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Review - Analytical Techniques of Urban Municipal Solid Waste Management System in City of Lakes : Bhopal

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Abstract: In the past few decades, Solid Waste Management System in Bhopal have involved complex & multi faceted trade off technological, economic and regulatory framework. These changes resulted in various environmental, economic social impacts in waste management policies which not only complicate policy analysis, but also change the sustainable development. System analysis a discipline that integrated solid waste management strategies, has been uniquely providing interdisciplinary support for decision making in this area. This paper conducts a thorough literature review of models & tools illuminating possibilities of waste management policies in city of lakes: Bhopal which encompassing the prospects and constrains of waste management in the city.

Key words : Collection, segregation, analysis of solid waste management and sustainable development in the city of lake: Bhopal

Introduction

Disposal of solid waste is a growing environmental problem. Municipal solid waste (MSW) includes degradable (paper, textiles, food waste, straw and yard waste), partially degradable (wood, disposable napkins and sludge, sanitary residues) and non-degradable materials (leather, plastics, rubbers, metals, glass, ash from fuel burning like coal, briquettes or woods, dust and electronic waste) (Herat 2009; Jha *et al.* 2007; Tchobanoglous *et al.* 1993). MSW management is a complex issue due to changing lifestyle of people, rapid urbanization, and under-estimated contributors and stakeholders (Contreras *et al.* 2008; Da Zhu *et al.* 2008). Municipal bodies in low-income group of cities dispose MSW in low lying areas in the outskirt of the city and fill these areas one after the other haphazardly due to limited knowledge and awareness regarding contamination, waste reduction techniques and other aspects of MSW management (Da Zhu *et al.* 2008; Sharholy *et al.* 2008). We have attempted in this article to examine traditional practices of MSW management, constraints towards achieving sustainable MSW management in low-income group of cities and their remedial measures.

Municipal solid waste management

MSW management encompasses planning, engineering, organization, administration, financial and legal aspects of activities associated with generation, growth, storage, collection, transport, processing and disposal in an environmentally compatible manner adopting principles of economy, aesthetics. Bhopal produces about 295650 MT of municipal waste every year. Municipal bodies spend approximately Rs. 1877.55 per ton for solid waste management. About 60 - 70 % of this amount is spent on collection, 20 - 30 % on transportation and less than 5 % on final disposal.

Criteria

Criteria Indicates the elements, which identify and analyze even those elements which do not have individual direct influence on MSW management (Goran *et al.* 2008; Humphreys *et al.* 2003; Ristic 2005; Sahely *et al.* 2005). Criteria indicators of MSW management need to be identified and addressed in each city in areas such as public health, environmental scenario, cost to the society, social aspects relating to poor residents, etc. These elements help to assess and identify gray areas of present MSW management practices and formulate future measures to combat challenges and to achieve sustainable solid waste management.

MSW management system

Traditional system evolved to manage rural and dispersed populations have been applied to urban MSW management. This system is insufficient to tackle densely populated areas and requires better infrastructure and skill and incorporation of all major steps of management. Primary collection of MSW and its transfer to community bin or self disposal, care of transfer station, secondary collection and transport to the waste disposal site; waste reduction and disposal in designated dumping grounds is a generalized approach (Tschobanoglous *et al.* 1993). Quantum and complexity of MSW management in urban area in post economic boom period, after the year 1990, are changed (Bogner *et al.* 2007) however, municipalities have not been strengthened correspondingly. A dearth of well-defined study exists leading to primary data inadequacy. MSW records of different sources also have data mismatch and larger uncertainties, emphasizing the need of comprehensive survey with precision (Bogner *et al.* 2007). Therefore, improvement is required in demarcating elements of MSW system and their influence potential.

2. Materials and Methods

2.1. Sample collection and segregation :

MSW samples were collected for five working days (excluding Mondays) from each of four different community bins and their locations are shown in Table 1. This means a total of 20 samples were segregated on-site. Each time, the municipality labourers mixed the bin contents and removed 25 kg of the bulk mixed sample. This sample was then segregated manually into different physical components like paper, plastics, rubber, leather, glass, metals, textiles and polyethylene bags. Each of these recyclable materials was weighed to determine its fraction in the total solid

waste sample collected. T he remaining material was a uniform mixture of organic material along with soil, mud, sand and other inert materials that were not manually separable, and is termed mixed residue in this paper. 2 kg of this mix from each sample was collected in polyethylene bags, brought to the laboratory, and analyzed for moisture content immediately.

