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Mechanical-Biological Treatment of Mixed Municipal Solid Waste: Two Plants in Bengaluru, India

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Abstract: In recent times, there have been an enormous increase in the number and capacity of mechanical–biological treatment (MBT) plants all over the world owing to the need for finding sustainable solutions to the mixed municipal solid waste (MSW) problem. The objective of this study was to understand the technical and financial aspects of two MBT plants located in Bengaluru, India. Both plants treat mixed MSW. Of the two plants in Bengaluru, only one is financially stable and operating since 1975. The major product generated by this plant is compost. The second one was started in 2015 and closed after a year of operation. It was generating refuse-derived fuel (RdF) and compost. Compost and RdF generated by these MBT plants have limited market acceptance. Major challenges faced by both MBT plants in Bengaluru are untrained human resources, limited market demand for their products, budgetary constraints, inadequate infrastructure and unreliable MSW generation and composition data.

Key words: Recycling, waste generation, waste composition, composting, RdF, vermi-composting.

Introduction

Source segregation of municipal solid wastes (MSW) into biodegradable and non-biodegradable fractions is essential for the success of waste treatment methods such as composting or anaerobic digestion. However, MSWs collected in India and other countries are generally mixed and difficult to treat in their original state. A potential solution to the mixed MSW problem is the use of mechanical-biological treatment (MBT) which has been widely and successfully implemented in developed countries, especially in Europe for solid waste treatment. The concept of MBT originated in Germany, and it was also the first country where such a plant started operating in 1970. As the name suggests, mechanical-biological treatment (MBT) of waste involves a combination of both mechanical and biological methods to treat waste. MBT is ideally suited for mixed waste processing such as household waste as well as household like-commercial and industrial waste and allows sorting of mixed waste into different fractions suitable for different end uses as dictated by market needs (DEFRA, 2013). The sorting component of an MBT facility includes mechanical processes such as shredding, screening, grinding, density and magnetic separation and densification. The biological treatment methods include anaerobic digestion or composting or both methods for treating the organic fraction of mechanically separated MSW. A key advantage of MBT is that the plants can be configured in a variety of ways to attain the required recycling, resource recovery and performance in diverting biodegradable municipal waste from landfilling. Therefore, these plants vary greatly in their complexity and functionality. The objective of this study was to understand the nature of operations of two MBT plants in Bengaluru, India, one operational and the other not functioning.

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Methodology

Two MBT plants in Bengaluru, India were visited in October 2016. The objective of the site visits was to understand how the two MBT plants treat mixed MSW and the different treatment units involved. The visits also helped in understanding the actual waste processing scenarios, waste characteristics, problems faced by the plant authorities and the remedial measures taken. Data for the two MBT plants were collected by interviewing plant staff as well as from the literature and government reports.

Results and Discussion

MBTs are used for treating MSW and can be configured as per waste characteristics and generation of end-products. Potential end-products include material recoveries such as metals, energy recovery in the form of refuse-derived fuel (RdF) and resource recovery as compost or vermicompost. The quality of both RdF and compost will depend on the degree to which non-compostable items are removed in the mechanical separation processes adopted in MBT plants. It is important to understand the present MSWM system in Bengaluru to understand the nature of the MBT plants described here.

Present Waste Management System Scenario in Bengaluru

Bengaluru, the capital of the state of Karnataka, is the fourth largest city in India with a burgeoning population and booming IT industry. Presently, the Bruhat Bengaluru Mahanagara Palike (BBMP) is the administrative body responsible for the collection, transportation, processing and disposal of solid waste. Within BBMP, the department of solid waste management is directly involved in managing Bengaluru's municipal solid waste. For efficient waste management, BBMP has followed a decentralised approach according to which the city is divided into 8 zones, and MSW generated from each zone is collected and processed in the nearest treatment facility.

