Journal of Urban and Environmental Engineering, v.6, n.2, p.67-73

ISSN 1982-3932
doi: 10.4090/juee.2012.v6n2.067073

Journal of Urban and Environmental Engineering

www.journal-uee.org

URBAN SOLID WASTE MANAGEMENT OF GUWAHATI CITY IN NORTH-EAST INDIA

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Received 6 May 2012; received in revised form 1 June 2012; accepted 7 July 2012

Abstract: In recent years municipal solid waste (MSW) management has been one of the most environmental concerns for all urban areas of India. Most of the urban centers have neither adequate land nor any facility for MSW disposal. In view of scarcity of lands for making landfill sites, solid wastes can be used for energy recovery resulting in volume reduction, thus requires less area for its disposal. Guwahati is one such city of North-East India, having the potential to recover the energy from solid wastes and at the same time the waste management system of the city can be improved. This paper attempts to characterize the urban solid waste of the city as well as its energy potential for various uses. Results showed that the average generation rate of MSW was 0.7 kg/capita/day and the city has the potential to generate the power of 30 MW from the solid waste.

Keywords: C/N ratio; energy content; solid waste; volatility

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INTRODUCTION

Economic development, rapid industrialization, urbanization and population growth have accelerated the dynamics of the urbanization process in developing countries (Suocheng *et al*., 2001). In India alone, the urban population has increased from 26% in 2001 to 32% in 2011 (Census of India 2011). The rapid growth rates of many cities, combined with their huge population base, has left many Indian cities deficient in infrastructure services like water supply, sewerage and solid waste management.

Due to lack of serious efforts by town/city authorities, the management of garbage has become a tenacious problem. Municipal solid waste (MSW) generation in Asia in 1998 was 0.76 million tons per day (Jin *et al*., 2006), with an annual growth rate of 2–3% in developing countries and 3.2–4.5% in developed countries. Indian cities generate an estimated 0.115 million metric tonnes of waste per day and 42 million metric tones annually (3iNetwork, 2006).

The per capita waste generation ranges between 0.2 and 0.6 kg per day in the Indian cities that is lower than that in developed countries. However, lifestyle changes due to economic growth and fast rates of urbanization have resulted in per capita waste generation increasing by about 1.3% per year. The Energy Resources Institute (TERI) has estimated that waste generation will exceed 260 million tones per year by the year 2047—more than five times the present level (3iNetwork, 2006). It is observed that bigger the size of the city (population and density wise), greater is the quantity of waste generated. This is the phenomenon observed world over and India is no exception to this. Population more than 0.1 million generates a major portion of this generated waste. They contribute 72.5% of the waste generated in the country against the other 3955 urban centers producing only 17.5% of the total waste. **Table 1** shows waste generation in urban centers in India.

In many metropolitan areas in developing countries, government and local authorities are responsible for the management of the MSW system from the initial point of collection to final processing, but most organizations fail to provide good service, due to several reasons (Kassim and Ali, 2006).

Table 1. Waste generation in urban centers in India

Num.	Type of cities	Tonnes/day	% of total garbage
1	07 mega cities	21,100	18.8
2	28 metro cities	19,643	17.1
3	388 class I cities	42,635	37.1
4	3955 urban centers	20,125	17.5

Source: MOUD Report (2005)

The current practice of municipal solid waste management (MSWM) in all urban centers of the country is biased towards achieving 100% collection and its subsequent disposal, with partial or no treatment/ processing. Thus, open cycle for waste management is being adopted unlike the waste management techniques present in nature (closed cycles). To achieve the objective of sustainable development, there is therefore, an urgent need to shift the paradigm from open cycle to closed cycle of waste management to achieve the following: (i) to reduce the fast depletion of natural resources, (ii) reduce the environmental stress caused by various elements of solid waste management (SWM), (iii) to promote public health and avoid economic losses due to poor health on account of pollution caused by various SWM practices.

Integrated solid waste management (ISWM) is the most widely accepted and practiced concept for the management of solid wastes (Tchobanoglous *et al*., 1993; Kreith, 1994; CPHEEO, 2000). The Waste Hierarchy is a key element of ISWM and is widely applied in industrialized countries. It is based on environmental principles and shown in **Fig. 1**.

