A Study on Solid Waste Management System of Dhaka City Corporation: Effect of Composting and Landfill Location

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Abstract

This study has analyzed the generation and characteristics of solid waste in Dhaka city, along with the associated environmental impacts and existing solid waste management practices. Special focus was given on the effect of composting on final disposal of solid waste and effect of landfill site location on transportation cost. An estimate of the future generation rate indicates that the present generation rate of 3500 tons/day may exceed 30 thousand tons/day by the year 2020.The mixed waste dumped at dumping sites is characterized with high organic content and high moisture content (about 80% and 50-70% by weight, respectively). According to required landfilling 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. With composting, the peak rate of greenhouse gas methane generation would be as low as half of that for without any composting. 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.

Keywords: Composting; Dhaka City Corporation; Landfill; Solid waste

Introduction

Until recently, environment was not an issue in a developing country like Bangladesh and solid waste management was definitely not the prime concern of environmentalists and the government, when the awakening to the issue finally did happen. It is only in very recent times, when certain NGO's started working and highlighting the pathetic state of municipal waste services provision in the country, that the decision makers realized the importance of this particular aspect of environmental management (Yousuf 1996, Sarmin 2000).

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.

The Dhaka City Corporation (DCC) is responsible for solid waste management of Dhaka city. 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.

This paper 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:

a. Analysis of solid waste generation trends and rates, and compilation of available data on characteristic of solid waste generated in Dhaka City;
b. An evaluation of the existing solid waste management system of Dhaka City Corporation; and
c. Assessment of impacts related to final disposal of solid waste, with special focus on the effect of composting on land requirement and landfill gas generation, along with the effect of landfill location on transportation cost.

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Materials and Methods

This study focuses mainly on domestic solid waste management under the jurisdiction of DCC. The data used in this study were derived from secondary sources, mainly from research papers and study reports on solid waste management. In addition, valuable information was gathered during consultations with DCC officials, made as a part of this study. The collected information was analyzed to develop an understanding of the existing solid waste management system and its drawbacks. Discrepancies among available data and information have been identified at the relevant sections.

USEPA's Landfill Gas Emission Model (LandGEM, version 2.01) was used to estimate methane generation rate at landfill. This model is based on a first order decomposition model, which estimates the landfill gas generation rate using two parameters: Lo, the potential methane generation capacity of the refuse and k, methane generation decay rate, which accounts for the rate of decrease of the methane generation rate, once it reaches its peak rate (USEPA 1998).

Solid Waste Generation Rate

Solid Waste: Generation and Distribution by Source

Reliable estimate of the quantity of solid waste generated in the city is very important in the planning for proper solid waste management. Reported estimates (Table 1) of solid waste generation vary widely ranging from 1040 tons/day (1985-86*)* to 5000 tons/day (in 1997). Most of the reported values have been derived rather empirically with assumptions regarding population, number of trucks available for transportation of wastes and capacities of trucks. Reported solid waste density values used in calculating waste quantity also vary widely ranging from 0.35 ton/m^3 to 0.80 ton/m^3. Most of the studies assumed collection efficiency of 50% without providing any basis for it.

Table 1 Total waste generation and its distribution by source

Data Source*	Solid Waste Generation (ton/day)	Contribution of Different Sources (%)				
		Residential	Commercial	Industrial	Hospital	Street
MMI 1991[a]	1300	46.8	17.3	12.9	0.50	22.6
PAS 1997[a]	3000-5000	46.7	20.0	26.7	6.70	--
RSWC 1998[a]	1200-1600	47.0	17.0	13.5	0.50	22.0
BCAS 1998[b]	2398	81.9	13.9	2.31	1.87	--
DCC 1999	3500	49.0	21.0	24.0	6.00	--

* Please refer to the 'Index Notations' at the end of the paper
[a] As quoted in BCAS (1998)
[b] Estimates are for the portion of waste that are dumped at the dumping sites

The DCC estimate (DCC 1999) shows that, of the total daily generation of 3500 tons of solid waste, 1800 tons are collected and dumped by the DCC, 900 tons go to backyard and land filling, 400 tons go to road side and open space, 300 tons are recycled by the *Tokais* (mostly the children of slum dwellers), and 100 tons are recycled at the generation point. However, the quantity of solid waste varies depending on month and season by a factor of about 20%, the generation being higher during wet months and fruit seasons.

Municipal solid wastes in Dhaka City are mostly generated from residential, industrial and commercial sources. Also a significant portion, initially resulting from widespread littering, comes from street sweeping (Table 1). Hazardous wastes from industries and hospitals are frequently mixed with municipal wastes, which in turn are poorly collected and disposed, thereby creating public health hazards.

BCAS (1998) estimates show that the contribution from the residential source is almost twice as much compared to other estimates and that from the industrial source is almost an order of magnitude lower (Table 1). They gave an apologia for low contribution of industrial source by the argument that wastes from the garment factories are removed from the source and most of the industrial wastes of the Hazaribagh site are dumped in the adjoining low lying sites. The diversity of the nature of available data obviously would restrain the formulation of a management policy and hence a rigorous study is essential to come up with reasonable estimates of solid wastes generated by different sources.

