

# Review on –Analysis of Solid Waste Management Scenarios in Bhopal City

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**Abstract :** *Solid Waste Management (SWM) system in Bhopal has deteriorated recently to the point that only limited waste collection is undertaken in certain urban areas and disposal is largely to uncontrolled dump sites. In this study, the technical, economical, and environmental aspects of three SWM scenarios were investigated aiming to compare the scenarios and select the most appropriate one for implementation. Waste disposal into a sanitary landfill, waste transportation to transfer station before disposal to a sanitary landfill & also considered waste sorting, recycling and composting followed by landfill disposal in an integrated treatment disposal facility. The current open dumping practice was considered as the baseline scenario. According to economic analysis, the benefits from the revenues of selling the produced recyclables and compost did not improve.*

**Keywords:** *Cost Analysis, Environmental Analysis, Economical Cost, Integrated SWM Plan*

## 1. Introduction and Methods

Solid waste has been produced since the beginning of civilization. During the earliest periods, solid wastes were conveniently and unobtrusively disposed of in large open land spaces, as long as the density of the population was low. Nowadays, one of the consequences of global urbanization is an increased amount of solid waste. About  $1.3 \times 10^9$  ton of municipal solid waste (MSW) was generated globally in 1990 [1], and, at present, the annual generation is approximately  $1.6 \times 10^9$  ton.

The state of the economy influences waste generation [2]. Usually, greater economic prosperity and a larger urban population results in a larger amount of solid waste generation [3]. Improper disposal of waste impairs additional expenditure to fight the spread of communicable diseases and increase treatment cost to remove pollutants [4].

Poor MSW disposal and management systems are direct threats to nature and health [5,6]. Environmentally acceptable management of MSW has become a global challenge due to limited resources, an exponentially increasing population, rapid urbanization and worldwide industrialization. These factors are further exacerbated by inadequate financial resources, and management.

This century has witnessed a changing perspective in waste management, brought about primarily as an outcome of the initiation of the environmental movement in the 1970s. This new perspective holds that waste should be recovered or disposed of without jeopardizing human health and without using processes or methods which could harm the environment [7]. Linked with these ecological issues are concerns arising from the depletion of natural resources and the need for resources conservation.

Hence, resource recovery is now firmly entrenched as a component of waste management strategies stimulating the development of comprehensive treatment and disposal approaches, and at the same time setting integrated waste management methods.

Integrated MSW disposal systems are not yet implemented in Bhopal. The most common disposal methods currently are open dumping and burning in open spaces even in big cities, such as Bhopal. Generally, the low-lying areas and outskirts of the towns and cities are used for this purpose. These practices have negative impacts on the environment and are socially unacceptable.

Several waste management and disposal methods are being used in various parts of the world and the most prominent of these are: open dumping, sanitary landfilling, composting, and recycling. Sanitary landfilling is a controlled engineered operation, designed and operated according to acceptable standards. It may be defined as a controlled method of disposing of refuse onto or into land while minimizing nuisances or hazards to public health or safety. The operation is carried out without environmental damage and in areas already spoiled or in need of restoration.

In contrast to a sanitary landfill, composting of refuse is an aerobic method of decomposing solid waste. Many types of microorganisms already present in the waste biostabilize the organic matter in the waste and produce a soil conditioner as a result of the process. The potential benefits of composting organic wastes are improved organic waste handling; reduced odor, fly, and other vector problems; and reduced weed seeds and pathogens. Composting organic materials reduces risk of leachate and other contaminants from polluting water resources. Land applied compost improves soil fertility, and water holding capacity. It is also free of offensive odors and can be stored for extended periods. These qualities make it suitable for use on farms or for sale.

Solid wastes contain significant amounts of recyclables like paper, plastics, glass and metals which, if they are recycled, and reused, would reduce the volume of the wastes to be collected and at the same time would yield significant salvage and resale income, and will help to save valuable natural resources and turn wastes into useful products.

Many studies have been reported on strategies to achieve municipal solid waste management [8-10]. A fundamental difficulty in planning a MSW management system is the need to simultaneously account for conflicting objectives. Planners must develop the best practicable and environmentally

sustainable waste management strategies, which can be very difficult. The different objectives are not all related to economic costs, and must therefore be considered in a proper multi-objective framework. Generally speaking, the objectives are partly economic and partly environmental. This paper presents an approach that explicitly considers at least three aspects: financial affordability, environmental effectiveness and social acceptability. In Bhopal, as in other developing cities, environmental considerations are not a priority in many decisions. The perception of managers is that it would be expensive if environmentally responsive methods are applied. Furthermore, existing environmental legislations do not have specific beneficial targets and are in the early stage of reform.

Methodologies for analyzing waste management systems or strategies include material flow analysis (MFA) [11], cost-benefit analysis (CBA) [12] and life cycle analysis (LCA) [13]. In this study, different scenarios for the management of solid waste management in Bhopal were considered and compared using (CBA) approach.

## 2. Materials and Methods

### 2.1. Assessment of Current Solid Waste Management Scenarios in Bhopal

As part of this study, the current situation of the solid waste management in Madhya Pradesh Government was assessed from the standpoints of waste generation, Solid Waste Management (SWM) facilities, equipment, personnel, recycling practices, and the overall institutional frame- work, including private sector participation.

More than 90% of MSW generated in Bhopal is directly disposed on land in an unsatisfactory manner. The problem is already acute in cities and towns as disposal facilities have not been able to keep pace with the quantity of wastes generated. It is common to find large heaps of garbage lying in a disorganized manner in every nook and corner in large cities. Bhopal, one of Madhya Pradesh largest city, like other large cities faces similar problems of poor solid waste management. The objective of this paper is to analyze some of the strengths and deficiencies in the current MSW management system in Bhopal City, propose different SWM scenarios and perform a cost benefit analysis to select the most economically feasible scenario.

