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## **Environmental audit of Municipal Solid Waste Management**

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**Abstract:** The management of municipal solid waste has become an acute problem due to enhanced economic activities and rapid urbanisation. Increased attention has been given by the government in recent years to handle this problem in a safe and hygienic manner. In this regard, Municipal Solid Waste Management (MSWM) environmental audit has been carried out for Bangalore city through the collection of secondary data from government agencies, and interviews with stakeholders and field surveys. Field surveys were carried out in seven wards (representative samples of the city) to understand the practice and identify the lacunae. The MSWM audit that was carried out functional-element-wise in selected wards to understand the efficacy and shortfalls, if any, is discussed in this paper.

**Keywords:** solid waste; environmental auditing; functional elements; composting; landfill sites; municipal solid waste management; MSWM.

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## 1 Introduction

Solid waste generation is a continually growing problem at global, regional and local levels. Solid wastes are those organic and inorganic waste materials produced by various activities of the society, which have lost their value to the first user. Improper disposal of solid wastes pollutes all the vital components of the living environment (i.e., air, land and water) at local and global levels. Urban society rejects and generates solid material regularly due to rapid increase in production and consumption. The problem is more acute in developing nations than in developed nations, as their economic growth as well as urbanisation is more rapid. This necessitates management of solid waste at generation, storage, collection, transfer and transport, processing, and disposal stages in an environmentally sound manner in accordance with the best principles of public health, economics, engineering, conservation, aesthetics and environmental considerations. Thus, solid waste management includes all administrative, financial, legal, planning, and engineering functions (Ramachandra, 2006; Ramachandra and Varghese, 2003).

The environmentally sound management of solid wastes issue had received the attention of international and national policy making bodies and citizens (Subramanian, 2005). At the international level, the awareness regarding waste began in 1992 with the Rio Conference, where efficient handling of waste was made one of the priorities of Agenda 21 (<http://www.un.org/esa/sustdev/agenda21.htm>). The Johannesburg World Summit on Sustainable Development in 2002 focused on initiatives to accelerate the shift to sustainable consumption and production, and the reduction of resource degradation, pollution, and waste (<http://www.un.org/esa/sustdev/csd/aboutCsd.htm>). Priority is being given to waste minimisation, recycle and reuse, followed by the safe disposal of waste to minimise pollution.

The government of India has taken many initiatives and implemented new technologies and methods by giving loans for setting up composting plants to encourage proper management of solid waste since the 1960s (MoEF, 2005). The MSWM problem was compounded with rapid urbanisation. Due to increased public awareness of MSWM, a public litigation was filed in the Supreme Court, which resulted in the Municipal Solid Wastes (Management and Handling) Rules, 2000. Government, for the first time, now has included private organisations in providing this public service (DPCC, 2002). New methods of storage, collection, transportation, processing and disposal are being explored and implemented. It is necessary to evaluate the current process at this stage to understand if the methods being implemented are suitable for the Indian scenario and to identify the lacunae in the adopted methods. This requires an auditing of all functional elements of MSWM, considering the environmental constraints. An environmental audit of MSWM in Bangalore city was undertaken apart from evaluating the Indian MSWM scenario to understand the shortcomings.

Environmental auditing first began with the principle of 'polluters pay', to prevent liabilities towards the government. The companies voluntarily carried out audits of their operations and processes to prove that their products are environment friendly, with the increasing awareness of the public about environmental protection. Waste audits are undertaken for a variety of reasons, which is to

- ensure regulatory compliance
- compare actual practices to best practice guidelines
- develop baseline generation data
- identify waste minimisation opportunities
- establish sustainable development indicators or bench marks (Ashwood et al., 1996).

In general, there are three different approaches for conducting a solid waste audit, namely

- the back end approach, which measures the material generated by the entire facility, i.e., no attempt is made to assess the manner in which the wastes and recyclables are generated within the facility
- the activities approach, which tracks the waste and recyclables as they are generated throughout the facility, by performing waste audits within each activity area, e.g., an office, warehouse, or cafeteria
- the input/output approach, which tracks the material input and output associated with each activity area (CCME, 1996; Dowie et al., 1998).

Environmental audit was introduced in India to minimise generation of wastes and pollution. In this regard, a gazette notification was issued by the Ministry of Environment and Forests on March 13th, 1992 and later amended on April 22nd, 1993. This applies to an industry, operation or process requiring consent to operate under Section 25 of the water (Prevention and Control of Pollution) Act, 1974 or under Section 21 of the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981), or both, or authorisation under the Environmental Protection Act, 1986 (29 of 1986) (Srivastava, 2003). The notification requires that an Environmental Statement for the financial year ending on 31st March be submitted to the concerned State Pollution Control Board, on or before 30th September of the same year.

The improvement of solid waste management is one of the greatest challenges faced by the Indian Government. The Government and the local municipal authorities have taken many initiatives towards the improvement of the current situation (The Expert Committee, 2000). The private sector has been included in the management of the MSW recently. To understand the level of success in the initiatives, it is necessary to carry out an audit. An audit will identify and bring out the lacunae and the loopholes in the current system with respect to the compliance with environmental regulations, occupational health, resource management, pollution prevention systems and occupational health and safety. This could be one of the best ways to increase awareness about the most suitable approaches to MSWM, the issues likely to be faced and the alternative measures that can be adopted, considering the local scenario.