Per Capita Waste Generation

Per capita waste generation would obviously depend on a number of socio-economic parameters affecting consumption and other behavioral characteristics. DCC (1999) 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. 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 (according to DCC 1999), such a small sample size is quite inadequate.

BCAS (1998) and DCC (1999) provide the most recent estimates of per capita waste generation. On the basis of the 1981 and 1991 census data, BCAS (1998) 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. With estimated daily generation of 2398 tons, this gives a per capita generation of 0.52 kg/capita/day. DCC (1999), on the other hand, reported a population of 7 million for the DCC area, almost 1.5 times higher than that estimated by BCAS (1998). However, since the waste generation estimate of DCC (1999) is also much higher (3500 tons/day), per capita generation calculated from DCC (1999) data (0.50 kg/capita/day) is very close to the value reported by the BCAS (1998). This is probably a coincidence, as these two studies are miles apart in their estimates of waste generation and population. However since DCC projected the population from the 1991 census and used it with waste generation data of 1999, this calculation seems more appropriate.

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 (1998) used a simple procedure for predicting future waste generation. The inter-censal 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 $4 \times 0.070 = 2.8\%$. Based on this growth rate and a 1998 per capita generation of 0.52 kg/capita/day, BCAS (1998) predicted waste generations for the future years up to 2021 (Fig. 1). Using the same procedure as followed by BCAS (1998), another estimate for future waste generation is made based on the population of 1991 (census) and population of 1999 (DCC 1999). 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 (Fig.1). Comparing above two estimates it is observed that according to the predictions of BCAS (1998) 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

Information about physical and chemical properties of solid waste is important in evaluating equipment needs, systems and management programs and plans, especially with respect to the implementation of disposal and resource and energy recovery options. Characterization of waste is also important to determine its possible environmental impacts. The waste components, although vary widely with the location and season of the year, include food wastes, paper, plastic, cloths, metal, glass, construction materials and others (DCC 1999).

A number of studies have been conducted (e.g., BCAS 1998, DCC 1999, Hossain et al. 2000) to determine the composition of solid waste generated in the city. BCAS (1998) collected

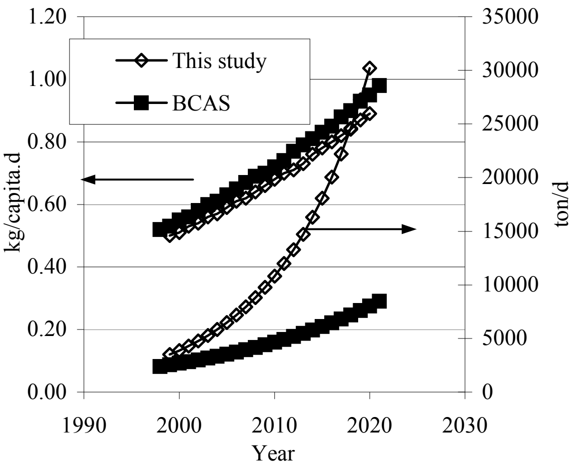

Fig. 1 Projection of future waste generation by BCAS (1998) and this study

solid waste samples from residential, commercial and industrial areas as well as mixed samples from the dumping locations in order to determine their composition. DCC (1999) concentrated its study on residential solid waste and determined its composition for different income-groups of population. Hossain et al. (2000) determined composition of residential (for different income groups), commercial, industrial and hospital wastes.

In all the above studies relatively small number of samples was analyzed (from less than 1 kg to a maximum of 30 kg, in contrast to recommended 100-200 kg) due to resource and other constraints. Nevertheless, these studies provide a good estimate of the composition of solid waste generated in Dhaka.

From the composition of residential solid waste reported in different studies (IFRD 1998, DCC 1999, Hossain et al. 2000), the average values of different components for each income group (High income group HIG, Middle income group MIG, Low income group LIG) and an average value for all residential wastes are calculated and plotted in Fig. 2.

Fig. 3 represents the composition of solid wastes from commercial locations (IFRD 1998, Hossain et al. 2000). It appears that the composition of commercial wastes depends on the characteristics of commercial activities in the vicinity of the collection area, for example, food wastes constituting a major part of the wastes from the Motijheel area where a large number of hotels and restaurants are 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.

Fig. 4 shows composition of solid waste samples from industrial locations, two from Tejgaon area and two from the Hazaribagh area (IFRD 1998, Hossain et al. 2000). As mentioned in Hossain et al. (2000), most of the industries in the Tejgaon area handle solid waste on their own and the DCC dustbins in this area primarily receive wastes from the nearby commercial activities (restaurants, shops) and residential settlements. On the other hand, solid wastes collected from Hazaribagh area contain shredded skin and leather more than any other components. Fig. 5 shows composition of mixed solid waste from the waste dumping locations (BCAS 1998). Since solid wastes from different sources are typically dumped into the same container/truck and obviously get mixed, the composition presented in Fig. 5 probably represents the average composition of solid waste from all sources. As observed for the residential solid waste, food wastes constitute 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. Other important constituents include polythene/plastic, paper, cloth, garden wastes, and brick/stone/metal/glass/ceramic.

