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Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: An insight

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ABSTRACT

Solid waste management is one of the most challenging issues in urban cities, which are facing a serious pollution problem due to the generation of huge quantities of solid waste. This paper presents an assessment of the existing situation of municipal solid waste management (MSWM) in major cities in India. The quantity and composition of MSW vary from place to place, and bear a rather consistent correlation with the average standard of living. Extensive field investigations were carried out for quantification, analysis of physical composition, and characterization of MSW in each of the identified cities. The MSW management status (per the MSW Rules, 2000) has also been assessed, and an action plan for better management has been formulated; both are presented in this paper. Studies carried out in 59 selected cities in India have revealed that there are many shortcomings in the existing practices used in managing the MSW. These shortcomings pertain mainly to inadequate manpower, financial resources, implements, and machinery required for effectively carrying out various activities for MSWM. To overcome the deficiencies in the existing MSWM systems, an indicative action plan has been presented incorporating strategies and guidelines. Based on this plan, municipal agencies can prepare specific action plans for their respective cities.

1. Introduction

India is an agriculturally based country with a present population of approximately 1020 million (Union Health Ministry, 2004). There are 28 states and seven union territories in the country. Due to rapid industrial growth, the urban population is increasing rapidly. As a result, the 677 Class I cities and Class II towns existing in 1991 have increased to more than 700 by 2001 (CPCB, 2002). The quantity of MSW has also increased tremendously with improved life style and social status of the populations in urban centers (Sharholy et al., 2007). The annual waste generation has been observed to increase in proportion to the rise in population and urbanization, and issues related to disposal have become challenging as more land is needed for the ultimate disposal of these solid wastes (Idris et al., 2004).

During the last three decades, the National Environmental Engineering Research Institute (NEERI) has carried out studies in more than 50 cities and towns in India. Characterization of MSW indicated that the waste consists of 30–45% organic matter, 6–10% recyclables, and the rest as inert matter. The organic matter in solid waste in developing countries is much higher than that in the waste in developed countries (Bhide and Sundersan, 1983), and organic matter can be converted into useful products to reduce the burden on existing landfills (Richard, 1992). Biomethanation is a potential route for energy recovery from MSW (Bhattacharyya et al., 2008). The MSW (Management and Handling) Rules, 2000 recommend source-specific waste collection and transportation in addition to appropriate processing and disposal. It has been observed that knowledge of the quantity and characteristics of MSW aids in preparation of a long-term plan for a MSW management (MSWM) system. However, accurate data and information are not available from the majority of local bodies. Hence, it was deemed necessary by the CPCB, Government of India, New Delhi, to assess the existing status of the MSWM system in 59 identified cities in India, covering 35 metro cities with a population greater than 1 million, as well as 24 state capitals and union territories. As per the directions of the Honorable Supreme Court of India, New Delhi, NEERI was retained by CPCB, New Delhi to assess the status of MSWM in these cities and towns. Under this study, extensive field investigations were carried out for quantification, analysis of physical composition, and characterization of MSW in each of the identified cities; the MSWM status (per the MSW Rules, 2000) has also been assessed and an action plan for better management has been formulated.

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2. Objectives of the study

The study was undertaken with the following objectives:

- Assessment of waste quantity.
- Assessment of waste characteristics.
- Assessment of existing status of collection, storage, transportation, treatment, and disposal activities.
- Studies on financial and institutional aspects.
- Review of status with respect to existing legislation.
- Suggestions for indicative strategies and guidelines enabling the municipal authorities to formulate an action plan for better management of MSW.

3. MSWM in India: at a Glance

In India, the community bin collection system is the main practice used for waste collection. In this system, residents deposit their waste into the nearest community bins located at street corners at specific intervals (NEERI Report, 2005). Waste segregation at the source is minimal. Segregation of MSW into dry and wet wastes is carried out only in limited areas of a few cities, and in these areas, separate containers are used for collection of dry and wet wastes.

Waste generated in households is generally accumulated in small containers (often plastic buckets) and then disposed of into community bins. Containers for household storage of solid wastes are of many shapes and sizes, and are fabricated from a variety of materials. Residents usually store waste in 16–20 l plastic buckets. The type of container generally reflects the economic status of the waste generator. The containers generally are constructed of metal, concrete, or a combination of the two.

Various types of community bins, such as RCC bins, masonry bins, metallic containers, and plastic containers, are used in India, although RCC and masonry bins are being gradually phased out. Metallic containers of 4.5–6 m^3 capacity are now being promoted in various cities. These containers are carried to the disposal site by dumper placers, and after discharging the material at the disposal site, the containers are placed back in their original positions. This system avoids double handling of waste.

House-to-house collection is becoming common in India, except for in a few cities. In those cities that use house-to-house collection, handcarts and tricycles are used for waste collection from individual houses at a specific time in the morning, when residents deposit the stored waste into the handcarts. Sometimes a bell is attached to the handcarts to alert the citizens. The waste in the handcarts is either transferred to community bins or directly transferred to vehicles going to the disposal site. Recent legislation emphasizes the house-to-house collection system, and it is expected that this collection method will be promoted as an improvement to the existing system in various cities and towns.

Street sweepings are also collected in the community bins along with domestic waste. Corporate staff sweep the road and collect the waste in handcarts and baskets, which are emptied into the community bins.

Community storage may reduce the cost of waste collection and can minimize problems associated with lack of on-site storage space. However, unless these community storage arrangements are conveniently located, householders tend to throw their waste into the roadside gutters for clearance by street sweeping crews. Even where storage arrangements are conveniently located, waste tends to be strewn around the storage area, partly due to lack of discipline and partly as a result of scavenging by rag pickers and stray animals.

Due to the absence of adequate storage capacity for generated refuse and poor discipline among the generators, waste is also continually dumped on the road (Bhoyar et al., 1996). In a country like India, collection methods are based mostly on manual labour, which is less costly than the mechanized collection systems adopted in developed countries.

Commercial sectors, such as shops, offices, and hotels, also use the community waste bin system, and their waste is also collected along with household waste except in a rare number of commercial complexes, which pay a negotiated fee to the municipal authorities for collecting waste from their premises. Most of the shops do not open before 9 AM and so do not put their waste out on the street, as it would then be left until the next day's collection.

The following deficiencies have been observed in the storage and collection of MSW:

- Sweeping and collection implements are poorly designed.
- Dustbins are not emptied regularly.
- RCC bins and metallic containers are in broken or bad condition in many places.
- Scattered waste causes choking of drains.
- The number of bins is inadequate.
- There are no separate bins for collection of litter.

Different types of vehicles, varying from bullock carts to compactors, ordinary trucks, tractor and trailers, dumper placers, and tippers, are used for waste transportation. However, general-purpose open body trucks of 5–9 ton capacity are in common use. In smaller towns, tractor–trailers are used despite being noisy and inefficient. In a few cities, compactor vehicles are also being used. It has been observed that many of the vehicles have outlived their normal lives, resulting in high fuel consumption and low efficiency. Municipal corporations employ staff and vehicles for clearing the community bins. The waste is loaded into the vehicles from the community bins by the corporation staff. Finally, the waste is transferred to the disposal site. The metallic containers are directly carried by the dumper placer for unloading at the disposal site. The waste is transported mostly by municipal vehicles, although, in some large towns, private vehicles are also hired to augment the fleet. Vehicle maintenance is carried out in a general municipal workshop along with other municipal vehicles where the refuse vehicles receive the least priority. Most of these workshops have facilities for only minor repairs. Although preventive maintenance is necessary to maintain the collection fleet in proper operating condition, preventive maintenance is commonly neglected. Transfer stations are in place in only a few metropolitan cities (Joseph, 2002).

To improve conservancy operations, authorities feel that a lack of civic awareness among city residents is proving to be a major hurdle in maintaining the cleanliness of the city. The problem is most acute in slums and in low and middle income areas. It will be nearly impossible for the civic body to provide better surroundings if residents do not make an effort to deposit waste into the bins and stop the practice of throwing garbage onto the road (Joseph, 2002). A conservancy worker needs to cover a certain area by a specific time. If garbage is distributed all along the road by the public, the conservancy worker cannot cover the complete area assigned and hence some areas may not be covered on some days. Because of the poor conditions for temporary storage of wastes, non-government organizations (NGOs) have been involved in some areas to make arrangements for household waste collection, which has led to improvement in local street cleanliness (Shekdar, 1999).