Waste Generation

Bengaluru has a population of about 8.4 million as per Census 2011 and the city generates about 5680 metric tons/day of municipal solid waste. It has a per capita solid waste generation rate that varies from 0.4-0.6 kg per day and is expected to increase to 0.8 kg/person-day by 2025 (BBMP, 2017). Waste generating sources can be broadly categorised as individual generators and bulk generators. Individual generators are households, street sweeping and community dumping grounds (litter spots) while bulk generators include hotels, restaurants, wedding halls, and other large businesses and institutions. The household population is divided into two categories- regular and slums based on household income and size. Waste generation per household from regular households in the city is about 1.24 kg/day and that from slums is 1.5 kg/day (BBMP, 2018). About 90-95 % of the total waste generated is collected. Out of this collected waste, only 26.4% undergo processing and 33.5 % are disposed at authorised disposal sites. Nearly 1700-2000 tons/day of collected waste is unaccounted and assumed to be dumped on open land. The disparity in waste generation and collection quantities is attributed partly to the recycling activities of the informal sector and partly to inefficiencies in the collection system such as overflowing bins which result in scattering of waste, and bins that are not collected due to accessibility problems.

Collection, Storage and Transportation

MSW generated in Bengaluru is collected primarily in three ways: door-to-door collection, street sweeping and unauthorised small community dumping grounds which are also termed 'black spots' as per BBMP. The present door-to-door collection covers only 50 % of the generated MSW in Bangalore whereas the rest is collected from community dumping grounds or black spots (30%) and streets (20%). The door-to-door collection is done for every residential lane which has around 30-40 households. The primary collection of waste is done by using auto tippers and pushcarts which collect mixed waste only (KSPCB, 2016).

Source segregation is followed only in some parts of the BBMP area (BBMP, 2018). To encourage segregation at source, 188 Dry Waste Collection Centres (DWCC) have been established by BBMP which accept only dry waste from different parts of the city. However, the vehicles allotted for collection have no dedicated compartments for separate collection. Hence, segregated waste gets mixed at the time of collection defeating the very purpose of segregation. Segregation at source is limited to biodegradable and non-biodegradable waste. White canvas bags hang at the edges of the collection vehicle for collecting recyclables whereas the biodegradable (wet) waste goes into the vehicle container. The waste collected by these vehicles is brought to a common point or secondary location from where it is transferred to secondary collection vehicles such as compactors and tipper lorries that carry the waste to the processing facilities or the landfill. Most often waste in these vehicles is transported without an external covering resulting in waste spillage on the roads (BBMP, 2017).

Characteristics and Composition of MSW Waste

Reliable data on the composition and the quantity of MSW generated is necessary for designing an effective management system. In India, MSW differs greatly with regard to its composition when compared to MSW in western countries (Hoornweg & Bhada-Tata, 2012). Waste composition data for of the city Bengaluru are shown in Table 1 (BBMP, 2018), whereas waste characterisation data are presented in Table 2. There is a significant increase in the recyclables fractions (paper, plastics, glass, cardboard) within a span of 10 years while the compostable fractions have reduced significantly.

Table 1: Waste composition data for Bengaluru

		Waste composition	
Components	*Units*	*(BBMP, 2018)*	*(BBMP, 2008)*
Organic waste	%	33	52
Grass, leaves, wood	%	8	6
Paper	%	13	9
Plastics	%	17	12
Glass	%	4	3
Metal	%	1	1
Biomedical waste	%	3	2
Cardboard	%	6	4
Textile	%	6	4
Electronics	%	3	2
Dust, debris	%	6	5
Total	**%**	100	100

Table 2: Waste characterization data for Bengaluru (BBMP, 2008)

Measured parameters	*Units*	*Range*
Carbon	%	13 - 42.6
Nitrogen	%	0.28 - 1.23
Phosphorous (as P_2O_5)	%	0.46 - 0.92
Potassium (as K_2O)	%	0.45 - 1.07
Moisture content	%	13.8 - 40.9
Bulk density	kg/m^3	341 - 491
Calorific value	kcal/kg	684 - 1240

Waste Processing and Disposal

Bengaluru follows a decentralised waste collection and processing system. Based on the stream of waste and its generation, an appropriate treatment method such as composting, bio-methanisation, vermi-composting or RdF generation is selected (BBMP, 2017). Specific fractions and streams of waste such as leaf litter, coconut waste and sanitary waste are treated in separate processing units while mixed MSW continues to be treated in waste processing plants. As per schedule II of the Solid Waste Management Rules (MoEFCC, 2016) in India, every waste facility shall include composting as one of the technologies for processing biodegradable waste.

