Journal of ENVIRONMENTAL Treatment Techniques

J. Environ. Treat. Tech.
ISSN: 2309-1185

Journal web link: http://www.jett.dormaj.com

Solid Waste Management in Commercial City of Bangladesh

Satyajit Roy Das[1], Md. Lokman Hossain[2,*], Snigdha Talukder[1], Mohammed Kamal Hossain[3]

1- Assistant Commissioner and Executive Magistrate, Office of Deputy Commissioner, Gazipur, Bangladesh
2- Faculty of Biology, Chemistry and Geosciences, University of Bayreuth, D-95440 Bayreuth, Germany
3- Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh

Received: 19/09/2014 Accepted: 28/02/2015 Published: 30/03/2015

Abstract

Solid wastes production and their disposal has become a matter of great concern in developing countries. Bangladesh is no exception to it. The study was conducted to assess the present waste management system in Chittagong City Corporation. The study revealed that the lack of resources such as financing, infrastructure, suitable planning and data, and the leadership are the main barriers in municipal solid waste management in Chittagong. Although the present municipal solid waste management (MSWM) scenario is far from satisfactory, several findings and estimations in the study revealed that there are sufficient opportunities to handle and improve the situation. The study recommends that institutional/ organizational strengthening of the conservancy section should be given the top priority as without proper set-up, adequate manpower and equipment it will not be possible to achieve the desired improvements.

Key words: Solid waste, waste collection, waste disposal, primary collection, waste management

1 Introduction

Municipal solid waste (MSW) disposal is a global concern [1], most especially in developing countries across the world, as poverty, population growth and high urbanization rates combine with ineffectual and under-funded governments to prevent the efficient management of wastes [2, 3]. MSW management systems are becoming more complex in many countries with movement from landfill-base systems to resource- recovery-based solutions [4,5]. Cities in developing countries are confronting a twin dilemma namely rapid growth of urban population resulting in increased demand of waste management services and poorly developed traditional public sector to the growing demand for such services [6]. The issue of poor solid waste management (SWM) has become a challenge for governments of developing countries in Asia and Africa [7-11]. Hence, this has huge consequences in terms of collection, disposal and the elimination of waste [12, 13]. Improper SWM is considered to be one of the most burning and serious environmental problems in developing countries like Bangladesh [14]. The progress of modern civilization and the associated increase in population worldwide has contributed significantly to the increase in the quantity and variety of waste generated. SWM is a multidimensional challenge faced by urban authorities, especially in developing countries like Bangladesh [15]. It is an integral part of the urban environment and planning of the urban infrastructure to ensure a safe and healthy human environment while considering the promotion of sustainable economic growth. The management of MSW is a highly neglected area of the overall environmental management in most developing countries. SWM systems in developing countries must deal with many difficulties, including low technical experience and low financial resources which often cover only collection and transfer costs, leaving no resources for safe final disposal, these factors are further exacerbated by inadequate financial resources, and inadequate management and technical skills within municipalities and government authorities. Developing nations are now seriously concerned with the consequences of improper handling of MSW [16]. MSW management in most low and middle income countries draws on a significant proportion of the municipal budget, yet current practices pose a serious threat to the environment and to public health and well being. This may result in such consequences as pollution, reduction of aesthetic values and economic losses due to failures in recycling and composting valuable components of MSW. Furthermore, poor management of solid waste (SW) may result in serious urban, sanitary and environmental problems such as an unpleasant odor and the risk of explosion in landfill areas, as well as groundwater contamination because of leachate percolation [17].

Municipal waste (MW) includes domestic as well as commercial and industrial refuge, street sweepings and construction and debris [18]. In the developed world, for example the USA, industrial refuge is not a part of

Corresponding author: Md. Lokman Hossain, Faculty of Biology, Chemistry and Geosciences, University of Bayreuth, D-95440 Bayreuth, Germany, E-mail: lokmanbbd@gmail.com, Cell: +4915217901197

municipal refuge. In the developing countries, MW may include industrial waste but domestic wastes generally account for between 60% and 80% of total MSW. Currently, a gigantic volume of MSW is generated every day in the big cities of Bangladesh and consequently, a blocking created between demand and supply for MSW management in most of the urban bodies. In high income countries, though MSW can be around 3000 grams per capita daily, in low-income countries it is sometimes around only 300 grams per person daily. In some south Asian cities, for example, in Karachi, daily average per capita SW amounts to around 700 grams and in Calcutta it is 500 grams. In Dhaka and Chittagong cities it is 350 grams per person per day [18]. The major constituents of SW originating in the cities of the developed countries are non-biodegradable packaging materials and containers. In contrast, vegetables and putrescibles make up between 40-85% of total MWs in low-income countries; whereas, for mid and high-income countries is 20-65% and 20-50%, respectively. The major constituents of waste in Dhaka and Chittagong cities are organic and compostable materials [18].

