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Characterization and management of municipal solid waste: a case study of Varanasi city, India

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Municipal Solid waste management, Characterization, Energy content, Methane Production.

A B S T R A C T

The paper aims to characterise the waste generated in municipality of Varanasi, the most populated city in the state of Uttar Pradesh, India. Municipal Solid waste (MSW) is a heterogeneous waste and composition of the waste varied from place to place. The objective of the paper was to study the amount of solid waste generated during one year (2012-2013) of study period at four different places in Varanasi and evaluation and recommendations made on data collected in order to improve the current Solid Waste Management System of Varanasi City. The research gathered data from two main sources namely: secondary and primary sources. The three main techniques employed in gathering the primary data were: preliminary field investigation, questionnaire survey and face-to-face interview. Characterization of municipal solid waste shows Varanasi waste comprise maximum food waste (31.9 %) followed by plastic (22%), textile (10.6%), paper (9.6%), glass (6.7%), cardboard (6.2%), ash (5.3%), leather (5.7%) and minimum metals waste (2.8). Surveys showed that per capita MSW waste generation rate is 800 MT per day, 0.217kg/person/day. Sample from Ordalibazar showed the highest amount of energy content according to Modified Dulong Formula with a value of 254524.46 KJ/Kg followed by Daphi 167545.84 KJ/Kg, Nakhighat 96455.80 KJ,/Kg Puranapull 16147.11 KJ/Kg. Orderlybazar site have highest energy capacity compared to other sites and we can obtained more methane from NakiGhat site. Thus, on the basis of this study we may conclude that solid waste management and recycling is major issue of Varanasi district. We can reuse various types of waste depending upon the nature of waste. We can also make alternate use of that waste like energy production.

Introduction

The waste quantity is increasing at an alarming rate in India due to rapid urbanization and a high population growth. The growth rate of population for India in the last decade was 17.6% (Census of India 2011). The issue is exacerbating in urban areas due to rapid population growth, coupled by an economic boom that encourages the consumption of goods and hence waste generation. 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 urban solid waste management system is not getting the required attention, resulting in heaps of waste scattered in almost all cities. The organic matter in solid waste in developing countries like India is much higher than that in the waste in developed countries (Bhide &Sundaresan 1983). Within India, 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 km^2. The urban area is stretched between 82° 56'E - 83° 03'E and 25° 14'N - 25° 23.5'N. The daily generation of MSW is approximately 650 metric ton (MT) of which 450 MT is collected and disposed. 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 (average maximum temperature of 45°C) due to the faster degradation of organic compounds (Dasgupta et al. 2013). 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). There 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).

According to an estimate, residential waste (including waste from apartment houses) accounts to 55 percent to 65 percent of the total municipal solid waste generation. Waste from schools and commercial locations, such as hospitals and businesses, amounted to 35 to 45% (EPA, Municipal Solid Waste Generation, Recycling, Disposal, 2006). Solid waste consists of many different materials, some can burn, some cannot, some can be recycled, and some cannot. Therefore, a detailed understanding of the composition of solid waste will indicate the management methods that will be used. Solid waste is composed of combustibles and non-combustible materials.

The combustible materials include paper, plastics, yard debris, food waste, wood, textiles, disposable diapers, bones, leather and other organics. Non-combustibles also include glass, metal, and aluminium (Denison & Ruston 1990; Kreith 1994; Zerbock 2003). In the present study an attempt has been made to find the physical composition, proximate analysis and chemical characteristics of the waste collected from four different locations of Varanasi. 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.

Material and methods

The research gathered data from two main sources namely: secondary and primary sources. In secondary source, the three main techniques employed in gathering the primary data were preliminary field investigation, questionnaire survey and face-to-face interview. For primary source of data generation, sampling was done at four different sites.

Sample collection

Sample collection was done for one year at monthly interval starting from July 2012 and ended in June 2013. Sample was collected in triplicate at four sites i.e. Dafhi bypass (DP), Ordalibazar (OB), Nakhighat (NG) and Purana pull (PP) in Varanasi. The analysis was done once a month and average of twelve months were shown in result. MSW samples were collected in the first week of every month for four consecutive working days from dumping ground. 100 kg samples were taken from predetermined points in the load (each corner and middle of each side) and mix the sample. These samples were analyzed physically and chemically. All separable physical components were segregated manually on-site

Sample size and classification of waste

The waste collected for 5 days was mixed thoroughly on 5th day and a 100 kg sample from each site was taken. 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. Now the wastes were categorized into different components like food waste, plastic, garden waste, paper, textile, leather, ash, cardboard and inert waste etc. These wastes were analyzed further.

