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Identification of Types and Source-Specific Characterization and Quantification Study of Solid Waste in Guwahati City, Assam, India

Amarjyoti Kashyap and Ruli Borthakur

Abstract Study was conducted for the identification of types of solid waste along with the source-specific characterization and quantification of Guwahati city. Different types of solid wastes were classified as organic, paper, plastic, glass, metal, rubbish and others. Sources of solid wastes generation were identified as regular and occasional source which is essential for proper quantification study. Regular solid waste-generating sources are households, commercial areas, marketplaces, hotels, restaurants, hospitals and nursing homes, educational institutes, cinema halls, offices, railway stations, bus stations, industries, street sweeping and drain cleaning, etc. On the other hand, occasional sources are 'Bihu', 'Durga Puja', 'Kali Puja', 'Idd', 'Book fair', 'Trade fair', 'Expo', etc. The 'Total Generation of Solid Waste' from Guwahati City was found to be 390 tons/day. The 'Combined Per Capita Generation of Solid Waste' was calculated as 379 gm/cap/day. Characterisation of the waste revealed that out of the total solid waste generation in Guwahati City, organic waste contributes 57.4% followed by paper 18.2%, others 11.3%, plastic 5.6%, rubbish 2.8%, glass 2.6% and metal 2.2%. The average per capita generation of household waste worked out to be 0.175 gm/day, out of which 73.93% was organic followed by paper 15.35%, plastic 2.54%, glass 0.83%, metal 2.41%, rubbish 1.23% and others 3.70%.

Keywords Organic · Paper · Plastic · Glass · Metal · Rubbish
Regular source · Occasional source

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1 Introduction

Generally, municipal solid waste management (MSWM) in most of the cities is not planned rationally due to the non-availability of authentic or relevant information on waste generation and its characterization [11]. Presently, majority of urban local bodies (ULB) do not weigh their waste, but the quantities are estimated on the basis of the number of trips of trucks which carry the waste to the disposal sites. Since MSWM handles huge quantity of waste, it becomes necessary to have detailed information on sources of solid waste generation, their characterization and quantification so as to plan different elements for handling the wastes. The source-specific solid waste characterization and quantification are helpful in predicting the waste quality and quantity from various waste-generating sources in a city, and this can be used as a basis for the planning of a solid waste management system.

Different types of solid wastes were classified as organic, paper, plastic, glass, metal, rubbish and others. Sources of solid wastes generation were identified as regular and occasional source which is essential for proper quantification study. Regular solid waste-generating sources are households, commercial areas, marketplaces, hotels, restaurants, hospitals and nursing homes, educational institutes, cinema halls, offices, railway stations, bus stations, industries, street sweeping and drain cleaning, etc. On the other hand, occasional sources are 'Bihu', 'Durga Puja', 'Kali Puja', 'Idd', 'Book fair', 'Trade fair', 'Expo', etc. The 'Total Generation of Solid Waste' from Guwahati City was found to be 390 tons/day.

2 Reviews on Characterization and Quantification of Solid Waste

Daskalopoulus et al. [2] pointed out that since the municipal solid waste management (MSWM) system handles huge quantity of waste, it becomes necessary to have detailed information on the sources of solid waste generation, their quantification and characterization. The source-specific solid waste quantification and characterization is helpful in predicting the waste quantity from various waste-generating sources in a city and this can be used as a basis for the planning of a system [17]. Parizeau et al. [14] conducted study on the need of waste characterization for successful waste management planning in Siem Reap, Cambodia. On the other hand, Mor et al. [12] studied on municipal solid waste characterization to assess the potential methane generation from the landfill sites. Sharma et al. [15] tried to develop a methodology for solid waste characterization based on diminishing marginal returns. Deshpande [4] pointed out that the municipal solid waste contains vegetable market waste, glass, paper, plastic and other organic fractions and inert matter from different sources, such as residential, commercial and institutional areas. Harilal et al. [8], on the basis of their study in quantification,

