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Municipal solid waste characteristics and management in Allahabad, India

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Abstract

Increasing population levels, rapid economic growth and rise in community living standard accelerates the generation rate of municipal solid waste (MSW) in Indian cities. Improper management of MSW causes hazards to inhabitants. The objectives of the study are to determine the quantitative and qualitative characteristics of MSW along with basic information and to create GIS maps for Allahabad city. The samples have been randomly collected from various locations and analyzed to determine the characteristics of MSW. A questionnaire survey has been carried out to collect data from inhabitants including MSW quantity, collection frequency, satisfaction level, etc. The Geographic Information System (GIS) has been used to analyze existing maps and data, to digitize the existing sanitary ward boundaries and to enter the data about the wards and disposal sites. The total quantity of MSW has been reported as 500 ton/day, and the average generation rate of MSW has been estimated at 0.39 kg/capita/day. The generated ArcGIS maps give efficient information concerning static and dynamic parameters of the municipal solid waste management (MSWM) problem such as the generation rate of MSW in different wards, collection point locations, MSW transport means and their routes, and the number of disposal sites and their attributes.

1. Introduction

MSWM is the major problem being faced by municipalities because it involves a huge expenditure and receives scant attention (Bhide and Sundersan, 1983). It is not only a technical problem but it also is strongly influenced by political, legal, socio-cultural, environmental and economic factors, as well as available resources. Moreover, these factors have interrelationships that are usually complex in waste management systems (Kum et al., 2005). Many cities in developing Asian countries face serious problems in managing their solid waste. The annual waste generation increases in proportion to the rise in population and urbanization, and issues related to disposal have become challenging as more land is needed for the ultimate disposal of these solid wastes (Idris et al., 2004). MSW is normally disposed of in an open dump in many Indian cities and towns, which is not the proper way of disposal because such crude dumps pose environmental hazards causing ecological imbalances with respect to land, water and air pollution (Kansal et al., 1998). Increasing population levels, rapid economic growth and rise in community living standards will accelerate the future MSW generation rate within Indian cities. The present annual quantity of solid waste generated in Indian cities has increased from 6 million tons in 1947 to 48 million tons in 1997 with an annual growth rate of 4.25%, and it is expected to increase to 300 million tons by 2047 (CPCB, 2004).

Improper management of MSW constitutes a growing concern for cities in developing nations. Proper management requires the construction and installation of essential facilities and machinery, based on a suitable management plan (Shimura et al., 2001). More than 90% of MSW in India is directly disposed of on the land in an unsatisfactory manner (Das et al., 1998). The problem is already

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acute in cities and towns as the disposal facilities have not been able to keep space with the quantum of wastes being generated. It is common to find large heaps of garbage lying in a disorganized manner at every nook and corner in the cities (Kansal, 2002). Therefore, the present study aims at to determine the quantitative and qualitative characteristics of MSW along with basic information, which is desirable for MSWM, and to create GIS maps for Allahabad city.

2. Status of MSW: an overview

Allahabad is a major city of east Uttar Pradesh State, situated at 25.25° North latitude and 81.58° East longitude. It is about 627 km from Delhi and about 815 km from Calcutta. Allahabad is an ancient city of India, considered holy because it is built on the confluence (Sangam) of the rivers Ganga, Yamuna and Saraswati (Tourism Department, 1989). The city has a population of about 1,025,000 inhabitants (AMC, 2003). Allahabad Municipal Corporation (AMC) is responsible for the management of the MSW generated in the city. The city is divided into 20 sanitary wards (Fig. 1) and the entire operation of solid waste management (SWM) system is performed under four heads, namely, cleaning, collection, transportation and disposal. In the city area of about 63 km^2, the cleaning and collection operations are performed by the public health wing of AMC; while transportation and disposal of MSW are being performed by the transportation wing of AMC. In Allahabad city the cleaning and collection process involves collection of MSW from the street in wheelbarrows and thereafter, it is dumped into depots (49 depots). MSW is then loaded into the transportation vehicles, which transport the waste to different disposal sites. Every year AMC spends on average 18% of its total budget on solid waste management.