According to IFRD (1998), the mixed waste dumped at DCC dumping sites is characterized with high organic content (about 80% by weight), high moisture content (50 to 70% by weight), high ash content (13-33% by weight, sometimes containing heavy metals), low calorific value (1386-2600 Btu/lb), low volatile matter (7-23% by weight) and low fixed carbon content (2-9% by weight).

Primary Collection System of Solid Waste

The management of solid waste in Dhaka city is neither community based nor community participated (Yousuf 1996, Salam 2000). The household, commercial and industrial wastes are deposited from the source to the collection bins (concrete/C.I. sheet) located on the streets. In some areas demountable containers are used for onsite storage of municipal solid waste. All parts of the city are not provided with these bins and there are no specific rules and criteria of placing the dustbins. In cases where there are no bins, waste is simply dumped on the ground.

In some residential areas like Kalabagan, Dhanmondi, Banani, Gulshan, Baridhara and Uttara, *'house to house'* waste collection service has been organized by some private initiatives. Rickshaw vans are used for collection of waste from houses and conveying to municipal containers (Yousuf 1996, Kazi 1999, Salam 2000).

Processing, Recycle and Reuse of Solid Waste

Recycling and reclamation of waste are now strongly promoted for conservation of resources and prevention of environmental degradation. The following is a brief representation of the recycling processes practiced in Bangladesh.

Informal Reclamation, Processing and Reuse

In Bangladesh, wastes having some market value are being reclaimed or salvaged in three stages (Ahmed and Rahman 2000). In the first stage, housewives separate refuse of higher market value such as papers, bottles, fresh containers, old clothes, shoes, etc. and sell them to street hawkers. The *Tokais* carry out the second stage of salvaging by collecting different items of low market value, including broken glass, cans, cardboard, waste papers, rags, plastics, metals and miscellaneous commercial wastes discarded by households, from waste collection bins. The scavengers at the final disposal sites do the third stage of salvaging when municipal trucks unload fresh refuse.

The reclaimed materials reach the waste and old materials shop from where these are either sold to consumers following intermediate processing, or supplied, as raw materials, to appropriate processing factories for reuse.

Composting of Solid Waste

The composition of solid wastes in Bangladesh is favorable for composting, with a higher percentage of organic matter, precisely the right moisture content and C/N ratio slightly higher but adjustable (Ahmed and Rahman 2000).

Experience in many developing countries show that large scale centralized and mechanized composting plants had to be closed down due to high operational, transportation and maintenance costs. Financial and technical viability of composting projects can be achieved if such projects are decentralized, located close to the source of waste generation and, the most vital element, low-cost manual technologies are adopted, taking into consideration the socio-economic condition. ‘Waste Concern’, an NGO, has demonstrated that such a venture can be profitable if land is provided, and if the government promotes the sale of organic fertilizer. In 1995, for the first time in Dhaka, ‘Waste Concern’ initiated a Community based decentralized Composting Project at Section-2, Mirpur. Since then the plant is running satisfactorily and have been replicated in other communities with land being provided by public agencies along with local government bodies, who were initially skeptical about the project. Yearly net earning from a 3-ton compost plant is Tk. 2.48 lakh, while the associated fixed cost and yearly operational cost are Tk. 4.75 lakh and Tk. 5.51 lakh, respectively. Against the vacant land requirement of 31.6 acres for decentralized community based composting plants to serve the households in all ten zones of DCC, 40.82 acres of potential land have been identified by ‘Waste Concern’. Map agro Ltd. Bangladesh purchases (Tk. 2.5-5.0/kg) bulk of the compost (N = 2.1%, P = 4%, K = 2.6%) produced by Waste Concern, enriches it, and markets the product at a price ranging between Tk. 6-8 per kg (Enayetullah & Sinha 2002).

Transportation of Solid Waste

The fleet of DCC vehicles, which vary in size, age and design, carries out the collection of household, commercial and industrial wastes from collection bins and then transportation to the dumping sites. DCC has 96 open truck (3 ton and 5 ton pay load) and 100 demountable container-carrying vehicles. Presently DCC’s waste disposal site is at Matuail, which is located 10 km from city center and 30 km from farthest boundary at Uttara and Mirpur. DCC has no transfer station (DCC 1999).

The transport department, according to the requirement of the conservancy department, fixes number of trips of vehicles and schedule. Unplanned distribution of trips and under-utilization of vehicles cause reduction of collection efficiency and increases cost. It is also observed that 15%-25% trip/vehicle.day are not executed / completed by the vehicle driver to save fuel. In case of open truck, wastes are overloaded to save trip. Most of the vehicle drivers are drawing overtime bill at an average of 250 hour/month, which is equal to additional one shift (8hr). MMI, BKH studies reported that 25%-30% of the vehicles remain off road due to technical problem (Salam 2000).

