Chapter 6
Sustainable Municipal Waste Management in Indian Cities

Tapas Kumar Ghatak

1 Introduction

Municipal solid waste (MSW) and its management is a major issue for most of the urban local bodies (ULBs) in India, where un-intervened urbanisation along with a change of consumption pattern have impacted MSW generation substantially. We are in an era when plastic is an unavoidable commodity. From the morning tooth-brush to every activity, polymers play an important role in our daily life. We cannot ignore the need of polymer in our daily life and also its impact on the waste plastic and its management.

Effective solid waste management (SWM) is a major challenge in most of the cities with high and increasing population density. A substantial increase in urban population with constant increment of in-migration of rural population along with unassessed floating population specially in large megacities, religious cities and hill cities have prevented any perfect policy framing and its execution. Achieving sustainable development within a country experiencing rapid population growth and improvement in living standards are made more difficult in India, because it is a diverse country with varied economic groups, cultures and traditions.

Despite significant development in social, economic and environmental areas, SWM systems in India have remained relatively unchanged. The informal sector has a key role in extracting value from waste, with approximately 90% of residual waste currently dumped rather than properly landfilled (Narayan, 2008). There is an urgent need to move towards more sustainable SWM and this requires new management systems and waste management facilities. Current SWM systems are inefficient, with waste having a negative impact on public health, the environment and the economy.

T. K. Ghatak (✉)
CREDAI, New Delhi, India

Environmental Cell, KMDA, Government of West Bengal, Kolkata, West Bengal

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The Municipal Solid Wastes (Management & Handling) Rules, 2000 in India were introduced by the Ministry of Environment and Forests (MoEF), which have been duly modified in 2016 (MoEF, 2016), and are expected to address the challenges and show a workable path in the coming years. However, these recent modifications and the implementation of Solid Waste Management Rules 2016 by the Indian Government will surely improve the situation and the benefit is already visible.

This chapter reviews the challenges, barriers and opportunities associated with improving waste management in India. It is the output from an international seminar on 'Sustainable solid waste management for cities: opportunities in SAARC countries' organised by the Council of Scientific and Industrial Research-National Environmental Engineering Research Institute (CSIR-NEERI) and held in Nagpur, India in 2015. SAARC is the South Asian Association for Regional Cooperation and includes Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka and Afghanistan.

Thus, in a nutshell population explosion coupled with change in life style of people results in increased generation of solid wastes in urban as well as rural areas of the country. At present, the municipal solid waste disposal methods followed in many of the cities and towns are unsystematic and unscientific and involve dumping in low-lying areas. Most of the dumping sites are just uncontrolled dumps where a mixture of domestic, commercial, industrial and medical wastes is 'thrown away'.

Apart from polluting air, soil and groundwater, open dumping of wastes generally becomes breeding ground for various dreadful disease-causing pathogens and vectors, particularly in the vicinity of the disposal sites. Thus, scientific disposal of solid waste is needed to make a sustainable future with healthy and hygienic environment.

Presently, land scarcity is a major problem to develop a landfill site. So, emphasis is being given on reduce, reuse and recycle policy of waste management. Moreover, the distance of landfill site from the source of waste generation increases the expense of transportation. Thus, decentralised waste management centre will surely reduce the burden of the land-fill. At the same time, it can be mentioned that proper utilisation of waste can generate revenue for the management. Only the hazardous and unmanageable waste should go for landfilling. Therefore, proper waste management can help in reducing at least 80% burden at landfill site, thus increasing the life of the site and at the same time helping to use the waste as resource. Solid Waste Management Rules, 2016 has more or less addressed all these issues and also encouraged an introduction of entrepreneurship model in waste management in Indian Cities and also in its non-urban areas.

2 Growth of Urban India and its Waste

The process of urbanisation in developed countries are characterised by high level of urbanisation and some of them are in final stage of urbanisation process. In majority of the developing countries, the rate of urbanisation is very fast and it is not accompanied by industrialisation but by rapid growth of service sector in economies

(Macbeth and Collins, 2002). Future growth of world's population is supposed to take place in the urban areas of less developed countries and the contribution of India in terms of urban population size, is quite substantial (Table 6.1). The population further increased to 1252 million in 2013 (Bhalla et al. 2013). Population growth is a major contributor to increasing MSW in India (Table 6.2).

2.1 Demographic Changes

India's total population has increased from 238.4 million in 1901 to 1028 million in 2001 whereas urban population has increased from 25.8 million in 1901 to 286.1 million in 2001 (nearly 30% of total population). India's urban population of 286 million was larger in size as compared to the combined total population of 12 countries in West Asia (=192.4 million) or five countries in East Asia (=206.8 million) excluding China (=1285 million), 40% of the European continent (=726.3 million) (Muttur, 2008). The percentage of urban population living in Class I cities (>100,000 population) has increased from 65% in 1991 to 69% in 2001 (Ministry of Housing and Urban Poverty Alleviation, 2007).

