सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

Training Module on

Solid Waste Management

Sustainable Cities Integrated Approach Pilot in India

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UNIDO
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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THE FULL MODULE SHOULD BE REFERENCED AS FOLLOWS
NIUA (2022) “Training Module on Solid Waste Management”. Text from this report can be quoted provided the source is acknowledged.

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About this Module	This module is a part of the second deliverable for the project to provide training modules for three sectors.

ABOUT THE PROJECT

"Sustainable Cities Integrated Approach Pilot in India" is one of the child projects under GEF's Sustainable Cities Programme in the GEF 6 cycle. The aim of the project is to integrate sustainability strategies into urban planning and management to create a favourable environment for investment in infrastructure and service delivery, thus building resilience of pilot cities. The three main project components comprise- Sustainable Urban Planning and Management, Investment Projects and Technology Demonstration and Partnerships and Knowledge Management Platform.

National Institute of Urban Affairs (NIUA) has been engaged to undertake the implementation of Component 3 – Partnerships, Knowledge Management and Capacity Building. As a part of this component of the Project, a Training and Assistance Needs Assessment (TANA) was conducted from February 2020 to August 2020 for the ULBs of five cities - Bhopal, Jaipur, Mysuru, Vijayawada and Guntur to assess and identify the needs of the ULB officials to prepare on-the-job training modules.

ABOUT THE TRAINING MODULE

Based on the results of TANA, training modules on Solid Waste, Wastewater and Water Management have been developed by NIUA. The modules are an outcome of the activity 2 of the project which included the following tasks:

- On the basis of TANA results, training modules were prepared for relevant stakeholders
- For developing the Module & Pedagogy, NIUA has synergized the experience of practitioners and subject experts.
- The modules have been finalized in coordination with experts and officials from cities.

This module on Solid Waste Management is a part of the series of modules that would supplement the training activities.

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List of abbreviations and acronyms

ADS	Air Density Separator
AFR	Alternative Fuel Resource
BoQ	Bill of Qualities
C and D	Construction and Demolition
CBO	Community Based Organizations
CPHEEO	Central Public Health and Environmental Engineering Organization
CSR	Corporate Social Responsibility
CPCB	Central Pollution Control Board
CNG	Compressed Natural Gas
DPR	Detailed Project Report
DWCC	Dry Waste collection Centre
DHW	Domestic Hazardous Waste
EM	Effective Micro organisms
EoI	Expression of Interest
FCO	Fertilizer Control Order
GVP	Garbage Vulnerable Points
GAIL	Gas Authority of India Limited
GCV	Gross Calorific Value
GIS	Geographic Information Systems
IoT	Internet of Things
HAG	Hot Air Generator
HDPE	High-Density Polyethylene
HPEC	High Powered Expert Committee
HC	Home composting
ICCC	Integrated Control and Command Centre
ICT	Information, Communication and technology
IEC	Information, Education and Communication
IL and FS	Infrastructure Leasing and Financial Services
ISWM	Integrated Solid Waste Management
LDO	Low Density Oil
LFG	Landfill Gas

LTP	Leachate Treatment Plant
LoI	Letter of Intent
LMV	Light Motor Vehicle
MoEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoU	Memorandum of understanding
MRF	Material Recovery Facility
MTD	Metric tonnes per day
MSW	Municipal Solid Waste
NBCC	National Building Construction Corporation ltd.
NGO	Non-Governmental Organization
NPK	Nitrogen Phosphorous Potassium
PET	Polyethylene Terephthalate
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
PET	Polyethylene terephthalate
HDPE	High Density Polyethylene
PVC	Poly Vinyl Chloride
PS	Polystyrene
PP	Polypropylene
LDPE	Low Density Polyethylene
PERT	Program Evaluation and Review Technique
PPP	Public Private Partnership
QCI	Quality Council of India
RCA	Recycled Concrete Aggregate
RDF	Refuse-Derived Fuel
RWA	Residents' Welfare Association
RFP	Request for Proposal
RFID	Radio Frequency Identification
SBM	Swachh Bharat Mission
SLF	Sanitary Landfill
SLNA	State Level Nodal Agency
SWM	Solid Waste Management
STV	Secondary Transportation Vehicles
TPD	Tonnes per day
ULBs	Urban Local Bodies
UV	Ultraviolet
WtE	Waste to Energy
VTMS	Vehicle Tracking Management System

Chapter

1

Overview of Municipal Solid Waste Management in India

Summary

The current status of SWM at national and international level has been discussed in detail. The chapter includes existing SWM challenges, ongoing policies and programmes to efficiently manage waste.

Training Objectives

- To get an overview of the SWM scenario at national and international level
- Understand the applicable SWM rules and policies

Training Outcomes

- Able to understand the various roles and responsibilites of different stakeholders involved in solid waste management.
- Current approaches towards efficient SWM in India along with the challenges faced.

Chapter Contents

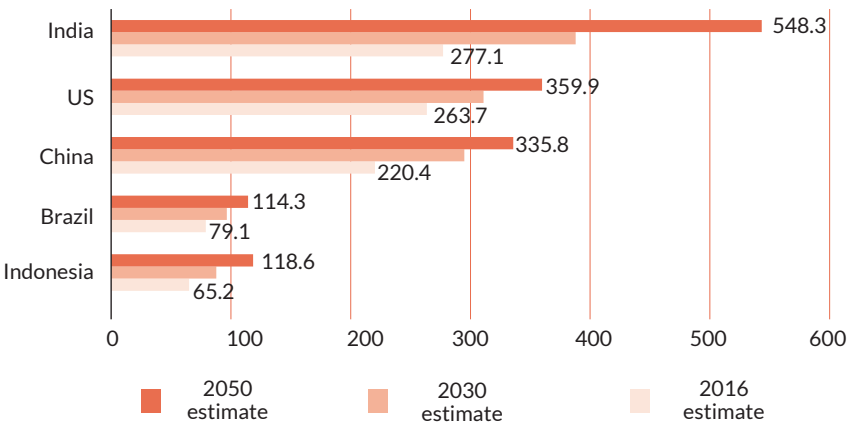
1.1 Introduction
1.2 Significance of SWM in Sustainable Development Goals
1.3 Waste management in the context of climate change, health andenvironment
1.4 Challenges of Solid Waste Management
1.5 Integrated Solid Waste Management
1.6 Progress on SWM in India
1.7 Further Readings
References
Quick Assessment

1.1 Introduction

About 2.01 billion tonnes of municipal waste is being generated worldwide every year and it may increase up to 70% by the end of 2050 (The World Bank, n.d.). India is considered to be a major contributor and accounts for more than a tenth (nearly 13%) of the world's total waste generated, owing to its huge population.

According to the World Banks's 2016 estimate, India accounts for 80% of the total waste generated in South Asian countries accounting to 227 million tonnes of waste every year. Among the top 5 countries, the waste generated in India is likely to increase from 227 million tonnes to 387.8 million tonnes in 2030 and it can reach the highest in 2050 by generating 543.3 million tonnes of waste. According to 2030 and 2050 estimates, the US will produce 311 and 359.9 million tonnes of waste and China produces 295 and 335.8 million tonnes of waste. India tops by generating double the amount of these countries. To efficiently manage this large amount of waste, India requires effective and innovative ideas.

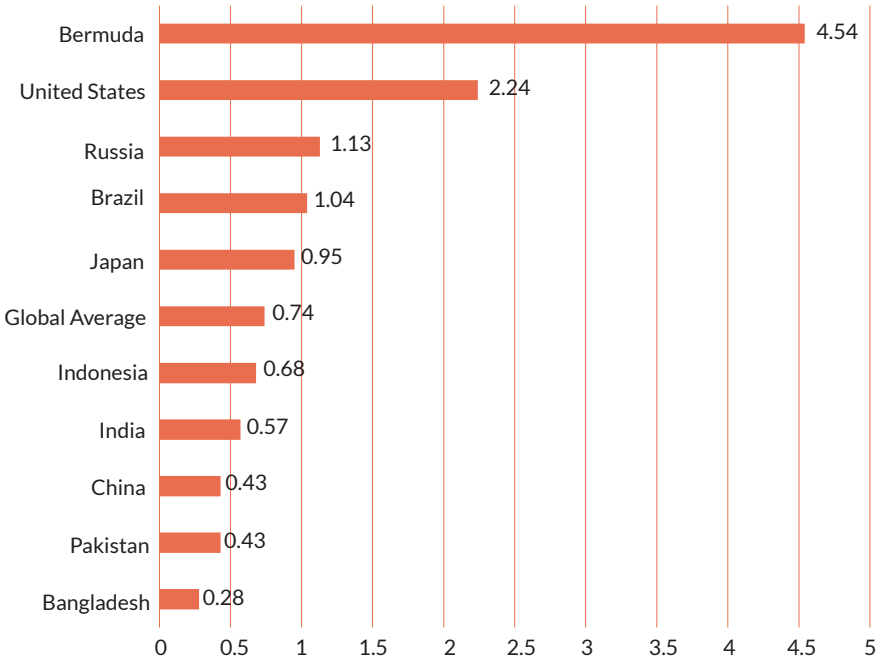
Figure 1.1: Top five countries generating MSW annually (in millions tonnes)



Source: What a Waste 2.0, World Bank

While the total quantum of waste generated in India is large, the average per capita per day waste generation is less than many developed countries. At present, this figure stands at 0.57 kg per capita per day and is expected to grow to 0.90 kg of waste per person per day by 2050. This is due to changes in lifestyle associated with economic growth. It is therefore imperative to scientifically manage waste.

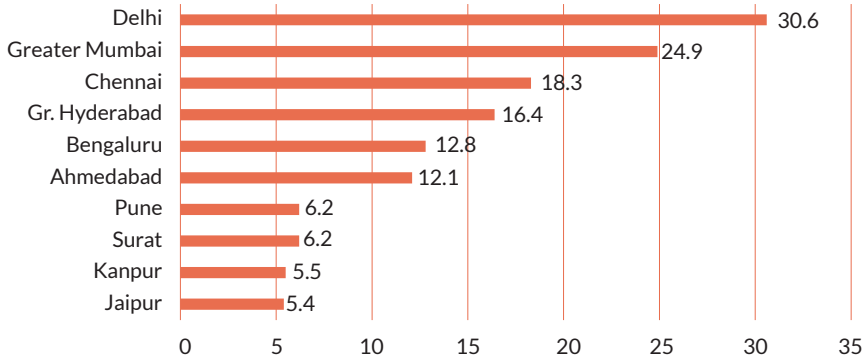
Figure 1.2: Waste generation per person per day (in kg) in selected countries



Source: What a Waste 2.0, World Bank

India's urban population has been increasing rapidly over the last few decades. As per Census of India, 1951, India had an urban population of 17.29%, which increased to 31.16% in 2011 (The World Bank, n.d.). Waste generation has now become a serious issue, which posses threat to public health, environment and economy. Urban areas are the growth engines of economic development in India and are the major contributors to the total waste generated in the country. As India progresses with economic development, the quantum of Municipal Solid Waste (MSW) generated is expected to increase significantly from the current 65 million tonnes per annum to 165 million tonnes by 2031. Not only the quantum of waste will increase but also the waste characteristics is expected to change over a period of time.

Figure 1.3: Highest waste generators in India (in lakh tonnes)

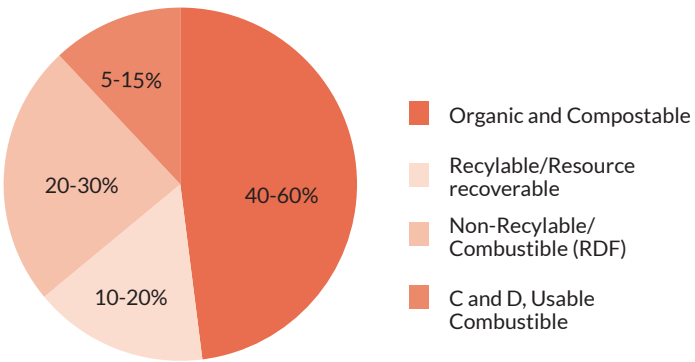


Source: What a Waste 2.0, World Bank

Sources, Types and Composition of MSW in India

In India, MSW consists of household waste, construction and demolition debris, horticulture and waste from streets. This waste is generated mainly from residential, commercial and institutional areas. With rising population and change in lifestyle, the volume of municipal solid waste has been rapidly increasing and its composition is changing. Around 40-60% of MSW is biodegradable waste, 10-20% is recyclables and 20-30% is non-recyclable. The statistics as per figure 1.4 might vary from location to location like in vegetable market the organic waste generation is more whereas in commercial areas (shopping malls) the inorganic or dry waste generation is considerably higher, while in residential areas the quantity of organic waste generation is more. Waste generation composition is also linked to the income levels of the concered area.

Figure 1.4: Urban India's waste composition



Source: (MoHUA, 2020)

Community Composting at Officer's Colony, Silvassa, Dadra And Nagar Haveli
Source: Author

1.2 Significance of SWM in Sustainable Development Goals (SDGs)

SWM is one of the important targets to be achieved under the SDGs. Significance of proper treatment of solid waste is recognized in SDGs and it is embedded within the 17 goals either explicitly or implicitly. SDG 11, "Make cities and human settlements inclusive, safe, resilient and sustainable", explicitly discusses about SWM. Target no. 11.6 of SDG 11, says, member states to reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. Waste management has strong linkages to a range of global challenges, such as health (SDG 3), climate change (SDG 13), clean water and sanitation (SDG 6) and sustainable production and consumption (SDG 12).

Figure 1.5: The SDGs linked with Solid Waste Management

Source: Author

Table 1.1 shows in detail the goals and targets associated with solid waste management.

Table 1.1: The Sustainable Development Goals and Targets associated with Solid Waste Management

SDG Number	Goal	Target Number	Target
3	Ensure healthy lives and promote well-being for all at all ages	3.3	By 2030 end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases
		3.9	By 2030 substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination

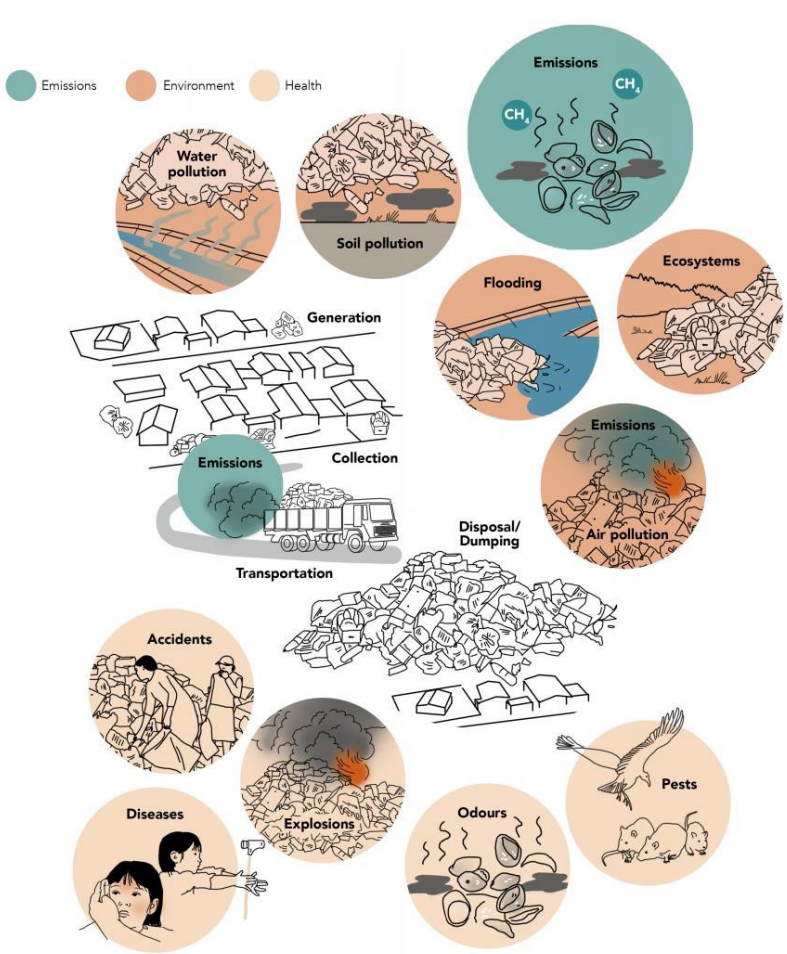
SDG Number	Goal	Target Number	Target
6	Ensure availability and sustainable management of water and sanitation for all	6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and increasing recycling and safe reuse globally.
11	Make cities and human settlements inclusive, safe, resilient and sustainable	11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
12	Ensure sustainable consumption and production patterns	12.4	By 2020 achieve environmentally sound management of chemicals and all wastes throughout their life cycle in accordance with agreed international frameworks and significantly reduce their release to air, water and soil to minimize their adverse impacts on human health and the environment
		12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
13	Climate action	13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

Source: (United Nations, 2021)

1.3 Waste Management in context of climate change, health and environment

Increasing waste generation and unscientific management of solid waste leads to higher Greenhouse Gas (GHG) emmisions, negative impacts on public health and environmental degradation. The Intergovernmental Panel on Climate Change (IPCC) estimates that solid waste management accounted for around 3% of GHG emissions in 2010, with most of this associated with methane emissions from landfill sites. These emmisions are due to unscientific disposal of waste by burning, open composting, direct disposal in dumpyards, etc. This pollutes the air, water and soil ecosystems. The collection and transportation vehicles also consume fossil fuels adding to the air pollution. Leachate from landfill contaminate ground water and surface water. Open dumping of waste can contaminate soils and block drainage network in cities. This unscientific management of waste leads to public health issues like diarrhoea, respiratory infections and gastrointestinal parasites.

Figure 1.6: Impact on climate, environment and human health



Source: CSD Engineers,adapted by Zoi

Using a lifecycle approach, it has been estimated that a 10 to 15% reduction in GHG emissions can be achieved through landfill mitigation and diversion, energy from waste, recycling, and other types of improved solid waste management process. Reducing waste generation can potentially further increase this contribution to 15 to 20%. (Wilson, 2015)

1.4 Challenges to Solid Waste Management

Some of challenges faced by cities in India as regards SWM are as follows:

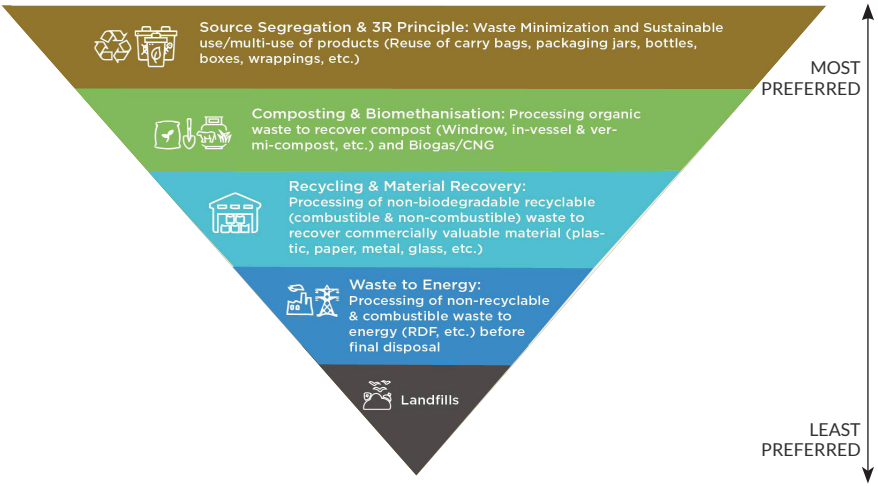
1. Excessive littering by citizens and lack of pride among the city dwellers for cleanliness.
2. Less availability of appropriate bins in public places for waste deposition and collection.
3. Lack of human resource for regular cleaning, improper enforcement of penalties by ULBs.
4. Inadequate systems and technologies for segregated collection and processing of solid waste from households, commercial establishments and institutions.
5. Inadequate systems of primary, secondary collection and transportation.
6. Inability to meet revenue expenses including human resource cost, safety equipment and Personal Protective Equipment (PPE).
7. Lack of motivation and skills among staff to implement new and innovative practices.
8. Inadequate funds for upgrading or modernizing SWM and adopting new technologies.
9. Less or no collection of user charges because of poor services and hence cannot meet day to day expenses leading to a vicious cycle of poor performance.
10. As per CPCB estimates (2016-2017), there are 2120 legacy waste dumpsites in India across 23 states. With the increasing waste generation, the need for dumpsites will grow exponentitlly if scientific treatment of waste is not immediately adopted by ULBs.

1.5 Integrated Solid Waste Management (ISWM)

To overcome the challenges of SWM, ISWM is one of the guiding principles of MSW management. It proposes a waste management hierarchy, with an aim to reduce the amount of waste being disposed, while maximizing resource conservation and resource efficiency.

The waste management hierarchy emphasizes to take action first and foremost on preventing the generation of waste, followed by actions to reduce waste generation (e.g. through re-use). Recycling, is the next preferred action, followed by recovery of materials and waste-to-energy generation. The aim is to extract the maximum practical benefits from products and to generate the minimum amount of waste. The application of the waste management hierarchy has the following benefits - prevents emissions of greenhouse gases, reduce pollutants, save energy, conserve resources, create jobs and stimulate the development of green technologies. Often the waste hierarchy is referred to as the "3 Rs", which identify the choices, in order of preference, as "Reduce, Reuse, Recycle".

Figure 1.7: Hierarchy of waste



Source: (CPHEEO, 2020)

Integrated solid waste management refers to the strategic approach to sustainable management of solid wastes. An effective ISWM system considers how to prevent, recycle and manage solid waste in ways that most effectively protect human health and the environment. It involves evaluating local needs and conditions, and then combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, combustion and disposal in properly designed, constructed, and managed landfills with an emphasis on maximising resource use efficiency.

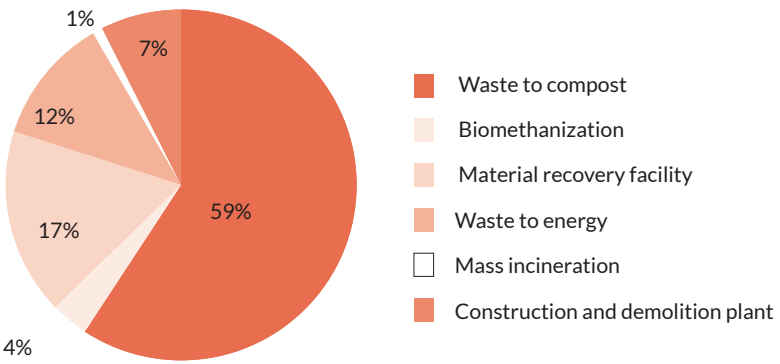
The selection of the most appropriate waste management systems and sustainable technologies is needed to deliver an optimum and sustainable ISWM system. In combination with economic and social considerations, this approach will help waste managers to design more sustainable solid waste management systems. Cleaner and safe neighbourhoods, high resource use efficiency, monetory savings, employment and business opportunities are some of the benefits of ISWM. In Urban India, Solid Waste Management is one of the 18 functions of Urban Local Bodies (ULBs) as per the Twelfth Schedule of the 74th Constitutional Amendment Act (74th CAA).

Up-cycled old tyres into pots, Panchgani Maharashtra
Source: Author

1.6 Progress of SWM in India

To efficiently manage and overcome the challenges related to growing municipal solid waste, steps have been taken at various levels. To scale-up effective SWM practices, Government of India launched Swachh Bharat Mission (SBM) on October 2, 2014. The SBM (Urban) initiative provides technical and financial support to ULBs for MSW management. This initative operates under the Ministry of Housing and Urban Affairs. Since the beginning of the SBM initative, ULBs across India has successfully been able to achieve the following (NIUA, 2020):

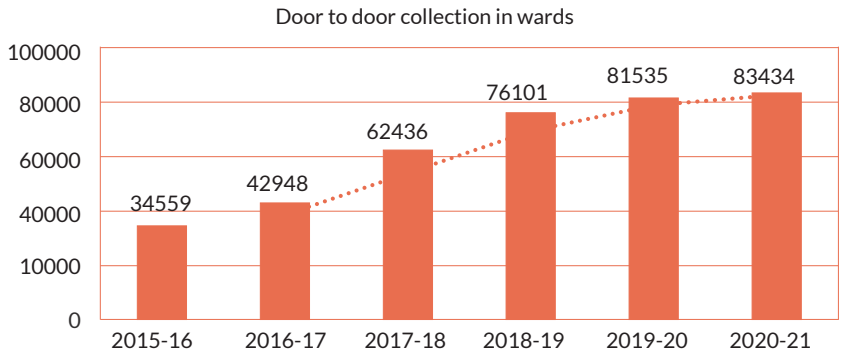
Figure 1.8: Current Processing Capacities in India



Source: (MoHUA, 2020)

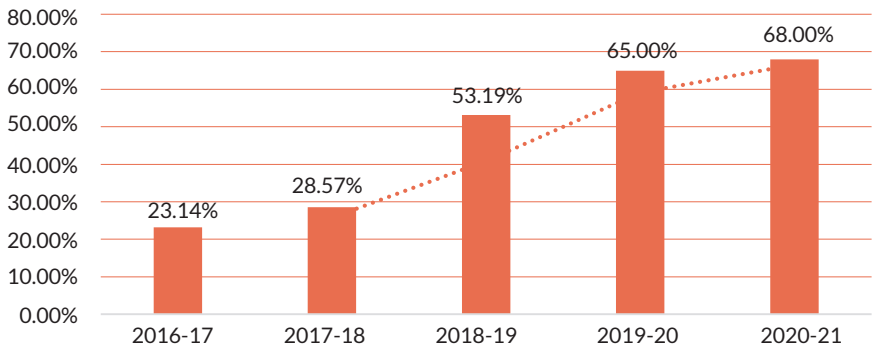
- 83,434 wards out of 84,420 wards (99% wards) are practicing door to door collection
- Approximately 68% of the total waste generated is being processed and 66,307 wards (77%) of wards are practicing source segregation.
- 685 functional waste to compost plants (centralized) with capacity to process 188 lakh tonnes waste per annum, and another 232 plants are under construction, with approximate input capacity of 47 lakh tonnes per annum. Current production of Compost is 43.87 lakh metric tonnes.
- 7 functional Waste to Electricity plants with production capacity of 88.4 MW, and another 56 plants under construction with production capacity of 415 MW.
- Additionally, 384 bio gas and bio-methanation plants with input capacity of 33 lakh TPA and another 21 plants under construction with potential input capacity of 25 lakh metric tonnes.