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Physical and chemical analyses

Physical and chemical analyses were shown in Table 4-6. 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% to 42.20%. On average the LCV of waste is about 2000k cal/ kg from residential area, about 4000 kcal/kg from commercial area and about 400 kcal/kg from weekly market whereas about 2800kcal/ kg from vegetable and fruit markets. On average the HCV of waste is about 2200-2400 kcal/kg from residential area, about 4000 kcal/ kg from commercial area and about 400 kcal/ kg from weekly market where as about 3000 kcal/kg from vegetables and fruit markets. There is not significant difference in LCV and HCV of waste. The calorificvalue varies between 378 to 4680 kcal/kg as lower alorific value. The LCV indicates the calorific value of the solid waste in the existing state. The calorific value varies between 402 to 4705 kcal per kg as higher calorific value. While the carbon content of the refuse range between 22.05 to 34.28%. The hydrogen, oxygen and sulphur content of the refuse are in the range of 4 to 7.28%; 39.06 to 53.15% and 0.15 to 0.55% respectively. C/N ratio is between 16.53 to 33.77. High volatile matter is 32.3-52.20%. Recyclable components such as plastic, paper metal and textiles are smaller fractions in developing countries than in advanced cities/ countries, which is attributable to greater usage of paper and plastic along with electronic media in advanced countries. 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. T he solid waste generated in Kharagpur consists of considerable moisture, a favorable condition for composting waste. However, the low organic content makes it unsuitable for composting in 'as-is' conditions. Therefore, segregation at source of the biodegradable (mainly kitchen and garden waste) and no biodegradable components of household waste is recommended so that the high organic content of wet waste can be used for composting.

Table-1 : Average quantity of waste disposal per day to Bhanpura dumping site.

S. No.	Date	Quantity of SWM disposal
1.	18-12-2009	368. 59
2.	19-12-2009	353. 65
3.	20-12-2009	347. 65
4.	21-12-2009	329. 05
5.	22-12-2009	309. 35
6.	23-12-2009	337. 01
7.	24-12-2009	Holiday
8.	25-12-2009	345.635
	Average	**341 .56**

Daily collection of solid waste is essential due to the high moisture content of MSW, considerable amounts of biodegradable materials in the waste and extremely hot, and humid climate. The waste 'as-is' has low organic content and cannot be easily composted. However, if the biodegradable component can be separated from the non-biodegradable materials at source, compost can be generated, and used as a soil conditioner for farming and horticultural purposes. Composting options include home composting, full-scale aerobic or anaerobic composting and vermicomposting4. Home composting requires voluntary action from residents where they segregate their 'wet' and 'dry' waste at source. Wet waste includes mainly food and kitchen waste, which is highly biodegradable while the remaining waste, which is mostly dry includes sand, soil, paper, plastic, metals, etc. Separation of the biodegradable components of waste will allow compost to be generated for domestic use and prevent this waste fraction from going to a landfill. This is in keeping with the Municipal Solid waste (Management and Handling) Rules, 2000, and is a proactive method for diverting organics from the waste stream, leading to cost savings associated with reduced storage, transport and ultimate disposal requirements. Where home composting is not done, large-scale composting plants can be setup that would allow huge amounts of organic wastes to be converted to useful compost. This compost can then be sold to farmers for its beneficial uses as a soil conditioner and supplemental fertilizer.

Conclusions

Average value of different proximate parameter were moisture content (31.1%), volatile matter (44.5%), Ash (15.58%), fixed carbon (8.79%), respectively. Some of ultimate analysis parameter were calculated: Average value of C (27.02%), H (5.78%), O (46.9%), N (1.06), S (0.34%), P(0.84%), K (0.8%) and C/N ratio (26.3%), respectively. This results were showed that proper utilization of solid waste from different wards in Bhopal to make effective energy recovery and save for future purposes.

Waste analysis, material balance solid waste may be helpful in sustainable waste management. Sustainable management may not be possible in absence of complete understanding and required capacity enhancement along with financial support.

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Table-2 : Solid waste generation from yea r 2 008 -202 3.

Ward number	Name of the ward	Population 2008	Waste Generation (MT/day) 2008	Population 2013	Waste Generation (MT/day) 2013	Population 2018	Waste Generation (MT/day) 2018	Population 2023	Waste Generation (MT/day) 2023
1	Mahatma Gandhi	41098	12.38	50321	15.93	59669	19.86	66467	23.25
2	C.T.O.	22256	6.71	27470	8.70	32808	10.92	36691	12.83
3	Hemu Kalani	20700	6.24	24351	7.71	27924	9.29	30522	10.68
4	Sadhu waswani	30227	9.11	36056	11.42	41850	13.93	46.64	16.11
5	Koh-E-Fiza	21552	6.49	25507	8.08	29394	9.78	32222	10.27
6	Noor mahal	20220	6.09	23768	7.53	27235	9.06	29757	10.41
7	Malipura	17005	5.12	20036	6.34	23006	7.66	25165	8.80
8	Bagh Munsi Husain	21020	6.33	25703	8.14	30469	10.14	33936	11.87
9	Idgah hills	29306	8.83	34393	10.89	39345	13.09	42947	15.02
10	Babu Jagjivan	19408	5.85	20856	6.60	21894	7.29	22649	7.92
11	Gufa mandir	45850	13.81	53706	17.01	61330	20.41	66874	23.39
12	Geetanjali	25949	7.82	30459	9.64	34862	11.60	38065	13.31
13	Shahjanabad	26014	7.84	29284	9.27	32229	10.73	34372	12.02
14	Congress Nagar	23730	7.15	27904	8.84	31986	10.64	34953	12.23
15	Motilal Nehru	26319	7.93	30757	9.74	35058	11.67	38185	13.36

