 2004). Frequently, the failure of under-resourced authorities to collect waste leads to unpleasant city conditions and decomposing waste constitutes in improper places create a serious health and environmental hazard. Therefore, proper initiative should be taken in these great potential sectors as well as attention is also need to be paid to the potential economic and environmental benefits of reducing waste through integrating the role of non-government recyclers, NGOs, CBOs, local and national government authorities.

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