In the waste stream, biodegradables are present along with recyclable items such as plastic, metal, glass, and paper. Several thousands of urban dwellers in India are employed in many small industries for the recovery of plastics, tin cans, bottles, bones, hair, leather, glass, and metal from MSW. All metals, unsoiled paper, plastics, glass, cardboard, etc. are readily marketable and are therefore recycled by householders themselves or by rag pickers. However, biodegradables are not fully utilized. Segregation of paper, plastic, metal, and glass is carried out by the informal sector. The materials are segregated by rag pickers and thereafter reach different industries for reuse and recycling.

By the time waste reaches the community bins, it contains very little recyclable material and consists mainly of vegetable/fruit peelings, scraps of soiled paper and plastic, used toiletries, etc. The larger proportion of organic matter in MSW indicates the desirability of biological processing of waste. Although composting was a prevalent biological processing practice in India in the past, it has been discontinued due to non-availability of adequate space in the urban centers and poor segregation of wastes. Recently, efforts are being taken to popularize waste segregation and composting. The high organic content of Indian MSW indicates that a self-sustaining combustion reaction cannot be obtained from a majority of MSW, and auxiliary fuel would be required to aid waste combustion (Joseph, 2002).

In a majority of the urban centers, waste is disposed of by deposition in low-lying areas, and uncontrolled landfilling is practiced in most of the cities. The disposal sites are selected on the basis of their proximity to the collection areas, and new disposal sites are normally identified only when the existing ones are completely filled up. In most cases, the waste is simply dumped at such sites and bulldozers are rarely used for compaction at the disposal site (Joseph, 2002), except in the four metropolitan cities; even in these cities, bulldozers are used only for leveling of the deposited waste. The incoming MSW vehicles are not weighed and no specific plan is followed when filling the dumpsites. Provisions for leachate and gas control do not exist, and soil cover is rarely provided except at the time of closure of the site. Most of the disposal sites are unfenced and waste picking is commonly practiced, posing problems for controlled operation of the sites. The landfills are not lined, compaction of waste is not carried out, and soil cover is also not applied over the waste. As a result, the landfills create unhygienic conditions and cause degradation of environmental quality. In rainy seasons, rain water percolates through the waste and soil strata and pollutes the groundwater. Fly and mosquito breeding take place at the disposal sites. Moreover, a smoke nuisance is caused by the unauthorized burning of waste practiced by rag pickers; open incineration of MSW at disposal sites is common for reducing the volume of waste and also for easy rag picking (Diaz et al., 1997). In India, hazardous and biomedical wastes are governed by separate rules. Separate collection, storage, transportation, treatment, and disposal systems need to be adopted for management of these wastes. However, it has been observed at times that MSW is mixed with biomedical and hazardous wastes due to poor supervision and lack of awareness.

4. MSW (Management and Handling) Rules, 2000

According to MSW Rules, 2000, every municipal authority is responsible for setting up a waste processing and disposal facility, and for preparing an annual report. The State governments and Union Territory Administrations have the overall responsibility for enforcement of the provisions of these rules in the metropolitan cities and within territorial limits of their jurisdiction (MSW Rules, 2000).

The CPCB, State Boards, and the other committees are required to monitor the compliance of the standards regarding groundwater, ambient air, leachate quality, and compost quality including incineration standards, and they are to examine the proposal taking into consideration the views of other agencies.

As per implementation rules, setup of waste processing and disposal facilities are to be done first. These facilities must be monitored once every 6 months. Existing landfill sites must be improved, and identification of landfill sites for future use must be carried out.

Waste collection by any method (community bin, house-to-house collection, etc.) must be conducted by using bell ringing or a musical vehicle to alert citizens without exceeding permissible noise levels. Biomedical and industrial wastes must not be mixed with MSW. Municipal authorities are to establish and maintain MSW storage facilities that do not create unhygienic and unsanitary conditions in the area. Citizens must be encouraged by the municipal authority to segregate wastes. Vehicles for transportation must be covered and the MSW must be processed in such as way as to reduce the burden on landfills. Biodegradables are to be processed by composting, and anaerobic digestion with landfilling restricted to those wastes that are non-biodegradable or inert, or which are not suitable for recycling. Specifications for maintenance of landfill sites and various other processing techniques such as composting, treated leachates, and incineration are given in the MSW Rules, 2000.

No single municipality or local body has complied with the guidelines stipulated by MSW Rules, 2000.

5. Methodology adopted for present study

In the present study, cities were selected with the aim of covering all the metropolitan areas and state capitals, including union territory headquarters, representing the demography and geography of the country. The map in Fig. 1 shows the study area. The major activities included performing field investigations to assess the quantity of MSW generation per day and determining waste composition and characteristics. In addition, requisite secondary data were collected from the municipal authorities using a predesigned questionnaire.

Initial planning and scheduling of the field visits with the sampling program were undertaken through a reconnaissance survey in each city. The entire city was divided into various zones such as high income, middle income, low income, slum areas, and commercial areas. MSW deposited in dustbins for the different population groups was identified.

Necessary information for initiation of the sampling and weighing exercises was finalized in consultation with municipal authorities during the reconnaissance survey. Primary data related to quantification of MSW, physical composition, and chemical characteristics of the representative MSW samples were subsequently collected.

Various types of sampling procedures have been suggested by different organizations and researchers. The Warran Spring Laboratory in the UK suggests a sampling method which involves separation of the waste by size using a rotating drum with a 160-mm diameter aperture designed specially for the purpose of screening raw waste. The waste is segregated into two streams, oversize (+160 mm) and undersized (−160 mm). Samples of the oversize and undersize streams are taken at 5–10 min intervals beginning approximately 10 min after startup of the trommel (NEERI Report, 1997). Composite samples of 100 kg for the oversize category and 200 kg for the undersize are prepared by adding the incremental samples. The composite samples are divided into sub-samples for determining moisture content and bulk density and also for hand sorting and chemical analysis. This method is highly mechanized and there are constraints in applying this method under Indian conditions (NEERI Report, 1997).