Estimates of urban solid waste generation rates and composition in Madhya Pradesh Government were obtained from published reports on Solid waste management in Bhopal City [14] and discussion with solid waste management officials.

Information regarding solid waste stream composition was obtained from field sampling data as provided in Table 1 to 4, the percentage of Bhopal City municipal solid waste stream consisting of materials which are considered to be recyclable or compostable is significant. Findings based on field data estimate recyclable or compostable material to be about 84%. Al- though there is no data on waste composition for commercial and small to medium-sized industrial waste, it is anticipated that this waste

will significantly contribute to the recyclable portion. This large percentage of recyclable/compostable material in the waste stream provides optimism that large-scale recycling and composting will be feasible and significantly reduce the volume of solid waste transferred to landfill.

Information regarding solid waste management practices in Bhopal City, including inventory of sanitation equipment and vehicles, were based on data provided by relevant authorities and field verified using questionnaires. A brief description of current solid waste management operations are provided hereinafter.

Collection and transfer of solid waste in Bhopal City is the responsibility of the municipality. Current solid waste management (SWM) operations in Bhopal city rely on the stationary container system (common bins) and a fleet of mechanical equipment and vehicles that are owned by the municipalities. For this system, residents place their waste in bins that are located at central points throughout the city. Current deficiency in the number of bins distributed throughout the urban areas has resulted in waste filling the bins and accumulating around on streets. In addition to the formal sector, the informal sector plays a minor role in the collection and transfer of waste in some areas of the city of high income level. Waste is collected from household and they are transferred to open areas where they are manually recover salvageable material, that is then sold.

At the time of the study, no transfer stations were available in Bhopal City.

Bhopal city had a designated waste disposal area located outside the urban limits of the city. However, this site was not built, operated, or managed to any accept- able standards and generally classified as open dumpsite.

Assessment of the current solid waste management (SWM) situation in Bhopal City revealed the following features:

- Waste collection, transport, and disposal systems operate at reduced capacities due to civil unrest, looking of SWM facilities and equipment, lack of maintenance, and insufficient numbers of qualified SWM managers, supervisors, and specialist personnel. Results include substantial waste accumulations around public waste containers and in streets and public areas.
- There are no sanitary landfills and most of the dumpsites in Bhopal City are at the limits of their capacity to accept wastes.
- There is an informal recycling economy, although its size is difficult to estimate. Materials are provided by informal waste collectors who engage in door-to-door collection from higher-income neighborhoods and sort the dry wastes. Small enterprises buy these materials, perform some levels of processing, and sell them to end-users.
- Composting of urban wet wastes does not appear to be practiced.

## 2.2. Integrated Solid Waste Management Master Plan

In an attempt to improve public and environmental health in Bhopal City provisions were taken for the development of an integrated solid waste management Master Plan (ISWMMP). This plan will be implemented for a time horizon of 20 years divided into three terms; Short Term (2015-2010), Medium Term (2020-2025), and Long Term (2026-2035). Construction and organization of SWM activities will be implemented in phases, with specific activities and geographic areas receiving improved service over the three periods of the Master Plan. As part of this ISWMMP, different scenarios for the management of solid waste management in Bhopal City were considered and compared using Cost-Benefit Analysis approach (CBA).

## 2.3. Cost Analysis

Cost estimates for the SWM scenarios include capital costs and operation and maintenance (O&M) costs. The capital cost is the sum of civil works cost and mechanical equipment cost. Operation cost is represented by the annual expenditure for power, fuel, and labor. Maintenance cost is taken as a percentage of the capital cost.

The objective of cost estimates in this study is mainly to serve the cost benefit analysis and recommendations that will follow. The capital as well as O&M costs are determined as a function of the yearly MSW generation.

Estimated capital and O&M costs up to year 2035 are carried out for all considered SWM scenarios on spread-sheets in response to short term, medium term and long term needs. A comparative life cycle costing (LCC) analysis has been applied to identify the least cost scenario. The analysis of alternative Master Plan scenarios has considered economical, environmental and social aspects to the greatest extent possible.

Minimum cost is one of the criteria to select the most economical scenario. However, environmental impacts and benefits may divert the recommendations towards sustainability, which is currently more desired by societies seeking long term environmental benefits and conserving natural air, water and soil resources.

The LCC analysis has been conducted based on the following assumptions:

- 1) An infinite horizon is assumed. This time frame is used in order to account for the different service times of the facilities and/or equipment.
- 2) Capital and O&M costs are discounted at a constant interest rate of 10%.
- 3) Basically the total cost of a SWM scenario on an infinite horizon consists of 1) the total discounted capital cost and 2) the total discounted O&M cost.

## Conclusions

In this study, the technical, economical, and environmental aspects of different SWM scenarios were investigated to compare the options available for MSW management in Bhopal City. Three scenarios were compared namely; direct waste disposal into a sanitary landfill, waste transportation to transfer station and then to a sanitary landfill, sorting, recycling and composting followed by landfill disposal in an integrated treatment disposal facility. In addition, the current open dumping practice was included as the baseline scenario.

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**Table-1 : Solid waste generation from year 2008 -2023.**

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 Munsai 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
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
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-2 : 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
	<b>Average</b>	<b>290</b>	<b>2376</b>	<b>2193</b>

**Table-3 : 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
<b>Average</b>	<b>31.10</b>	<b>44.52</b>	<b>15.58</b>	<b>8.79</b>

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

**Table-4 : 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
<b>Average</b>	<b>27.02</b>	<b>5.78</b>	<b>46.91</b>	<b>1.06</b>	<b>0.38</b>	<b>0.84</b>	<b>0.80</b>	<b>17.21</b>	<b>26.30</b>

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