Final Disposal of Solid Waste

DCC disposes solid wastes adopting crude dumping methods, and thereby, creates environmental hazards and health risks. The dumped solid wastes are dressed irregularly by payloaders, excavator, tyre dozer, chain dozer etc.

According to DCC (1999), six dumping sites have already been abandoned after filling to their capacities. These sites are: (1) Kulsi, (2) Chalkbari-Mirpur, (3) Gabtoli-Mirpur, (4) Lalbagh Shosan Ghat, (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. But at present almost all the wastes go to Matuail, and others are used when Matuail site is inaccessible due to rain or damage of driveways, repairing and maintenance of unloading platforms.

Matuail landfill covers about 52 acres of low-lying agricultural land acquired by DCC in 1986 (Yousuf 1996). Out of this, 13 acres have been developed for parking/platform and the rest 39 acres is used for landfilling. It is being used for dumping of solid waste since 1993. Earth dyke for isolation encloses the dumpsite. According to DCC estimates, the existing sites would be filled up shortly and DCC would have to arrange for new dumping sites for waste disposal. Accordingly, DCC selected three new sites for dumping of solid wastes located at Matuail, Boliarpur and Gazipur (Sarmin 2000). However, little advancement has been made up to now in this respect. In the mean time DCC is planning to construct roads on the earth dykes of Matuail and then dump waste from those roads into the still vacant land (about 20%) within the site near the dykes.

Impacts Related to Final Disposal of Solid Waste

Land Requirement for Landfilling of Solid Waste

An estimate of future requirement for land area of disposal site is made on the basis of the projected future solid waste generation presented in Fig. 1. From the estimated waste generation, the required land area is calculated assuming 6m dumping height and a compacted solid waste density of 1.1 ton/m^3 (Enayetullah & Sinha 2002). Different collection efficiencies, ranging from 50% to 75%, have been assumed in the estimation. Land requirement was calculated as follows:

$$\text{Volume disposed at landfill (m}^3\text{/yr)} = \frac{\text{Proj. waste generation (ton/yr)*Collection efficiency}}{\text{Compacted waste density (ton/m}^3\text{)}}$$

Then,
Landfilling area required (m^2/ yr)= [Volume disposed at landfill (m^3/ yr)] / [dumping height (m)]

From the projection of future landfilling area (Fig. 6) it is observed that, since the solid waste generation rate increases with time, the landfill area required for disposal also increases rapidly. Thus solid waste will demand an area of 206.31 acre for disposal on the year 2020 if 50% collection efficiency is assumed. If 75% collection efficiency is assumed, the area requirement will reach 309.46 acre. This is likely to create a serious crisis in the years to come.

Solid Waste Composting and its Impact on Land Requirement

To minimize the crisis of land area for disposal of solid waste in the future, an effective option would be to reduce the volume of solid waste prior to disposal by composting of organic wastes, along with, recycling of inorganic wastes. To assess the effect of solid waste composting on landfill requirement, an estimate of future requirement of land area for waste disposal, on the basis of the same projection of future solid waste generation as shown in Fig. 1, has been made for different percentage of composting.

In this calculation, 25% of the collected inorganic waste was considered to bear some market value, being reclaimed and recycled by informal sectors. The remaining 75% is assumed

