Towards a sustainable waste management system for Bangalore

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Towards a sustainable waste management system for Bangalore

Abstract

Bangalore generates around 3000-4000 t/d of USW and a major constituent (72%) of which is organic waste. Today, primary and secondary collection, and transportation have been reasonably satisfactory to enable the city to remain clean. The existing solid waste treatment system in the city is not very effective. Between the 70s and 90s a significant fraction of the fermentable wastes was composted or used directly in the fields. In spite of rapid growth in USW production over the years, the capacity of compost plants has not increased. Various forms of waste recycling processes are currently functioning in Bangalore (reaching an estimated 67% of total recyclable content). This level is inadequate and it results in the production of non-fermentable wastes to be land-filled. A significant fraction of the total USW is also dumped in about 60 shifting open dump sites and poses environmental problems. The total MSW generated in Bangalore city has increased from 650 t/d (1988) to 1450 t/d (2000) and today it has become 3500 t/d. From 1988 to 2000 there is reasonable change in waste composition: fermentable, paper and plastic has increased by 7%, 3% and 0.2%, respectively. Generation rate has also increased from 0.16 (1988) to 0.58 kg/capita/day (2009) attributable to development and lifestyle changes. There is now a potential to reduce the quantity of wastes transported by adopting source segregation and facilitating decentralized treatment wherever possible. Open dumping is conducive to the generation and release of GHGs, such as methane – having 21 times more GHG potential than CO_2. As we head into a climate conscious society, it is imperative that we plan to reduce the potential GHG emissions from waste management. Our estimates indicate that there is potential for a maximum of 21.84 tCH_4/d and using IPCC default this value is estimated to be 87.32 t/d. Most components of USW incur multiple level of reuse which finally change the carbon content at each stage and offset the final dumpsite level of CO_2 and CH_4 emission estimates. No CH_4 emissions were detected at these dumpsites. A better understanding of processes and underlying factors is required to explain these findings. Conventional approaches have a limited the ability to predict C-cycle changes and resultant GHG emissions. All these pose challenges to the sustainability of Bangalore waste management system: lack of people's participation at various stages, insufficient segregation, inadequate recycling, insufficient commercial incentives for processing fermentable and an absence of a value system for health are possible causes. The paper discusses the potential for decentralized options as possible solutions to overcome this lacuna.

Keywords: Bangalore, Municipal solid waste, Sustainability, Methane.

Introduction

With an estimated population of 6 million, Bangalore is among the largest five cities of India. It generates around 3000-4000 t/d of USW and a major constituent (72%) of which is organic waste. Presently, Bangalore employs a quasi-centralized collection system leading to a predominantly open dumping of collected wastes. Various forms of informal waste recycling processes function in the cities of Karnataka and their value addition has been described (Van Beukering, 1994), However, there are constant changes in the extent recycled prior to dumping because the direct collection from houses provides little chance for itinerant collectors to collect the recyclables. However, when wastes were dumped by households in street bins, this provided a good opportunity for rag-pickers to recover many of the recyclables (Chanakya and Sharatchandra, 2005). Today, much of the recycling is done by waste collectors collecting wastes from individual households and the quantity of waste recovered this way is very small.

Today the waste collection system from house holds closely follows the Hon. Supreme Court Guidelines and MSW (H&M) Rules 2000, employing a range of small powered and non-powered vehicles for direct door-to-door collection of wastes. The extent of wastes collected ranges from 75-90% of the wastes generated. In this way there is a significant level of satisfaction among the users for cleanliness thus achieved, albeit occasional lapses at the local level. The primary collection systems transfer the wastes to large bins that are directly transported by tippers and dumper placer trucks to locations outside the city. During the early stages, a large part of the city wastes were sent to a compost plant situated outside the city limits (KCDC). Although the original machinery set up at this unit failed, it was quickly adapted to Indian conditions and made to work till recently when the city grew to encircle the composting yard itself. When the city produced about 650 tpd (1988), about 100 tpd of market wastes were taken back for direct application on land and another 150 tpd was handled by KCDC (Karnataka Compost Development Corporation). The rest, comprising a large fraction of decomposable was 'open dumped' along various arterial roads leading out the city (Rajabapaiah, 1988). This trend of open dumping had continued till about 1999-2000 where the extent of wastes removed had increased but the proportion of wastes carried out of these arterial roads remained roughly the same (Chanakya and Sharatchandra, 2005; TIDE, 2000). Today as the wastes generated has increased significantly, most wastes are being openly dumped at about 60 known dumping sites and many unrecorded sites. Composting accounts for 3.14%, but with increase of USW, the number of compost plants has not increased. A significant fraction of the total USW is generally dumped in about 60 shifting open dump sites in and around the city. Among these, more than 35 sites possess a mixture of domestic and industrial waste (Lakshmikantha, 2006). The existing solid waste treatment system in the city is therefore not very effective and not sustainable. Attempts have been made to carry out decentralized waste treatment by rapid aerobic composting with some degree of success (Subramanya, 2009, per.

