Disposal options for solid waste of Bangalore city based on its characteristics

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Abstract: A detailed analysis of Bangalore's solid waste has been done to suggest various management options for safe disposal. It has been observed that Bangalore's solid waste contains a larger proportion of degradable waste compared to many other cities. Based on detailed analysis of available data, it has been suggested that a landfill with a leachate and gas collection system is better than an inert landfill for Bangalore. Further, separation of degradable waste with an inert landfill is another option, but at the moment, the former option is preferred, for technical and economical reasons.

Keywords: solid waste; landfill; leachate; gas collection.

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1 Introduction

Solid waste management is a very complex and common problem in both developing and developed countries. Improper waste management can generally lead to transmission of illnesses, direct risks to those who come into contact with garbage, indirect risks of proliferation of animals that are carriers of micro-organisms, aesthetic deterioration, degradation of the natural landscape and water, soil and air pollution. In integrated solid waste management, priority is given to reuse of waste after proper segregation and separation. After separation of paper, glass, metals etc., the degradable waste is composted or sent to a landfill with a gas abstraction system. The rest of the inert waste is landfilled. The characteristics of waste play an important role in the selection.

Environmentally safe and economically viable options for disposal of solid waste are a challenging task for any city and Bangalore city is no exception. Over the years, Bangalore city has grown significantly, both in population and in density, which has resulted in great pressures being exerted on the resources of the city, which in turn has contributed to exponential increases in the generation of solid wastes. Solid waste includes garbage, ashes, rubbish, dust, etc., The characteristics of solid wastes produced in any city depend on the type of the city, its population, living standards of the residents and degree of commercialisation, industrialisation and various activates prevailing in that city and hence, changing with time. The adopted methods of refuse disposal normally vary, but the most common methods include reuse, composting, incineration, sanitary landfilling, etc. Reuse of segregated waste is very important and is applied for some constituents if available in sufficient quantity. Composting of refuse is by biological degradation by aerobic decomposition. Gasification is by anaerobic process to extract the methane gas and use it advantageously. Incineration is neither economically viable nor desirable for municipal solid waste, as it may cause air pollution. The selection of any particular option or combination of options depends on the characteristics of waste, climate and economy. At present, Bangalore city's Municipal Solid Waste Management (MSWM) does not have proper planning with regard to the quality and quantity of the solid waste generated; work is carried out based on historical practices. In this paper, an attempt has been to study the characteristics of the solid waste of Bangalore city and suggest a viable scheme for its scientific disposal, keeping in mind not only the characteristics of the present scenario, but also future trends.

1.1 Bangalore solid waste and quantity and characteristics

The city of Bangalore (12.97°N and 77.56°E), the state capital of Karnataka, is located on the southern part of the Deccan Plateau, at the border of two other South Indian states, Tamil Nadu and Andhra Pradesh. At an elevation of 900 m, it is known for its mild, salubrious climate. Since the 1980s, Bangalore has enjoyed the reputation of being one of the fastest growing cities in Asia (Dittrich, 2004). The Bangalore metropolitan area covers an area of 223 sq km and is the fifth largest city in India. However, with a burgeoning population and the increasing necessities of the Information Technology (IT) sector, the local authorities are struggling to provide proper solid waste management at a satisfactory level. Recently, the authorities have taken initiatives and measures to organise the MSWM sector. The present paper would help to identify techniques suitable for the present scenario, the lacunae or the loopholes in the adopted methods and the possible alternatives.

1.2 Present scenario

Presently, the BBMP, the agency vested with responsibility of disposal of solid waste, is engaged in various efforts to provide an effective Solid Waste Management (SWM) system for the city, incorporating a series of approaches such as citizen involvement, investment in appropriate infrastructure and technology, as well as monitoring of the various systems that are at this time managing the present mix of actors and techniques. For a more effective and efficient approach, the city has been divided into different administrative units, the smallest of which is the health ward. Currently, there are 294 health wards within the Bruhat Bengaluru Mahanagara Palike (BBMP) structure. Two to three health wards form a political ward, which represents the basic unit of administration. Presently, there are 100 such administrative or political wards in Bangalore. In addition to this, two to four wards form an intermediate unit called a range. There are currently 30 ranges within the city, which in turn are grouped into 3 zones – south, east and west.

Within the BBMP, there are two departments which are directly involved in solid waste management, the Health Department and the Engineering Department. The Health Department is primarily responsible for collection, transportation and disposal of municipal waste. The Engineering Department of BBMP is responsible for the removal of construction and demolition waste and also provides technical and infrastructural support to the health department.