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16	J.P.Nagar	17179	5.13	20655	6.54	24141	8.03	26676	9.33
17	Ibrahim Ganj	28812	8.68	33812	10.71	38688	12.88	42235	14.77
18	Ram Mandir	15433	4.65	18187	5.76	20890	6.95	22857	7.99
19	Mangala wara	15182	4.57	17909	5.67	20588	6.85	22535	7.88
20	Lal Bhadur Shastri	16195	4.88	18586	5.89	20836	6.93	22473	7.86
21	Mahavir	15808	4.76	18629	5.90	21394	7.12	23406	8.19
22	Jain Mandir	12881	3.83	15209	4.82	17497	5.82	19160	6.70
23	Moti Masjid	22540	6.79	25701	8.14	28637	9.53	30773	10.76
24	Islam pura	15222	4.59	16772	5.31	18069	6.01	19011	6.65
25	Bhojpura	20795	6.27	24466	7.75	28055	9.34	30665	10.73
26	Rani Kamlapati	18158	5.47	21469	6.80	24721	8.23	27086	9.47
27	Vivekanand	25067	7.55	30080	9.52	35111	11.68	38769	13.56
28	Ambedkar	29369	8.85	34453	10.91	39403	13.11	43003	15.04
29	Tulsi Nagar	31686	9.55	37051	11.73	42255	14.06	46040	16.10
30	Pansheel Nagar	19117	5.76	22474	7.12	25758	8.57	28145	9.84
31	Maulana Azad	44611	13.44	53856	17.05	63165	21.02	69935	24.46
32	Shivaji Nagar	21989	6.62	26376	8.35	30761	10.24	33949	11.87
33	T.T.Nagar	14094	4.24	16695	5.29	19258	6.41	21122	7.79
34	Jawahar Lal Nehru	15459	4.66	18223	5.77	20938	6.97	22912	8.01
35	Pt.Madan mohan	31929	9.62	37777	11.96	43550	14.49	47748	16.70
36	R.N.Tagore	23204	6.99	27928	8.84	32670	10.87	36117	12.63
37	Jahangirabad	21575	6.50	25352	8.03	29039	9.66	31721	11.10
38	Berkhedi	20901	6.30	24167	7.65	27282	9.08	29547	10.33
39	Chandbad	22478	6.77	26421	8.37	30273	10.08	33075	11.57
40	Kapda Mill	32193	9.70	37949	12.02	43561	14.50	47643	16.66
41	Bagh umrao dulah	36760	11.08	43087	13.64	49245	16.39	53723	18.79
42	Aish Bagh	44062	13.28	51653	16.36	59036	19.65	64405	22.53
43	Maharani lax,bai	18163	5.47	20730	6.56	23117	7.69	24853	8.69
44	Zinci	16400	4.94	16800	5.32	17200	5.59	17600	5.88
45	Maida Mill	22550	6.79	26501	8.39	30357	10.10	33161	11.60s
46	Neta Subchandra	31115	9.37	36671	11.61	42120	14.02	46082	16.12
47	Maharana Pratap	19295	5.81	22714	7.19	26058	8.67	28491	9.97
48	Ravishankar Ngr.	24974	7.52	29357	9.30	33632	11.19	36740	12.85
49	Dr. Rajendra Prasad	36123	10.88	43366	13.73	50600	16.84	55861	19.54
50	Indra Gandhi	30174	9.09	35404	11.21	40498	13.48	44202	15.46
51	Shahpura	29609	8.92	34754	11.00	39774	13.24	43425	15.19
52	Asha Niketan	52709	15.88	61787	19.56	70626	23.50	77053	26.95
53	Barkatullah	44125	13.29	54597	17.29	65114	21.67	72762	25.45
54	Berkheda Pathani	40690	12.26	49991	15.83	59524	19.81	66456	23.25
55	Saket,Shakti Nagar	17816	5.37	20930	6.63	23994	7.99	26221	9.17
56	Kasturba Nagar	23607	7.11	27791	8.80	31875	10.61	34846	12.19
57	Anna Nagar	14816	4.46	17469	5.33	20072	6.68	21964	7.68

Ward number	Name of the ward	Population 2008	Waste Generation (MT/day) 2008	Population 2013	Waste Generation (MT/day) 2013	Population 2018	Waste Generation (MT/day) 2018	Population 2023	Waste Generation (MT/day) 2023
58	Berkheda (BHEL)	16533	4.98	19445	6.16	22285	7.42	24351	8.52
59	Govindpura	17629	5.31	20744	6.57	23772	7.91	25975	9.09
60	Piplani	29506	8.89	37561	11.89	45969	15.30	52084	18.22
61	Gautam Budh	15788	4.76	18612	5.89	21354	7.11	23348	8.17
62	Sonagiri	46412	13.98	56098	17.76	65821	21.91	72893	25.50
63	Indrapu ri	56587	17.05	66280	20.99	75725	25.20	82593	28.89
64	Guru Nanak	47181	14.21	55262	17.50	63120	21.01	68835	24.08
65	Rajeev Nagar	44867	13.52	56319	17.83	68225	22.71	76883	26.89
66	Nabi Bagh	84495	25.46	100856	31.94	117221	39.01	129124	45.16