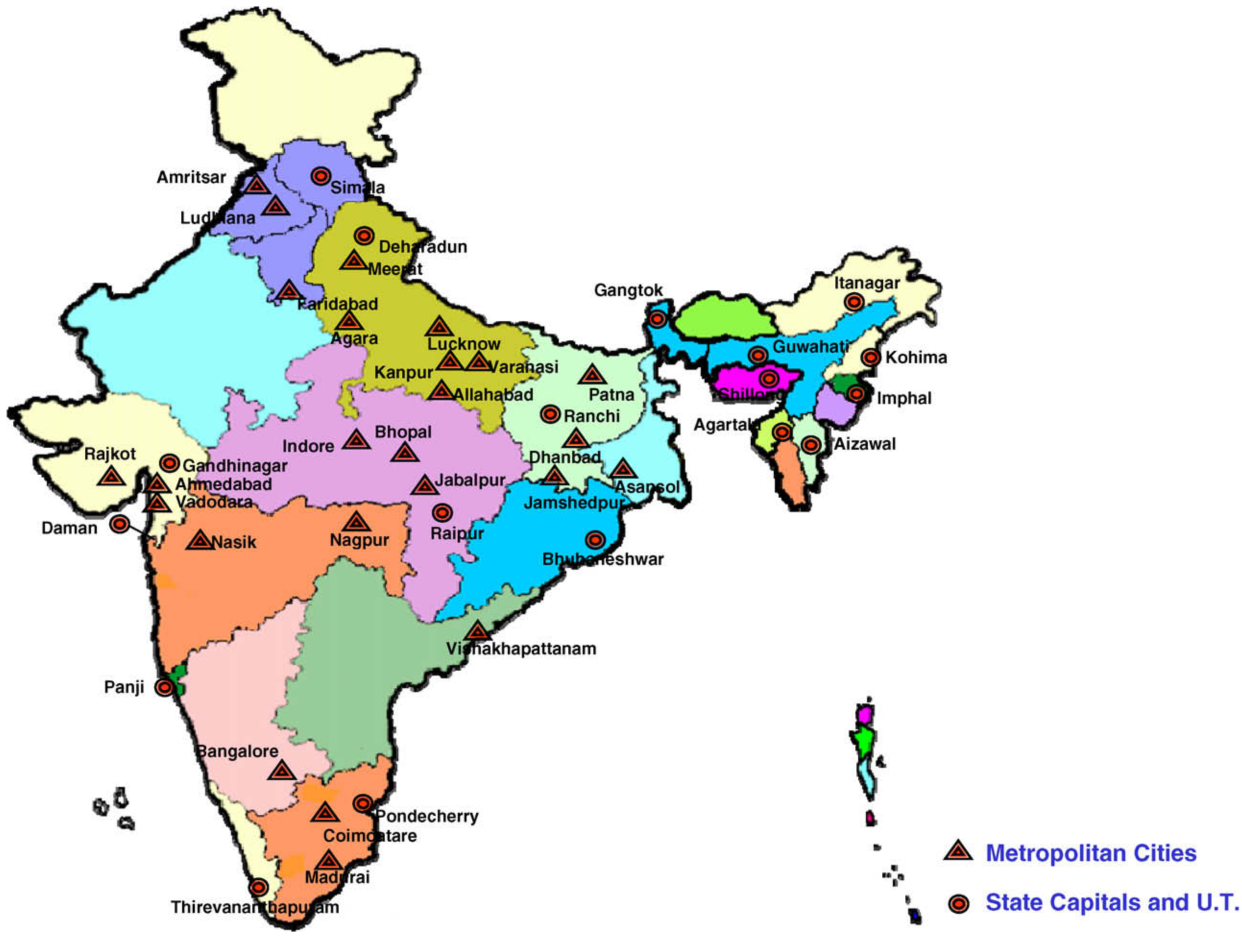

Fig. 1. Map showing study area and selected cities.

ASTM methods of sampling involve sampling of waste from vehicles employed for collection and transportation of MSW (D5231-92). As per this method, vehicles for sampling are selected randomly during a 1-week sampling period. About 1816 kg of sample is reduced to 454 kg by a quartering technique (NEERI Report, 1997). This method is suitable for the house-to-house collection system adopted in western countries.

In the present study, representative types of municipal and hired vehicles operated in various zones of the city on daily basis were weighed on the weigh bridge located near the disposal site or in other areas. The weighing exercise was carried out on five consecutive days, and the number of trips performed by all categories of vehicles on a daily basis was recorded. Moreover, past trip records were obtained to determine the average number of trips performed by each category of vehicle/day. The daily waste quantity was computed and waste generation in kg/capita/day was calculated based on the urban population.

The waste from identified bins was thoroughly mixed and grab samples were collected from various dustbins located in a particular category of the selected area. About 100 kg of sample was collected, thoroughly mixed, and reduced to 12.5 kg by a quartering technique. Using the quartering technique, the total waste mass was divided into four parts and waste from two diagonally opposite portions was taken and mixed. The other two portions were discarded. This procedure was repeated until a waste sample of approximately 12.5 kg weight was obtained.

Characterization studies were conducted to assess the recycling and pollution potential of MSW. Various components from the 12.5 kg sample, such as plastics, paper, metal, organic fractions, etc., were segregated and weighed, and these were expressed as a percentage of the total weight. The organic fraction was taken to the laboratory for chemical analysis.

Chemical analysis was performed as per standard methods (BIS No. 9234/1979). The parameters studied were pH, moisture, nitrogen, phosphorus, potassium, loss on ignition, and calorific value, among others.

Critical analysis of existing MSWM systems comprising collection, storage, transportation, processing, and disposal was performed in keeping with the provisions made under MSW (Management and Handling) Rules, 2000, and shortcomings in the systems were identified. With a view to overcoming these shortcomings, indicative strategies and guidelines for action plan preparation were formulated. The methodology adopted for the present study is shown in Fig. 2.

6. Current situation of the MSW management system in India

6.1. Storage of MSW

In India, in most of the cities, residents collect waste in plastic buckets and deposit it regularly in community bins located near the house. In some areas, the waste is collected from individual houses by corporate staff. Street sweepings are also collected in community bins. There are no separate bins exclusively for collection of waste paper, plastic, etc.

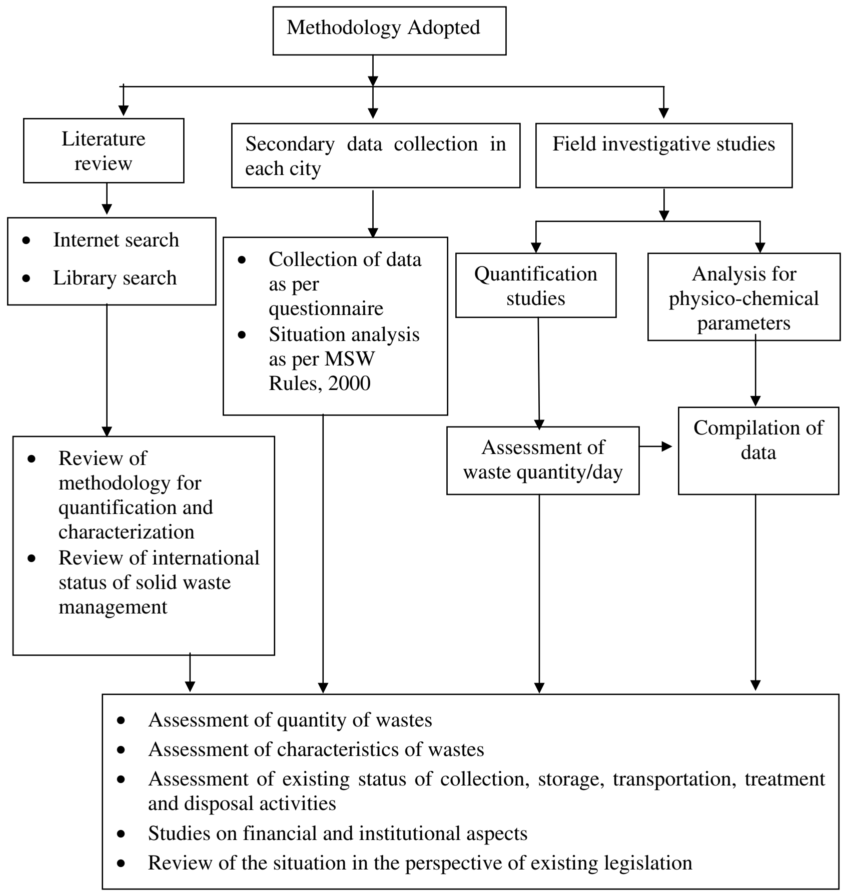

Fig. 2. Methodology adopted for the study.

6.2. Collection and transportation of MSW

The community bin collection system is adopted in most of the cities. In a few cities, the waste generated from various sources such as residential, street sweepings, garden, parks, offices, and shopping complexes is collected separately. Waste from slaughterhouses and hospitals are mixed with the MSW at the storage bins. A number of open collection spots exist in many cities, and these cause poor sanitary conditions and pose health hazards to the workers and nearby population (Gupta, 2001). The MSW (Management and Handling) Rules, 2000 suggest the provision of appropriate containers based on waste quantity generation by the nearby population. Assorted types of brick masonry bins/RCC bins, as well as M.S. and PVC containers, are used for collection of waste. It was observed that the size of the bins and their spacing are not based on the quantity of waste contributed by the citizens in the neighborhoods. Front end loaders are deployed for solid waste loading at storage bins in a few cities. Manual handling of waste at community bins is largely adopted in 52 out of 59 cities. At Nashik, house-to-house collection has been adopted in the entire city without segregation of dry and wet waste. The vehicles (tractor–trailer system) known as Ghanta Gadi directly transport solid waste to a processing plant managed by the municipal corporation. Sweeping of important roads and wards during the night has been practiced by workers deployed by the contractors in the cities like Hyderabad, Bangalore, and Chennai.

Around 27–28 cities have partially initiated house-to-house collection and a few cities (about 7) have implemented it for the entire city. The cities fully covered under house-to-house collection are Nashik, Chennai, Panjim, Vijaywada, Vishakhpattanam, Nagpur, and Pondicherry. The cities where house-to-house collection does not exist are Kolkata, Delhi, Hyderabad, Kanpur, Patna, Vadodara, Meerut, Jamshedpur, Dhanbad, Faridabad, Allahabad, Amritsar, Rajkot, Port Blair, Guwahati, Gandhinagar, Ranchi, Aizawal, Kohima, Bhubaneshwar, Itanagar, Daman, and Silvasa. The current waste collection systems in the different cities are shown in Fig. 3.

