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# Seasonal characterization and present status of municipal solid waste (MSW) management in Varanasi, India

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**Abstract.** The paper aims to characterise the waste generated in municipality of Varanasi, the most populated city in the state of Uttar Pradesh, India. MSW is a heterogeneous waste and composition of the waste varied from season to season. The generation, collection and management of waste have become a major environmental problem in most of the developing cities. MSW was collected from open dumping grounds for 2 consecutive years. Each year was classified into 3 seasons of 4 months. On analysis it was found that the biodegradable fraction is always more than other fractions with a minimum of 48.25% in rainy season. With such a high fraction of biodegradable wastes, options such as composting and biomethanation could be tried to convert waste into energy. The average weight of waste generation at present is 0.460 kg per capita per day. The study showed that waste generation and collection were increasing every year, which may be attributed to increase in population.

**Keywords:** characterization; seasons; MSW generation; collection; Varanasi

## 1. Introduction

As a result of rapid urbanization and a high population growth, the waste quantity is increasing at an alarming rate. India is the second most populated country. As per 2011 census, 1210 million people live in the country. The growth rate of population for India in the last decade was 17.6% (Census of India 2011). The urban population in India has gone up five times in the last six decades. Problems of solid waste management are growing with rapid urbanization and change in the lifestyle of the people. The situation is becoming critical with the passage of time (Talyan *et al.* 2008). Domestic, commercial, biomedical and variety of toxic and domestic hazardous wastes are generally disposed of by the citizens on the streets, drains, open spaces, water bodies, etc., causing serious problems of health and environment (Abbasi *et al.* 2012). It is an obligatory duty of municipal authorities in the country to keep cities/towns clean and provide a good quality of life to the citizens (The gazette of India 2000). The urban solid waste management system is not getting the required attention, resulting in heaps of waste scattered in almost all cities. However, the services provided by the municipal authorities are outdated and very inefficient. The management of MSW requires proper infrastructure as well as financial back up (Sharholy *et al.* 2008). There

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are many wastes to energy projects in practice, but defining a sustainable energy for urban waste treatment that can be applied to a city is particularly difficult task, since geographic location, climate, demographics and socioeconomic factors determine the amount and composition of waste (Gomez *et al.* 2009).

The State of Uttar Pradesh is the most populous state in the country. The state is having five cities above one million populations, in which Varanasi is one of the cities. The Varanasi Urban Agglomeration, an agglomeration of seven urban sub-units covers an area of 112.26 km² (Fig. 1). The urban agglomeration is stretched between 82° 56'E - 83° 03'E and 25° 14'N - 25° 23.5'N (Wikipedia). The daily generation of MSW is approximately 650 metric ton (MT) of which 450 MT is collected and disposed. After the privatization of waste management in some parts of the city, major changes are observed in terms of littering on the street. Technical bins are provided in large numbers and it really helped in changing the face of city. The city has a large number of hotels and restaurants and approximately 170,000 households. There are 20 vegetable, 5 fruits, 5 meat and 5 fish markets in the city leaving behind a large quantity of mixed waste rich in organic


Fig. 1 Map of study area Varanasi

contents (DPR 2009). The organic matter in solid waste in developing countries is much higher than that in the waste in developed countries (Bhide and Sundaresan 1983). All these wastes are disposed in the open dumping ground, slightly away from city and adjacent to river Ganges. As these dumping grounds are not engineered sanitary landfills, it emits foul smelling gases and produces leachate which affects soil and water. The problems are very serious during summer season due to the faster degradation of organic compounds. Varanasi with its extreme climate has a hot summer season with an average maximum temperature of 45°C. Amount of waste generated in the city of Varanasi increased every year and presently 650 MT of waste is generated daily. To have a proper waste management programme characterisation of waste is necessary (Al-Khatib *et al.* 2010). In the present study an attempt has been made to find the physical composition, proximate analysis and chemical characteristics of the waste collected from different parts of Varanasi during three seasons in a year for two consecutive years. The characterization was mainly done to find out the amount of biodegradable fraction generated in the city and the suitability of this biodegradable fraction to be converted into energy production.