This hierarchy is an open system and faces a lot of criticism. Some country try to minimize the waste and some country give emphasis to manage the waste in useful ways, Recently, it has given more emphasis for reducing waste i.e. ‘‘Zero waste’’ concept, which was

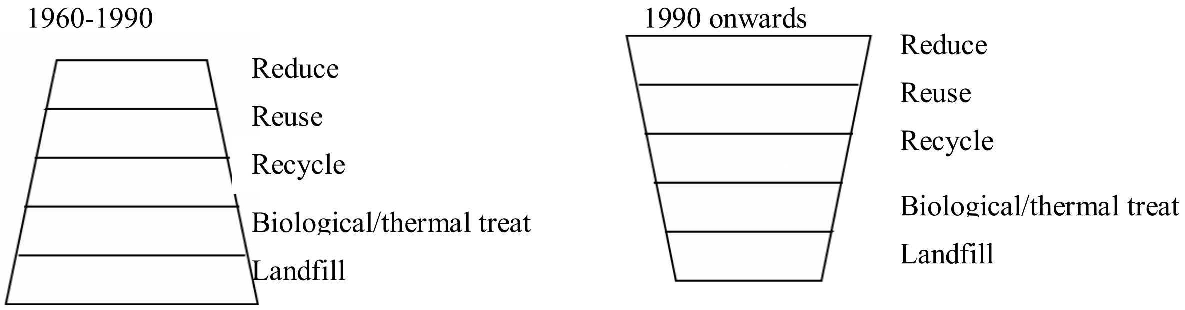

Fig. 1 Change in Waste Management Strategy over the years.

started at Canberra, Australia, and aims to eliminate rather than ''manage'' waste; it is a whole system approach that aims for a massive change in the way materials flow through society–resulting in NO WASTE and is both an end of pipe solution, which encourages waste diversion through recycling and resource recovery, and a guiding design philosophy for eliminating waste at source and at all points down the supply chain (ACT Government, 1996). Developed countries like US, Japan and Western Europe have attempted to manage the solid wastes generated in a more comprehensive manner unlike most of the developing nations. A remarkable change is observed in strategies adopted by these countries over the years as presented in **Fig. 1**. However, in most of Indian cities, solid wastes have not been properly managed in order to follow the said hierarchy.

Solid waste composition (physical and chemical) plays a critical role in solid waste management systems. For example, the physical composition of solid wastes is important for the selection and operation of equipment and facilities, for assessing the feasibility of resources and energy recovery and for the analysis and design of disposal facilities. Its chemical composition is utilized in determining the fuel value as well as in evaluating various alternative processing and recovery options. Due to the shortage of available land for disposal, many communities have been forced to consider recycling and resource recovery options.

In this paper, an attempt has been made to characterize the solid wastes generated from Guwahati's municipal corporation area in detail and its potential to generate power has been studied. Guwahati is largest city in North-East part of the India and is among the first 100 fastest growing city in the world, lying at latitude 26° 11' North and longitude 91° 44' East (**Fig. 2**). Its climate overall is cool and dry, and the mean air temperature is 24°C with a mean maximum and minimum of 42° and 5° C, respectively, and annual precipitation of 1800 mm. Its 296 km^2 territory comprises 60 wards. According to the latest census conducted in 2011, it has a population of 1.8 million with 3.2 lakhs households. The average population density in this metropolis is about 6047 inhabitants per km^2 (Census of India 2011).

