

MUNICIPAL SOLID WASTE QUANTIFICATION, TRANSPORTATION AND MANAGEMENT IN KHULNA CITY

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Received: 10 September 2018

Accepted: 24 November 2019

ABSTRACT

Solid waste management is an integral part of modern development and it could be viewed as a combination of collection, transportation, recovery, and safe disposal of waste. This paper presents a summary of current waste management in Khulna city regarding the quantity of Municipal Solid Waste (MSW), and the daily driven distance with fuel consumption of collection and transportation trucks. With this view questionnaire survey, key informant interview and field investigation have been done at 67 number of MSW transfer sites throughout the city. The study reveals that 374000 kg d⁻¹ of MSW is collected and transported by the Khulna city corporation (KCC) in which 183750 kg d⁻¹, 99125 kg d⁻¹, 15875 kg d⁻¹, and 75250 kg d⁻¹ of MSW from 17 secondary disposal sites, 27 large hauled container points, 11 small hauled container points, and 12 distinct collection routes respectively. At present the total managed MSW is found as 91.33% of total generated MSW by applying the waste management technique such as composting (4.38%), recycling (9.05%), and landfilling (86.57%). Moreover, the unattended MSW is found as 8.62% of generated MSW. The daily driven distance of the collection and transportation trucks of KCC is found as 2632.10 km consuming 623.26 L d⁻¹ diesel as fuel.

Keywords: Daily Driven Distance; Daily Managed Waste; Final Dumping Site; Fuel Consumption; Municipal Solid Waste; Secondary Disposal Site

1. INTRODUCTION

Generation of municipal solid waste (MSW) rapidly, and the inclusion of harmful chemicals, and additives in different waste portions lead to sustainable management of solid waste is a critical issue of the municipal authority in the most of the cities in the world (Jeswani and Azapagic, 2016; Tulokhonova and Ulanova, 2013; Demirbas, 2010). In case of Asian countries, about 90% of MSW are dumped in open dumping condition as a result of social, economic, and technological changes which is posing problems in storage, collection, transportation, and ultimate disposal (Pangkaj and Rafizul, 2019; Yaseen *et al.*, 2017). Waste directive framework state that the main objective of any waste policy is to reduce the adverse effects on human health and the environment (European Commission, 2008).

In developing countries, much of the MSW is generated where variable human activities are encountered as a percentage of 55-80 from households, as a percentage of 10-30 from commercial or market areas and as varying percentage from streets, industries, institutions among others (Miezhah *et al.*, 2015; Nabegu, 2010). In Khulna city, the total amount of solid waste generation is found as 450000 kg d⁻¹ (Basic Statics about KCC, 2017). The Khulna city corporation (KCC) authority is responsible for waste management in this city (Islam *et al.*, 2017). MSW is generally deposited in roadside, hauled container points and secondary disposal sites either by the residents themselves or community-based organizations or non-government organizations through their door to door collection system. The KCC workers generally do not collect MSW from household (Islam *et al.*, 2017). KCC workers collect MSW from SDS and transport it to the final disposal site situated at Rajbandh which is 10 kilometers far from city Headquarter in the direction of the west (Sanjida and Rafizul, 2018). In developing countries, unskilled handling of MSW leads to contamination of water, soil, and atmosphere and is a major impact on public health (Batool and Ch, 2009; Sharholy *et al.*, 2008). Similarly, the existing trends in production, consumption and waste management have led to numerous emissions of heat-trapping greenhouse gases in which carbon dioxide released during the production of new materials and methane from the decomposition of organic waste in landfills (Bari *et al.*, 2012). This paper presents an overview of current waste management in Khulna city, firstly, with regard to the quantity of managed MSW, and secondly, with regard to the daily driven distance, and the fuel consumption of collection and transportation trucks.

2. METHODOLOGY

2.1 Study Area

Khulna is located at the southwest of the country and is situated below the tropic of cancer, around the intersection of latitude 22.49° N and longitude 89.34° E, which are the third largest city as well as the second

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port entry of Bangladesh. The city has an estimated total area of 45.65 sq. km and the population density of 67994 sq. km (Basic Statics about KCC, 2017). There are 31 wards throughout the city corporation and a separate department for the solid waste management namely conservancy department. All the wards of the city are selected as the study area. The location of study area in the context of Bangladesh is shown in Figure 1.