characterization and management of solid waste from Mahe, union territory of Pondicherry, commented that since the magnitude of issues related to solid waste varies with location and time. Even et al. [5] in their study reported that 20 collection routes serving the nine road lanes were chosen which covered 88% of the city's population. Selected 20 collection routes were comprised eight Monday-Thursday routes, eight Tuesday-Friday routes and four Wednesday-Saturday routes. The original data was from weight-scale readings at the landfill site in operation. Jeevanrao and Shantaram [9] selected three landfill sites in their quantification and characterization study in Hyderabad. Samples of fresh urban solid waste as well as stabilized solid waste were collected from different locations of each landfill sites. The study revealed that fresh solid waste represented the material disposed of at the landfill sites within eight days of the date of collection, whereas stabilized solid waste represented the materials disposed of at least 180 days before the date of collection. Major portion of waste generated was from market yard and public eating places like hotels, tea shops and residential area. As per the study, weight–volume relationship of the wastes for Hyderabad City was varied from 365 to 410 kg/m^3 for fresh solid waste and 265–480 kg/m^3 for stabilized waste.

Yu and Maclaven [17] compared two waste streams quantification and characterization methodologies which contained direct waste analysis for determining the waste quantity and waste composition by questionnaire survey. In contrast to DWA and the questionnaire survey, methodology was normally restricted to collection of data at the point of generation. David and Lipt'ak [3] had been detailed out characterization methods where represented samples are sorted into separate sections such as organic matter, glass, paper, rags, metal, plastic, fine earth and others and weighed. These fractions are then represented as percent by weight. From this, the total percentage of different solid waste was calculated. Ojeda-Benitez et al. [13] also studied the characterization and quantification of household solid wastes in Mexican City.

Gawaikar et al. [6] pointed out some commonly used methodology to assess the quantities of solid waste. The most important aspect of solid waste management is the quantity of waste to be managed. The quantity determines the size and number of functional units and equipments required for managing the waste. The quantities are measured in terms of weight and volume. The weight is fairly constant for a given set of discarded objects, whereas volume is highly variable. In the characterization study of solid waste, Kumar et al. [11] segregated various components such as plastics, paper, metal, organic fractions from the 12.5 kg samples and weighed, and these fractions were expressed as a percentage of the total weight. The Waste Wise Resource Centre [16] also carried out a study on quantification.

Bolaane et al. [1] conducted some research work related on sampling of household waste at source in Gaborone, the capital city of Republic of Botswana. Gawaikar et al. [6] also pointed out in their study that the source-specific solid waste quantification and characterization will be helpful in predicting the waste quantity from various waste-generating sources in a city and this can be used as a basis for the planning of the system. This will also enable in saving of time, manpower and financial inputs required to be spent for estimating the waste

quantity for the entire city. Such a developed methodology can be very easily adopted by the municipal agency and would help them in managing the system in a befitting manner. Gomez et al. [7] studied seasonal characterization of municipal solid waste (MSW) in the city of Chihuahua, Mexico, while Khatib et al. [10] studied the same in Nablus district of Palestine.

3 Study Area

Guwahati, the capital city of Assam, is one of the large and densely populated cities in India and largest city in the north-east region of India. Geographically, Guwahati City is located in 26° 5′N to 26° 12′N latitudes and 91° 34′E to 91° 51′E longitudes. The area under the jurisdiction of the municipal corporation of the city called as Guwahati Municipal Corporation is limited to 216 km^2. Mighty Brahmaputra River is on the northern boundary of the city. The southern and the eastern boundaries of the city are made by some small hills of comparatively low heights. On the west, Jalukbari constitutes the border of the city. The city spreads around 27–28 km. in the east west direction and about 10–12 km. in the north south direction. For administrative purposes, the city is divided into 60 wards as shown in Fig. 1.