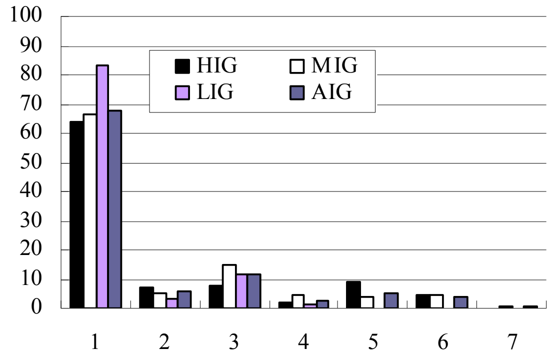

Fig. 2 Composition of residential waste

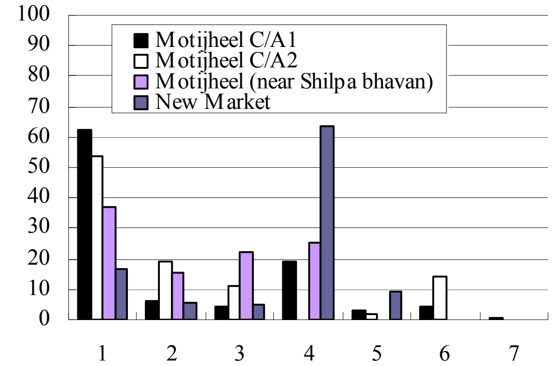

Fig. 3 Composition of commercial waste

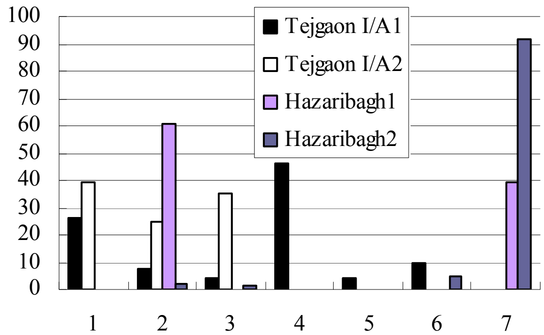

Fig. 4 Composition of industrial waste

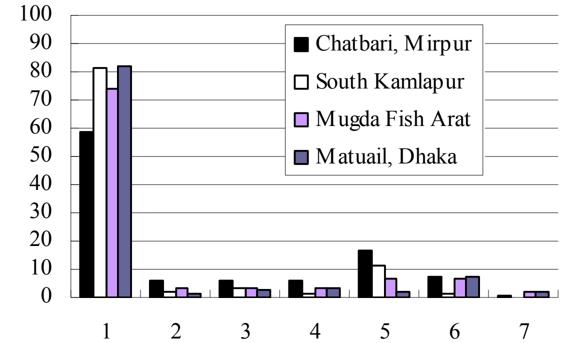

Fig. 5 Composition of mixed waste at dumping

For Figs. 2, 3, 5 1 = Food waste, 2 = Paper, 3 = Polythene, plastic, 4 = Cloth, 5 = Garden trimmings, leaves & branches, 6 = Brick/ stone, wood, metal, glass/ ceramic, 7 = Others
For Fig. 4 Same as the others, except that 7 = Shredded skin & leather

transported and dumped in disposal sites. Different studies suggest that solid waste of Dhaka city can be considered to consist of as much as 80% organic material (Figs. 2~5 and Yousuf 1996). Again, during composting, 85% of the organic waste may be converted into compost and remaining 15% is required to be land filled (Enayetullah & Sinha 2002). Land requirements with and without composting were compared assuming a collection efficiency of 50%. From the estimated waste generation, the required land area is calculated assuming a compacted solid waste density of 1.1 ton/m^3 and a 6m dumping height. Land requirement was calculated as follows:

Volume disposed at landfill (m^3/yr) =

$$\frac{\text{Proj. waste gen. (ton/yr.)}*\eta*[0.2*0.75+n*0.15+(1-n)]}{\text{Compacted waste density (ton/m}^3\text{)}}$$

where, η = % of efficiency, n = % of composting $\leq$ 80%

Then, Landfilling area required (m^2/ yr) = [Volume disposed at landfill (m^3/ yr)] / [dumping height (m)]

According to required landfilling areas (Fig. 7), 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. This indicates considerable reduction of waste dumping through composting of waste.

New Landfilling Location and its Impact on SWM

DCC currently dumps about 2585m^3 of solid waste at seven disposal sites (DCC 1999). Assuming a dumping height of six meters, this quantity of waste fills up an area of about 430 meter^2 per day. This corresponds to about 3.2 acres of land per month or 39 acres of land per year. If DCC is able to increase collection efficiency successfully, spaces at the dumping sites would be covered at a faster rate. So within a short time DCC would definitely be forced to move its dumping sites away from the city center due to the unavailability of land and higher land price. In fact one of the three newly selected dumping areas is located at Gazipur far away from DCC boundary (Sarmin 2000). Fuel costs account for about 18% of DCC's total expenditures for conservancy service (Kazi 1999); thus dumping of wastes at sites increasingly away from the city center without any provision for transfer station would become a major financial burden for the DCC in the coming years. Besides fuel cost, this would also increase the cost for maintenance and spare parts for waste-carrying vehicles. Moreover as more hauling distance would have to be traveled, the possibility of spillage of solid waste during transportation will increase.

In an attempt to have a rough estimate of the imminent increase in cost of waste-transportation, it was assumed that all the waste (amount considered to be the same as present) would be dumped at a site in Gazipur after the Matuail landfill site is filled up. Using the zone-wise data of 'amount of waste (ton/d)' transported to Matuail and the corresponding 'transportation cost (Tk./ton)', the cost of waste-transportation per day at each zone was calculated.