1.1 MSW scenario in different Asian countries

The quantity of SW generation is mostly associated with the economic status of a society. Accordingly, Table 1 shows GDP together with waste generation rates for some of the largest Asian countries. It can readily be seen that waste generation rates are lower for developing economics that have lower GDP.

1.2 MSW: Bangladesh perspective

Total number of urban areas in Bangladesh is 514, which includes 11 City Corporations, 298 Pouroshavas (Municipalities) and the rest are urban centres. Table 2 depicts total waste generated in the urban areas of Bangladesh per day is 13,332.89 tons. Based on the total estimated urban population of the year 2005, per capita waste generation rate is computed as 0.41 kg/capita/day (Table 2). In order to deal with the prevailing situation in a planned way, proper study is required to analyze the MWM scenario of Bangladesh [19]. Recent information on MSW both at national [14, 18-30, 34-36; and international level [16, 31, 32] considering municipal solid waste management. A number of studies have been conducted in Bangladesh and few studies have also been conducted in Chittagong on the issue of waste management. But an integrated study enveloping manifold aspects of waste management have got little focus in previous studies. This research gap has created proclivity in present researchers to conduct a research on the issue.

Table 1: Current urban MSW generations in some Asian countries

Country	GDP per capita estimated for 2007 (USD)	Waste generation (Kg/ capita/day)
Hong Kong	37,385	2.25
Japan	33,010	1.1
Singapore	31,165	1.1
Taiwan	31,040	0.667
South Korea	23,331	1.0
Thailand	12,702	0.5-0.8
Malaysia	9426	1.1
China	8854	0.8
Philippines	5409	0.3-0.7
Indonesia	5096	0.8-1
Srilanka	5047	0.2-0.9
India	3794	0.3-0.6
Vietnam	3502	0.55
Lao PDR	2260	0.7
Nepal	1760	0.2-0.5

Source: [33]

Table 2: Estimated quantities of SWG in Bangladesh

City /Town	Total population	Waste Generation Rate (kg/cap/day)	Average Total Waste Generation (TWG) (ton/day)
Dhaka	6,728,404	0.56	4,634.52
Chittagong	2,622098	0.48	1,548.09
Rajshahi	468,378	0.3	172.83
Khulna	967,365	0.27	321.26
Barisal	437,009	0.25	134.38
Sylhet	386896	0.3	142.76
Pourashavas	15,214,306	0.25	4,678.40
Other Urban Centers	9,217612	0.15	1,700.65
Total	36042,067	0.41 (avg)	13,332.89

Source: [19]

2 Methodology

The study was based on secondary information collected from various sources like; Chittagong city corporation (2000-2009), Bangladesh Bureau of Statistics (2000-2009), Department of Environment (Chittagong divisional office) (2005-2009), Japan International Cooperation Agency (JICA) (2005), and Waste Concern (2000-2005). Apart from these, various documents published scientific papers, books, and articles pertaining the WM information of last ten years of Chittagong were critically reviewed and significantly utilized during the present study.

3 Results and Discussion

3.1 Waste Management

3.1.1 Primary collection

Primary waste collection system

In Chittagong city, waste collection consists of two parts, namely primary collection and secondary collection (Figure 1). CCC is responsible for secondary waste collection to remove waste from its dustbins/containers, and transport the waste to final disposal sites. Residents are responsible for bringing their waste to CCC's waste collection points where dustbins/containers are located. NGO/CBOs/private sector provide primary collection services to collect waste door-to-door and transport the waste to dustbins/containers, or sometimes to vacant lands, by rickshaw vans. At present, NGOs/ CBOs/ private initiative primary collection services are prevalent in wide areas of Chittagong city.

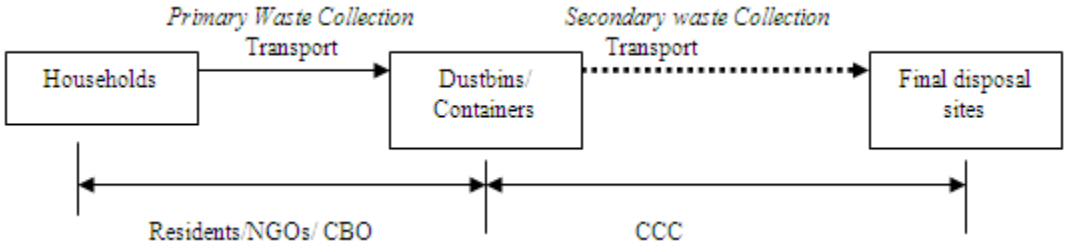

Figure 1: Waste Collection System in Chittagong City

3.1.1.2 Responsibility of primary collection according to Chittagong City Corporation Ordinance

Chittagong City Corporation Ordinance is the basic law regarding street/drain cleaning, waste collection and transportation. According to section 93 of the ordinance, CCC is allowed to provide dustbins or other receptacles at suitable places, and to required residents to bring their waste to the dustbins or receptacles. However, it is not clearly mentioned who takes responsibility of primary waste collection where such dustbins or receptacles are not provided.