Analysis of waste

For analysis of waste different samples were collected in poybags. Percent moisture content, density, energy content, energy content on dry basis were estimated by following way (Peavy et al., 2009):

Moisture content (%) = (Initial mass-Final mass) X 100 / Initial mass
Density = mass (m)/ volume (v).
Energy content = kj/kg (as discarded) X 100/ 100 - %moisture

Energy content on dry basis = (unit energy content / (100 - %moisture) X 100

Energy content was also estimated by modified dulong formula i.e. 337C + 1428 (H-O/8) +95S

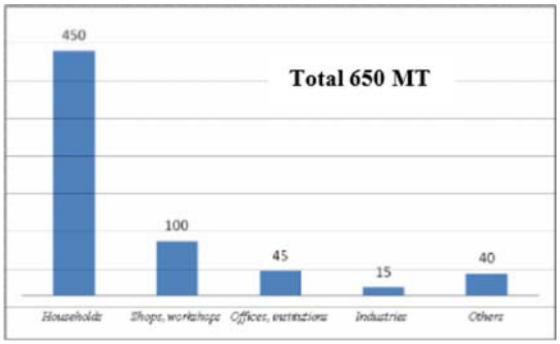
Statistical analysis (LSD) was calculated by SPSS version18.

Results and Discussions

There are different sources of municipal solid waste, which contain different types of wastes (Table 1). 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 different categories of estimated waste generated from different sources is given in Fig. 1. In an earlier study by central pollution control board (CPCB), the waste generation was put at 425 MT per day.

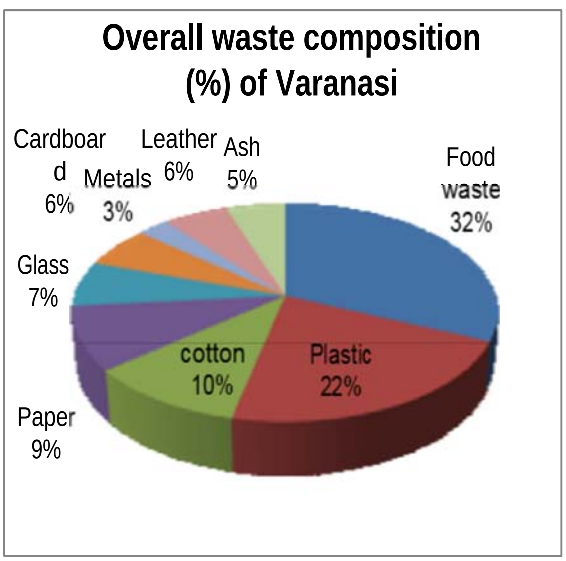
Figure.1 Sources and quantity of waste generated in Varanasi city (values in MT)



Source:Varanasi municipal corporation

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. 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 800 MT per day, 0.217kg/person/day (DPR 2009).

Figure.2 Average physical composition of Municipal solid waste of Varanasi city



The average physical composition of MSW of Varanasi after one year of study is shown in Fig. 2. Characterization of Varanasi MSW shows maximum 32% of food waste followed by plastic waste, textile waste, paper, glass, cardboard, ash, leather and metals.

Waste composition depends on a wide range of factors such as food habits, cultural traditions, lifestyles, climate and income, etc. (Gupta et al., 1998). The city has a large number of hotels and restaurants and more than 180,000 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 contents (DPR 2009). The organic matter in solid waste in developing countries like India is much higher than that in the waste in developed countries (Bhide & Sundaresan 1983).

Table.1 Type and sources of municipal waste

S.N.	Source	Type of waste
1	Residential areas	Food waste, paper, cardboard, plastic, textiles, glass, metal and non-hazardous waste, batteries, construction debris and demolition waste
2	Commercial areas	Paper, cardboard, plastic waste, glass, metal and e-waste
3	Institutional areas	Paper, cardboard, plastic waste, glass, metal and e-waste, hazardous waste, processing waste, ashes, infectious and toxic waste
4	Industrial areas	Paper, cardboard, plastic waste, metal, e-waste, hazardous waste, and nonhazardous waste
5	Municipal services like street cleaning, parks, water and wastewater treatments	Green trash, silt/ashes, construction and demolition waste, sludge

The physical component which falls under different groups at four different sites of Varanasi city is shown in Table 2. The typical values used in the calculation are shown in Table 3. Results of waste shows that OB site have maximum food waste compared to DP, NG and PP sites. However, plastic, glass and leather wastes were higher at DP site. In case of cotton waste it value was greater at site NG (16 kg/100 kg waste) (Table 2). The DP site is the biggest and highly used domestic as well as industrial dumping site of Varanasi city this is the reason for maximum plastic waste in DP site.

The domestic and industrial sources contain plastic bottles, pipes, plastic containers and packaging polybags. The OB site contain highest amount of food waste because it is located in the main city and many high profile hotels and restaurants, slaughter house and meat shops are situated here that generate high amount of food as waste.
The presence of high amount of Textile (cloths) waste in NG is due to fact that there is presence of large amount of textile and cotton industries and cotton mills.