Figure 1.9: Progress in source segregation in wards under Swachh Bharat Mission (Urban)



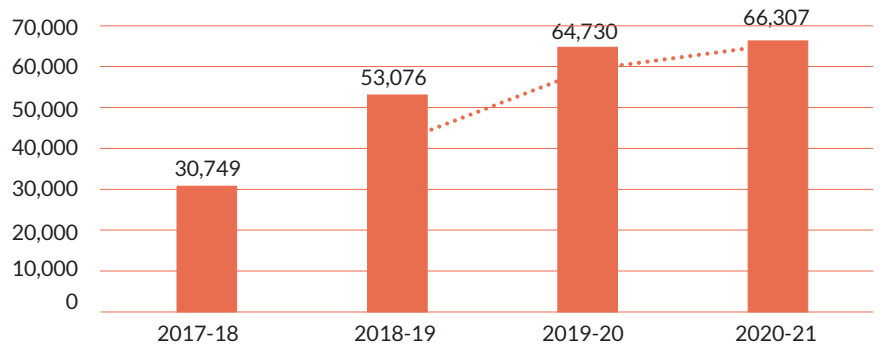
Source: Yojana, December 2020

Figure 1.10: Progress in Waste Processing capacity under Swachh Bharat Mission (Urban)



Source: Yojana, December 2020

Figure 1.11: Progress in source segregation in wards under Swachh Bharat Mission (Urban)



Source: Yojana, December 2020

Evolution of SWM Policy and Programs in India

The first comprehensive solid waste management rules were promulgated in 2000 by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India (GoI). The rules provided detailed mandates on various aspects of Municipal Solid Waste Management (MSWM) and identified the Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs) as nodal agencies to monitor its implementation directly in the union territories and the states respectively. Thereafter, due to its poor implementation and monitoring, in several states of India, the rules were revised in 2016 by the MoEFCC, thus releasing the latest Solid Waste Management (SWM) Rules in 2016. Under these rules, the responsibility of management of Solid Waste in cities has been entrusted with Urban Development Departments and Urban Local Bodies (ULBs) in the States. All Municipal Corporations and Municipalities have to prepare a Solid Waste Management Plan. Besides that, to operationalize the SWM Rules 2016, the Ministry of Housing and Urban Affairs (MoHUA) through Central Public Health Environment Engineering Organization (CPHEEO), has published manuals in October 2016 which has incorporated the necessary specifications and actions for ULBs to implement them in their cities.

Table 1.2: Policy evolution of SWM in India

Year	Initiative
2021	• Swachh Bharat Mission (Urban) 2.0 would be implemented over five years in more than 4300 ULBs • Amendment in Plastic Waste Management Rule 2016
2016	• Solid Waste Management rules include six rules (Solid Waste Management Rules, Plastic Waste management Rules, Construction and Demolition Waste Management Rules, E-waste Management Rules, Bio-medical Waste Management Rules, Hazardous and other Wastes (Management and Transboundary Movement) Rules • Swachh Survekshan - annual cleanliness survey across ULBS in India (covering more than 4200 ULBs)
2014	• Swachh Bharat Mission (SBM) • Report of task force on Waste to Energy by Planning Commission
2013	• Framing of MSW Rule
2011	• Plastic Waste (Management and Handling) Rules • E-Waste (Management and Handling) Rules
2009	• The National Action Plan for Climate Change
2008	• National Sanitation Policy • Hazardous Waste (Management and Handling Movement) Rules
2006	• National Environment Policy • Strategy and action plan for compost usage
2005	• The technology advisory group on SWM • Inter-ministerial task force on Integrated Plant and Nutrient Management using city compost

Year	Initiative
2000	• Municipal Waste (Management and Handling) Rule
1999	• Committee submitted the report • Ministry of Urban Development set up technology advisory group • MoEFCC issued draft rule for Municipal Waste (Management and Handling)
1998	• Bio-medical Waste (Management andHandling) Rules • Supreme Court appointed Expert Barman Committee
1995	• High power committee under the chairmanship of prof. J.S. Bajaj (Member, Planning Commission) was establish • Ministry of Health and family welfare undertook national mission on environmental health and sanitation • Central Public Health and Environment Engineering Organisation (CPHEEO), under the ministry of urban development and Poverty Alleviation drafted a policy paper that detailed issues and funding requirements of SWM in India
1989	• Hazardous Waste (Management and Handling) Rules
1986	• Environment (Protection) Act
1975	• GOI constituted first high power committee in fifth five year plan and committee covered eight area of waste management and made recommendation
1974	• GOI introduced a modified scheme to revive urban waste composting facilities in cities with a population over 0.3 million
1969 to 1974	• Fourth Five-year plan provide grant to state government for setting up MSW composting
1960	• Ministry of Food and Agriculture - offered soft loan to local bodies for promoting composting of urban solid waste

Source: (CPHEEO, 2016)

Rules and regulations for Solid Waste Management

The most recent legislation pertaining to SWM is the Solid Waste Management rules, 2016. It consists of 6 sets of rules-

1. Solid Waste Management Rules, 2016
2. Plastic Waste Management Rules, 2016
3. Bio-Medical Waste Management, 2016
4. E-Waste Management Rules, 2016
5. Construction and Demolition Waste Management Rules, 2016
6. Hazardous and other Wastes (Management and Transboundary Movement) Rules, 2016

Solid Waste Management Rules, 2016

The Solid Waste Management Rules, 2016 shall apply to every domestic, institutional, commercial and any other non-residential solid waste generator situated in the areas except industrial waste, hazardous waste, hazardous chemicals, bio medical wastes, e-waste, lead acid batteries and radio-active waste, that are covered under separate rules framed under the Environment (Protection) Act, 1986. Every waste generator has the following duties to be complied as per the rules. These provisions are given below in Table 1-3.

Sorting of flower waste, Tirupati, Andhra Pradesh
Source: Author

Besides emphasizing the role of waste generators as an important part of the Solid Waste Management process, the SWM rules, 2016 have also mentioned duties for various concerned authorities/ stakeholders.

Table 1.3: Duties and responsibilites of an Urban Local Body

Category	Provisions
SWM policy, strategy, byelaws	• Prepare a SWM Plan as per State policy and strategy • Frame bye-laws incorporating provisions of SWM Rules, 2016 within 1 year of notification, and ensure timely implementation
Informal sectors	• Promote integration of informal waste collectors • Facilitate formation of Self Help Groups (SHG) and encourage integration in SWM including door-to-door collection of waste • Provide training on SWM to waste-pickers and waste collectors • Educate workers including contract workers and supervisors on door-to-door collection of waste and transportation of segregated waste • Ensure personal protection equipment including uniform, fluorescent jacket, hand gloves, raincoat, appropriate footwear and masks given to all workers handling solid waste
Waste Segregation, Collection and Transportation	• Arrange for door-to-door collection of segregated waste from all households and commercial and institutional premises, and from designated locations for large complexes • Establish waste deposition centres for domestic hazardous waste (1 centre per 20 sq. km) and direct waste generators to deposit hazardous waste for safe disposal • Direct waste generators not to litter, burn or bury waste on streets, open public spaces, drains or water bodies; segregate the waste at source and handover to authorized collectors • Ensure safe storage and transportation of domestic hazardous waste to the hazardous waste disposal facility or as maybe directed by the State Pollution Control Board/Committee • Collect horticulture, parks and garden waste separately and process in the parks and gardens as far as possible • Transport segregated bio-degradable waste to processing facilities such as compost/bio-methanation plants. Preference to be given for on-site processing of such waste • Transport non-bio-degradable waste to processing/material recovery/secondary storage facilities • Transport Construction and Demolition (C and D) waste as per the provisions of the C and D Waste Management Rules, 2016 • Preference to be given to decentralized processing for bio-degradable waste, and for waste-to-energy processes such as Refuse Derived Fuel • Undertake Construction and O and M of sanitary landfill for disposal of residual wastes (Schedule I of the Rules) • Ensure provisions for collection, segregation and storage of segregated wastes are incorporated in building plans while granting approval for group housing society/market
Secondary storage facilities	• Setup material recovery/secondary storage facilities and provide access to waste pickers/recyclers to segregated recyclable waste

Category	Provisions
Street Sweeping	• Collect waste from all markets on a daily basis, promote decentralized compost/bio-methanation plants at or near the markets • Direct street sweepers not to burn leaves from trees, store it separately and handover to authorized waste collectors • Collect separately waste from sweeping of streets on alternate days or twice a week depending on density of population, commercial activity and local situation • Setup covered secondary storage facility for street sweepings and silt removed from drains, and dispose at regular intervals
Processing and Treatment facilities	• Collect waste from all markets on a daily basis, promote decentralized compost/bio-methanation plants at or near the markets • Phase out use of chemical fertilizer in 2 years and use compost in all parks and gardens maintained by the local body
Financial provisions	• Make adequate provision of funds for capital investment as well as O and M of SWM services in the annual budget
PPP	• Facilitate Construction and O and M of solid waste processing facilities on its own or through private sector participation adhering to the MoHUA guidelines and CPCB standards
Levy user charges and fines	• Prescribe appropriate user fee and collect from waste generators on own or through authorized agency • Frame bye-laws and prescribe criteria for levying of spot fine for open littering
Community engagement	• Involve communities in waste management and promote decentralized processing of waste at community-level (home composting, bio gas generation) • Create Public awareness through Information, Education and Communication (IEC) campaigns and educate waste generators on their duties
SPCB and CPCB	• Get authorization from the State Pollution Control Board/ Committee for setting up waste processing, treatment or disposal facility if volume of waste exceeds 5 metric tonnes per day • Prepare and submit Annual Report (Form IV)
Waste Disposal	• Stop landfilling or dumping of mixed waste after specified timeline for operations of sanitary landfill is over (Rule 23) • Allow only residual insert wastes to go to sanitary landfills, explore potential to bio-mine or bio-remediate operational dumpsites

Source: (CPHEEO, 2016)

Table 1.4: Duties and responsibilities of waste generators

Category	Provisions
Household waste	• Segregate and store the waste generated in 3 separate streams - biodegradable, non-biodegradable and domestic hazardous in suitable bins and handover it to waste pickers.
	• Wrap securely the used sanitary waste like diapers, sanitary pads etc.
Construction and Demolition (C and D) Waste	• Separately store the C and D waste and dispose as per C and D Waste Management Rules, 2016.
Horticulture waste	• Store horticulture waste separately and dispose as per the ULBs
Commercial waste	• Suitable waste bins to be kept by street vendors and the waste is to be deposited to a waste storage depot / container/ vehicle.
Bulk Waste generators	• All Residence welfare, market associations, gated communities with more than 5,000 sq.m area or institutions and hotels and restaurants, have to ensure waste segregation, and handing over of recyclable material to waste pickers/ recyclers.
Prohibition of Littering and Burning	• Throwing, burning or burying the solid waste generated by people, on streets, open public spaces or in the drain or water bodies is prohibited.
User fees	• All waste generators shall pay such user fee for solid waste management, as specified in the bye-laws of the local bodies

Source: (CPHEEO, 2016)

Table 1.5: Duties and responsibilities of other Ministries and stakeholders

Ministries/ Stakeholders	Duties Undertaken
Ministry of Environment, Forest and Climate Change (MoEFCC)	• Responsible for overall monitoring of the implementation of these rules across country
Ministry of Housing and Urban Affairs (MoHUA)	• Coordinate, provide technical guidelines and project finance to states, union territories and local bodies • Taking periodic review of the states and local bodies • Undertake training and capacity building for local bodies and other stakeholders • Formulate national policy and strategy on solid waste management • Promote research and development
Ministry of Chemicals and Fertilizers (MoC and F)	• Ensure promotion of co-marketing of compost with chemical fertilisers by the fertiliser companies. Provide market development assistance on city compost
Ministry of Agriculture and Farmers Welfare (MoAFW)	• Provide flexibility in Fertilizer Control Order (FCO) for manufacturing and sale of compost • Propagate utilization of compost on farm land • Set up laboratories to test quality of compost produced • Issue suitable guidelines for maintaining the quality of compost and ratio of use of compost visa-a-vis chemical fertilizers while applying compost to farmland

Ministries/ Stakeholders	Duties Undertaken
Ministry of Power	• Decide on tariff or charges for the power generated from the waste to energy plants based on solid waste • Compulsory purchase power generated from such waste to energy plants
Ministry of New and Renewable Energy (MNRE)	• Facilitate infrastructure creation for 'waste to energy' plants • Provide appropriate subsidy or incentives for such 'waste to energy' plants
Manufacturers or Brand Owners of Disposable Products and Sanitary Napkins and Diapers	• The manufacturers have to provide necessary financial assistance to the local authorities for the establishment of waste management system. • The products should come in packaging materials that are non-biodegradable and shall put in place a system for collection
Refuse Derived Fuel (RDF)	• All industrial units using fuel and located within 100 km from a solid waste based refuse derived fuel plant shall make arrangements to replace at least five percent of their fuel requirement by refuse derived fuel so produced
State and UTs Urban Development	• Prepare a state policy and solid waste management strategy for the state or the union territory in consultation with stakeholders • Lay emphasis to ensure minimisation of waste going to landfills • Provide broad guidelines regarding integration of waste picker or informal waste collectors in the waste management system • Ensure implementation of the rules by the local authorities • Direct town planning departments to ensure the master plans of each city have a provision of setting up Solid waste processing and disposal facilities • Ensure identification and allocation of suitable land for setting up of processing and disposal facilities • Direct the town planning department to demarcate separate space for segregation, storage, decentralized processing of solid waste in the development plan for group housing or commercial, institutional or any other non-residential complex exceeding 200 dwellings or having a plot area exceeding 5,000 square meters • Direct the developers of industrial areas to earmark at least 5% of the total area of the plot or minimum five plots or sheds for recovery and recycling facility • Facilitate establishment of common regional sanitary land fill for a group of cities and towns falling within a distance of 50 km (or more) • Arrange for capacity building of local bodies • Notify buffer zone for the solid waste processing and disposal facilities of more than five tons per day
District Magistrate or District Collector or Deputy Commissioner	• Facilitate identification and allocation of suitable land for setting up solid waste processing and disposal facilities to local authorities review the performance of local bodies

Source: (CPHEEO, 2016)

Plastic Waste Management Rules, 2016

The Government of India notified Plastic Waste Management (PWM) Rules, 2016 on 18th March, 2016, superseding Plastic Waste (Management and Handling) Rules, 2011.

The Plastic Waste Management Rules, 2016 applies to every waste generator, but can be classified to local bodies, gram panchayats, manufacturers, importers and producers, event organisers, etc.

Table 1.6: Responsibilities of Urban Local Bodies

• Development and setting up of infrastructure for segregation, collection, storage, transportation, processing and disposal of the plastic waste.
Ensuring: • no damage is caused to the environment • channelization of recyclable plastic waste fraction to recyclers; • processing and disposal on non-recyclable fraction of plastic waste in accordance with the guidelines issued by CPCB • creating awareness among all stakeholders of responsibilities; open burning of plastic waste does not take place
• Local body to frame bye-laws incorporating the provisions of these rules.

Construction and Demolition Waste Management Rules, 2016

C and D waste management was covered under the Municipal Solid Wastes (Management and Handling) Rules 2000, notified by the erstwhile Ministry of Environment and Forests. After reviewing the existing rules, the Ministry considered it necessary to make separate rules in 2016 for the management of C and D waste. Every waste generator has the following duties to be complied with as per the rules. These rules are as given below.

Table 1.7: Responsibilities of Manufacturers

Category	Provisions
Segregation and collection	• Be responsible for collection, segregation of concrete, soil and others, and storage of C and D waste generated
Prohibition of Littering	• Keep C and D waste within the premise, deposit at a collection centre or handover to authorized processing facilities. • Ensure that there is no littering or deposition of C and D Waste so as to prevent obstruction to the traffic or the public or drains.
User fees	• Pay relevant charges for collection, transportation, processing and disposal as notified by the concerned authorities. • Bulk generators additionally pay for processing and disposal of C and D waste generated by them
Bulk C and D waste generators	• Submit waste management plan and get approvals from the local authority prior to construction/demolition/remodeling

Source: (CPHEEO, 2016)

Table 1.8: Responsibilities of ULBs

Category	Provisions
Waste Collection and transportation	• Place appropriate containers for collection of waste and remove at regular intervals on its own or through private operators • Transport the C and D waste to appropriate sites for processing and disposal • Incentivize generators for salvaging, processing and or recycling, preferably in-situ • Issue directions with regard to proper management of C and D waste within its jurisdiction, and seek plan/undertaking from waste generator
Plan approval	• Examine and sanction the waste management plan of bulk generators within a period of one month • Keep track of the generation of C and D waste within its jurisdiction, establish a data base and update once in a year
Awareness	• Create a system for Information, Education and Communication (IEC) for C and D waste
Incentivisation on recycled materials	• Incentivize use of material made from C and D waste in construction activities

Source: (CPHEEO, 2016)

E-Waste Management Rules, 2016

'E-waste' means Electrical and Electronic Equipment, whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment and repair processes. Efficient e-waste management enables, the recovery and/or reuse of useful precious material from Waste Electrical and Electronic Equipment (WEEE), thereby reducing the hazardous wastes destined for disposal and ensures environmentally sound management of all types of WEEE.

Examples of e-waste includes unwanted computer monitors, keyboards, televisions, audio equipment, printers and other home electrical and electronic devices including CFLs and tube lights. Due to the toxic nature of many heavy metals, inorganic and organic compounds, that are associated with manufacturing of electronic equipment and hazardous waste generated during dismantling and recycling at the end of their use, e-waste management is an issue of environmental health and concern. There are different management options for e-waste such as adoption of cleaner technologies, eco-designing of the products, zero waste discharge, waste source reduction, recycling, and reuse of waste materials, incineration and scientific landfilling.

Table 1.9: Responsibilities of Manufacturers

Provisions
• Collect e-waste generated during the manufacture and channelize it for recycling or disposal
• Ensure that no damage is caused to the environment during storage and transportation of e-waste
• Maintain records of the e-waste generated, handled and disposed
• File annual returns in Form-3, to the concerned SPCB on or before the 30th day of June following the financial year

Source: (CPHEEO, 2016)

Table 1.10: Responsibilities of ULBs

Provisions
• Ensure that e-waste if found to be mixed with MSW is properly segregated, collected and is channelized to authorised dismantler or recycler
• Ensure e-waste pertaining to orphan products is collected and channelized to authorised dismantler or recycler

Source: (CPHEEO, 2016)

1.7 Further readings

- Improving Municipal Solid Waste Management in India, WBI, The World Bank, 2008, available at https://openknowledge.worldbank.org/handle/10986/6916
- Report of the Task Force on Waste to Energy, Vol.I, Planning Commission, May, 2014. Available at http://swachhbharaturban.gov.in/writereaddata/Task_force_report_on_WTE.pdf
- Solid Waste Management Rules 2016, and CPCB Guidelines on SWM, Government of India available at https://cpcb.nic.in/municipal-solid-waste-rules/
- CPHEEO manual on Solid Waste Management 2016, Ministry of Housing and Urban Affairs, Government of India available at http://cpheeo.gov.in/cms/manual-on-municipal-solid-waste-management-2016.php
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Quick assessment

1. Which of the following solid wastes best describes the term 'Municipal Solid Waste'?
   a. Toxic
   b. Hazardous
   c. Non-toxic
   d. Non-hazardous

2 Which of the following should be done on an individual level?
   a. Burning
   b. Disposal
   c. Recycling
   d. Source reduction

3 Which of the following plans is used as a waste management plan?
   a. Plan for reuse
   b. Integrated Solid Waste Management Plan
   c. Plan for recycling
   d. Plan for reducing

4. The burning of solid waste is not recommended because
   a. It is very costly
   b. It requires a lot of space
   c. It requires modern technologies
   d. It causes several environmental issues

5. Which of the following statements is true about zero waste management?
    a. Separate collection of each kind of waste
    b. Segregation of garbage at the source
    c. Community involvement
    d. All of the above

6. The average person living in the India produces about... of solid waste per day

7. The 3Rs of solving the garbage problem are
    a. Replace recover remove
    b. Remove rewind and recover
    c. Reduce reuse and recycle

** For answers please refer annexure II*

Compost packaging shed, Lucknow, Uttar Pradesh
Source: Author

Chapter
2

Planning for Solid Waste Management

Recap

The previous chapter focused on developing a brief understanding of current status of solid waste management and existing legislations governing the sector. This chapter details various strategies related to planning for SWM.

Training Objectives

- Understand various steps involved in formulation of SWM strategy for a city
- To learn about the action plan components of SWM
- Understand the process of engaging the stakeholders in the implementation process

Training Outcomes

- Understanding of SWM strategy to formulate nuanced management and action plan for a city
- Get an overview of stakeholder engagement in planning and implementation process

Chapter Contents

2.1 Introduction
2.2 Visioning exercise
2.3 Drafting the Action Plan
2.4 Strategy and Action Plan components
2.5 Further Readings
References
Quick assessment

2.1 Introduction

Municipal Solid Waste Management (MSWM) is an important service. It is one of the mandatory functions of an ULB, as per the 12th Schedule of the 74th Constitutional Amendment Act. According to Clause 15(a) of Solid Waste Management (SWM) Rules, 2016, all local authorities shall "Prepare a solid waste management plan as per state policy and strategy on solid waste management within six months from the date of notification of state policy and strategy and submit a copy to respective departments of State Government or Union territory Administration or agency authorised by the State Government or Union territory Administration". This chapter provides stepwise direction to ULBs for the preparation of MSWM plans.

Vision

Visioning exercise stimulates us to step back from our daily activities and look at the macro picture. We all start our work towards a goal and or achieve a purpose. However, many a times we get so immersed in our daily activities and associated challenges that we lose sight of the bigger picture. We therefore need to revisit our goals.

Defining what we want to achieve is known as the vision. The vision is something that we aspire for and which inspires us daily. It can be lofty, idealistic, ambitious and seemingly unachievable. To achieve the whole or part of this vision, we have to take several steps. These steps to achieve our vision is our plan. It consists of several decisions and actions over a period of time.

The Need for a Strategic plan

A plan will guide us towards our goal and help us to achieve it. It has to be based on certain decided values, principles and ideals. This ensures that every decision, action, and project we undertake always meets the larger goal even if it is not explicitly stated in our plan.

Strategic planning is necessary to ensure that MSWM services keep pace with demand, are appropriate to needs, contribute to a sound and sanitary environment, are cost-effective and build continuously on existing and new opportunities offered. (Waste Portal)

The SWM rules 2016 state the following as the first duty and responsibility of local authorities:

The local authorities and Panchayats shall:
(a) prepare a solid waste management plan as per state policy and strategy on solid waste management within six months from the date of notification of state policy and strategy and submit a copy to respective departments of State Government or Union territory Administration or agency authorised by the State Government or Union territory administration; Operations – planning. Thus strategic planning for SWM is also a regulatory requirement.

SWM has been a challenge for most ULBs. With rapid rate of urbanization, ULB officials heading the SWM department, often find themselves fighting operational, political, public and regulatory issues on a daily basis.

Figure 2.1: Components of SWM Strategic plan

Source: Author

A well-defined and Strategic plan provides a path for the entire SWM team, from the Head of the department to the sanitary workers. With the frequent rotations and changes in the officials, a departmental plan will also ensure continuity in work with the larger welfare of the citizens.

What is a SWM Strategy?