comm.). Simple waste management systems capable of handling between 5-20 tpd corresponding to the output from a single ward (population 30,000) has been tried in a few pockets of the city e.g. Yelahanka. This comprises of a primary segregation system that removes a lot of the recyclables and leaves behind the fermentables that is composted in 50 kg lots. The plastics (LDPE/HDPE) are washed with hot water and sent for recycling. Composting as the main method for rendering acceptable the fermentable fraction of USW, especially in the residential areas, does not yield high throughputs for successful enterprises. Thus considering the operational feasibility having been established for such a decentralized waste system, we propose a more sustainable waste management and processing system based on biomethanation of wastes at the decentralized scale. We attempt to show that this would greatly reduce the costs of SWM at the city level and will pave way for many small entrepreneurs to carry out decentralized processing facilities and be economically, environmentally and socially sustainable.

Changing composition of USW and its impact

The composition of the wastes generated both at the residence levels as well as the city level has changed significantly over the last two decades. Tables 1 and 2 show the municipal solid waste generation and physical composition of Bangalore wastes collected from different types of waste generators. Municipal waste recorded, comprises of wastes generated from residences, markets, hotels and restaurants, commercial premises, slums, street sweepings and parks. Residences contribute 55% of total of wastes, which is highest among all sources (TIDE, 2000). Waste generated from hotels and eateries form about 20%, fruit and vegetable markets contribute about 15%, trade and commerce about 6% and from street sweeping and parks about 3%, . The slum areas contribute only 1% of total, since in Bangalore slum population and area is low in comparison to other city town. Table 2 shows the waste composition of Bangalore comprising: 72% fermentables, 11.6% paper and cardboard, 1.01% cloth, rubber, PVC and leather, 1.43% glass, 6.23% polythene, 0.23% metals and 6.53% of dust and sweeping.

Bangalore's waste is characterized by a high content of fermentable components (72%). These wet and fermentable waste, require daily removal from places of generation. In a decentralized system, wastes gathered from primary collection by handcarts may be subject to immediate treatment by aerobic composting or biomethanation within the locality or ward. This will avoid transportation costs of around Rs1000-1500/t and thus will be more sustainable and economic. In the past a significant component of the wastes placed in open street bins were rapidly sought by rag-pickers who removed the recyclables. The impact of this is presented in Figures 1a, 1b and 2, which show that the percentage of organic waste will quickly increase in MSW from primary collection point to the time it reaches the dump site due to multilevel recovery of recyclable wastes. This also changes the extent of decomposable C of the wastes and presents various forms of environmental implications (Chanakya and Sharatchandra, 2005). As the wastes gradually becomes enriched easily decomposable material, it also becomes easily amenable to anaerobic fermentation processes that convert the carbon to CO_2 and CH_4, the latter being a greenhouse gas of interest. From 1988 to 2000 there is reasonable change in waste composition: fermentable, paper and plastic has increased by 7%, 3% and 0.2%, respectively.

Table 1: MSW generation in Bangalore

Source	Quantity (t/d)	Composition (% by weight)
Domestic	780	55
Markets	210	15
Hotels and eatery	290	20
Trade and commercial	85	6
Slums	20	1
Street sweeping and parks	40	3
Source: Chanakya and Sharatchandra, 2005		

Table 2: Physical composition of MSW in Bangalore

Waste type	Composition (% by weight)						
	Domestic	Markets	Hotels and eatery	Trade and commercial	Slums	Street sweepings and parks	All sources
Fermentable	71.5	90	76	15.6	29.9	90	72
Paper and cardboard	8.39	3	17	56.4	2.49	2	11.6
cloth, rubber, PVC, leather	1.39		0.33	3.95	0.54	0	1.01
Glass	2.29		0.23	0.65	8.43	0	1.43
Polythene/plastics	6.94	7	2	16.6	1.72	3	6.23
Metals	0.29		0.26	0.38	0.23	0	0.23
Dust and sweeping	8.06		4	8.17	56.7	5	6.53
Source: TIDE, 2000							