Developed countries have provided technical assistance in SWM to developing countries focusing on SWM as a technical problem with the assumption that the solid waste problem can be solved with mechanisation (Lardinios and van de Klundert, 1997). The 'blind technology transfer' of machinery from developed countries to developing countries and its subsequent failure has brought attention to the need for appropriate technology (Beukering et al., 1999) to suit the conditions in developing countries (type of waste, composition, treatment, etc.). Composition of the waste provides a description of the constituents of the waste; this varies widely from place to place as is evident from Table 1. The most striking difference that can be seen is the difference in organic content which is much higher in the low income countries than the high income countries, while the paper and plastic content is much higher in high income countries than low income countries. This shows the difference in consumption pattern, cultural and educational differences. In higher income countries disposable material, magazines and packaged food are used in higher quantities; this results in the waste having higher calorific value, lower specific density and lower moisture content. In the case of lower income countries, the usage of fresh vegetables to packaged food is much higher and mostly materials that are reusable are used. This results in a waste composition that has high moisture content, high specific weight and low calorific value.

**Table 1** Relative composition of household waste in low, medium and high-income countries

<i>Parameter</i>		<i>Low-income countries</i>	<i>Medium-income countries</i>	<i>High-income countries</i>
Contents physical and chemical properties	Organic (putrecible), %	40–85	20–65	20–30
	Paper, %	1–10	15–30	15–40
	Plastics, %	1–5	2–6	2–10
	Metal, %	1–5	1–5	3–13
	Glass, %	1–10	1–10	4–10
	Rubber, leather, etc., %	1–5	1–5	2–10
	Other, %	15–60	15–50	2–10
	Moisture content, %	40–80	40–60	5–20
	Specific weight, kg/m <sup>3</sup>	250–500	170–330	100–170
	Calorific value, kcal/kg	800–1100	1000–1300	1500–2700

*Source:* INTOSAI working group on environmental auditing (2002)

## 2 Municipal Solid Waste Management (MSWM) audit

Auditing has become an increasingly popular tool to assess the environmental policies, quality of implementation, compliance with national law and regulation, etc. Auditing has also been widely used in India, especially in industries. The most popular audits that are carried out in India are energy audits (TERI, 2002) followed by environmental management systems audits of which a waste minimisation audit is an integral part (Mannan, 2002). Audits on MSWM in India are however, very rare. In western countries however, audits on urban waste management have increasingly been carried out with respect to performance, compliance, risk, monitoring, existence of waste policy, quality of implementation, etc. Most of the countries have established an auditing institution to carry out the above given assessments.

The Estonian Government had carried out an audit to assess the necessary conditions for successful implementation of the waste policy. Reports and questionnaires were used for the audit and it was observed that the management had serious shortcomings, such as insufficient finance, in comparison to the goal, lack of organisation in the management no national waste management plan and poor monitoring (Linnas, 2001). The Audit Institution of Costa Rica had carried out an audit on SWM in two municipalities, with multiple focus such as pollution prevention system, management system and site audit. The audit was carried out by going through the reports, questionnaire interviews, and site surveys. The various aspects that were looked included compliance with national law and regulation, occupational health and safety, operational risk, pollution prevention and resource management. The audit identified that the ministries were not integrated, resulting in repetition of many working plans. The other findings were, insufficient public awareness programmes, lack of new methodologies and technologies, insufficient financial support and improper monitoring. The management and control of the dump was investigated with regard to national health legislation and technical regulations. Checklists and site surveys were used as tools for this audit. From this audit, it was observed that there was no urban cleanliness plan charted out by the municipal authority, serious violations of the legislations, no proper monitoring by the supervision agency and delayed closure of the dump (INTOSAI, 2002).

This paper presents an audit of the MSWM in Bangalore city. This would help to disseminate the innovative practices that have been adopted for managing municipal solid waste. The study explores the role of various stakeholders in MSWM, the current practices, the role of each entity, the shortcomings of the current practices and issues to be addressed to improve the condition. Auditing of MSWM involved the following objectives:

- to review the existing MSWM practices
- to audit the MSWM practices, considering the case of Bangalore city.

### 3 Methods

The approach to the case study was mainly qualitative. Information was gathered using a variety of methods to gain a better understanding of the situation, issues, perspectives and priorities. Data collection methods included document/literature review, semi-structured interviews, checklists and observation. Different types of audits were carried out to achieve various objectives:

- *Compliance audit.* To check if the current waste management process is being carried out as per the legislation.
- *Operational risk audit in combination with pollution prevention audit.* To check the frequency with which an environmental damage occurs and what the consequence of it is. The measures that have been taken against these possible environmental damages were verified.
- *Resource management audit.* To check the optimal utilisation of water, energy and material resources.
- *Occupational risk audit.* To verify the measures of occupational safety.

#### 4 A case study- environmental audit of MSWM in Bangalore city

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 not able to provide the necessary services like solid waste management, water supply, road maintenance, etc., to a satisfactory level. The authorities however have taken initiatives and measures to achieve compliance with regulations and reduce complaints from citizens, especially in the MSWM sector. The case study would help to identify techniques suitable for the present scenario, the lacunae or the loopholes in the adopted methods and the possible alternatives.

The Bangalore City Corporation (BCC), which has 100 wards within its municipal jurisdiction, has a population of 4,292,223 accounting for 75.48% of the total population of Bangalore Urban Agglomeration of which 2,240,956 are males and 2,051,267 are females. The decadal growth rate of population for the decade 1991–2001 for Bangalore City is as high as 61.36%. This high growth rate can be attributed not only to the extension of the municipal limits of Bangalore City but also to the ever-increasing population.

The amount of waste generated in Bangalore city varies from 1700 MT/day to 2300 MT/day and the composition of waste is given in Table 2. The Bangalore Metropolitan Area is, on the whole, divided into 30 ranges and 100 Revenue wards under the jurisdiction of Bangalore Mahanagara Palike (BMP). BMP is responsible for the SWM policy, setting up targets and objectives. Revenue wards are further divided into 294 health wards for proper management of the sanitation functions. Out of these 294 health wards 112 are managed by BMP, while 182 wards have been assigned to private agencies on contract basis.