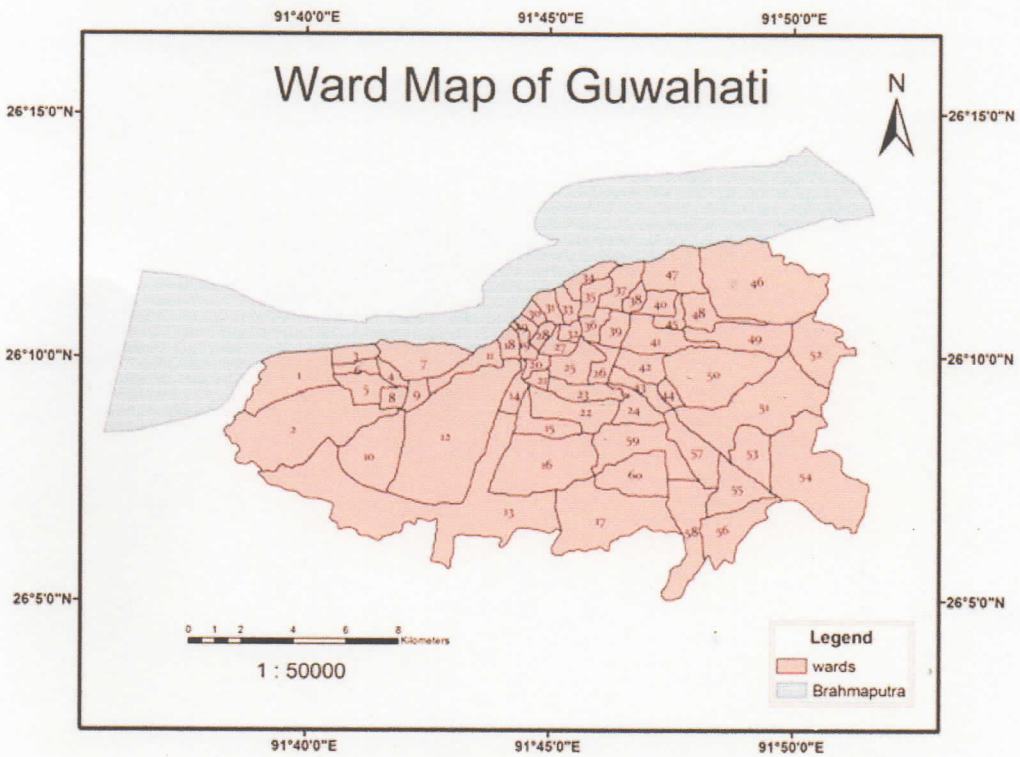

Fig. 1 Ward map of Guwahati City. *Source* Guwahati Municipal Corporation

4 Population Distribution Pattern

Guwahati is one of the most rapidly growing cities in India. The city's population grew from just two lakhs in 1971 to more than five lakhs in 1991. In the census of 2001, the city's population was estimated at 809,895 out of 189,524 households which were found to be 1,028,563 in 2012 out of 208,476 households. On the average, population density in the city was 4,762 persons per km^2.

5 Methodology

A. Identification of types of solid waste of different sources

To know about the different types of solid waste and its different sources, three steps were followed. These include:

Survey: Survey was carried out in greater Guwahati to identify the different sources of solid waste. In this respect, each of the solid waste-generating sources was investigated for proper identification.
Fieldwork: Information and data of various solid waste-generating sources were identified, classified and listed. Primarily, 50 samples were collected from all the identified sources for classification of the different types of solid waste generation.
Laboratory investigation: Samples from respective locations were brought to laboratory and separated into different components and accordingly classified the different types of solid waste.
Organic—includes kitchen waste, vegetable and fruit peels including coconut shell, flowers and garden waste, agricultural waste, leaves, wooden pieces, dead animals and waste from slaughterhouse.
Paper—newspapers, hard papers, books, poster and leaflets, sweet boxes, carbon papers, laminated papers, etc.
Plastic—thermoset, thermoplastic including PS, LDPE, PET, HDPE, PVC and PP and other multi-layered plastic, etc.
Glass—used for building construction, windows for vehicle, mirror, medicine and cosmetic bottles, liquor bottles, etc.
Metal—all type of metals especially tin, iron, aluminium, etc.
Rubbish—stones, bricks, concrete and ceramic, etc.
Others—include sand and soil, batteries, hazardous waste, clothes and woollen items, thermo coal, rubber and leather.