2.2 Growth of Urban Real Estate

India's globalisation and consequently urbanisation have shown remarkable selective growth by city sizes, regions and sectors. Higher growth and larger concentration of urban population in metropolitan areas are important features of India's urbanisation in post-globalisation period. The globalisation period has seen changes

Table 6.1 Population growth in India between 1911 and 2011

Census year	*Population* $\times 10^6$	*Decadal growth* $\times 10^6$	*Average annual exponential growth rate (%)*	*Progressive growth rate compared with 1911 (%)*
1911	252.0	13.7	0.56	5.75
1921	251.3	−0.8	−0.03	5.42
1931	278.9	27.6	1.04	17.02
1941	318.6	39.7	1.33	33.67
1951	361.1	42.4	1.25	51.47
1961	439.2	78.1	1.96	84.25
1971	548.1	108.9	2.20	129.94
1981	683.3	135.1	2.22	186.64
1991	846.4	163.1	2.16	255.05
2001	1028.7	182.3	1.97	331.52
2011	1210.2	181.4	1.64	407.64

(*Source*: Chandramouli, 2011)

Table 6.2 Predicted population growth and overall impact on waste generation

Year	*Population ($\times 10^6$)*	*Per capita generation (kg per day)*	*Total waste generation ($\times 10^3$ tonnes per year)*
2001	197.3	0.439	31.63
2011	260.1	0.498	47.30
2021	342.8	0.569	71.15
2031	451.8	0.649	107.01
2036	518.6	0.693	131.24
2041	595.4	0.741	160.96

(*Source*: Annepu, 2012)

in key urban sectors like housing, transport, commercial and information technology enabled services/business process outsourcing (ITES/BPO) segments. The opening up of 100% FDI in real estate had brought in big boom to the industry and was able to attract international private players to invest in Indian cities in joint venture with local partners (Chadchan and Shankar, 2012).

The vested interests in urban development have increased through the route of private sector participation in urban services sector. Privatisation has pushed the governments (national, state and local) to withdraw from certain development sectors like housing, infrastructure services including water supply, sanitation, sewage systems, urban transport, tourism, health services, telecommunication and electricity. The demand for infrastructure investment during the 11th Five Year Plan (2007–2012) was estimated to be US$ 492.5 billion (Planning Commission, 2008). To meet this growing demand, Government of India raised the investment in infrastructure from 4.7% of GDP to around 7.5–8% of GDP in the 11th Five Year Plan. In general, efforts towards infrastructure development have continued to focus on the key areas of physical and social infrastructure mostly in urban sectors. The spatial manifestation of investments and economic change are discernible through continuous or discontinuous sprawl with poly-nodal centres along the corridors (Fig. 6.1).

2.3 Waste Generation and Waste Characterisation Data

Estimating the quantity and characteristics of MSW in India and forecasting future waste generation are fundamentals to successful waste management planning (Rana et al., 2014). The quantity of MSW generated depends on living standards, the extent and type of commercial activity, eating habits and season (Kaushal et al., 2012). India generates approximately 133,760 tonnes of MSW per day, of which approximately 91,152 tonnes is collected and approximately 25,884 tonnes is treated (Kumar and Goel, 2009). MSW generation per capita in Indian cities ranges from approximately 0.17 kg per person per day in small towns to approximately 0.62 kg per person per day in cities (Table 6.3).