A total of 11 waste processing plants exist in Bengaluru of which nine are composting-based MBT plants. There is one sanitary landfill in Bengaluru and open dumping is done at several disposal sites. Out of the nine aerobic composting-based MBT plants, two are non-operational. Of the seven operational and two non-functional MBT plants, one in each category is discussed in detail in this paper to understand the reasons and challenges that rendered one of the plants non-operational. A summary of the characteristics of the two MBT plants is presented in Table 3.

Case study 1: Karnataka Compost Development Corporation (KCDC) MBT Processing Plant

KCDC plant was commissioned in 1975 along with 12 other plants in India based on WHO-recommended technology and is the only plant running successfully. The other 12 plants turned non-operational within one year of their establishment because the technology was not suitable for Indian conditions and lacked economic viability. The KCDC plant spans an area of 29 acres with a treatment capacity of 300 tons/day. However, the plant currently processes only 200 tons/day of city waste, agricultural waste and organic market waste and produces around 30 tons/day (15%) of compost (NIUA, 2015). The waste received is aerobically treated by the windrow method of composting and vermicomposting. Photos of the KCDC plant are shown in Figure 1. The process flow diagram of the mechanical and biological treatment sections of the KCDC plant is shown in Figure 2.

Table 3: Comparison between two MBTs in Bengaluru, India

	CMBT, Bengaluru, India	*KCDC, Bengaluru, India*
Established	*2015*	*1975*
Current status	Not operational since 2016. Currently, awaiting BBMP review for reopening	Operational
Area	25 acres	29 acres
Capacity	500 tons/day	500 tons/day
Input waste stream	Mixed MSW	Mixed city waste, organic market waste, agricultural waste
Manual segregation at receiving belt, if any	Manual segregation performed	No manual segregation
Biological treatment	Windrow composting	Vermicomposting and windrow composting
Inoculum added during biological treatment	No	Yes
RdF generation and utilization	Yes, utilized in cement factory	No
Storage capacity	6000 tons	20,000 tons
Odour control	No bio-filters	Bio-filter installed but ineffective
CAPEX	INR 70 crore	INR 41.25 lakhs
Cost of production	-	INR 2700/ton of compost
Gate fees	No	No
Financially sustainable	No	Not self-sustainable (financed by property taxes and government subsidies)
Outputs	Recyclables (ferrous metals) RdF Compost for sale Rejects for landfilling	Recyclables (ferrous metals) Vermicompost Compost for sale Rejects for landfilling
Community awareness and participation	Low	Low

Figure 1: Images of the KCDC plant: (a) MSW receiving area; (b) waste screening through trommel; (c) Windrow composting and (d) Final compost.