2.1. Sources and quantity of MSW

AMC reported the percentage of MSW generated for various sources in Allahabad city as shown in Table 1. The inhabitants of the Allahabad city generate approximately 500 ton of MSW daily. AMC estimated the annual

Table 1
MSW sources in Allahabad

Sources of waste	Percentage
Households	40
Restaurants	27.2
Street sweeping	9.1
Market	9
Shops and workshop	6.1
Offices	5.8
Hospitals	1.5
Hotels	1.3
Total	100

Source. AMC (2003).

Table 2
MSW generation amount in Allahabad

Year	Population	Per capita waste generation (kg/capita/day)	Total waste generation (ton/day)
1997	861,129	0.474	408
2001	990,298	0.506	501
2006	1,138,843	0.541	616
2011	1,309,669	0.578	757
2016	1,506,119	0.617	929
2021	1,732,037	0.66	1143
2026	1,991,843	0.705	1404

Source. AMC (2003).

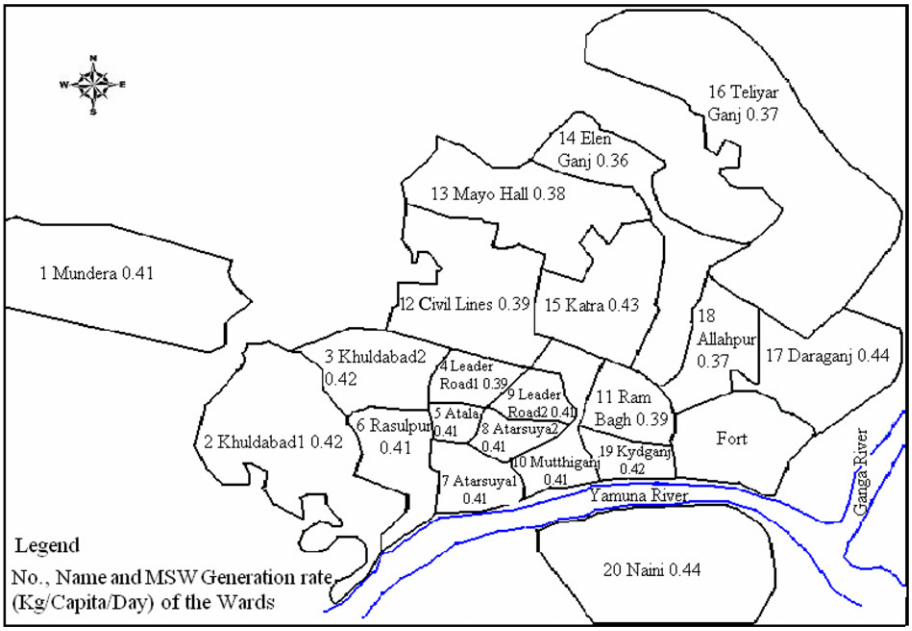

Fig. 1. MSW sanitary wards in Allahabad city.

per capita growth rate for MSW generation as 1.33% and forecasted the quantity of MSW from 2006–2026 as shown in Table 2.

2.2. Primary collection of MSW

Sweepers collect the MSW from the roads/streets and carry it to the nearest collection points (depots or community bins). MSW produced from individual households is taken to the collection point or just deposited on the adjacent roadside from where it is collected when the roads are swept. This type of collection is called primary collection.

2.3. Methods of storage

AMC has provided 49 depots for the temporary storage of MSW, which are scattered throughout the city. The depots are an open space enclosed on three sides with a masonry wall of about 1.35 m height, with capacities ranging from 15 to 40 m^3 and located in a congested area containing narrow winding streets. Unfortunately, only 38% of the depots are in good condition and the rest have been damaged during loading by the loader and by animals; 16% of the depots having no wall (AMC, 2003).

AMC has also provided two types of community bin containers for MSW storage. The first one has wheels and its capacity is 1 m^3. The bin is placed along the roadside in areas where this system has been adopted; 19 wards are covered by this system (597 bins) and the distance between the containers ranges from 100 to 150 m. The second type of community bin is without wheels and its capacity is 4.4 m^3. Six such bins are provided in big markets and road crossings (4 bins in Leader Road II Ward and 2 bins in Mutthiganj Ward), where collection of MSW seems to be heavy.