Strategy for SWM has to be a very adaptable methodology where the only thing fixed is the final objective of an efficient sustainable solid waste management for the city. A SWM Strategy will be the guiding tool for the urban local body in the following:

Figure 2.2: Guiding tools for SWM Strategy

Source: Author

Areas covered under a SWM Strategy include:

- Overall Vision
- Goals and Objectives (National/ state/ municipal)
- National Policy framework

- Roles and Responsibilities
- Waste streams to be covered
- Waste collection targets and systems
- Promotion of recycling
- Waste treatment and disposal policy
- Public awareness requirements
- Policy on private sector participation
- Cost recovery and financial management policy
- Outline of investments required

Process to formulate SWM Strategy and Action Plan

Strategic Planning is a process with the end objective of creating a Plan. The process follows four distinct steps:

Figure 2.3: Strategic planning process

Source: Author

Baseline assessment

This is the 'as is' current situation of solid waste management in the ULB. The assessment is meant to give in-depth and precise understanding of the ground level conditions in waste management. It should cover all the aspects of SWM as given below.

- Segregation
- Collection system – gate collection, door to door collection, bin collection, etc.
- Primary transportation – wheel barrows, push carts, cycles rickshaw, ghanta gadi, tractor, etc.
- Secondary transportation
- Transfer stations
- Processing systems
- Human resource – sweepers issues.
- Existing policies, byelaws, fees, fines

A baseline assessment should preferably be conducted by an unbiased third party. It should capture all the practical, logistic, functional, socio-economic, cultural and geographical factors affecting the waste management.

It should be done at the lowest management level such as at ward level. A uniform survey form or checklist should be used to assess all areas of the same parameters.

The data and information collected should be collated and analysed thoroughly to precisely present the issues and challenges for the ULB. The detailed proforma of Baseline Assessment is provided in the CPHEEO Manual.

Future Projections

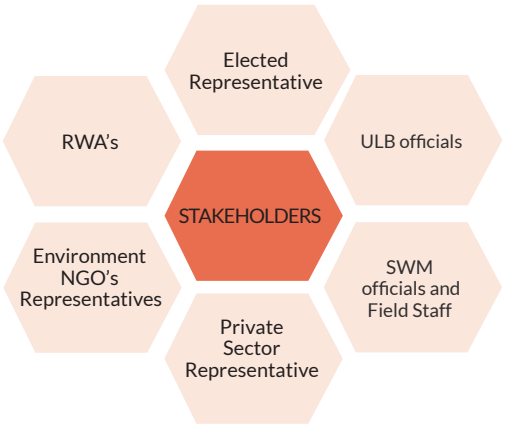
Considering a 5 to 10-years future scenario, and the current rate of growth, estimation of future waste quantities should be undertaken. Waste generation of each type of waste should be estimated.

Stakeholders in the process

The visioning and strategy formation exercise has to be conducted by involvement of all stakeholders.

The figure below enumerates the citizen representatives of different socio-economic groups and geographies in the city

Figure 2.4: Stakeholders for the SWM strategy plan



Source: Author

Citizen feedback surveys could also be conducted to assess the citizen's perspectives.

Participation of all the stakeholders is essential for future implementation of the strategy plan, to get the buy in of everyone.

2.2. Visioning exercise

Establishing a common vision is very critical to develop the strategy plan for the ULB. Every stakeholder in every city will have a different perspective in defining the problem and the most crucial issue to solve. Bringing all the stakeholders to a consensus for a common vision requires that a visioning exercise is facilitated.

To get the participation of all the stakeholders the visioning exercise can be coordinating and scheduled in phases. The first step in the exercise should be the presentation of the findings from the baseline assessment. The second step is to provide the projections of future waste scenarios and challenges.

Engaging the major stakeholders in the implementation (MARGG and ITDG, 2005)

Stakeholder participation is the fulcrum of the new strategy. The strategy is built on the premise that solid waste management is not mere public health engineering exercise. It requires the participation of every single resident and user of city facilities. An ULB may use the following approaches to mobilize their cooperation to its citizens.

- Creation of institutional mechanisms such as working groups and regular city consultations to involve the residents individually and collectively
- Conduct of community-based civic education programmes
- Setting up ward level Environment Management Committees (EMC) in each ward under the leadership of the clergy
- Setting up of Lane Committees for environment
- Revitalizing School Environment Committees to get involved in social mobilization
- Publication of waste collection schedules
- Promotion of urban horticulture
- Recognition and facilitation of the private informal sector
- Engagement and facilitation of NGOs and CBOs

Target Setting

The visioning exercise has to be concluded by setting the target timelines and goals. Targets such as – 100% segregation to be achieved in one year, or 10% waste reduction in two years, or zero plastic waste in two years. These targets are essential to set milestones in the strategy plan.

While setting the targets, consideration has to be given the following aspects: (Peter Schübeler, 1996)

1. Political
2. Social

3. Institutional
4. Financial
5. Technical

These targets have to be in relation to the financial outlays of the ULB. Targets also need to be realistic and achievable.

Strategy formulation

The vision and targets set the outer boundary for preparing the strategy. Ideally the method for strategy formulation can be where a core team of five to six persons is entrusted the responsibility of developing the potential strategies to reach the targets. These proposed strategies are presented to senior SWM officials and/or a subcommittee consisting of all stakeholders. The strategies are debated, discussed and appropriate strategies are finalized. Keep in mind that although certain decisions can be made, it can change based on circumstances in the future.

Strategy formulation has to encompass all the areas of solid waste management, these components are listed in the next section and for further details the CPHEEO manual can be referred.

Strategy formulation is a decision making exercise by reviewing all the resources available and taking the best technologically suited and financially feasible option. This is elaborated in the next section.

2.3. Drafting the Action Plan

The strategy must be further converted to actionable steps to meet the targets and milestones decided. Actions should meet the 'SMART' principles, i.e. they need to be Specific, Measurable, Achievable, Realistic and Timely. The actions should be planned by the Core team in consultation with the departments implementing officers. Case studies and success stories from other cities should be studied to identify realistic actions and steps. The overview of an Action plan is elaborated in the next section.

Approval of SWM Strategy and Action Plan

The SWM strategy and Action plan should be vetted and approved by the ULB through its general body and then submitted to the State for approval.

The strategy and action plan thus become the basis for preparing a Detailed Project Report (DPR) for SWM.

2.4. Strategy and Action Plan components

The entire process and decisions must be captured into a report/document to form the SWM Strategy and Action Plan. The framing of the strategy and action plan should be clear and precise; it should not depict any ambiguity. It should layout a clear goal, target, milestones, strategy and specific actions to achieve the targets. It does not have to be a lengthy document, but a crisp and precise guide.

For each of the SWM component areas, below is a process flow chart that highlights the decision-making aspects of a SWM Strategy and the potential actions based on the decisions.

Disposal

ULB shall plan for a Sanitary Landfill for disposal of the inerts. Here land availability is the critical parameter. The life of the existing landfill, and area required for a new landfill are major decisions and require administrative process.

In case, the existing site is not a Sanitary landfill, than compliance issues have to be met. Bioremediation of existing landfill and reclaiming the land is another decision.

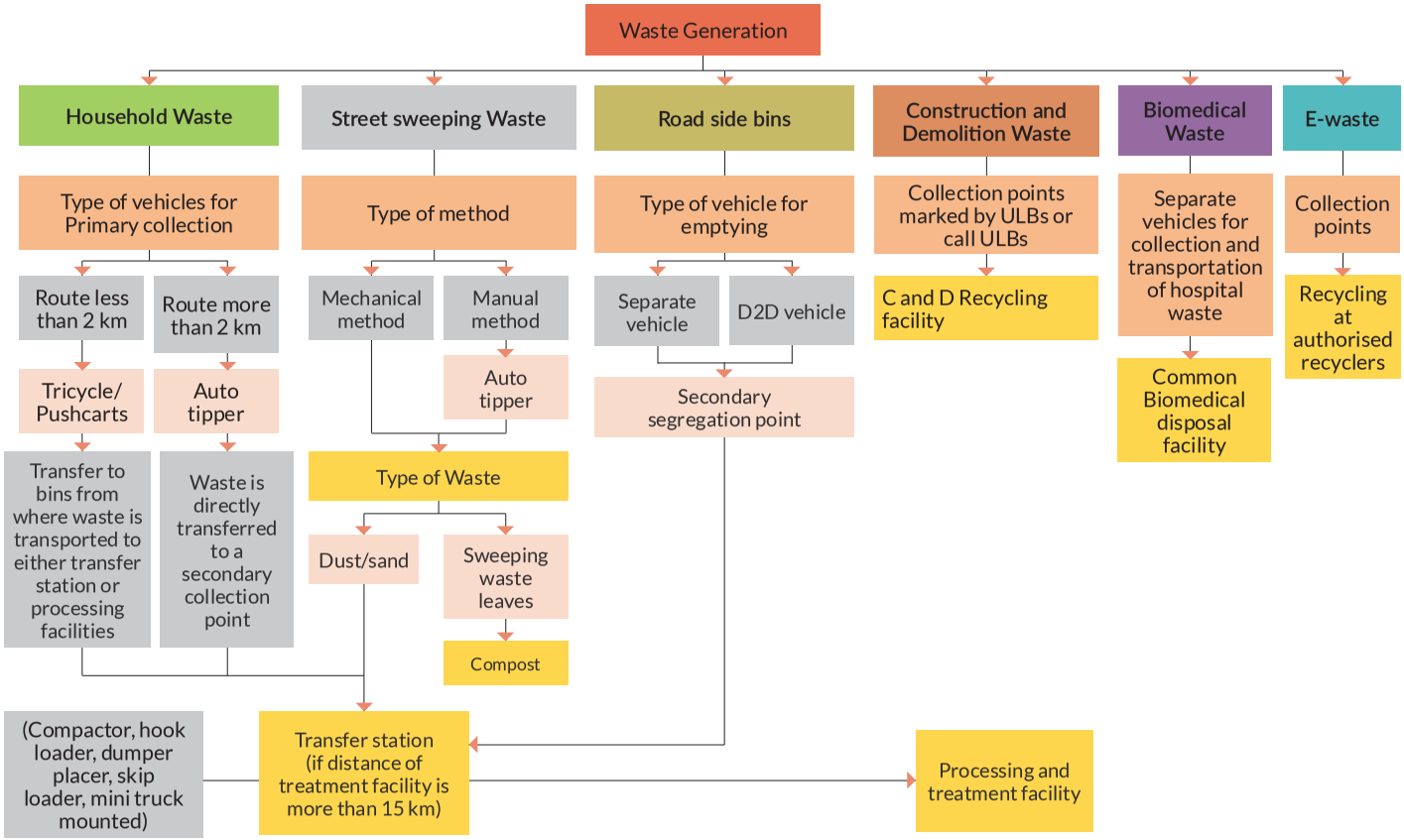
Citizen engagement

Active citizen involvement is critical for an efficient waste management and to achieve a visually clean city. Strategy for citizen engagement should be based on consideration of the following factors:

- ULBs should approach citizen engagement as equal to the SWM infrastructure development and provide equal resources in terms of human and financial resources for it.
- The strategy should identify the focus areas, such as segregation, littering, no to plastic waste, etc. as the goal for citizen engagement. These could be time bound and cumulative.
- Citizen participation is a continuous operation; it is not a onetime activity that can provide immediate tangible results. Failure to keep a constant engagement will result in spurts of successes, and again a lapse to earlier habits. Thus, ULBs should appoint either an in-house resource or outsource the activity to a capable agency on a long-term basis.
- Innovation and novelty are essential to maintain public interest and involvement; thus the continuous IEC has to be undertaken creatively.
- To see long term tangible results, Behavior Change Communication (BCC) tools could be incorporated.
- ULB field staff is the face of SWM for the citizens and they are the best messengers too. Enabling the staff to play this role effectively requires measures in staff capacity building.

Leaf Composter in community Park, Silvassa Dadra and Nagar Haveli
Source: Author

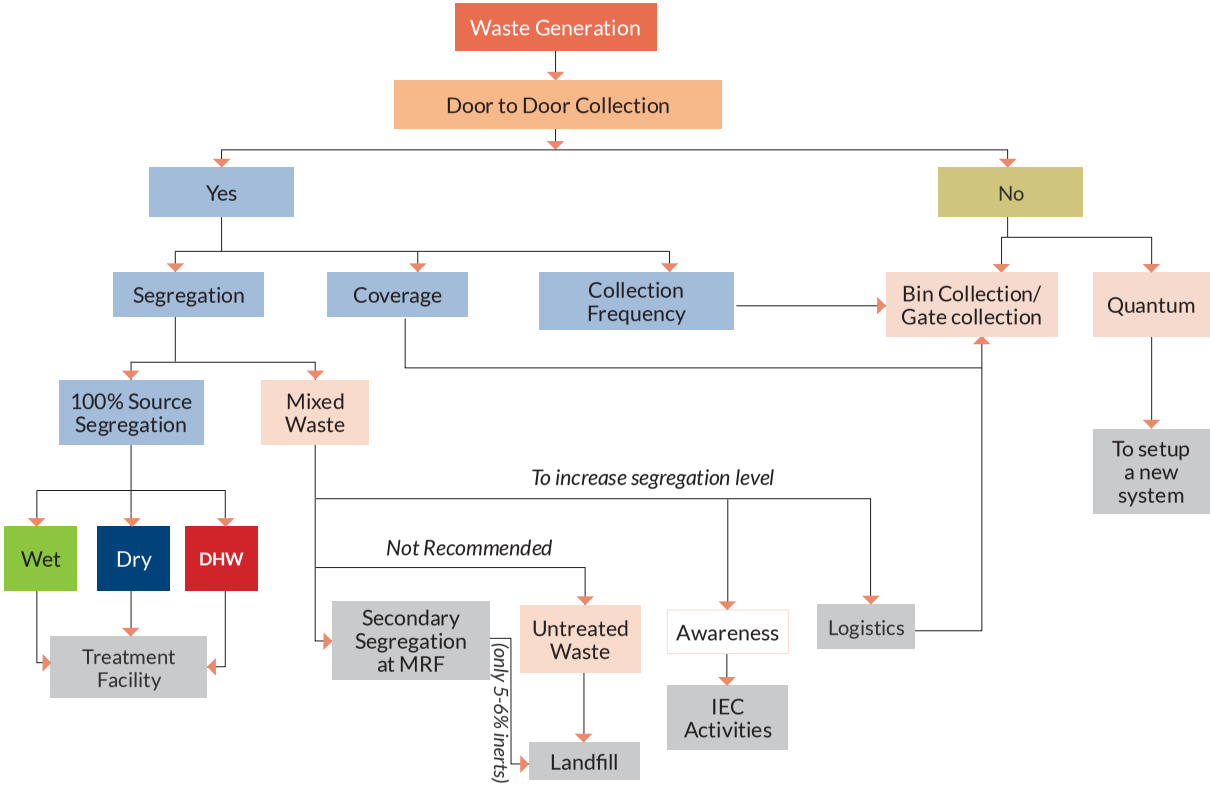
Figure 2.5: Waste Collection and Transportation - Decision points



Source: Author

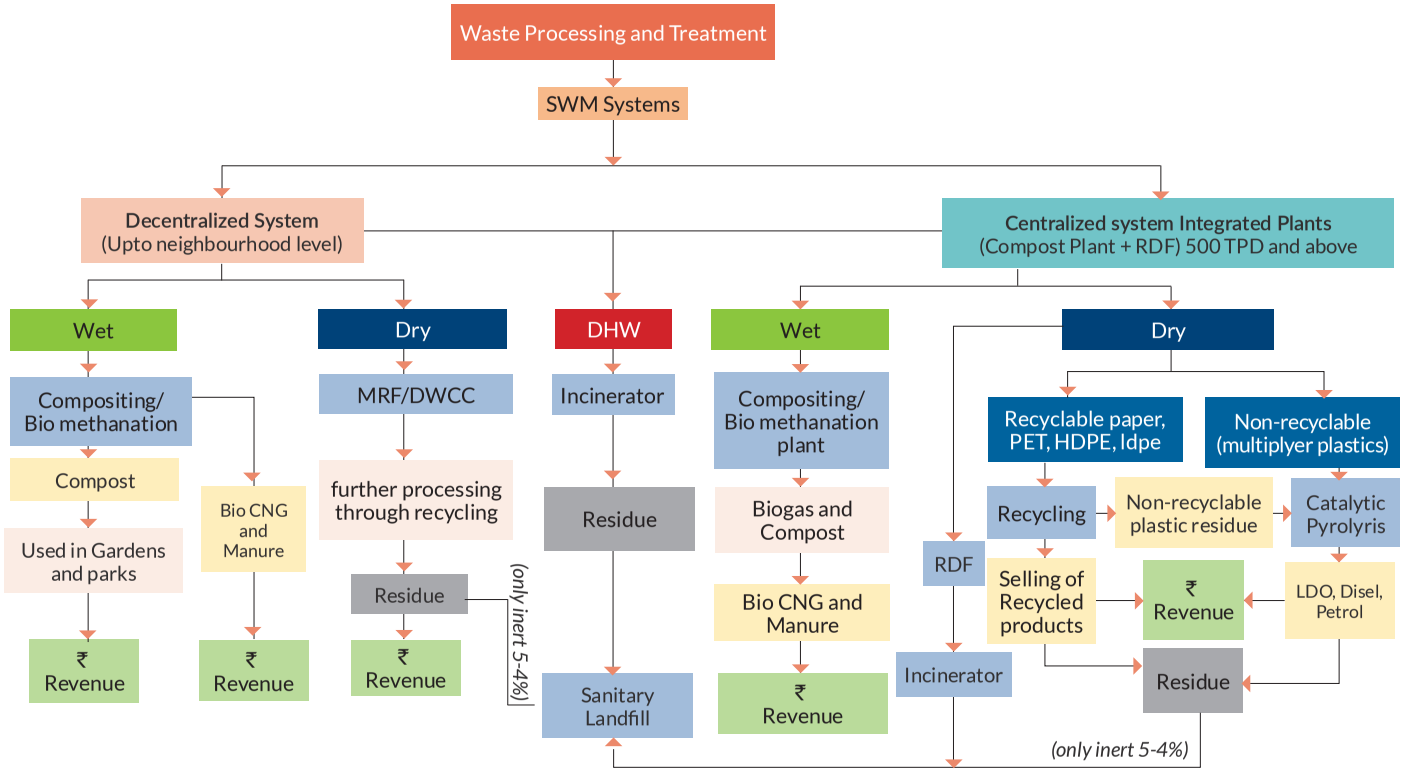
Waste Segregation

Figure 2.6: Waste Segregation - Decision points



Source: Author

Figure 2.7: Waste Processing and Treatment - Decision points



Source: Author

Policy

The SWM strategy will dictate the policies to be framed. For example, if the ULB decides to create a system for separate garden waste collection using a separate service charge, this must be notified to the citizens as a notification. On a broad basis, three areas of policy have to be framed:

- **Byelaws** – as mandated by the SWM Rules 2016, and in line with the SWM strategy, the ULB should frame the byelaws, or if required modify the existing byelaws. The byelaws act as a guide to the citizens and ULB, as it details the roles and responsibilities of each as per the SWM strategy. It is also an enforcement tool to implement the strategy.
- **User fees** – the amount, period and means of collection for different categories of establishments must be established. Any additional or other fees, such as C and D collection fees to be levied at the time of construction permit should be identified.
- **Penalties and fines** – for any non-compliance to the byelaws, stringent punitive actions and fines should be defined for citizens to respect the seriousness of SWM.

Monitoring and Governance

For successful implementation of the SWM strategy, designing a monitoring and governance system is essential. Strategy for monitoring and governance should be based on consideration of the following factors:

- **MIS systems** – operations work efficiently only when monitored in a manner such that accountability is clearly defined. Management Information Systems, should be designed as per the level of staff capability. Thus, these may be basic paper pencil registers or Mobile apps, any form that provides a daily/ regular update to the senior, and which facilitates decision making in a proactive way, instead of reactive actions.
- **IT interventions** - several IT interventions such as VTMS, Biometrics, RFIDs, GPS etc. are available for use. These should be explored as suitable for the ULBs. IT interventions should support the human based reporting systems, and the purpose should not be to entirely replace the human based systems.

  In several cities it is seen that an IT intervention such as VTMS is adopted, but no person is designated the responsibility to monitor and review the data on a day to day basis. Thus, the actual efficiency gain from the intervention is never harnessed.
- **Institutional structure** – the implementation of a SWM strategy depends on the ULBs institutional structure and decision-making centres. As the scale of city expands, the ideal structure is to have decentralized decision making for day to day operation and a centralized decision making for matters of policy and new projects. It is also important to avoid dual reporting within the staff.

  SWM is also labour intensive, and it is human nature to bypass any monitoring efforts of the organizations. Thus, equal emphasis should also be given to improve the ethical morale of the field staff as well as taking stringent actions to instill discipline.

Action plan components

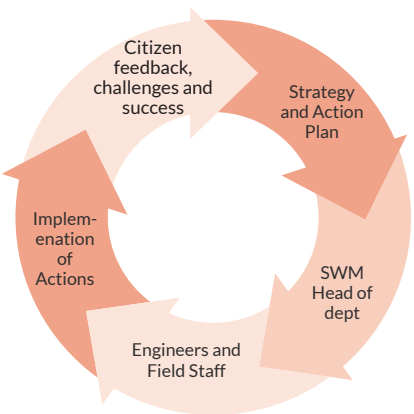
The Strategy decisions shall be converted to actionable steps to reach the vision. As mentioned above each action should be a SMART action. To set achievable milestones, the Action plan can be divided into three stages- Short, medium and long, as given below:

- **Short term (Next 6 months to 1 year)** – these consists of certain immediate actions that need to be implemented to address urgent concerns, such as completion of ongoing processing plant projects, streamlining the vehicle allotment and movement, hiring contractual labour to address any specific area needs, etc. Short term actions should be achievable within the available financial and human resources.
- **Medium term (Next 1 to 3 year)** – these are actions that will chart the way towards the new strategy. These are actions that can be implemented by allocating budgets in the next few years, and lay the base for the long term actions. Examples of medium term action are, setting up a project for plastic collection and processing, construction of new MRFs, taking concrete steps for citizen engagement, promoting new IEC campaigns for citizen or making a program for staff capacity building.
- **Long term (3 to 10 year)** – these actions work towards creating the vision. These can be financial costly actions, that need to be planned over few years. These are also actions that will need acceptance from policy makers. These are actions such as changing the collection vehicle fleet, constructing a new Sanitary landfill, installing new waste processing plants.

Even when actions are categorized as short, medium and long term, the work for each of the sectors has to start from the first day.

Decision process flow for corrective actions – While implementing the strategy and action plan it is important to maintain a closed loop cycle of information flow as shown below:

Figure 2.8: Closed loop cycle of information flow



Source: Author

Wherever possible, actions should be piloted, and feedback taken of practical challenges and related negative consequences if any. These inputs can be used to reframe the actions. Throughout the implementation period, the decision makers must be cognizant of the current situations and applicability of the changing scenarios.

2.5. Further reading

- CPHEEO manual on Solid Waste Management 2016, Ministry of Housing and Urban Affairs, Government of India available at http://cpheeo.gov.in/cms/manual-on-municipal-solid-waste-management-2016.php
- Global Waste Management Outlook, 2015, UNEP, available at https://www.uncclearn.org/wp-content/uploads/library/unep23092015.pdf
- Municipal Solid Waste Management: A Roadmap for Reform for Policy Makers, 2018, World Bank, available at https://openknowledge.worldbank.org/handle/10986/30434

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- CPHEEO, 2016. Municipal Solid Waste Management Manual. Part II ed. s.l.:Central Public Health and Environmental Engineering Organisation.
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Quick Assessment

1. Transfer station is installed, if travel distance is more than ___ Km
   a. 15 km
   b. 20km
   c. 50km
   d. 5 km

2. One of the major stakeholders in the solid waste management whose contribution needs to be accounted in waste management service chain is
   a. Non-governmental organizations
   b. Individuals/households
   c. State governments
   d. Informal sector

3. As per SWM Rules, 2016 every state shall prepare a SWM _____ and ULB's shall prepare a _____.

4. The MSWM plan is prepared for
   a. 5-10 years
   b. 10-15 years
   c. 15-20 years
   d. 20–25 years

5. EPR stands for _____

6. In order to reduce the burden of handling large volumes of MSW and reduce related costs, _____ system shall be adopted

7. As per CPHEEO manual on SWM, MSW density in India is typically around _____
   a. 200-350 kg/m^3
   b. 350-450 kg/m^3
   c. 450–500 kg/m^3
   d. 600-750 kg/m^3

** For answers please refer annexure I*

Automated MRF Facility, Indore, Madhya Pradesh
Source: Author

Solid Waste Management Strategy Plan 2017 – 2025 (Pune Municipal Corporation)

Highlights	
State	Maharashtra
Area	331 sq. km
Total Population	3132142
Total Households	Nearly 1 million
Number of Wards	15
Waste generated	1600 – 1700 MT per day

Pune, the second largest metropolitan city in Maharashtra, is rapidly changing its character from a Pensioner's city to Educational –Administrative Center and now to an important IT hub. Pune Municipal Corporation (PMC) is the civic body that governs Pune. The success of 'Pune Model' of solid waste management is often discussed as a model that worth replicating. The model of SWM showcases 'stakeholder engagement' that extends from rag pickers' collectives, to citizen groups, NGOs, educational institutions and corporators.