Source : BMC, 2009

Table-3: Calculation of containers

Assuming Density 300 Kg Solid Waste Generation 0.303 kg/Cap/day						Assuming Density 300 Kg Solid Waste Generation 0.5kg /Cap/day					Assuming Density 300 Kg Solid Waste Generation 0.7kg/Cap/day				
Ward No.	Total Volume	No. of 4.5m^3 container	Total volume of 4.5m3	Balance Volume	No. of 1.1m^3 container	Total Volume	No. of 4.5m^3 container	Total volume of 4.5m3	Balance Volume	No. of 1.1m^3 container	Total Volume	No. of 4.5m^3 container	Total volume of 4.5m^3	Balance Volume	No. of 1.1m^3 container
1.	44.7	2	9	35.77	32	73.88	2	9	64.88	58	103.43	2	9	94.43	85
2.	24.28	2	9	15.28	13	40.08	2	9	31.08	28	56.11	2	9	47.11	42
3.	22.28	3	13.5	8.78	7	36.76	3	13.5	23.26	21	51.47	3	13.5	37.97	34
4.	32.66	2	9	23.66	21	53.90	2	9	44.9	40	75.46	2	9	66.46	60
5.	23.24	NA	NA	NA	NA	38.35	NA	NA	NA	NA	53.69	NA	NA	44.69	NA
6.	21.76	2	9	12.76	11	35.90	2	9	26.9	24	50.27	2	9	41.27	37
7.	18.31	2	9	9.31	8	30.32	2	9	21.22	19	42.30	2	9	33.3	30
8.	22.87	3	13.5	9.37	8	37.74	3	13.5	24.24	22	52.84	3	13.5	39.34	35
9.	31.53	1	4.5	27.03	24	52.03	1	4.5	47.53	43	72.84	1	4.5	68	62
10.	20.39	2	9	11.39	10	33.65	2	9	24.65	22	47.17	2	9	38.17	34
11.	49.30	1	4.5	44.8	40	81.36	1	4.5	76.86	69	113.91	1	4.5	109.41	99
12.	27.91	NA	NA	NA	NA	46.06	NA	NA	NA	NA	64.48	NA	NA	NA	NA
13.	27.66	NA	NA	NA	NA	45.66	NA	NA	NA	NA	63.92	NA	NA	NA	NA
14.	25.54	NA	NA	NA	NA	42.14	NA	NA	NA	NA	59.00	NA	NA	NA	NA
15.	28.28	1	4.5	23.78	21	46.66	1	4.5	42.16	38	65.33	1	4.5	60.83	55
16.	18.60	NA	NA	NA	NA	30.70		NA	NA	NA	42.98		NA	NA	NA
17.	30.99	7	31.5	-0.91	.82	51.44	7	NA	NA	NA	71.60	7	NA	NA	NA
18.	16.61	5	NA	NA	NA	27.42	5	NA	NA	NA	38.39	5	NA	NA	NA
19.	16.35	NA	NA	NA	NA	26.98	NA	NA	NA	NA	37.78	NA	NA	NA	NA
20.	17.31	1	4.5	12.81	11	28.57	1	4.5	24.07	21	40	1	4.5	35.5	32
21.	17.02	2	9	8.02	7	28.09	2	9	19.09	17	39.33	2	9	30.33	27
22.	13.87	2	9	4.87	4	22.90	2	9	13.9	12	32.06	2	9	23,06	20
23.	24.05	2	9	15.05	13	39.69	2	9	30.69	27	55.37	2	9	46.57	42
24.	16.10	3	13.5	2.6	2	26.56	3	13.5	13.06	11	37.19	3	13.5	23.69	21
25.	22.38	1	4.5	17.88	16	36.94	1	4.5	32.44	29	51.71	1	4.5	47.21	42
26.	19.57	1	4.5	15.07	13	32.30	1	4.5	27.8	25	45.22	1	4.5	40.72	37
27.	27.12	1	4.5	22.62	20	44.75	1	4.5	40.25	36	62.66	1	4.5	58.16	52
28.	51.59	2	9	22.59	20	52.13	2	9	43.13	39	72.98	2	9	63.98	58
29.	34.05	NA	NA	NA	NA	56.19	NA	NA	NA	NA	78.66	NA	NA	NA	NA
30.	20.57	NA	NA	NA	NA	33.94	NA	NA	NA	NA	47.52	NA	NA	NA	NA
31.	48.36	NA	NA	NA	NA	79.11	NA	NA	NA	NA	111.74	NA	NA	NA	NA
32.	23.80	NA	NA	NA	NA	39.27	NA	NA	NA	NA	54.98	NA	NA	NA	NA
33.	15.20	NA	NA	NA	NA	25.08	NA	NA	NA	NA	35.11	NA	NA	NA	NA