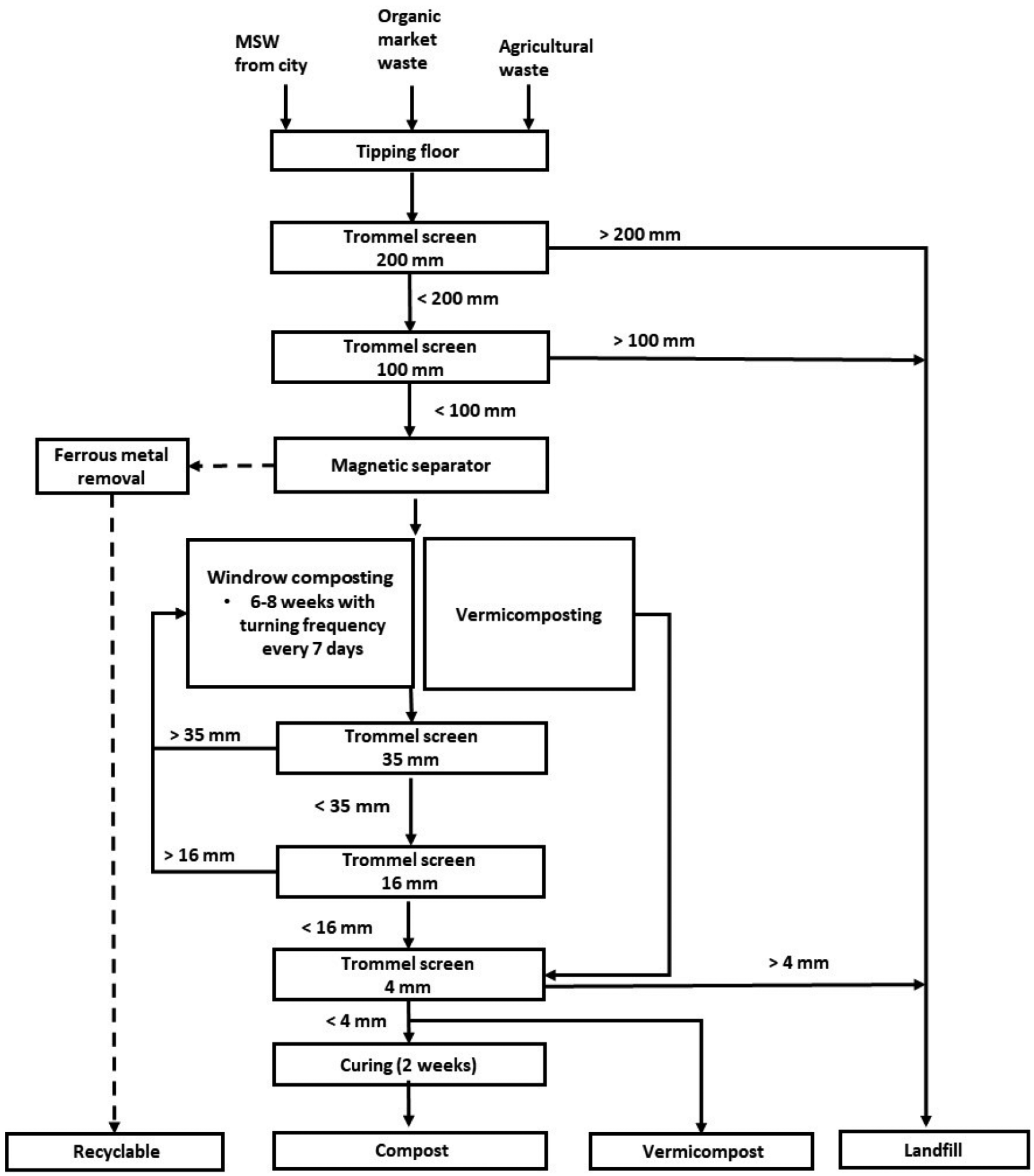

Figure 2: Process flow schematics of the KCDC MBT plant.

Mechanical Treatment

After the collected wastes are received on the tipping floor of the receiving, the wastes are sorted through a series of trommel screens of screen sizes 200 mm and 100 mm. The coarse fraction includes used fabrics, banana fibres, used plastic bottles and containers, stones and inert material and is directly disposed into a small area landfill located within the allotted KCDC area. The fine fraction is then passed through a magnetic separator for the removal of ferrous metals. The metal-free fraction is then taken for windrow composting and vermicomposting.

Biological Treatment

Biological treatment at the KCDC MBT plant is achieved by windrow composting and vermicomposting. To facilitate quicker decomposition in the windrows, an inoculant containing nitrogen-fixing bacteria is sprayed on the mixed waste. Sometimes, cow dung slurry is also sprayed. The windrows are turned every 7 days for proper aeration so that the biodegradation process continues uninterrupted. Water is sprayed as and when required depending on the moisture content. Composting is completed within 7 to 8 weeks and the composted fraction is passed through a series of trommel screens of screen sizes 35 mm, 16 mm and 4 mm. The rejects of 35 mm and 16 mm screen sizes are returned for composting. The rejects (coarse fraction), after 4 mm screening, are directly landfilled and the finer fraction is left for curing for a period of two weeks prior to being sold. As for vermicomposting (organic market and household waste), the composted materials from the vermicompost beds are sieved through a sieve size of 4 mm as a final step and the finer fraction is sold to farmers.

