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Characterisation Of Municipal Solid Waste Generated By The City Of Bhopal, India

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Abstract : The characteristics of municipal solid waste (MSW) is major factor, which considered as a basis for the design of efficient, cost effective and envrionmentally compatible waste management system. Solid waste management system requires a greater knowledge about composition of MSW. In present study, the compositions of Bhopal municipality waste were estimated and analysis for better MSW management. Inappropriate bin locations and poorly designed community bins, collection vehicles that are in poor condition, inadequate labour for collection and transport of waste, and lack of waste treatment and disposal facilities were major problems in Bhopal. Thirteen samples were characterized physicochemically and their promixate, ultimate analyses and calorific value were done in the laboratory. The average values of various parameters were density=314.9 kg/m^3, low and higher calorific values= 2244.2 and 2411.7 kcal/kg respectively, moisture content= 28.1 percent, ash= 15.6 percent, fixed carbon=9.5 percent, volatile matter= 46.6 percent, Carbon= 26.6 percent, Hydrogen=5.9 percent, Oxygen=47.7 percent, Nitrogen=1.1 percent, Sulphur=0.98 percent, Phosphorus= 0.84 percent, Potash=0.93 percent, C/N Ratio=26.6. Segregation helps inproper utilization of organic waste for composting. MSW in Bhopal has high moisture content and low calorific value, making aerobic composting the best treatment strategy.
Key words: solid waste management, bhopal, composition, promixate and ultimate analyses.

1. Introduction

Dramatically increase in municipal solid waste (MSW) due to more population and change life style in the country[1,2].In developing countries, these factors intensify by inadequate financial resources & management and technical skills within municipalities and government authorities. More than 92% of the MSW generated in country is directly disposed on open dumping in an unsecure manner[3]. Basically, India ia an agricultural country and particularly cities are conjusted and required special attention to MSW management[3]. Only 40% of the waste is an agricultural and therefore organic waste is more in the MSW. Since earlier studies were not enough Govt. of India adviced Central Pollution Control Board[4] and National Environmental Engineering Research Insitute[5]

jointly to assess the waste in various cities of India. Currently there is no any specific site for segration of solid waste. It is manually done by Rag pickers at the origin site of solid waste at very small level. There is no concept of transfer station in Bhopal city at present. In old practice of SWM in Bhopal, no data is properly maintained as required under the present system. So, it was not possible to assess performance of present system. Things will be improve with initative from authorized for development new sanitary landfill sites. The collection efficiency about 70% which needs improvement. The objective of this paper is to solid waste from bhopal municipality was characterized by physico-chemically and their promixate, ultimate analyses and calorific value were done in the laboratory.

2. Materials and methods

2.1. Sample collection

The samples were collected from different locations such as commercial area, residential areas, weekly market, fruit and vegetable markets, slaughter house, fish and meat market, hotels, restaurant, garden, hospitals and nursing homes, industries and Bhanpura dumping ground. The samples were collected for 7 days (from 17.05.2010 to 24.05.2010) in a row from two to four sources in each category and community bins and their locations. For each source samples were collected from three waste generating points. Samples collected every day was packed in poly bags and were sent to laboratory for analysis. After weighing each sample again accurately in laboratory, composite samples of each category were prepared for physical and chemical analysis. Fig. 1 and Fig. 2 shows the sample fractions and parameters analyzed after collection.

2.2. Sample analyses

Samples of 100 g were taken in triplicate, and dried to a constant weight in an oven at 105 ◦C for 24 h, cooled in a desiccator and the difference in weight recorded. Moisture content is the percent sample weight lost in drying. Calorific value was determined in the laboratory using a bomb calorimeter, which provides the gross calorific value at constant volume. Since there are no standard methods for analyzing solids in MSW samples, the different fractions of solids in the waste samples were analyzed based on the same methods recommended for river and lake sediment samples and sludge samples[6]. Total solids are defined as the solids left in the sample after it has been dried to a constant weight at 103–105 ^{o}C. When total solids are ignited in a muffle furnace at 550±50 ^{o}C, the fraction of solids remaining is defined as fixed solids and the fraction lost during ignition is termed volatile solids.