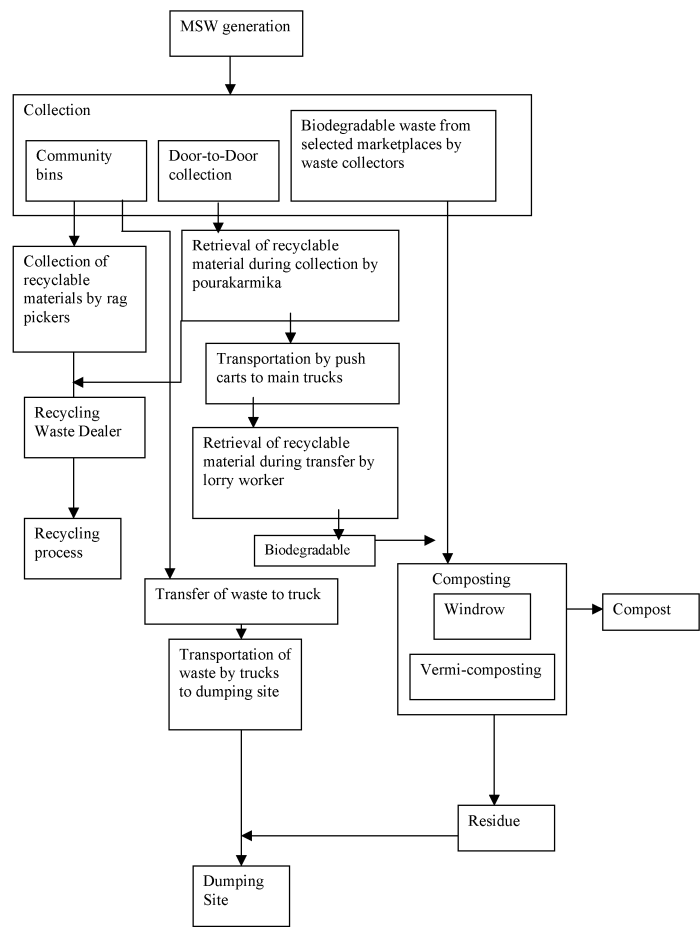
**Table 2** Physical characteristics of Bangalore MSW

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:* BMP

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, Malleswaram, Koramangala, Indian Institute of Science campus (IISc), Hindustan Machine Tools colony (HMT), Airport Road and Chikpet). 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, success, failure of strategies and the issues faced while implementing strategies. The site 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 Bomanhalli were done during the study to understand waste processing and disposal. The current MSWM is explained in detail in Figure 1.

**Figure 1** Current MSWM practice in Bangalore city



#### 4.1 Collection

The most common method of collection in Bangalore city is door-to-door collection, followed by community bin collection. In 2003, the door-to-door collection method was implemented in 60 health wards. As per the BMP, all wards in the city are supposed to have door-to-door collection and all the community bins have been removed. However, during the site survey, it was observed that many of the wards still have community bins that are in a very dilapidated state. A large quantity of organic waste is generated from 12 commercial vegetable markets. This waste is collected using separate trucks every morning and evening.

The waste collected in pushcarts from lanes is transferred to a truck at a meeting point called a synchronisation point. The truck arrives at the designated point at a specified time and place. The waste is transported to the disposal site by means of a large capacity tipper truck, and in a few wards by a small capacity tipper truck or dumper placers. The truck is covered with a mesh and a polythene sheet to prevent scattering. Currently, Bangalore city has no transfer stations for intermediate storage of waste and intermediate segregation of waste.

#### 4.2 Processing of wastes

The Karnataka Compost Development Corporation (KCDC) was one of the 11 composting units set up in 1975, based on the technology suggested by WHO (2002). Within a year, 10 of these units had to be closed, because the technology suggested by WHO was unable to successfully handle unsegregated Indian waste for composting. Also the usage of crushing and grinding machines caused problems while selling the compost because the quality was poor due to the existence of glass splinters and other non-biodegradable material. In the 1970s, KCDC processed 50–60 tons of mixed waste per day. By 2002 the capacity was expanded to 150 tons/day. Currently the units process 250 tons/day of mixed waste, plus 50 tons/day of market waste, which is collected using vehicles owned by KCDC.

#### 4.3 Disposal

City waste is disposed off at Betahalli (Mavallipuram) dump yard situated 18 km north west of Bangalore city. The waste is brought in by the municipal and contract lorries. This waste is dumped in the yard in the form of a heap. There are three JCB's (Front End Loaders) in the dump yard for waste levelling. The waste is sprayed with Effective Microorganisms (EM) solution, covered with a 10 cm layer of debris and sprayed with water after levelling. The solution used for spraying is prepared by mixing 4 litres of EM solution with 8 kg of molasses or jaggery and 150 litres of water. After mixing it is allowed to stand for 7–8 days, after which the pH reduces to 3.4. The EM stock solution consists of actinomycetes, photosynthetic bacteria, and yeast, Lactic acid bacteria (*Lactobacillus sp.*, *Streptococcus sp.*, *Streptomyces sp.*, *Rhodospseudomonas sp.*, *Saccharomyces sp.*, *Propionibacterium sp.*), which speed up the degradation process and reduce the volume, the flies and the odour. The observations made on the site are:



- a large number of rag pickers collect recyclable waste from the landfill and pay a small amount to have access to the waste
- there is a recycling dealer in the dump yard who buys the recyclable material from the rag pickers and there is one dealer on the way to the dump yard who buys the recyclable waste from the lorry driver
- the levelling of MSW after dumping is not carried out efficiently due to fewer number of front-end loaders
- the foul odour was strong and could be inhaled at long distances
- large number of flies, birds and stray dogs
- there is emission of methane gas from the dump yard, due to which the waste can be easily set on fire
- there is always a queue of at least 5–10 Lorries waiting to unload; this is due to the lack of number of front-end loaders to level the MSW
- this dump yard has no fencing, weigh bridge or no proper approach roads.