3.1.1.3 NGO's, CBOs and private initiatives in primary collection

Recently door –to-door waste collection activities are prevailing in Chittagong city, due to high pressure of population growth. Various local civil societies or CBOs duplicated the system of door-to-door collection introduced in Sugandha in 1997 that uses rickshaw van. It is difficult to grasp the accurate overall number of the organizations/persons engaged in door-to-door waste collection or the coverage of their services in Chittagong city. A variety of organizations and individual persons are working in this field in large to small scale, in many cases using only one or two rickshaw vans, and the number is still increasing. At present 6 NGOs and 57 CBOs work in primary solid waste collection throughout 41 wards. Primary collection is a labour-intensive work that uses rickshaw vans usually manned with one van driver and one or two helpers. They go to each house, collect waste from residents and put the waste into the rickshaw van. In some areas, residents bring their waste to rickshaw vans using buckets/bags by themselves. After collecting waste from house-to-house, the rickshaw drivers and helpers dispose of the waste in CCC dustbins/containers, or at vacant lands.

3.1.1.6 Services coverage of primary collection at the ward level

At present, various types of coverage of primary collection service working at the ward level.

Type A: Full coverage by one to two NGOs,

Type B: Partial coverage by various local organizations,

Type C: Full coverage by various local organizations,

Type D: Informal door-to-door collection by CCC cleaners, and

3.1.1.4 CCC Initiative in Primary Waste Collection

In 2004, CCC introduced primary waste collection initiative for providing door-to-door waste collection services ward-wide for few specific ward. Those activities regulated under the supervision of the respective ward councilor. CCC do not has any approvals system for giving approvals to the NGOs, CBOs/ Private organization. There has no coordination between CCC and NGOs/CBOs/ private organization that provide primary solid waste collection services.

3.1.1.5 Role of ward councilor in primary collection:

Ward commissioners/ female councilors are a key in the local level activities. Ward councilor play important roles in mediation and coordination among different organizations. Ward councilor supports the organizations to implement the activities and in some wards, they themselves are taking initiatives to provide door-to-door waste collection services in their wards.

Type E: No primary collection services.

3.1.2 Secondary Collection/ Transport and Road cleaning

3.1.2.1 Task of CCC

Chittagong City Corporation Ordinance is the basic law regarding street/drain cleaning, waste collection and transportation. According to section 93 of the ordinance, CCC is allowed to provide dustbins or other receptacles at suitable places, and to required residents to bring their waste to the dustbins or receptacles. CCC is responsible for secondary waste collection to remove waste from its

dustbins/containers, and transport the waste to final disposal sites.

3.1.2.2 Relevant organizations

3.1.2.2.1 Conservancy department

Conservancy department is the core organization for solid waste management and is in charge of street and drain cleaning, carrying street and drain waste to dustbins/containers, and loading and unloading of waste to and from truck at places of dustbins/containers and disposal sites (Figure 2). Conservancy department comprises a predominant portion of field workers and very few officers for planning and administration at City Corporation.

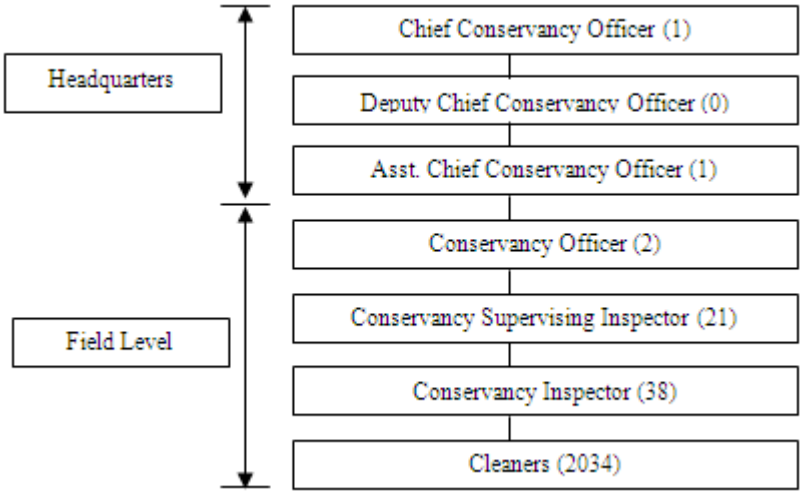

Figure 2: Organogram of Conservancy Department (Source: CCC)

3.1.2.2.2 Transport department

Transport department comprises two parts: one for operation of vehicles of CCC and the other for management of bus and truck terminals. The part for vehicle operation is composed of central pool and conservancy pool. The conservancy pool is in charge of transportation of waste from dustbins/containers to disposal sites. Transport department also consists of a large portion of field staff and a small number of officers at City Corporation. The number of drivers in the conservancy pool is less than the number of open trucks and container carrier. Some drivers are working two shifts to cover the insufficiency.