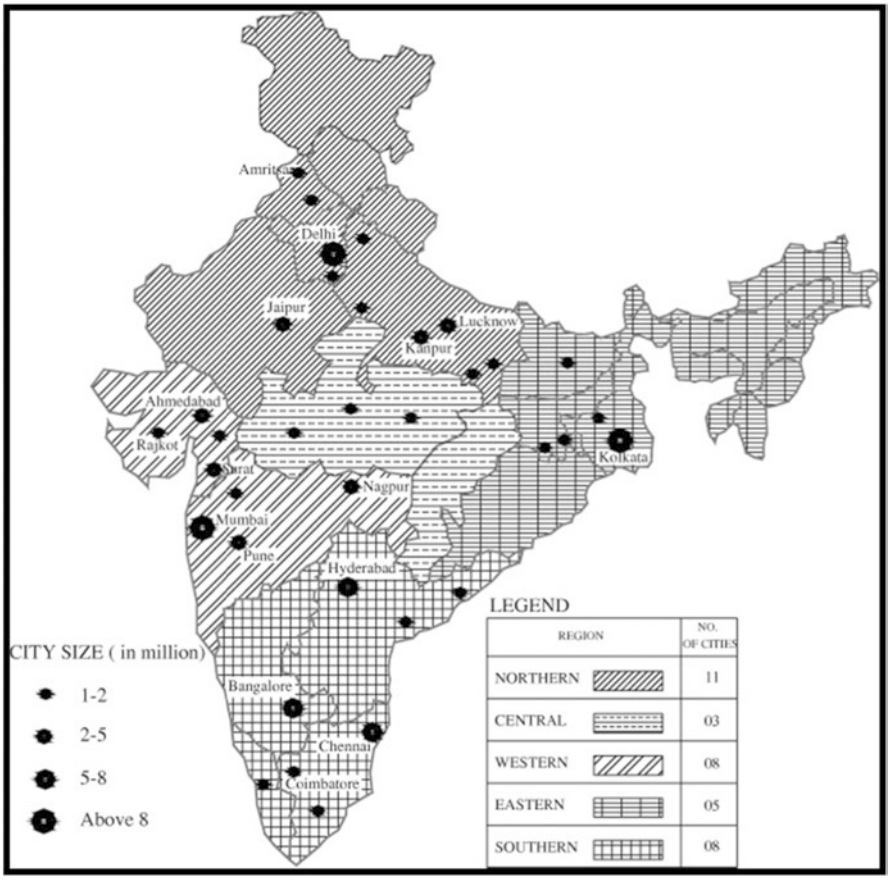

Fig. 6.1 Distribution of 35 million + cities across different regions. (*Source*: Author based on Census of India 1971, 1981, 1991, 2001)

Table 6.3 Waste generation per capita in Indian cities

Population	*Waste generation rate (kg per capita per day)*
Cities with a population <0.1 million (eight cities)	0.17–0.54
Cities with a population of 0.1–0.5 million (11 cities)	0.22–0.59
Cities with a population 1–2 million (16 cities)	0.19–0.53
Cities with a population >2 million (13 cities)	0.22–0.62

(*Source*: Kumar et al., 2009; Kumar and Goel, 2009)

2.4 Waste Generation Per Capita in Indian Cities

Waste generation rate depends on factors such as population density, economic status, level of commercial activity, culture and city/region. Figure 6.2 provides data on MSW generation in different states, that indicates high waste generation in Maharashtra (15,364–19,204 tonnes per day), Uttar Pradesh, Tamil Nadu, West Bengal (11,523–15,363 tonnes per day), Andhra Pradesh, Kerala (7683–11,522 tonnes per day) and Madhya Pradesh, Rajasthan, Gujarat, Karnataka and Mizoram (3842–7682 tonnes per day). Lower waste generation occurs in Jammu and Kashmir, Bihar, Jharkhand, Chhattisgarh, Orissa, Goa, Assam,

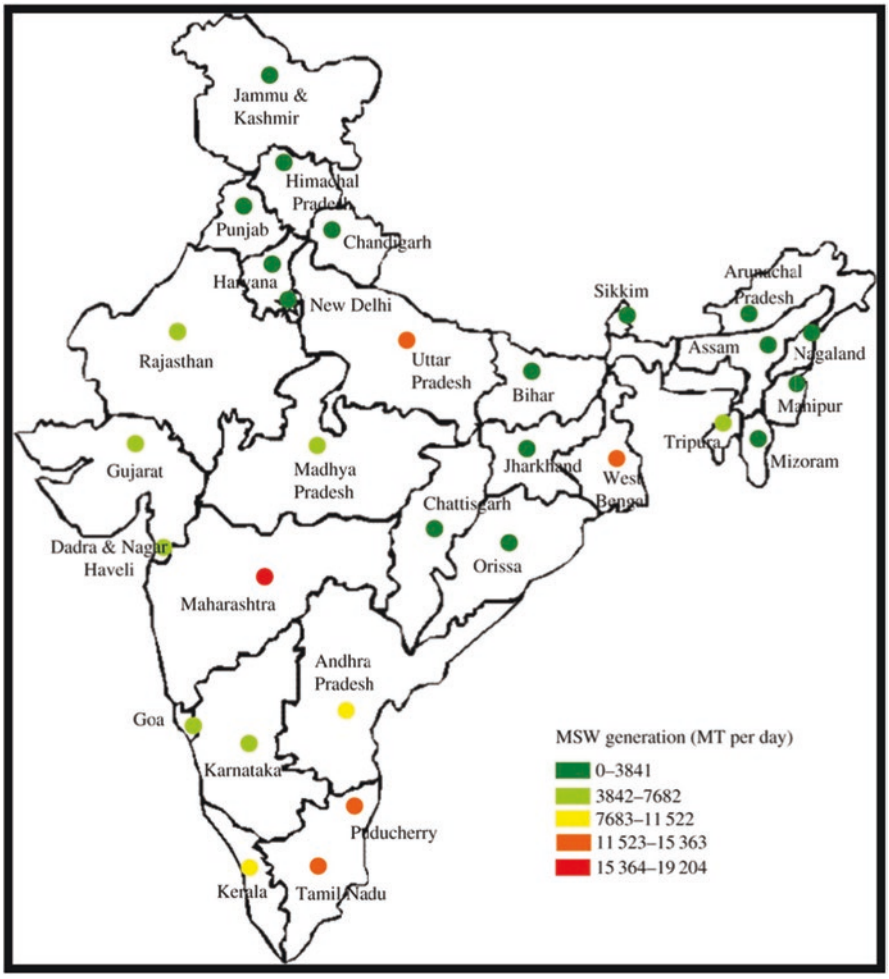

Fig. 6.2 State wise MSW generation (2009–2012) (*Source*: Kumar et al. 2017)

Arunachal Pradesh, Meghalaya, Tripura, Nagaland and Manipur (<3841 tonnes per day).