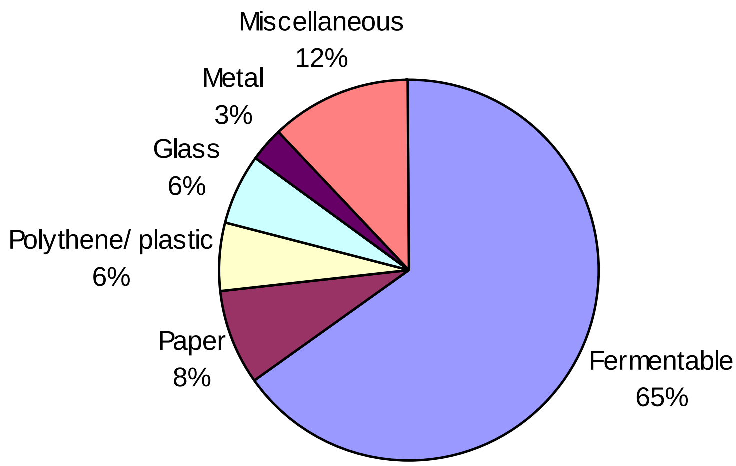

Figure 1a: Composition of USW immediately after being places in bins (Rajabapaiah, 1988)

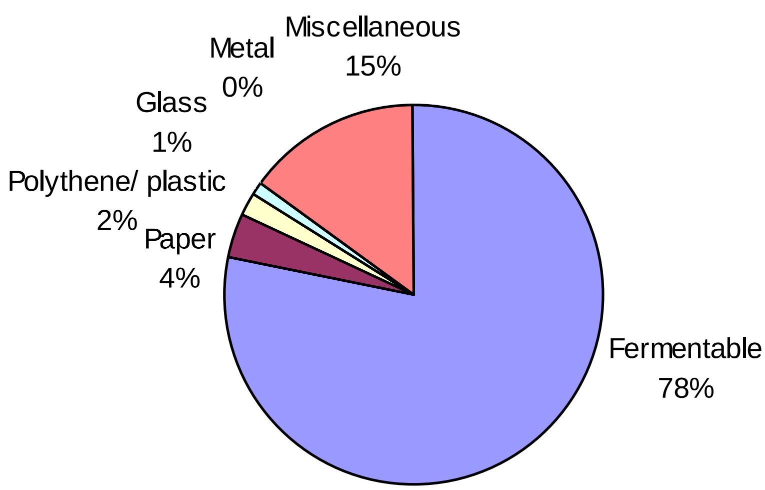

Figure 1b: Composition of USW after ragpickers sort and recycled materials (Rajabapaiah, 1988)

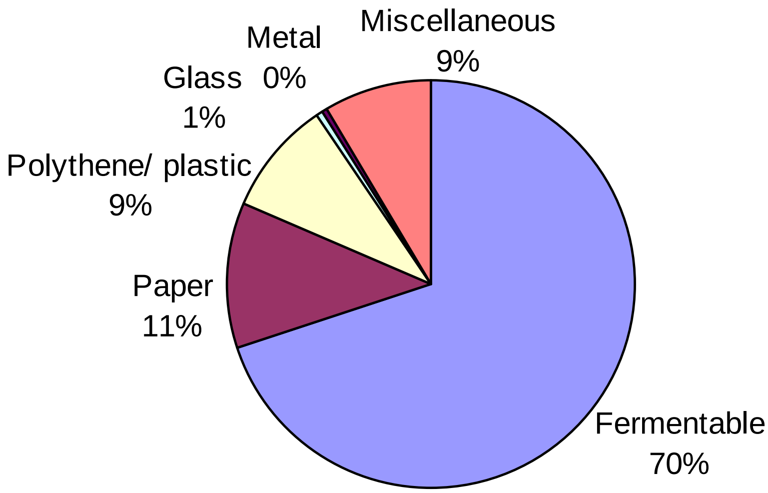

Figure 2: Composition of USW found at the dumpsites (TIDE, 2000)