Estimation of Transportation Cost for a New Dumping Site at Gazipur

Zone-wise Transportation Cost (Tk./ton):

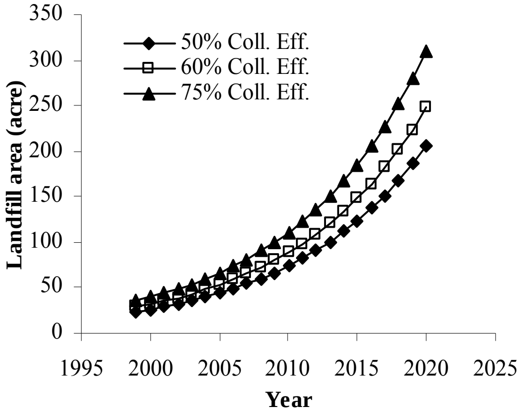

Fig. 6 Projection of future landfill requirement (without composting)

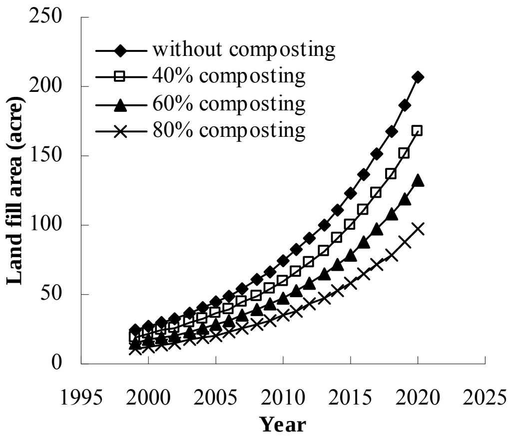

Fig. 7 Projection of future landfill requirement for different % of composting (50% collection)

Available data (Table 2) revealed that transportation cost was higher for zone with greater round-trip distance. In this study, for simplification, a single weighted 'transportation cost/ cu.m' (Table 2) was assigned for each zone irrespective of the type (i.e., 3 or 5 ton) of vehicle or the type of transportation system (open truck or demountable container system). While estimating the weighted average cost, the relationship between round-trip distance and transportation cost in some cases were found to be inconsistent with the usual trend of higher cost associated with higher round-trip distance. This may be explained by the fact that the zone with more vehicles of higher payload type incurs less cost. The data of zone-wise transported waste is available in ton/day form. So the cost/cu.m. was converted to cost/ton, by dividing the former by 0.55, i.e., using a waste density of 0.55 ton/cu.m (Yousuf 1996).

Zone-wise Waste Transportation (ton/day):

The data of zone-wise waste transported to Matuail site is available from BCAS (1998) as shown in Table 3. This data is of the time when other dumping sites were also under use. At that time a large portion of waste from zone 7 and zone 8 was dumped to Chatbari and Kachukhet sites. During this study, those sites were no longer under operation, and that portion (268 tons/d) of waste was dumped to Mirpur no.11 site. However, for simplification, this portion was considered to be contributed to Matuail site. In calculation, this waste was attributed, considering due weightage, to zone 7 and 8 only, as those sites were very near to these zones. The waste previously dumped (1066 ton/day) at other temporary sites (Mugdapara fish arat, Kamlapur playground) were considered coming from different zones (except zone 7 and 8) in amounts calculated from 1066 ton/day giving due zone-wise weightage. Table 3 shows the estimated zone-wise waste transportation (ton/day).

Zone-wise Cost of Waste-transportation (Tk./day):

Using the zone-wise data of 'amount of waste (ton/day)' transported to Matuail and the 'transportation cost (Tk./ton)', the cost of waste-transportation per day at each zone was calculated. To find the increased cost of waste-transportation per day at each zone the changed round trip distance for each zone was estimated. Taking average distance of zone 10 (situated at the boundary of DCC area, Fig. 8) from Gazipur landfill site as 10 km and noting that the average distance of zone 10 from Matuail is 30 km (round trip distance 60 km), which makes the new landfill site at a distance of 40 km from Matuail, the changed round trip distance for each zone was estimated.

While performing this calculation we kept in mind the relative locations of the DCC zones and the present and the proposed landfill site (Fig. 8). For each of the zone 1 and zone 2, we added the 'zone distances (half of round trip distances) from Matuail' with 40 km, doubled those and took the rounded off values as the new round trip distances (95 and 100 km, respectively). The other sites are located in between the present and the proposed site. So, for those, the respective 'zone distances from Matuail' were subtracted from 40 km. The new round trip distances for zone 3 and 4 are 60 km; for zone 6 it is 55 km; 40 km for zone 7; 35 km for zone 8 and 9, while for zone 10 it is 20 km. Once the changed round trip distances were estimated, the increased cost of waste-transportation per day at each zone was calculated assuming a linear variation.

Increased Transportation Cost for a New Dumping Site at Gazipur:

With the new landfill site at Gazipur, the daily total transportation cost was estimated to be Tk. 18.44 lakh (Table 4) which indicates a huge increase in cost when compared to the estimated transportation cost (Tk. 6.01 lakh) at the time of this study. To avoid this, transfer stations have to be established. Planned distribution of trips and optimum utilization of vehicles would also reduce the cost. Moreover reduction of waste volume (e.g., composting), recycle and reuse methods should be adopted.

Limitations of the Calculation:

Data provided on the same item by DCC and BCAS tend to differ as observed, for example, in case of estimate of waste generation (Table 1). But due to lack of the related data from a single source, we had to use the 'amount of waste transportation' data from BCAS (1998) with the 'cost of transportation' data from DCC (as quoted by Salam 2000). This is 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. However this problem is offset to some extent by the fact that the amount of transported waste was assumed the same in cases of both the landfill sites (existing and proposed).