2.5 Characterisation of Waste

The economic impacts on waste composition is quite significant. High-income groups use more packaged products, resulting more waste in higher volumes of plastics, paper, glass, metals and textiles. Therefore, changes in waste composition have a significant impact on waste management practices (Rawat et al., 2013). MSW also contains hazardous wastes such as pesticides, paints, used medicine and batteries along with some unidentified waste like sanitary napkins, adult diapers (still not identified as medical waste). Compostable organics are generally fruits, vegetables and food waste. Most of these wastes are now required to be managed by Solid Waste Management Rules, 2016.

2.6 Salient Features of SWM Rules, 2016

The earlier MSW (M&H) Rules, 2000 were applicable to municipal authorities only. These covered 4041 urban local bodies in the country. The new Solid Waste Management Rules, 2016 are applicable beyond municipal areas and extend to urban agglomerations, census towns, notified industrial townships, areas under the control of Indian railways, airports, airbase, port and harbour, defence establishments, special economic zones, state and central government organisations, places of pilgrimage, religious and historical importance. Some of the significant changes in the rules which are expected to increase community (waste generator) participation and lead the waste management towards a sustainable format are as follows:

Rule 4 Section 1a. The source segregation of waste has been mandated to channelise the waste to wealth by recovery, reuse and recycle.

Rule 4 Section 6. New townships and group housing societies have been made responsible to develop in-house waste handling, and processing arrangements for bio-degradable waste.

Rule 4 Section 7. All resident welfare and market associations, gated communities and institution with an area >5000 m^2 should segregate waste at source – into valuable dry waste like plastic, tin, glass, paper, etc. and handover recyclable material to either the authorised waste pickers or the authorised recyclers, or to the urban local body. The bio-degradable waste should be processed, treated and disposed off through composting or bio-methanation within the premises as far as possible. The residual waste shall be given to the waste collectors or agency as directed by the local authority.

Table 6.4 Average (% by weight) composition of MSW in Indian metro cities

Percentage (%) by weight							
Compostable	*Inert*	*Paper*	*Plastic*	*Glass*	*Metals*	*Textile*	*Leather*
41	40	6	4	2	2	4	1

(*Source*: Sharholy et al., 2008)

Healthcare waste contains disposable syringes, sanitary materials and blood containing textiles and is governed by the Biomedical Waste Management Rules, 2016 and the Amended Rules, 2018 and 2019, and these are not to be mixed with MSW. The average composition of MSW produced by Indian cities is approximately 41 wt.% organic, approximately 40 wt.% inert, with approximately 19 wt.% potentially recyclable materials, as shown in Table 6.4 (Kumar et al., 2009). Most of the organic waste is generated from households, and inert waste is generated from construction, demolition and road sweeping. Waste samples collected from Delhi, Ahmedabad and Bangalore indicate that MSW composition varies between cities (Kumar and Goel, 2009; Rawat et al., 2013).

3 Current Waste Management Status in India

The MOEF issued Solid Waste Management Rules, 2016, which have already been discussed earlier in Section 2.6 to ensure proper waste management in India along with the pre-existing Municipal Solid Wastes (Management and Handling) Rules, 2000. These have clearly vested the power with the municipal authorities and made them responsible for implementing these rules and developing infrastructure for collection, storage, segregation, transportation, processing and disposal of MSW. Quite a few cities like Pune, Mumbai, cities in Kerala have initiated the process.

3.1 Role of the Informal Sector in Waste Materials Reuse and Recycling

The informal sector at present has a very important role in India and this must be integrated into formal and institutionalised SWM systems. The informal sector at present is characterised by small-scale, labour-intensive, largely unregulated and unregistered low-technology, untrained man powers leading to manufacturing or provision of materials and services. Waste pickers collect household or commercial/industrial waste and many hundreds of thousands of waste pickers in India depend on waste for an income without any health and social protection. Pickers extract potential value from waste bins, trucks, streets, waterways and dumpsites. Some work in recycling plants owned by unrecognised agencies. Waste picking is often

the only source of income for families, providing a livelihood for significant numbers of urban poor and usable materials to other enterprises. Waste pickers in Pune collect organic waste for composting and biogas generation. Waste pickers also make a significant contribution by keeping cities clean.

On the contrary, waste segregation at source as defined in Solid Waste Management Rules, 2016 and use of specialised waste processing facilities to separate recyclable materials have a key role in the waste management. Disposal of residual waste after extraction of material resources needs much less engineered landfill sites with waste-to-energy facilities. Therefore, promotion of a team of young entrepreneurs is required to execute the above management step, which at present lies with a hand-picked people from the municipal corporation along with a few hired contractual agencies with minimum stake in the entire process. The potential for energy generation from landfill via methane extraction or thermal treatment, generation of bio-fertiliser from bio-degradable waste are few of the major opportunities. The key barrier to these opportunities is the shortage of qualified engineers/entrepreneurs and environmental professionals with the experience to deliver improved waste management systems in India. A few trials in selected cities are surely an encouraging step but miles to travel to reach even the first pillar of success.