The stakeholders and their responsibilities.

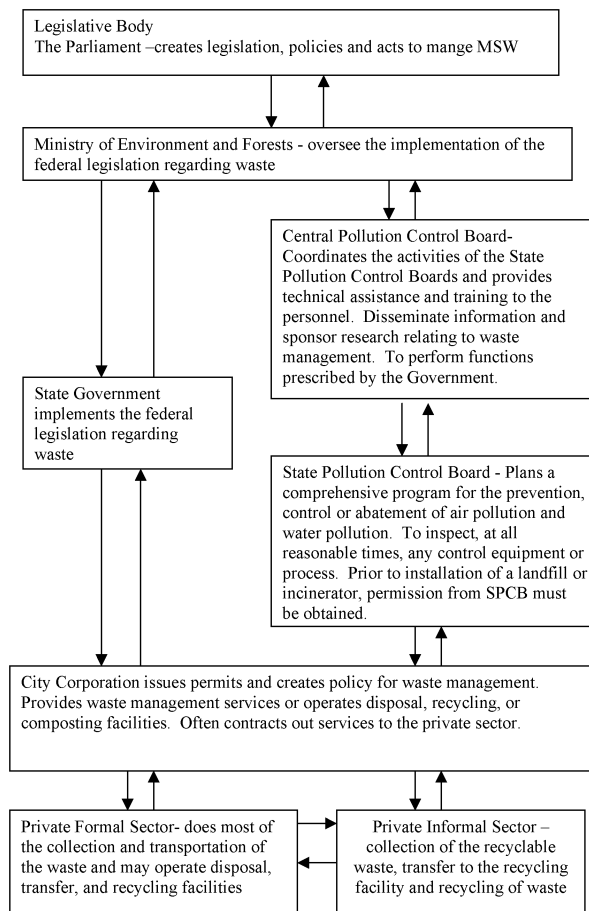
*The MSWM system and the relationship among the stakeholders are depicted in Figure 2. Various stakeholders are*

- Ministry of Environment and Forests is responsible for all of the environmental policies at the national level, including the management of waste. The Ministry has an overview of all the activities of the MSWM sector and makes sure that it is performed well.
- Central Pollution Control Board keeps a check on all the activities that have potential to pollute the environment, which includes the monitoring of the MSWM in the country. It has divisions in each state that report to CPCB on the environmentally hazardous activities in the state, the actions taken to check them and the improvements made by the industries and public towards a cleaner environment (CPCB, 1998).
- Karnataka Pollution Control Board keeps a check on all the activities that have the potential to pollute the environment, which includes the monitoring of the MSWM in the state. It reviews the Environmental Impact Assessment carried out by the agencies prior to the construction of a landfill site, installation of an incinerator or any other processing plant. It carries out public participation meetings to make the public aware of the proposed project and its benefits. Public participation is especially important so that once the project is started there should not be any agitation against the project.
- Bangalore Mahanagara Palike is responsible for management policy, setting up the targets and objectives. They are responsible for managing the solid waste in the city and are answerable to the Karnataka State Pollution Control Board. They also have the authority to privatise the solid waste management sector.

- *Organisational Structure of the Health Department.* The hierarchy of the Health Department in charge of SWM is a pyramidal structure headed by the Chief Health Officer. For effective administration, the city has been divided into three zones namely east, west and south. A Zonal Health Officer administers each zone. There are two Deputy Health Officers to assist him. Each zone consists of ten ranges headed by a Medical Officer of Health. Each Medical Officer of Health is assisted by Senior, Junior Health Inspectors and Sanitary Daffedars. The field worker who is employed in the sanitation work is known as Pourakarmika.
- *NGO.* Swabhimana, Waste wise, Swachha Bangalore, Shuchi Mitras, etc., are some Non Governmental Organisations (NGOs) that support the MSWM. Their functions are stated below:
  - they carry out public grievance meetings to identify the problem spots and convey these complaints to the authorities
  - they collaborate with authorities to carry out door-to-door collection of segregated waste
  - they identify public volunteers to monitor the SWM in their respective areas
  - few NGOs have also set up decentralised composting plants in residential areas and for this they also carry out door-to-door collection and educate the public to segregate the waste prior to disposal
  - they carry out public meetings in schools, colleges, public places etc., to educate the public about segregation of waste, non-littering, etc.
- *Private formal sector.* Currently, out of the 294 health wards in Bangalore city, 182 wards have been given out on a private contract. This includes the functions of collection of waste, transfer of waste to trucks, transport of waste to the specified dump yard. The dump yards that are currently being used are all owned by private entities. They have the responsibility of disposing of the waste by alternative layering of waste and soil, spraying it with EM solution and water. Processing of wastes is done by:
  - Karnataka Compost Development Corporation (KCDC), which is a government-aided organisation. This carries out the function of composting (windrow and vermicomposting)
  - Terra Firma Biotechnologies, which is a private organisation that carries out vermicomposting
  - Ramky Consultants, which is a private consultancy proposing to set up a sanitary landfill site in Bangalore
  - Srinivas Gayathri Resource Recovery, which is a private consultancy proposing to set up a waste to energy plant and a sanitary landfill site in Bangalore.