Note: The strategy of Pune Municipal Corporation as documented above was prepared in 2017 any modifications post 2017 have not been captured in this case study. This case study can be used as a reference for preparing SWM Strategy

The SWM strategy of PMC, prepared in 2017, is discussed below in detail for reference.

Vision of Strategic SWM plan

A clean Pune through citizen engagement for efficient solid waste management.

**Details w.r.t. visioning exercise adopted by PMC can be refered at section 2.2 (visioning exercise).*

Objectives

The objective adopted by PMC is as mentioned below:

- To achieve 100 % door to door coverage of segregated waste collection.
- To minimize waste generation
- To process 100% of waste collected in Pune city
- To develop an integrated waste management system through citizen engagement using IT solutions for monitoring the entire system
- To completely stop open dumping at landfill site

Components of SWM Strategy

The SWM strategy plan of PMC focused on the following eight components across the solid waste management value chain to achieve their vision in an effective manner. To develop sustainable SWM plan, understanding the current and future demands is important. The PMC conducted a baseline assessment to understand the current status of SWM in the city that included the following elements:

1. Waste Generation and Segregation
2. Primary Collection
3. Secondary Transportation
4. Processing and Landfill
5. Citizen Engagement
6. Monitoring and Governance
7. Policy
8. Land Acquisition

Based on the assessment of the current status of SWM in the city, the following gaps were identified:

Sl. No.	SWM components	Gaps Identified
01	Waste generation and segregation	• Daily door step collection is inadequate • Source segregation is limited
02	Primary Collection	• SWaCH Waste pickers' reliability (daily and on time) and coverage • Large variation in user fees being charged • Lack of viability of user fee driven model in most slums and goathan areas. • Inadequate secondary collection capacity (for example Transfer stations, etc.) • Lack of reliability of collection vehicle in terms of breakdowns, timing and off route.
03	Secondary Transportation	• Capacity of secondary transportation is only 70%. • Lack of coordination between primary collection and primary and secondary transportation. • Insufficient number of Bulk Refuse Carriers leading to pile up of primary collection vehicles at transfer stations. • Only 40% vehicle drivers are available. • Outdated weighbridges and equipment call for modernization of transfer stations

Sl. No.	SWM components	Gaps Identified
04	Processing and Landfill	• Extent of recyclable waste collection system is limited • Provision of decentralized recycling and treatment facilities is limited • Shortfall in treatment capacity because of inadequate land • Utilization of treatment infrastructure very low • Over-dependence on landfill leading to environmental and social issues • Landfill current capacity for additional 5 years
05	Citizen Engagement	• No high-outreach programme promoting domestic or commercial waste avoidance • Focus on cost-recovery for services limited, hence, financial sustainability under stress • Approximately 52% of households segregate waste • NIMBY attitude towards waste plants • Nonpayment of user fee • Littering /dumping of waste
06	Monitoring and Governance	• Lack of robust monitoring systems. • Lack of regular vehicle route monitoring in spite of installing GPS tracking devices on vehicles. • Lack of technically qualified staff for monitoring processing plants. • Gap in support to undertake monitoring of entire collection system • Lack of systems to generate comprehensive data for monitoring key operations • Absence of service level benchmarks
07	Policy	• Lack of enforceable SWM Byelaws as mandated by the SWM Rules 2016 • Lack of clear policy for plastic waste management.
08	Land Acquisition	• Lack of reservation of adequate land in DP for SWM facilities and processing plants and lack of buffer zones at various processing sites • Delays in acquiring existing land parcels marked in DP for SWM activities

To achieve the desired outcomes for effective solid waste management, every component of the plan included a set of targeted and achievable action points planned across two phases. Every component had specific action points. The following sections provide a brief overview of various action points across the value chain.

Overall approach (with action points) for strengthening primary collection till 2025

Primary collection refers to the process of collecting, lifting and removal of segregated solid waste from source of its generation and taking the waste to a storage depot or transfer station or directly to the disposal site. Primary collection must ensure separate collection of certain waste streams or fractions depending on the separation and reuse system applied by the respective town or city. The approaches adopted by PMC for improving the primary waste collection system is as discussed below:

Component	Target till the year 2025	Overall approach	Action points	Phase-wise Action Plan	
				Phase 1 2017 - 2019	Phase 2 2020 - 2025
Primary collection	• Increase source segregation levels from 52% to 100% • Improve door to door collection levels from 55% to 100%	• Reviewing options for outsourcing door step collection • Number of HHs / estimated quantity of waste • Rework on waste collection practice from slums	• The entire garden waste collection and processing from the city shall be outsourced. • Installing an incinerator for fish, chicken and mutton waste. Register fish, chicken and mutton waste vendors and provide separate vehicles for waste collection. • Segregate plastic waste. Use plastic waste for repairing existing roads and developing new roads. • Set up the collection, transportation and processing system for C and D waste. Using IT based system to monitor the entire process. • Setup a few e-waste collection centers and carry out e-waste collection drives on a regular basis. • In order to enhance the quality and speed of cleaning all major roads in the city, mechanized street sweeping shall be introduced • The smaller internal roads in residential areas and internal wards will continue to be swept by the existing staff	• Move towards 100% DTDC contracts • Providing primary collection vehicles for segregated waste collection in each ward as per requirement • Plan routes of Ghantagadi through participation of local residents and housing societies for feeder points at Prabhag levels. • Install segregated waste community bin with improved collection efficiency • Enlisting all medical establishments to be covered by the Bio-Medical Waste Management (BMW) system • Establish vigilance and action squads to monitor dumping of waste by nearby villages within PMC limits. • Create a Waste Park that will have permanent exhibition area for household level waste processing technologies. The park will exhibit technologies of different vendors.	100% segregated waste collection and DTDC

Overall approach and action points for secondary collection

The synchronization between waste collection and transportation is an important aspect for efficient waste management. Aspects such as choosing appropriate site for secondary waste collection, appropriate vehicle selection for transportation of waste to respective processing facility, route optimization, etc. have to be carefully planned. In order to bridge the gaps identified across the secondary collection and transportation of waste, following approaches and action points were adopted by the Pune Municipal Corporation.

Component	Target	Overall approach	Action points	Phase-wise Action Plan	
				Phase 1 2017 - 2019	Phase 2 2020 - 2025
Secondary collection and Transportation	Secondary transportation of 100% segregated waste	• Improve fleet efficiency of secondary waste collection of the transfer stations • Shift waste movement from existing transfer station to processing plant/landfill, • Introduce accountability of official by providing targets w.r.t., type and quantity of waste being send from each ward/ transfer station.	• Dumper placers for collection of container bin waste will be replaced with Compactor vehicles • Provision of vehicles for collecting 100% waste • Dumper placer vehicles will be phased out from bin collection and used for garden waste collection. • Other vehicles for Hotel waste collection will be have to be procured as per requirement. • C and D waste collection is to be outsourced.	• Commissioning of three more transfer station • Provision of Electronic Weighbridges at all transfer stations, processing plants and landfill • Replace old vehicles and procure additional Ghantagadi as required • Outsource the transportation of waste from transfer stations • In case of incorporation of new villages, new transfer stations (3-4) will have to be planned and developed. • Revamping the existing transfer stations	Procure additional vehicles for primary collection

Approaches and action points for processing and landfill

While strategies to minimize waste generation and ensure source segregation are important to effectively manage the quantum of waste generated by the city, proper processing and disposal of waste is equally important. Promoting efficient resource recovery from waste can help the city generate wealth from waste and in turn provide livelihood opportunities to many. Proper disposal of waste is essential to minimize any adverse impact on the environment. Aspects such as selecting a site for a sanitary landfill, choosing appropriate technology, resource recovery, etc. have to be planned. Pune Municipal Corporation adopted the following approaches to ensure that 100% of waste generated in the city is processed, with no open dumping at the landfill.

Component	Target	Overall approach	Action points	Phase-wise Action Plan	
				Phase 1 2017 - 2019	Phase 2 2020 - 2025
Processing and landfill	100% of waste generated in the city to be processed completely with no open dumping at the landfill	• Technical audit of all processing plants • Maximizing the utilization capacity of all existing processing plants • Promoting and enforcing in-situ wet waste processing in Housing societies • Formation of a Technical Advisory Committee (TAC) • All new processing plant projects to be developed on Engineering Procurement Construction (EPC) model • Acquisition of land for installing new processing plants • Providing buffer zone for all processing plants	• The existing landfill site can be reclaimed to partially mitigate the environmental impacts. • Employment for youths of the villages • Return of land to landowners after appropriate capping of the landfills	• Provide support for in-situ processing at housing societies • Technical Audit of processing plants • Prepare prefeasibility, feasibility and detailed project reports for all new proposed plants • C and D waste processing to be commissioned • Approval for tender process for preparation and maintenance of existing sanitary landfill • Complete capping of dumpsite for remaining area • Quarterly audit of each plant by engineer staff. • Introduce a system of payment for quantity of waste processed	• Additional capacity 300 MT* to be commissioned by installing 2 new decentralized locations • Additional capacity 700 MT to be commissioned by installing 4 new decentralized locations (with 34 villages) • Set up a sanitary waste processing facility • Tender for preparation and maintenance of landfill

Approaches and action points for citizen engagement

Citizen engagement is very important to ensure smooth service delivery and acceptance of any waste management plan. Enabling citizens to not just voice their opinion but also actively participate in the achieving the desired outcomes set across the strategy plan. Engaging with citizens also helps to anticipate and mitigate risks in an effective and sustainable manner. The following section showcases the approaches adopted by the Pune Municipal Corporation to enhance citizen engagement for achieving various desired outcomes.

Component	Target	Overall approach	Action points	Phase-wise Action Plan	
				Phase 1 2017 - 2019	Phase 2 2020 - 2025
Citizen Engagement	• Increase source segregation levels from 45% to 100% • Reduce the waste by 25% by 2025	• Targeted focus on HHs covered under DTDC but are not segregating waste • Intensive campaign on source segregation • Identification of at least 1 'Swachhata Mitra' for every 250 HHs • Introducing citizen wards for innovative solutions	• High Level Citywide Campaign (includes Large Media Campaign, Pledge Drive) • Outreach through special groups - Schools and Colleges, Corporates, Lions and Rotary Clubs, SHGs, etc. • Ward level rallies, exhibitions and competitions • 4-5 public events by Mayor/MC/Party leaders across the city • Pledge drive in every ward with goal of collecting 10 lakh signatures across the city in one day • Use Billboards/Banners/ Social Media to broadcast goals, roadmap, methods for grievance redressal and complaints.	• Targeted focus on HHs covered under DTDC but are not segregating at source • Intensive campaign on source segregation: • Involving school/NCC students for IEC campaigns • Identification and training of 'Swachhata Mitras' • Exhibition of various waste processing technologies • Citizen engagement by instituting various 'Swachh' Awards • Establishment of Waste Technology Park in Pune city • Standardization of in-situ compost plant to be done and made available to developers, builders	• Sustained campaigns on source segregation • Continuation of citizen engagement programs by instituting 'Swachh' Awards

Monitoring and Governance for overall operation and maintenance of SWM with action points

Efficient Monitoring ensures proper implementation of the strategy plan. It helps in keeping a track on the progress for achieving the targets set forth across the plan and suggest necessary course corrections. An efficient monitoring and governance system ensures smooth operation and maintenance of the solid waste management plan. Effective monitoring mechanisms require efficient data collection systems, and effective governance structure are important for achieving defined strategic goals and objectives. An effective governance structure must be lean, simple and straightforward and aligned with all levels of the organization. The monitoring and governance approaches adopted by Pune Municipal Corporation is discussed as below.

Component	Target	Overall approach	Action points	Phase-wise Action Plan	
				Phase 1 2017 - 2019	Phase 2 2020 - 2025
Monitoring and Governance	• Formation of a Monitoring Committee • Instituting IT based system for monitoring of operations • Restructuring of the department • Capacity building of existing staff	• Monitoring committee to monitor the progress of action plan • Development of IT based monitoring system • Periodical audit of all processing plants • Monthly Swachh Survekshan at prabhag/ ward level to monitor the segregation levels and link to ward budgeting • Expert Technical Advisory Committee for inputs on processing technologies and waste management technologies • Technically qualified staff	• Formation of Monitoring Committee • Creation of a dashboard to provide information on all indicators • Ward wise budget allocation to be linked to performance of the wards on the indicators from 2018 • PMU is also expected to assist the dept. in preparing tender documents and providing transaction advisory services • Estimated budget for setting up a PMU • Engineers from Projects team will be for long term durations and will not be transferred until projects assigned to them are completed satisfactorily. • Entire staff will be supported with ground level SI/DSI	• Quarterly meeting of monitoring committee • Identification of dashboard parameters • Monthly Swachh Survekshan review of audit report • Availability of live data in public domain • Appoint an expert Technical Advisory Committee • Orders for restructuring of the department • Establishing PMU • Identification of training needs and developing training modules • Appointment of staff as per new framework • Conducting capacity building trainings • Instituting a rewards and recognition program • Engaging CSR funds for various SWM activities	• Continuous availability of live data in public domain • Additional staff positions as per requirement

Policy

The policy for efficient Solid Waste Management should ensure minimization of waste at source and promote the concepts of reuse and recycling. The policy should aim to bring about behavioral change among citizens and decision makers for smooth implementation of waste management strategies and plans. The policies should clearly suggest the desired outcomes to ensure efficient management. While the policies should address the current needs, planning for the future needs is also important. The policy adopted by Pune Municipal Corporation for efficient solid waste management is discussed as below:

Component	Target	Overall approach	Action points	Phase-wise Action Plan	
				Phase 1 2017 - 2019	Phase 2 2020 - 2025

Policy	• Approval and enforcement of SWM Byelaws
	• Enforce Plastic Waste Management Rules
		Approval and enforcement of SWM Byelaws	• Approval of SWM Byelaws in General Body
			• Unequivocal commitment/support from elected representatives for promoting 100% DTDC services – support PMC and allied agencies providing door step collection services by providing a written commitment stating their support for:
			  • Increasing the coverage by PMC and/or allied agencies for DTDC service
			  • Issue a written statement in their respective wards directing the citizens to segregate their household waste and give only segregated waste to the waste pickers daily and consequences of not adhering to the same.
			  • Issue a written statement in their respective wards directing the citizens to pay user fee and on time.
			  • Issue a written statement in their respective wards directing all the housing societies to set up in-situ wet waste processing plants and consequences of not adhering to the same.
			• Commitment from elected representatives that they agree to follow the service level standards introduced by the SWM dept. before purchasing vehicles, if any, from cooperators' funds for primary collection.
			• Approval for linking monthly Swachh Survekshan to ward level budget allocation
				• Approval of SWM Byelaws in PMC General Body
				• Enforcement of payment of user fee for collection
				• Promote source segregation of waste in all Ward
				• Approval for linking monthly Swachh Survekshan to budget allocation at ward level
				• Issue notices to housing societies constructed post 2002, that do not have an on-site wet waste processing facility in working condition.
				• Designating authorities within the staff for issuing notices or penalties
				• Levy of fines and penalties for non-compliance
					Formation of voluntary wardens for monitoring and enforcement

Land Acquisition

Land acquisition is a major challenge in SWM projects and a major cause of delay; especially in processing and landfill facilities. Depending on the type of the waste management facility to be established, various factors come into play while selecting land for the facilities. Aspects like managing encroachments, assessing feasibility of project with respect to the environment and social context, etc. need to be analyzed in depth. The concerned departments of Pune Municipal Corporation undertook the survey to identify land for the proposed projects and did the necessary actions to speed up the process. The details of the same are shared as below.

	Location	Details	Area		Actions
	PMC		(in Acres)	Expected time for acquisition	
1	Baner	Additional private land next to Nobel Exchange Processing Plant	2.39	Dec 2017	City engineer dept. and Estate dept. to undertake due process immediately
2	Wadgaon Budruk	50 MT segregation plant installed	4.92	Dec 2017	
3	Hadapsar	Survey no 95, Final plot no 104 and 87 Ramtekdi - MP33 Reservation	13.00	Aug 2017	
4	Ambegaon Budruk		5.18	Aug 2017	
5	Hadapsar	Survey no. 88	10.00	Aug 2017	
	State				
6	Kondhwa Budruk	Land under the name of Director of Public Health	4.88	Jun 2018	Organize a meeting of Guardian Minister and Director of Public Health
7	Hadapsar	Social welfare department and Forest Department	4.96	Jun 2018	Organize a meeting of Guardian Minister with concerned officers
		TOTAL	45.84		

Waste transfer ,Station, Bhopal, Madhya Pradesh
Source: Author

Chapter
3

Process of Formulating a Detailed Project Report (DPR)

Recap

The previous chapter detailed various steps involved in preparation of SWM strategy and action plan. Moving ahead this chapter details the DPR preparation process, for implementing SWM projects as per the action.

Training Objectives

- To understand the process and components of DPRs
- To gain knowledge preparing Request for Proposal (RFP) for SWM projects.

Training Outcomes

- Acquire knowledge on DPR preparation
- Learn basic concepts of tendering process and RFP preparation

Chapter Contents

3.1 Introduction
3.2 Major sections of Detail Project Report
3.3 Process of writing a Request for Proposal
3.4 Tendering process
3.5 Formulating Request for Proposal (RFP)
3.6 Further Reading
References
Quick Assessment

Automated MRF Facility, Indore, Madhya Pradesh
Source: Author

3.1 Introduction

DPR is a base document for planning and implementation of any project, and helps in delivering sustainable services and infrastructure effectively. DPRs are used for appraisal, approval and subsequent implementation of the project and hence should be made carefully with all the required details.

3.2 Major sections of Detail Project Report

1. **Sector background context and broad project rationale:** This section of the DPR must provide the following details:
   a. It must tell about the existing status of the physical infrastructure.
   b. Information of user coverage and access (by different user categories/segments including urban poor)
   c. It must give a list of other supported projects with capital expenditure supported by other schemes.
   d. Cost recovery method with existing tariff must be mentioned.
   e. It must have a detail of past five year trends.
   f. It must provide detail on existing per unit cost and existing per unit service delivery price in terms of per capita basis and the method of calculation should be provided.
   g. Any other qualitative information for example list of key issues that are of importance to the project, Importance of the project to the sector.

2. **Project definition, concept and scope:** The complete scope and extent of the project must be clearly demarcated in this portion of the DPR. Along with the "to be constructed portion" the project scope should also include the infrastructure which already exists for use. Hence this part of the DPR includes:
   a. Land:
      - Total land required and being provided for the project
      - Confirmation and proof that the required land is owned /already purchased by the ULB
   b Physical Infrastructure: **This section includes the detailed description of physical** infrastructure required and available for the project. The physical infrastructure required for a Solid Waste Management Project can be divided into various components (Component 1, Component 2, Component 3……) as can be seen in the below table.

Table 3.1: Physical infrastructure requirements

Major component	Sub component
Primary Collection	• System of Collection (door-to-door collection, segregation of waste) • Waste storage and collection bins (Household bins, Community bins) • Primary collection vehicles (for collection and transfer to transfer stations)
Transfer Stations	• Development of Transfer Stations • Equipment
Transportation	• Vehicles (for transfer from transfer stations to disposal site) • Vehicle Depot
Disposal of Waste	• Development of disposal site (land-fill site, compost plant, vehicle depot) • Equipment at disposal site • Recycling plant (briquette, waste-to-energy, etc.)

Source: Adapted from JNNRUM Detailed Project report Preparation toolkit

c. Environmental compliance / Protection measures / Improvement Measures:
   - Environmental Impact Assessment
   - Environment Management Plan

d. Rehabilitation and Resettlement

e. Specialized procured services for design, independent supervision, and quality assurance

f. Other information:
   - Details of surveys and investigations required to be carried out (site, customer, etc.)
   - Assessment of requirements related to utilities shifting
   - List of clearances and agencies from which these are to be obtained
   - Disaster related risk assessment and broad countermeasures (including earthquake/other natural disaster resistant design of structures)

3. **Project cost:** The project (construction) cost should cover distinct elements listed below.
   a. Physical infrastructure component-wise cost
   b. Environmental compliance cost
   c. Rehabilitation and resettlement cost (to be borne by ULB/ parastatal/ state government)
   d. Cost of surveys and investigations
   e. Cost of shifting utilities
   f. Cost of consultancy services:
      - Design
      - Supervision
      - Quality Assurance
   g. Other statutory compliance costs if applicable
   h. Finance/interest cost during construction
   i. Contingency
   j. Any other

All cost assumptions (rates, methods of calculations etc.) are to be clearly stated either in the main text or attached in the appendix of the DPR.

4. **Financial Structuring:** The financial structuring is done for the examination of the sources of funding of the project. In this section, the DPR must provide the detailed information. For financing of a project ULBs can use a combination equity, grant, debt and finance from private participation.

5. **Project Phasing:** In this part of the DPR project implementation schedules are to be presented. Schedule planning is one of the most important part of DPR and need to be prepared for the activities as per requirement of the city planners. The various schedules are as follows:
   a. Schedule for tendering/selection for procurement of services.
   b. Schedule for bringing in State level and ULB level contributions to the project.
   c. Schedule for obtaining all clearances (along with list of major clearances).
   d. Schedule for shifting utilities

6. **Project Operations and Maintenance (O and M) framework and planning:** The O and M framework is planned in terms of:
   a. **Institution framework and Billing strategy:** Under this the DPRs should have information on the following:
      - About the institution which will be engaged in O and M of the assets.
      - About the method used in making bills and collection.
      - Description of the key issues and obstacles in regard to O and M.
      - It should tell if there is any scope for private entity/NGO in terms of O and M.
   b. **Tariff and user cost recovery:** With regard to tariff and user cost recovery, the DPR should provide:
      - Unit cost of service and unit price.
      - A plan to arrange tariff system full cost recovery user charges

7. **Project Financial Viability / Sustainability:** Project viability assessment is based on a combination of the perspectives given below:
   a. **Overall project perspectives:** The DPR is to provide financial analysis for Net Present Value (NPV) and Internal Rate of Return (IRR) defined in the following two ways:
      - **NPV and IRR (overall):** examines overall project viability, including finance cost and asset replacement cost
      - **NPV and IRR (O and M):** examines only O and M viability

The complete supporting project cash flow projections along with underlying assumptions have to be presented. (A reference project cash flow template is provided in Table 3-4). The Project financial assessment should clearly state the cost of capital considered and the calculation methods used.

b. ULB level perspectives and financial situation assessment
The DPR is to provide the following information:

- **ULB cash flow:** This includes a complete cash flow covering the last 5 years on an actual basis and projections for the next 20 years. The underlying assumptions for the projections also need to be mentioned (a reference format for ULB Cash flow is given in Table 3-4).
  An assessment of the annual impact of the project on the ULB's finances for the Mission Period is to be provided showing the impact being high/medium/low (more than 20 %; between 20% and 5%; less than 5% respectively). The base year to be considered for this exercise is the last completed financial year. A format for providing the impact is given in below table

Table 3.2: Annual Financial impact of Project on ULBs

S. No	Head	Impact Low/ Medium/ High (more than 20 %; between 20% and 5%; less than 5% respectively)						
		2014-15	2015-16	2016-17	2017-18	2018- 19	2019-20	2020-21
1	2	3	4	5	6	7	8	9
1.	Revenue Receipt							
2.	Revenue Expenditure							
3.	Capital Receipt							
4.	Capital Expenditure							

Source: Adapted from JNNRUM Detailed Project report Preparation toolkit

Base year: _____ (last completed financial year)

- **Debt situation assessment:** This includes
  - Debt schedules and terms for all debt taken (to be provided in Appendices to the DPR.
  - Debt service coverage ratio (DSCR) Debt-equity ratio for the project and the ULB
- **Other financial information:**
  - Has the ULB been credit rated? If yes: provide the name of the rating agency, type of rating and existing rating details.

In case of Special Purpose Vehicle (SPV) or Joint Venture (JV) as a separate legal project implementation entity, the Profit and Loss (P and L) Statement and Balance Sheet forecasts for the next 20 years shall be provided. In this context, the given project cash-flow template (as per Table 3-4) may be used as the initial reference format on which appropriate modifications can be made.

8. **Project Benefit Assessment:** This part of the DPR provides a critical assessment of the project from a societal stand point. This should include:
   a. List of benefits (Social and Economic)
   b. Benefits are to be focused on project outcomes and specially on their impact on citizen's/user segments covering elements
   c. List of negative externalities or adverse effects (Social and economic)
   d. Identification of adverse impacts facilitates planning for possible countermeasures and also recognizes possible trade-offs in taking up the project
   e. Along with explanation of the benefits and adverse effects in qualitative terms
   f. Quantitative analysis of the benefits and adverse impact of the project.

The following table can be used for this purpose:

Table 3.3: Project benefit assessment table

S. No	Benefits Description	Comments	Quantitative Impacts and Underlying Assumptions
Societal Benefits			
1.			
2.			
Societal Negative effects			
1.			
2.			

Source: Adapted from JNNRUM Detailed Project report Preparation toolkit

For projects above 100 crores a structured estimation of the Economic Internal Rate of Return (EIRR) would be prescribed as a part of the Social Cost-Benefit Assessment. The EIRR would incorporate monetization of the identified (quantifiable) social benefits and adverse impacts.

