



LAKE 2012

LAKE 2012: National Conference on Conservation and Management of Wetland Ecosystems

06th - 09th November 2012



**School of Environmental Sciences
Mahatma Gandhi University, Kottayam, Kerala**

In association with

Energy and Wetlands Research Group, Centre for Ecological Sciences, Indian Institute of Science, Bangalore



Advanced Centre of Environmental Studies and Sustainable Development, Mahatma Gandhi University, Kottayam, Kerala

Waste Management

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Carbon Footprint of Municipal Solid Waste in Greater Bangalore

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Carbon footprint refers to the quantity of carbon emitted from anthropogenic sources. Municipal solid waste plays a significant role in carbon footprint of urban society. Municipal solid waste mainly consists of degradable materials and non-degradable materials. The increasing municipal solid waste generation along with the high fraction of organic waste and its unscientific disposal is leading to emission of methane in the atmosphere. A questionnaire survey was conducted during August-December 2011 which has covered 1967 households in Bangalore city. The survey considered various parameters such as process of collection of waste, time, frequency number of persons involved in waste collection, bin size, distance of bin from house, bin clearance time, transportation of waste landfill site, distance of transportation of waste was investigated and analyzed. The outcome revealed that average household waste generated is in the range of 87.9 gm/per/day to 156.0 gm/per day. Survey reveals that organic fraction constitute about 80% of the waste generated in each zone. This suggests of strong recovery potential and conversion to energy or compost. This paper provides the information on both quantity and composition of residential waste is important to enhance the sustainable solid waste management and planning of household waste treatment and infrastructure.

Keywords: Global warming; Solid waste; Methane; Greater Bangalore.

1.0 INTRODUCTION

Carbon footprint refers to the total amount of carbon dioxide and methane emitted due to the various anthropogenic sources. Methane is regarded as an important source of global warming with the warming potential (GWP) of 25 times greater than that of carbon dioxide and concentration of atmospheric methane is increasing in the range of 1-2% yearly (Sunil et al., 2004; IPCC 1996; Mohammed et al, 2009). Improper management of municipal solid waste constitute a potent GHG and hence plays a significant role in carbon footprint of urban society at local level (Ramachandra and Shwetmala, 2012).

Solid waste generated in municipality is commonly known as garbage consists of degradable and non-degradable waste materials (ex: food scraps, product packaging, grass clippings, furniture, clothing, bottles, paper, appliances) produced in the society by various domestic activities. It comprises similar and dissimilar accumulation of wastes from urban, agricultural, industrial and mineral wastes. Residential solid waste refers to wastes from houses, apartments consists of leftover food, vegetable peel, plastic, clothes, ashes, glass, metal, paper etc., (Ramachandra 2006). The percentage of carbon dioxide and methane varies according to the waste composition, age, quantity, moisture content and ratio of hydrogen/oxygen availability at the time of decomposition, (Arvind et al., 2008). Emission of methane from landfill accounted 3-9% of the anthropogenic source in the world (IPCC, 1996; Sunil 2004).

Rapid urbanization, industrialization, raised standard of living and change in the pattern of consumption, etc. have enhanced the generation of solid waste and its management has become the major problem in municipalities throughout the world (Seo et al., 2004; Issam 2010). The unscientific management and disposal of solid waste in urban cities have resulted in the adverse effects on public health risks (ex: disease vectors,

flies, mosquitoes, roaches, rodents), environment such as air, water and land pollution and unaesthetic appearance. Moreover, Municipal solid waste is a vital source of anthropogenic greenhouse gas (GHG) emissions such as methane (CH₄), biogenic carbon dioxide (CO₂) and non-methane volatile organic compounds (NMVOCs), etc. (Ramachandra 2006; Nguyen Phuc 2010).