6.3. Segregation of waste

Segregation of recyclables (i.e., paper, cardboard, and plastics) by rag pickers was observed to be practiced in 22 cities. Rag pickers were not observed in cities like Kolkata, Chennai, Surat, Kanpur, Coimbatore, Kochi, Vasakhapattanam, and Panjim. In a few cities, NGOs were observed to be involved in the collection of waste through the services of rag pickers. Proper segregation of waste would lead to better options and opportunities for its scientific disposal (Singhal and Pande, 2000).

6.4. Processing of waste

In metropolitan cities like Bangalore, Hyderabad, Ahmedabad, and Kolkata (13 cities total), compost plants have been established and commissioned by private agencies. The plants have installed capacity in the range of 40–700 tonnes/day. However, the plants in operation are underutilized for various reasons; the major reason is the poor quality of compost resulting in reduced demand from the end users. Although MSW Handling Rules, 2000 under Schedule I suggest installation and commissioning of processing plants, the desired success is yet to be achieved due to non-availability of any proven technologies for Indian wastes and

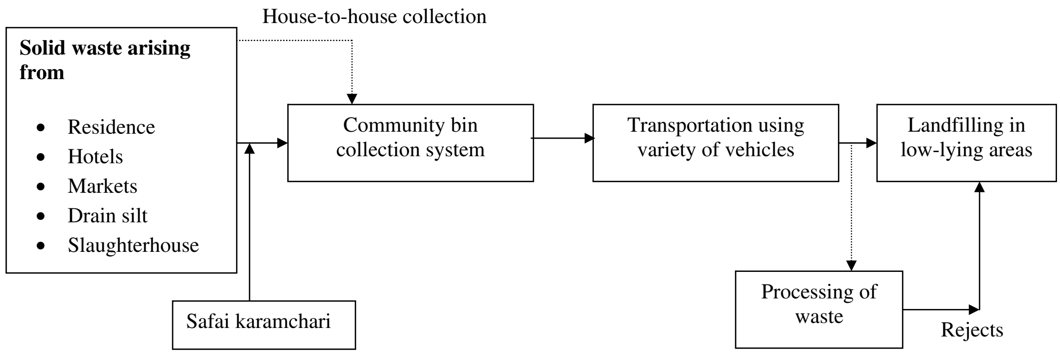

Fig. 3. Existing MSW management system in India.

conditions. Many municipal bodies have applied to State Pollution Control Boards for authorization for installation of compost plants.

A waste-to-energy plant established at Vijaywada by Shriram Energy Systems, Ltd., Hyderabad, with a capacity of about 500 TPD of MSW and a power generating capacity of 6 MW, has been in operation since December 2003. Another plant, with a capacity of about 700 TPD of MSW with a power generating capacity of 6.6 MW, established by M/s SELCO International, Ltd., at Gandhamguda near Hyderabad has been in operation since November 2003. M/s Shriram Energy Systems, Ltd., Hyderabad, will commission a third waste-to-energy plant at Vishakhapattanam. A waste-to-energy plant (600 TPD capacity) is also underway at Chennai. Vermicomposting of MSW has been initiated in five cities i.e., Hyderabad (7 TPD), Nagpur (30 TPD), Pune (50 TPD), Indore (1.25 TPD), and Pondicherry (5 TPD).

One biomethanation plant for the treatment of MSW (300 TPD capacity) has been commissioned at Lucknow to generate electrical energy. Presently, it is in operation but is underutilized.

6.5. Disposal of waste

MSW is normally disposed of in an open dump in many Indian cities and towns, which is not a proper method of disposal because open dumps pose environmental hazards which cause ecological imbalances with respect to land, water, and air pollution (Kansal, 2002). More than 90% of MSW in India is directly disposed of on the land in an unsatisfactory manner (Das et al., 1998).

Almost all of the cities have adopted open dumping for waste disposalexcept at Pune, where a partial sanitary landfill is under development, and at Nashik, where waste disposal is carried out in different cells which have adopted a method of sanitary landfilling. Leachate collection and treatment, and also biogas recovery, at landfills are not practiced in most of the cities. Earth cover is partly provided in a few cities including Mumbai, Kolkata, Chennai, Ahmedabad, Kanpur, Lucknow, Coimbatore, Nashik, Vadodara, Jamshedpur, Allahabad, Amritsar, Rajkot, Simla, Thiruvananthapuram, and Dehradun. Compaction of waste is carried out by compactor/bulldozers in 26 cities. In hilly region cities, disposal of waste is carried out along the valley ridges. Facilities such as fencing around the landfill, check-posts, firefighting, water, electricity, record maintenance, approach roads, and a plan for filling of different cells of the landfill in different seasons of the year are not available. It was observed that weighing of waste is not practiced in a large number of cities and the quantity of waste is estimated based on number of trips/day. The status of existing scenarios of MSWM systems as per MSW Rules, 2000 in 59 cities is presented in Table 1.

6.5.1. Impact of solid waste disposal on water quality

With a view to assessing the impact on water quality due to solid waste disposal at landfills, field data were collected in nine selected cities: Kolkata, Delhi, Chennai, Jammu, Sringar, Trivendrum, Coimbatore, Kochi, and Hyderabad. Groundwater samples from various sources, such as tube wells and bore wells located around landfill sites, were collected and analyzed for relevant physico-chemical parameters, including heavy metals.

Samples collected from cities like Jammu, Srinagar, Trivendrum, and Coimbatore indicated an impact on water quality in terms of excessive concentrations of iron and lead. In Kochi and Hyderabad, deterioration in water quality was observed due to higher chloride and TDS content than the permissible limits.

Overall, it was observed that the landfilling of MSW has an adverse impact on groundwater quality. However, to confirm this, and to further assess the magnitude of impact, detailed investigations are required that consider various aspects related to the landfills and groundwater.

6.5.2. Biomedical waste management

In a number of cities, biomedical waste from hospitals and healthcare units was found to be disposed of at MSW disposal sites, even though incinerators are installed in hospitals. Incinerators have been installed in a number of cities but are not properly operated to destroy infectious waste. According to Biomedical Wastes (Management and Handling) Rules, 1998, centralized facilities are in the developmental stage and large metropolitan cities have initiated collection of hospital/clinical wastes from different residential areas; these would be burnt at a centralized facility. Separate vehicles for biomedical waste collection are provided in Nashik, Nagpur, and Kolkata with proper manifests, which are operated by private agencies. The cost of the collection service is recovered from hospitals/dispensaries/clinics based on either number of beds or on a monthly basis.

At Mumbai, Hyderabad, Bangalore, Kolkata, and Delhi, vehicles are operated during the night shift and weight records are maintained.

6.6. Solid waste quantities

It was observed that the quantity of solid waste transported each day from various community bins/containers was not properly recorded by a large number of municipal agencies. Estimation of quantity was based on trips/vehicle to the disposal site as a majority of cities do not have a weighing facility. Improper placement of vehicles and improper vehicle routes often result in a situation where the waste remains uncollected in spite of the availability of vehicles in garages. This can be avoided by maintaining a continuous dialogue between the staff of the conservancy department and the transport wing, especially in metropolitan cities.

During field studies, the solid waste transported per trip by different vehicles was determined by weighing the vehicles on weighbridges for 5 consecutive days. In large cities like Mumbai, Delhi, Kolkata, Chennai, and Hyderabad, municipal corporations have installed weighbridges. In other cities, small state capitals, and union territories, weighing of MSW is carried out through private weighbridges. On the basis of the number of trips/day from different wards/zones of the city, the quantities collected from various wards were also determined. Knowing the population of the city, the waste generation rate in terms of kg/capita/day was computed.

The estimated waste generation rates in kg/capita/day for various population ranges are as categorized as follows:

- Cities with a population < 0.1 million (8 cities): waste generation was 0.17–0.54 kg/capita/day.
- Cities with a population of 0.1–0.5 million (11 cities): waste generation was 0.22–0.59 kg/capita/day.
- Cities with a population of 1–2 million (16 cities): waste generation was 0.19–0.53 kg/capita/day.
- Cities with a population > 2 million (13 cities): waste generation was 0.22–0.62 kg/capita/day.