3.1.2.2.3 Engineering department

Engineering department is involved in solid waste management for repair of transport vehicles, while mechanical division 1 is in charge of repair of transportation vehicles, while mechanical division 2 is undertaking repair of heavy equipment operating disposal sites. Major repair works of transport vehicles are outsourced to private workshops with contracts. Foreman of mechanical division 2 gives a kind of instruction to heavy equipment operators, who also belong to the division. Mechanical division 1 also is in charge of manufacturing steel containers at demands of the conservancy department.

3.1.2.2.4 Store and purchase department

Store and purchase department procures conservancy appliances, such as brooms and baskets, at the demand of the conservancy department. Store and purchase department also purchases spare parts for vehicles and equipment.

3.1.3 Deployment of Manpower allocation to collection and transport sector

3.1.3.1 Regulatory Basis of Deployment

There are neither regulations, by- laws/guidelines of dustbins and container nor public notice. According CCC officers, ward councilor makes a request to the Mayor for the installation of such receptacles. When the mayor approves the request, the order is given to the conservancy department to install them. The conservancy department then asks engineering department to install them. The conservancy department then asks engineering department to construct new dustbins or to install containers. Deployment of additional conservancy vehicles/drivers as well as additional cleaners also starts with requests by ward councilors, followed by the approval of the Mayor.

3.1.3.2 Manpower allocation to collection and transport sector

Manpower allocation is summarized by assignment in table 3. Drivers belong to transport department and cleaners are under conservancy department.

3.1.3.3 Task of cleaners and actual condition of work

There are five groups of cleaners besides truck/container cleaner as shown in Table 4. These cleaners also do other tasks than their own subject to the order of the conservancy inspector.

3.1.3.4 Working area of cleaners

Responsibility of CCC is cleaning of all of roads in the city except roads located in private land. According to conservancy inspector (CI), even very narrow road less than 2 meters wide, is also cleaned by CCC, though this kind of narrow road is not cleaned every day. Roads located inside the slum areas are not included in CCC's road cleaning. CCC is cleaning all of the channels beside the roads and drainage under the footpath and some roads. Cleaning of main drainage line and small stream (Ex-Chaktai khal etc.) is also undertaken by CCC. Table 5 shows data for zones such as number of cleaners in each category, quantity of estimated waste generation and population.

Table 3: Total number of cleaners and drivers of CCC

Workers category	Assignment	Number		Percentage
		Permanent	Temporary	
Road cleaners	Ward	253	606	42.2
Drain cleaners	Ward	239	367	29.8
Market cleaner	Specific	0	44	2.2
Others Cleaners	Specific	65	15	4.0
Drivers	Central	0	120	5.9
VIP waste collection worker	Central	0	31	1.5
Large drain collection / Storm sewage cleaners	Central	0	26	1.3
Special team	Central	0	82	4.0
Waste carrying vehicle worker	Central	0	186	9.1
Grand total		557 (M=420, F= 137)	1477 (M=1215, F=262)	100

Source: CCC

Table 4: Responsibility of cleaners

Cleaners	Responsibility
Road cleaners	1. Road sweeping 2. Carry waste to bin/containers
Deep drain cleaners	1. Cleaning drains/ manholes 2. Carry waste to bin/container
Large drain collection / Storm sewage cleaners	1. Cleaning drainage pipeline 2. Carry waste to bin/containers
Market cleaner	1. Road sweeping around market 2. Cleaning market place
Others Cleaners	1. Cleaning parks or lakes and surrounding areas

Source: CCC

3.1.3.5 Working hours of CCC cleaners and primary waste collector (Private)

CCC cleaners start work earlier than private cleaners as shown in table 6. Average working time for CCC cleaners is shorter (approximately 4 hours a day), whereas for primary waste collector (Assigned by CBOs / NGOs/ Private Organization), it is approximately 6 hours a day (Figure 3).

3.1.3.6 Dustbins and waste containers

Both movable and fixed bins are used for collecting waste. The movable bins are flexible in transportation but lacking in durability, while the fixed bins are more durable but their positions cannot be changed once they have constructed. Table 7 shows total number of storage container and their capacity and amount of daily collected waste from those containers in CCC.