- Private informal sector.* The informal sector in the city is very large and plays a very vital role in the MSWM. It comprises the rag pickers who retrieve recyclable waste from the community bins and landfills, the people who buy recyclable waste from households usually called as ‘batli wallas’, the middlemen who buy waste from the rag pickers and ‘batli wallas’ and sell it to either bigger dealers or to recycling factories. Municipal workers like the pourakarmika collect waste from the households and retrieve the recyclable waste; even the lorry workers retrieve the recyclable waste before transferring the waste into the lorry. The waste retrieved by them is sold to the informal sector.
- Donor agencies.* Development corporation of Norway (DCN), Deutsch Gesellschaft fur Technische Zusammenarbeit (GTZ) and World Health Organization (WHO) are a few of the international organisations that have sponsored projects in Bangalore. WHO has sponsored large scale composting plants all over India and DCN has sponsored decentralised plants all over Bangalore.
- Service users comprise the entire public in the city, including the tourists visiting the city.

**Figure 2** Municipal Solid Waste Management (MSWM) system in India



## 5 Results and discussion

The techniques and the shortcomings of the techniques adopted have been identified in all sampled wards and Table 3 lists the Malleswaram ward. Door-to-door collection is adopted in Malleswaram area, which has resulted in efficient collection of waste and reduction of littering, foul odour and unaesthetic appearance of bins. However, in commercial areas, due to the absence of community bins, sudden waste, generated at odd hours, is disposed in the street. A few waste heaps can be found on the roadsides in commercial areas. All the trucks that are used for transportation of waste have meshes that prevent littering of waste, but 40% of the trucks have partial polythene cover and 20% have no polythene cover and this results in scattering of waste and foul odour during transport. The recycling process is carried out by the informal sector that has resulted in high efficiency of recovery of recyclable material. There is no other process carried out, leading to the entire waste being disposed. There is a large quantity of organic waste that is produced in this ward, including organic waste generated in a market. The waste is disposed off in the Betahalli dump yard, causing foul odour, scattering, leachate formation, and air pollution from burning and methane emission from decomposing organic matter.

**Table 3** MSWM in Malleswaram (Ward 7) (Malleswaram Population- 37760, Area- 1.69263 sq km)

<i>Function</i>	<i>Shortcoming</i>	<i>Suggestion</i>
<i>Storage</i>		
The waste is stored in households and in shops until it is collected by the door to door collector	–	–
<i>Collection</i>		
Door-to-Door method – Adopted in the whole ward, for residential and commercial areas	Seventy percent of drums are not painted as per the regulations of green for biodegradable, white for recyclable and black for mixed	Painting of drums at regular intervals to make it more convenient to workers
	Segregation not carried out by worker nor householder, though separate bins are provided	Workers accept only segregated waste from households
The recyclable waste is retrieved by the worker and sells it separately to the informal sector	PET bottles and thin plastic bags are not retrieved. The soiled recyclable material cannot be retrieved	
	Waste heaps found near commercial areas	Placement of large community bins in commercial areas (in commercial area there is a possibility of sudden generation of a large quantity of waste that cannot be stored in the shop till the next day)  Small litter bins should be provided for the pedestrians in commercial areas and bus stands

**Table 3** MSWM in Malleswaram (Ward 7) (Malleswaram Population- 37760, Area- 1.69263 sq km) (continued)

<i>Function</i>	<i>Shortcoming</i>	<i>Suggestion</i>
Sweeping	The dirt is pushed into the drains which blocks the drains  Workers do not use the gloves and footwear that are provided for protection	The workers educated on the affects of blocked drains and regular inspection of drains  Mandatory usage of the protection gear provided
<i>Transfer and transport</i>		
The waste collected in pushcarts from narrow lanes and meet at a synchronisation point at a specified time. The waste is transferred from the pushcart to the truck	The waste even if segregated by the workers and stored in separate drums, the waste gets mixed during transfer from pushcarts to lorry. This is because there is no facility in the lorry for separate storage of waste	A small capacity truck and a large capacity truck can be assigned for the collection of dry and wet waste respectively. A better option is to have a partition in a single truck for the collection of segregated waste
The lorry worker retrieves recyclable material during transfer of waste from push cart to lorry	PET bottles and thin plastic bags are not retrieved. The soiled recyclable material cannot be retrieved	Only segregated waste should be accepted to be filled into the lorry
BMP truck – 3 large capacity tipper	Mesh covering – 5 trucks, No Polythene covering – 1, Partial Polythene covering – 2 trucks, Complete polythene covering – 2 trucks	Trucks completely covered with polythene to prevent scattering of waste and foul odour
Contract truck –1 large capacity tipper	There is leakage of wet waste from truck during transportation	Provision of proper enclosure
Trip truck – 1 large capacity tipper	Foul odour emitted from the waste during transportation  The waste is not segregated at an intermediate level and is directly transported to the disposal site  Long distance from ward to dump site, hence only one trip a day is made by each truck  Manual transfer of waste	Regular inspections  Transfer stations to be provided where waste can be further segregated and higher efficiency for transportation can be achieved by increasing the number of trips made by each truck  Mechanical loading collection vehicles or proper equipment for transfer of waste
Process	No processing carried out prior to disposal	Recycling of the recyclable material retrieved from waste  Composting  High quantity of yard waste generated in the ward and also high quantity of organic waste generated from the market and households

**Table 3** MSWM in Malleswaram (Ward 7) (Malleswaram Population- 37760, Area- 1.69263 sq km) (continued)

<i>Function</i>	<i>Shortcoming</i>	<i>Suggestion</i>
<i>Disposal</i>		
Dump yard in Betahalli	Foul odour, flies and bird menace	Usage of higher quantity of EM solution
	Stray dog nuisance	
	Waste burnt emitting toxic fumes and causing air pollution	Waste burning should be prohibited and strict action should be taken if still continued
	Waste is dumped in heaps causing scattering	Usage of front end loaders for levelling and use soil cover
	Soil contamination	
Rag pickers retrieve the recyclable material from the landfill	The lorry workers and drivers are exposed to diseases	Provision of masks and safety gear
	High exposure to diseases	Provision of masks and safety gear
		Closure of dumpsite and replacement with sanitary landfill