2.4. Secondary collection of MSW

In Allahabad city the disposal sites are generally within 15 km of the collection points, hence, transfer stations are not in use and the MSW is directly hauled by the collection vehicle from the collection points to the disposal site. Since the MSW is collected again from the collection points for transportation to the disposal site, it is termed secondary collection. The hauled container, stationary container, manually loaded dumper and mechanically loaded dumper systems are used during secondary collection, transportation and disposal of MSW. The hauled container system (HCS) is a collection system in which the containers used for the storage of wastes are hauled to the processing, transfer or disposal sites, and then emptied and returned to either their original location or some other location. A dumper placer is used to carry the large size of community bins (4.4 m^3) containing MSW from its fixed point to the disposal site where it is unloaded mechanically by a hydraulic arm. Then, the empty container is brought back from the disposal site to its original point. The stationary container system (SCS) is the collection system in which the containers used for storage of MSW remain at the point of waste generation. The capacity of each container is 1 m^3. The manually loaded dumper system is adopted in areas where it is not possible to use a pay loader and dumper trucks. The workers collect the MSW from the collection points in baskets and then transfer it into the vehicle manually, while in the mechanically loaded dumper system the MSW is taken from various collection points and is loaded using various types of loading machines (loaders).

2.5. Final disposal of MSW

Allahabad does not have a sanitary landfill for proper disposal of MSW. There are six open disposal sites where the MSW of the city is being disposed of (Singh, 1997). A brief description of all sites is presented in Table 3.

3. Geographic information system (GIS)

ArcGIS is a complete and integrated system for the creation, management, integration, and analysis of geographic data. It consists of a geo-referenced spatial database, which includes all required parameters for MSWM. These parameters involve sanitary wards, collection points, transportation road network, as well as the location and capacity of disposal sites and its connection with different wards. ArcGIS has the capability to input and store the geographic (coordinate) and tabular (attribute) data, to find specific features based on location or attribute value, to answer questions regarding the interaction between multiple datasets, to visualize geographic features using a variety of symbols and to display the results in a variety of formats, such as maps and graphs.

The GIS Desktop includes three integrated applications, i.e., ArcMap, ArcCatalog and ArcToolbox. ArcMap is the primary GIS application for performing analysis and

Table 3
Details of the existing disposal sites

Name of disposal site	Area (ha)	Round trip distance (km)	The average disposed of MSW (ton/day)	MSW received from ward numbers
Kareli	50	12	170	2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 19
Chandpur Salori	2	16	110	11, 12, 14, 15, 16 and 18
Phaphamau	25	18	105	10, 11, 12, 13, 14, 15 and 16
Sulem Sarai	1.5	6	25	1 and 2
Alopi Bagh	1.5	10	75	11, 17, 18 and 19
Naini	2	8	15	20

Source. Singh (1997) and AMC (2003).

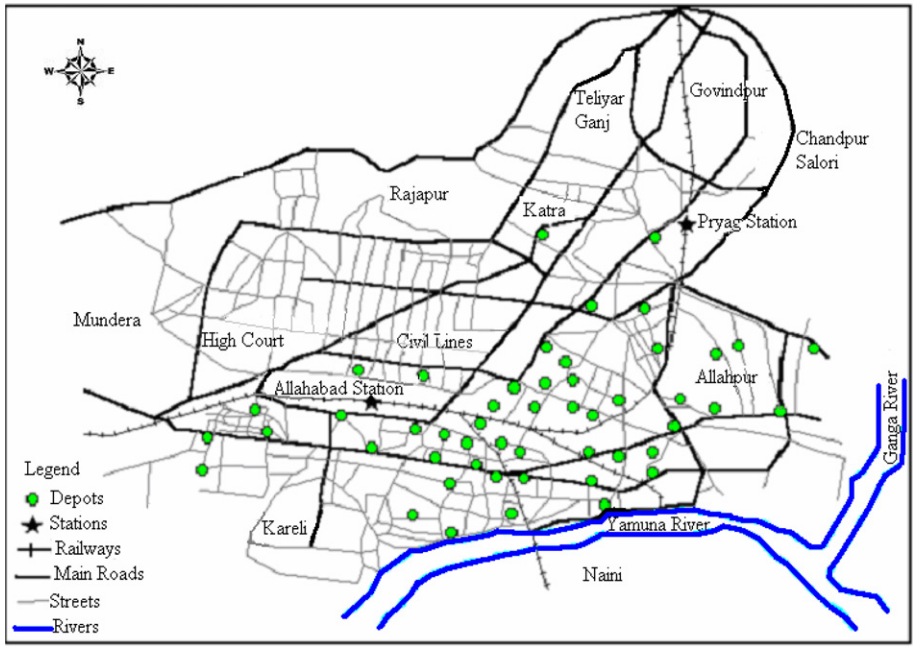

Fig. 2. Location of MSW depots in Allahabad city.

making maps; it is used for displaying, querying, editing, creating and analyzing GIS data. ArcCatalog application helps to organize and manage all GIS data. It includes tools for browsing and finding geographic information, recording and viewing metadata, quickly viewing any dataset and defining the schema structure for geographic data layers. ArcToolbox application provides tools for data conversion, managing coordinate systems, and changing map projections (ESRI, 2003).