3.1.3.7 Waste transport vehicles

There are 120 units of vehicles of CCC allocated for collection and transportation services. The breakdown of the vehicles in operation is shown in Table 8. Out of 120 units, 36 units are under repair as of January 2010.

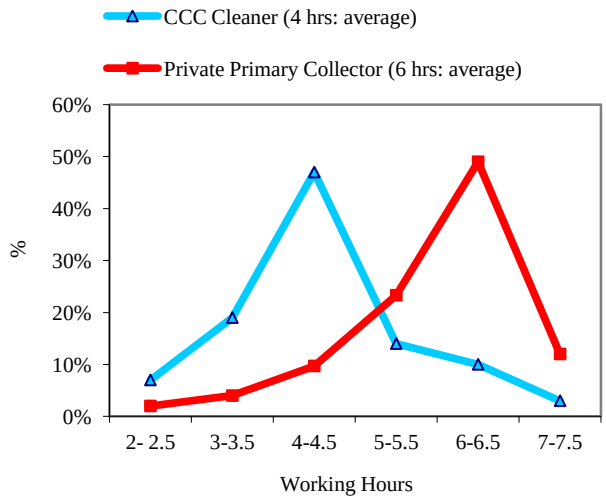

Figure 3: Working hours of CCC cleaner and private primary collector in CCC

Table 5: Comparative ward data for cleaners, waste generation & collection and population

Symbol ⟶		A	B	C	D	E	F	G	H
Ward No	Ward name	Total cleaner assigned (t/d)	Estimated waste generation (t/d)	Waste collected by CCC (ton/day)	Virtual # of cleaners relative to present collection amount	Excess (+) / Shortage (-) of cleaners (A-D)	Population in Ward	Population/ Cleaner (N/I)	Ratio of Population / Cleaner (1.00= Avg)
1	South Pahartoly	28	39.050	0	0	28	71000	2536	1.45
2	Jalalabad	48	49.5	16	34	14	90000	1875	1.07
3	Panslishe	35	37.4	0	0	35	68000	1943	1.11
4	Chandgong	39	38.5	34	72	-33	70000	1795	1.02
5	Mohora	31	36.3	10	21	10	66000	2129	1.22
6	East Sholoshahar	39	35.2	28	60	-21	64000	1641	0.94
7	West Sholoshahar	47	42.625	32	68	-21	77500	1649	0.94
8	Sholokbahar	78	42.9	36	76	2	78000	1000	0.57
9	North Pahartoly	29	41.8	25	53	-24	76000	2621	1.5
10	North Kattoly	58	34.375	22	47	11	62500	1078	0.62
11	South Kattoly	32	33.825	27	57	-25	61500	1922	1.1
12	Soraipara	50	41.8	27	57	-7	76000	1520	0.87
13	Pahartoly	27	36.16	21	45	-18	65750	2435	1.4
14	Lalkhan bazar	46	54.18	25	53	-7	98500	2141	1.22
15	Bagmoniram	72	56.1	50	106	-34	102000	1417	0.81
16	Chawkbazar	76	48.76	42	89	-13	88650	1166	0.67
17	West Bakolia	33	53.49	10	21	12	97250	2947	1.68
18	East Bakolia	34	35.2	0	0	34	64000	1882	1.07
19	South Bakolia	40	42.9	10	21	19	78000	1950	1.11
20	Dewanbazar	45	36.85	25	53	-8	67000	1489	0.85
21	Jamalkhan	61	26.82	28	60	1	48750	799	0.46
22	Enayetbazar	57	32.45	20	42	15	59000	1035	0.59
23	North Pathantuly	59	30.03	20	42	17	54600	925	0.57
24	North Agrabad	76	75.35	55	117	-41	137000	1803	1.03
25	Rampur	43	31.9	18	38	5	58000	1349	0.77
26	North Halishahar	34	64.63	35	74	-40	117500	3456	1.97
27	South Agrabad	56	60.31	20	42	14	109650	1958	1.12
28	Pathantuly	59	42.1	24	51	8	76500	1297	0.74
29	West Madarbari	56	37.8	25	53	3	68750	1228	0.7
30	East Madarbari	71	40.43	36	76	-5	73500	1035	0.59
31	Alkoron	75	29.7	23	49	26	54000	720	0.41
32	Andarkilla	84	36.58	32	68	16	66500	792	0.45
33	Firingi Bazar	66	39.1	25	53	13	71000	1076	0.61
34	Pathorghata	65	44.74	25	53	12	81350	1252	0.71
35	Baxirhat	54	35.9	28	60	-6	65300	1209	0.69
36	Goshaildanga	57	39.33	8	17	40	71500	1254	0.72
37	Halishahar Munirnagar	37	43.78	16	34	3	79600	2151	1.23
38	South Middle Halishahar	33	80.30	25	53	-20	146000	4424	2.5
39	South Halishahar	45	70.95	34	72	-27	129000	2867	1.64
40	North Patenga	33	37.68	16	34	-1	68500	2076	1.18
41	South Patenga	26	28.60	6	13	13	52000	2000	1.14
Total		2034	1772	958	2034	-	3209650	1752 (Avg.)	1 (Avg.)