B. Source-specific characterization and quantification of solid waste

The method followed in this study is based on the characterization and quantification of solid waste collected from different sources. Samples were collected from different sites selected randomly covering all the 60 wards of the city. For this purpose, all the sixty wards of greater Guwahati were grouped into five zones as presented in Table 1.

Table 1 Ward-wise study area as per the zones

Zone	Ward No.
East	41, 45, 46, 48, 49, 50, 51, 52, 53, 54, 55, 56
West	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
North	18, 19, 29, 30, 31, 33, 34, 35, 37, 38, 40, 47
South	13, 14, 15, 16, 17, 22, 23, 24, 57, 58, 59, 60
Middle	20, 21, 25, 26, 27, 28, 32, 36, 39, 42, 43, 44

For household sampling, each ward was again farther divided into five sampling points. In this process, all the 60 wards of Guwahati City were stratified into 300 nos. sampling points. On the other hand, rests of the sampling points of different sources were selected and classified as per the generation of waste, and accordingly, all the sample points and the number of samples were identified and stratified for systematic study as presented in Table 2.

Four different coloured litter bins (L_1, L_2, L_3 and L_4) were supplied to each sampling point for the collection of different segregated waste (Fig. 2) and informed about the source segregation process for farther investigation in the laboratory. In this process, altogether 20 (5 of each colour) litter bins were used. Collection and laboratory analysis of the samples were performed on daily basis.

The waste was collected from the source by the hand-picking method and it was segregated at source as organic; plastic, paper, glass and metal; rubbish and other solid waste and kept in four different coloured litter bins which were marked as L_1 (Green colour), L_2 (Blue colour), L_3 (Yellow colour) and L_4 (Red colour).

L_1: Used for collection of organic waste.
L_2: Used for collection of plastic, paper, glass and metal.
L_3: Used for collection of rubbish like stones, bricks and concrete.
L_4: Used for collection of all the other solid waste like sand and soil, batteries, thermocoal, rubber and leather, clothes and woollen items, etc.

Size of the litter bins (L_1, L_2, L_3, L_4):
Volume: 60 L
Breadth = 18 in. and
Length = 22 in.

After selection of sample points and sampling numbers, following methods were adopted for systematic characterization and quantification of different types of solid waste at their generating sources.

(a) **Analysis of household Solid Waste**

Segregated solid waste collected from five different selected points (household) of each ward was mixed as per their category and kept in four different heaps.

(b) **Analysis of commercial and institutional Solid Waste**

The MSW samples were collected through stratified random processes and accordingly fixed the sampling points based on population density, generation of

Table 2 Sample points and numbers of sample

S. No.	Sample points	No. of sampling points	No. of samples	Description of sampling numbers
Regular sources				
1	Household	60	300	5 nos. stratified random samples from each ward
2	Commercial areas	19	95	5 nos. stratified random samples from selected location
3	Marketplaces	17	118	Stratified random samples of different nature from all the 17 nos. market
4	Hotels	32	32	Single sample from each hotel
5	Restaurants	60	120	2 nos. stratified random samples from each ward
6	Hospital and nursing homes	20	40	2 nos. samples from all the 20 nos. hospital and nursing home
7	Educational institutes including hostels	60	180	3 nos. stratified random samples from each ward
8	Cinema halls	15	15	Single sample from each cinema halls
9	Offices	20	100	5 nos. stratified random samples from 20 nos govt. offices
10	Railway stations	2	10	5 nos. samples from all the 2 nos. railway stations
11	Bus stands (long distance)	3	15	5 nos. samples from all the 3 nos. long-distance bus stands
12	Industries	250	250	Single sample from each industries of all the 3 industrial estate
13	Street sweepings and drain cleanings	32	32	Single sample from each 'carrier truck'
14	Other sources	60	180	3 nos. samples from each ward
Occasional sources				
1	Bihu	30	30	10% stratified random samples
2	Durga Puja	50	50	10% stratified random samples
3	Kali Puja	60	60	10% stratified random samples
4	Idd	10	50	5 nos. stratified random samples from 10 wards
Different fair				
a	Book fair	06	30	5 nos. samples from 6 different book fair
b	Trade fair	03	15	5 nos. samples from 3 different trade fair
c	Expo	03	15	5 nos. samples from 3 different Expo