Amongst the 59 cities studied, a few cities have similar populations: Itanagar and Daman (population around 0.035 million),

Table 1
Status of Cities and state capitals in implementation of MSW (Management and Handling) Rules, 2000

Name of City	Waste Qty. (TPD)	MSW Management Scenario			Collection of MSW			Transportation of MSW				Processing of MSW				Disposal of MSW – Situation Analysis at Landfill Site						
		Organization in charge	Penalty clause	Manual handling	Community bin system	House to house collection	Segregation by rag pickers at community bin/landfill	Municipal vehicles	Private vehicles	Provision of tarpaulin/ good quality cover	Transfer station facility	Composting (TPD)	Vermicomposting (TPD)	Pelletization & waste to energy	Biomethanation & any other	Uncontrolled dumping	Sanitary landfill site	Earth cover	Compaction of SW	Leachate collection & treatment facility	Biogas recovery facility	Remaining useful life of landfill (yr)
Greater Mumbai	5320	DMC	✓	✓	✓	Partially	✓	✓	✓	✓	✓	*	×	×	×	✓	×	✓	✓	×	×	N
Kolkata	2653	DCE	×	✓	✓	Partially	✓	✓	×	×	×	700	×	×	×	✓	×	✓	×	×	×	N
Delhi	5922	EE	✓	✓	✓	Partially	✓	✓	×	✓	✓	×	53	×	×	✓	×	×	✓	×	×	N
Chennai	3036	SE	×	×	×	Fully	✓	✓	×	✓	✓	*	×	×	×	✓	×	✓	×	×	×	3
Bangalore	1669	DMC	×	×	×	Fully	✓	✓	✓	✓	×	300	×	×	×	✓	×	×	×	×	×	N
Hyderabad	2187	MCH	✓	✓	✓	Partially	✓	✓	×	✓	✓	700	7	×	×	✓	×	×	✓	×	×	20
Ahmedabad	1302	Director	×	✓	✓	Partially	✓	✓	×	×	×	500	×	×	×	✓	×	✓	✓	×	×	10
Pune	1175	DHO	✓	✓	✓	Partially	✓	✓	×	✓	✓	*	50	×	✓	✓	×	×	✓	✓	×	N
Surat	1000	CE	×	✓	✓	Partially	×	✓	×	✓	✓	*	×	×	×	✓	×	×	×	×	×	N
Kanpur	1100	HO	×	✓	✓	No	×	✓	×	✓	×	*	×	×	×	✓	×	✓	×	×	×	N
Jaipur	904	DMC	✓	✓	✓	Partially	✓	✓	✓	✓	×	*	×	×	×	✓	×	✓	✓	×	×	N
Lucknow	475	HO	×	✓	✓	Partially	✓	✓	×	✓	×	*	×	×	300	✓	×	×	✓	×	×	N

DMC: Dy. Municipal Commissioner, **DCE**: Dy. Chief Engineer, **HO**: Health Officer, **CE**: Chief Engineer, **SE**: Superintending Engineer, **DHO**: Dy. Health Officer, **EE**: Executive Engineer; MCH: Municipal Corporation of Hyderabad
N: Life of Existing Landfill not indicated by municipal agency, * Capacity data not available

Name of City	Waste Qty. (TPD)	MSW Management Scenario			Collection of MSW			Transportation of MSW				Processing of MSW				Disposal of MSW – Situation Analysis at Landfill Site						
		Organization in charge	Penalty clause	Manual handling	Community bin system	House to house collection	Segregation by rag pickers at community bin/landfill	Municipal vehicles	Private vehicles	Provision of tarpaulin/ good quality cover	Transfer station facility	Composting (TPD)	Vermicomposting (TPD)	Pelletization & waste to energy	Biomethanation & any other	Uncontrolled dumping	Sanitary landfill site	Earth cover	Compaction of SW	Leachate collection & treatment facility	Biogas recovery facility	Remaining useful life of landfill (yr)
Nagpur	504	HO	✓	×	×	Fully	×	✓	×	✓	×	*	30	×	×	✓	×	×	×	×	×	7
Patna	511	CEO	×	✓	✓	No	×	✓	×	×	×	*	×	×	×	✓	×	×	×	×	×	1
Indore	557	CHO	×	✓	✓	Partially	×	✓	×	✓	×	×	1.25	×	×	✓	×	×	✓	×	×	N
Vadodara	357	MC	×	✓	✓	Partially	✓	✓	×	×	✓	×	×	×	×	✓	×	✓	×	×	×	N
Bhopal	574	DMC	×	✓	✓	Partially	×	✓	×	×	×	100	×	×	×	✓	×	×	✓	×	×	N
Coimbatore	530	HO	×	✓	✓	Partially	×	✓	×	×	×	*	×	×	×	✓	×	✓	×	×	×	N
Ludhiana	735	HO	×	✓	✓	Partially	✓	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Kochi	400	HO	×	✓	✓	Partially	×	✓	✓	×	×	×	×	×	×	✓	×	×	×	×	×	N
Vishakha-pattanam	584	HO	×	✓	✓	Partially	×	✓	×	×	×	×	×	×	×	✓	×	×	✓	×	×	N
Agra	654	HO	×	✓	✓	Partially	×	×	×	×	×	×	×	×	×	✓	×	×	✓	×	×	N
Varanasi	425	HO	×	✓	✓	Partially	✓	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Madurai	275	HO	×	✓	✓	Partially	✓	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N

CHO: Chief Health Officer, **CEO**: Chief Executive Officer, **MC**: Municipal Commissioner

(*continued on next page*)

Table 1 (*continued*)

Name of City	**Waste Qty. (TPD)**	**MSW Management Scenario**			**Collection of MSW**			**Transportation of MSW**				**Processing of MSW**				**Disposal of MSW – Situation Analysis at Landfill Site**						
		Organization in charge	Penalty clause	Manual handling	Community bin system	House to house collection	Segregation by rag pickers at community bin/landfill	Municipal vehicles	Private vehicles	Provision of tarpaulin/ good quality cover	Transfer station facility	Composting (TPD)	Vermicomposting (TPD)	Pelletisation & waste to energy	Biomethanation & any other	Uncontrolled dumping	Sanitary landfill site	Earth cover	Compaction of SW	Leachate collection & treatment facility	Biogas recovery facility	Remaining useful life of landfill (yr)
Meerut	490	HO	×	✓	✓	No	✓	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Nashik	200	HO	×	×	×	Fully	✓	✓	✓	✓	×	300	×	×	×	✓	×	✓	✓	×	×	N
Jabalpur	216	HO	×	✓	✓	Partially	×	✓	✓	×	×	×	×	×	×	✓	×	×	×	×	×	N
Jamshedpur	338	PP	×	✓	✓	No	×	×	✓	×	×	40	×	×	×	✓	×	✓	✓	×	×	N
Asansol	207	ME	×	✓	✓	Partially	×	×	✓	×	×	×	×	×	×	×	×	×	✓	×	×	15
Dhanbad	77	SO	×	✓	✓	No	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	1
Faridabad	448	HO	×	✓	✓	Partially	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	5
Allahabad	509	AHO	×	✓	✓	No	×	✓	×	✓	×	×	×	×	×	✓	×	✓	✓	×	×	5
Amritsar	438	MHO	×	✓	✓	Partially	×	✓	×	✓	×	×	×	×	×	✓	×	✓	✓	×	×	N
Vijaywada	374	MC	×	✓	✓	Partially	×	✓	×	×	×	×	×	✓	✓	✓	×	×	✓	×	×	N
Rajkot	207	DMC	×	✓	✓	No	✓	✓	×	✓	✓	×	×	×	×	✓	×	✓	×	×	×	N
Port Blair	76	SO	×	✓	✓	No	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N

PP: Private Party, **ME**: Municipal Engineer, **SO**: Special Officer, **AHO**: Asst. Health Officer, **MHO**: Municipal Health Officer, **MC**: Municipal Commissioner