The conversion of data on waste transportation cost from the available to the required form may cause inconsistency. Calculation of the new round trip distances was based more on judgment and observation rather than actual route study.

Table 2 Zone wise estimated average waste transportation cost

1	2	3	4	5	6	7	8	9	10	11	12	13
DCC Zone	Round trip Distance (km)	Open Truck Collection System							Demountable Container System			Final Weighted Average Cost Tk./ ton
		3 ton		5 ton		Weighted Average cost						
		Tk./ cu.m	No. of Vehicle	Tk./ cu.m	No. of Vehicle	Tk./cu.m	Tk./ ton	Total Vehicle	Tk./ cu.m	Tk./ ton	Total vehicle	
1	14	124.50	22	94.70	1	123.20	224	23	101	184	2	221
2	18	139.80	32	104	1	138.72	252	33	116	211	18	237.5
3	22	145.33	19	109	1	143.51	261	20	121.80	221.5	5	253
4	18	139.80	11	104	2	134.29	244	13	116	211	23	223
5	22	145.33	8	109	10	125.15	227.5	18	121.80	221.5	20	224
6	26	145.33	10	109	6	131.71	239.5	16	121.80	221.5	11	232
7	42	158.14	8	127.23	X	158.14	287.5	8	144.20	262	3	280.5
8	44	158.14	1	127.23	7	131.1	238	8	144.20	262	8	250
9	35	148.31	7	122.83	3	140.67	256	10	141.20	257	5	256
10	60	170.95	X	136	2	153.48	279	2	158	287.5	1	282
TOTAL			118		33			151			96	

At each zone, under open truck system, 5, 3, 2 and 1.5-ton trucks are operating. But data are available for 3 and 5-ton trucks only. For trucks of 2 and 1.5-ton, the 'transportation cost/ cu.m was assumed to be similar to that of 3-ton trucks.
At each zone, under demountable container collection system, 5 and 3-ton trucks are operating. But data are available for 3-ton trucks only. For trucks of 5-ton, the 'transportation cost/ cu.m' was assumed to be similar to that of 3-ton truck.
The weighted average in column 7 is calculated using the values in columns 3, 4, 5 and 6.
The value in column 8 is derived by dividing the value in column 7 by 0.55 (i.e., considering waste density of 0.55 ton/cu.m)
For demountable container system, since only cost data available is that of 3-ton payload, weighted average for that system could not be taken.
The final weighted average in column 13 is calculated using the values in columns 8, 9, 11 and 12.
Data source for those in the columns 2-6 and 10, 12: DCC, as quoted by Salam (2000).

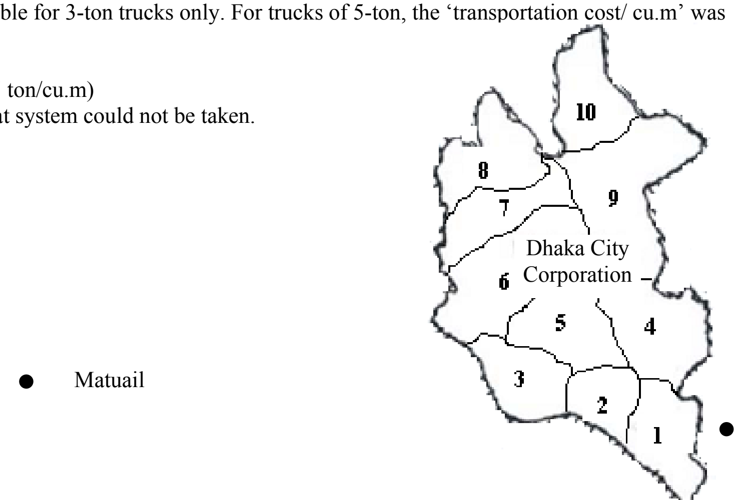

Fig. 8 Relative location of DCC zones

Table 3 Estimated Zone-wise daily transportation of wastes to Matuail site (Assuming all waste going to Matuail site)

1	2	3	4		
DCC Zone	Total Waste (ton) to Matuail		Waste Flow to Temporary Sites*		
	Available Data*	Estimated (from Col^m 2,4)	Sites		Amount (ton)
1	130.38	250			
2	200.77	385	Mugdapara Fish Arat	468	1066
3	122.30	235	Kamlapur Playground	598	
4	194.90	374	Chatbari	238	268
5	211.78	407	Kachukhet	30	
6	151.19	290	Sample Calculation:		
7	8.78	73.35	Zone 1= 130.38+130.38*1066/1160.76		
8	27.66	231	Zone 7= 8.78+8.78*268/36.44		
9	118.42	227			
10	31.02	60			

*BCAS (1998)

Table 4 Daily waste transportation cost for existing and proposed distant landfill site