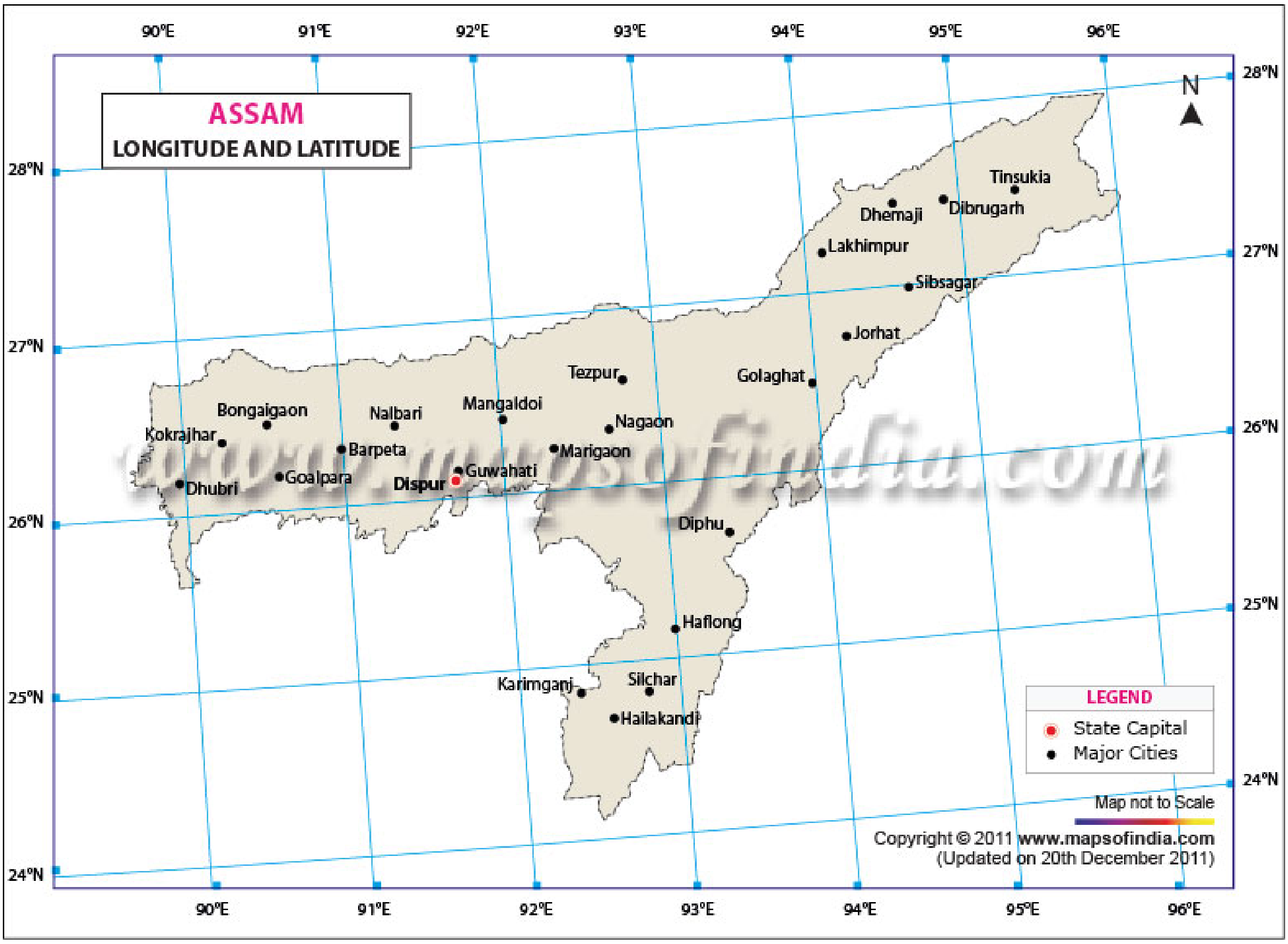

Fig. 2 Geographical location of Guwahati city with latitude and longitude (*source: mapsofindia.com*).

METHODOLOGY

Sample Collection

At the outset, extensive literature study has been done on the available and employed methods for SWM. Subsequently, information about general information on waste management was collected from various government reports and Guwahati Municipal Corporation. Field studies were conducted by the Authors to understand the various issues regarding collection, transportation and disposal of municipal waste. Survey research method is employed to collect data at the household level. The city is sub-divided into six zones for administrative purpose. All the six zones have their own special features. These six sub-divisions together have 60 wards. An attempt was made to select households from selected wards from all six zones.

Purposive sampling technique has been employed for the selection of 34 wards. Ward wise list of households were obtained from the Municipal Corporation and simple random sampling technique was employed for the selection of 340 households from the selected wards.

SAMPLE ANALYSIS

Proximity Analysis

The proximity analysis of the waste samples was conducted to evaluate the different parameters of the waste. This analysis indicates the behavior of MSW when it is heated. Moisture content was determined by keeping 1 gm sample at a temperature of about 105°C (which is above the boiling temperature of water/moisture) for a period of one hour. The loss in weight of sample gave the moisture contents.