Construction and demolition plant, Tirupati, Andhra Pradesh
Source: Author

Format for Submission

Checklist for submission and scrutiny of DPR by Ministry of Housing and Urban Affairs (MoHUA).

(to be filled in and certified by the highest city–level Officials, both technical and administrative, such as Chief Engineer/City Engineer/ Municipal Commissioner)

Instructions

- The DPR shall be formulated as per the Manual on Municipal Solid Waste Management published by the Ministry and as per the Department procedures.
- DPR shall be technically sanctioned by the Competent Authority the State Govt./ULB before forwarding it to the Ministry.
- Each and every page has to be signed at the bottom by the officials.
- Each field has to be filled in appropriately as "yes", "no", "not required", "not done", "not used" etc. No field has to be left blank. Give explanatory comments wherever 'no' is indicated.
- Non- definite entries such as "will be done later", "will be furnished later" etc. will not be accepted.

Certificate

This is to certify that the undersigned have read the contents of the check list fully and have responsibly made the entries true to the best of knowledge and understanding. In case the information furnished in the check list enclosed is found to be incorrect for any reason, whatsoever, the undersigned may be held liable for disciplinary action as per applicable Government rules.

Certified that

i. The designs and drawings have been approved by the Competent Authority.
ii. The detailed estimates and cost estimates are as per the current schedule of rate and/ or rate analysis and latest pro-forma invoices (current market rates).
iii. The DPR has been technically sanctioned by the Competent Authority in the State Govt./ ULB.

Signed:

Name:

Designation:

A sample structure of Detailed Project Report (DPR) is annexed as Annexure-I

Table 3.4: Checklist for Submission and Scrutiny of DPR (Municipal Solid Waste Management System)

S. No.	Description	Write 'Yes' or 'No' etc. in the column below If Yes, give Page No./DPR volume reference. If No, reasons thereof
3	General Components	
3.1	Name of the town/city/District/State for which scheme has been formulated with name of the scheme Name of the City/Town: Name of the District: Name of the State: Name of the Scheme:	
3.2	Date of DPR appraised by State Level Nodal Agency (SLNA) and whether a copy of appraisal report (duly authenticated by the competent authority) has been forwarded with DPR. Date of appraisal: Name of the appraisal agency: Original Estimated cost: Appraised cost: Major comments/observations made by appraisal agency.	
3.3	Whether Administrative approval of State Government is obtained to implement the scheme immediately after approval of GOI and enclosed in DPR?	
3.4	Whether Project formulation justification (need for the project) has been furnished in DPR	
3.5	Whether linkages of this scheme have been established with ANY other municipal solid waste management (MSW) schemes being funded by the Central/State Govt./other agencies, if any. Please specify.	
3.6	Whether the compatibility between existing MSW system (if applicable) and proposed MSW system has been provided in DPR	
3.7	Whether the map showing administrative and political jurisdiction has been given in DPR	
3.8	Whether the land use pattern of the city / town - Master Plan has been given in DPR	
3.9	Whether the DPR was authenticated by Competent Authority of State Govt./ ULB.	
3.10	(A) Whether the Certificate of Land Acquisition / possession for setting up MSW Treatment Plant (MSWTP), landfill and MSW transfer stations by ULBs and Right of Way (ROW)/spots for setting up community MSW storage containers has been attached with DPR.	
	(B) If not, whether the action plan for acquiring the required land has been furnished in the DPR.	

S. No.	Description	Write 'Yes' or 'No' etc. in the column below If Yes, give Page No./DPR volume reference. If No, reasons thereof
3.11	Whether the proposals for setting up MSW treatment plants and landfill received clearance / consent from the State Pollution Control Board, Airport / Airfield Authorities, Flood Control/ Ground water Management Authorities etc. Whether clearance for environmental impact assessment obtained for the proposed sanitary landfill site. If not, whether a status note and the date by which the clearance is expected to be received has been enclosed	
3.12	Whether the provision for separate electric feeder line to MSW treatment plant, landfill and transfer stations from HT line and an agreement between Electricity Dept. and Urban Local Bodies (ULBs) has been furnished in the DPR	
3.13	Whether the commitment from Electricity Department for un-interrupted power supply is obtained	
3.14	Whether the Topographic map of the city/town/project area to scale –has been given in DPR / Zone wise Maps to scale showing all Streets	
3.15	Whether geo-technical (soil) investigation reports and bore hole logs for the site of MSW treatment plant and landfill has been furnished with DPR	
3.16	Whether Executive Summary of the project is enclosed in the DPR.	
4	Engineering Components	
4.1	a) Whether population pattern identification of urban / urban agglomeration and population projection has been adopted as per CPHEEO Manual and given in DPR • Area of the city/town ..... Sq. Km. • Extent of Project Area ..... Sq. Km • No. of households (present) ..... no's • Population projection ..... lakhs • 2001 Census ..... lakhs • 2011 Census ..... % per year • Population Growth rate ..... lakhs • Initial Stage (year of commissioning). ..... lakhs • Floating population, if any ..... Lakhs • Design population including floating ..... No. and % b) population ..... No. c) Whether basis for adopting tourist/floating pop documents annexed ..... No. and % ..... No.	

<table>
<tr><th>S. No.</th><th>Description</th><th>Write 'Yes' or 'No' etc. in the column below
If Yes, give Page No./DPR volume reference. If No, reasons thereof</th></tr>
<tr><td></td><td>Whether initial year has been taken as the likely year of completion of the project population has been described in the report and related
xii. Total no. of vehicles for transportation of waste
Total .....nos.
Govt. .....nos.
Private ..... nos.
Total ..... nos.</td><td></td></tr>
<tr><td>4.2</td><td>Whether the rationale for location of the transfer station and operating schedule of primary and secondary collection vehicles for synchronization has been calculated and attached with the DPR</td><td></td></tr>
<tr><td>4.3</td><td>Whether the number of trips for each of the primary and secondary collection vehicles along with timing has been calculated and given in the DPR for calculating the number of vehicles required
Whether the existing vehicles have been considered while calculating the additional vehicles required and whether such calculations form a part of the DPR.</td><td></td></tr>
<tr><td>4.4</td><td>Whether the system of segregation at source has been considered and if yes, the design of vehicles for carrying the organic and recyclable waste separately has been incorporated and explained in the DPR.</td><td></td></tr>
<tr><td>4.5</td><td><table><tr><th colspan="2">Details of ongoing project</th></tr><tr><th>Estimated cost</th><th>Rs..... Lakh</th></tr><tr><td>• Year of sanction</td><td></td></tr><tr><td>• Funding agency and funding pattern</td><td></td></tr><tr><td>• Population coverage</td><td></td></tr><tr><td>• Infrastructure for collection, transportation has been envisaged or ..... MT/day not</td><td></td></tr><tr><td>• .....MT/day
Capacity of compost plant</td><td></td></tr><tr><td>• ..... MT/Day and Year</td><td></td></tr><tr><td colspan="2">Capacity of sanitary landfill (please specify design period and qty. of waste disposed/day)</td></tr></table></td><td></td></tr>
<tr><td>4.6</td><td>Please furnish the proposed major components and component-wise cost (Rs. In lakh)</td><td></td></tr>
</table>

S. No.	Description	Write 'Yes' or 'No' etc. in the column below If Yes, give Page No./DPR volume reference. If No, reasons thereof
4.7	c) Details of Secondary collection and transportation • Transfer stations • Transportation vehicles (Refuse collectors, compacters, dumper placers) • Standy provision for vehicles iv. Machinery proposed for mechanical sweeping of roads d) Details of the capacity of various treatment and disposal facilities • Compost plant • Sanitary land (5 years) • RDF plant • Other technologies • Brick manufacturing • Reusable material • Total Design of Leachate collection system furnished in the DPR Whether the treated leachate effluent shall conform to the standards/effluent discharge guidelines of the Pollution Control Board Capacity of Leachate treatment facility Technology proposed for leachate treatment	..... No. ..... No. ..... % ..... No. ..... MT/day ..... MT/day ..... MT/day ..... MT/day ..... MT/day ..... MT/day Yes/No Yes/No ..... MLD .....
4.8	Hazardous waste generated ..... MT/day Any facility for hazardous waste treatment is available or not	
4.9	Whether Biomedical waste is separately collected and treated as per BMW Rules	
4.10	Whether the calculation for the requirement of number of primary and secondary transport vehicles has been shown along with route map to the scale and quantum of waste to be collected from each route in the DPR	
4.11	Whether the process Flow Diagram for entire MSW management system involving all components has been furnished in DPR	
4.12	Whether drawings to scale of the components such as landfill, transfer station, weigh-bridges, building, toilets etc., have been furnished in DPR	
4.13	Whether geometry of the land available for locating MSW treatment plant / landfill / transfer stations has been certified and furnished.	
4.14	Whether the MSW treatment process has been adopted using different proven technologies duly considering the temperature/ climate existing in the city/town	
4.15	Whether the site of the proposed MSW treatment plant / landfill / transfer facilities has been located	
4.16	Whether the provision of the land for MSW treatment plant / landfill / transfer facilities has been made as per 30 years' requirement and future expansion in the DPR a) Total requirement of land (Pl also specify the design period) Landfill Compost Plant	..... Ha ..... Ha ..... Ha

S. No.	Description	Write 'Yes' or 'No' etc. in the column below If Yes, give Page No./DPR volume reference. If No, reasons thereof
	Transfer Station RDF Plant Total Land possession with Implementing Agency Whether Govt. land is yet to be transferred to the Implementing Agency and specifying time required to transfer. Whether Private Land under acquisition and time required for acquisition Status of action initiated for transfer of Govt. land and acquisition of Private land (please specify)	..... Ha ..... Ha ..... Ha ..... Ha ..... Ha, ... months ..... Ha, ... months
4.17	Whether modular approach has been adopted to facilitate "addition" units to MSW treatment plants/landfills at a future date, whenever required	
4.18	Whether Bill of Qualities (BOQ) and cost estimates of individual component of MSW management system prepared as per latest SOR and copy of latest Schedule of Rates (SOR) and Pro-forma invoices have been provided with DPR. Prevailing SOR ..... Year Market price ..... Year Whether the authenticated document for various equipment/ machinery is enclosed (invoice) c)Whether provision has been made for IEC expenditure required for commissioning the new SWM system. If so, details thereof.	
4.19	Whether detailed drawing, estimation and detailed BOQ for ancillary works such as boundary wall / fencing, approach and internal road, electrification, buildings, water supply and drainage, site development / landscaping etc. has been provided in the DPR	
4.20	Whether provision for DG set has been made in the DPR to take care of interruptions in power supply, if any	
4.21	In case provision for DG set has been given in the DPR, whether the calculations to arrive at the capacity of the same has been mentioned in the technical statement	
4.22	Whether detailed PERT/CPM network showing implementation schedule has been furnished in DPR	
4.23	Whether Internal rate of return (IRR) / Economic rate of return (ERR) has been furnished in DPR	
4.24	Whether traffic diversion/ control arrangements for public and workers' safety, arising out of construction phase of MSW management works have been furnished in the DPR	
4.25	Whether Institutional and financial status of Project Executing Agency (PEA) has been reported in DPR	
4.26	Whether mechanism for marketing of compost/RDF has been tied Up with any agency Name of the agency with whom the marketing arrangement is tied up for compost and RDF	

<table>
<tr><th>S. No.</th><th>Description</th><th>Write 'Yes' or 'No' etc. in the column below
If Yes, give Page No./DPR volume reference. If No, reasons thereof</th></tr>
<tr><td>4.27</td><td>Annual Revenue (in Rs. Lakhs)
Existing (last 5 years)
Proposed
(d)Whether the proposed tariff charges has different rates for different categories such as residential, commercial, establishments, hotels, restaurants, vegetable markets etc. if yes, whether these have been arrived at after adequate public consultation and if yes, whether summary of such consultation has been provided with the DPR</td><td>1 2 3 4 5</td></tr>
<tr><td>4.28</td><td>Whether Service Level Benchmarking has been furnished in DPR. Please furnish S
<table>
<tr><th>Sl. No.</th><th>Indicators</th><th>Benchmark</th><th></th></tr>
<tr><td></td><td>Household Level Coverage</td><td>100%</td><td rowspan="8">After implementation of the proposed project</td></tr>
<tr><td></td><td>Efficiency in Collection of Solid Waste</td><td>100%</td></tr>
<tr><td></td><td>Extent of Segregation of MSW</td><td>100%</td></tr>
<tr><td></td><td>Extent of MSW Recovered</td><td>80%</td></tr>
<tr><td></td><td>Extent of Scientific Disposal of MSW</td><td>100%</td></tr>
<tr><td></td><td>Extent of Cost Recovery</td><td>100%</td></tr>
<tr><td colspan="3">Efficiency in Collection of SWM Charges 90% 8</td></tr>
<tr><td colspan="3">Efficiency in Redressal of Customer Complaints 80%</td></tr>
</table></td><td></td></tr>
<tr><td>4.29</td><td>Whether Environmental and social problems (if applicable) has been furnished in DPR</td><td></td></tr>
<tr><td>4.30</td><td>Whether provision has been made @ 0.5% of the project cost in the DPR for capacity building of ULBs for further OandM of the scheme after taking over the scheme from implementing agency. Please furnish the action plan for conducting capacity building programme. The action plan must specify specific actions such as the number of officials to be deployed in the project post commissioning, their designations, qualifications and training proposed to be given.</td><td></td></tr>
</table>

S. No.	Description	Write 'Yes' or 'No' etc. in the column below If Yes, give Page No./DPR volume reference. If No, reasons thereof
4.31	Whether any PPP component involved in the DPR. Please specify the PPP components and funding pattern by Govt. and Private Party. Whether the options of method of operation of SWM collection i.e. departmentally or PPP mode has been considered and reasons for selection mentioned in the DPR. If PPP mode, whether the financial viability of the PPP has been calculated and attached with the DPR Whether key points to safeguard the interest of the department and the provision of regulation has been provided in case the PPP mode has been selected.	
4.32	Whether there is any association with the waste pickers organizations No. of waste pickers working in the town ..... Nos. Any plan to engage them in the door to door collection activities No. of waste pickers proposed to be involved in the door to door collection ..... Nos.	
4.33	Whether Rehabilitation and Resettlement plan (if applicable) has been given in DPR	
4.34	Whether all the hard copies of the DPR furnished along with soft copies	
4.35	Period of completion of the project	

This part to be filled-in by the Ministry

Sl. No	Description	Remarks
1	Details of project area (State/District/City/Town)	
2	Whether the SLNA/SLSC recommendation is attached with DPR	
3	Project cost recommended by SLNA/SLSC	
4	Period of project implementation	
5	Date of receipt of first DPR	
6	Date of final acceptance of DPR	
7	Date of checklist confirmation	
8	Date of first information sent to the State Govt. on scrutiny of check list	
9	Date of receipt of DPR after reformulation (revision) if applicable	
10	Date of DPR sent to the Appraisal Agency (CPHEEO)	
11	Date of Comments / appraisal report of appraisal agency	
12	Date of comments conveyed by the Admin. Division to the State Govt. and ULBs for revision of DPR, if any	
13	Date of Receipt of Revised DPR for appraisal	

NOTE: The DPR should be forwarded to the Ministry along with the complete checklist duly filled in without which DPR shall not be processed and shall be returned to the State Government.

The DPR should be scrutinized for techno economic sustainability. In particulars, the validity of al l assumption should be tested such as

- Realistic population projection
- Quantity of waste and their basis
- Composition and calorific value
- Site suitability
- Appropriateness of technology for the scale considered
- Requirement of water, power, earth, energy, fuel,
- Availability of technical, skilled and unskilled manpower
- Expected products and their quantity, product sale and marketing plan and price.
- Is the technology indigenous, can it be serviced locally, are spares available immediately
- Project cost and financial structuring
- Project phasing and timelines
- Project operation and maintenance planning
- Sales and marketing plan
- Procurement plan for raw materials/ inputs etc.
- Technical specifications of project, including drawings (if applicable)
- Project financial viability and sustainability including
    - Detailed business plan, with investment and operating cost estimates
    - Details of loan sought, and security/ collateral offered
    - Cash flow estimates for debt service
    - Sources of funds/ means of financing
- Experience of the ULB to manage such a project/ contract
- Market size and market share, customer segments, product/ service sold by borrower
- Site suitability, whether it conforms to MoEF guidelines for siting, whether location already part of approved town planning and part of “no development zone” notified
- Any risks of public protest/ opposition

3.3. Bid Process Management

Procurement procedure of PPP: After a DPR is approved a standard transparent procurement procedure is adopted for the selection of the PPP partner. This process includes:

1. Preparation of Scope of works to be tendered out
2. Finalizing the contract model and concession period/ contract period
3. Finalizing the payment terms, financial support provided
4. Responsibilities of the ULB and the Operator including product marketing and CDM benefits
5. Modalities of Bank and performance guarantees, Monitoring and certifications process
6. Identification of Technical qualification and Financial qualification
7. Mode of tendering- Single stage, two stage, Single cover, two cover etc
8. Preparation of expression of interest (EoI) (Model EoI), Request for proposal (RFP), and concessionaire agreement
9. Obtaining approval from concerned authority
10. Issue of notice for pre-qualification or EoI
11. Short-listing of firms
12. Issue of RFP to the shortlisted firms
13. Conducting pre-bid meeting
14. Receiving technical and financial bids in separate packets in response to the RFP and opening of technical bids
15. Evaluation of the technical bid document received
16. Opening of financial bids of the bidders
17. Evaluation of financial bids
18. Selection of most preferred bidder
19. Negotiation and signing of agreement
20. Award of contract

3.4 Tendering Process

This tendering process can either be a single stage process or a two Stage process. In a Single stage bidding process technical and financial bids are submitted simultaneously in response to a RFP. Whereas the two stage selection process includes an initial prequalification stage, followed by RFP stage, which is applicable only to pre-qualified bidders. The bidding schedule for the two tendering process are as follows:

Schedule for Bidding – Two Stage Process

Stage 1: Pre-Qualification Stage (Minimum: 3 months)

1. Sale of request for qualification (RFQ): zero date
2. Submission of query by the perspective applicants: +15 days
3. Pre-bid meeting: +20 days
4. Authority response to queries: +30 days
5. Bid submission due date: +60 days
6. Opening of technical qualification bids: +60 days
7. Acceptance of technical qualification evaluation report by Tender Committee: +80 days

Stage 2: Bid Stage (Minimum: 6 months)

1. Sale of request for proposal (RFP) short-listed applicants: +90 days
2. Submission of query by the perspective applicants: +105 days
3. Pre-bid meeting: +110 days
4. Authority response to queries: +130 days
5. Bid submission due date: +150 days
6. Opening of bids: +150 days
7. Letter of Intent (LOI): within 30 days of bid opening date
8. Contract signing: +30 days of award of LOI

Notes: The bidding process takes 6 months minimum. However, depending upon the urgency and requirement of the project execution the bidding process could be done within 60 days. 2 + "x" days means time duration from the zero date, i.e., date of publication of RFP

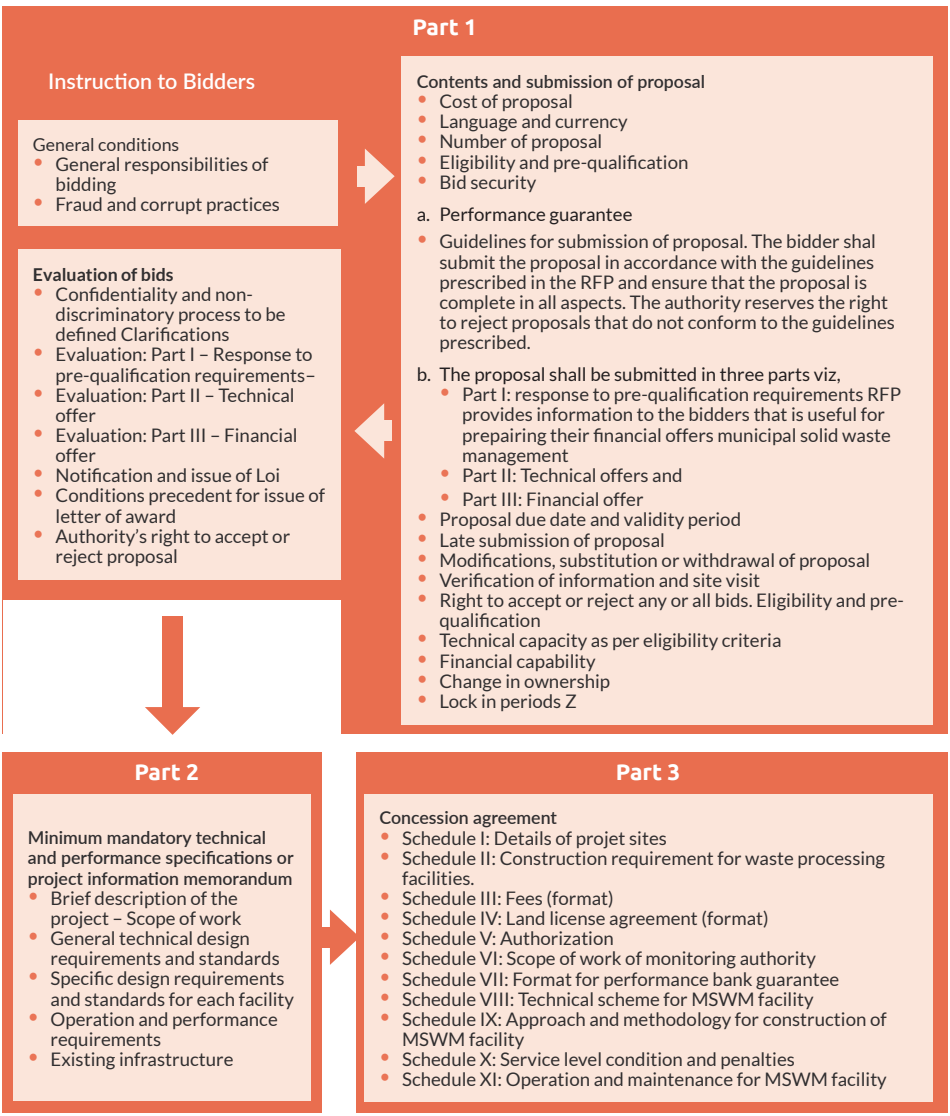
Schedule for Bidding: Single Stage Process

1. Sale of bid or request for proposal (RFP) to short-listed applicants: zero date
2. Submission of query by the perspective applicants: +15 days
3. Pre-bid meeting: +20 days
4. Authority response to queries: +30 days
5. Bid submission due date: +60 days
6. Opening of technical bids: +60 days
7. Acceptance of technical evaluation report by Tender Committee: +80 days
8. Financial bid opening: +90 days
9. Letter of intent (LOI): within 30 days of bid opening date
10. Issue of letter of award to bidder: +30 days of issue of LOI
11. Contract signing: within 30 days of award of LOI

Notes: The bidding process takes 4 months minimum. However, depending upon the urgency and requirement of the project execution the bidding process could be done within 60 days.
2. + "x" days means time duration from the zero date, i.e., RFP's date of publication.

Both the bidding processes require formulation of a Request for Proposal (RFP) by the ULBs

Figure 3.1: RFP content list



Source: Adapted from CPHEEO Manual on Municipal Solid Waste Management 2016

3.5 Formulating Request for Proposal

A Request for a Proposal (RFP) is a document formulated by the ULBs to obtain bids from the service vendors for projects specified in the DPR. A well written RFP is essential in ensuring well costed, innovative bids from the suppliers. A good RFP is crucial for effective project management as it enables the service vendors to understand the project and facilitates them to write a proposal or a bid explaining how they can meet the requirements for the project. An RFP clearly describes the deliverables of the project and various assumptions and assessments by the authority in relation to the project. A standard Request for Proposal must be divided in three parts:

Part 1: Instruction to Bidders

Abbreviations

1. Introduction
    - 1.1 Background
    - 1.2 Brief description of bidding process
    - 1.3 Schedule of bidding process
        - A. Notice inviting tender
    - 1.4 Contents of request for proposal (rfp)
    - 1.5 Clarifications on rfp and pre-bid meeting
    - 1.6 Amendment of rfp
2. General conditions
3. Contents and submission of proposal
4. Eligibility and pre-qualification
5. Evaluation of bids

Clarifications

Appendices

Appendix- 1.1: Scope of work
Appendix- 1.2: Technical evaluation and marking system
Appendix- 1.3: Adjustments to tipping fee

Forms

Form i: Covering letter for proposal submission
Form ii: Details of bidder/bidding consortium
Form iii: Power of attorney for signing of bid (name, title and address)
Form iv: Memorandum of Agreement (MoA) in case of consortium proposal
Form v: Power of attorney for lead member of consortium
Form vi: Format for board resolution of companies
Form vii: Format for non-criminality
Form viii: Format for anti-collusion certificate
Form ix: Details and proof of technical capacity

Form x: Details and proof of financial capacity
Form xi: a - Format for technical proposal
b - Technical plan for project facilities
c - Technical plan for collection and transportation
Form xii: Details of expert team
Form xiii: Format for financial offer
Form xiv: Assumptions project cost
Form xv: Letter of award/letter of intent
Form xvi: Details of arbitration and litigation history
Form xvii: Format for performance guarantee

Part 2: Minimum mandatory technical and performance specifications or project information memorandum

1 Brief description of the project
1.1 Scope of work

2 General technical design requirements and standards
2.1 General design standards

List of Schedule

Schedule 1 – List of Equipment
Schedule 2 – Site Plan
Schedule 3 – Layout with landfill
Schedule 4 – Landfill plan
Schedule 5 – Landfill cross section
Schedule 6 – Detailed Project Report

Part 3: Concession agreement

The concession agreement shall outline the complete scope of works, concessionaire obligations, Implementation schedules, responsibility of client and contractor, Minimum Shareholding, Force majeure condition, conditions for termination, payments during the concession, Events of default and payment on termination, Dispute resolution, Insurance and Warranties, Sale of Products, Service level benchmarks and penalties, bank guarantee, land license agreement.