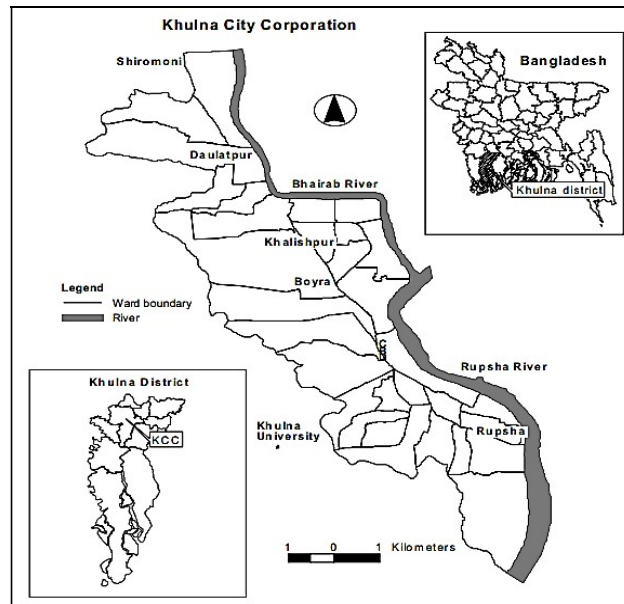


Figure 1: Location of study area in context of Bangladesh (KCC Yearbook, 2000)

2.2 Survey in the Selected Study Area

In order to reach the goal of the study, the overall methodology being used is shown in Figure 2. Two types of data are mainly gathered to conduct this research. First one is primary data which have been collected by field visits, questionnaire survey and key informant interviews. The second one is secondary data which have been gathered from different journal papers, reports, and online resources.

2.2.1 Location of Sites

The selected sites are secondary disposal sites (SDS), large hauled container points (LHCP), small hauled container points (SHCP) and distinct collection routes (DCR). The field visit has been performed throughout the city to find out the location of the aforementioned sites. For this purpose, questionnaire survey has been done to the drivers and helpers of the waste collection truck to know the location of the site. At the same time the location has been justified to the ward wise map of KCC. It is to be mentioned that all the sites of SDS, LHCP and SHCP have been renamed as site number due to space constraint of the article and the simplicity of the graphical presentation. In case of SDS the number has been assigned as SDS 1 to SDS 17. Likewise, in case of LHCP and SHCP the number has been assigned as LHCP 1 to LHCP 27 and SHCP 1 to SHCP 11 respectively.

2.2.2 Quantity of Collected and Transported Waste

A series of questionnaire surveys have been conducted with workers of the MSW transportation trucks throughout the city to find the amount of collected and transported MSW. The questionnaire surveys have been conducted at each site of SDS, LHCP, SHCP and DCR. For the simplicity of research, the year is sub-divided into the two seasons, i.e. dry season (October to March) and wet season (April to September). The amount of collected and transported MSW from each site of SDS, LHCP, SHCP and DCR have been recorded on throughout the entire November 2016 for the dry season and on throughout the entire July 2017 for the wet season.

2.2.3 Daily Driven Distance of Transportation Truck

The equation of daily driven distance for SDS, LHCP, SHCP, and DCR are given below which is determined by the using of Google Map and GIS software.

*Daily driven distance for SDS, $S_{SDS} = (\text{Distance driven by loader truck from the KCC garage to SDS} + \text{Distance driven by loader truck from SDS to KCC garage}) + \text{No. By trip required} * (\text{distance driven by the collection$*

truck from the garage to SDS + distance driven by the collection truck from SDS to dumping site + distance driven by the collection truck from dumping site to KCC garage).

$$S_{SDS} = 2 * S_1 + N (S_1 + S_2 + S_3) \quad (1)$$

Where,

S_1 = Driven distance between KCC garage and SDS/LHCP/ SHCP/ DCR

S_2 = Driven distance between SDS/ LHCP / SHCP/ DCR and final dumping sites

S_3 = Driven distance between final dumping sites and KCC garage

N = Number of trips required

Daily driven distance for LHCP/ SHCP, $S_{LHCP/SHCP}$ = No. of trip required * (distance driven by hauled container carrier truck from the KCC garage to LHCP/ SHCP + distance driven by hauled container carrier truck from LHCP/ SHCP to dumping site + distance driven by hauled container carrier truck from dumping site to LHCP/ SHCP + distance driven by hauled container carrier truck from LHCP/SHCP to KCC garage).