4. Methodology

In the first phase of the study, samples of MSW from different wards were collected during August 2003 to April 2004 to determine its characteristics. The sampling and analysis of MSW were carried out as per standard procedures described in Peavy et al. (1985). Twenty samples were randomly collected from wards (one sample/ward), and two samples were collected from the disposal sites (Phaphamau and Kareli).

In the second phase of the study, a questionnaire survey was carried out on 844 randomly selected houses in various areas in the city. A questionnaire was prepared according to Raje et al. (2001) and Buenrostro et al. (2001) using door-to-door surveying in order to obtain data about MSW quantity, daily disposal, availability of containers, collection frequency and satisfaction level, etc. The data collected from the survey was analyzed using Microsoft Excel for calculating simple statistics; average (arithmetic mean), standard deviations and the error at 90% confidence. Further, the per capita generation rate was evaluated from the population taken into account during survey work and the quantity of MSW generated as follows:

$$\text{Generation rate (kg/capita/day)} = \frac{\text{Quantity of solid waste (kg/day)}}{\text{Population (capita)}}.$$

In the third phase of the study, ArcGIS was used to create maps for MSWM. The original map of Allahabad was scanned and registered/geo-referenced to specify its location by inputting coordinates. Thereafter, the collected data for various sanitary wards, collection routes, depots locations, and disposal sites were given as input parameters for the generation of MSWM maps for Allahabad city using ArcGIS applications. The sanitary wards were drawn and input properties such as name, number, generation rate, and the disposal site connected for each ward have been inserted (Fig. 1). The location of depots in each ward, and the collection routes of hauled container system and stationary container system, are determined (Figs. 2 and 3). Then, the properties of each disposal site, such as name, capacity, amount of MSW disposed daily and the wards connected to it are defined (Fig. 4).

5. Results and discussion

The results of the analyses show that MSW contains 45.3% organic matter and 40% miscellaneous materials (bricks, fine dust, rubber, wood, leather, wastewater, etc.) as shown in Table 4. The percentage of recyclable materials (glass, paper, plastic, metals) has been found to be very low. This may be due to rag pickers, who collect and segregate recyclable materials from collection points and disposal sites.

The results from the survey reveal that the per capita MSW generation rate is 0.39 kg/capita/day. The per capita generation rate for various areas in Allahabad city is shown

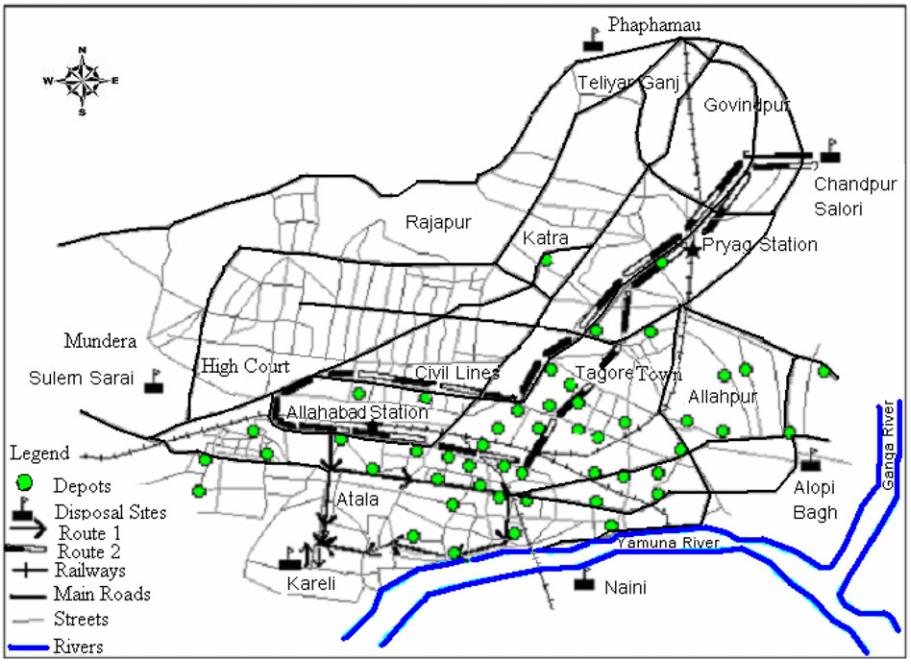

Fig. 3. Collection routes of hauled container system.