When 1 gm MSW sample was placed in a covered platinum crucible and heated to 950°C (which is above the combustion temperature of organic components) and maintained at that temperature for about 7 minutes. There was a loss in weight due to elimination of moisture and volatile matter (VM). The later was determined since moisture has been calculated from previous test. Volatile mater consists of Hydrogen, and certain hydrogen-carbon compounds which are helpful for ignition, the amount of volatile indicates whether the fuel will burn with short or long flame, but too much volatile produce higher smoke. Remaining matter is fixed carbon (FC) and ash percentage. So the proximate analysis gives:

$$M+VM+FC+Ash=100\% \text{ by mass} \quad (1)$$

Ultimate analysis

The ultimate analysis of MSW component typically involves the determination of percentage of C (carbon), H (hydrogen), O (oxygen), N (nitrogen) and S (sulfur) etc. The results of ultimate analysis are used to characterize the chemical analysis. They are also used to define the proper mix of waste materials to achieve suitable C/N ratio for biological conversion processes. This is done by Vermicompost Kits.

Energy Content Test

Energy content of MSW was determined by using laboratory Bomb calorimeter (Model C 4000 A, Make: IKA, shown in **Fig. 3**). An accurate weighed amount of the substance was enclosed in pressure vessel. The substance was put into contact with ignition device. This substance was offered an excess supply of oxygen to achieve complete combustion. Therefore, after closing the bomb, it is filled with 30 bar pure oxygen. The bomb was then filled with water, into which protrudes a highly accurate thermometer. Moreover water was permanently stirred so as to avoid local temperature difference. The sample was ignited and passed it to the bomb and to the water.

The heat of combustion produced increases the temperature of the calorimeter system. After10/15 minutes of ignition the heat exchange between the calorimeter and the water surrounding it in the inner vessel completed. The temperature rise was then measured and served to calculate the gross calorific value (Ho). After knowing heat capacity C of adiabatic system by burning a reference fuel (benzoic acid), 'Ho' of any substance can be calculated.

Heat capacity

The heat capacity C of the calorimeter system is the amount of heat which is required to raise the temperature of measuring system.

$$C = \{(H_{OB} \text{ x } M_R) + Q_F\}/\Delta t \quad \text{(J/K)} \quad (2)$$

Fig. 3 Photograph of Bomb Calorimeter used in the study.

Table 2. Generators of waste and type of waste

Num.	Sources	Types of waste
1	Households and institutions	Mostly organic with some plastics, glass, metals, inert materials and hazardous waste
2	Schools	Mostly papers
3	Vegetable/fruit markets, restaurants, etc.	Mostly organic
4	Commercial centers	Mostly paper and plastics
5	Healthcare facilities	Infectious and non-infectious waste
6	Industries	Leather wastes, metals, plastics, etc.
7	Slaughterhouses	Bones, blood, intestines, carcasses, etc.
8	Animal husbandry and diaries	Dung and used straw, kanaa (used to feed pigs)
9	Wastewater treatment plants	Chromium-rich toxic wastes

where H_{OB} = Gross calorific value of standard substance (J/gm), M_R = Mass of reference fuel (benzoic acid) weighed in air (gm), Q_F = sum of all extraneous heat (J), Δt = Temperature increases measured in the calorie-meter system (°K).

Gross Calorific Value (Ho)

The gross calorific value is the quantity of heat released on complete combustion of the MSW sample.

$$Ho = \{(C \times \Delta t) - Q_F\}/Ms. \text{ (J/gm)} \quad (3)$$

where C = Heat capacity of the calorimeter system (J/K), Δt = measured temperature difference (°K), Q_F = sum of all extraneous energies (J), and Ms =Mass of sample (gm).

RESULTS AND DISCUSSION

Generations of urban solid waste

When municipal solid wastes are discharged into containers without any separation, the result is a mix having a complex physical composition making treatment more difficult. The knowledge of MSW physical composition and evolution is crucial to planning the methods and technologies to be applied as treatment. It is a prerequisite to any waste management plan to have adequate knowledge of the generators of waste, its physical and chemical characteristics. The major generators and types of waste generated in the study area are given in **Table 2**.

Characteristics of urban solid waste

To analyze the physical and chemical composition of wastes in Guwahati city, wastes generated from different sources, such as, different income-groups, commercial waste, waste from industries, waste from vegetable markets, collection depots and disposal site have been considered. The average generation rate of MSW was 0.7 kg/capita/day. **Tables 3** and **4** illustrate characteristics of waste samples collected from various sources. It has also been observed that the average density of municipal wastes in the city is 673 kg/m^3 based on the 10 samples collected from various generation points. This average density is very high compared to that in other Indian cities of comparable size whose average waste density is 425 kg/m^3 (MOUDPA, 2000). The possible reasons of this wide variation in density of wastes might be due to the small sample size, and secondly due to the higher amount of cow dung, wet waste and inert materials in the rubbish depots at the time of sampling.