## 2. Materials and methods

### *2.1 Sample collection*

Sample collection was done for two years starting from March 2009 and ended in 2011 February. Each year was divided into three different seasons; naming it as summer (March to June), Rainy (July to October), winter (November to February). The analysis was done once a month and average of four months were shown as result of one season. MSW samples were collected in the first week of every month for five consecutive working days from dumping ground. The collection was done when the trucks were unloading. Each day material was collected from 5 trucks which come from five different areas. This way by the end of 5 days, almost whole of city was covered. Approximately 100 kg of material was collected from each truck and a total of 500 kg daily was collected and kept in sacks. At the end of $5^{th}$ day all the sacks which were collected for 5 days weighed approximately 2500 kg.

### *2.2 Classification of waste into different components*

The waste collected for 5 days was mixed thoroughly on $6^{th}$ day (2500 kg). It was divided into 10 equal parts. From each part approximately 50 kg was taken and thus collected a total of 500 kg. Various components like paper, plastics, polythene, plastic bottles, tetrapaks, paper pouches, cardboard, polyester, rubber, leather, batteries, concrete, stone, ash, sand, glass, metals, plastic, soft drink cans, carton packs,synthetic textiles, coating chemicals like latex etc. was segregated manually under the categories like combustibles, inert and recyclables and weighed to express as a percentage of total weight. The sum of combustibles, inert and recyclables was subtracted from 100 to get the biodegradable fraction. The remaining part which is termed as organic fraction (mixture of food, vegetable, flowers, fruit, leaves, degradable textiles like wool, cotton along with sand and mud) was weighed and 10 packets of approximately 2 kg was taken for chemical and proximate analysis to laboratory. The average physical composition of MSW of Varanasi after two years of study is shown in Fig. 2.

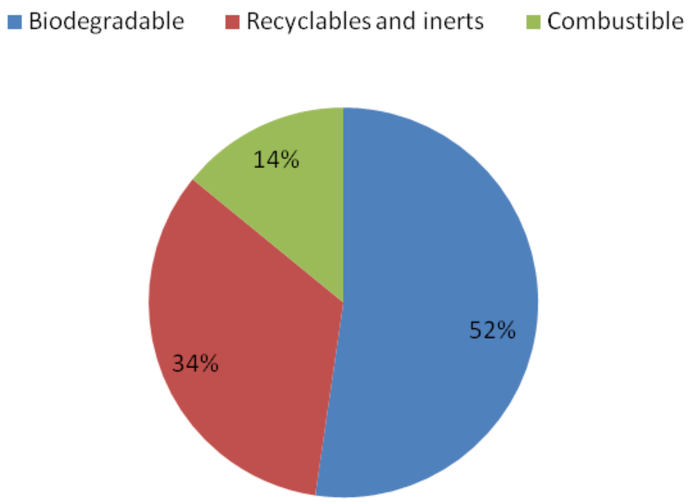


Fig. 2 Physical composition of waste

### *2.3 Analysis in the laboratory*

The proximate analysis was carried out to determine moisture content, ash and volatile matter. Total Solids percentage (TS %) of the biodegradable fraction was measured by heating a known weight of sample at 105°C according to the Laboratory Analytical Procedure (LAP-001 1994). Volatile Solids percentage (VS %) of biodegradable fraction was measured according to the Laboratory Analytical Procedure (LAP-005 1994). The parameters nitrogen, carbon and hydrogen were done using Perkin Elmer 2400 CHN analyser. Calorific value was determined using bomb calorimeter (RSB 3, Rajdhani Scientific Instruments Co., New Delhi). The pH value was measured with a pH meter (CL54, Toshniwal Instruments Mfg. Pvt. Ltd.). Total organic carbon (TOC) of the solid sample was measured using titration method (Walkley and Black 1934). The soluble chemical oxygen demand (SCOD) was measured using potassium dichromate-ferrous ammonium sulphate method in accordance with standard methods (APHA 1975).

## 3. Results and discussions

### *3.1 Waste generation rate*

No systematic analysis of wastes by Municipal Corporation of Varanasi has done so far which is dumped in the open dumping grounds. As per the estimate, waste generation rate estimated by the municipal corporation is 650 MT per day, out of which approximately 450 MT waste is collected each day. The break up of estimated waste generated from different sources is given in Table 1. In an earlier study by central pollution control board (CPCB), the waste generation was put at 425 MT per day. In order to come to a correct figure of waste generated per day, an exercise was undertaken to weigh the waste transported to dump site. Weighing was carried out for seven consecutive days, which revealed that average waste generation rate is 480 MT per day. The