$$S_{LHCP/SHCP} = N (S_1 + 2 * S_2 + S_3) \quad (2)$$

Daily driven distance for DCR, S_{DCR} = No. of trip required * (distance driven by the collection truck from the KCC garage to DCR + distance driven by Collection truck from DCR to dumping sites + distance driven by the collection truck from dumping sites to KCC garage).

$$S_{DCR} = N (S_1 + S_2 + S_3) \quad (3)$$

$$\text{Hence, Total driven distance, } S = S_{SDS} + S_{LHCP} + S_{SHCP} + S_{DCR} \quad (4)$$

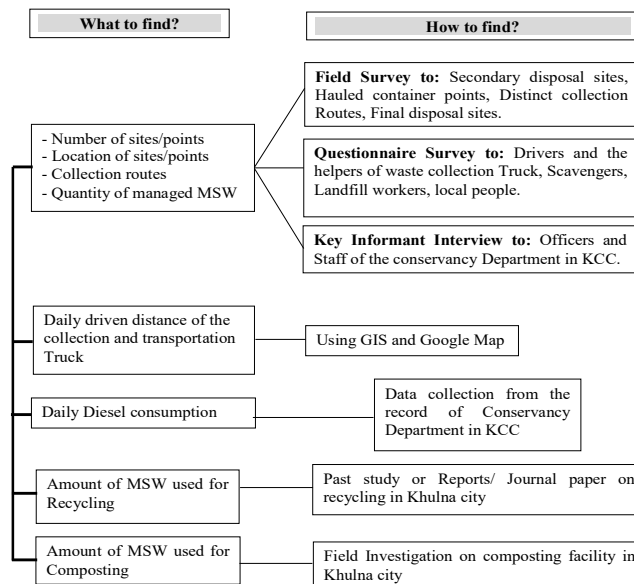


Figure 2: Workflow diagram of the data collection

3. RESULTS AND DISCUSSION

3.1 Overview of the Present MSW Management

This section describes the services of the MSW management in Khulna city. The key components of how MSW is managed from the generation of waste to the collection, diversion and then finally, disposal are presented in Figure 3. In case of domestic, commercial and institutional waste collection, community-based organizations (CBOs) distribute a group of waste collector (WC) or worker to collect MSW from each household by a monthly payment from dwellers, currently Tk. 50 (\$ 0.60). WC collect MSW by using non-motorized vehicle namely, tricycle (or locally called Van) and transport to the nearest SDS, LHCP, SHCP. In case of roadside MSW, KCC worker collects directly from the roadside and transport to final dumping sites. But in case of hospital or medical waste, non-government organization collect and transport waste to a fixed dumping site namely, Rajbandh dumping site 2. For medical waste, only open-air burning technique is applied to manage.