34.	16.64	2	9	7.64	6	27.47	9	18.47	18.47	16	38.46	2	9	29.46	26
35.	34.41	2	9	25.41	23	56.79	2	9	47.79	43	79.51	2	9	70.51	64
36.	25.13	4	18	7.13	6	41.48	4	18	23.48	21	58.07	4	18	40.07	36
37.	23.21	1	4.5	18.71	17	38.31	1	4.5	33.81	30	53.63	1	4.549	44	34
38.	22.39	2	9	13.39	12	36.95	2	9	27.95	25	51.73	2	9	42.73	38
39.	24.19	2	9	15.19	13	39.92	2	9	30.92	28	55.88	2	9	46.88	42
40.	34.69	2	9	25.69	23	57.25	2	9	48.25	43	80.15	2	9	71.15	64
41.	39.53	NA	NA	NA	NA	65.23	NA	NA	NA	NA	91.32	NA	NA	NA	NA
42.	47.39	2	9	38.39	34	78.20	2	9	69.2	62	109.48	2	9	100.48	91
43.	19.39	2	9	10.39	9	32.0	2	9	23	20	44.08	2	9	35.08	31
44.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
45.	24.26	2	9	15.26	13	40.04	2	9	31.04	28	56.06	2	9	47.06	42
46.	33.51	3	13.5	20.01	18	55.29	3	13.5	41.79	37	77.41	3	13.5	63.91	58
47.	20.77	NA	NA	NA	NA	34.28	NA	NA	NA	NA	47.99	NA	NA	NA	NA
48.	26.88	1	4.5	22.38	20	44.36	1	4.5	39.86	36	62.10	1	4.5	57.6	52
49.	39.11	1	4.5	34.61	31	64.54	1	4.5	60.04	54	90.36	1	4.5	85.86	78
50.	32.45	3	13.5	18.95	17	53.56	3	13.5	40.06	36	74.94	3	13.5	61.48	55
51.	31.85	2	9	22.85	20	52.56	2	9	43.56	39	73.58	2	9	64.58	58
52.	56.68	NA	NA	NA	NA	19.53	NA	NA	NA	NA	130.95	NA	NA	NA	NA
53.	48.33	1	4.5	43.83	39	79.76	1	4.5	75.26	68	111.66	1	4.5	107.16	97
54.	44.31	NA	NA	NA	NA	73.13	NA	NA	NA	NA	102.38	NA	NA	NA	NA
55.	19.15	1	4.5	14.65	13	31.61	1	4.5	27.11	24	44.25	1	4.5	39.75	36
56.	25.42	NA	NA	NA	NA	41.95	NA	NA	NA	NA	58.73	NA	NA	NA	NA
57.	15.95	NA	NA	NA	NA	26.33	NA	NA	NA	NA	36.86	NA	NA	NA	NA
58.	17.80	NA	NA	NA	NA	29.37	NA	NA	NA	NA	41.12	NA	NA	NA	NA
59.	18.99	NA	NA	NA	NA	31.33	NA	NA	NA	NA	43.87	NA	NA	NA	NA
60.	32.49	NA	NA	NA	NA	53.61	NA	NA	NA	NA	75.06	NA	NA	NA	NA
61.	17.02	1	4.512.5	212.52	11	28.09	1	4.5	23.59	21	39.32	1	4.5	34.82	31
62.	50.36	NA	NA	NA	NA	83.10	NA	NA	NA	NA	116.35	NA	NA	NA	NA
63.	60.82	NA	NA	NA	NA	100.37	NA	NA	NA	NA	140.52	NA	NA	NA	NA
64.	50.72	NA	NA	NA	NA	83.70	NA	NA	NA	NA	117.19	NA	NA	NA	NA
65.	49.17	NA	NA	NA	NA	81.14	NA	NA	NA	NA	113.60	NA	NA	NA	NA
66.	91.26	NA	NA	NA	NA	150.61	NA	NA	NA	NA	210.85	NA	NA	NA	NA
	Total	82			626		82			1189		82			1847

Source: BMC,2009

Table-4 : Calculation of Containers

Assuming Density 400Kg Solid Waste Generation 0.303kg / Cap /day						Assuming Density 400Kg Solid Waste Generation 0.5kg/Cap/day					Assuming Density 400Kg Solid Waste Generation 0.7kg/Cap/day				
Ward No.	Total Volume	No. of 4.5m^3 container	Total volume of 4.5m^3	Balance Volume	No .of 1.1m^3 container	Total Volume	No. of 4.5m^3 container	Total volume of 4.5m^3	Balance Volume	No. of 1.1m^3 container	Total Volume	No. of 4.5m^3 container	Total volume of 4.5m^3	Balance Volume	No. of 1.1m^3 container
1.	33.57	2	9	24.57	22	55.41	2	9	46.41	42	77.57	2	9	68.57	62
2.	18.21	2	9	9.21	8	30.06	2	9	21.06	19	42.08	2	9	33.08	30
3.	16.71	3	13.5	3.21	2	27.57	3	13.5	14.07	12	38.60	3	13.5	25.1	22
4.	24.49	2	9	15.44	14	40.42	2	9	31.42	28	56.59	2	9	47.59	43
5.	17.43	NA	NA	NA	NA	28.76	NA	NA	NA	NA	40.26	NA	NA	NA	NA
6.	16.32	2	9	7.32	6	26.92	2	9	17.92	16	37.70	2	9	28.7	26
7.	13.73	2	9	4.73	4	22.69	2	9	13.66	12	31.72	2	9	22.72	20
8.	17.15	3	13.5	8.15	7	28.30	3	13.5	14.8	13	39.63	3	13.5	26.13	23
9.	23.64	1	4.5	19.14	17	39.02	1	4.5	34.52	31	54.63	1	4.5	50.13	45
10.	15.29	2	9	6.29	5	25.23	2	9	16.23	14	35.37	2	9	26.37	23
11.	36.97	1	4.5	32.47	29	61.02	1	4.5	56.52	51	85.43	1	4.5	80.	73
12.	20.93	NA	NA	NA	NA	34.54	NA	NA	NA	NA	48.36	NA	NA	NA	NA
13.	20.74	NA	NA	NA	NA	34.24	NA	NA	NA	NA	47.94	NA	NA	NA	NA