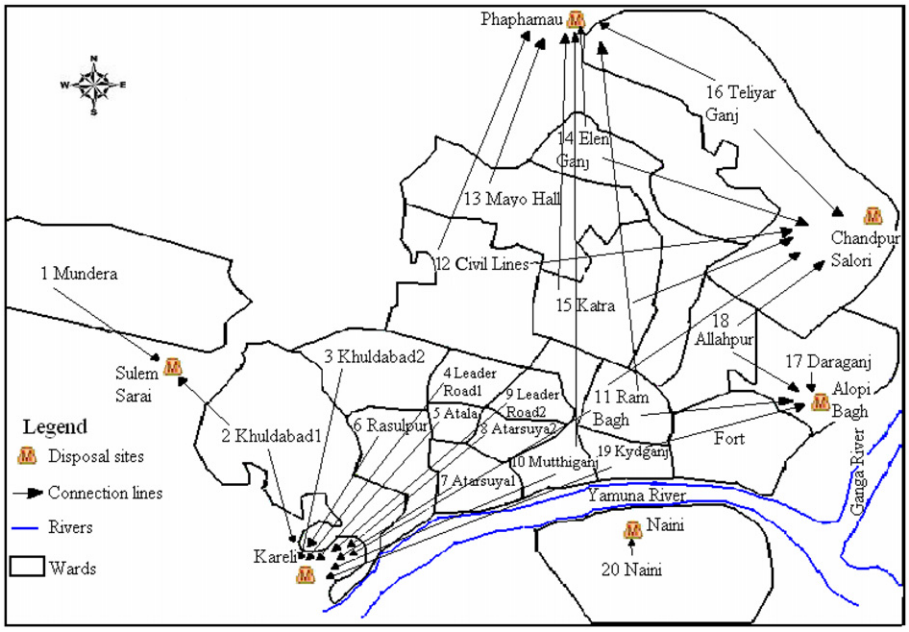

Fig. 4. Existing MSW disposal sites connected to sanitary wards.

in Fig. 5. It is also revealed that 88 ± 3.6% of people living in houses dispose of their garbage daily, in which 53.4 ± 4% are disposing waste in containers, whereas 46.4 ± 4.2% are disposing on the streets. Further, 20.4 ± 6.8% of houses are segregating their solid waste (biodegradable/non-biodegradable), 39.5% are using polyethylene bags for storage and 63.5 ± 5.9% of houses are fully aware of government's policy (government bans the using of plastic and polythene bags because they are not easily biodegradable and they create many problems to the environment).

The collection frequency of MSW is carried out as shown in Fig. 6. The figure shows that 42.7 ± 5% of houses are paying for solid waste collection services to local sweepers, and 45.6 ± 3.5% are willing to pay for the improvement of solid waste services. About 23 ± 3.6% of houses have complained of poor services and others (39.7 ± 5.4%) have been satisfied by the complaint office. The survey also reveals that 34.8 ± 4.1% of the people are satisfied with solid waste collection services and their satisfaction levels are shown in Fig. 7.

Table 4
Estimation of the MSW constituents in Allahabad

Constituents	% Of weight	Standard deviation	% Error at 90% confidence
Paper	3.6	1.08	0.38
Cardboard	1.09	0.55	0.19
Metal, tin cans	2.54	1.07	0.37
Glass	0.73	0.71	0.25
Food wastes (vegetable leaves and peels)	45.3	4.59	1.61
Textile rags	2.22	0.71	0.25
Plastic (poly bags)	2.86	0.87	0.31
Miscellaneous (bricks, ash, fine dust, rubber, wood, leather, wastewater, etc.)	41.66	4.65	1.63
Total	100		
Moisture content	25.86	4.54	1.59

$n = 22$.