The ward-wise auditing of functional components of MSWM is given in Table 4. In the sampled wards of Bangalore, the waste is stored in open or closed community bins. Out of the community bins present, the average percentage of bins covered is 49%. The collection of the waste is carried out by the community bin method and the door-to-door method. It is essential to have community bins along with the door-to-door collection in commercial areas to avoid littering. The percentage of area covered by community bin in commercial areas is 17.5%. The door-to-door collection method has been implemented in all areas of the city as it is a suitable method for collection from residential areas and also suitable for collection of segregated waste. In Bangalore door-to-door collection has been implemented in 94% of the residential areas. However, only 3% of the waste is segregated at source. There are currently no transfer stations in Bangalore and all the waste is directly transported to the disposal site. This is very expensive and the efficiency of the trucks is not utilised to the maximum. As per the regulations, all trucks should have mesh and polythene covering. However, only 96% of the trucks have mesh covering and 41.43% of the trucks have polythene covering. The quantity of waste processed is very small. The informal sector in the city manages the recycling sector, 18% of the total waste generated is recycled by this sector. The other process method adopted in the city is composting. 3.14% of the waste is reduced through composting. The final quantity of waste sent to the dump yard and quarry (open dump) is 60.71% and 21.14%, respectively. The compliance audit through checklist was attempted and results listed in Table 5 indicate that the regulations being followed by the authorities and private companies responsible for the MSWM. Functional unit wise compliance of regulations are as given below:

- *Storage.* From the audit it was observed that the placement of bins has not been done keeping in mind the population density and the quantity of waste generated. There is a lack of community bins in a few of the commercial areas. Due to the high generation of waste in commercial areas, the waste is not always stored on site, but is disposed on the roadsides, causing unaesthetic appearances. Well-designed community bins have to be placed in commercial areas, depending on the quantity of waste generated. The maintenance of the present bins is poor and has resulted in rusted bins having sharp edges. This can prove to be dangerous to the collection staff and also to the users. The staff must be provided with well fitting gloves for safety. Community bins should be provided with a partition for separate collection of waste and proper colouring and labelling on the bins. To improve the separation of waste at source and throughout the MSWM process, adequate staffing, supervision, procedures, training, posters, verbal reminders, reporting, meetings and equipments are required.
- *Collection.* Adopting the door-to-door collection method has proved to have many advantages. The complaints from residents due to unaesthetic bins near their houses have stopped, the number of stray dogs and stray cattle has reduced and the no bin system has also improved the waste handling by people or residents. This method is also better suited for collection of segregated waste. However, the door-to-door collection method has its own considerations. In commercial areas, due to the higher quantity of waste generation, the shopkeepers find it difficult to store the waste on site and hence this waste ends up on the street. Though separate drums have been provided for collection of segregated waste, neither the household nor the pourakarmika carry out segregation. This is due to the poor awareness and the general attitude of public and pourakarmikas. The number of awareness programmes and training programmes carried out by the authorities need to be increased and should be at a regular frequency. It has to be kept in mind that such practices are not easy to instil and will take many months, or even years, to implement. Here again, adequate staffing, supervision, procedures, training, posters, verbal reminders, reporting, meetings and equipment are required to make it possible. The participation of NGOs in such programmes can prove to be very helpful to the authorities in making this a success. During door-to-door collection the pourakarmika manually segregates the waste. It is very important that this is carried out with proper protection. The staff should be provided with gloves, footwear, apron, masks and goggles for safety, as they are constantly exposed to waste every day.
- *Transfer and transport.* The innovative idea of synchronisation that has been adopted by the municipality to transfer waste from pushcarts to trucks has proved to be successful. This has reduced the spillage, no space is occupied for intermediate storage and collection happens on time as the workers and trucks have to meet at a specified time and location for the transfer. The transfer of small drums is also much easier and safer than the transfer of waste from large community bins. The trucks that are currently used do not have provision for separate collection of waste. This results in the mixing of waste even if the waste is collected separately. Trucks can either be provided with partition or two trucks can be provided – one truck for the collection of organic and mixed waste and another truck for collection

of recyclable waste. The truck for recyclable waste can have a frequency of once in three days as the quantity of recyclable waste generated is less when compared to organic waste. Transfer of waste is carried out manually so it is very important to have proper safety gear like gloves, apron, masks and goggles during transfer. The vehicles used for the transportation of waste should be in a good condition. Most of the trucks have a mesh covering and about 50–60% also have polythene covering. However, there is no proper enclosure provided to prevent the wet waste from leaking on to the road. It is very essential that all trucks have mesh and polythene covering with a proper enclosure to prevent scattering of waste, foul odour and leakage while travelling on crowded roads.

- *Treatment process.* The only treatment option that is provided for Bangalore city is composting. This is carried out only for 400 MT/day while the total amount of waste generated is about 2300 MT/day. There have been proposals for setting up three integrated waste management sites that have composting and sanitary landfills. This action needs to be hastened to prevent the excessive damage being caused by open dumping of large quantities of waste every day. Other treatment options also should be considered like decentralised anaerobic digesters near markets. This will not only produce biogas but also reduce the transportation cost of waste to landfill sites. Waste to energy plants like production of refuse derived fuels and incineration plants can be set up to use waste from commercial areas once the source segregation process is set in place.
- *Disposal.* In the current MSWM system, the function that has been totally ignored is that of final disposal of MSW. The current method of disposal adopted, as explained earlier, is extremely hazardous to the environment and can cause irreversible damage to the surrounding areas. Unauthorised open dumping of waste is also carried out near crowded slum areas. This is extremely hazardous to the people living around that area. The identification and closure of such dumps should be given the topmost priority. The setting up of the proposed sanitary landfill sites with integrated composting plants should be hastened.