Table.2 Waste sample collected at different places of Varanasi (kg/100kg). Abbreviations: Dafhi bypass (DP), Nakhighat (NG), Purana pull (PP) and Ordalibazar (OB).

REFUSE TYPE (kg)	DP	NG	PP	OB	*LSD*
Food waste	33.2	30.0	31.2	36.1	*2.2*
Plastics	26.4	22.4	20.5	20.8	*1.2*
Paper	10.2	10.5	9.7	8.2	*1.8*
Cardboard	6.1	6.4	6.3	6.2	*1.0*
Cotton	4.5	16.1	8.4	10.3	*3.2*
Glass	7.2	5.1	8.0	6.6	*2.1*
Metals	2.1	2.1	4.8	2.2	*0.5*
Leather	4.0	2.2	6.8	10.1	*2.2*
Ash	6.3	5.1	4.3	5.8	*1.2*

There is no significant difference in moisture content at four sites; however, density was slightly greater at PP and DP sites (Table 4). Energy content according to modified Dulong formula (kj/kg) was significantly greater at OB site followed by DP, NG and PP sites. However, methane generation capacity (m^3/kg) was maximum at PP site.

Thus, our work gives a comparative account of solid waste in different places of Varanasi city this will helpful in management of solid waste as well use of that waste as alternate energy source. Because most of waste is decomposable and organic so we can also recycle that waste and used as compost. Gautam et al. (2009) in their study in Jabalpur had shown the 47% of urban solid waste were degradable and 53% non-degradable, they tried to recycle the waste. The results of their study clearly indicate that the recycling of solid urban waste can transform garbage or municipal solid waste to enriched composts. As most of urban waste contain high amount of organic carbon due to presence of cow dung and green manure (high C: N ratio), it can be used in urban waste composting. This is practical significance if adopted by urban farmers as a result of soil health and in turn the productivity of soil can be maintained for further agriculture.

Esaaku et al. (2007) have worked on municipal solid waste generation in Chennai, the fourth largest metropolitan city in India, has increased from 600 to 3500 tons per day (tpd) within 20 years.

Table.3 Typical values used for calculation (source: Peavy et al. 2009).

Refuse type (kg)	Typical moisture (%)	Typical density (kg/m^3)	Typical energy (kJ/kg)
Food waste	70	290	4650
Plastic	2	65	32600
Paper	6	85	16750
Cardboard	5	50	16300
Glass	2	195	150
Metals	2-3	320	-
Textile	10	65	17450
Leather	10	160	17450
Ash	8	480	7000

Table.4 Percent moisture content, density, energy content and methane generation capacity of four solid waste dumping sites of Varanasi

Parameters	DP	NG	PP	OB	*LSD*
Moisture content (%)	74.4	75.2	74.7	72.0	*1.8*
Density(kg/m^3)	102.8	95.5	105.8	76.3	*8.8*
Energy content(Kj/kg)	14921	14749	13784	15090	*940*
Energy content on dry basis(kj/kg)	58182	59302	54451	53914	*443*
Energy content according to modified Dulong formula (kj/kg)	167545	96455	16147	254524	*1020*
Methane Generation capacity (m^3/kg)	44	57	61	48	*4.6*

The highest per capita solid waste generation rate in India is in Chennai (0.6 kg/d). Chennai is the first city in India to contract out MSWM services to a foreign private agency- ONYX, a Singapore based company. A high rate biomethanation plant for power generation is in operation at the Koyembedu market. So there is lots of scope in MSW management in India and Varanasi.

Sarholy et al. (2008) provides a comprehensive review of the characteristics, generation, collection and transportation, disposal and treatment technologies of MSW practiced in India. The study is concluded with a few fruitful suggestions, which may be beneficial to encourage the competent authorities /researchers to work towards further improvement of the present system. The results indicated that the organic waste was the highest among other components of the wastes.

A considerable proportion of organic carbon was found which causes the health problem to the workers. In order to avoid this situation small community pots with revolving axis are needed along with the disposal vehicles, small auto rickshaws or paddle tricycles to maximize the collection of wastes. Annual report of the addition of the wastes due to increasing population and the strategies for collection of wastes shall have to be formulated (Pandey et al. 2007).Thus, we can say that solid waste management in Varanasi and its proper recycling is major issue of today. There is need to intensive work on it.

Conclusion

Thus, on the basis of this study we may conclude that solid waste management and recycling is major issue of Varanasi district. We can reuse various types of waste depending upon the nature of waste. We can also make alternate use of that waste like energy production. This study showed that OB site have highest energy capacity compared to other sites and we can obtained more methane from NG. We can use this site for energy generation purpose.

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