Name of City	**Waste Qty. (TPD)**	**MSW Management Scenario**			**Collection of MSW**			**Transportation of MSW**				**Processing of MSW**				**Disposal of MSW – Situation Analysis at Landfill Site**						
		Organizational In charge	Penalty clause	Manual handling	Community bin system	House to house collection	Segregation by rag pickers at community bin/landfill	Municipal vehicles	Private vehicles	Provision of tarpaulin/ good quality cover	Transfer tation facility	Composting (TPD)	Vermicomposting (TPD)	Pelletisation & waste to energy	Biomethanation & any other	Uncontrolled dumping	Sanitary landfill site	Earth cover	Compaction of SW	Leachate collection & treatment facility	Biogas recovery facility	Remaining useful life of landfill (yr)
Guwahati	166	MC	✓	✓	✓	No	×	×	✓	✓	×	×	×	×	×	✓	×	×	✓	×	×	N
Chandigarh	326	MOH	×	×	×	Fully	×	✓	×	✓	×	×	*	×	×	✓	✓	×	×	×	×	N
Raipur	184	HO	×	✓	✓	Partially	×	✓	×	×	×	100	×	×	×	✓	×	×	×	×	×	N
Panjim	32	AO/TO	×	×	×	Fully	×	✓	×	✓	×	×	*	×	×	✓	×	×	✓	×	×	N
Gandhinagar	44	DC	×	✓	✓	No	✓	✓	×	✓	×	×	×	×	×	✓	×	×	×	×	×	N
simla	39	HO	×	✓	✓	Partially	✓	✓	×	×	×	40	×	×	×	✓	×	✓	✓	×	×	N
Srinagar	428	HO	×	✓	✓	Partially	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Ranchi	208	HO	×	✓	✓	Partially	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Thiruvanamthapuram	171	HO	×	✓	✓	Partially	×	✓	×	✓	×	150	×	×	×	✓	×	✓	✓	×	×	N
Imphal	43	HO	×	✓	✓	Partially	×	✓	×	×	×	×	×	×	×	✓	×	×	✓	×	×	N
Shillong	45	CEO	×	✓	✓	Partially	✓	✓	×	✓	×	100	×	×	×	✓	×	×	×	×	×	N
Aizawal	57	SO	×	✓	✓	No	×	✓	×	×	×	×	×	×	×	✓	×	×	✓	×	×	N

CEO: Chief Executive Officer, **DC**: District Collector, **MOH**: Municipal Officer (Health), **AO/TO**: Accounts Officer/Tax Officer

(*continued on next page*)

Gandhinagar and Dhanbad (population around 0.2 million), Pondicherry and Imphal (population around 0.221 million), Chandigarh and Guwahati (population around 0.81 million), Ranchi and Vijaywada (population around 0.85 million), Madurai, Coimbatore and Jabalpur (population around 0.930), and Amritsar and Rajkot (population around 0.967 million.

In these cities, in spite of similar populations, variations in waste generation rates have been observed. One reason for variations in waste generation rates may be that the field studies were conducted in these cities during different seasons of the year. Other possible reasons are differences in standard of living, food habits, geographical status, employment of workers per 1,000 population, road conditions, difference in implements, equipment and machinery used, and climatic conditions, which all vary from city to city. The MSW systems of cities with similar populations can ideally be compared under similar conditions. However, it is difficult to identify any specific reasons for variations in waste generation rates for the cities covered under the present project because of wide variations in the parameters prevailing in different cities.

Very few metropolitan cities, such as Mumbai, have separate collection vehicles for debris, and separate collection of slaughterhouse waste was not observed in the majority of the cities. Slaughterhouse waste was usually transported along with the MSW to the disposal sites, which is a very unhealthy practice.

Table 1 (*continued*)

Name of City	Waste Qty. (TPD)	MSW Management Scenario			Collection of MSW			Transportation of MSW				Processing of MSW				Disposal of MSW – Situation Analysis at Landfill Site						
		Organization in charge	Penalty clause	Manual handling	Community bin system	House to house collection	Segregation by rag pickers at community bin/landfill	Municipal vehicles	Private vehicles	Provision of tarpaulin/ good quality cover	Transfer station facility	Composting (TPD)	Vermicomposting (TPD)	Pelletisation & waste to energy	Biomethanation & any other	Uncontrolled dumping	Sanitary landfill site	Earth cover	Compaction of SW	Leachate collection & treatment facility	Biogas recovery facility	Remaining useful life of landfill (yr)
Kohima	13	AO	×	✓	✓	No	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Bhuveneshwar	234	HO	×	✓	✓	Partially	×	✓	✓	×	×	×	×	×	×	✓	×	×	×	×	×	N
Agartala	77	CEO	×	✓	✓	Partially	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Dehradun	131	SHO	×	✓	✓	Partially	✓	✓	×	×	×	×	×	×	×	✓	×	✓	✓	×	×	N
Pondicherry	130	HO	×	✓	✓	Partially	✓	✓	×	✓	×	×	5	×	×	✓	×	×	×	×	×	N
Itanagar	12	DC	×	✓	✓	No	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Gangtok	13	JS	✓	×	×	Fully	×	✓	×	✓	×	50	×	×	×	✓	×	×	✓	×	×	N
Kavaratti	3	CP	×	✓	✓	Partially	×	×	✓	×	×	×	×	×	×	✓	×	×	×	×	×	N
Daman	15	ME	×	✓	✓	No	×	✓	×	×	×	×	×	×	×	✓	×	×	✓	×	×	N
Jammu	215	HO	×	✓	✓	Partially	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N
Silvassa	16	CMO	×	✓	✓	No	×	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	N

DC: Dy. Commissioner, JS: Joint Secretary, **CP**: Chairperson (Village Panchayat), **CMO**: Chief Medical Officer, **SHO:** Senior Health Officer

6.7. Solid waste characteristics

Waste composition depends on a wide range of factors such as food habits, cultural traditions, lifestyles, climate and income, etc. (Gupta et al., 1998). Sampling points were selected in posh localities and areas of medium and low standard of living, in consultation with the municipal authorities of all cities. These represented various residential, commercial, market, and industrial areas. The waste samples were analyzed for various physico-chemical parameters using standard procedures. The NPK values follow the usual trend in 59 cities. The compostable organic and recyclable fractions were observed to be higher in some cities and may be due to improved standard of living. For cities having population < 0.1 million and between 0.11–0.5 million (19 cities), the C/N ratio was 18–37, the compostable fraction was 29–63%, and total recyclables were observed to be 13.68–36.64%. A higher moisture content in the MSW was observed at Shillong, Kohima (65%), Simla, and Agartala due to heavy rains. High calorific value on a dry weight basis was observed to vary from 591 to 3766 kcal/kg.

For cities with a population of 0.5–1 million (16 cities), many constituents were variable such as compostable matter of 35–65%, recyclables of 11–24%, a C/N ratio of 17–52, high calorific value on a dry weight basis of 591–2391 kcal/kg, and moisture content of 17–64%.

For cities having a population of 1–2 million (11 cities), the ranges for various constituents varied, with a compostable fraction of 39–54%, recyclables of 9–25%, C/N ratio of 18–52, high calorific value (on dry weight basis) of 520–2559 kcal/kg, and moisture content of 25–65%.

In the case of cities with populations greater than 2 million (13 cities), the constituents varied such that the compostable fraction was 40–62%, recyclables were 11–22%, the C/N ratio was 21–39, the high calorific value (on a dry weight basis) was 800–2632 kcal/kg, and moisture content was 21–63%.

7. Diagnostic analysis of existing practices of MSWM in India

In many cities, the Health Officers/Chief Medical Officer/Deputy Commissioner/Assistant Health Officer is in charge of the MSWM activities and, in a few smaller cities, the activities are administrated by the Chief Officer/Special Officer/CEO/Jt. Secretary/Tax Officer, etc. Mega cities such as Mumbai, Delhi, and Kolkata have separate solid waste management departments.

Manpower provisions range between 2–3 workers per thousand in 32 out of 59 (or 54%) of the cities. Manpower deployment in the range between 1–2 workers per thousand has been reported for cities such as Ludhiana, Surat, and Thiruvananthapuram. Cities with less than 1 worker per thousand are Agra, Dhanbad, Ranchi, Aizawal, Gangtok, Imphal, Kanpur, Silvasa, etc. The largest workforce was observed at Port Blair and the lowest at Gangtok.

For effective solid waste management in a city, the desired strength of workers is 2–3 workers per thousand, which has been indicated as adequate based on earlier studies carried out by NEERI in more than 40 Indian cities. However, this number may change based on local conditions. For MSWM, every municipal agency can decide the strength of workers by considering the productivity of workers, which can be considered to be 200–250 kg/worker/8 h shifts.