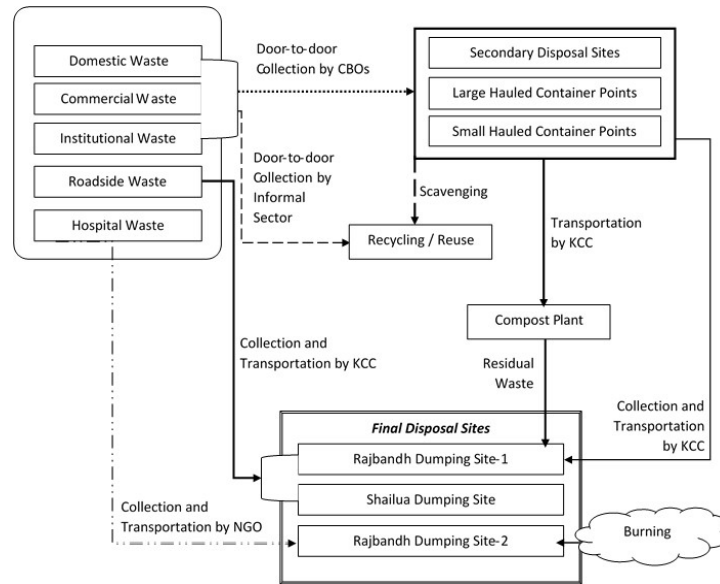


Figure 3: Flow diagram of the present MSW management system in Khulna city

3.2 Quantity of Collected and Transported MSW with Daily Driven Distance

The field survey reveals that there are 17 SDS in different location of Khulna city as shown in Figure 4. For larger quantity of MSW, SDS is considered as the major sites. The field investigation yields that the quantity of collected and transported MSW from SDS to final dumping sites is about 50% (183750 kg d^{-1}) of the total collected and transported MSW by KCC. The quantity of collected and transported MSW at different SDS in the wet season and the dry season is found as 209500 kg d^{-1} and 158000 kg d^{-1} respectively. The quantity of MSW in the wet season is about 25% higher than that of dry season because of a large amount of seasonal fruits in summer season. However, SDS 1 located at Galkhali Koborstan, the quantity of collected and transported MSW in the wet season is less than that of dry season because of the addition of a new large hauled container point. In the wet season the maximum quantity collected and transported MSW is found as 51000 kg d^{-1} located at PTI Mor (SDS 10). In the dry season there is no SDS found on Zilla School (SDS 16) and Sadar hospital (SDS 17), but in wet season new SDS found and the quantity of collected and transported MSW is recorded and shown in Figure 4.

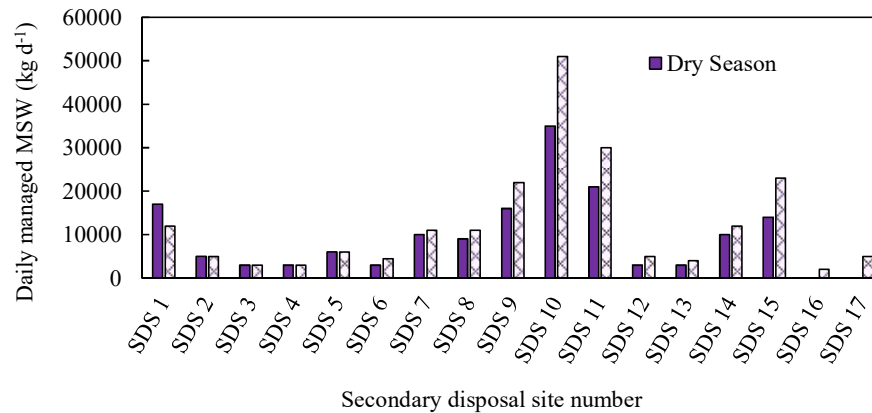


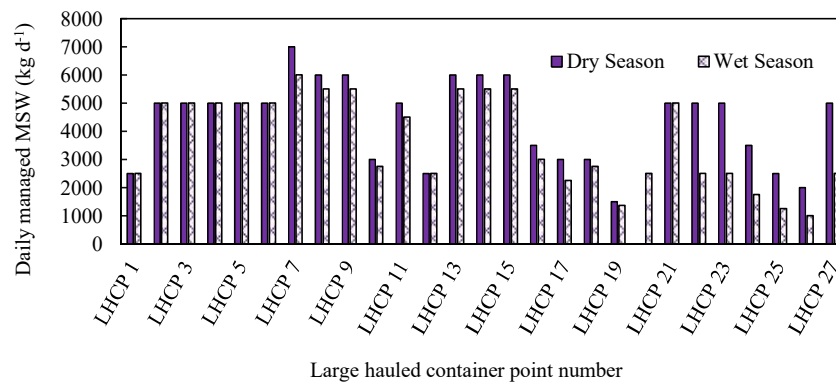
Figure 4: Daily managed MSW from secondary disposal sites to final dumping sites

The daily driven distance for transportation of MSW from different SDS to final dumping sites is calculated by using Equation (1) as described in methodology section and presented in Table 1. The total number of trips per day for transportation of MSW from SDS to final dumping sites is found as 40. The total daily driven distance from SDS to final dumping sites is found as 843.90 km. The maximum trip required per day is found as 9 at SDS 10. In addition, the maximum daily driven distance of the transportation truck is found as 157.1 km at SDS 10. From figure 4, it is to be noted that SDS 10 is the site where the maximum quantity of MSW managed.