3.2 Waste Collection and Transport

Waste collection, storage and transport are essential elements of any SWM system and can be major challenges in cities. The salient points of solid waste transportation route analysis in Kolkata Municipal Corporation (KMC) as a case study are as follows:

- The total major usable road length in KMC is about 4416 km and the waste transportation for all the 141 wards use about 1736 km, which is 39% of the total road length.
- A total number of 270 roads either in full or in part segments are being utilised for such transportation only during day time adding a very high load in the peak hours of the city traffic.
- Trip counts of the total wards in these roads are around 60,000 per year or about 170 trips per day.
- The running time varies from 25 to 60 minutes one-way with an average speed of 20 km/h and travels about 9–20 km one-way distance from a centralised point of each ward of KMC.
- This requires minimum one trip in some wards to four trips in some wards for removing all the waste generated in the ward.
- The entire process is being operated between 9 AM and 4 PM with peak hours through the busiest roads of the city.

Waste collection is the responsibility of the municipal corporations in India, and bins are normally provided for biodegradable and inert waste. The biodegradable as

well as inert waste is collected by hired unidentified person without any ID proof from the generator of various category and dumped in the dumping ground not necessarily a scientific landfill site as defined in the rule. The required expenditure of the local body for waste collection, transport and disposal is much above the allocated budget and no waste management charge is collected from the generator. Improvements to waste collection and transport infrastructure in India will create jobs, improve public health and increase stake holder participation.

4 Waste Disposal: Landfills

More than 70% of collected urban waste is dumped at landfills, which are essentially non-segregate type, and most of them are full to the point of overflowing. Few of them are listed in Table 6.5.

In India >90% of waste is unsegregated and is dumped in an unsatisfactory and unscientific manner. It is estimated that approximately 1400 km^2 will be occupied by waste dumps by 2050 which was 400 km^2 in the early part of this century (Fig. 6.3).

Treatment of the waste prior to its disposal and well designed waste disposal sites with scientific disposal mechanism will not only protect public health but will also control pollution of the air, surface water, soil and groundwater. The treatment facilities before final disposal that are available in India are composting, vermicomposting, bio-methanation, pelletization and waste to energy (Table 6.6).

5 Challenges for Improved Waste Management in India

The waste management in India is presently quite poor because the best and most appropriate methods from waste collection to disposal are not being used. With the introduction of Solid Waste Management Rules, 2016, it is expected that a community-based participatory approach will allow to take a financially sustainable

Table 6.5 City wise availability of Land Fill Sites (LFS) and their area

S. No.	*City*	*No. of LFS*	*Area in hectares*
1	Delhi	3	66.4
2	Ahmedabad	1	84
3	Kolkata	1	27.4
4	Chennai	2	465.5
5	Hyderabad	1	121.5
6	Mumbai	2	140
7	Bangalore	2	47

(*Source*: Parvathamma, 2014)

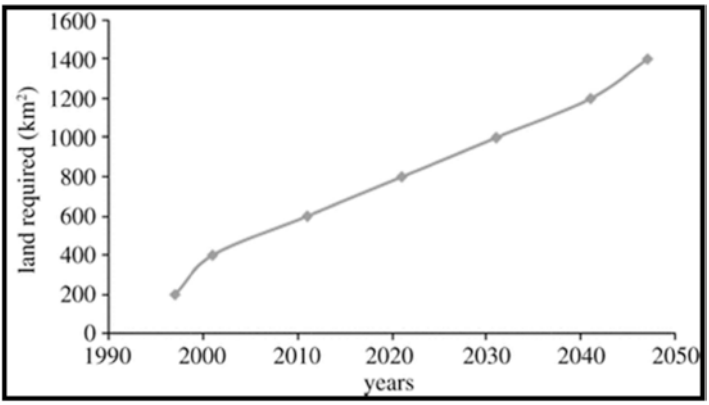

Fig. 6.3 Cumulative land required (km^2) for disposal of MSW (*Source*: Singhal and Pandey, 2001).

Table 6.6 State-wise[a] status of MSW processing facilities in India in 2011 (*Source*: Planning Commission, 2014)

State	*Composting*	*Vermicomposting*	*Biomethanation*	*Pelletisation*	*Waste to energy*
Andaman and Nicobar	1	Nil	Nil	Nil	Nil
Andhra Pradesh	24	Nil	Nil	11	2
Assam	1	Nil	Nil	Nil	Nil
Chandigarh	Nil	Nil	Nil	1	Nil
Chattisgarh	6	Nil	Nil	Nil	Nil
Delhi	3	Nil	Nil	Nil	3
Goa	14	Nil	Nil	Nil	Nil
Gujarat	3	93	Nil	6	Nil
Himachal Pradesh	10	Nil	Nil	Nil	Nil
Jammu and Kashmir	1	Nil	Nil	Nil	Nil
Jharkhand	4	Nil	Nil	Nil	Nil
Kerala	21	7	10	1	1
Madhya Pradesh	7	Nil	Nil	2	Nil
Maharashtra	6	2	5	5	2
Meghalaya	1	1	Nil	Nil	Nil
Nagaland	1	1	Nil	Nil	Nil
Orissa	1	Nil	Nil	Nil	Nil
Punjab	1	3	Nil	Nil	Nil
Sikkim	1	Nil	Nil	Nil	Nil
Tamil Nadu	162	24	Nil	3	Nil
Tripura	1	Nil	Nil	Nil	Nil
West Bengal	13	7	Nil	Nil	Nil
total	279	138	172	29	8