Figure 4 shows a typical example representing the MSW physical composition for a mixed area. In both cases (**Table 2** and **Fig. 4**), the figures indicated represent the percentage (dry weight) of mixed collected waste, which excludes the materials collected separately. The comparison between the different physical waste compositions is not always an easy task because different analysis are performed by different sample gathering methods and different procedures to analyze the waste may be adopted.

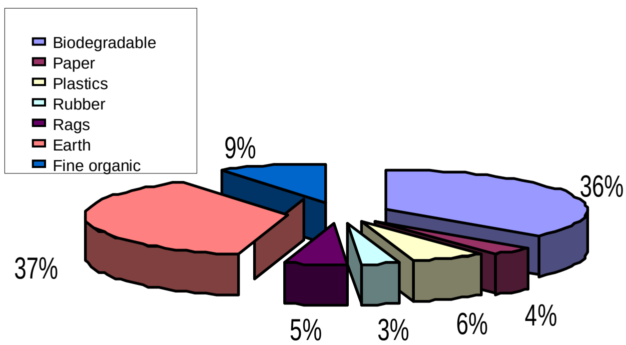

Fig. 4 Physical composition of MSW in an urban region (weight percentage on dry basis).

Table 3. Physical analysis of Guwahati city refuses (in %)

Types of Waste	Biodegradable	Paper	Plastics	Plastics	Rags	Earth	Others
Mixed	36.0	12.6	16.1	3.1	5.1	17.5	9.6
HIG	29.0	15.8	14.2	7.9	10.6	16.3	6.2
MIG	28.0	13.8	15.1	7.1	9.0	17.2	9.8
LIG	29.3	12.6	14.2	5.6	8.3	19.4	10.6
Veg. Market	44.9	13.7	6.2	2.7	5.1	12.8	14.6
Industrial Area	18.6	15.1	15.4	12.5	17.6	15.1	5.7
Disposal site	28.7	6.8	14.1	7.1	8.0	31.4	3.9

Table 4. Chemical analysis of Guwahati city refuses

Types of Waste	pH	C/N	Moisture (%)	Volatile matter (%)	Organic carbon (%)	Nitrogen (%)
Mixed	6.65	31.0	40.2	26.9	18.6	0.6
HIG	6.62	35.0	38.0	35.0	21.5	0.65
MIG	6.69	38.0	40.1	28.3	19.0	0.5
LIG	7.1	31.2	44.0	27.0	12.0	0.4
Veg. Market	6.66	34.6	61.2	21.2	12.1	0.4
Industrial Area	7.5	33.2	23.8	52.0	16.6	0.55
Disposal site	6.8	34.9	35.5	31.1	12.2	0.30

Table 5. Calorific Value of Guwahati city refuse

Types of Waste	Calorific Value (kJ/kg)
Mixed	5,017.28
HIG	8,116.12
MIG	6,715.29
LIG	5,437.26
Veg. Market	4,495.20
Industrial Area	8,221.20
Disposal site	4,937.21

Energy potential

Table 5 shows the calorific value of Guwahati city refuse which has potential to generate power of 26.5 MW considering the population of city as per 2011 census. However in fact city has the capacity to generate power around 30 MW, as the population of city at present has been increased 10% in the mean time.

Biological waste treatment

For biological waste treatment like composting, the desirable range of C/N ratio is 30 and moisture content is more than 50%. **Table 4** shows the C/N ratio and moisture contents of different type solid waste. Among these, waste collected from vegetable market is more suitable for composting. There is also some other biological waste treatment like bio-methanon. For such treatment, desirable C/N ratio is in between 25 to 30 and should be volatile. Some of the waste satisfying these criteria can be used for such treatment.

CONCLUSIONS

The volume of solid waste generation of Guwahati city is being increased day by day due its population growth and economic development. The city has the potential to generate approximately 30 MW power from the solid wastes. There is also some other utilization of solid waste like composting or generation of bio-methanon according to their chemical and physical properties. By converting its wastes into wealth, it shall enhance social, economic and environmental efficiency, and promotes sustainable development. The world has already recognized environmental protection-related industries as a key economic growth point in every field (Suocheng *et al.*, 2001). The efficient and effective solid waste management approach can give an opportunity for better and healthier urban life in the highly populated city.

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