2 Waste generation

2.1 Identifying and quantifying of household hazardous waste (HHW)

A survey (IUEIP, 1999) of municipal solid waste revealed that approximately 1,500 tonnes of municipal solid waste, excluding industrial waste and construction/demolition waste, is produced each day in Bangalore city and is estimated to be about 4,500 MT/day by 2006. This equated to an average waste generation rate per capita of 0.27 kg/day. Municipal waste generation by source is presented in Table 1.

Table 1 Sources of municipal waste generated in Bangalore (2006)

Source	*Quantity* (t/day)	*Composition, %* (by weight)
Residential	780	54
Markets	210	14
Hotels and restaurants	290	20
Commercial premises	85	6
Slums	20	1
Hospitals	25	2
Street sweepings, parks, open places	40	3

Source: Chanakya and Sharatchandra, 2005

This is mostly due to the occurrence of shift in the usage of recyclable materials namely plastic, paper etc (results of rag picking). Within India, there is a vast difference in physical characteristic of garbage generated by different cities is given in Table 2.

Table 2 Physical characteristics of solid waste from some cities in India (in percentage)

Cities	*Paper*	*Plastic*	*Metal*	*Glass*	*Ash & Earth*	*Total compostable*
Calcutta	3.18	0.65	0.66	0.38	34.00	47.00
Delhi	6.29	0.85	1.21	0.57	36.00	35.00
Chennai	5.90	–	0.70	–	16.35	56.24
Nagpur	1.88	1.35	1.33	1.34	41.42	34.81
Bangalore	4.00	2.00	–	1.00	15.00	78.00
Bombay	10.00	2.00	3.60	0.20	45.60	40.00

As seen in Table 2, most of the cities in India have less than 50% of compostable waste. Unlike other cities, the major constituents of municipal solid waste in Bangalore are organic matter/putrescible waste. Typically, this comprises 74% of the municipal waste stream. The proportion of organic matter/putrescible waste is source-dependent, ranging from approximately 16% of waste from commercial premises to 90% for market waste and street sweeping waste.

A list of necessities was listed in a checklist with regard to the specific target and the presence and absence of each was marked for MSWM auditing. Site survey was done in seven representative sample wards (Shivajinagar, Malleshwaram, Koramangala, Indian Institute of Science campus (IISc), Hindustan Machine Tools colony (HMT), Airport Road and Chickpet). A checklist was prepared prior to the visit to check the presence or absence of techniques used, safety measures adopted, compliance with regulatory measures and the pollution prevention system adopted. Interviews with health inspectors, workers and lorry drivers were done at the ward level. Discussions with range health officers, zonal health officers, the chief health officer and the special commissioner helped in understanding the structure and management of the system, which helped to understand the objectives, strategies, successes and failures of strategies and the issues faced while implementing strategies. The sites surveys and ward level interviews helped to verify the process and to identify the lacunae in each functional element. Site visits to the Karnataka Compost

Development Authority, Terra Firma Biotechnologies, Betahalli dump yard, K.R. Puram dump yard and the quarry site in Bomanahalli were done during the study to understand waste processing and disposal.

Table 3 Physical composition of municipal waste in Bangalore

	Composition (% by weight)						
Waste type	*Residential*	*Commercial*	*Hotels & Restaurants*	*Markets*	*Slums*	*Street sweepings*	*All sources*
Purtrescible	71.5	15.6	76.0	90	29.9	90	72.0
Paper	8.4	54.6	17.0	3	2.5	2	11.6
Plastics	6.9	16.6	2.0	7	1.7	3	6.2
Glass	2.3	0.7	0.2	–	8.4	–	1.4
Metals	0.3	0.4	0.3	–	0.2	–	0.2
Dust and Ash	8.1	8.2	4.0	–	56.7	5	6.5
Cloth, Rags and Rubber	1.3	4.0	0.4	–	0.5	–	1.0
Hazardous	1.2	–	–	–	–	–	0.9

Source: Tide, 2000

Table 4 Physical characteristics of Bangalore MSW

Organic waste (%)	60
Dust (%)	5
Paper (%)	12
Plastic (%)	14
Glass (%)	4
Metal (%)	1
Bio Medical Waste (%)	1
Card Board (%)	1
Rubber (%)	1
Miscellaneous (%)	1

Source: Ramachandra and Shruthi, 2006

2.2 Present methods of handling and disposal of HHW

The waste generated from households is mostly organic in nature, with some recyclable material like paper, plastic, glass, leather, cloth and HHW. Presently, household waste is either put into the community collection bins or dumped along the roadside, or disposed of by burning. The municipal contractors assigned to an area come and collect the waste once a day, or in some cases, once a week. The waste collected will be disposed of on open land in the outskirts of the town/city.