KCDC produces 3 grades of compost: 'city compost' from mixed municipal solid waste; 'vermicompost' from household, market and agricultural waste; and 'AgriGold' which uses mineral (gypsum and rock phosphate) and manure additives. End-products of the KCDC plant are Compost, Vermicompost and Ferrous metals as recyclables.

Financial Costs and Sustainability

KCDC plant was installed with a capital expenditure of INR 41.25 lakhs and is jointly owned by Karnataka Agro Industries Corporation, BBMP and Karnataka State Co-operative Marketing Federation Limited with 52%, 24% and 24% shares, respectively. Operational and maintenance costs include labour, electricity and fuel charges, raw materials, packing materials, additives, administration expenses, taxes, bank charges, contract service charges, and marketing expenses which amount to INR 2,700 per ton of compost produced. KCDC does not charge any gate fees nor does it receive tipping fees from the BBMP. However, the functioning of the plant has not been up to standards. Since it is located amidst a residential locality, its expansion is limited. The plant does not have a leachate treatment facility and the bio-filters for odour control are ineffective. As a result, nearby residents often complain of unbearable stench from the plant, and discharge of leachate into the lake nearby (Kaza et al., 2017).

Case Study 2: Chikkanamangala MBT Waste Processing Plant

Chikkanamangala MBT plant is one of seven newly established plants and was commissioned in November 2015. It has a processing capacity of about 500 tons/day of MSW. The plant received mixed MSW from the city's west and south zones. However, the plant stopped operating a year after it was commissioned and is awaiting BBMP's review for its reopening. The plant received more waste than it could process. Photos of the CMBT plant are shown in Figure 3. The flowchart of the various treatment processes in this plant is more complex than the KCDC plant and is shown in Figure 4.

Figure 3: Images of the CMBT plant: (a) Waste tipping floor; (b) Windrow composting; (c) Waste screening through trommel and (d) RdF storage.