MUNICIPAL WASTE MANAGEMENT PRACTICES IN BANGALORE: AN OVERVIEW

Greater Bangalore known as the garden city in early 1970's, is the fifth metropolis city of India (Ramachandra and Uttam, 2010). Population of Bangalore city has increased from 6,537,124 (2001) to 95,88,910 (2011) (<http://censuskarnataka.gov.in>). Bangalore has grown spatially more than ten times (from 69 to 741 sq.kms) since 1949-2007. The city is facing severe shortage of landfills to dump garbage due to the enormous urbanization, affluence, steep increase in the necessity of the Information Technology (IT) sectors and community standard of living. Bruhat Bangalore Mahanagara Palike (BBMP) is responsible for management of solid waste and to set up the targets and objectives in the city. The city has been divided into 30 ranges and 198 revenue wards for administrative purposes including the management of solid waste, health, etc. Further these revenue wards are divided into 294 health wards for the proper management of the sanitation functions. Out of these 113 are managed by BMMP, while 182 wards managed by the private agencies on contract basis (Ramachandra and Shruthi, 2007; Sudhira et al., 2007).

In Bangalore, Municipal solid waste originates from Domestic (55%), Markets (15%), Hotels and eatery (20%), trade and commercial (6%), Slums (1%) and Street sweeping and parks (3%). The composition of the waste generated at the residences level as well as the city level has changed over the last two decades. Table 1 shows the composition of MSW generation of

Bangalore. Residence (household wastes) is the major contributor of the total wastes and it is distinguished by a high content of organic waste (72%). The total Municipal Solid Waste has increased from 650 tpd (1988) to 1450 tpd (2000) and about 3600 (2010) tons per day (tpd) with a per capita generation from 0.16 kg/d (1988) to 0.58 kg/d (2009). Presently, a quasi-centralized collection system is employed in Bangalore. The waste collection system from households (HH) closely follows the Municipal solid waste (handling and management) MSW (H&M) Rules 2000, employing door-to-door collection. In most of residential area the provision of dustbin is removed to avoid the multiple handling of waste (Chanakya et al., 2010; TIDE, 2000).

Components	Composition (% by weight)
Fermentables	72
Paper	11
Miscellaneous	1.9
Glass	1.4
Polythene/plastics	6.2
Metals	1
Dust and sweepings	6.5
Source: Rajabapaiah(1998), Chanakya et al. (2006), Ramachandra (2011)	

Table1. Composition of MSW generation in Bangalore

During the early stages, a large part of the city wastes were sent to a compost plant operated efficiently by KCDC (Karnataka Compost Development Corporation) situated outside the city limits. In late 80's the city was producing about 650tpd of waste and among this, about 100 tpd of market wastes (vegetable) were taken back for direct application on the land and another 150 tpd was handled by KCDC. A large portion of decomposable waste was 'open dumped' along with various arterial roads at outskirts of the city (Rajabapaiah 1988). This trend of open dumping continued till 1999-2000. Today as the wastes

generated has increased drastically, city wastes are being openly dumped at about 60 known dumping sites and many unrecorded sites. Existing solid waste treatment system in the city is not well-organised as composting accounts for 3.14%, but with increase in urban solid waste, the compost plants have not increased. Among these, more than 35 sites possess a mixture of domestic and industrial waste (Lakshmikantha, 2006). Due to the open dumping of large quantum of untreated waste there are serious implications on the land, water and air environment including public health.

The main objective of this study is to assess the CO₂ equivalent emission from the household solid waste. This includes determination of total and per capita waste generation and its composition, in household sector of Bangalore. This has been done through compilation of data by stratified random survey of households using the structured questionnaire. The data collection and analysis at local level helps in understanding the waste dynamics for environmentally sound management of solid waste through planning of appropriate treatment options and its infrastructure.

2.0 STUDY AREA

This study estimated the household solid waste (HSW) generation of the Bangalore city, capital of Karnataka with population of 7 million with an area of 741 km². It comprises of 198 wards. It is located at 12°59' north latitude and 77°57' east longitude more or less equidistant from eastern and western coast of the South Indian peninsula. Altitude of 920 meters above the sea level where as the winter temperature ranges from 12° C– 25° C, while summer temperature ranges from 18° C– 38° C. Mean annual precipitation is 880 mm. Thus the city enjoys the salubrious climate throughout the year (Fig. 1). (Ramachandra and Uttam, 2010; Sudhira et al., 2007).