Table 1 Sources of waste and quantity of waste generated

| Source* of waste | Estimated quantity of waste (MT) |
|---|---|
| Households | 450 |
| Shops, workshops | 100 |
| offices, institutions | 45 |
| Industries | 15 |
| Others | 40 |
| Total | 650 |

*Source: Varanasi Municipal Corporation

Table 2 Physical composition of waste

| Composition | Components |
|---|---|
| Biodegradable | Food, vegetables ,fruits, leaves, degradable textiles like wool, cotton, silk, tree trims, lawn grass, dung, tissue paper, jute sacks, hay, straw, flowers from temples, bamboo baskets |
| Combustible | Paper, tetrapaks, paper pouches, cardboard, polyester fibres, rubber, leather, egg tray, crockery packs, coating chemicals like latex, jute bags |
| Inert | batteries, concrete, stones, ash, sand, human hair, etc. |
| Recyclable | Glass (window glass, bottles), metals (cans and other metals), plastic (polythene bags, HDPE, LDPE), carton packs, synthetic fibres (nylon ropes, nylon sacks), toys |

Table 3 Individual fraction of MSW components for a period of two years

| Component | Summer | Rainy | Winter |
|---|---|---|---|
| Biodegradable (%) | 52.75 (± 2.73) | 48.25 (± 2.16) | 56 (± 2.03) |
| Recyclable and Inert (%) | 31.25 (± 3.14) | 35.75 (± 2.92) | 33.75 (± 3.71) |
| Combustible (%) | 16 (± 2.44) | 16 (± 2.78) | 10.25 (± 1.73) |

- All numbers are percentage of total sample weight which is 50 kg; Numbers in brackets are standard deviation

weighing was done at dumping ground which shows the amount collected and dumped and it does not show the correct figure of generation. As the collection and disposal is not fully done, it was assumed that only 70% of the generated waste is collected and disposed which gives the figure approximately 650 MT per day (DPR 2009).

### *3.2 Waste composition*

The physical component which falls under four different groups was classified into biodegradable, inert, recyclable and combustible category. The waste in this category comes from road sweepings, commercial and construction waste, drain cleaning, cottage industry and wastes from temple. The physical components under different categories are shown in Table 2. The results of physical composition of waste on the basis of weight percentage after two years of study

Table 4 Results of chemical and proximate analyses of biodegradable fraction of MSW samples

| Component | Summer | Rainy | Winter |
|---|---|---|---|
| Moisture content (%) | 64.85 (± 3.13) | 85.78 (± 3.48) | 75.95 (± 3.76) |
| Total solids (%) | 35.15 (± 2.18) | 14.22 (± 2.24) | 24.05 (± 2.47) |
| Volatile solids (% of total solids) | 61.19 (± 2.34) | 73.5 (± 2.67) | 82.2 (± 2.87) |
| pH | 6.63 (± 0.24) | 5.97 (± 0.18) | 6.24 (± 0.27) |
| Soluble COD (mg/L) | 52.75 (± 2.54) | 55.35 (± 2.43) | 64.65 (± 2.34) |
| C (%) | 39.7 | 42.91 | 43.83 |
| H (%) | 6.8 | 5.91 | 4.35 |
| N (%) | 2.5 | 1.96 | 2.16 |
| C/N | 15.88 | 21.89 | 20.29 |

are shown in Fig. 2. Table 3 shows the percentage of individual fraction of MSW components for a period of two years.

### 3.3 Characterization of solid waste

Separation of biodegradable was slightly difficult due to the degradation and mixing up with soil. The results of chemical, proximate and elemental analyses are given in the Table 4. Moisture content was varied from 65 to 85% showing the highest value in rainy season. The low moisture in summer is due to the extremely high temperature (45-46°C), which lead to drying and degradation at high temperatures. The volatile solid was found in the range of 61 to 76% results in the high organic content of waste. The total volatile solid content in the fresh Indian MSW is much higher than that of other places; it has comparatively better properties as feed for biomethanation digesters (Ambulkar and Shekdar 2004).