Changing quantity

Spatial increase in city area and increase in population has increased the total amount of MSW from 650 tpd (1988) to 1450 tpd (2000). With time there is slight change in composition of waste. The current estimates indicate that between 3000 to 4000 tons of MSW is produced each day in the city – the daily collection is estimated at 3600 tpd. This has increased the per capita generation from 0.16 (1988) to 0.58 kg/d (2009). The rapid increase in the USW generation rate has been due to the rapid changes in lifestyles of the residents brought about by the high demands for software professionals and ancillary and support professions. The rapid increase from 1450 in 2000 to 3600 tpd in 2008-09 itself corroborates the above change and rising generation rate. This has brought about problems by the way of safe processing and disposal of USW around Bangalore. In addition, the city has expanded from about 400 km^2 in the 90's to about 800 km^2 of greater Bangalore. This has in the first place brought many of the traditional dumping sites close to the city or within its boundary and therefore a need to find new locations has arisen. The quantum of wastes generated is far greater than the capacity of the three permitted waste treatment and disposal sites, namely, Mavallipura, Bandur and Singehalli. As these locations are quite far-off, many of the trucks illegally dump on new locations on the roadsides and interior areas around Bangalore so as to reduce their transportation costs. The numbers of the shifting dumpsites has thus grown from the original reported 60 (Lakshmikantha, 2006) to much more than this number. There is now a need to determine the new locations where the city wastes are being dumped and assess the economic and environmental harm posed by these short term dumpsites.

Extent of recycling

Bangalore wastes have 21.27% of the recyclable materials: paper, polythene, cloth, rubber, glass and metals. Recyclable materials are one of the major source of income, below in Table 3 we indicate a 1 tpd scale decentralized biomethanation and recyclable recovery system. The results show that recycling of recyclable material of one ton waste will provide income of Rs.1451/t. A decentralized system with biomethanation and resource recovery through recyclable materials is running in Yelahanka.

Table 3: Proposed 1 tpd scale decentralized biomethanation and recyclable recovery system

		Quantity	Recovery (%)	Rate	Rs/ton
INPUT	Capital cost/d	1200 Rs			1200
	O, M&D/d	450 Rs			450
Total input					1650
OUTPUT	Gas output	60 m^3/d	100	900 Rs as gas	900
	Paper	116 kg	50	15 Rs/kg	870
	Cloth, rubber, PVC, leather	10.1 kg	50	12 Rs/kg	61
	Glass	14.3 kg	50	3 Rs/kg	21
	Polythene/plastics	62.3 kg	50	12 Rs/kg	374
	Metals	10 kg	50	25 Rs/kg	125
Total output					2351
NET GAIN					701

Sustainability

Sustainability of a waste management system requires satisfaction of a minimum of three bottomline: Economic, Environmental and Social sustainability. At present, city employs a door to door collection system, where waste is collected directly from households and is not dumped in the street bins as before. This provides little opportunities for conventional ragpickers to receive the recyclables. From the primary collection, the collection personnel recover a few of the easily saleable recyclable materials from where it goes to dumpsite without any segregation or treatment process. At two of the three processing sites, there are frontline segregation units that discard lighter materials and break polythene bags containing domestic wastes. This separates out plastics, rags and fluff, wet fermentables and also heavy materials such as metals, glass, tyres and stones. With such a pre-processing the fermentable content rises significantly. Earlier mentioned composition of MSW shows that it has 72% of fermentable waste, with high moisture content. This situation is conducive to composting or biomethanation. When composting of such high moisture feedstock is attempted by conventional windrow based composting process it generates excessive amount of leachates in the rainy season and its fermentation results in malodors due to inadequate supply of air (Chanakya et al., 2007). So it is important that such wastes are treated rapidly in decentralized units of 5 to 10 t/unit. At this scale of 500-1000 tpd there are few working technologies for Indian USW for biomethanation. It is estimated that one ton of wastes requires about Rs.250 for processing by windrow composting (Basavaiah, 2008 per comm.). As a result a large quantity of wastes are found untreated at these large treatment facilities and it is therefore suggested that, when waste collection is zoned and collected zone-wise, the predominant resident and hotel wastes could be collected separately and treated nearer the site of production by biomethanation within each ward as has been done in the case of Yelahanka trial process with small scale (50 kg) composting. This firstly avoids the need for transportation and thus saves the transportations costs. This has the capability of recovering a large extent of plastics and other recyclables making the overall process more sustainable. The sustainability of such decentralized biomethanation systems is discussed. Small scale biomethanation plants have been in operation in three towns of Karnataka on a trial basis and that in Siraguppa town has been in operation since 2003. At this location there are three 0.5 tpd capacity 3-zone fermenters daily fed a total of 1.5-2.5 t of secondary segregated USW of Sirguppa town. The digested material is then subject to vermi-composting and the recovered vermi-compost is re-used in various town gardens etc.