Note: Waste Generation= Estimated by Field survey, Number of Cleaner= CCC, Conservancy department

Table 6: Working hours of cleaners in CCC

Working hour	CCC cleaners	Primary waste collector (Private)
7-8 hours	0.7 %	25 %
6-6.5 hours	15 %	49 %
5-5.5 hours	9.3 %	20 %
4-4.5 hours	45.6 %	6 %
3-3.5 hours	22.9 %	0 %
2-2.5 hours	6.5 %	0 %
Starting time of work		
At 5.00 a.m.	32.8 %	--
At 6.00 a.m.	50.7 %	31.3 %
After 7.00 a.m.	16.5%	68.7%
Average working hour	4.12 hours	6.14 hours
Duration of work		
-Maximum	8 hours (6.00-14.00)	8 hours (6.00- 11.00 & 14.00- 17.00)
-Minimum	2 hours (7.00-9.00	4 hours (6.00-10.00)

Table 7: Waste storage facilities of CCC

Type	Total dustbin/container	Average capacity (m^3)	Total capacity (m^3)	Conversion to Weight of waste	Total daily collection from all dustbin/ containers (ton)
1. Construct dustbins	892	2	1784	446	
2. Open dustbins	491	2	982	246	818
3. Containers	42	12	504	126	

Source: CCC and Field survey.

Note: These are assumed: Size of dustbins at 2 m^3 per unit, bulk density of waste at 0.25 ton/ m^3 (DCC & JICA, 2004)

Table 8 Allocated number of collection/transport vehicles of CCC

Type	Manufacturer/Model	Rated capacity (Ton)	No of vehicle (Unit)
Isuzu NKR Truck	Isuzu NKR, Japan	3	40
Compactor Mitsubishi	Mitsubishi, Japan	1	09
Compactor-Isuzu	Isuzu, Japan	1	09
Bedford Truck	Bedford, India	4	06
Aoulas truck	Aoulas, India	4	04
Volvo Container Mover	Volvo, Belgium	6	06
Open Volvo Truck	Volvo, Belgium	5	02
Tractor Wagon	Tata, India	--	06
3 t Open Truck	Tata 608, India	3	12
5 t Open Truck	Tata1613, India	5	10
Container Carrier	Tata 909, India	5	06
Tata Lift vehicle	Tata, India	5	10
Total			120

Source: CCC

4 Conclusion and Recommendations

4.1 Conclusion

Developing integrated solutions for waste management problems requires public involvement. To economically and efficiently operate a waste management program requires significant cooperation from generators. When waste generation is unavoidable, the materials can be viewed as a resource. There is also a need for effective solid waste management policy for Bangladesh. The issues related to waste separation, waste reduction, recycling, public-private and community partnership, appropriate technology, innovative local solutions, harnessing CDM opportunities in waste sector are given special emphasis in rules. The objectives of the study were largely met, giving what may be considered as baseline data on the solid waste situation in Chittagong. This should lead to a better understanding of the solid waste management problems in Bangladesh. A waste stream assessment is not a one-time activity. As management programs are implemented, periodic waste stream assessments will be required to identify successful protocols as well as areas needing improvements.

Table 9: Estimated collection and transport capacity of CCC vehicles

Type and capacity of vehicle	Rated capacity	Loading ratio (%)	# of vehicles (Unit)	Two trips (t/d)	Four trips (t/d)	Eight trips (t/d)	Total (t/d)
A) Registered Vehicles							
Isuzu NKR Truck	3	80	40	240	0	0	240
Compactor Mitsubishi	1	100	09	0	0	72	72
Compactor-Isuzu	1	100	09	0	0	72	72
Bedford Truck	4	80	6	48	0	0	48
Aoulas truck	4	80	4	32	0	0	32
Volvo Container	5	80	6	0	120	0	120
Open Volvo Truck	5	80	2	0	40	0	40
Tractor Wagon	--	80	6	0	0	0	0
3 t Open Truck	3	80	12	72	0	0	72
5 t Open Truck	5	80	10	0	200	0	200
Container Carrier	5	80	6	0	0	240	240
Tata Lift vehicle	5	80	10	0	0	400	400
Total			**120**	**392**	**360**	**784**	**1536**
B) Vehicles under repair							
Isuzu NKR Truck	3	80	32	192	0	0	192
Compactor Mitsubishi	1	100	6	0	0	48	48
Compactor-Isuzu	1	100	4	0	0	32	32
Bedford Truck	4	80	3	24	0	0	24
Aoulas truck	4	80	2	16	0	0	16
Volvo Container	5	80	3	0	60	0	60
Open Volvo Truck	5	80	1	0	20	0	20
Tractor Wagon	--	80	3	0	0	0	0
Tata Lift vehicle	5	80	4	0	0	160	160
5 t open truck	5	80	1	0	20	0	40
3 t open truck	3	80	1	6	0	0	6
Total			60	238	100	240	578
Estimated Transport Capacity as of September 2009.			60	154	260	544	958

Source: CCC and Field survey.