3. Results and discussions

3.1. Solid waste generation characteristics

The density of solid waste generated is ranging from 300 to 400 kg/m^3. Hence, compaction of waste is unnecessary during transportation. Per capita solid waste generation rates for Indian towns and cities were found to range from 220 to 660 g/capita/day[7]. If Bhopal is assumed to have a per capita solid waste generation of 300-500 g/capita/day, and an estimated current population of 1.9 million approximately, the total solid waste generated is 800 metric tons/day. The waste in the community bins is manually transferred to a truck/tractor for transportation of MSW solid waste to the disposal site. Bhopal municipality has 17 truck of 3 metric tons capacity, 8 tractors of 2.5 metric tons capacity and 32 tractors of 2 metric ton capacities to transport solid waste to the disposal site. Each vehicle with one driver and 5–7 collection laborers makes 4 trips per day (8h work day). Some data on solid waste generation, collection and transport were provided by Bhopal Municipality and are summarized here:

Solid waste generation rate	400 g/capita/day
Total quantity of solid waste generated	800 metric tons/day
Total number of community bins	
1.4 m^3 yellow open	752
1.1 m^3 green/blue closed)	617
4.5 m^3 open	58
4.5 m^3 green close	49
4.5 m^3 yellow close	13
Total annual expenditure for SWM	15% of municipal budget. Current cost recovery includes a conservancy tax as part of property

	tax/sanitary tax
No of Refuse compacter of 7 metric ton capacity	19
No of dumper placer of 2.5 metric ton capacity	20
No of dumper of 4 metric ton capacity	9
No of trucks of 3 metric ton capacity	17
No of trucks of 2.5 metric ton capacity	8
No of trucks of 2 metric ton capacity	32
No of tipper of 4 metric ton capacity	10
No of mini garbage of 0.5 metric ton capacity	20
No of Auto of 100 kg capacity	24
No of handcarts (volume of 6–9 cft)	500

All vehicles in current use are very old and are in deplorable condition. In Bhopal, Open trucks are used to transport waste to the duming site. This causes dropping of garbage, contaimination of soil, odour, nuisance problems proceed along the route of transport. Moreover, leachate (liquid coming out of biodegradable waste) from the waste drips all the way while transporting waste, more so during the monsoon. Existing handcarts have metal wheels with a layer of neoprene rubber wrapped around the perimeter; these are comparatively difficult to operate compared to tricycles with pneumatic tyres. Therefore, the municipality has decided to replace these handcarts with tricycle carts. About 40-45% of waste is food and fruit waste out of which approximately 50% of waste is from residential areas and 45% from vegetable and fruit Markets. It means high concentration of biodegradable waste and therefore it is suitable for composting. High percentage recyclable matter. Pre-sorting at landfill sites can be done. 10% of inert waste, high inert and bio-resistant contents and high ash contents (15-20%). It can be used as cover material. Metals are very less (about 1%). The density of solid waste is about 300 kg/m^3 from residential areas, about 400 kg/m^3 from hotels and nearly 285 kg/m^3 from vegetable and fruit market. This density is at the source of generation (shown in Table 1). Fig. 1 shows percentage of various physical components of the MSW in Bhopal (BMC, 2009). Characterization of the waste shows that Bhopal has the highest proportion of mixed residue (organic material mixed with soil, mud, sand and other inert materials) to the extent of 81%. This material has an organic content measured as volatile solids of approximately 20% and demonstrates the high inert or inorganic content of the waste. The inert material is mostly dust, sand, and soil, and is a large fraction of Indian MSW due to the largely unpaved areas. Fig. 2 shows chemical characteristics of MSW of Bhopal (BMC, 2009).

Table 1. Density and Calorific value of Municipal Solid Waste, Bhopal

Sample Code No.	Sample Category	Density (kg/m^3)	Lower Calorific Value (kcal/kg)	Higher Calorific Value (kcal/kg)
1	HIG	320	2344	2566
2	MIG	282	1827	2184
3	LIG	215	2387	2576
4	EWS	212	2425	2615
5	Commercial	332	4682	4704
6	Vegetable &Fruit market	282	2717	2911
7	Weekly Market	411	401	424
8	Hotels	384	2344	2561
9	Restaurants	362	2395	2582
10	Garden	222	2033	2260
11	Dumping Site (Fresh Garbage)	382	2112	2274
12	Dumping Site (Old Garbage)	375	1263	1284
	Average	314.9	2244.2	2411.7

Note: All the values are in percentage on dry weight basis.