[a]All other states and UTs currently have no processing facilities.

step and a new mode of management with entrepreneurship approach will take a lead role. There is a lack of training in SWM and the availability of qualified waste management professionals is limited. A prospective plan of introducing a waste management cadre with a professional training in established institution will be a pillar of success in waste management in India. There is also a lack of accountability in current SWM system throughout India. Municipal authorities are responsible for managing MSW in India but have budgets that are insufficient to cover the costs associated with developing proper waste collection, storage, treatment and disposal. The lack of strategic MSW plans, waste collection/segregation and a government finance regulatory framework are presently the major barriers to achieving effective SWM in India.

Limited environmental awareness combined with low motivation has inhibited innovation and the adoption of new technologies that could transform waste management in India. Public attitudes to waste are also a major barrier to improve SWM in India.

5.1 Implementation Strategy of Plastic Waste Management

As understood earlier the major problem in the cities lies with the usage of poly bags. Since they do not have any formal recycling potential they remain unattended. These bag manufacturing units in most of the cities operate only with trade licenses and do not require Consent to Operate (CTO) or Consent to Establish (CTE) and thus do not come under the direct purview of State Pollution Control Board. Thus, problem of managing plastic waste needs to be addressed from different angles:

1. Implementing the ban of manufacturing and using poly bags less than 40 μm.
2. Ways to manage plastic waste generated from households and other institutions.
3. Rehabilitation of people involved in manufacturing and selling of poly bags.
4. Alternatives to poly bag, which can also be reused.
5. Addressing behavioural pattern in terms of usage of poly bags and also disposal of waste.
6. Involving rag pickers who are involved in collection and segregation and bringing them into the formal pay structure.

In order to take these steps, the other important factors to be considered and the interventions required are:

1. The political economy of the state.
2. Willingness of political party is essential for success of a planned initiative and the potential of success in this domain can be explored if ruling party takes a proactive role in implementing the recommendations.
3. Poly bag manufacturing units are generally very small and operate with only trade license. Closing them may be politically resisted, which can be mitigated

through generation of alternative livelihood or shifting to higher micron poly bags.
4. The greater problems are water logging, clogged drainage channels, and oversaturated landfills, which affect the entire city and need to be addressed. This will, in turn reduce environmental pollution and aid in creating a better quality of life for citizens.

The issue of plastic segregation and reuse or recycle needs to be addressed in the context of integrated solid waste management. Hence, the issues have been addressed in Plastic Waste Management Rules, 2016 from the context of waste generation and then each step of implementation is addressed. The following interventions have been promulgated:

1. Rural areas have been brought in ambit of these Rules since plastic has reached to rural areas also. Responsibility for implementation of the rules is given to the Gram Panchayat.
2. First time, responsibility of waste generators is being introduced. Individual and bulk generators like offices, commercial establishments, industries are to segregate the plastic waste at source, handover segregated waste, pay user fee as per bye-laws of the local bodies.
3. Plastic products are left littered after the public events (marriage functions, religious gatherings, public meetings etc) held in open spaces. First time, persons organising such events have been made responsible for management of waste generated from these events.
4. Use of plastic sheet for packaging, wrapping the commodity except those plastic sheet's thickness, which will impair the functionality of the product are brought under the ambit of these rules. A large number of commodities are being packed/wrapped in to plastic sheets and thereafter such sheets are left for littering. Provisions have been introduced to ensure their collection and channelization to authorised recycling facilities.
5. Extended Producer Responsibility (EPR): Earlier, EPR was left to the discretion of the local bodies. First time, the producers (i.e. persons engaged in manufacture, or import of carry bags, multi-layered packaging and sheets or like and the persons using these for packaging or wrapping their products) and brand owners have been made responsible for collecting waste generated from their products. They have to approach local bodies for formulation of plan/system for the plastic waste management within the prescribed time frame.
6. State Pollution Control Boards (SPCBs) will not grant/renew registration of plastic bags, or multi-layered packaging unless the producer proposes the action plan endorsed by the concerned State Development Department.
7. Producers to keep a record of their vendors to whom they have supplied raw materials for manufacturing carry bags, plastic sheets, and multi-layered packaging. This is to curb manufacturing of these products in unorganised sector.
8. The entry points of plastic bags/plastic sheets/multi-layered packaging in to commodity supply chain are primarily the retailers and street vendors. They have been assigned the responsibility of not to provide the commodities in plas-

tic bags/plastic sheets/multi-layered packaging which do not conform to these rules. Otherwise, they will have to pay fine.
9. Plastic carry bag will be available only with shopkeepers/street vendors pre-registered with local bodies on payment of certain registration fee. The amount collected as registration fee by local bodies is to be used for waste management.
10. Central Pollution Control Board (CPCB) has been mandated to formulate the guidelines for thermoset plastic (plastic difficult to recycle). In the earlier Rules, there was no specific provision for such type of plastic.
11. Manufacturing and use of non-recyclable multi-layered plastic to be phased out in two years.