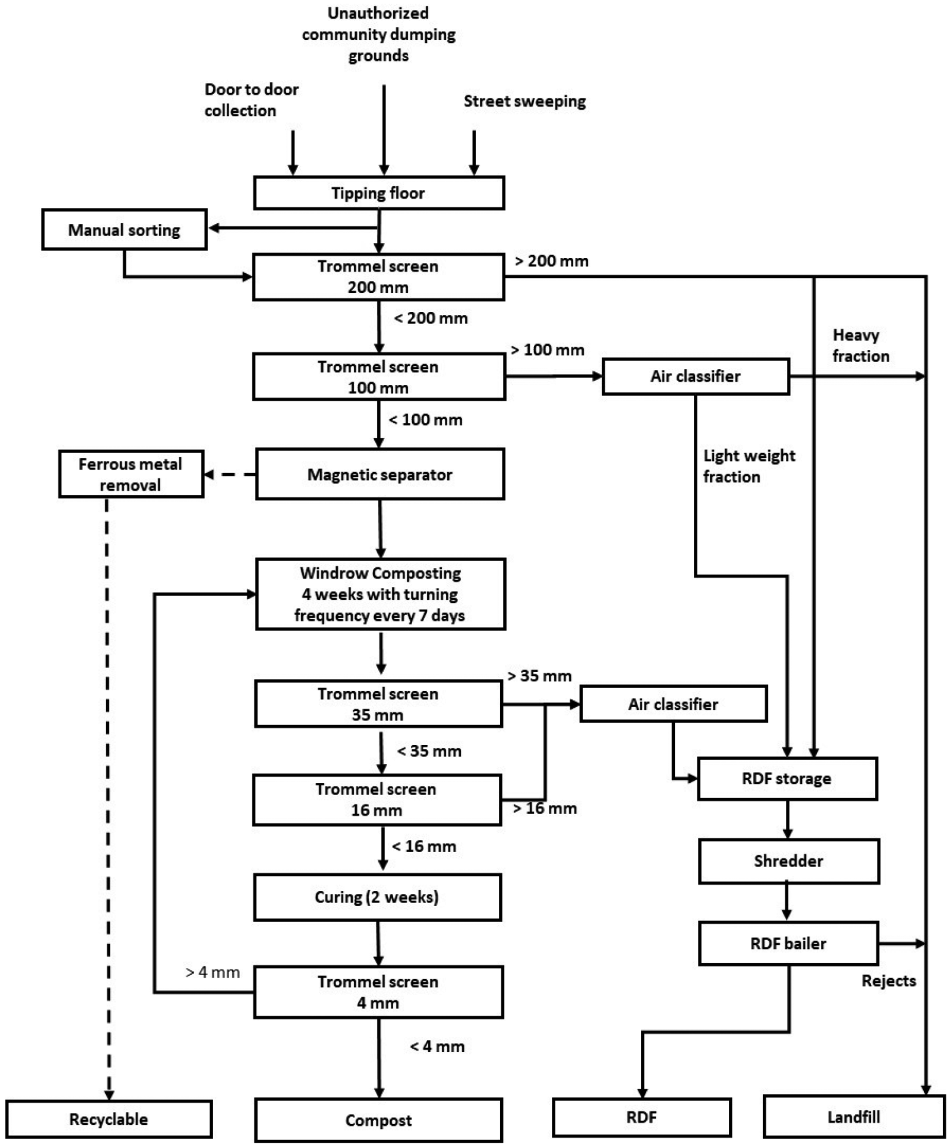

Figure 4: Process flow schematic of the Chikkanamangala MBT plant.

Mechanical Treatment

The Chikkanamangala plant received unsegregated MSW on the tipping floor. Sorting at this stage was done by manual and mechanical means. A parallel conveyor belt was provided for opening bags manually. Input from both mechanical as well as manual sorting was then passed through a trommel screen of mesh size 200 mm. The lighter rejects such as paper, cardboard, plastics and fabrics were collected, shredded and baled as RdF while the remaining (eg., shoes, glass, organics, stones, etc.) were landfilled. The waste (<200 mm) is then passed through a trommel of screen size 100 mm. The rejects from here are separated into light and heavy fractions based on air classification. The lighter non-degradable fraction was baled as RdF and stored while the heavy fraction was taken for disposal. The fraction passing through the 100 mm trommel was subjected to magnetic separation for the removal of ferrous metals. The remaining metal-free fraction was then taken for windrow composting. The rejects of both trommels were subjected to air classification and the lighter fraction was shredded and baled as RDF while the heavier fraction was landfilled.

Biological Treatment

Biological treatment was done by windrow composting. The material in the windrows was composted for about 4 weeks in which it was turned once every 7 days. Water was sprayed on the windrows as and when required to maintain the necessary moisture content. The fine fraction after 16 mm screening was left for curing for a period of 2 weeks to obtain a stable end product. During the curing period, the rate of decomposition slows down and the temperature in the windrows starts approaching an ambient temperature. After the curing period is over, the end product is screened through a mesh size of 4 mm and the finer fraction is packaged. The coarse fraction is taken back for composting again. The final stabilised end product at the end of the curing period was sent to KCDC for sale. End products obtained at the Chikkanamangala plants include compost, high calorific fraction as refuse derived fuel (RdF) and ferrous metals as recyclables.

The Chikkanamangala plant stopped functioning in 2016 due to poor odour control, shortage of labour (only 15 labourers were employed as against a requirement for 124), failure to follow Standard Operating Procedures (SOP), and poor RdF storage and its utilisation.

The RdF produced in the sorting process was stored in the plant occupying most of its working space. This is the case for most other processing plants in Bengaluru. Even after the plant stopped operating, the stored RdF was neither utilised nor disposed off. As a result, about 25,000 tons of RdF were piled up in these plants. The pile-up was mainly because of the absence of any waste-to-energy plants or cement factories under BBMP jurisdiction. The closest cement factory is about 600 km away. Providing RdF to nearby cement kilns would require additional transportation charges to be borne by plant authorities. Piled-up RdF resulted in fire accidents in two MBT plants (Chikkanamangala and Kannahalli plants) which caused major damage to the environment and property. To prevent such problems in the future, Karnataka State Pollution Control Board (KSPCB) has instructed all cement factories in the state to collect and transport RdF at their own cost and utilise it in their kilns for co-processing as part of their commitment under Corporate Social Responsibility (CSR) scheme. So far, 26,000 tons of accumulated RdF from BBMP were taken by the cement kilns in the state and about 4,000 tons were taken by cement plants outside the state (KSPCB, 2016).