Typically, the Waste Wise Trust collects segregated waste from offices, apartments, institutions, etc., in its own trucks. At the segregation centre 'Land Lab', the waste is sorted – dry waste is recycled, organic waste is composted and used for urban agriculture and gardening, hazardous waste is given to professional dealers and the rest is dumped in landfills. The compost can be used in gardens. Bangalore City Corporation has identified 4 landfill sites – Kannahalli, Medhiagrahara, Gidennhalli and Seegehalli – for land filling.

Problems associated with the present system of waste management: Generally the problem in solid waste management is associated with its quality and quantity as it varies from place to place and depends on the economic standards and life styles of the communities. The following are the major problems associated with the present system of waste management.

Lack of awareness: The major problem to be addressed is lack of awareness among the community. It is because of lack of awareness that people are mixing up hazardous waste and non-hazardous waste at the source itself; this arises from lack of a civil information dissemination system on waste minimisation techniques and procedures.

Lack of infrastructure: In the collection, storage, transportation, processing and disposal procedures, noticeable shortcomings like improper collection and disposal systems, lack of house to house collection systems, inefficient waste collection and handling by staff exist. Other problems relate to improper or no storage at the household level, haphazard dumping by citizens, improper design of community collection bins, no quantification of waste, lack of infrastructure for processing the waste and, finally, absence of scientific disposal sites like engineered landfill facilities.

3 Landfill for Bangalore

3.1 Landfill site location – criteria, capacity and acceptability

For many years, rubbish has simply been dumped into open areas of ground, generally natural pits or hollows. When the site gets full, earth is bulldozed over the top and the area is left to settle, or the landfill is simply left as it is – an eyesore and health hazard. It must be admitted that the last-mentioned practice has fortunately fallen into disuse and today, every effort is made to reclaim the land after use. This is naturally dependant on the settling of the dumped rubbish and reduction of odours, etc.

3.2 Content of a landfill

A landfill is generally used for all types of general household waste, without any attempt at sorting or recycling. As a result, it consists of mixed metals, food scraps and other kitchen waste, paper, plastic and glass. Generally sorting of rubbish mainly content of kitchen scraps, paper and plastic but this will not apply to the older landfill sites.

The organic waste dumped in a landfill site will decompose with time. Assuming a relatively impervious surface below the waste, the waste will become waterlogged and decomposition will be basically anaerobic. This will lead to a production of mostly methane gas from the waste. This methane will slowly work its way up through the waste and be vented into the atmosphere. There will be other gases produced as well, which are generally responsible for the odour level of a landfill site. Should there be efficient draining of the site, then there will be a mixed form of decomposition, anaerobic producing methane and aerobic decomposition producing carbon dioxide.

3.3 *Landfill gas*

As stated above, the main gases produced by a landfill site are methane and carbon dioxide. Methane is a gas that can be burned easily. In fact, it is the main component of natural gas. If a landfill is covered after use, this gas will slowly seep through the earth covering and dissipate into the atmosphere, causing a long-term source of pollution and possible irritation for the local population. Until the landfill site has settled and the gas production has died down, there is no way of reclaiming the land for building purposes, although the planting of trees and grass is possible in the interim. The production of gas will probably continue for around 20–30 years in many cases from a landfill site, with a gradual reduction after about 10 years. A covered landfill will generally tend to anaerobic decomposition, which is usually slower, since it develops less heat. This means that mostly methane will be produced.

During the active life of the landfill site, this will mainly mean ambient monitoring for the methane and carbon dioxide produced by decomposition, together with other factors that cause an odour problem downwind from a landfill site. Borings may now also be taken to discover the activity level in 'older' portions of the waste heap. These borings are the main points of monitoring for 'old' inactive landfill sites. The monitoring will show the amount of methane and carbon dioxide still being produced by the landfill site, together with the internal temperature. These will give indications of when the activity should stop or reach a level that makes land reclamation possible.