Some important factors that need to be considered for the overall improvement of the waste management system are:

- *Data management.* To improve data management there should be commitment to improving reliability of the data on waste from the staff and authorities. Greater confidence in data will help in monitoring the efficiency of the collection, transportation, process and disposal options. Geoinformatics would help in monitoring the unauthorised activities, by monitoring the number of trucks and trips made by trucks to the specified disposal site.
- *Training and education.* Environmental education is a way of increasing understanding of problems, cooperation among stakeholders, environmental entrepreneurship and environmental performance. The training should be a regular feature of MSWM, with hands on training on sorting and collection. After training there should be follow up of the practices.



- *Health and safety programmes.* It has been a common observation that in Bangalore, maintenance staffs do not use the protection gear that is provided to them. Regular health and safety programmes are required to educate the staff on the ill effects of manual handling of waste, walking bare foot in dump yards and continuous exposure to waste. Regular health check ups should be carried out to monitor the health of the workers.
- *Involvement of the community.* Community involvement in waste management monitoring programmes like that of Suchi Mitra should be encouraged and more people should be involved in such activities. This increases the environmental awareness of the participants and other people. This is one of the fastest and most effective ways to make the public understand the importance of activities like sorting.
- *Integration of waste pickers.* NGOs should organise waste pickers, and, instead of the waste pickers retrieving waste at the dump yard which is extremely hazardous to their health, safer methods of retrieving waste from the source by the waste pickers should be developed. Additionally, the waste pickers should be paid to retrieve waste from process plants and dump yards, instead of them paying to access the waste. Ways of improving the working conditions of the waste pickers and providing safety gear for them should be developed.
- *Planning.* The waste management that is carried out currently comprises more low cost measures in order to comply with regulation and avoid public agitation and complaints. There is no environmental management planning that is taken into consideration. Improper planning before setting up the sanitary landfill sites has led to increased public agitation and legal complications that have delayed the projects for a very long period. Although an informal approach to problem solving may have worked reasonably well while the programme was relatively small, a more systematic and proactive approach to management is required when the complexity of the programme increases. This would help to ensure that requirements are handled in a consistent and professional way and problems are addressed promptly and effectively. This would also ensure that the staff has clear objectives and goals while carrying out their activities.
- *Monitoring.* Monitoring during collection, transfer, process and disposal needs to become an integral part of the waste management system. The municipal authority not only has to monitor their own staff's activities but also the activities carried out by the private organisations. The State pollution control board has to carry out regular inspections of the dump yards and stop open dumping as it causes serious air and water pollution problems.

- *Public participation.* Currently the main hindrance to the implementation of the sanitary landfill sites is due to lack of information dissemination to the public. It is very essential that before any project is implemented, a public participation meeting be held to make the public aware of the technology used in sanitary landfill and the impacts.

**Table 4** Ward wise Auditing of functional components of MSWM

<i>Function</i>	<i>Technique</i>		<i>Shivajinagar</i>	<i>Malleswaram</i>	<i>Koramangala</i>	<i>IISc</i>	<i>HMT</i>	<i>Airport road</i>	<i>Chikpet</i>	<i>Average %age</i>
Storage	Community bin	Percentage of covered bins	30	–	–	33	–	–	84	49.00*
Collection	Community bin	Percentage of area covered in commercial areas	40	0	0	–	–	–	30	17.5**
	Door to door	Percentage of area covered in residential areas	100	100	100	60	100	100	100	94.29
		Percentage of waste segregated	0	0	20	5	0	0	0	3.57
Transfer	Transfer station		A	A	A	A	A	A	A	A
Transport	Truck	Truck with mesh (%)	100	100	100	75	100	100	100	96.43
		Truck with mesh and polythene cover (%)	75	40	75	0	0	0	100	41.43
Process	Percentage of waste recycled	Informal	18	18	18	18	18	18	18	18.00
		Formal								
	Percentage of waste composted			22						3.14
	Percentage of waste for anaerobic digestion									
Disposal	Sanitary landfill	Percentage of waste incinerated								
		Dump yard	85	85		85	85		85	60.71
		Quarry			63				85	21.14

A: Absent.

\*Only the areas having bins are taken into consideration.

\*\*Only the commercial areas have been taken into consideration i.e., Shivajinagar, Malleswaram, Koramangala and Chikpet.

**Table 5** Compliance audit of MSWM

Checklist for compliance	Sample wards						
	Shivajinagar 79	Malleswaram 7	Koramangala 67	ITC 5	HMT 1	Airport Road 73	Chickpet 28
<i>Function Regulation</i>							
<i>Storage</i>							
No littering on the streets?	X	X	X	√	√	X	X
No littering around bins?	X	na	na	X	X	√	X
Are the bins covered?	X	na	na	X	X	√	X
Are the bins cleared every 24 hrs?	√	na	na	√	√	√	√
The storage facility is designed taking into account the quantity of waste generated in a given area and the population density	X	na	na	√	√	X	X
Aesthetically acceptable	X	na	na	√	X	X	X
Bins have easy to operate design	X	na	na	√	X	X	X
Bins for biodegradable waste are painted green, for recyclable waste they are painted white and for other waste they are painted black	X	√	√	X	√	√	√
No manual handling of waste	X	X	X	X	X	X	X
Manual handling with proper precaution and safety	√	√	√	√	√	√	√
<i>Segregation</i>							
Organisation of awareness programmes to ensure community participation in waste segregation	√	√	√	X	X	X	√
Arranging meeting at quarterly intervals	X	X	X	X	X	X	X
Arranging meetings at monthly intervals	X	X	X	X	X	X	X
Arranging meetings once in every six months	√	√	√	X	X	X	√
<i>Collection</i>							
Door-to-door collection/ community bin/ block collection	√	√	√	√	√	√	√
Segregation done at source	X	X	X	X	X	X	X
Collection from slums and squatter area	X	√	√	√	√	√	X
Collection from hotels/ restaurants/ office complexes	√	√	√	√	√	√	√
Separate collection of waste from slaughter houses/ meat and fish markets/ fruit and vegetable markets	√	√	√	√	√	√	√
No mixing of biomedical wastes and industrial wastes with MSW	√	√	√	X	√	√	√
Usage of hand driven container carts for the collection and transfer of waste to trucks or community bins	√	√	√	X	√	√	√
Horticulture, dairies and construction and demolition waste is collected separately	√	√	√	√	√	√	√