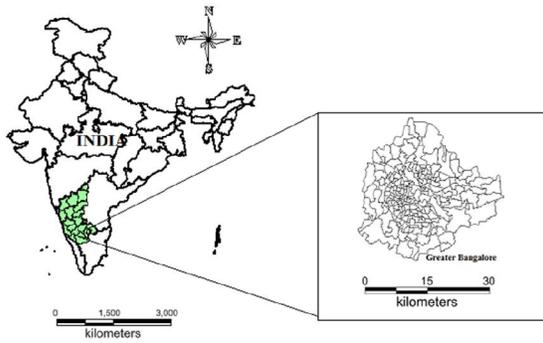


Figure1. Study area: Greater Bangalore

3.0 METHOD

Stratified random survey of households in select wards of Bangalore city through a structured and pre-validated questionnaire was undertaken during August-December 2011. The aim of the questionnaire is to collect information about community attitude towards waste management behaviors (disposal and separation of waste). Figure 2 illustrates the spatial spread of 1967 households covering 138 wards. The survey considered various parameters such as waste

collection, time, frequency, number of persons involved in waste collection, collection time, size of bins, distance of the bin from house, bin clearance time, transportation of waste, landfill site, and distance of transportation of waste. Analysis was done to compute 1) share of biodegradable waste -wardwise, 2) ward-wise per capita waste, 3) GHG emissions – wardwise. In addition, the per capita generation rate from the population and quantity of MSW generated taken into account using equation 1 and methane emission is computed using equation 2.

$$\text{Waste generation (gram/capita/day)} = \frac{\text{Quantity of household waste (gram/day)}}{\text{Population (capita)}} \dots\dots\dots 1$$

The CH₄ emission from the HSW is calculated as below;

$$\text{CO}_2 \text{ equivalent emission} = W * EF \dots\dots\dots 2$$

Where, W is ward-wise organic waste (gram/day); EF is the emission factor (0.016 Gg/Gg of waste for methane and 2.25 Gg/Gg of waste for carbon dioxide).

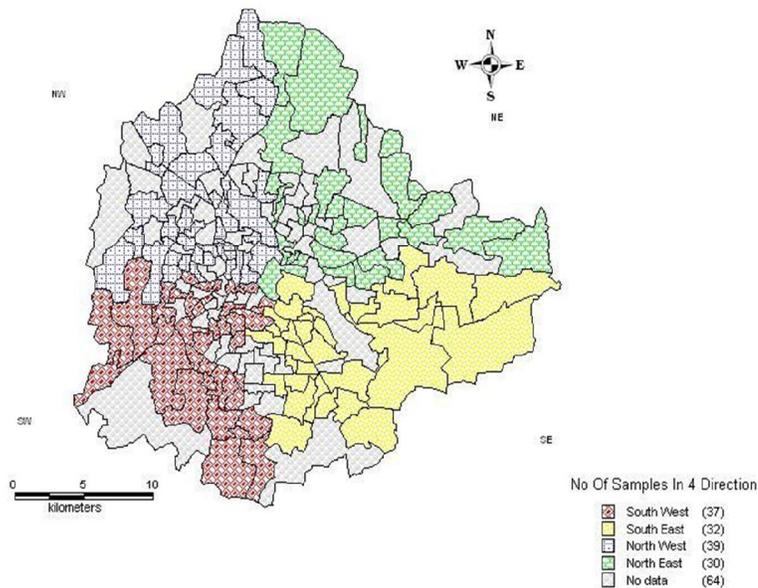


Figure 2: Spatial distribution of samples.