Table 1: Daily driven distance with a number of trips from SDS to final dumping sites

SDS number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SDS location at KCC Ward	10	13	15	16	16	16	17	17	20	23	26	22	30	21	18	22	21
Trip per day	3	1	1	1	1	1	2	2	4	9	5	1	1	2	4	1	1
Daily driven distance (km)	88.3	40.1	28.6	26.2	33.8	32.1	38.6	38.6	66.6	157.1	82.9	25.2	32.9	34.2	70.4	22.1	26.2

The field survey reveals that there are 27 large hauled container points (LHCP) having capacity of 5000 kg each through the city as shown in Figure 5. The quantity of collected and transported MSW from LHCP to final dumping sites is about 26% (99125 kg d⁻¹) of the total collected and transported MSW by KCC. The quantity of collected and transported MSW at LHCP in the dry season is about 84250 kg d⁻¹. On the other hand, the quantity of collected and transported MSW at LHCP in the wet season is about 114000 kg d⁻¹, which is 26% higher than that of dry season because of a large amount of seasonal fruits in summer season. There are 8 numbers of LHCP where the amount of collected and transported MSW are same in both season because of the presence of SDS at the same location. Similarly, there are 6 numbers of LHCP where the quantity of the collected and transported MSW is larger than the capacity of the container because the data are recorded based on total number of containers emptied in a week. Especially in fruit season, the KCC staff managed waste at the early morning as well as evening in a day. In the dry season there is no existence of LHCP at South central road (LHCP 22), Rupsha fish market (LHCP 23), Kulibagan (LHCP 24), Sromik Bhaban (LHCP 25), Janata cinema hall (LHCP 26), and Goalkhali Koborstan (LHCP 27) but in the wet season new LHCP found and quantity of collected and transported MSW is recorded.

**Figure 5:** Daily managed MSW from large hauled container points to final dumping sites

The daily driven distance for transportation of MSW from different LHCP to final dumping sites is calculated by using equation (2) and presented in Table 2. The total number of trips per day for transportation of MSW from LHCP to final dumping sites is found as 27. The total daily driven distance from LHCP to final dumping sites is found as 893.60 km. Due to the one-time emptying frequency of LHCP a day, the trip per day for all points are found as 1. In addition, the maximum daily driven distance of the transportation truck is found as 65.6 km at the Janata cinema Hall (LHCP 19) which is situated at the longest distance compared to other sites.

Table 2: Daily driven distance with several trips from LHCP to final dumping sites

LHCP number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
LHCP location at KCC Ward	23	22	22	21	21	25	14	6	5	13	8	7	15	9	9	31	15	9	2	17	13	22	30	5	12	2	10
Trip per day	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Daily driven distance (km)	21.8	27.2	24.6	26.4	20.6	18.8	24.6	30.2	44.8	46	39.4	42.8	32.4	32.8	36.8	34.2	37.6	41	65.6	22.2	40.6	18.4	19.8	42	12	52	39

The field survey reveals that there are 11 small hauled container points (SHCP) having capacity of 3000 kg each through the city as shown in Figure 6. The quantity of collected and transported MSW from SHCP to final dumping sites is about only 4 % (15875 kg d⁻¹) of the total collected and transported MSW by KCC. The quantity of collected and transported MSW at SHCP in the dry season is about 16500 kg d⁻¹. On the other hand,

the quantity of collected and transported MSW at SHCP in the wet season is about 15250 kg d⁻¹ which is 8% lower than that of dry season because of the absence of the 2 container points. In case of LHCP 1 and 2, the maximum quantity collected and transported MSW found as 3000 kg d⁻¹.