### 3.4 Comparison of solid waste composition

The solid waste composition of Varanasi is compared with other cities of India and is presented in Table 5. It shows that Varanasi city has an average organic fraction more than that of many cities. As per the CPCB report on status of solid waste generation, collection, treatment and disposal in metro cities, out of the 23 listed cities only 2 cities Kochi and Pune have compostable fraction more than that of Varanasi. Organic fraction present in MSW has highest potential to emit green house gases if not treated properly (Diaz *et al.* 1993). The solid waste generated in Varanasi have considerable amount of moisture which is a favourable condition for biomethanation or composting. High moisture content causes biodegradable waste fractions to decompose more rapidly than in dry conditions. It also makes the waste unsuitable for thermo-chemical conversion (incineration, pyrolysis/gasification) for energy recovery as heat must first be supplied to remove moisture. In biomethanation, the organic fractions undergo bio-degradation producing methane-rich biogas and sludge. The biogas can be utilized either for heating applications, or through dual fuel or gas engines for generating motive power or electricity. The sludge from anaerobic digestion, after stabilization, can be used as a soil conditioner, or even sold as manure depending upon its composition, which is determined mainly by the composition of the input waste (González *et al.* 2011).

Table 5 Comparison of physical characteristics of MSW of present study with other Indian cities (Sharholy *et al.* 2008)

| Fractions | Lucknow | Varanasi (Literature) | Varanasi (present study) | Pune | Mumbai | Chennai | Kochi |
|---|---|---|---|---|---|---|---|
| Compostable matter | 40 | 48 | 52 | 55 | 40 | 44 | 58 |
| Ash, fine earth and others | 49 | 35 | 38 | 15 | 44 | 33 | 36 |
| Paper | 4 | 3 | | 5 | 10 | 10 | 4.9 |
| Textiles | 2 | 4 | | - | 3.6 | 5 | - |
| Plastic | 4 | 10 | 10 | 5 | 2 | 3 | 1.1 |
| Metals | 1 | - | | - | - | - | - |
| Glass | - | - | | 10 | 0.2 | - | - |

- All values are shown in weight percentage

### 3.5 Waste disposal

The city is unfortunately having no landfill site for treatment and disposal of waste. About 450MT of mixed waste brought from the city is haphazardly disposed of in the area near Varuna tributary of river Ganges Ramna and Ramnagar dumping grounds. Previously waste has been deposited in river Assi as well as several low lying areas and is lying there exposed. The waste is neither spread, compressed or covered. Waste is seen lying there in plenty of 1 to 10 metre height. Presently in absence of construction of a sanitary landfill, the disposal of waste as per the MSW rules is not being carried out.

### 3.6 Recyclable waste

Plastics dominated among the recyclable components. Metals and glass components were also present but the wastes which came to the dumping ground were searched by rag pickers, hence latter components were minimal. In the plastics section, plastic covers which are used as carry bags accounted for the maximum part with the presence of crushed bottles, glass, etc.

### 3.7 Hazardous waste

Varanasi city does not have many industries producing hazardous goods; hence the presence of industrial hazardous waste was low. However, house hold hazardous waste like detergents, pesticides, medicines which have crossed expiry date, cleaning products, automobile wastes, batteries, etc. were seen in plenty. These types of things were observed more during October, November months due to annual cleaning associated with festive seasons.

### 3.8 Variation of MSW generation between different seasons

The monthly average physical composition of waste is shown in the Fig. 3. The physical composition of waste during different seasons is given in Fig. 4 and it is noticeable that the biodegradable fraction is more in all the seasons with the highest in winter season followed