Process of writing a Request for Proposal

Procurement procedure of PPP: After a DPR is approved a standard transparent procurement procedure is adopted for the selection of the PPP partner. This process includes:

1. Preparation of Scope of works to be tendered out
2. Finalizing the contract model and concession period/ contract period
3. Finalizing the payment terms, financial support provided
4. Responsibilities of the ULB and the Operator including product marketing and CDM benefits
5. Modalities of Bank and performance guarantees, Monitoring and certifications process
6. Identification of Technical qualification and Financial qualification
7. Mode of tendering- Single stage, two stage, Single cover, two cover etc.
8. Preparation of expression of interest (EoI) (Model EOI), Request for proposal (RFP), and concessionaire agreement
9. Obtaining approval from concerned authority
10. Issue of notice for pre-qualification or EOI
11. Short-listing of firms
12. Issue of RFP to the shortlisted firms
13. Conducting pre-bid meeting
14. Receiving technical and financial bids in separate packets in response to the RFP and opening of technical bids
15. Evaluation of the technical bid document received
16. Opening of financial bids of the bidders
17. Evaluation of financial bids
18. Selection of most preferred bidder
19. Negotiation and signing of agreement
20. Award of contract

3.6. Bid Evaluation and recommendation

The bid is evaluated as per the terms of the RFP. The committee or panel evaluating the bids should be conversant with the SWM function and also aware about the project context. They should have read and understood the DPR.

The various steps are

- Receipt and opening of tenders- Only those tenders that have received at the time place and in the form specified shall be accepted. All others are summarily rejected
- Examination of tenders – The documents are examined for completeness and correctness as requested in the tender documents. Key inclusions, Bank guarantee, Tender fee, EMD, power of Attorney etc are checked

- Seeking written clarifications from tenderers – If allowed only
- Rejection of tenders that are not substantially responsive
- Evaluation and comparison of substantially responsive tenders – The financial bids of only those tenderers that have scored more than the minimum specified in the technical evaluation are opened
- Determination of the winning tender- The highest evaluated tender is as per the formula mentioned in the Vol I of the RFP. In case of QCBS system, the technical bids are given a weightage as specified in and added to the financial score.
- Award recommendation -- The first highest evaluated bidder is considered the preferred bidder, followed by the second highest bidder and third
- Evaluation report – the evaluation report is signed off by the committee, with their recommendation
- Notification of award- The winner is invited to sign the contract; it shall follow all the condition mentioned in the RFP such as submission of performance bank guarantee etc.
- Return of EMD of all unsuccessful bidders- following the successful signing of contract, the EMD of all others have to be returned

3.7. Post Award Project Management Consultancy (PMC)

The Project management team shall provide overall Project Management services for the planning, design, engineering, and construction of the Infrastructure related to Solid Waste Management as specified in the RFP and within the project duration. The PMC team may be drawn from in-house resource or could be outsourced. PMC duties include broadly:

1. General Management

- Prepare and maintain project budget and master project schedule.
- Attend and/or lead project meetings; provide agendas and document meeting notes as appropriate.
- Coordinate with project team comprising contractors, client and consultants to identify any shortcomings with scope, schedule, and budget and advise any revision required
- Provide the Client with Cash flow projections.
- Consultant management.
- Contract Administration.

2. Preconstruction

- Coordinate and oversee the efforts of the consultants during the preconstruction
- phase.
- Coordinate development of plans and specifications and advise on revision needed.
- Maintain a design decision matrix to be used as a design document quality assurance tool.

- Assist in obtaining all statutory permissions
- Review the design drawings to ensure compliance to DPR, RFP and Environmental clearance and recommend approval for construction.
- Ensure appropriate ESI, PF, insurance, guarantees bonds, etc. are provided prior to execution of the construction contract.
- Coordinate meetings with Utility companies as necessary.

3. Construction

- Provide necessary on-site supervision and inspection to ensure contract design and
- specification compliance.
- Coordinate and facilitate statutory requirements are complied with
- Administrate contract, process change orders and pay requests.
- Carry out inspection at works, and or site, Review and witness site/ factory tests reports of materials and machinery and provide acceptance of the same
- Assist in any negotiations with the consultants
- Attend periodic project progress meetings as an Independent Engineer of the Client, taking notes and providing progress reports to Client
- Provide fund flow schedules to the client.
- Confirm delivery and storage of all materials, supplies, and equipment.
- Take the lead in resolving any disputes arising from the performance of the contractor
- and sub-contractors.
- Ensure that the Contractor has an appropriate safety program in place.
- Witness load test, pre-commissioning checks and commissioning of the infrastructure as per accepted protocol

4. Post Construction

- In conjunction with the Client and consultants, prepare and punch list of defective work and ensure work is corrected and inspected within the defects liability period.
- Ensure all spares are maintained as per RFP or manufacturers recommendation
- Compute and certify the liquidated damages that may be levied on the contractor
- Ensure as built drawings are prepared and checked and submitted to client
- Complete the set of documentation comprising warranties, Standard operating procedures, spares list, photographs, videos and training is completed
- Accomplish final accounting for the construction contract.
- Coordinate and confirm final lien releases and delivery of all final close-out documents.
- Provide final budget report to the client.

3.8 Further reading

- CPHEEO manual on Solid Waste Management 2016, Ministry of Housing and Urban Affairs, Government of India available at http://cpheeo.gov.in/cms/manual-on-municipal-solid-waste-management-2016.php
- Toolkit for Solid Waste Management Jawaharlal Nehru National Urban Renewal Mission,2012, Ministry of Housing and Urban Affairs, Government of India available at http://www.hpccc.gov.in/PDF/Solid_Waste/SWMtoolkit.pdf
- Guidelines for Preparation of Detailed Project Reports and Selection of Technologies for Processing and Final Disposal of Municipal Solid Waste using 12th Finance Commission Grants available at http://moud.gov.in/sites/upload_files/moud/files/GUIDELINES%20of%20DPR%20and% 20technologiy%20selection%20for%20SW M%20with%20 12th%20Finace%20commiss ion%20grant.pdf

References

- CPHEEO, 2016. Municipal Solid Waste Management Manual. Part II ed. s.l.:Central Public Health and Environmental Engineering Organisation.

Quick Assessment

1. What NPV Stands for (Net Present Value)

2. Types of costs considered for Full Cost Accounting (FCA) of MSWM are
   a. Environmental and Social costs
   b. Capital and Operating Costs
   c. Front-end and Back-end Costs
   d. All of the above

3. Which of the following is NOT a PPP model?
   a. BOOT
   b. BOT
   c. BOO
   d. SPV

4. VGF stands for Viability Gap funding

** For answers please refer annexure II*

Bio-methanation Plant, Tirupati, Andhra Pradesh
Source: Author


BALLOON PLANT

Chapter
4

Value chain for Solid Waste Management

Recap

The previous chapter provides brief overview of DPR preparation, tendering process, RFP preparation and bidding process. This chapter explains in detail the functional elements of SWM value chain

Training Objectives

- Present an overview of the functional elements of SWM value chain
- Describe main features of the management of Solid Waste and of the technologies involved in the various treatment processes.
- Learn about the financial, technical, and operational aspects of technologies along the chain through case studies

Training Outcomes

- Develop understanding on various technological options for processing of waste and their disposals in various ways.
- Acquire knowledge on successful SWM practices in Indian cities with the help of different case studies.

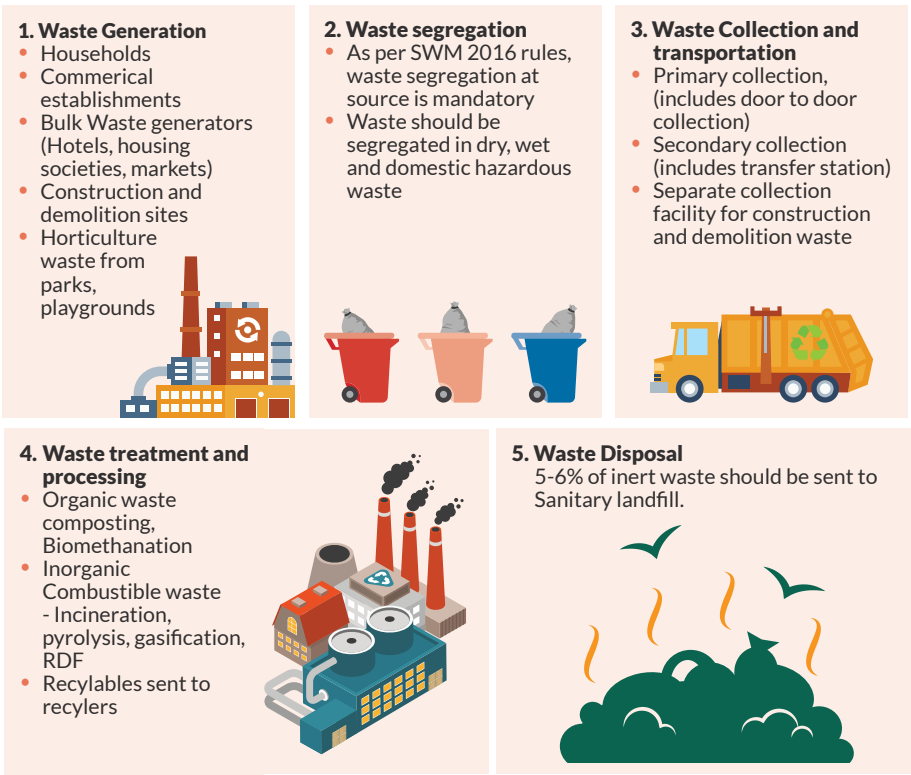
Chapter Contents

4.1 Introduction
4.2 Waste generation
4.3 Waste segregation
4.4 Storage, collection and transportation of waste
4.5 Secondary storage
4.6 ICT for efficient waste management
4.7 Processing and treatment technologies
4.8 Waste disposal technology
4.9 Further reading
References

4.1 Introduction

The solid waste management system consists of five main elements. It starts with source segregation followed by segregated collection and transportation to the respective processing site as per the waste composition and finally scientific disposal of the inert as illustrated in figure below:

Figure 4.1: Outline of the elements of solid waste management value chain



Source: Author

4.2 Waste Generation

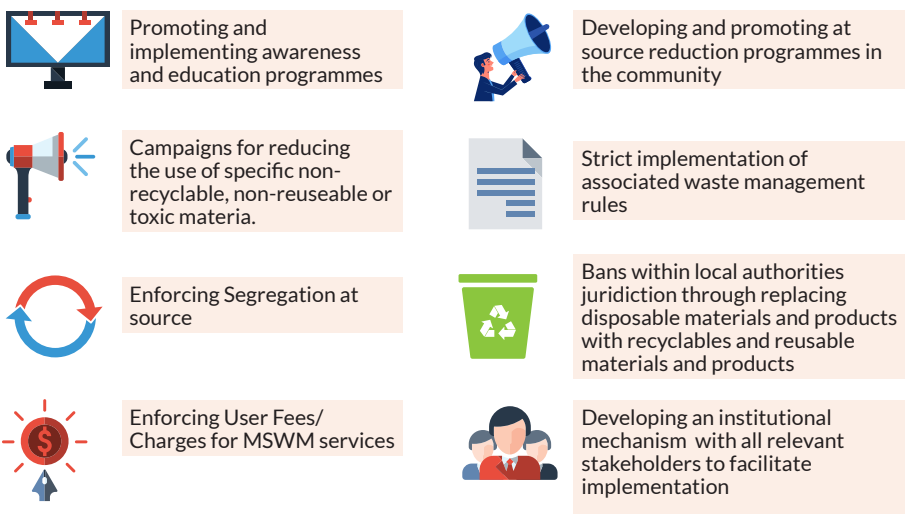
As per the SWM Rules, 2016, the ULB should create public awareness for minimising waste generation and reusing waste to the extent possible. Source reduction is the most ideal option to reduce the quantity of waste generated and hence reduce the cost associated with its handling, storage, transport, processing and disposal. The responsibility is on every waste generators to minimize or reduce waste from being generated. It is to be considered as the first step towards implementation of an efficient solid waste management.

Merits of waste minimization

- Reduces the quantity and density of the waste generated
- Results in savings, which reduces the collection, treatment, and disposal costs.
- Reduction in the impact on environmental resources.
- Leads to a reduction in greenhouse gas emissions and associated climate change impacts.

It needs to be understood that efficient segregation and collection of waste by themselves minimize waste generated as significant part of waste is taken away for recycling. Following initiatives can be taken to minimize the waste generation.

Figure 4.2: Waste Minimization methods



Source: (CPHEEO, 2016)

Waste minimisation programmes should be spearheaded by ULBs, not only to ascertain an organized and coordinated approach, but also to ensure the essential backward linkages (e.g. segregated collection of recyclables) and forward linkages (e.g. market linkages for recycling and reuse).

4.3 Waste Segregation

Ideally waste should be segregated at the source of generation. Wet, dry and domestic hazardous waste should be stored separately in different bins. Segregation of waste at source not only helps in proper management of waste, but also aids in useful recovery from waste. In addition to segregating waste at source, wet waste at the household level can be processed through composting either individually or at a community level. The compost thus obtained can be used for gardening at household level or in municipal parks. It sold depending upon the quantity generated. Garden waste generated in municipal parks should be treated at a decentralized level. thus, the cost meant to be spent on transporting the waste to the processing site can be reduced. In India, various initiatives have been taken by citizens and urban local bodies to process the wet waste at source. Examples are given

Merits of collecting segregated waste

- Reduces municipal efforts and resources spent on the process of waste segregation post-collection.
- Improvement in quality of life of rag pickers and more employment opportunities
- Reduction in disposal of waste to landfills, resultant lower transportation costs. Thus prevent ground water pollution from leachates.
- High resource recovery including from dry waste (3R principles) and reduce landfilling
- Increase resource efficiency and circular economy

Constraints of collecting mixed waste

- Unprocessed waste and higher amounts of process rejects disposal at Landfills
- Low resource recovery
- Contamination of ground water and soil
- Mass Incineration does not generate enough energy
- Recyclable potential of C and D waste is lost

Effective segregation depends upon the type and quantum of waste generated in municipal areas. In a typical city the generators of municipal solid waste are broadly include households, commercial establishments, religious centres, offices, institutions and other bulk waste generators. The type of waste generated by each of these generators is discussed in detail below.

Table 4.1: Types of waste generated

Waste generators	Type of waste generated
Domestic	• Biodegradable waste or wet waste • Non- biodegradable waste or dry waste • Domestic hazardous waste • Sanitary waste like diapers, sanitary pads, etc. • Garden waste • Construction and Demolition (C and D) waste, e-waste
Vegetable markets and Meat market	• Vegetable, fruits and flower waste etc. • Meat, poultry and fish waste etc.
Temples and religious premises	• Flower waste • Fruit and food waste • Dry waste
Street vendors and Eateries	• Food, vegetable and fruit waste • Dry and disposable waste such as plates, cups, cans, wrapping material, etc.
Places of public gatherings	• Fruit and food waste • Dry waste
Others bulk waste generators	Hotels, restaurants etc.

Source: (CPHEEO, 2016)

Table 4.2: Indicative list for Segregation of Household Wastes

Wet Waste (Green Bin)	Dry Waste (Blue Bin) With further sub segregation BASIC+				Domestic Hazardous (to be stored and disposed separately)
Food wastes of all kinds, cooked and uncooked, including eggshells and bones, flower, fruit and waste including juice, vegetable peels and household garden/plant wastes. Soiled tissues, food wrappers, paper towels; fish and meat	Paper, cardboard and Household cartons,	Containers and Packaging of all kinds excluding those containing hazardous materials, Compound packaging (tetra pack, blisters etc.) Plastics	Rags, Rubber, Wood, Discarded clothing, Furniture	Metals Glass (all kinds) Inerts House sweepings and Inerts (not garden, yard or street sweepings)	E-waste* Hazardous wastes** Household medical waste*** Batteries from flashlights and button cells. Lights bulbs, tube lights and Compact Fluorescent Lamps (CFL) Car batteries, oil filters and car care products and consumables

** E-waste: Printer and printer cartridges, electronic parts and equipment and others*

*** Hazardous wastes: Chemicals and solvents and their empty containers, paints, oil, lubricants,glues, thinners and their empty containers, insecticides, pesticides and herbicides and their emptycontainers, photographic chemicals, bleaches and household kitchen and drain cleaning agents*

**** Household Medical Waste: Thermometers and other mercury containing products, discarded medicines, injection needles and syringes after destroying them both*

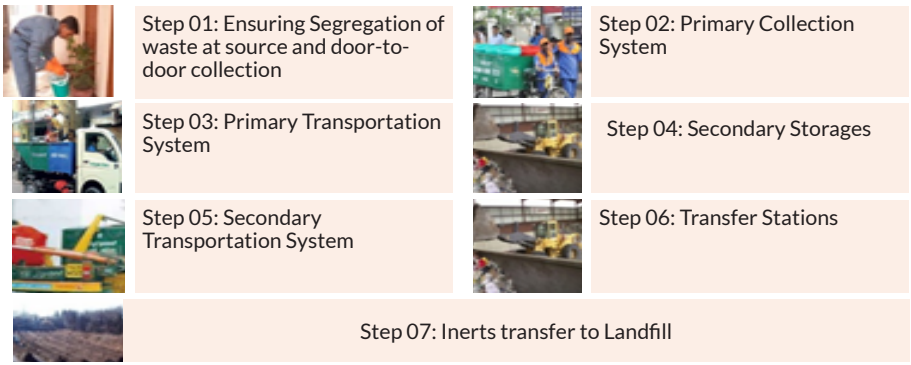
*****Sanitary waste should be collected separately and daily*

Source: (CPHEEO, 2016)

4.4 Storage, Collection and Transportation of Waste

Segregated waste from the source should be collected in vehicles with demarcated containers for wet waste, dry waste and domestic hazardous waste. These vehicles could either be motorized or non-motorized, depending upon the locality and area covered. Once the waste is collected, it should be brought to a common collection point or transfer station. Here the waste is measured followed by secondary segregation of waste. The waste should then be treated and processed, such that only inert residue goes to a sanitary landfill. The main steps involved in collection and transportation component of Municipal Solid Waste Management MSWM is shown in the figure below. Collection efficiency is the direct measurement of cleanlines. Once segregated waste is collected its transportation system needs to be very efficient. It will ensure that the segregated waste is transported to the appropriate processing facility on time.

Figure 4.3: Basic steps in collection and transfer of waste



Source: (CPHEEO, 2020)

Table 4.3: Main principles of waste collection and transportation

Effective and Efficient System	As ULBs are vested with the responsibility of maintaining a disease-free environment for citizens, they should ensure proper solid waste collection and transport.
Cost Effectiveness	It is essential to assess the efficiency of the service and develop ways to reduce costs and/or increase services within the current budget.
Environmentally Appropriate	Efficient collection and transport of solid waste will provide citizens with a clean environment in which communicable diseases will be greatly reduced
Citizen Involvement	The successful collection and transport of waste material not only depends on the efficient operations of the ULBs, but also on the active involvement of citizens.
Human Behaviour	ULBs should ensure that trash is collected and litter cleared regularly. When trash and litter accumulates in the environment, it encourages people to add even more to the pile.
Capacity building of staff	Though the waste is segregated at household level, during the process of collection and transportation, the segregated portions may be carelessly mixed by the staff themselves.

Source: (CPHEEO, 2020)

Primary Collection and Storage (from Individual Households/Premises)

Primary collection of segregated waste from individual households and commercial establishments (door-to-door collection) is accomplished through the use of containerised pushcarts, tricycles or small mechanised vehicles or tipping vehicles depending on the terrain of the locality, width of streets and building density.

The containers installed in the vehicles should be separate without any chance for re-mixing of the 3 segregated characteristics of waste – wet, dry and the domestic hazardous and sanitary waste. Construction and demolition waste has to be segregated and collected by different collection vehicles. It is considered as a different category of waste and is managed, processed and treated differently than the municipal solid waste. Similarly, biomedical and e-waste is also segregated, processed and treated as a different waste stream.

The frequency of door-to-door collection for wet waste should be every day or most days of the week as wet waste creates problems due to putrification, decomposition, etc. Dry waste does not have such problems and can be collected once or twice a week or as decided by ULB and citizens.

Vehicles and equipment for primary collection

Primary collection vehicles should meet the local requirements for capacity, ease of operation, segregation and transportation as well as statutory requirements of Motor Vehicle Act. As maintaining segregation of waste is of utmost importance, the design and fabrication of container body or compartments should not allow any cross-mixing of waste at any point of time during collection, storage in the vehicle, movement and transfer or unloading of waste. Before selecting a vehicle for primary collection, it is advised to assess the quantity of waste generated, local climatic conditions, topography of the area and the available facilities for repair and maintenance of vehicles.

Figure 4.4:
Tricycles withBins

Figure 4.5:
Hand Carts – Bins can be placed

Source: (CPHEEO, 2020)

All vehicles and equipment should be colour coded properly such as green/blue/black, along with partitioned areas, to signify the type of waste handled therein. All should have GPS enabled to track the vehicle movement. Some of the options are given below.

1. **Handcarts or Tricycles with containers or bins:** Handcarts should have a space to carry 4 to 6 containers of 40 to 60 litre capacity. The containers should be green for wet waste and blue for dry waste. Bins should be made of HDPE, injection or roto molded, UV tested standard garbage handling bins. Containerised handcarts are suitable for door-to door collection of MSW from households, shops, and establishments in narrow lanes and hilly areas and also for collection of street sweepings. (CPHEEO, 2020)

Table 4.4: Estimated Deployment of Vehicles and Manpower for Primary Collection

Vehicle type for primary collection	Number of households/premises covered in different kinds of areas (density of premises)			
	Congested areas	Well-planned / medium density areas	Scattered areas	Hilly areas
Push Cart, Wheel barrow	250-300	200	125	80
Tricycle	300	250	200	125
E-Rickshaw	500-700			NA
LCV up to 700 kg payload	1,000			
LCV > 700 kg up to 1500 kg payload	1,500-2,000			

Source: (CPHEEO, 2020)

Figure 4.6: Tricycle with Tipping

Source: (CPHEEO, 2020)

2. **Tricycles with hydraulic tipping containers:** These tricycles have painted mild steel tipping containers of 350 litres (140 kg per trip). The tipping containers should be mounted on a standard tricycle. These tricycles are suitable for door-to-door collection from small lanes and by-lanes. (CPHEEO, 2020)

Figure 4.7:

(a) Auto tipper with Hydraulic Container;

(b) Direct transfer of solid waste from Primary collection vehicle

(c) Auto tipper with separate containers for collection of Dry and Wet Waste

Source: (CPHEEO, 2020)

3. **Light Motor Vehicles (mini trucks) with hydraulic tipping containers:** Light Motor Vehicles (LMV - Mini Trucks) with Hydraulic Tipping Containers are suitable for door-to-door collection of segregated waste from roads / lanes with less than 5m width. They have capacity of nearly 600–900 kg per trip. The loading height is approximately 1500 mm from the ground level. They should have a leak-proof mild steel load body with drainage tube and plug. (CPHEEO, 2020)

In India various initiatives have been taken by ULBs towards efficient collection of waste segregates at source the following case studies from ULBs across the country are some such examples

Case study: Waste segregation and collection model, Indore

Highlights	
Area in sq. km	276
Wards	85
Population	27,50,000
Waste Generated in Metric Tons (MT) per day	980
Door to door collection	100%
At source waste segregation	100%

Source: (NIUA, 2020)

Almost all the waste generated in Indore is segregated at source. A typical collection vehicle has a container that has two chambers wherein wet and dry waste are collected separately. In addition, It comprises a separate container for collecting sanitary waste and sharp items. Shopkeepers are advise to give segregated waste to the collection vehicle. Across the city, the following collection vehicle have been employed - 400 small tippers have been used for bigger lanes; 400 cycle rickshaws and 350 wheel barrows for narrow lanes. A Separate partition has been made in all door to door collection vehicles. Collection services by municipal authorities are offered to almost every household (including slum areas and unauthorised neighbourhood) at the payment @ ₹60 per month. The collection of waste from commercial institutions is done from 7am to 12 noon in the morning and 4 pm to 12 pm in the evening. All the waste collection vehicles collect waste twice daily from each and every commercial institution. 2000 twin litter bins have been placed at all the commercial areas of the city, along with a separate system and dedicated vehicles to collect waste from litter bins.