4.0 RESULTS

Figure 3 illustrates that about 64.57% households served have door-to-door waste collection system where as 35.43% uses the community bin. In Bangalore city, door-to-door collection system is most common method of collection of waste which is implemented in 2003, as it is suitable for collection of segregated waste from residential area. Figure 4 depicts the time of waste collection from households. Waste is being collected from the households in the morning time (63.5%) compared to afternoon (0.36%) and evening (1.07%). Frequency of door-to-door waste collection is given in Figure 5. The frequency of collection of wastes varies from place to place, depending on the locality. In majority of the area such as in raja rajeshwari ward, mallechwaram, rajajinagar, jayanagar etc. the waste is collected daily (47%) followed by weekly 4 times (12%), once (3%), thrice (2%) and twice (1%). 35% of the households dispose the waste in the locality bins. Number of persons involved in door-to-door waste collection is represented in Figure 6. In most of the wards 2 persons were involved in collecting the waste (41%) followed by one person (21%) and 35% households have the facility of community bins. Most parts of the city, municipality (90%) in engaged in waste collection (from household) to final dumping sites or transfer stations while Private contractor and NGO's (Swabhimana, Swachha Bangalore, Shuchi Mitras) represents 8% and 2% respectively (Figure 7). The distance of community bin from the houses in the surveyed area are given in Figure 8. The dustbin is within 100 meter in 29% of the surveyed area, while in 13.22% area bin is in the range of 100-500 meter and in the rest the region is served with the door-to-door collection system. Figure 9 reveals the size of bin in surveyed area. Majority of the wards the bin size is 1 m³ (24%) followed by less than 1 m³ bins (12%) and in remaining wards door-to-door collection of waste (54%). The storage bins are of two types; stationary bin and hauled bin. Depending on the

local culture, tradition and attitudes towards waste, bins are allocated to the community.

The segregation of waste carried out at the household level is represented in Figure 10. It reveals that majority of households (78.34%) of the city do not segregate the waste before dumping into dustbin because of lack of awareness and general attitude of public towards segregation of solid waste, only 20% of the total population segregate into organic and inorganic waste or dry and wet waste. Street bin is cleared of litter by the municipality in the locality shown in Figure 11. Bins are cleared weekly in majority of wards (45%), while bins are cleared in 42% wards daily and 13% wards once in 2/3 days. Figures 12 and 13 illustrate the transportation of waste and distance travelled for disposal of waste. About 85% of the city population do not know where the waste is transported, only 15% population were aware about the transportation of waste. Of the total, only in 9% of the wards the waste is transported in the range of 10-100 km. This highlights of poor environment literacy among the residents of Bangalore.

Figure 14 illustrates that of 71% of the region in the surveyed area has no landfill sites, while landfill exists only in 28% at outskirts of the Bangalore. Figure 15 illustrates of zonewise per capita household waste generated. Per capita household waste generated is maximum in South zone accounting to 156.0 gm/per/day followed by Northwest (130.9 gm/per/day), East (127.9 gm/per/day), South west (123.2gm/per/day), South east (116.7gm/per/day), North (113.5 gm/per/day), West (110.3gm/per/day) and North east (87.9 gm/per/day). The variation can be attributed to different lifestyle and food habits of the residents between the zones. The organic fraction is the largest component accounting to 82% as shown in Figure 16. This is followed by paper waste (13%), metal content (2%) and glass waste (1%). Others include dust, batteries, ashes etc. accounts to 2 %.