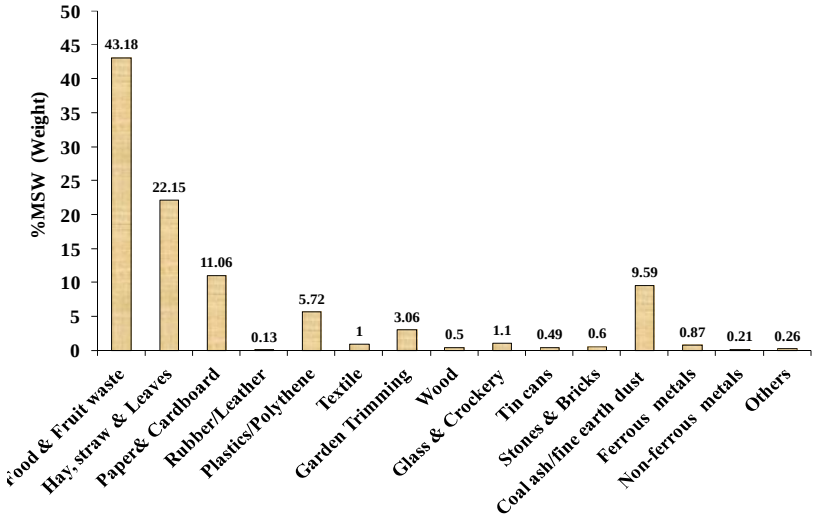

Figure 1. Percentage of various physical components of the MSW in Bhopal (adapted from BMC, 2009).

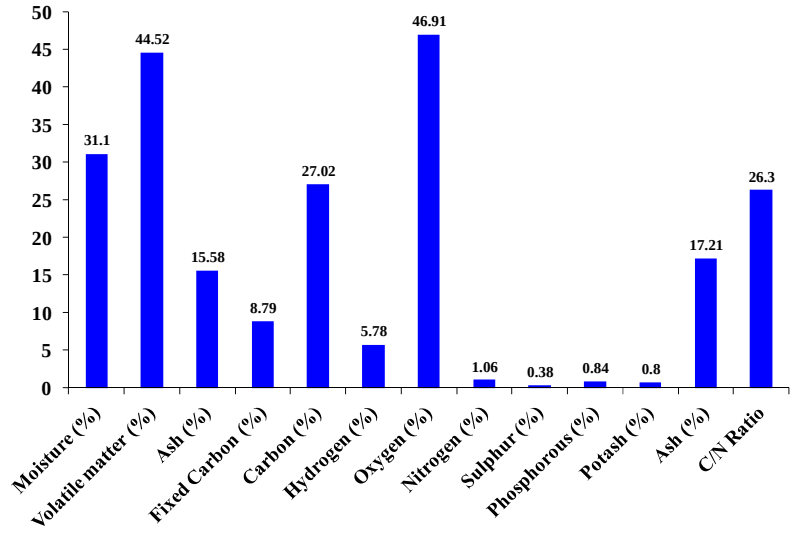

Figure 2. Chemical characteristics of MSW of Bhopal (adapted from BMC, 2009).