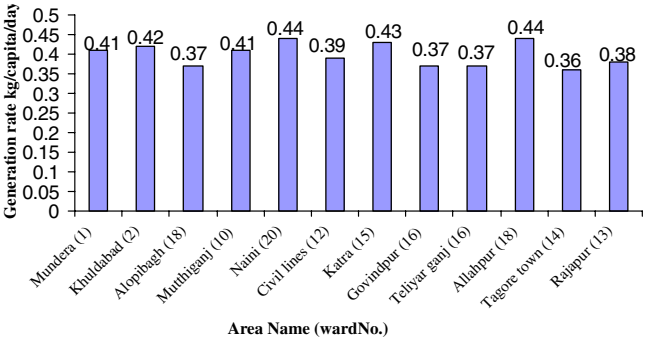

Fig. 5. MSW generation rate for various areas in Allahabad city.

The results from data analysis in GIS are products of the appropriate format maps concerning static and dynamic parameters of the MSWM problem, such as the productivity of MSW in the different wards, collection point locations, types of MSW transport means and their routes, and the number of disposal sites and their attributes. Fig. 1 shows the number and name of different wards and their boundaries, as well as the MSW per capita generation rate for each ward. This rate varies from 0.37 kg/capita/day in Teliyar Ganj and Allahpur to 0.44 kg/capita/day in Naini and Daraganj. The MSW collection depots are shown in Fig. 2. The locations of these depots are scattered, unplanned and cover only about 50% of total area. The information in Fig. 2 clearly indicates the poor MSW services of Allahabad city having scant attention in establishment of depots for different prime locations of the city. Fig. 3 shows the existing collection routes of MSW using

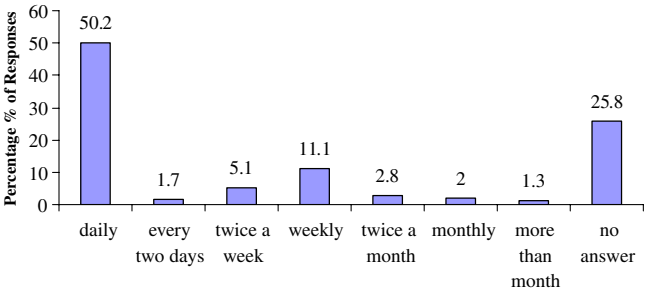

Fig. 6. Collection frequency.

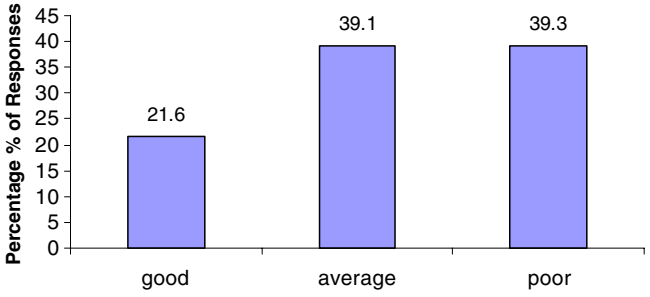

Fig. 7. Satisfaction levels of the residents.

a hauled container system. These routes cover only a few wards and connect only with two disposal sites. Fig. 4 shows the details of disposal sites and its connection with different wards. The Kareli disposal site serves the maximum number of wards, whereas Naini/Sulem Sarai serves the minimum. This can be balanced by diverting MSW from a few wards towards Sulem Sarai/Naini, but the enhancement of capacity of these sites is required. The MSWM data obtained from ArcGIS maps are responsible for the retrieval, update and visualization of the information required. The produced maps can provide AMC, environmental engineers and decision makers with data about the present MSWM system, which is required for improvement of the existing system and for future planning.

6. Concluding remarks

The segregation of waste at source and promotion of recycling or reuse of segregated materials reduces the quantity of waste and the burden on landfills, and provides raw materials for manufacturers. The composition of MSW shows mostly organic matter (45.3%), so composting is a good method for the treatment and production of soil amendment. The rapid increase in the quantities of MSW and the inability to provide daily collection service cause a nuisance and health hazards. The study presents the current scenario of MSWM, which will be helpful in creating awareness among the people. The MSWM data obtained from ArcGIS maps are responsible for the retrieval, update and visualization of the information required. The produced

maps can provide AMC, environmental engineers and decision makers with data about the present MSWM system, which is required for the improvement of the existing system and for future planning.

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