**Table 5** Compliance audit of MSWM (continued)

<i>Checklist for compliance</i>		<i>Sample wards</i>						
		<i>Shivajinagar 79</i>	<i>Malleswaram 7</i>	<i>Koramangala 67</i>	<i>IISc 5</i>	<i>HMT 1</i>	<i>Airport Road 73</i>	<i>Chickpet 28</i>
<i>Function Regulation</i>								
<i>Collection</i>								
	No burning of waste (garbage, dry leaves)	√	√	√	√	√	√	√
	No stray animals allowed to move around waste storage facilities	X	X	X	X	X	X	X
	No stray animals allowed to move around other places in city or town	X	X	X	X	X	X	X
	Notification of the waste collection schedule and the likely method to be adopted for public benefit by Municipal authority	X	X	X	X	X	X	X
	Has the public been educated about the law stating that it is the responsibility of the waste generator to avoid littering and ensure delivery of wastes in accordance with the collection and segregation system notified by the Municipal authority	X	X	X	X	X	X	X
<i>Transportation</i>								
	Waste transportation vehicles are covered	√	√	√	X	√	√	√
	Waste during transportation not visible to public	X	X	X	X	X	X	X
	Waste not scattered during transportation	X	X	X	X	X	X	X
	Waste collected daily and before overflow of bin	√	√	√	√	√	√	√
	Multiple handling of waste avoided	√	√	√	√	√	√	√
<i>Process</i>	<i>Regulations</i>	<i>KCDC</i>		<i>Terra firma</i>				
Composting	Agreement between the private agency and the municipal authority for supply of solid waste	√		√				
	Waste storage area should be covered, else it should have an impermeable base with facility for collection of leachate and surface water run-off into lined drains leading to a leachate treatment and disposal facility	√		√				
	Precautions shall be taken to minimise nuisance of odour, flies, rodents, bird menace and fire hazard	√		√				
	During breakdown of plant the waste intake is stopped and is diverted into a landfill	√		√				
	Segregation prior to process and constant removal of rejects	X		X				
	Constant removal of rejects post processing	√		√				
	Recyclables routed through appropriate vendors	√		√				
	Non-recyclables sent to well designed landfill sites	√		√				

**Table 5** Compliance audit of MSWM (continued)

<i>Process</i>	<i>Regulations</i>	<i>KCDC</i>	<i>Terra firma</i>
	For windrow composting provided with impermeable base	√	na
	Made of concrete or compacted clay, 50 cm thick, having permeability coefficient less than $10^{-7}$ cm/sec	√	na
	The base shall be provided with 1–2% slope and circled by lined drains for the collection of leachate or surface run-off	√	na
	Ambient air quality monitoring is regularly carried out	√	X
	Compost quality as per standards	√	√
	Treated leachate complies to standards	na	na
<i>Disposal</i>	<i>Regulation</i>	<i>Mandur</i>	<i>Mavallipura</i>
<i>Site selection (proposed sites)</i>			
	The landfill site shall be large enough to last for 20–25 years	√	√
	The landfill site is away from habitation clusters	√	√
	The landfill site is away from forest areas	√	√
	The landfill site is away from waterbodies	√	√
	The landfill site is away from monuments	√	√
	The landfill site is away from National Parks	√	√
	The landfill site is away from Wetlands	√	√
	The landfill site is away from places of important cultural, historical or religious interest	√	√
	The landfill site is at least 20 km away from airport including airbase	√	X
	If not, necessary approval should be obtained	na	X
	Waste processing facility shall be planned as an integral part of the landfill site	√	√
	A buffer zone of no-development is maintained around landfill site and incorporated in the Town Planning Department's land use plans	X	X

## 6 Conclusion

The audit has brought out the key issues that need immediate attention and minor lacunae that pose major hindrances in the further process of the system. In the storage function, only 49% of the present bins are covered. In collection, 17.5% of the commercial areas have community bins and 94% of the residential areas have adopted the door-to-door method. With these methods of collection, only 3% of waste segregation has been achieved. There are no transfer stations present and out of the trucks present, only 41.43% have polythene covering. Recycling is carried out mainly by the informal sector

achieving a high level of efficiency. 3.14% of waste reduction is achieved through composting and 60.71% of the waste is disposed in dump yards and 21.14% is disposed in open quarry sites.

Waste disposal needs immediate attention and strict monitoring. The setting up of sanitary landfill sites has to speed-up and this needs to be given top priority. The number of treatment process plants has to be increased to manage total quantity of waste generated. Many new techniques have been implemented for storage, collection, transfer and transportation. These techniques have brought about many positive changes and have increased the efficiency of the MSWM system. However, segregation of waste at each step is not being carried out. The segregation of waste during storage, collection and transportation has to be set in place for the efficient running of the process plants. Proper training and education needs to be provided to the workers and public awareness programmes should be conducted regularly. The occupational and health and safety measures taken by the authorities are not sufficient. Health and safety programmes have to be conducted regularly to check the health condition of the workers in the various areas of MSWM and they should be educated on the health hazards related to their work and the importance of wearing the safety gear.

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