3.4 *Factors affecting composition*

The composition of the waste depends on a wide range of factors such as food, food habits, cultural traditions, lifestyles, climate and income, etc. (Deepa et al., 2002; Daskalopoulos et al., 1998) showed that the population and mean living standard of the country are the two main parameters affecting the annual quantity and composition of the Use of Solid Waste (USW) generated. Because USW arises as a direct consequence of human activities, the population of a country has been chosen as the first major parameter determining the quantity of waste generated: the more the people living in a country, the more waste produced, as is clearly seen in Table 5. The mean living standard (refers to the quality and quantity of goods available to the people) of the population of a country is the second major parameter that can be related to the rate of USW generation. It indicates the ability of the population to consume goods and products and, therefore, generate waste.

Table 5 Status of urban solid waste generation in metro cities

City	*Bangalore*	*Kolkata*	*Chennai*	*Delhi*	*Mumbai*
Area (km^2)	226	187	174	1,484	437
Population (Million)	5.31	6.00	5.00	12.20	12.50
USW generation (Tons/day)	2200	3100	3050	6000	6000
USW/capita (kg/d)	0.41	0.52	0.61	0.49	0.48
Garbage pressure t/km^2	9.73	16.55	17.53	4.04	13.71

Source: TEDDY, 2002

3.5 Physical characteristics of USW composition

USW in India can be broadly categorised into organic matter (putrescibles), recyclables and ash material. Of these three, the organic waste component has remained constant over the past few decades at the level of 40% (according to EPTRI, 1995, in India 42.5% was the total compostable matter). The ratio between the other two components has changed in the past few decades and is likely to show further changes in the future (Shuchi et al., 1998). This is mostly due to the occurrence of shift in the usage of recyclable materials, namely, plastic, paper, etc., (results of rag picking). Within India, there is a vast difference in the physical characteristics of garbage generated by different cities, as given in Table 6. Paper is the main source of variation and increases with increase in the population. In the Indian context, paper waste generally falls in the range of 3–7% when the waste reaches the disposal site (Asnani, 1998). The plastic and metal contents are lower than the paper content and do not exceed 1%, except in metropolises. This is mainly due to the fact that large-scale recycling of these constituents takes place in most medium and large cities (as a result of rag picking). The biodegradable fraction is quite high, arising from the practice of using fresh vegetables in India.

Table 6 Physical characteristics of solid waste from some cities in India (in percentage)

Cities	*Paper*	*Plastic*	*Metal*	*Glass*	*Ash & Earth*	*Total compostable*
Calcutta	3.18	0.65	0.66	0.38	34.00	47.00
Delhi	6.29	0.85	1.21	0.57	36.00	35.00
Chennai	5.90	–	0.70	–	16.35	56.24
Nagpur	1.88	1.35	1.33	1.34	41.42	34.81
Bangalore	4.00	2.00	–	1.00	15.00	78.00
Bombay	10.00	2.00	3.6	0.2	45.60	40.00

3.6 Chemical characteristic of waste

Knowledge in chemical composition is essential in selecting proper treatment options for urban waste. Chemical analysis of Indian wastes carried out by NEERI, India and others has shown that total nitrogen varies from 0.56 to 0.71%, phosphorous from 0.52 to 0.82%, potassium from 0.52 to 0.83% and C/N ratio between 21 – 31%.

Hence, calorific value has been found to be ranging between 800 and 1,010 Kcal/kg and density of waste between 330 and 560 kg/m^3.

3.7 Comparison of USW composition with other countries

Comparative physical characteristic of solid waste produced by cities in developed countries versus that found in Indian cities are given in Table 7. This table clearly shows that the quantity of waste produced in developing countries is lesser than that in developed countries.

Unlike in developed countries, the wastes of Indian cities have a high fraction of degradable organic matter, from 35 to 75%. This fraction of garbage has a high energy potential, compared to only 12%–15% in the USA and the UK.

Table 7 Comparative study of waste production (as percentages of total weight) in India and developed countries

Particulars/component	*India*	*UK*	*USA*	*Switzerland*	*Japan*
USW generated (kg/day)	0.3–0.6	0.82	2.5	0.6	1.47*
Putrescible waste (%)	31–67	13.00	15.0	14.5	36.9
Paper (%)	0.25–8.75	50.00	54.5	33.5	24.8
Glass (%)	0.07–1.0	6.00	9.1	8.5	3.3
Rags (%)	0.3–7.3	3.00	2.6	3.0	3.6
Plastics (%)	0.15–0.7	1.00	1.7	2.0	2.2
Carbon/nitrogen ratio, (C:N)	25–40	44.00	50.0	40.9	NA
Density (kg/m^3)	250–500	128.0	NA	NA	NA

NA-not applicable.