DCC Zone	Total Waste (ton)	Land Site					
		Matuail			Proposed (at Gazipur)		
		Round Trip distance, km	Cost, Tk./ ton	Total Cost, Tk.	Round Trip distance, km	Cost, Tk./ ton	Total Cost, Tk.
1	250	14	221	55250	95	1500	375000
2	385	18	237.5	91437.5	100	1320	508200
3	235	22	253	59455	60	690	162150
4	374	18	223	83402	60	745	278630
5	407	22	224	91168	60	611	248677
6	290	26	232	67280	55	491	142390
7	73.35	42	280.5	20575	40	267	19585
8	231	44	250	57750	35	200	46200
9	227	35	256	58112	35	256	58112
10	60	60	282	16920	20	94	5640
Total				601350			1844020

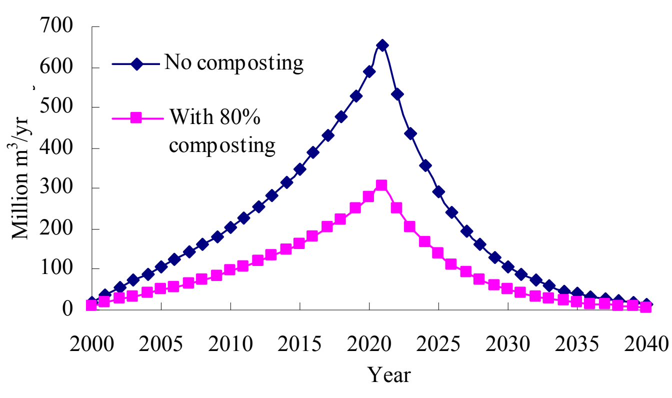

Fig. 9 Methane gas evolution at a fictitious dumping site under two scenarios - with/without composting

As a whole, the calculation performed here is expected to provide a rough idea about the probable cost increase and may also serve as a reference for further detailed study.

Environmental Impact of Improper Land Filling

The open air dumping of solid wastes at the dumping locations, besides 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 is further aggravated by the indiscriminate disposal of hazardous hospital and clinical wastes in the roadside bins and dumpsters.

Analysis of leachate samples collected from the dumping sites by drilling bores at five dumping sites (Hossain et al. 2000) show that the leachate samples have very high values of BOD_5 (980-10,000 mg/l), COD_{Mn} (1,300 - 12,200 mg/l) and very high concentrations of chloride (800-36,000 mg/l) and faecal coliform (200,000-1,500,000/100 ml) posing enormous threat to the water bodies that may eventually receive these leachates. In addition, the leachates have very high concentration of a number of toxic heavy metals including lead (1.58-13.51 mg/l) and chromium (0.18-51.04 mg/l). This is not surprising in view of the high concentrations of lead and chromium found in the ash residues of solid waste (BCAS 1998).

The methane produced from anaerobic decomposition of the organic solid waste components at landfill, besides being a Greenhouse gas, is highly combustible. All the dumping sites in Dhaka City run the risk of explosions due to complete absence of provisions for the escape and/or collection of gases generated continuously, no matter whether it is a filled site or an operating site. In this context, a comparison of methane production rate under two scenarios, with and without composting of organic waste, is deemed interesting. Fig. 9 depicts such a comparison following calculation, using LandGEM model, of methane production rate at a fictitious dumping site, which would be operated from 1999 to 2020. Without any composting, the landfill site would receive waste every year at a rate as shown in Fig. 1 and, with composting of 80% of the organic waste, it would receive waste at a rate as explained earlier, assuming a 50% waste collection efficiency in both cases. For the other two key parameters in the model – Lo and k, mentioned in the section 'Materials and Methods', appropriate values ($170m^3$/mg and 0.2/yr, respectively) were selected following guidelines from literature (USEPA 1998, Eam-o-pas et al. 2000) and keeping in mind the waste characteristics of Dhaka city. Results from the model (Fig. 9) suggest that with composting, the peak rate of methane generation would be as low as half of that for without any composting. Trace amount of methane will continue to be generated even after 100 years of landfill site closure (data not shown here).

Conclusion

Dhaka City Corporation (DCC) is unable to offer the desired level of services with the existing capacity and trend of waste management. Projection of future generation rate indicates that by the year 2020 it may exceed 30 thousand tons/day, which in turn will require over 200 acres/yr of landfill area. Experts have suggested that a community based solid waste management system involving recycling and composting in conjunction with sanitary landfilling with possible provision for transfer station to account for long distance of landfill sites may be the possible way out of the current inefficient system. To reduce the undesirable adverse impacts of overflowing of waste bins and accumulated wastes on roadsides, strict rules must be applied on the management related activities and the level of public awareness should be increased.

Index Notations

BCAS ≡ Bangladesh Center for Advanced Studies
DCC ≡ Dhaka City Corporation
IFRD ≡ Institute of Fuel Research and Development
MMI ≡ Mott MacDonald International
PAS ≡ Pan Asia Services
RSWC ≡ Rotted Solid Waste Consultancy
USEPA ≡ United States Environmental Protection Agency

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