It will be necessary to carry out time and motion studies in various wards in a city with different population densities to assess the average productivity of a worker; the required number of workers can be decided by keeping a standby arrangement of 15–20%.

Many cities do not have correct data on an allocated budget for solid waste management. However, based on the secondary data on budget allocation provided by every civic agency, it has been concluded that most of the municipalities in bigger cities spend 5–10% of their total budget on solid waste management. This number is low and priority is given to other activities. Municipal corporations in 9 cities, namely Greater Mumbai, Delhi, Hyderabad, Pune, Jaipur, Nagpur, Guwahati, and Gangtok, have imposed penalty clauses on the public for non-compliance.

The transfer and transport of waste, involving deployment of vehicles, provision of garages for vehicle parking, and workshops for repair and maintenance are the responsibilities of the transport wing of the municipal authority in all the cities. However, in a few cities such as Aizawal, Kavaratti, Imphal, Shillong, Daman, Kolkata, Allahabad, and Patna, these are managed by private parties. A mixed fleet of vehicles, such as open body trucks, tippers, dumper

Table 2
Statistical analysis of categories of MSW in different cities of India

Category of waste	*F* ratio	Significant values
Compostables	1.228	0.509
Recyclables	2.971	0.201
C/N Ratio	0.255	0.987
HCV	0.612	0.808

F: Fisher ratio = variance between groups/variance within sample.

placers, compactors vehicles, tractor–trailers, three-wheeler autos, and tricycles are used for primary collection. bulk refuse carriers (Mumbai) and large capacity tippers at transfer stations are used in Hyderabad as secondary vehicles. The vehicles are provided with a PVC/tarpaulin cover during transportation of MSW to disposal sites to minimize spillage of solid waste. The vehicles are parked in an open space where they are exposed to variable weather conditions. As these vehicles are also used to transport highly corrosive material, faster corrosion of the vehicles occur, thus reducing their economic life. Routine and preventive maintenance facilities were observed to be meager. Many vehicles used for transportation have outlived their economic life, resulting into higher expenditure on breakdown repairs. Private agencies are involved in parts of the urban population for transportation of waste in a few metropolitan cities and state capitals like Mumbai, Chennai, Bangalore, Jaipur, Kochi, Nashik, Jabalpur, Jamshedpur, Asansol, Bhubaneshwar, and Kavaratti. Transfer stations exist in few metro cities like Mumbai, Chennai, Delhi, Hyderabad, Surat, Vadodara, Rajkot, and Pune.

Biological treatment methods for waste reduction have been adopted in a large number of cities. These include aerobic composting (13 cities), vermicomposting (5 cities), and biomethanation at Lucknow. However, their performance is not satisfactory. Thermal processing using incineration of MSW with a capacity of 700 TPD has been initiated at Hyderabad.

Solid waste disposal at landfill sites, without following the guidelines stipulated in MSW (Management and Handling) Rules, 2000, is being practiced in most of the cities.

Based on the data collected and extensive field investigations, the salient findings with respect to different components such as waste quantity, waste generation rate, and different categories of waste of MSWM systems in all 59 cities are shown in Fig. 4. The statistical analysis of the results is presented in Table 2.

The statistically significant values for different categories of waste were calculated by the ANOVA technique and were compared; the significant values found were: compostables, 0.509; recyclables, 0.201; C/N ratio, 0.987; and HCV, 0.808. The standard significant values vary between -1 and +1, and the calculated significant values for different fractions of MSW estimated using the ANOVA technique lie between 0.201and 0.987, which indicate reliability of the results. It is observed that the significant values are moderate, and for better MSWM, more suitable and sustainable management policies should be implemented.

8. City/Location specific constraints in implementation of MSWM recommendations

During field investigations, it was observed that, in some cities located in hilly and coastal areas as well as on islands, there are specific problems posing constraints in the implementation of a MSWM system. The problems of cities at specific locations are mentioned in this section.

8.1. Cities located in hilly areas

- Waste is often disposed of in valleys, spoiling the aesthetics
- The roads are very narrow; hence, the installation of large dustbins is not possible
- Conventional types of waste transfer equipment are not suitable due to variable terrain conditions
- Efficiency of sweepers is low due to slopes along the roads
- Vehicles with a longer turning radius are not suitable due to narrow roads and one-way traffic
- Setup of a large capacity processing plant is constrained due to scarcity of land
- Dependency on nearby city on plains for various resources causes hurdles in the handling and management of MSW

8.2. Coastal cities

- Dumping of solid waste causes carryover of waste to the sea when the disposal site is located near the seashore
- High rainfall in coastal cities causes more leachate generation
- Sandy soil strata results in infiltration of leachate to groundwater
- Scarcity of land adversely affects implementation of MSWM system

8.3. Island cities

- High groundwater table and high permeability of soil cause water pollution
- Scarcity of land makes landfill development and processing plant installation difficult
- Distance from the mainland makes the progress of SWM activities slow
- Chances of natural calamity are higher due to surrounding sea
- Implements and equipment easily corrode due to high humidity conditions
- Since rag pickers do not segregate recyclables for use, their storage and disposal becomes a problem due to scarcity of land
- Huge quantities of tender coconuts are generated as waste, which pose a disposal problem

9. Indicative strategies and guidelines for formulation of an action plan for MSWM

To achieve discernible improvements in existing MSWM systems in all the 59 cities, strategies and indicative guidelines have been formulated to enable preparation of an action plan for effective MSWM. These are presented in this section.

9.1. Collection of waste

Proper work norms suited to local conditions should be adopted with improved supervision. House-to-house collection by containerized handcart/tricycle as stipulated in MSW (Management and Handling) Rules, 2000 should be initiated in more residential areas and supported by public awareness campaigns. These activities will be beneficial in the long term. Additional welfare facilities for workers engaged in MSWM activities should be provided.

9.2. Efficient collection and transportation

Better designed containers for collection should be used instead of assorted types of RCC/masonry community bins, and their design should be compatible with the transport vehicle. Additionally, active involvement of citizens will lead to improved collection efficiency. Initiation of house-to-house collection using PVC contain-