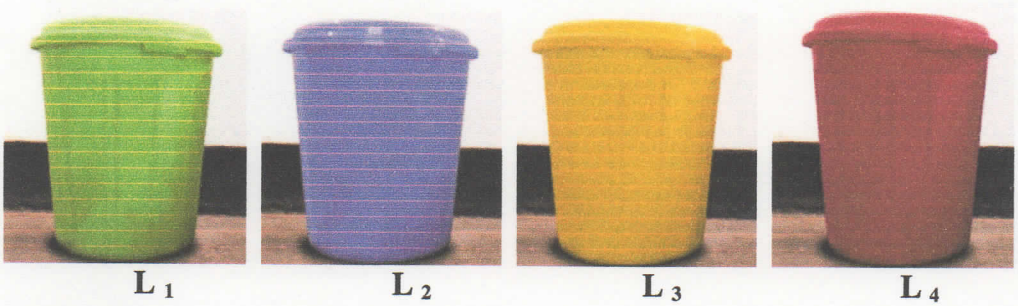

Fig. 2 Litter bins used for collection of source-segregated solid waste

waste and location. It was ensured that establishments were intimated about the waste sampling process. At each establishment, segregation and collection of the sample were done [6].

(c) **Analysis of Solid Waste of Railway Station and long-distance Bus Terminus/Stand**

All the daily generated solid wastes were first divided into five different heaps in each station. Accordingly, samples were collected from all the five nos. sample point (heaps) for systematic analysis of different component of solid waste to measure the total daily generated solid waste.

(d) **Analysis of solid waste of Street Sweepings and Drain Cleaning**

Samples were collected from each truck and weights were measured as per the methodology adopted by Guwahati Municipal Corporation. Samples were collected from each truck for determination of different types of waste and its weight. Accordingly, average weight of each waste type was calculated and finally distributed the average weight of each waste type in whole amount of waste to measure total generation.

Finally, following steps were adopted for systematic study:

Step 1: Organic solid waste was air and oven dried to remove the water component.
Step 2: After proper mixing, all the samples heaps were farther segregated to different components.
Step 3: The weight of the different segregated waste components was taken on weighing scale of 1 and 5 kg, respectively, for accuracy of weight measurement.
Step 4: The waste characteristics from various categories are averaged and weighed against the number of population and different sources to analyse the average solid waste generation rates which were farther differentiated in the different components. These fractions are then represented as percent by weighed. From these, the total generation and percentage of generated MSW was calculated. Secondary data sources (Guwahati Municipal Corporation; Guwahati Metro Development Authority; Directorate of Population Census, Assam).

6 Results and Discussion

After systematic analysis, total solid waste generated from household was found 180.00 tons/day which was followed by from commercial establishments 56.62 tons/day, markets 17 tons/day, hotels 2.68 tons/day, restaurants 9.4 tons/day, educational institutions 23 tons/day, hospitals and nursing homes 4.81 tons/day, cinema halls 0.65 tons/day, offices 5.35 tons/day, railway stations 2.4 tons/day, long-distance bus stations 1.09 tons/day, industries 3.5 tons/day, street sweeping and drain cleaning 48 tons/day, other sources 15.45 tons/day and from occasional sources 19.75 tons/day (Table 3). Percentage of solid waste generated from different sources in Guwahati City/day is shown in Fig. 3. Thus, the 'Total Generation of Solid Waste' from Guwahati City was found to be 390 tons/day. The 'Combined Per Capita Generation of Solid Waste' was calculated as 379 gm/cap/day. Category-wise breakup of solid waste reveals the total generation of different types of solid waste was—organic waste 223889.83 kg/day followed by paper waste 70831.49 kg/day, plastic waste 21872.85 kg/day, glass waste 9934.48 kg/day, metal waste 8386.64 kg/day, rubbish 10943.55 kg/day and 'other' waste 44078.10 kg/day. The percentages of different types of solid waste generated in different sources are tabulated in Table 4. It shows that the contribution of organic waste was 73.93% in case of waste generating from household which was above 80% in case of the waste generated from markets, hotels and restaurants. It was observed that most of the solid