Figure 4.8: Separate compartment for dry waste, wet waste, domestic hazardous waste and sharp items

Source: (NIUA, 2020)

Waste collection from bulk generators - Indore Municipal Corporation collects waste from 155 hotels, 17 malls and super bazaars, 190 hospitals and nursing homes, 104 marriage gardens and *dharamshalas* through dedicated vehicles. Eight dedicated vehicles are used for this purpose. In addition to this, waste is also collected from 68 hotels during night hours. User charges are also collected from commercial establishments.

As a result of the above mentioned initiatives - 2000 open dump spots in the city have been eliminated. All the garbage bins that were placed in all the 1170 locations in the city have been removed

Case Study: Pune Swachh model "Improved Collection through Public Private Partnership"

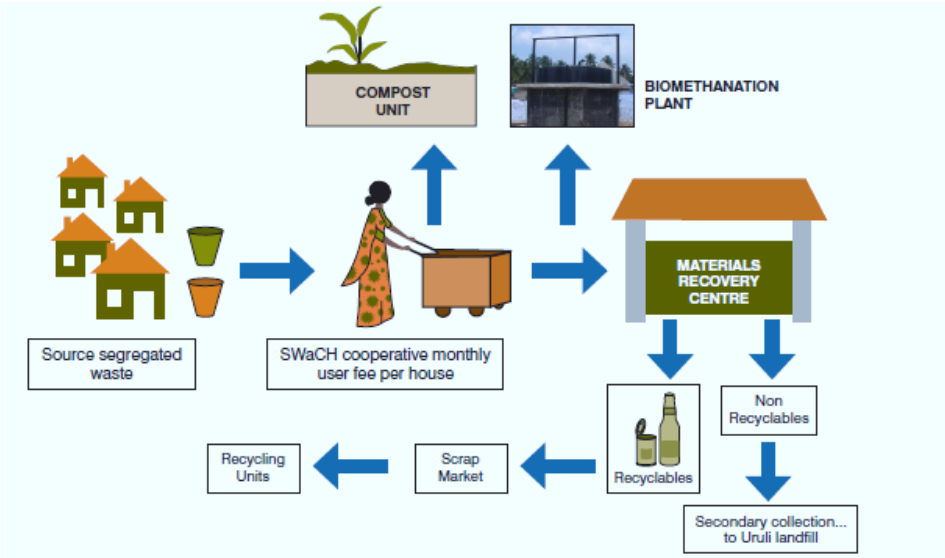
Highlights	
Door to door collection coverage by Swachh	6.42 lakh households (60% of total households)
Waste Pickers involved	2688 members
Total Waste handled (Annually)	3.5 lakh MT

Source - (SWACH, n.d.)

In Pune, Swachh provides door-to-door waste collection services to 6,42,000 households in the city and covers 60% of PMC's households. Remaining 40% households are dependent on PMC's ghanta trucks or community bins for disposal.

Currently 2688 waste pickers are members of Swachh and involved in door-to-door waste collection and local waste processing services in the city. The waste collectors sort the dry waste in sorting sheds and retrieve recyclables such as paper, glass and plastic. They retain the income from the sale of this material. In 2016, Swachh diverted 50000 TPD of waste through recycling. Below figure presents the Swachh model through thematic flow chart

Figure 4.9: Swachh Model



Source - (SWACH, n.d.)

The waste pickers collect a monthly user charges ranging from Rs. 10 –Rs. 40 per household for waste collection. Pune Municipal Corporation (PMC) has partially subsidized the cost of collection from slums to the tune of Rs.5 per household per month.

Figure 4.10: Impact of SWaCH Model

Benefits to Waste-Pickers	Social Impact	Environmental Impact
• Right to recyclables • Sorting sheds: Fine sorting and storage of recyclables • Personal Protective Equipment by PMC • Access to 8+ municipal schemes on occupational identity (health and life insurance, contributory pension etc.)	• Preservation of existing livelihoods • Maximum employment in SWM • Enhanced incomes for waste-pickers • Improved working conditions • Engagement between stakeholders across class divide	• 4 lakh trees saved p.a. • Green House Gas Reduction-1.65 lakh MT Co_2 • 7 Crore liters of petrol saved • Carbon sequestration equal to 35 lakh seedling grown for 10 years

Source - (SWACH, n.d.)

PMC provided an operational grant to Swachh for a period of five years to cover initial management costs and providing welfare benefits to all waste picker members of Swachh. The management of Swachh has reconciled two key objectives of providing good daily waste collection services that are compliant with waste management rules and also protects and upgrade the livelihoods of Swachh members.

Figure 4.11:

(a) 1500+ Push-carts specially designed manual waste-collection and painted with awareness messages are provided to waste-pickers across the city

(b) Uniforms, ID Cards and PPE provided by the PMC to Swachh waste-pickers

Source - (SWACH, n.d.)

Case study: No Dumping project at Sunnyside apartments, Peelamedu Coimbatore

Facility Highlights	
Door to door collection coverage	248 households
Waste Pickers involved	10 members
Total Waste handled (daily)	360 kg

Source: (The Better India, n.d.)

Sunnyside apartment at Peelamedu is a residential community with 4 blocks and 248 households. In order to bring about a shift in their age old habit of dumping mixed waste, Coimbatore Municipal Corporation has entered into a MoU with 'No Dumping', an organization to create awareness and management of solid waste. The initiative of segregation and door to door collection in Sunnyside apartments was started in 2016. The waste generation in this apartment is 360 kg daily which includes 165 kg of wet waste, 170 kg of dry recyclable waste and 25 kg of sanitary waste.

'No Dumping' organization carried out this initiative in the Sunnyside apartment. A total of 10 housekeeping staff of the apartment were trained in collection of segregated waste. Currently, they collect segregated waste for which No Dumping collects Rs. 100 per month from the households as user fees.

Every household uses the 'two-bin one-bag' system that includes one red bin, one green bin and a white bag. To make the segregation successful 'No Dumping' has trained the residents in the four rules of waste collection and segregation. The rule is articulated below

The four rules followed for door to door collection and segregation are as follows:

- **Rule 1** Each home follows the discipline of wrapping all its unhygienic, sanitary (diapers, sanitary pads, earbuds, etc.) and bio-medical waste in a newspaper, marking it with a red cross (X) and putting it in the red bin.
- **Rule 2** All the inorganic waste is to be kept in a dry condition. All broken glass bottles are also wrapped in newspaper. Also, they have to rinse and dry all plastic food packaging and put them in the white bag.
- **Rule 3** All the organic waste or wet waste like vegetable and fruit peels, seeds, food waste, etc. is segregated in the green bin without using any plastic bags or bin liners
- **Rule 4** Two bins and one bag are kept separate and handed over daily to the housekeeping staff that arrives at their doorstep at 9 AM every day

The organization uses customized pushcart with separate compartments for wet, dry and sanitary waste and places them at a designated centralised collection point in the apartment complex. After this, a Truck Taxi (No Dumping's transportation partner) sends separate trucks for wet and dry waste to apartments daily at an appointed time. The housekeeping staff then unloads the waste bins and bags into the respective vehicle's container. While all the raw organic wet waste is sent for vermicomposting, bio-composting and to produce biogas to fuel a crematorium, No Dumping also gives its wet waste directly to marginal farmers for mulching manurial purposes.

Figure 4.12: Waste collection in bags and bins from apartments

Source: (The Better India, n.d.)

All dry waste is sent to its material recovery facilities in Vellore and Kavundampalayam for another level of segregation. Recyclable raw materials are then sent to recyclers and processors to manufacture new products. Inorganic, non- recyclable and combustible waste is sent to the ACC cement factory to be used as Alternative Fuel Resource (AFR) by burning them at high temperatures, to avoid too much pollution.

4.5 Secondary Storage

The secondary storage of municipal solid waste (in bins) as defined in SWM Rules, is allowed only in bins kept at MRFs, storage depots and designated, controlled points. It further stipulates that the old method of placing bins all over the ULB shall be discontinued. Old arrangement should be replaced with the door to door collection system as soon as possible. In these secondary storages, deposition of waste of other streams such as hazardous, E-waste, C and D waste, street sweepings, drain silt or dead animals etc. should not be allowed. Appropriate penalties should be notified and levied.

Secondary waste storage capacities should be designed to accommodate at least double the expected daily in-flow of waste i.e. the storage capacity should be 100% more than the expected daily in-flow of waste, to take care of excess generation of waste due to any reason. It may be noted that this redundancy is only for the stationary waste storage equipment at the point.

Figure 4.13: Unhygienic condition due to secondary bins

Maintenance of waste storage depots or containers

According to collection and transportation advisory of SBM Urban, ULBs should ensure that secondary storage bins are water washed after every emptying and thoroughly cleaned at least once a month and should be painted at least once a year. Periodic inspection of waste storage depots should be carried out once in three months and any damages to the flooring, walls, etc. should be repaired. The metal sheet of the containers might corrode if not well maintained. As a minimum requirement, annual painting of the container from inside and outside must be carried out for increasing the life of containers. Necessary replacements should be provided from stand-by equipment already planned and procured, so that breakdown of containers does not lead to breakdown of entire system leading to unhygienic conditions. It should be monitored and ensured that only segregated waste is collected in these storage bins.

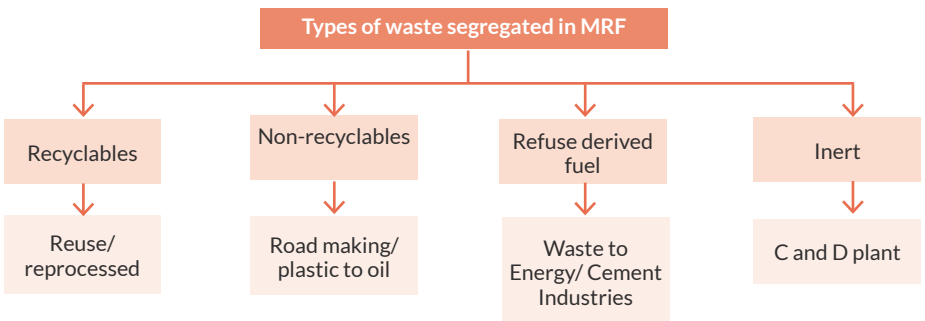
Constraints of Secondary bins

- These occupy the road and street places causing traffic congestion
- These are causing littering in the surrounding areas
- These attract a lot of pests, and vectors creating unhygienic conditions
- These originate bad odour, thus effecting the quality of life

Material Recovery Facility (MRF)

A Material Recovery Facility (MRF) accepts waste materials, whether source segregated or mixed, and further separates, processes and stores them for later use as raw materials for remanufacturing, reusing and reprocessing. MRF is also known as Material Reclamation Facility or Material Recycling Facility. A MRF is a place where waste is further segregated in various components of recyclable waste recovered from it for recycle or resale. In mechanized MRFs, the entire process is carried out with sophisticated systems and equipment that enable efficient separation of large quantity of material into different fractions. (CPHEEO, 2020)

Figure 4.14: Types of waste segregated in MRF



Source: (CPHEEO, 2020)

Need of Material Recovery Facility (MRF)

a. It receives, sorts, processes and stores recyclable or non-recyclables or RDF and inert materials, with the aim to maximize the quantity of recyclables processed, while producing materials that will generate the highest possible revenues in the market and maximize the reuse of other segregated fraction in different processes/ industries.
b. MRFs serve as an intermediate processing step between the collection of recyclable materials from waste generators and the sale of recyclable or non-recyclables or RDF or inert materials to the recycling market and for other processes and industries.

Types of Material Recovery Facility by Ownership and Operations

MRFs may be publicly owned and operated, publicly owned and privately operated, or privately owned and operated. Jointly owned and jointly operated MRFs are also possible. Below are the types of MRF

Figure 4.15: Types of MRFs

	**Mixed MRF** Unsegregated, mixed waste with biodegradable and non-biodegradable material is collected and sent to the MRF processing facility. At the mixed MRF, the mixed waste stream may be segregatedmanually or mechanically
	**Dry MRF** A "clean" MRF reduces the material contamination and can recycle more materials than mixed MRFs.
	**Manual MRF** In manual MRFs, sorting process is carried out manually. This type of MRFs are suitable for small quantities of MSW like 5-10 TPD only.
	**Semi automatic MRF** Semi-automated MRF can cater for 10- 100/200 plus TPD of segregated waste . Semi-automated MRFs also work as secondary collection points in which after segregation of wet and dry streams, further transportation of MSW is carried out in compacted manner to save on transportation cost.
	**Mechanical/ Automatic MRF** Mechanized material recovery facilities are fully mechanized/ automated facilities for material recovery in large quantities (>100 TPD) with least human intervention. These facilities are best suitable for segregation of recyclables/non-recyclables/ RDF/inert, when only source segregated dry waste is coming to the facility.

Source: (CPHEEO, 2020)

Merits of MRF

- Generates livelihood opportunities for informal, local vendors/recyclers in the recycling industry
- Recycling prevents waste from being dumped or disposed in landfills
- Recycled products reduce environmental impacts.
- The MRF reduces the burden of waste management on public authorities.
- Recycling can generate revenue, contributing to the cost recovery in the municipal solid waste service provision.

Design criteria for MRF (as per population)

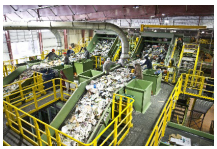
The details are listed below to provide better understanding regarding MRFs and the type of MRF required for cities.

Table 4.5: Type of material recovery facility required by cities based on their population

Population Range	Waste Generation (TPD)	Indicative% of Dry Fraction (incl. plastic waste)	Capacity of MRF	Area Required	Proposed Infrastructure/ Type of MRF	Per Facility Indicative capital Investment (excluding cost of land) in INR
Up to 50,000	15-20 TPD	<50%	1-5 TPD each capacity as per requirement of ULB	1500-2500 Sq. m.	**Manual MRF**	15-30 lakhs
50,001-1,00,000	Up to 40 TPD	<50%	2-10 TPD each capacity as per requirement of ULB	1500- 3000 Sq. m.	**Manual MRF**	15-45 lakhs
1,00,001 - 5,00,000	Up to 200 TPD	50 - 55%	50, 75, 100 TPD Each	6000-8000sqm (1.5-2.0 acres)	**MRF – Semiautomatic**	4.0 - 6.0 Cr
5,00,001-10,00,000	Up to 400 TPD	50- 55%	100+	8000-10000 (2.0-2.5 acres)	**MRF – Semiautomatic**	5.0 - 6.0 crores
10,00,001 – 20,00,000	Up to 1000 TPD	55-60%	100+	10000-12000 sq.m (2.5 - 3.0 acres)	**Semi-automatic / Automated MRF**	6.0 Cr / 18 – 20 Cr
20,00,001 Plus	More than 1000 TPD	55-60%	100/ 200/ 300	10000-20000 sq.m (2.5 - 5.0 acres)	**Automated MRF**	Rs. 18-20, 24-26 and 29-31 (for 100, 200, 300 TPD respectively)

Source: (CPHEEO, 2020)

Table 4.6: Processes and equipment involved at semi- automated or automated MRF

Equipment	Intended Use
Step 01: Receiving in operational area	
Step 02: Weighbridge	
 Weighbridge	Weighing of large quantities of incoming waste
Weighing scales	Weighing of incoming waste and sorted recyclables
Step 03: Unloading pit/ floor	
 Sorting tables	Manual sorting and segregation of recyclables
 Loaders	Loading of incoming waste into conveyor system, sorting tables; Loading of baled recyclables into outgoing vehicles; Moving of residual or rejected waste out of the facility to the processing/ disposal site
Step 04: Conveyer Belt	
Conveyor with hopper	Receiving waste from loader and movement of waste for segregation in to select recyclables
 Conveyor system	Mechanized and regulated movement of waste for segregation
Step 05: Sorting	
 Trommel	Segregation of dry waste or recyclables based on particle size
Magnetic separator	Separation of ferrous-bearing metals
Air classifier	Separation of materials such as paper and plastic based on size, shape, and density

Step 06: Compaction	
Bottle perforator	Perforation of plastic bottles prior to compaction to optimize baling
 Bailer	Compaction and binding of recyclables
Step 07: Waste moved for further processing	
 Forklift	Movement of baled waste within MRF

Source: (CPHEEO, 2020)

In India, cities have adopted automated MRF technology for higher and efficient resource recovery. The following section describes in details some of the models adopted by cities

Case study: Decentralised MRF, Bengaluru

Technology Highlights	
Area	1580 sq. m.
Land ownership	Leased land
Owner of the facility	Saahas Waste Management Private Limited
Year of establishment	2017
Type	Decentralised
Total manpower	60
Type of input	All types of non-biodegradable waste
Segregation level	In more than 25 categories
Recovery rate	>90%
Input capacity	250 MT per month

Source: (NIUA, 2020)

Saahas Zero Waste's (SZW's) Materials Recovery Facility (MRF) at Jigani, is one of its kind semi-mechanized materials recovery facility. Established in 2017, the facility is designed, built, financed, owned and operated by Saahas Waste Management Private Limited.

The unit spans over a leased land of 17,000 sq. ft. area and it has the capacity to manage 16 tonnes of waste per day. The recyclable and non-recyclable non-biodegradable waste is further sorted into more than 25 categories, baled and sent to appropriate recycling facilities and cement kilns for co-processing. Currently, the total manpower is 60 which includes segregation staff, baling personnel and loaders. At present, MRF receives waste mostly from the bulk waste generators where the waste is handled and managed by the Sahaas Zero Waste. In addition to this, waste also comes from smaller ULBs including Jigani and Bommasandra.

Figure 4.16:

(a) Waste sorting **(b) Paper bundles**

Source: (NIUA, 2020)

The capital cost of this facility is Rs. 60 lakh which was funded entirely by Saahas Waste Management Private Limited. The unit has been self-sustaining for last one year since its inception. The revenue generated from the sale of recyclables is sufficient to compensate for the expenses incurred in operating the unit. SZW's material recovery facility is receiving well segregated waste from bulk waste generators where waste is managed by SZW itself, which works on a semi-mechanized mode. The facility has a conveyor belt, which increases sorting efficiency (as compared to manual sorting) of material. In addition, there are balers to compress the sorted biodegradable waste into bales for optimal transportation not to various recycling facilities while the non-recyclable waste such as multi-layered packaging is sent. The segregated recyclable categories of waste such as paper, carton, recyclable plastic etc. are sent to cement plants for co-processing. Presently, the MRF is a zero waste to landfill facility.

Replicability: This model is more successful where the large amount of dry waste is generated such as plastic bottle waste, card boxes, multi-layer plastic bags, and paper waste (from tissues and stationary)

Case study: Automated MRF, Indore

Technology Highlights	
Capacity	300 TPD
Capex	INR 25 crore
Opex	INR 70-80 lakhs per month
Land	4.5 acre
Recovery rate	>90%
Technology	Fully Automated Mechanized Plant

Source: (NIUA, 2020)

The Material Recovery Facility in Indore is a fully automated. The waste is sorted in 13 categories with the help of optical sorting technology and robotics. The project is set up on PPP Model with Nepra Resource Management Pvt Ltd. The operator reuses, reduces, and recycles wastes including industrial wastes.

Figure 4.17:

a. Waste Sorting by waste pickers **b. Separate compartment for paper and glass**

Source: (NIUA, 2020)

This automated material recovery plant installation has a capacity of 300 TPD, which is equipped with an automated sorting system and conveyor belts that helps in sorting all kinds of dry waste more efficiently; making the process not only faster but also taking care of the health of the workers by minimizing their exposure to dust. At present 700 rag pickers are employed at the two MRF plants spread over an area of 10 acres. At these facilities, the dry waste is segregated into different components as metal, rubber, board, plastic, etc. The recyclable waste is sold to 14 Kabadiwallahs, which are registered and authorized by IMC. In dry waste processing, inert is recovered at both the MRFs. The inert is then transferred to the sanitary landfill located near the premises. Before the transfer, the inert is weighed at the weighbridge and logged in the system. The plant has been installed with an investment of Rs. 20 Crore by Nepra for which, it received a financial assistance from Aavishkaar Venture

Management Services. The company makes a payment of Rs. 1.50 Crore to the corporation every year.

Replicability: This type of facility is feasible for that have ensured 100% source segregation and have more dry waste content. IMC is planning to install two more MRF facilities at Sirpur and Kabitkhedi with a capacity of 150 TPD each in order to meet the processing capacities of the city's waste, which is around 500-600 TPD

Case study: Automated MRF, Ahmedabad

Technology Highlights	
Area of the facility	130 sq. m.
Sorting Capacity of the facility	100 MTD
Vehicles deployed	20-22
Capex	INR 13.5 crore

Source: (NIUA, 2019)

The Material Recovery Facility at Ahmedabad runs on a Public Private Partnership (PPP) model between Ahmedabad Municipal Corporation (AMC) and Nepra Resource Management Pvt. Ltd. Land for the facility is provided by AMC on a lease rent of Rs 2 per sq. m per year. The facility is designed, built, financed, owned and operated by Nepra Resource Management. The daily sorting capacity of dry waste of the plant is around 100 MT. More than 20 vehicles are deployed for collection of waste from various locations in the city through a cloud-based technology to ensure transparency in scheduled pick up. Through this cloud-based technology, clients are informed about the quantity of waste collected, and the commodity and carbon emission mitigated by these.

Figure 4.18:

(a) Manual Sorting

(b) Separate compartment for plastics, glass, etc.

(c) Segregated waste receiving chamber

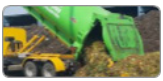
Dry Waste is collected with the help of waste pickers and through collection vehicles and brought to the MRF where it is automatically segregated into various categories and passed through a stringent quality check to meet the requirement and standards of the recyclers. The segregated waste is then sold to the authorized recyclers. The employed waste pickers are also provided with personal protective equipment like-helmet, mask, safety shoes, dress etc. The best employees of the month are also presented with token of appreciation to keep up the motivation. Indore MRF was set up after the successful implementation of this facility

4.6 Secondary Collection and Transportation

Secondary collection and transportation of waste involves collection from community bins, storage points or transfer station, and transportation to the final treatment facility or disposal site. It appears logistically much simpler than the primary collection and transportation. However, segregation of waste is hyper-sensitive to any failures in the secondary transportation stage as large quantities of waste are involved.

Secondary collection and transportation is required in large ULBs (population above 2-3 lakh) or in ULBs having processing and disposal facility far away from their core area. Secondary collection and transportation may not be required in ULBs having less than 2-3 lakh population or in ULBs with multiple decentralised processing facilities within their jurisdictional area.

Figure 4.19: Principles of Planning and deployment of vehicles for transportation

	Vehicle productivity and optimising the collection and transfer operations for efficient waste management
	**Planned collection routes** • to minimise transport distances • to ensure equitable distribution of workload among staff
	**Ensuring full utilisation of the fleet of vehicles** • vehicles may be utilised in at least two shifts, depending on waste generation • to limit the total fleet size
	**Bulk transfer may be done at night** • to avoid traffic congestion • ensuring empty storage containers / depots etc. at the peak morning hours of waste collection and deposition
	Suitable solutions need to be tailored according to the local conditions for area specific strategies of SWM
	Real time data on waste quantities and waste composition based on constant monitoring, evaluation and revision of route plans etc.

Source: (CPHEEO, 2020)

Skip Truck (Dumper Placer)

Skip trucks or dumper placers are used for transportation of skips (dumper bins) of different sizes to treatment or disposal sites. The usual skip sizes are 2.5 cu m, 3 cu m, 4.5 cu m, and 7 cu m. When a full skip (container) is lifted, an empty skip should be replaced immediately to prevent spillages. The system could be used to lift waste containers with wastes having densities up to 1,000 kg per cu m. Skip truck should be able to make at least 5–6 trips in an 8-hour shift within a radius of 15 km. Twin dumper placers can also be used to lift twice the number of containers in the given time. (CPHEEO, 2020)

Figure 4.20: Skip Truck (Dumper Placer Machines)

Source: (CPHEEO, 2020)

Rear Loading Compactor (Refuse compactor) Trucks used for transportation

Compactor trucks are used for transportation from smaller transfer vehicles/ points either to larger transfer stations or directly to treatment or disposal sites. Compactors can be of different sizes. Compaction capability to compress garbage or solid waste should be between 800 and 900kg/cu m.

Figure 4.21: Refuse Compactor Truck

Source: (CPHEEO, 2020)

The three sizes of compactor trucks used in India are:

1. Small compactors of 5–6 cu m for 4.5–5.5 tonnes of waste per trip;
2. Medium compactors of 8–10 cu m with a payload capacity of 7–7.5 tonnes of waste per trip; and
3. Large compactors of 12–16 cu m with a payload capacity of 10–12 tonnes of waste per trip. (CPHEEO, 2020)

Light Commercial Vehicle (LCV) with Tipping Floor

Wherever possible, municipal authorities should plan for direct transfer of waste collected from households to secondary collection vehicles. In such instances, mini trucks with a tipping floor are appropriate for secondary waste transportation. Door-to-door collectors and sanitation staff may be directed to transfer waste from primary collection vehicles or handcarts directly into these vehicles (CPHEEO, 2020).