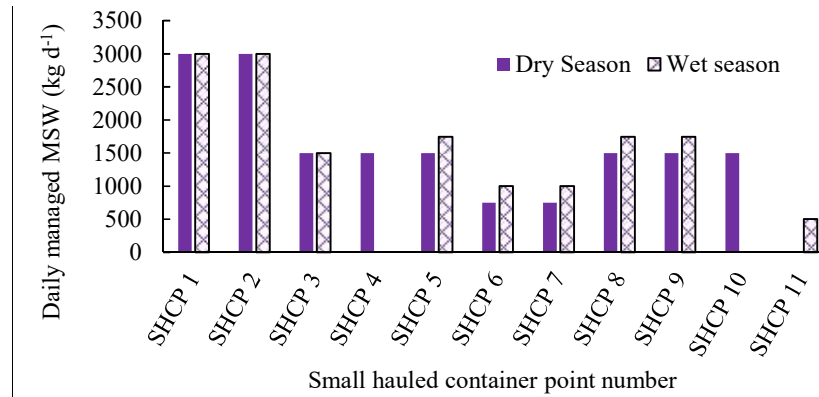


Figure 6: Daily managed MSW from small hauled container points to final dumping sites

The daily driven distance for transportation of MSW from different SHCP to final dumping sites is calculated by using equation (2) and presented in Table 3. The total number of trips per day for transportation of MSW from SHCP to final dumping sites is found as 11. The total daily driven distance from SHCP to final dumping sites is found as 314.0 km. Due to the one-time emptying frequency of SHCP a day, the trip per day for all points are found as 1.

Table 3: Daily driven distance with number of trips from SHCP to final dumping sites

SHCP number	1	2	3	4	5	6	7	8	9	10	11
SHCP location at KCC Ward	30	30	22	30	31	26	26	18	15	17	31
Trip per day	1	1	1	1	1	1	1	1	1	1	1
Daily driven distance (km)	29.8	26.2	27.6	30.6	33.8	20.8	36.4	14.2	32.4	22.2	40

The field survey reveals that there are 12 DCR excluding a conditional route through the city as shown in Table 4. The quantity of collected and transported MSW from DCR to final dumping sites is about 20% (75,250 kg d⁻¹) of the total collected and transported MSW by KCC. The total quantity of collected and transported MSW at different DCR in the wet season is about 22% higher than that of the dry season. In the wet season the maximum collected and transported MSW found at Route 5 (Ward 16, 17 and 18) which is about 10,000 kg d⁻¹. The daily driven distance for transportation of MSW different DCR to final dumping sites is calculated by using equation (3) and found as 580.6 km.

Table 4: Daily collected and transported MSW from distinct collection routes to final dumping sites

Route number	Route location at KCC Ward	Daily collected and transported MSW (kg d ⁻¹)		Trip per day	Daily driven distance (km)
		Dry Season	Wet Season		
Route 1	1 to 6	6000	7000	2	122
Route 2	7 to 14	6000	7000	2	58.2
Route 3	10, 12, 15, 16	6000	7000	2	50.4
Route 4	16, 17	6000	7000	2	34.0
Route 5	16, 17, 18	6000	10000	2	49.4
Route 6	18,19	6000	6000	2	35.4
Route 7	20, 21	6000	7000	2	36.2
Route 8	23, 24	6000	7000	2	34.0
Route 9	25, 26	6000	7000	2	26.4
Route 10	22, 27	6000	7000	2	29.4
Route 11	28, 30, 31	6000	7000	2	47.4
Route 12	5, 10, 29	2500	3000	2	57.8

The total quantity of collected and transported MSW from SDS, LHCP, SHCP and DCR is found about 374,000 kg d⁻¹ from the discussion. In addition, the total daily driven distance of collection and transportation truck is calculated by using equation (4) and found as 2632.10 km.

The mass balance of the MSW flow of Khulna city is shown in Figure 7. The total generated MSW is estimated at 450,000 kg d⁻¹ (Basic Statics about KCC, 2017). From the authors another study, the quantity of managed waste through recycling by informal sector is estimated at 37230 kg d⁻¹ (Moniruzzaman *et al.*, 2011). The total quantity of collected and transported MSW from SDS, LHCP, SHCP and DCR to final disposal sites is found as 374,000 kg d⁻¹. Hence, only 18,000 kg d⁻¹ of MSW is used for the composting purpose by non-government organization and 356000 kg d⁻¹ of MSW is managed through landfilling. Moreover, the remaining unmanaged MSW is found as 38,770 kg d⁻¹.