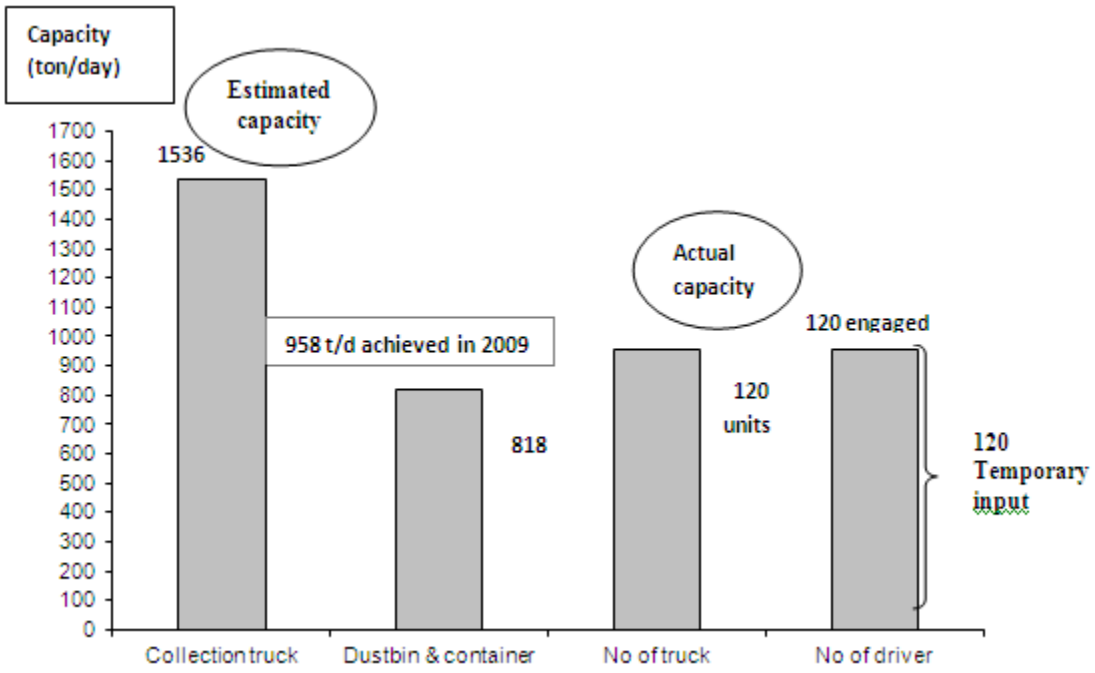

Figure 4: Evaluation of present waste collection capacity of CCC

4.2. Recommendations

4.2.1. Recommendation of improve current SWM system

For the implementation of the proper SMW plan, it is recommended for CCC to take the following into consideration.

Sorting system

In the existing system, biodegradable waste is mixed with inert as well as non-biodegradable waste. Introduce the 'segregation of waste at source', i.e., segregation of biodegradable waste from the non-biodegradable portion at the household level and storage in different containers (used plastic bins or buckets) is important. A sorting is necessary to eliminate any mixing of recyclable waste with the compostable waste and to reduce contamination.