14.	19.15	NA	NA	NA	NA	31.60	NA	NA	NA	NA	44.25	NA	NA	NA	NA
15.	21.21	1	4.5	16.71	15	34.99	1	4.5	30.49	27	48.99	1	4.5	44.49	40
16.	13.95	NA	NA	NA	NA	23.02	NA	NA	NA	NA	32.23	NA	NA	NA	NA
17.	23.34	7	31.5	8.26	7	38.58	7	31.5	7.08	6	53.7	7	31.5	22.2	20
18.	12.45	5	22.5	-10.05	-9	20.56	5	22.5	-1.94	-1	28.79	5	22.5	6.29	5
19.	12.26	NA	NA	NA	NA	20.23	NA	NA	NA	NA	28.33	NA	NA	NA	NA
20.	12.98	1	4.5	8.14	7	21.42	1	4.5	16.92	15	30.0	1	4.5	25.5	23
21.	12.76	2	9	3.76	3	21.06	2	9	12.06	10	29.49	2	9	20.49	18
22.	10.38	2	9	1.38	1	17.17	2	9	8.17	7	24.04	2	9	15.04	13
23.	18.03	2	9	9.03	8	29.76	2	9	20.76	18	41.67	2	9	32.67	29
24.	12.07	3	13.5	-1.43	-1.3	19.92	3	13.5	6.42	5	27.89	3	13.5	14.39	13
25.	16.78	1	4.5	12.28	11	27.70	1	4.5	23.2	21	38.78	1	4.5	34.28	31
26.	14.67	1	4.5	10.17	9	24.22	1	4.5	19.72	17	33.51	1	4.5	29.01	26
27.	20.34	1	4.5	15.84	14	33.56	1	4.5	29.06	26	46.99	1	4.5	42.43	38
28.	23.69	2	9	14.69	13	39.09	2	9	30.09	27	54.73	2	9	45.73	41
29.	25.53	NA	NA	NA	NA	42.14	NA	NA	NA	NA	58.99	NA	NA	NA	NA
30.	15.42	NA	NA	NA	NA	25.45	NA	NA	NA	NA	35.64	NA	NA	NA	NA
31.	36.27	NA	NA	NA	NA	59.85	NA	NA	NA	NA	83.80	NA	NA	NA	NA
32.	17.85	NA	NA	NA	NA	29.45	NA	NA	NA	NA	41.23	NA	NA	NA	NA
33.	11.4	NA	NA	NA	NA	18.81	NA	NA	NA	NA	26.33	NA	NA	NA	NA
34.	12.48	2	9	3.48	3	20.60	2	9	11.60	10	28.84	2	9	19.84	18
35.	25.80	2	9	16.8	15	42.59	2	9	33.59	30	59.63	2	9	50.63	46
36.	18.84	4	18	0.84	0.76	31.11	4	18	13.11	11	43.55	4	18	25.55	23
37.	17.40	1	4.5	12.9	11	28.73	1	4.5	24.23	22	40.22	1	4.5	35.72	32
38.	16.39	2	9	7.79	7	27.71	2	9	18.71	17	38.79	2	9	29.79	27
39.	15.14	2	9	9.14	8	29.94	2	9	20.94	19	41.91	2	9	32.91	29
40.	26.01	2	9	17.01	15	42.93	2	9	33.93	30	60.11	2	9	51.11	46
41.	29.64	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
42.	35.54	2	9	26.54	24	58.65	2	9	49.65	45	82.11	2	9	73.11	66
43.	14.54	2	9	5.54	5	24.00	2	9	15	13	33.06	2	9	24.06	21
44.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
45.	18.19	2	9	9.19	8	30.03	2	9	21.03	19	42.04	2	9	33.04	30
46.	25.13	3	13.5	11.63	10	41.46	3	13.5	27.96	25	58.05	3	13.5	44.55	40
47.	15.57	NA	NA	NA	NA	25.71	NA	NA	NA	NA	35.99	NA	NA	NA	NA
48.	20.16	1	4.5	15.66	14	33.27	1	4.5	28.77	26	46.57	1	4.5	42.07	38
49.	29.33	1	4.5	24.83	22	48.40	1	4.5	43.9	39	67.77	1	4.5	63.27	57
50.	24.33	3	13.5	10.83	9	40.17	3	13.5	26.67	24	56.23	3	13.5	42.73	38
51.	23.88	2	9	14.88	13	39.42	2	9	30.42	27	55.18	2	9	46.	41
52.	42.51	NA	NA	NA	NA	70.14	NA	NA	NA	NA	98.21	NA	NA	NA	NA
53.	36.24	1	4.5	31.74	28	59.82	1	4.5	55.32	50	83.74	1	4.5	79.24	72
54.	33.23	NA	NA	NA	NA	54.84	NA	NA	NA	NA	76.78	NA	NA	NA	NA
55.	14.36	1	4.5	9.86	8	23.70	1	4.5	19.2	17	33.18	1	4.5	28.68	26
56.	19.06	NA	NA	NA	NA	31.46	NA	NA	NA	NA	44.04	NA	NA	NA	NA
57.	11.96	NA	NA	NA	NA	19.74	NA	NA	NA	NA	27.64	NA	NA	NA	NA
58.	13.35	NA	NA	NA	NA	22.02	NA	NA	NA	NA	30.84	NA	NA	NA	NA
59.	14.24	NA	NA	NA	NA	23.49	NA	NA	NA	NA	32.90	NA	NA	NA	NA
60.	24.36	NA	NA	NA	NA	40.20	NA	NA	NA	NA	56.29	NA	NA	NA	NA
61.	12.76	1	4.5	8.26	7	21.06	1	4.5	16.56	15	29.59	1	4.5	24.99	22
62.	37.77	NA	NA	NA	NA	62.32	NA	NA	NA	NA	87.26	NA	NA	NA	NA
63.	45.61	NA	NA	NA	NA	75.27	NA	NA	NA	NA	105.39	NA	NA	NA	NA
64.	38.04	NA	NA	NA	NA	62.77	NA	NA	NA	NA	87.89	NA	NA	NA	NA
65.	36.87	NA	NA	NA	NA	60.85	NA	NA	NA	NA	85.2	NA	NA	NA	NA
66.	68.44	NA	NA	NA	NA	112.95	NA	NA	NA	NA	158.13	NA	NA	NA	NA
	Total	82			409		82			826		82			1336