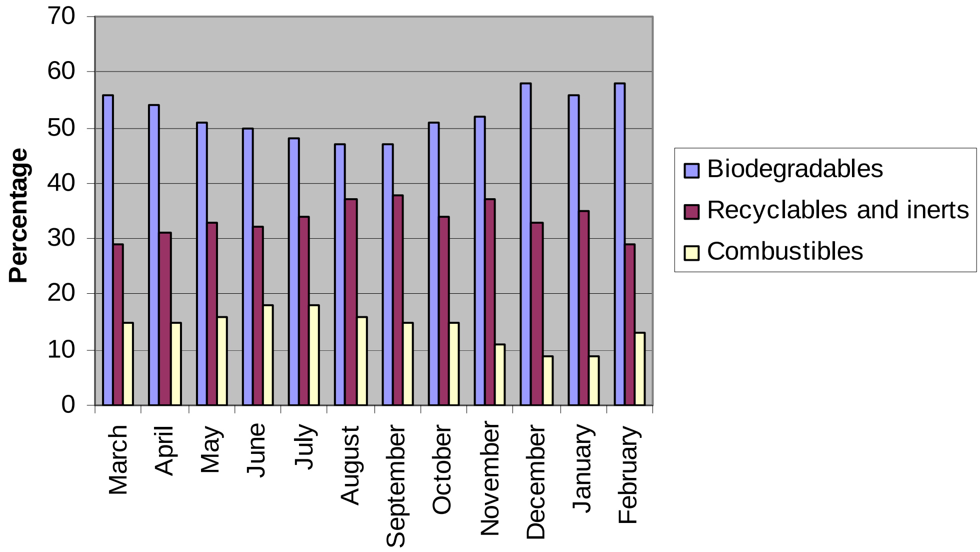


Fig. 3 Monthly average physical composition of MSW

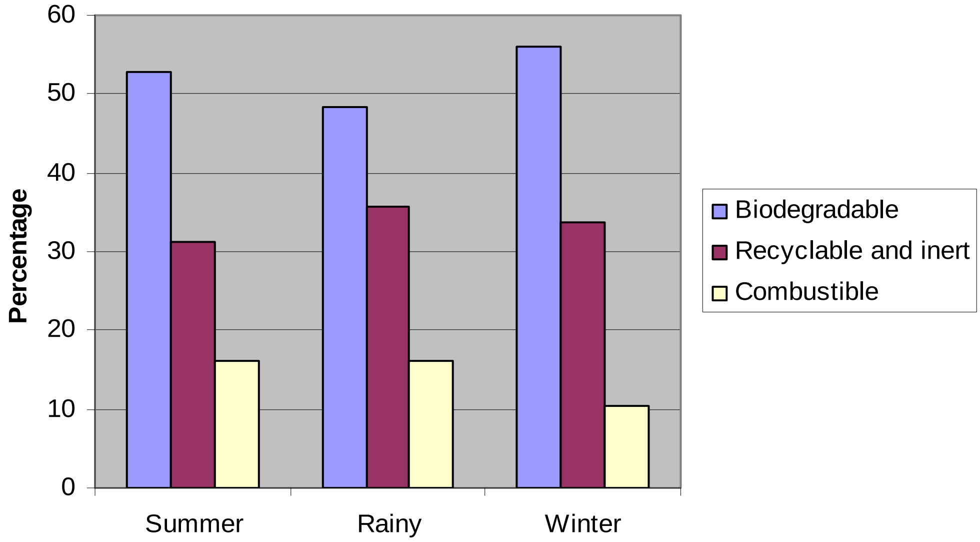


Fig. 4 Season wise physical composition of waste

by summer and rainy season. Biodegradable fraction mainly consists of food waste, vegetable, fruits, flowers etc. In winter the fresh vegetables like cauliflower, green peas, carrot etc availability in the region is very high due to the local production and it is visible in the waste. Consumption of vegetables and fruits are more in this season may be due to the availability and widespread marriage. More over the low temperature existing at that time prevents the waste from biodegradation. In summer season due to extreme heat and in rainy season due to excess moisture and water biodegradation was faster (Hernández-Berriel *et al.* 2008). The amount of combustibles was found to be lesser in winter months may be attributed to the fact that rag pickers and poor people may be doing more collection to arrange fire during winter. This shows that waste composition varies with season (Zeng *et al.* 2005). In summer the waste comprises of more soft drink cans, bottles, fruit juice tetrapaks, coconut shells, wood apple shells etc. Plastic cups and plastic carry bags were always a major part in the recyclable item.

## 4. Conclusions

The MSW generation in Varanasi is increasing every year due to the population explosion and poor management by the municipality. Waste is not segregated at source and people are still throwing the wastes on the road leads to poor condition of environment. As practised in many other cities of India, here also waste is dumped in open grounds leading to different health problems through water and air pollution.MSW generated in Varanasi in two successive years was characterised at three different seasons of the year. Approximately 2880 kg of MSW were analyzed to find the percentage of different fractions. The results showed a trend of high biodegradables in all the seasons with maximum in winter season. The moisture content of the waste was always high, hence waste to energy options like incineration, pyrolysis, etc would not be a good option. Composting and biomethanation in which moisture plays a major part could be pursued for the better usage of waste (Kawai *et al.* 2012). The quantity of waste was found maximum during winter season due to the seasonal availability of vegetables, high tourist inflow during cool season, marriages and other cultural and religious festivals. The composition of waste generated in different seasons is decided by economic and social factors (Issam *et al.* 2010). The present study provides accurate information of the waste generated and its composition in the city of Varanasi and this can be considered as a first step needed in a sustainable management planning.

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