Economic sustainability: The existing system of waste management requires a net input of revenue for continuous operation. Firstly, there is a need to spend Rs.1000-1500/t for transporting wastes after primary collection to locations where it to be tipped (waste treatment facilities) that are between 40-60 km outside the city. In addition the waste treatment facility charges Rs.600/t (of landfilled USW) as tipping fee. The tipping fee provided is calculated on the basis that 30% of the wastes will be landfilled and consequently 3.3t of input USW will lead to a cost of Rs.600 as tipping fee. This may be simplified to be Rs.200/t of USW brought into the waste treatment facility. This indicates that there is a net input of Rs.1450/t of wastes brought in for treatment at the integrated waste treatment site. There is very little revenue streams arising out of this type of facility and therefore it is considered not economically viable in the long run.

In the proposed decentralized system containing a biomethanation plant and primary segregation and resource recovery system as has been demonstrated in Yelahanka trials (size 5-20 tpd), one ton of USW would result in 60 m^3 of biogas whose value is Rs.900 as fuel gas or Rs. (Table 4). A decentralized system on the other hand would not require any transportation costs. One ton of wastes of the composition indicated earlier has the potential to recover the following at 100% recovery (although 100% recovery is difficult we indicate potential). In Table 3 we have indicated the potential costs and benefits from a 1 tpd scale decentralized biomethanation + recyclable recovery system. The results show that decentralized systems, not accounting for land costs, are more profitable and hence higher in the scale of economic sustainability than centralized large waste treatment systems currently practiced.

Table 4: Proposed decentralized system containing biomethanation plant

Invested capital (M)	1	0.5	Outputs	
Capital recovery /d, 10 yr	300	150	Gas output (m^3/d)	60
Interest (SI, @ 15%)	450	225	RETURNED AS	
O,M&D@10%+5%lbr	450	225	Power (1.5 kWh/m^3)	360
Profit	450	225	As gas	900
			Compost	270
	1650	825	Case 1, power	630
			Case 2, CNG	1170

Environmental sustainability:

Open dumping is conducive to the generation and release of GHGs, such as methane – having 21 times more GHG potential than CO_2 (Morgenstern, 1991). Methane is released when USW is dumped on open grounds with a large quantity of moisture as found in Bangalore USW. However, in this case not all the part of the fermentables are converted to methane. A significant part of it suffers aerobic decomposition due to large spaces within and IPCC default values suggest that about 50% is subject to anaerobic digestion and only that fraction contributes to methane generation. Our estimates indicate that fermentable of Bangalore waste has potential for a maximum of 6.24 kgCH_4/t and using IPCC default this value is estimated to be 24.95 kgCH_4/t. As USW in Bangalore has high moisture content, the IPCC default values need to be corrected for its moisture content to obtain sensible emission data. The key environmental sustainability gained here is by the fact that 6.24 kg of methane is not emitted from USW and consequently a C-footprint of 6.24 kg is reduced. Second, when accountable for such a C-footprint per ton USW, there is a cost avoided for methane not emitted. Third, if these fermentable wastes are used in decentralized manner to generate biogas, 70% of biochemical methane potential (BMP) can be recovered and can be a cheaper source of energy. This avoids the use of an equivalent quantity of fossil fuels in the vicinity. Fourth, the recycling of various components such as plastics, paper, glass and metal would offset various levels of GHG that are produced in the making of this primary product (not estimated in this paper). As we head into a climate conscious society, it is imperative that we plan to reduce the potential GHG emissions from waste management.

Social sustainability:

Decentralized waste treatment will provide livelihood to 2 persons /ton in the energy unit (biomethanation plant) as well as another two persons in the waste recycling unit. When compared to the centralized unit, the decentralized system would employ about 7000 persons daily. The treatment of wastes near the point of generation returns many value added product locally such as gas for use in domestic and commercial uses in the locality, vermi-compost or compost for local uses, recycled plastics for locally useful products including road laying etc. It will greatly increase the trade and social responsibility of wastes in the locality. The exact nature and extent of social sustainability will need to be quantified in a detailed study.

Conclusions

The existing solid waste system in Bangalore city is effective in carrying out the functions of primary collection and transport. However, there has been a significant problem in realizing the large sustainability goals due to the systems heavily relying on centralized waste treatment and disposal system. In fact the current payment mode is conducive to showing at least 30% landfilling fraction in the USW collected. This is not conducive to sustainability as there is no reward for complete recovery of recyclables and fermentables. On the other hand, with some modifications in the way waste is collected, it is possible to run decentralized, ward-wise or smaller systems that are more sustainable (economically, environmentally and socially), and overcome some of the lacunae faced in the centralized systems. Decentralized systems of the future can provide greater sustainability but will require a higher level of waste generation and handling discipline.

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