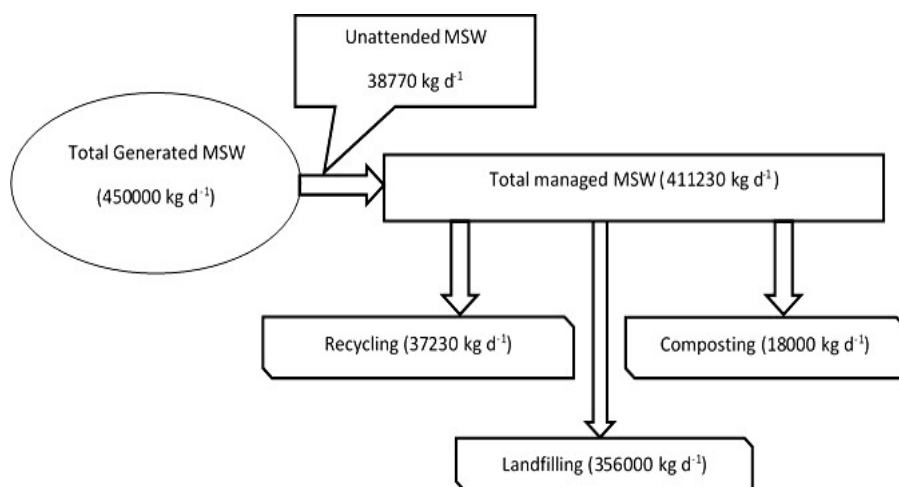


Figure 7: The mass balance of total MSW flow in Khulna City Corporation

3.3 Daily Diesel Consumption of the Collection and Transportation Trucks

The daily diesel consumption of collection and transportation truck is presented in Table 5. The total diesel consumption of transportation trucks is about 227,489 L yr⁻¹. Considering the daily driven distance 2632.10 km, the daily diesel consumption is found as 623.26 L d⁻¹. The daily diesel consumption in the wet season (April to September) and dry season (October to March) is found as 689.11 L d⁻¹ and 557.41 L d⁻¹ respectively. Due to the seasonal fruits during the wet season, the daily diesel consumption is 10% greater than that of the dry season. Diesel consumption varies with the capacity of the collection and transportation trucks. From the questionnaire survey to the drivers of transportation truck of KCC, the fuel efficiency of truck for 3,000 kg MSW carrying capacity is found as 4 to 4.5 km L⁻¹ and for 8,000 kg MSW carrying capacity is found as 3.00 to 3.50 km L⁻¹. Conversely, considering the daily driven distance and daily fuel consumption, the fuel efficiency is found as 4.22 km L⁻¹.

Table 5: Daily diesel consumption of collection and transportation trucks

Name of the season	Diesel consumption at the particular season (L)	Daily diesel consumption (L d ⁻¹)	Fuel efficiency (km L ⁻¹)
Wet Season	125762	623.26	4.22
Dry Season	101727		

4. CONCLUSIONS

The conclusions drawn from the present study are as follows:

- In case of domestic and commercial MSW collection, waste collector collects MSW from each household by a monthly payment from dwellers and transport to the nearest secondary disposal sites. KCC workers transport MSW from these sites to final dumping sites. In case of roadside MSW, KCC worker collects MSW directly from the roadside and transport to final dumping sites. But, in case of hospital or medical waste, non-government organization collect and transport waste to Rajbandh dumping site 2.
- The KCC workers collect and transport 374,000 kg d⁻¹ of MSW from 11 small hauled container points, 21 large hauled container points, 11 distinct collection routes and 17 secondary disposal sites to 3 final dumping sites near the city.

- At present 411,230 kg d⁻¹ of generated MSW is managed by composting (18,000 kg d⁻¹), recycling (37,230 kg d⁻¹) and landfilling (356,000 kg d⁻¹). Moreover 38,770 kg d⁻¹ of generated MSW is found as unattended.
- The daily driven distance of the collection and transportation trucks of KCC is found as 2632.10 km.
- The fuel consumption of collection and transportation truck is found as 623.26 L d⁻¹.

ACKNOWLEDGEMENT

The author of this report would like to thank to chief conservancy management officer, Department of conservancy, Khulna City Corporation for their good assistance and response. The author thankfully acknowledges to Khulna University of Engineering & Technology for the financial support to complete this research.

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