Table 3 Total quantity of solid waste generated from different sources in Guwahati/day

S. No.	Source	Unit generation per day	Total solid waste tons/day	In % of total
1	Household	0.175 kg/person	180.00	46.20
2	Commercial establishments	1.49 kg/unit	56.62	14.53
3	Markets	2 to 15 kg/unit	17.00	4.36
4	Hotels	83.75 kg/unit	2.68	0.69
5	Restaurants	16.50 kg/unit	9.40	2.41
6	Educational institutions	0.153 kg/person	23.00	5.90
7	Hospitals and nursing homes	1.035 kg/bed	4.81	1.23
8	Cinema halls	43.33 kg/unit	0.65	0.17
9	Offices	0.05 kg/person	5.35	1.37
10	Railway stations	800 kg/unit	2.40	0.62
11	Long-distance bus stations	363.33 kg/unit	1.09	0.28
12	Industries	14 kg/unit	3.50	0.90
13	Street sweeping and drain cleaning	1500 kg/truck	48.00	12.31
14	Other sources	15.45 kg/unit	15.45	3.96
15	Occasional sources		19.75	5.07

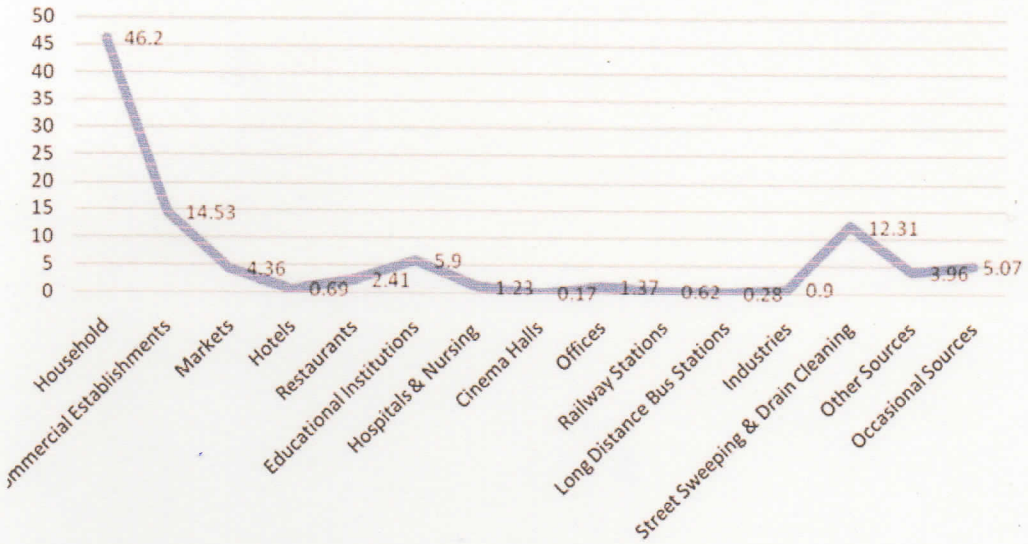

Fig. 3 Percentage of solid waste generated from different sources in Guwahati/day

Table 4 Percentage of different types of solid waste generated in different sources