Source: BMC,2009

Table-5 : Density and Calorific value of Municipal Solid Waste in Bhopal

Sample Code No.	Sample Category	Density (kg/cum)	Higher Calorific Value (kcal/kg	Lower Calorific Value (kcal/kg)
1.1	HIG	323	2567	2346
1.2	HIG	319	2411	2204
1.3	HIG	306	2195	1948
2.1	MIG	284	2186	1829
2.2	MIG	323	2087	1856
2.3	MIG	255	3215	3079
2.4	MIG	287	2307	2115
2.5	MIG	302	2460	2289
2.6	MIG	312	2340	2140
3.1	LIG	217	2578	2389
3.2	LIG	300	2260	2010
3.3	LIG	227	1454	1326
3.4	LIG	251	2574	2339
3.5	LIG	288	2390	2179
3.6	LIG	257	2294	2077
3.7	LIG	280	2294	2077
4.1	EWS	214	2616	2427
4.2	EWS	314	1270	1136
4.3	EWS	305	2249	2021
4.4	EWS	290	2181	1949
4.5	EWS	261	2613	2455
5.1	Commercial	334	4705	4680
5.2	Commercial	329	3656	3612
6.1	Vegetable &Fruit market	281	3001	2835
6.2	Vegetable &Fruit market	284	2912	2717
7.1	Weekly Market	45	402	378
7.2	Weekly Market	43	426	403
8.1	Hotels	414	2249	2028
8.2	Hotels	386	2562	2346
9.1	Restaurants	366	2584	2394
9.2	Restaurants	348	2721	2576
10.1	Garden	224	2261	2034
11.1	Dumping Site (Fresh Garbage)	380	2273	2113
11.2	Dumping Site (Old Garbage)	376	1283	1261
11.3	Dumping Site (Old Garbage)	411	490	488
	Average	**290**	**2376**	**2193**

Table-5 : Proximate Analysis of Municipal Solid Waste in Bhopal

Sample Code	Moisture %	Volatile matter %	Ash %	Fixed carbon %
1.1	25.63	48.3	15.03	11.03
1.2	34.76	44.96	11.3	9.03
1.3	24.33	46.23	17.93	11.5
2.1	24.93	52.2	12.5	10.36
2.2	30.33	44.86	12.56	12.23
2.3	27.03	45.86	16.13	10.96
2.4	31.13	44	16.76	8.1
2.5	25.03	47.7	16.66	10.6
2.6	29.86	47.36	12.93	9.83
3.1	28.33	47.83	14.3	9.53
3.2	42.2	38.83	12.6	6.36
3.3	34.1	40.73	14.46	10.7
3.4	28.36	44.53	17.93	9.16
3.5	34.73	40.9	17.56	6.8
3.6	26.63	40.73	14.56	8.06
3.7	34.93	38.7	18.13	8.23
4.1	30.1	47.33	11.9	10.66
4.2	26.53	51.16	16.9	5.4