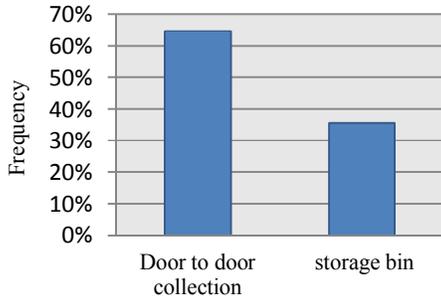


Figure 3: Share of door to door collection

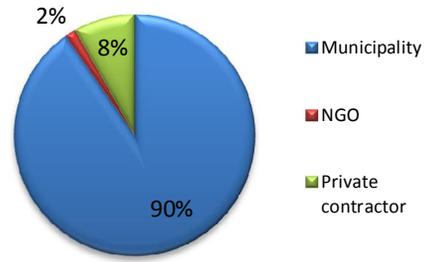


Figure 7: Waste collection

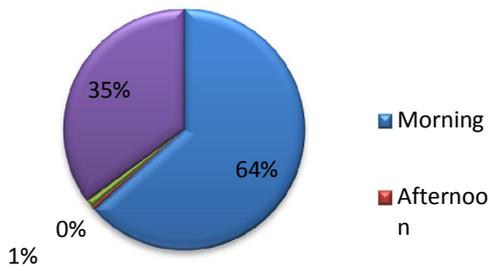


Figure 4: Time of waste collection

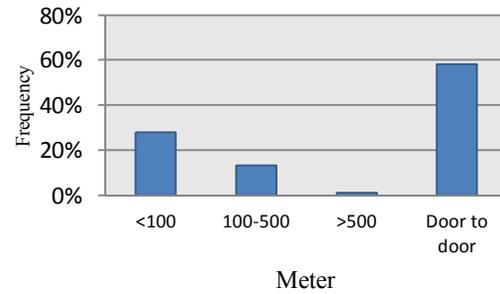


Figure 8: Distance of the community bin from house

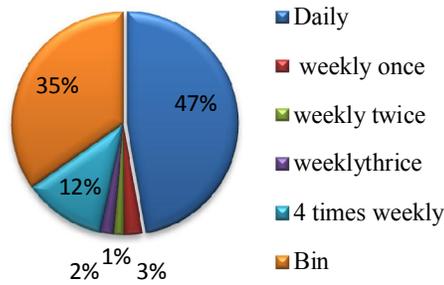


Figure 5: Frequency of waste collection from door-to-door

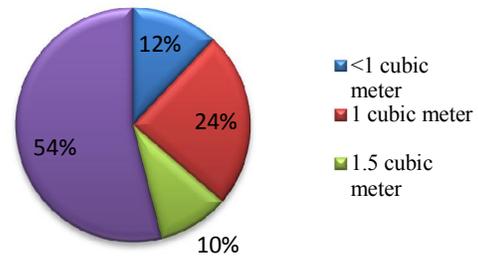


Figure 9: Size of the bin

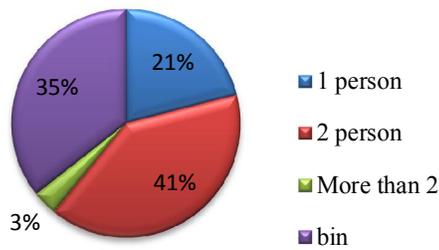


Figure 6: Persons involved in door-to-door collection system

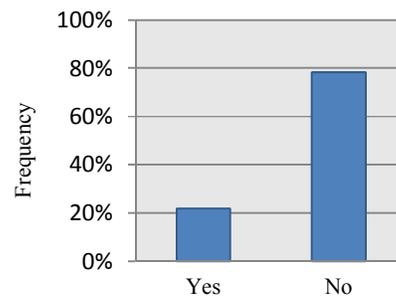


Figure 10: Segregation of waste

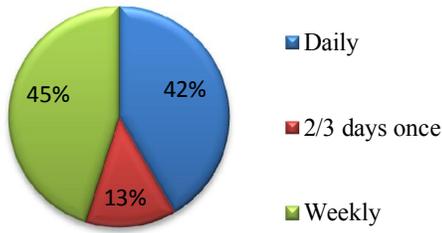


Figure 11: Bin clearance in the locality

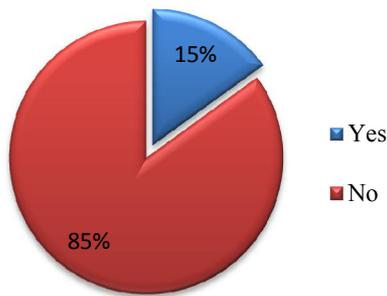
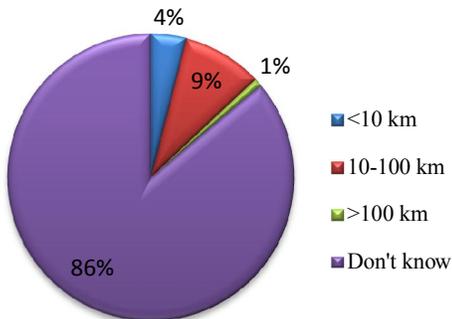