Storage and collection system

As the major portion of the generated waste remains uncollected, it is apparent that the current system needs augmentation and needs to be designed for 100% collection efficiency. House-to house collection of MSW should be organized through methods like collection on regular pre-informed timing and scheduling. Each household should use standard 120-L or 240-L waste bins that are placed outside for ease of collection. In area where this is not appropriate, centrally located waste collection points should be established that are shared by a number of households. The collection bins must be appropriately designed with feature like metallic containers with lids, and to have a large enough capacity to accommodate 20% more than the expected waste generation in the area, with a design for mechanical loading and un-loading, placement at appropriate location etc. The container location should be decided after accounting for factors like the waste collection route, road geometrics, and proximity to traffic intersections. During the study it was evident that most of the storage container and dustbins placed beside the road. Municipal authorities should maintain suitable placing of the storage device and maintain storage facilities in such a manner that they do not create unhygienic and unsanitary conditions. Medical waste may be treated as a special waste and managed separately. Another important aspect that can ensure a sound collection strategy is the rescheduling of vehicle trip for MSW collection. During the study it was evident that the collection of MSW restricted only in the daytime. Unfortunately, a huge amount of MSW augmenting with the waste stream at the evening or night hour especially from a number of *kachabazar* (vegetable market) are not considering while amounting the total waste of a particular day. This is another loophole of waste management practice in our country. Therefore, collection system should be practiced at night time. It is necessary to plan a new collection system that is appropriate for source-segregated waste. Organic wastes should be collected with compactor vehicles. The waste collection schedule should be planned according to the waste quantity, and the collected wastes should be transported to the sorting facility. The existing handcarts are to be replaced by tricycle carts with multiple bins since the former are comparatively difficult to operate compared to the tricycle carts. The proposed tricycle cart will have 6-8 bins of 25 L capacity each and can carry up to 200 kg of waste. To accelerate collection activities as well as SWM with capable and practical personnel assigned exclusively to the required position.

Transportation system

As the number of transportation vehicles is less than the required quantity, new vehicles should be bought to improve the current waste transport system. Vehicles need to be appropriate to the local conditions and with adequate carrying capacity. A programme of regular vehicle maintenance is required and appropriate vehicles should be used. Training needs to be provided, particularly for drivers operating waste tipping equipment, and more vehicles will be needed to cope with increasing waste generation. Hauled container systems need to be incorporated to improve the current transportation system. Hauled container system (HCS) is preferred over stationary container systems (SCS) as HCS provides greater flexibility in container location planning, it discourages scavenging and littering. It also helps keep the surrounding environment clean.

Disposal system

Most of the MSW in CCC is dumped on land in an uncontrolled manner. Such inadequate disposal practices lead to problems and result in economic, environmental and biological losses. Open dumping should be stopped immediately and be replaced with new safe options like control dumping. It is advisable to move from open dumping to sanitary landfilling in a phased manner. Sanitary landfilling technology should be much more widely adopted so that available landfill space can be utilized for longer periods and so that reclamation can become more cost-effected. Incineration may be considered for the treatment of infectious/hazardous bio-medical waste in absence of an appropriate non-burn technology.

Recycling system

Recycling and reuse should be given priority to reduce waste generation volume and lessen treatment and disposal cost. Planed recycling in the waste generation point, dustbins and transfer stations should be introduced. Recyclables could be straightway transported to recycling units that in turn would pay a certain amount to the corporations, thereby adding to their income. This would help in formalizing the existing informal set up of recycling units. Improving working conditions of the waste pickers and thereby reducing the occupational health hazards should improve informal waste picking practice. Encourage NGOs and private companies to establish community-based segregation at source, and to separate collection and resource recovery from waste with particular focus on composting. Promotion and development of recycling is a means of upgrading living and working conditions of rag pickers and other marginalized groups.

Financial management

The cost of SWM should be rationalized with the view to increase revenue in order to make the system financially viable. Both public and private operation should be considered for effective waste management. Waste

collection, treatment and disposal may be privatized to allow greater mobilization of capital. To acquire the government grant for the expense of specific project and program as soon as possible. To pursue foreign assistance for implementation of each project and program particularly for the training of CCC staff engaged in various assignments

Water contamination reduction

If sanitary/engineered land filling is the method adopted for the disposal of biodegradable waste, then soil rich in clay is preferred due to its low infiltration potential. Construct planed disposal site with proper embankment throughout the boundary region and provide leachate drainage system and leachate collecting reservoir.

Public awareness

The citizen support is essential to the effectiveness of any program aimed at SWM. A well-informed and concerned public greatly facilitates program implementation and ensures its success. Public awareness and attitudes to waste can affect all stages in the SWM process. This has an impact on MSW storage, segregation, recycling, collection frequency, and willingness to pay for waste management services, treatment and disposal facilities. In general, it was found during the people of CCC have a poor attitude towards waste management. Therefore, Ensure the promotion of the concept of recycling along with the citizens' sound environmental education, responsible authority like City Corporation or other relevant NGOs can take initiative to rehearsal the citizen so that they can act accordingly. Both electronic and printing media can simultaneously be utilized. The most important principles underlying effective programmes for the management of MSW include the awareness, assignment of legal responsibility, developing the rules and regulations and also need of a national waste management policy and national waste disposal and management guideline for Bangladesh concerning to the MSW.

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Authors' contributions

This work was carried out in collaboration between all authors. Authors Das S.R. and Hossain M.L. designed & performed the study, wrote the protocol, and prepared the first draft of the manuscript in collaboration with Hossain M.K. The mastermind behind all the statistical analyses and literature searches was author Das S.R. and Talukder S. All authors read and approved the final manuscript.