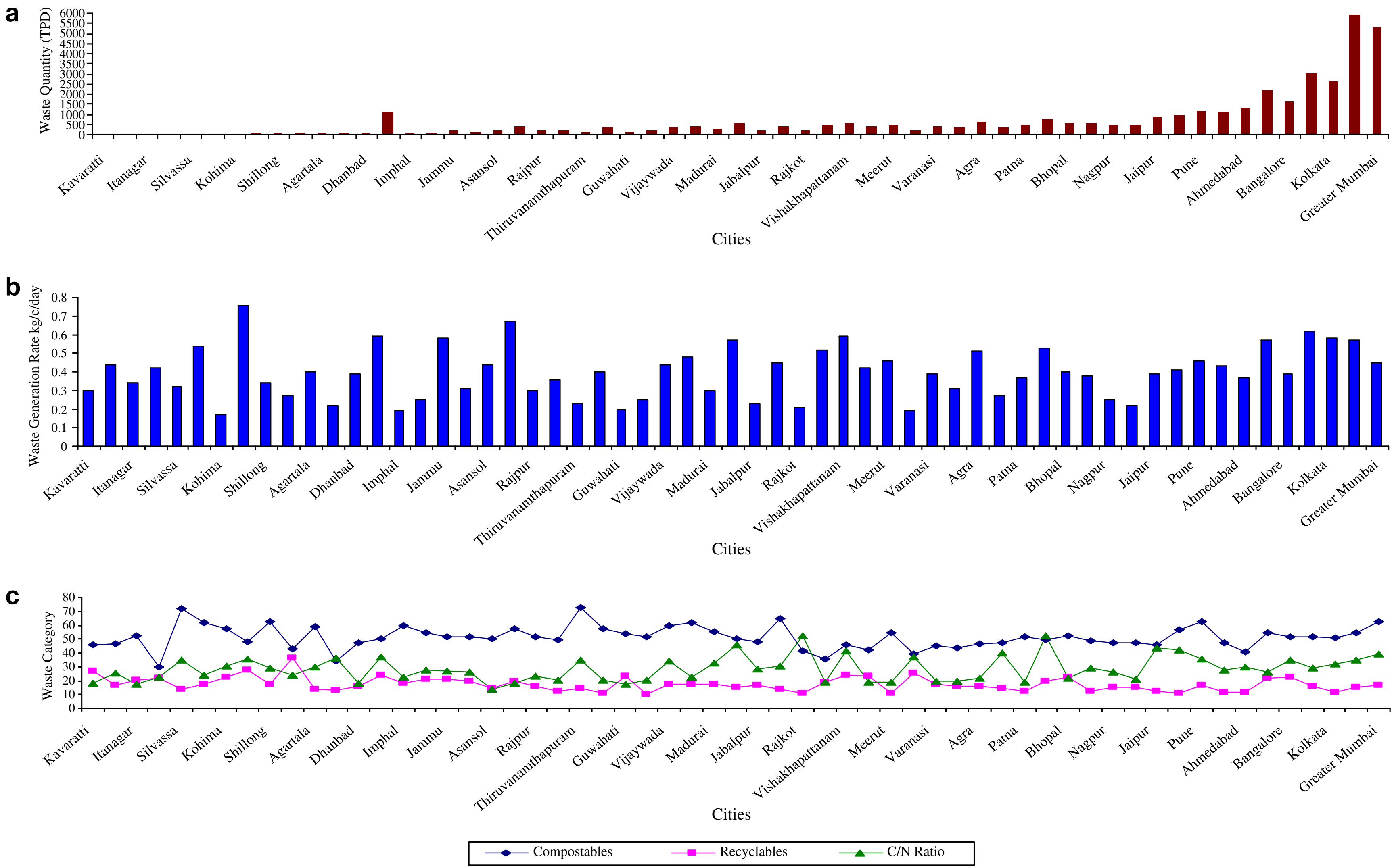

Fig. 4. Waste quantity generation rates, and waste category for cities in India. (a) Waste quantity (TPD) vs. cities, (b) waste generation rate (kg/c/day) vs. cities and (c) waste category vs. cities.

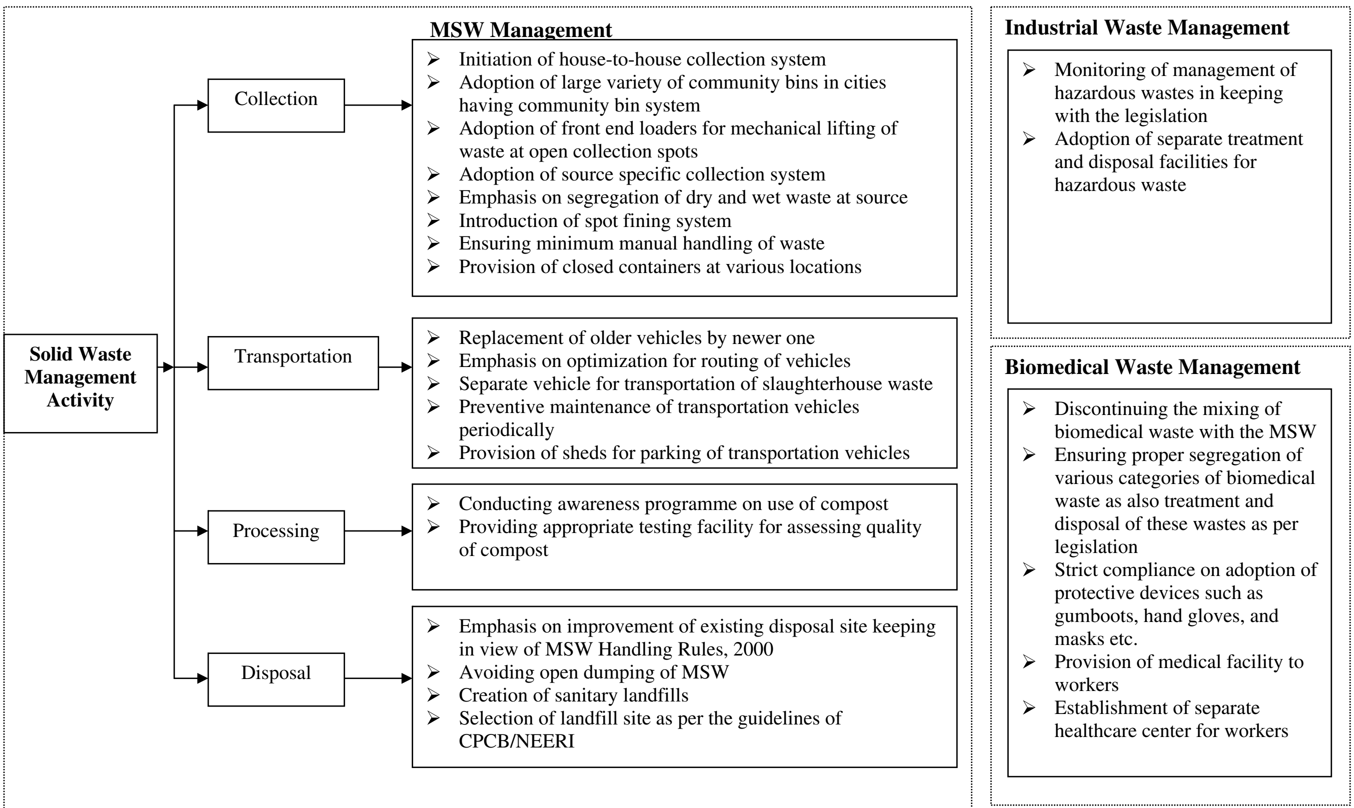

Fig. 5. Flow-diagram for indicative action plan for solid waste management.

ers for separate collection of wet and dry recyclable components is necessary. Appropriate vehicle selection, ensuring movement of vehicles along the planned routes, and adequate maintenance in the workshop will result in higher productivity.

9.3. Minimization of waste

Increased recycling, by the residents themselves or with the assistance of voluntary agencies, needs to be practiced. This will reduce the quantity of waste to be transported and disposed of, which will not only be economical but will also reduce the required landfill volume.

9.4. Processing of waste

For the biodegradable fraction of waste, processing technologies such as composting and vermicomposting should be adopted. This will reduce the waste quantity being transported and disposed of at the landfill site, thus reducing the required capacity of the landfill.

In addition, other technologies can also be adopted, such as incineration, pyrolysis, RDF, biomethanation, etc. However, such technologies can be attempted only after ensuring their suitability based on waste composition and economic aspects.

9.5. Sanitary landfill for waste

Landfills should have facilities for weighing of solid waste, an approach road, internal roads, a water supply for workers, facilities for extinguishing fires, adequate cover material, a compaction facility, a check post for maintenance of records, leachate collection and treatment, biogas recovery, fencing around landfills, and a tree plantation provision. A detailed plan should be prepared after identifying the areas to be filled during different periods, and development of sanitary landfilling should be initiated. However, city-specific detailed investigations need to be carried out to evolve an effective MSWM system.

9.6. Increased financial provision for MSWM system

Increases in allocation of funds are very much required for MSWM activities in all cities. The recurring costs on MSWM can be reduced by better control over operation of the system.

9.7. Long-term plans

A long-term plan should be developed based on projections for future solid waste quantities. Accordingly, the resources required should be estimated, including collection equipment and implements, vehicles for transportation, maintenance facilities, and landfill equipment.

9.8. Action plan

The above-mentioned strategies are of a general nature. In keeping with the provisions made under MSW (Management and Handling) Rules, 2000, each municipal agency is required to prepare a specific action plan for a particular city considering local conditions and the specific waste scenario. An indicative action plan for MSW management in India is presented in Fig. 5.

10. Conclusions

Studies carried out in the selected 59 cities have revealed that there are many shortcomings in the existing practices followed for the management of MSW. These pertain mainly to inadequate manpower, financial resources, and implements/machinery required to effectively carry out various activities of MSWM. In most of the cities, the waste quantity is not measured and is usually assessed based on number of trips made by transportation vehicles. Proper records for timely action are not maintained. Based on the data collected and the assessment carried out, it is necessary to initiate improvement measures. To overcome the deficiencies in the existing MSWM systems, an indicative action plan incorporating strategies and guidelines has been delineated. Based on this plan, municipal agencies can prepare specific action plans for their respective cities. A need also exists to strengthen existing monitoring mechanisms, particularly from the point of view of implementation of provisions made in MSW (Management and Handling) Rules, 2000.

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