The Ministry of Environment, Forest and Climate Change has notified the Plastic Waste Management (Amendment) Rules 2018 on March 27, 2018.The amended Rules lay down that the phasing out of Multilayered Plastic (MLP) is now applicable to MLP, which are "non-recyclable, or non-energy recoverable, or with no alternate use." The amended Rules also prescribe a central registration system for the registration of the producer/importer/brand owner. The Rules also lay down that any mechanism for the registration should be automated and should take into account ease of doing business for producers, recyclers and manufacturers. The centralised registration system will be evolved by the Central Pollution Control Board (CPCB) for the registration of the producer/importer/brand owner. While a national registry has been prescribed for producers with presence in more than two states, a state-level registration has been prescribed for smaller producers/brand owners operating within one or two states. In addition, Rule 15 of the Plastic Waste Management (Amendment) Rules 2018 on "explicit pricing of carry bags" has been omitted.

5.2 Current Scenario of e-Waste Management in India: Issues and Strategies

Electronic waste or e-waste refers to unwanted, obsolete or unusable electronic and electrical products, which includes discarded computer monitors, motherboards, mobile phones and chargers, compact discs, headphones, television sets, air conditioners and refrigerators. India's electronics industry is one of the fastest growing industries in the world. India generated about 2 million tonnes (MT) of e-waste in 2016 annually and ranks fifth among e-waste producing countries, after the US, China, Japan and Germany (Baldé et al. 2017). India also imports huge amount of e-wastes from other countries around the world. Out of the e-waste generated in India, only 0.036 MT was treated in 2016-17 (https://www.downtoearth.org.in/blog/waste/recycling-of-e-waste-in-india-and-its-potential-64034).

Till 2011 the e-waste generated in India was largely controlled by the unorganised sector who adopted crude practices that resulted in higher pollution and less recovery, thereby causing wastages of precious resources and damage to environment. Therefore, to channelize the huge e-waste generated in India for

environmentally sound recycling the E-waste (Management & Handling) Rules, 2011 was notified. The rules place main responsibility of e-waste management on the producers of the electrical and electronic equipment by introducing the concept of 'extended producer responsibility' (EPR), which is the global best practice to ensure the take-back of the end-of-life products. Further amendment to this rule came in 2015, which resulted in the E-waste (Management) Rule in 2016. The amendment in rules was done to channelize the e-waste generated in the country towards authorized dismantlers and recyclers in order to formalize the e-waste recycling sector. Over 21 products have been included under the purview of the rule including components or consumables or parts or spares of electrical and electronic equipment (EEE), along with their products. In the 2016 rules new arrangement called Producer Responsibility Organisation (PRO) has been introduced to strengthen the EPR further. PRO will be a professional organisation authorised or financed collectively or individually by producers, which can take the responsibility for collection and channelization of e-waste generated from the 'end-of-life' of their products to ensure environmentally sound management of such e-waste. The Rules also indicate the targets (quantity of e-waste to be collected to fulfil the EPR) that have to be met by the producers. The target for the first two years is 30% of the quantity of waste generation as indicated in EPR Plan. This will increase by 10 per cent up to a maximum of 70% from seventh year onwards. The law also says that the responsibility of producers is not confined to waste collection, but also to ensure that the waste reaches the authorised recycler/dismantler.

Although new rules have come into place to safely process e-waste, about 80 per cent of the waste such as old laptops, cell phones, cameras, air conditioners, televisions and LED lamps continues to be broken down by the informal sector, adversely affecting the environment and human health.

India has 312 registered e-waste recyclers as on 27.06.2019, accredited by the state governments to process e-waste with total install capacity of 782080.62 MTA (http://greene.gov.in/wp-content/uploads/2019/09/2019091881.pdf). But many of India's e-waste recyclers are not recycling waste at all. While some are storing it in hazardous conditions, others do not even have the capacity to handle such waste.

The Ministry of Electronics and Information Technology has initiated an e-waste awareness programme under Digital India, along with industry associations from 2015, to create awareness among the public about the hazards of e-waste recycling by the unorganised sector, and to educate them about alternate methods of disposing their e-waste. The programme stresses the need for adopting environment friendly e-waste recycling practices. The programme has adopted the best practices for e-waste recycling available globally, so that this sector could generate jobs as well as viable business prospects for locals.

The Ministry has also developed affordable technologies to recycle valuable materials and plastics in an environmentally sound manner which are been used at present. They are (i) processing technology for recycle of electronic wastes at NML Jamshedpur - facility includes eddy current separator, hammer mill, ion exchange column etc., (ii) processing technology for conversion of waste plastics from e-waste to value added products at Central Institute of Plastics Engineering &

Technology (CIPET), Bhubaneswar, and (iii) process technology for recovery of precious metals from printed circuit board (PCBs) at Centre C-MET, Hyderabad, with active participation of authorized recycler, M/s. E-parisara Pvt. Ltd., Bangalore.