Source	Organic	Paper	Plastic	Glass	Metal	Rubbish	Others
Household	73.93	15.42	2.60	0.84	2.42	1.21	3.58
Commercial establishments	41.86	44.71	7.36	1.00	1.36	1.14	2.50
Markets	83.75	5.58	6.12	0.71	1.00	0.79	2.04
Hotels	81.50	6.75	3.25	8.50	0	0	0
Restaurants	81.50	6.75	3.25	8.50	0	0	0
Hospitals and nursing homes	45.67	7.17	6.67	6.33	2.00	0	1.00
Educational institutes	57.80	26.40	5.00	5.80	0.30	1.70	3.00
Cinema halls	2.60	1.00	96.40	0	0	0	0
Offices	30.00	64.50	5.00	0	0	0	0.50
Railway stations	51.35	15.75	24.50	4.40	1.00	0.50	2.50
Bus stands (long distance)	32.33	15.67	43.67	4.00	0	0	2.67
Industries	5.00	6.00	7.00	3.00	60.00	4.00	15.00
Floating population	70.90	6.50	7.00	15.60	0	0	0
Street sweeping and drain cleaning	10.00	2.00	10.00	5.00	0	3.00	70.00
Other sources	44.19	5.00	9.00	0.50	3.00	37.31	1.00
Occasional sources	59.40	16.70	6.70	10.05	2.17	1.20	3.78

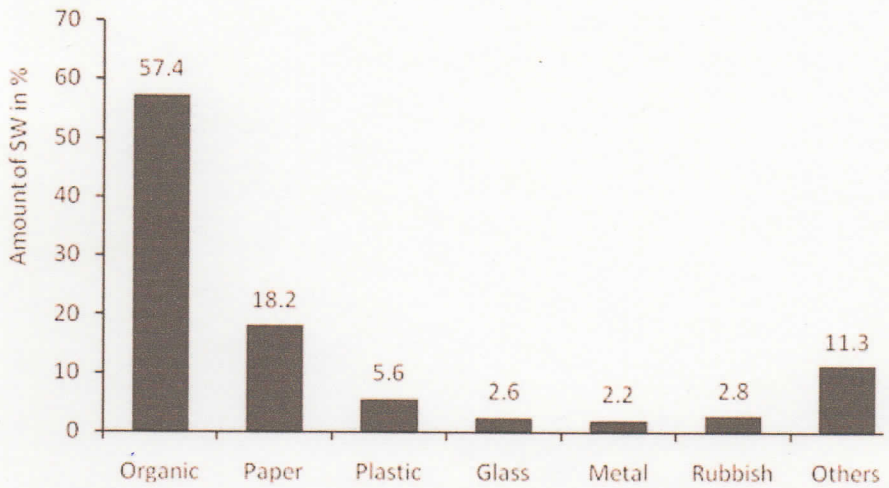

Fig. 4 Overall percentage-wise distribution of solid waste generated from Guwahati City/per day

wastes generated in the city were organic type (57.4%). The average per capita generation of household waste worked out to be 0.175 gm/day, out of which 73.93% was organic followed by paper 15.35%, plastic 2.54%, glass 0.83%, metal 2.41%, rubbish 1.23% and others 3.70%. Out of the total generating sources, household generating the highest amount of waste (46.20%) followed by commercial establishments (14.53%), street sweeping and drain cleaning (12.31%), educational institutions (5.90%), occasional sources (5.07%), markets (4.36%), different other sources (3.96%), restaurants (2.41%), offices (1.37%), hospitals and nursing homes (1.23%), industries (0.90%), hotels (0.69%), railway stations (0.62%), long-distance bus stations (0.28%) and cinema halls (0.17%). Characterisation of the waste revealed that out of the total solid waste generation in Guwahati City, organic waste contributes 57.4% followed by paper 18.2%, others 11.3%, plastic 5.6%, rubbish 2.8%, glass 2.6% and metal 2.2% (Fig. 4).

7 Conclusion

Investigation was made for collection of detailed information regarding solid waste generation in Guwahati City as per the methodology with the help of Guwahati Waste Management Company Private Limited. From the study, it was revealed that overall generation of organic waste in the Guwahati is 57.4% and plastic waste is 5.6%. On the other hand, households generating 73.93% organic waste followed by only 2.54% plastic waste. Though the amount of plastic waste was found to be comparatively less, due its huge volume and mixing with the organic waste, different problems are occurring. To reduce the problem, segregation of solid waste at source is most essential followed by the source reduction practice. The study is opening a path for designing a successful solid waste management plan not only for Guwahati but also for the other Indian urban habitat.

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