**Source*: CPHEEO, 2000

3.8 Power production potential from USW in India

The urban areas of India produce about 30 million t/yr of solid waste Table 8 from household and commercial activities every year. It is estimated that there is a potential of generating about 1000 MW of power , from MSW in India. Table 9 clearly depicts the estimated quantities of different wastes from urban and industrial sectors in the country produced every year (its potential is shown in Table 9). Its Energy Recovery Potential (MWe) is shown in Figure 1. If this potential sector be effectively used, it will not only contribute substantially to the overall power generation capacity but will also give a good return on investment, apart from improving the environment. In addition to this, pollution load on environment is reduced.

Table 8 Different categories of urban, municipal and industrial wastes and their quantities

Wastes	*Estimated quantity*
Municipal solid waste	30 Mt/y
Municipal liquid waste	12000 Mt/y
Food and fruit processing wastes	4.5 Mt/y
Paper and pulp industry wastes	1.6 × 10 3 m 3 /d
Press-mud	9 Mt/y

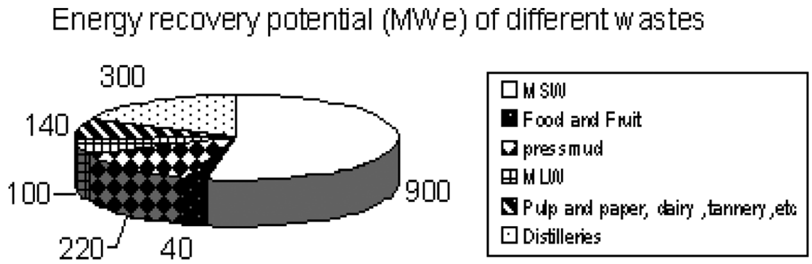
Source: TEDDY, 2002

Table 9 Power generation potential of urban and industrial wastes (MW)

Sources/technology	*Urban and industrial waste*
Units	MW
Potential	1700
Achieved Dec. 2000	15.20
Mar. 2003	25.8

Source: TEDDY, 2002–2003

Figure 1 Energy recovery potential (MW electrical) from urban and industrial sectors



3.9 Future trend

Space is becoming limited and the recycling of waste is finally becoming more common. This will tend to reduce the total amount of waste that is placed in landfill sites, as well as alter its consistency. Metals and plastics will slowly disappear, as will glass and other, easily recycled quantities. The factors that will have the most effect on the use of landfill sites for gas production are probably paper and cardboard. Kitchen wastes will probably still be present, but a lot of the paper, cardboard and wood that support long-term decomposition will no longer be available. The tendency to incineration will also reduce the total number of landfills available.

3.10 Generation rate and future scenario

The quantum of solid waste generated in the country is increasing day by day, on account of its increasing population and changing lifestyles. USW generated in the city increased from 3,200 to 5,355 tpd in this period (2004–2005) - registering a growth of around 67% (CPCB, 2000). On the other hand, the daily per capita waste generated in India, ranging from about 100 g in small towns to 500 g in large towns (NEERI, 2001), also results in the elevation of its quantity at the rate of 1.0–1.33% annually (TEDDY, 2002). A study conducted by the CPCB (2000) in the country estimates that waste generation is expected to increase from 48 Mtpd in 1997 to 300 Mtpd by 2047 (490–945 g per capita). This enormous increase in solid waste generation will have significant impact in terms of the land required for disposing of this waste, as well as on methane emissions. The burden that the increase in waste generation would impose is evident from the fact that the cumulative requirement of land for disposal of USW in India would reach around 169.6 km^2 by 2047, as against 20.2 km^2 in 1997 (CPCB, 2000). Hence, it is very clear that solid waste generation and population growth are highly competitive in the process.

4 Conclusion

Detailed analysis of the composition of municipal waste of different cities has lead to the following conclusions:

- The composition of Bangalore city is different from those of other cities within India.
- It is strongly recommended to go for composting, at least for a major portion which is biodegradable and which can be easily transported to the locations of composting factories.

- The waste originating from areas close to the landfill area can go for a facility having combined composing or landfill with a leachate and gas collection systems.
- Methods can be developed for economical recovery of energy from waste using available technology.

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