Figure 12: Transportation of waste



Survey shows that total organic waste generated in Bangalore is 192.37 Gg/year. Total (carbon dioxide and methane) emission from municipal solid waste is about 503.64 Gg/year. Figure 17 highlights GHG emissions from all the wards of Bangalore. 76 wards have total emission less than 2 Gg/year, while 11 wards have emission more than 4 Gg/year and 55% of total wards have total emission between 2-4 Gg/year.

Figure 13: Distance of the waste transportation

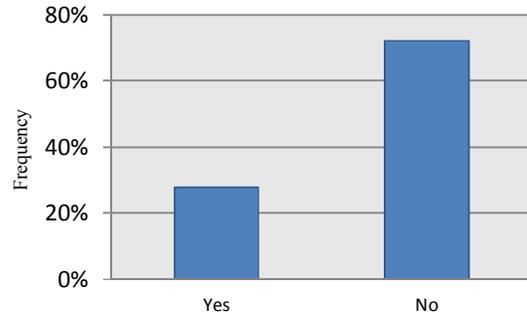


Figure 14: Landfill site in the region

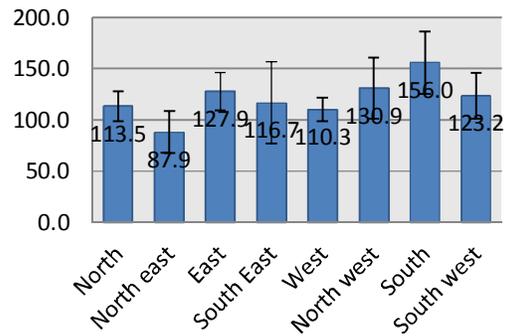


Figure 15: Per capita waste (gram/day)

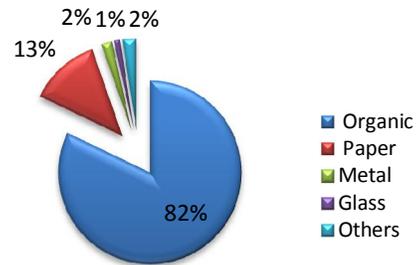


Figure 16: Composition of household waste

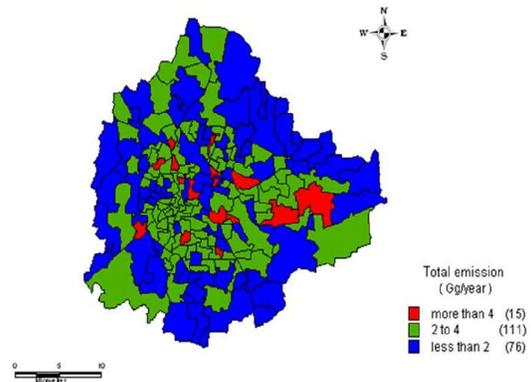


Figure 17: CO₂ equivalent emission from Bangalore.

5.0 CONCLUSION

The per capita household waste generated ranges from 156.0 gm/per/day (South zone) to 87.9 gm/per/day (North east). The variation could be attributed to different consumption pattern of residents between the zones. In majority of the wards the CO₂ equivalent emission is in the range of 2-4Gg/year. Organic fraction (82%) constitute the major component of household waste. This necessitates appropriate treatment options to treat the organic fractions of the waste to reduce GHG emissions. Decentralized treatment options of converting to energy (biogas) or compost (manure) would help in converting the waste to wealth.

ACKNOWLEDGEMENT

We are grateful to Asia-Pacific Network (APN) for Climate Change Research (ARCP2010-15NMY-Han) and the Ministry of Environment and Forests, Government of India and Indian Institute of Science for the financial and infrastructure support.

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