Installation Costs

The CMBT plant was installed with a capital expenditure (CAPEX) of INR 70 crores. In order to promote WtE plants in India, BBMP has signed an MoU with the French Company 3 Wayste for setting up a state-of-the-art WtE plant which would include modifying the existing CMBT plant at an estimated cost of INR 250 crore (new capacity of 600 tons). The energy generated from the waste would be sold to the Karnataka Power Corporation at Rs 7.08 per unit (Bangalore Mirror Bureau, 2019).

Recommendations for Proper MBT Plants in India

Major reasons for the failure of the MBT plants include design failure, power failure, lack of manpower and technical expertise and lack of financial resources. To overcome such failures, the following recommendations have been proposed.

1. Regular monitoring of MSW generation rate and composition are necessary for designing effective and sustainable MSWM systems. Region-specific differences can be accounted for only when local data accounting for the geographical, topographical and cultural diversity of the country is available.
2. Regular financial and environmental auditing is necessary to monitor the performance of the plant. A public complaint redressal mechanism is also needed. In addition, waste processing plants in India do not monitor the different fractions after each treatment unit. As a result, there is insufficient data for doing a materials flow analysis for any MBT plant.
3. Rigorous campaigns to promote good waste management practices are needed to increase awareness of rules and should be accompanied by fines for strict implementation of the rules.
4. Public-private partnerships can be effective in managing MSW through integrated plans. They can help ULBs to handle the waste load by undertaking methods to encourage behavioural change and promote source reduction and segregation. The majority of these PPP ventures are revenue-driven and can be financially viable (Mohan et al., 2016).

Conclusions

Two MBT plants in Bengaluru, India are described in this paper, one operational and the other non-operational. Both KCDC and CMBT plants receive mixed waste and despite the challenges faced, KCDC has proved to be economically stable over time. Failures described with regard to the CMBT plant are related to improper use of technology, lack of knowledge and awareness of waste characteristics, lack of technical skills, poor waste storage and its utilisation and inadequate odour control measures. Major challenges faced by MBTs in Bengaluru include lack of awareness and public attitude towards waste generation, untrained human resources, market acceptance for compost and RdF; budgetary constraints and financial failure in revenue generation; inadequate infrastructure and unreliable MSW generation and composition data. Until these fundamental concerns are addressed, MBT facilities will continue to be run poorly and cause adverse impacts on public health and the environment.

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References

Bangalore Mirror Bureau (2019). Bengaluru Civic Issues_ BBMP moves closer to a waste-to-energy plant, seals the deal.

BBMP (2008). Solid Waste Management in Bruhat Bangalore Mahanagara Palike. Bruhat Bangalore Mahanagara Palike, **38**.

BBMP (2017). Bengaluru's SWM Information Manual PART I: Overview.

BBMP (2018). *BBMP-SWM. Waste composition.*

CPCB (2018). Consolidated Annual Report (For the year 2016-2017) on Implemenetation of Solid Waste Management, 2016 (As per provision 24(4) of SWM Rules, New Delhi.

Department of Environment Food and Rural Affairs (DEFRA) (2013). Mechanical biological treatment of municipal solid waste.

Hoornweg, D. and P. Bhada-Tata (2012). What a waste: A global review of solid waste management. Urban Development Series Knowledge Papers. Washington DC, USA. https://doi.org/10.1111/febs.13058

Karnataka State Pollution Control Board (KSPCB) (2016). *Annual report*.

Kaza, S., Yao, L. and A. Stowell (2017). Sustainable financing and policy models for municipal composting. *The World Bank*, 1-124. https://doi.org/10.1596/26286

MoEFCC (2016). Solid Waste Management Rules. New Delhi.

Mohan, G., Sinha, U.K. and M. Lal (2016). Managing of solid waste through public private partnership model. *Procedia Environmental Sciences*, **35:** 158-168. https://doi.org/10.1016/j.proenv.2016.07.066

NIUA (2015). *Swachh Bharat: A monthly newsletter*, **1**.

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