4.3	28.4	49.06	14.66	7.86
4.4	34.06	43.33	14.86	7.73
4.5	33.16	41.33	17.96	7.53
5.1	31.63	45.6	15.26	7.5
5.2	39.86	33	17.83	9.3
6.1	24.33	49.23	16.06	10.36
6.2	30.3	44.33	16.36	9
7.1	24.5	50.6	17.33	7.56
7.2	27.46	48.43	16.2	7.9
8.1	32.1	51.4	9.9	6.6
8.2	38.1	37.3	21.21	3.4
9.1	41.8	32.3	16.93	9
9.2	28.3	46.6	15.47	9.7
10.1	32.4	39.9	18.44	9.3
11.1	33.1	37.3	18.18	11.5
11.2	21.6	46.3	22.93	9.2
11.3	16.2	58.1	14.54	11.2
Average	**31. 10**	**44. 52**	**15. 58**	**8. 79**

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

Table 6. Ultimate Analysis of Municipal Solid Waste in Bhopal.

Sample code	Carbon %	Hydrogen %	Oxygen %	Nitrogen %	Sulphur %	Phosphorus %	Potash %	Ash %	C/N Ratio
1.1	27.05	6.04	53.13	0.85	0.52	0.6	0.71	16.1	25.94
1.2	28.67	6.67	50.05	0.82	0.21	0.62	0.46	12.5	34.96
1.3	26.35	6.01	46.06	0.84	0.16	0.84	0.84	18.9	31.36
2.1	21.76	6.45	55.24	0.9	0.55	0.75	0.85	13.5	24.17
2.2	30.05	7.04	45.93	1.21	0.55	0.77	0.82	13.63	24.83
2.3	35.76	4.07	39.06	1.25	0.54	0.92	0.86	17.54	28.6
2.4	23.58	6.25	49.75	0.74	0.18	0.95	0.87	17.68	31.86
2.5	23.35	5.87	49.84	0.86	0.13	0.84	0.91	18.2	27.15
2.6	34.28	6.23	42.94	0.84	0.12	0.72	0.62	14.25	40.8
3.1	24.99	6.21	49.51	0.74	0.87	1.13	0.92	15.63	33.77
3.2	25.55	8.24	49.95	1.08	0.63	0.84	0.51	13.2	23.65
3.3	28.98	6.17	45.51	1.47	0.18	0.68	0.81	16.2	19.71
3.4	26.09	6.28	43.91	1.55	0.67	0.72	1.24	19.54	16.83
3.5	23.93	4.58	49.39	1.24	0.25	0.74	0.62	19.25	19.29
3.6	25.32	5.52	49.67	1.27	0.45	0.97	0.84	15.96	19.93
3.7	25.81	5.55	44.9	1.56	0.82	0.91	0.82	19.63	16.54
4.1	29.65	6.68	47.11	1.25	0.15	1.25	0.71	13.2	23.72
4.2	26.07	6.48	45.25	1.28	0.34	0.86	0.84	18.88	20.36
4.3	29.05	4.2	47.78	1.16	0.41	0.74	0.92	15.74	25.04
4.4	27.9	4.54	48.07	0.84	0.46	1.27	0.68	16.24	33.21
4.5	26.88	5.67	45.29	0.97	0.46	0.81	0.72	19.2	27.71
5.1	30.32	4.2	45.88	1.05	0.17	0.84	0.91	16.63	28.87
5.2	25.11	3.65	48.65	1.22	0.25	0.91	0.81	19.4	20.58
6.1	32.22	6.23	40.54	1.24	0.24	0.91	1.1	17.52	25.98
6.2	27.33	5.54	47.06	0.82	0.41	0.81	0.72	17.31	33.32
7.1	27.55	5.81	43.89	0.93	0.51	2	0.91	19.2	29.62
7.2	32.55	5.82	40.3	1.26	0.18	0.97	0.81	18.11	25.83
10.1	28.82	7.24	50.28	1.24	0.67	0.71	0.84	10.2	23.24
10.2	25.57	5.54	42.94	0.86	0.46	0.66	0.81	23.16	29.73
11.1	23.49	7.27	48.59	0.82	0.13	0.77	0.61	18.32	28.64
11.2	26.35	5.24	48.72	1.14	0.42	0.82	0.81	16.5	23.11
12	22.44	5.24	48.99	1.07	0.18	0.92	0.71	20.45	20.97
15.1	25.6	7.28	45.33	0.94	0.22	0.87	0.62	19.14	27.23
15.2	22.3	4.28	45.95	0.85	0.24	0.74	0.74	24.9	26.23
15.3	29.9	4.24	46.32	1.08	0.41	0.48	0.88	16.69	27.68
Average	**27.02**	**5.78**	**46.91**	**1.06**	**0.38**	**0.84**	**0.80**	**17.21**	**26.30**

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