6 Suggested Steps For Improved Waste Management In India

An execution plan, which will be required for waste management in India is the resource recovery from waste and a value addition to the generated waste with recycling, recovery and reuse. With the availability along with the legal support of Solid Waste Management Rules 2016, the execution role of ULBs is distinctly reducing in waste management sectors though the responsibility of the Commissioner as well as Chairman of the local bodies is becoming immensely pertinent for awareness promotion of the Rules 2016 and communication with the citizens of the city. Waste management needs to be regarded throughout Indian society as an essential service requiring sustainable financing. ULBs should develop a properly funded system that demonstrate the advantages of sound investment in waste management.

A strong and independent implementing authority is needed to regulate waste management who will not be directly involved in execution of waste management. SWM is expected to improve in India with a clear regulatory law through Solid Waste Management Rules, 2016 and its judicious enforcement. Strong waste regulations can drive innovation. The waste management sector needs to include attractive and profitable entrepreneur based models with clear performance requirements imposed by the Urban Local Bodies (Municipalities), with a provision of financial penalties when waste management services are not working effectively. Finance for waste management companies and funding for infrastructure must be raised from waste producers through a waste tax. An average charge of 1 rupee per person per day would generate close to 50,000 crores annually, and this level of funding would probably be sufficient to provide effective waste management throughout India.

Littering and waste in streets is a major problem in India that has serious impacts on public health and causes visual pollution. Academic institutes and NGOs may be encouraged to develop community participatory models which should include the role and responsibilities of each individual. One such scientific and innovative project called “Swachta Doot Aplya Dari’ which means sanitary worker at your doorstep was designed by Centre for Development Communication (CDC), Jaipur, Rajasthan and first implemented in Nagpur city. The key concept concept is daily door-to-door collection of segregated domestic wastes. The end consumer is both main contributor and main beneficiary, as he should segregate the waste instead of littering it and, in turn, profits from the cleanliness of the city. This model was selected as an example of good practice in waste management by UN HABITAT in 2007.

A successful waste management needs waste segregation at source, which is already a mandatory legal requirement, mentioned in Solid Waste Management Rules, 2016 to allow much more efficient value extraction and recycling. Separating dry (inorganic) and wet (biodegradable) waste would have significant benefits and should be the responsibility of the waste producer.

A sustainable waste management planning requires visionary project development by ULBs in consultation and support from the private sector and NGOs. The roles and responsibilities to deliver a sustainable system need to be defined, with an evaluation system to monitor progress with an elaborate public participation through workshops and focus discussions. Experiences will be required to be shared between different regions of India and different social groups. There are a number of research institutes, organisations, NGOs and private sector companies working on a holistic approach to SWM. Future waste management in India must extensively involve the informal sector throughout the system.

There is a need to develop training and capacity building at every level. School children should be made to understand the importance of waste management, the effects of poor waste management on the environment and public health, and the role and responsibilities of each individual in the waste management system. This will develop responsible citizens who will regard waste as a resource opportunity.

7 Conclusion

Population growth and particularly the development of megacities along with in migration and floating population in the city is making SWM in India a major challenge. The current situation is that the MSW Rule 2000, which was definitely inadequate to address the issues has now been replaced by Solid Waste Management Rules, 2016. The 2016 rules along with Plastic Waste Management Rules, 2016; Plastic Waste Management (Amendment) Rules 2018 and 2019 and E-waste (Management) Rules, 2016 have definitely helped to improve the management of municipal solid wastes in India. Waste management in India still lacks public participation in terms of sharing the cost involved through paying user fees and sharing some stake in the management process. In general there is a lack of involvement in waste management by the community. There is a need to promote community awareness and change the attitude of people towards waste, as this is the fundamental for developing proper and sustainable waste management systems.

However, the introduction of various rules related to municipal solid waste, plastic waste and e-waste is likely to play a significant role in management and handling of wastes. It is expected that a sustainable and economically viable waste management model describing the role of community and individual will evolve in the near future. Such a model must ensure maximum resource extraction from waste, combined with safe disposal of residual waste through the development of engineered landfill and waste-to-energy facilities. This will ensure attracting new entrepreneurs in the field of waste management who can ensure profit without any subsidy from

the government or other donor agencies. Organisation like CII (Confederation of Indian Industries) and CREDAI (Confederation of Real Estate Developer Association of India) have already initiated such entrepreneurship in their respective domain. There are several start-ups working towards the goal of a landfill-free future in several cities of India. They are (i) Saahas Zero Waste (Bengaluru), (ii) Hasiru Dala (Bengaluru), (iii) Citizengage (Bengaluru), (iv) Namo E-waste (Delhi), (v) GEM Enviro Management (Delhi) (vi) Paperman (Chennai), (vii) Vital Waste (Kolkata), (viii) ExtraCarbon (Gurgaon), (ix) Lets' Recycle (Ahmedabad), (x) Shivalik Solid Waste Management Ltd. (Mumbai), (xi) Eco-Wise (Noida) etc. More such start-ups will come up along the length and breath of India if the Community Participation Model is adopted instead of isolated effort from municipal corporation with government funding without any scope of sustainability.

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