In India, recyclables are mostly segregated at source and rag pickers take away any remaining portions from the waste that is brought to community bins or open dumps. For disposal of waste, incineration is uneconomical due to the low calorific value and high moisture content of MSW. The solid waste generated in Bhopal consists of considerable moisture, a favorable condition for composting waste[8]. Moisture content of solid waste is usually expressed as the weight of moisture per unit weight of wet material. The data indicates that moisture content of solid waste varies from 24.33-42.20%. On average the LCV of waste is about 2000kcal/kg from residential area, about 4000kcal/kg from commercial area and about 400kcal/kg from weekly market whereas about 2800kcal/kg from vegetable and fruit markets. On average the HCV of waste is about 2200-2400kcal/kg from residential area, about 4000kcal/kg from commercial area and about 400 kcal/kg from weekly market where as about 3000kcal/kg from vegetables and fruit markets. There is not significant difference in LCV and HCV of waste. The calorific value varies between 378-4680 kcal per kg as lower calorific value. Table 2 shows that proximate analysis of MSW in Bhopal. The LCV indicates the calorific value of the solid waste in the existing state. The average values of various parameters were density=314.9 kg/m^3, low and higher calorific values= 2244.2 and 2411.7 kcal/kg respectively, moisture content= 28.1 percent, ash= 15.6 percent, fixed carbon=9.5 percent, volatile matter= 46.6 percent, Carbon= 26.6 percent, Hydrogen=5.9 percent, Oxygen=47.7 percent, Nitrogen=1.1 percent, Sulphur=0.98 percent, Phosphorus= 0.84 percent, Potash=0.93 percent, C/N Ratio=26.6 (as shown in Table 3).

Table 2. Proximate Analysis of Municipal Solid Waste in Bhopal.

Sample	Moisture (%)	Ash (%)	Fixed carbon (%)	Volatile matter (%)
1	25.61	15.04	11.04	48.2
2	24.91	12.5	10.37	52.1
3	28.31	14.4	9.54	47.85
4	30.2	11.9	10.65	47.35
5	31.60	15.27	7.4	45.7
6	24.23	16.06	10.37	49.24
7	24.4	17.34	7.57	50.7
8	32.0	9.7	6.5	51.5
9	41.9	16.90	9.1	32.4
10	32.3	18.46	9.4	39.8
11	33.2	18.19	11.6	37.4
12	21.5	22.93	9.3	46.4
13	16.1	14.55	11.1	58.2
Average	28.1	15.6	9.5	46.6

Note: All the values are in percentage on dry weight basis.

Table 3. Ultimate Analysis of Municipal Solid Waste in Bhopal

Sample	Carbon (%)	Hydrogen (%)	Oxygen (%)	Nitrogen (%)	Sulphur (%)	Phosphorus (%)	Potash (%)	Ash (%)	C/N Ratio
1	27.06	6.03	53.14	0.83	0.51	0.7	0.70	16.2	25.95
2	21.77	6.47	55.23	0.8	0.54	0.74	0.86	13.6	24.16
3	24.98	6.22	49.53	0.75	0.85	1.14	0.93	15.64	33.76
4	29.66	6.69	47.13	1.26	0.16	1.24	0.72	13.3	23.73
5	30.33	4.3	45.89	1.06	0.18	0.85	0.92	16.64	28.88
6	32.23	6.24	40.53	1.25	0.23	0.90	1.2	17.53	25.99
7	27.54	5.83	43.88	0.95	0.52	2.1	0.21	19.1	29.63
8	28.81	7.25	50.27	1.25	0.66	0.70	0.85	10.3	23.25
9	23.48	7.28	48.57	0.81	0.12	0.78	0.62	18.35	28.63
10	22.45	5.25	48.96	1.05	0.17	0.91	0.70	20.43	20.96
11	25.7	7.26	45.35	0.93	0.20	0.88	0.63	19.16	27.22
12	22.4	4.26	45.97	0.83	0.25	0.75	0.73	24.7	26.24
13	29.7	4.25	46.35	1.06	0.42	0.49	0.87	16.69	27.69
Average	26.6	5.9	47.7	1.1	0.98	0.84	0.93	17.0	26.6

Note: All the values are in percentage on dry weight basis.

Conclusions

There are shortages in the collection systems and vehicles are not also adequate and are very old requiring frequence maintainance. Additional budget for maintenance is required. The current stationary container system needs to be replaced. Some community bins are not in good condition and disposal sites are not always in preferred locations. Community bins need to be relocated and one or more new disposal sites need to be developed in an appropriate manner with treatment and engineered landfilling. Solid waste was characterized physically and chemically and average values of various parameters were found to be density=314.9 kg/m^3, low and higher calorific values=2244.2 and 2411.7 kcal/kg respectively, moisture content= 28.1 percent on a dryweight basis. The nature of the wastes indicate that amongst all recovery options, composting would be most appropriate method and provide compost which can be used to enrich soils in fields and gardens.

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