Figure 4.22: LCV with tipping floor

Source: (CPHEEO, 2020)

Equipment for secondary storage collection

Bins for Community Places on Public Roads and for Bulk Generators

Galvanised iron movable garbage bins ranging from 1.10 cu. m to 7 cu. m capacity are available. The bins are designed to be lifted or emptied by mechanised container lifting devices such as compactors, dumper placers, etc. They can be used for storage and handling of biodegradable and recyclable waste. They can also be used for secondary storage of street sweeping and silt collected from drains. These bins are also suitable for bulk waste generators and for placement at waste storage depots, markets, tourist spots etc.

Stationary/Fixed Compactor Transfer Station (FCTS)

In large cities where disposal sites are often more than 15 km away from the collection area, it is economical to set up transfer stations as tertiary storage-cum-transfer depots to save transportation cost. The transfer station or tertiary storage depot can also be equipped with a material recovery facility, where DRY recyclables are sorted and recovered and sent for further processing or to recycler markets. Transfer stations usually consist of large containers of about 15– 25 cu m. A ramp can be provided to facilitate unloading by smaller vehicles or dumper placer containers directly into large vehicles or containers kept at a lower level just below the ramp. The transfer station can have the facility of a hopper, into which waste can be transferred, and then with the help of a static compactor, waste can be pushed into the large hauling vehicle or container.

The compactors are designed for transfer points on public places and are suitable for both biodegradable and recyclable waste. The containers are available at 7 cu m to 10 cu m, capacities or larger. They are designed for lifting by hook lift system mounted on heavy duty trucks.

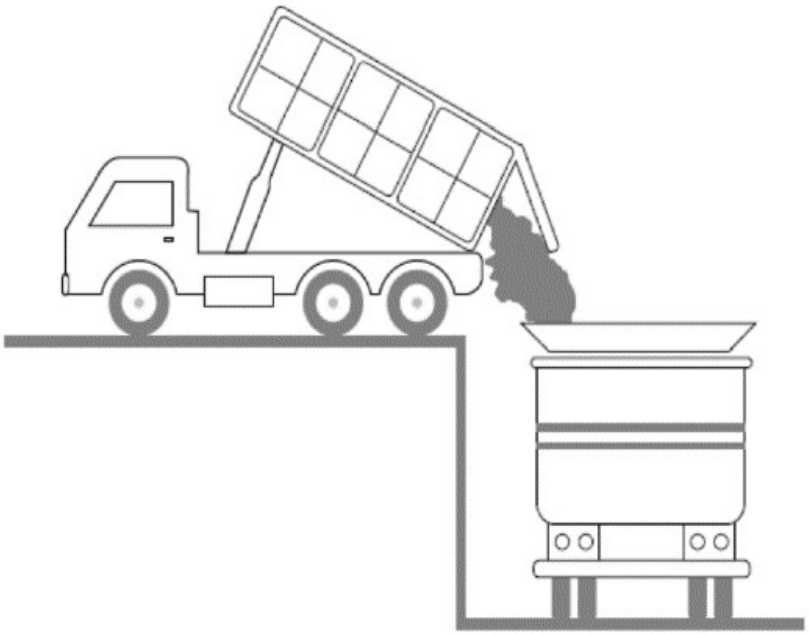
Of late, the modern fixed compactors are being introduced as ideal replacement for the traditional Dhalaos and act as mini transfer stations. Compared to transfer stations, the FCTs require much smaller area hence more number of them can be developed in a ULB.

Types of Transfer Stations (TS)

Waste is unloaded at a transfer station either directly into tertiary transport vehicles (direct unloading) or into a storage area.

1. **Direct Unloading:** A direct unloading system involves a two-level arrangement, wherein the collection vehicles drive up a ramp to the upper level to discharge waste into a transfer vehicle parked onsite or loading system. The direct unloading system is usually implemented only as a small-scale system, i.e., typically where the quantity of waste handled is less than 300 TPD. (CPHEEO, 2020)

Figure 4.23: Direct Transfer Station

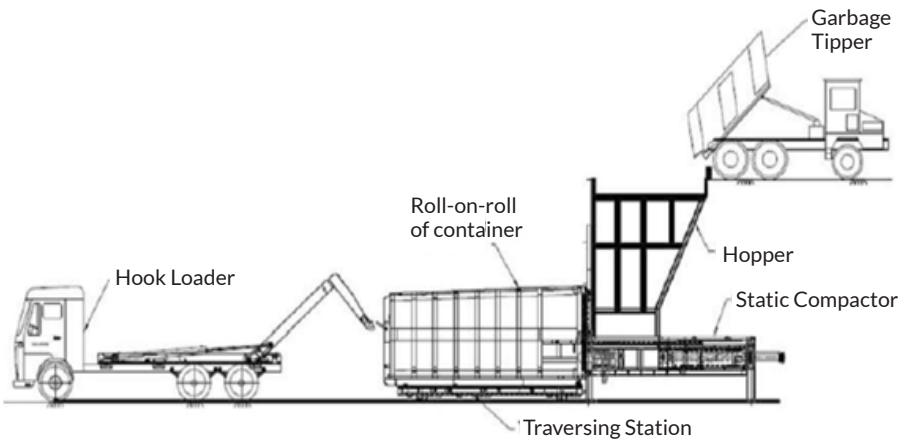


Source: (CPHEEO, 2020)

2. **Unloading-to-Storage:** An unloading-to-storage system involves collection vehicles discharging into a storage. From the storage area, wastes are subsequently loaded into transfer vehicles. The storage area may be a platform at the same level as the unloading level, in which case only a two-step arrangement of transfer is required.

   The storage area may be a pit, below the unloading level and above the level on which the transfer vehicle is parked, in which case a three-step arrangement of transfer is required. The storage area is commonly designed to hold the peak quantity of waste generated in a day. (CPHEEO, 2020)

Figure 4.24: Stationary Compactor Transfer Station Design



Source: (CPHEEO, 2020)

In India ULB have installed customised transfers stations or equipment's. Few example are illustrated in the following section

Green Transfer Stations, Indore

The collected waste is taken to the Green Transfer Stations (GTS) built in the city. Capacity of each GTS ranges between 150-200 MT of waste. The waste collecting vehicle which is bought to the GTS is weighed through the weigh bridges. The city has a total of 10 transfer stations, the capital cost of each transfer station being Rs. 6 Cr. The garbage transfer stations are known as 'Green Transfer stations' as each of the stations save approximately Rs. 20 Lakh per month on the fuel consumption and has its own biomethanation plant which uses 1.8MT of the waste to generate electricity which is used in the transfer stations itself.

Figure 4.25: Transfer station in Indore

Source: (NIUA, 2020)

Refuse Transfer Station, Ahmedabad

After collection, the waste is transported to the Refuse Transfer Stations (RTS) from where it is sent to the processing plants. 7 Transfer Stations of about 400 MT capacity have been constructed in 6 zones of the city. All the stations are functional and 1 RTS is in under construction. Segregated waste collected from the RTS is transported to AMC's composting plants operated by Excel Industries Ltd. and Bharuch Enviro Engineers Ltd.

Figure 4.26 Refuse Transfer Station, Ahmedabad

Transfer stations, Coimbatore

About 288 MT of waste is being collected and disposed of at the secondary collection points by these tractors. There are 4 Transfer Stations in the city at Peelaimedu, Ondipudur, Sathy Road, Ukkadam. Hook Loaders are used for secondary transportation of waste from transfer station to the compost yard or landfill site. (NIUA)

Figure 4.27: Transfer station in Coimbatore

Source: (ICRIER)

Transfer stations, Surat

Collected waste is transferred to closed body transfer stations. Surat Municipal Corporation (SMC) has 8 transfer stations located in 7 different zones, viz., Bhatar, Katargam, Varachha, Anjana, Pal and Bhestan, having varying capacities.

Figure 4.28: Transfer station at Surat

(a) Waste Container

(b) Weighing Bridge

Source: (Author)

4.7 Information, Communication and Technology (ICT) for Efficient Solid Waste Management

Communication between different stakeholders is of high importance in order to get a well-functioning waste management system in cities. As discussed in the earlier chapters, waste management at individual level can be done through reduction of waste generation, recycling or providing dustbins at regular intervals to avoid littering. Apart from these conventional methods, Information Technology is being used, which help in the creation of smart systems. Smart systems incorporate functions of sensing, actuation, and control in order to describe and analyse a situation, and make decisions based on the available data in a predictive or adaptive manner, thereby performing smart actions.

The ICT-Based Waste Management Framework employs the tools of ICT in monitoring and managing waste from the point of creation (household/ establishments waste) all the way to the point of final disposal either to the landfill for organic waste or to the recycling centre for plastic wastes.

This framework includes the interactions of technological components and services like Geographic Information Systems (GIS), Internet of Things (IOT), Machine to Machine Technology (M2M) and Geographic Positional System (GPS) for geo referencing. These combinations of ICT based technologies can be employed to better manage wastes in our communities.

ICT can provide visibility on city sanitation and solid waste management, route planning for garbage collection, resource optimisation, efficient asset management, efficient maintenance, visibility of waste bins, air quality measurements etc. Some of the key aspects that can be achieved are given. (Mehrotra, 2015)

Table 4.7: Technological options

Technological options	Description
Online Platforms	Provides options and alternatives to the user to reuse or sell and regain value from the product before discarding the product as waste
Analytics	Accurate projections on total waste generated, waste type and identification of high waste generation areas
Crowd Sourcing	Encourages citizens to report (web/mobile/social channels) waste-related activities which need urgent attention from the authorities
Sensor-based waste collection	Identifies status of waste bins (empty or filled) so as to customize the waste collection schedule
Automated waste collection system	A long-term solution using chute systems in buildings with waste being sucked through pipes
GPS devices and sensors on waste truck	Used to route the waste collection trucks to increase efficiency in waste collection Ensures contractors are dumping the waste in designated space and helps in determining waste generation per ward

Technological options	Description
Sensor based sorting	Recognises waste based on their chemical or physical character
Pollution sensor	Leverages the pollution sensors to gouge pollution at landfills
Energy Simulation (Waste to energy)	Provides projections of waste generation and energy production from waste
Analytics-based landfill management	Provides accurate waste generation and collection projection and the type of waste
Integrated asset management solutions	Helps in management of all waste assets like, data, processes, governance, etc.
Workforce and resource management	Improves workforce management and engagement
City performance management	Monitors the city performance, Helps in managing governance, performance and provides crisis management
Integrated command and operation centre	Monitors city services in real-time Improves maintenance activities
Geospatial dashboard	Locates bins, landfills, waste management assets and maps in geospatial system

Source: (MoHUA-SBM U, 2019)

Case study: Integrated Command and Control Centre, Agra

Highlights	
Waste collection monitoring	750 MT per day
Household covered	350,000 households
Vehicles deployed	342
Manpower	3500

Source: (NIUA, 2019)

Agra's ICT based Solid Waste Management Solution (SWMS) provides an end to end solution for primary and secondary waste collection, and enables coordination the efforts of a network of government and non-government agencies, and waste collection fleet of motorized and non-motorized vehicles.

Vehicles have been instrumented with GPS tracking and RFID readers, and route maps have been defined. Individual households have been tagged. As vehicles reach in proximity of a household, the RFID reader records position and garbage collection, thereby enabling the city to monitor the volume and location of primary waste collection in the city. The performance of each truck on each route is being monitored, compared, and managed, thereby improving primary waste collection performance.

Secondary waste bins have been instrumented with bin volume sensors, which trigger alarms when over-filled and ensure immediate action and removal of garbage.

City and contractor staff have been registered on the online portal and mobile app, and route planning, work scheduling, and performance monitoring is done online and real-time. Citizen's mobile app allows them to register and track complaints, and all grievances have an escalation matrix to assign the task to concerned area representative for immediate redressal.

Figure 4.29: Integrated Control Command Centre

Figure 4.30: RFID reader at household level

The SWMS helps to automate the logistics process which allows on-time performance of primary and secondary garbage collection processes. Post SWMS implementation, rating is significantly improved on cleanliness and sanitization parameters.

Case study: Intelligent Solid Waste Management through Integrated Control Command Centre, Indore

Under Smart City Mission; an Integrated Control and Command Centre (ICCC) has been developed in Indore. Intelligent Solid Waste Management (ISWM) is an ICT-enabled system for improving collection efficiency, transportation and processing. Also it integrated with citizen services mobile application. Following are the ICT based interventions under ISWM:

1. Applications for Citizens and Safai Mitra (sanitation worker) for data crowd sourcing and compilation of management information on primary and secondary waste collection.
2. GIS based Asset Management through Geo-fencing of waste bins, vehicles, personnel, Waste Transportation Route mapping and GPS based Vehicle Tracking Management System (VTMS)
3. Monitoring of real time tracking of SWM vehicles, Activity log for sweeping, monitoring of smart bins, monitoring of Garbage Vulnerable Points (GVP)

Figure 4.31: Vehicle Tracking and Monitoring System (VTMS) integrated in ICCC

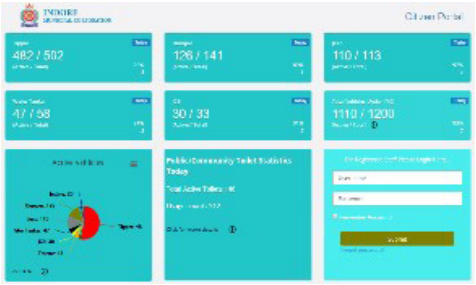
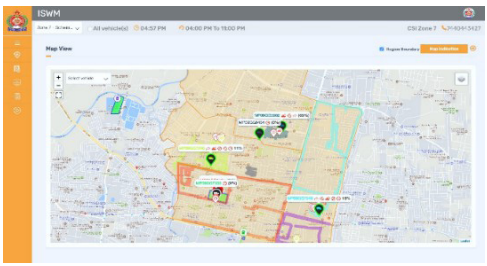
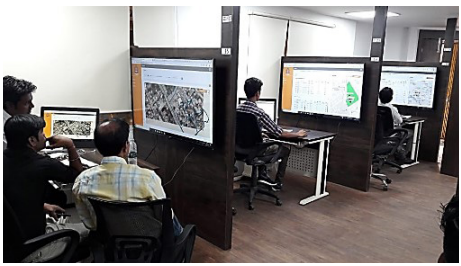


Figure 4.32: Real time Vehicle Monitoring and route tracking





Case study: ICT Enabled Collection and Transportation System– Bengaluru

Bengaluru uses ICT enabled waste collection and transportation which helps it to monitor and regularise the fleet movement. The city uses 4000+ Primary Collection Vehicle (PCV) and 500+ Secondary Transportation Vehicles (STV). All the transportation vehicles are installed with RFID (Radio Frequency Identification) tags. The RFID application also captures the PCVs/ STVs data at the weighbridge as an essential field to complete the scanning process.

Figure 4.33: Vehicle scanner at entry point

Each PCV is provided with an RFID tag which is fixed on the vehicle to enable easy scanning. This ensures that only authorized vehicles are allowed to enter the designated destinations, and enables stoppage of unauthorized waste transfers. This daily data forms the basis for calculating payments to be made to service providers based on vehicle performance. (MoHUA-SBM U, 2019)

Case Study: Internet-of-Things (IoT) based fill-sensor devices in garbage bins– Bhopal

Bhopal uses ICT enabled waste collection and transportation. The city is fighting the issue of overflowing garbage bins, especially in high density and traffic areas. Over 700 RFID and fuel sensors have been installed in the vehicles. 230 Internet of Things (IoT) sensors have been installed covering 460 twin-bins. The coverage of this installation is in the high priority zones/ wards as identified by the BMC. The fill-level sensors identify the fill status of the bins and start triggering alerts to Central Command Centre and respective ward officers upon 80 % fill capacity.

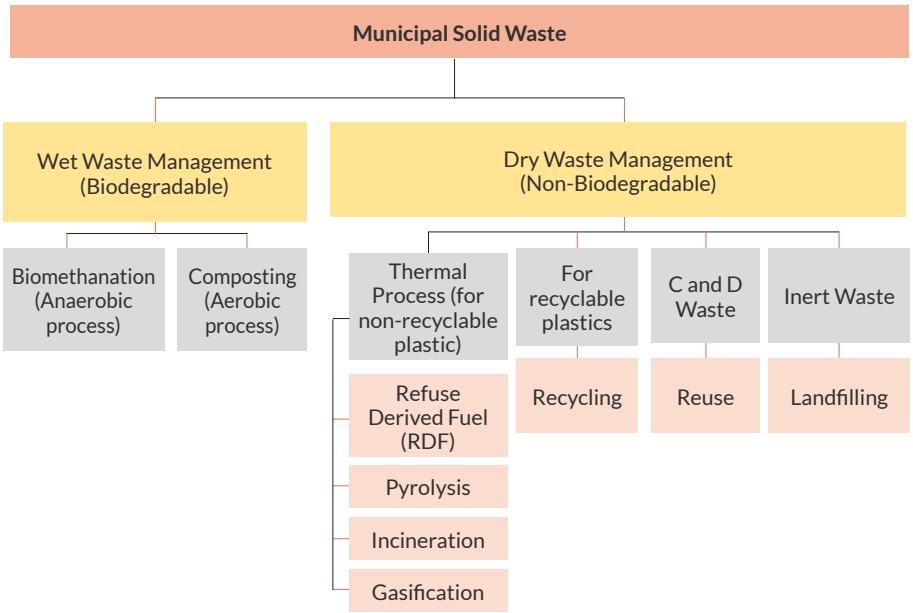
Figure 4.34: Smart dustbins

The IoT sensors have been integrated with Real Time Vehicle Tracking System which ensures Real Time Monitoring. This also helps in route planning and optimisation for waste collection. Real time analytics as the system generates reports and provides a garbage collection frequency.

4.8 Processing and Treatment Technologies

The processing of waste depends largely on its quantity and characteristics. Integrated Solid Waste Management (ISWM), as discussed in Chapter 01, is a strategic approach to manage solid waste in a sustainable manner by considering all aspects of MSWM, namely waste generation, source segregation and collection, transportation, processing and treatment, and disposal in an integrated manner, with an emphasis on maximising resource use efficiency. SWM rules do not permit disposal of mixed waste into sanitary landfills and mandate that only inert rejects (residual waste) from processing facilities, inert street sweepings, etc. can be landfilled.

Figure 4.35: Methods for processing MSW



Source: (MoHUA-SBM U, 2017)

The Municipal Solid Waste contains organic fraction (biodegradable waste) and inorganic fraction (dry waste including recyclable, combustible materials and C and D fractions) and the inert. There are various technologies by which different fractions of waste can be processed.

The several methods of processing and treatment of municipal solid waste can be classified as:

Wet Waste (Biodegradable Waste) Processing Techniques

Biodegradable waste, includes any organic matter in waste which can be broken down into carbon dioxide, water, methane or simple organic molecules by micro-organisms and other living organisms, using aerobic digestion or anaerobic digestion or similar processes. It is commonly found in municipal solid waste as green waste, food waste and paper waste. Other biodegradable wastes include human waste, sewage sludge and slaughterhouse waste, which however are to be kept out of the municipal waste.

Biological treatment of biodegradable (organic) waste involves using micro-organisms to decompose the biodegradable components of waste into useful products. Biodegradable waste can be decomposed in two ways:

1. **Anaerobic processes (in the absence of oxygen):** in the anaerobic process the utilizable product is methane gas (for energy recovery) and sludge, which can be composted. Biomethanation is an anaerobic slurry-phase process that can be used to recover nutrients and energy contained in biodegradable waste. Biogas can be used either as a source of thermal energy or to generate electricity by using gas engines or for gas lighting. Biomethanation will yield biogas as its output which can be used for production of electricity and heat/ light.
2. **Aerobic processes (in the presence of oxygen):** in the aerobic process the utilizable product is compost. Composting is an aerobic process in which biologically degradable wastes are converted through biochemical transformation to yield stable granular material commonly called City Compost - which could be used as soil conditioner and nutrient provider

Biomethanation Technology (Anaerobic Digestion Process)

Biomethanation plants require a consistent source of degradable organic matter, free from inert and toxic material. Slaughterhouse waste is eminently suitable for biomethanation.

Biomethanation is the anaerobic (in the absence of free oxygen) fermentation of biodegradable matter in an enclosed space under controlled conditions of temperature, moisture, pH, etc. The waste mass undergoes decomposition due to microbial activity, thereby generating biogas comprising mainly of methane and carbon dioxide (CO_2), and also digested sludge, which is stabilized but may contain some pathogens. Due to the anaerobic environment, Hydrogen Sulphide (H_2S) is generated with varying percentage depending on the Sulphur content in the system (in the form of protein, sulphate, etc.). Like composting, biomethanation is one of the most technically viable options for Indian municipal solid waste due to the presence of high organic and moisture content.

The Rules of Solid Wastes Management (2016), have clearly mentioned the Responsibilities and Duties of local authorities and village Panchayats of census towns and urban agglomerations and emphasized that the local authorities shall emphasize management of solid wastes at community and decentralized levels to overcome the problems of collection and transportation. It states that (i) "The local authorities and Panchayats shall involve communities in waste management and promotion of home composting and biogas generation, decentralized processing of wastes at community level subject to control of odour and maintenance of hygienic conditions around the facility" and (ii) Facilitate construction, operation and maintenance of solid waste processing facilities and associated infrastructure on their own or with private sector participation or through any agency for optimum utilisation of various components of solid waste.

Bacterial process for bio-methanation

Bio-methanation is the process of anaerobic digestion of any biodegradable organic matters producing biogas that mainly constitutes methane. The process is completed by the help of different groups of micro-organisms under anaerobic condition under 4 stages namely, i. Hydrolysis stage, ii. Acedogenesis stage, iii. Acetogenesis stage and iv. Methanigenesis stage. All the stages are in series, acted upon by specific group of bacteria- product of one group is the substrate of another group, finally producing methane, carbon dioxide and hydrogen sulphide.

Merits of Biomethanation plant

- Produced biogas can be used for cooking and production of electricity
- The stabilised sludge can be used as a soil manure
- Odour problems are also considerably reduced by adopting biomethanation

Different types of anaerobic digesters or biogas plants have been designed and used mainly depending upon the following factors:

1. Monophasic or biphasic number of digesters in the monophasic system;
2. Floating holder or fixed dome or combination of both;
3. Concentration of substrate (feed material);
4. Operating temperature — mesophilic (near ambient) or thermophilic (heated digesters maintained around 55°c–60°c);
5. Batch, semi-continuous or continuous; and
6. Suspended particulate, up flow anaerobic filter, up flow anaerobic sludge blanket, or hybrid systems. (MoHUA-SBM U, 2017)

Applicability of Biomethanation

Biomethanation can be adopted in both

1. **Decentralized systems:** up to 5 TPD (much smaller quantities can be processed where O and M is not outsourced). These can be used for Bulk Waste Generators, like canteen waste, hotel waste, institutional areas and market waste (fruit, vegetable, slaughterhouse waste, etc.)
2. **Centralized systems:** up to 50 TPD digesters (for higher capacity in one digester, the size may become unwieldy and difficult to maintain). Such large sized digesters can be implemented on entire city wet waste. (CPHEEO, 2016)

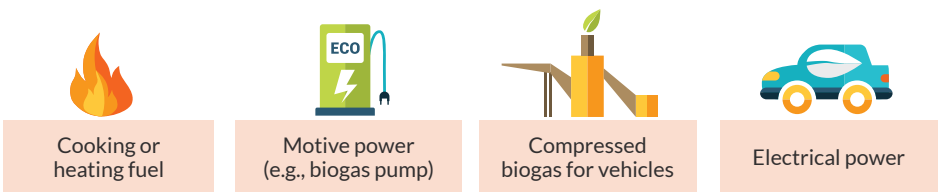
Biogas production rate: Biogas production rate depends on substrate quality- C/N ration, HRT, temperature inside biogas plant. However, on average, it varies from 50-60 cum of biogas per tones of solid wastes.

Composition of biogas: Depending on the nature of feed materials biogas contain 55-65% methane, 25-35% carbon dioxide and rest other gases

Uses of biogas: Biogas is used for the following purposes:

1. Cooking: Use of biogas for cooking purpose is the most convenient use. In this case biogas is supplied through pipe to household kitchen. There is no need of purification of biogas for cooking purpose
2. Electricity generation: Electricity can be generated from biogas through generator. Produced electricity is either used locally or supplied to the power grid when sufficient biogas is produced. In this case biogas needs to be purified from H_2S and CO_2, because the former causes corrosion in machinery and the later reduces calorific value of biogas. Absorption, Adsorption, water scrubbing and cryogenic process are some methods for the removal of H_2S and CO_2 from biogas.
3. Bio-CNG: After proper purification, biogas can be used as CNG. It can be used as fuel for motors, cars etc.

Figure 4.36: Utility of Biogas



Stages in Biomethanation

Biogas produced during biomethanation comprises of bio-methane gas (CH4) 50% - 60%, Carbon Dioxide (CO_2) 40 -50%, Water Vapour (H_2O) 0.1-0.5%, Hydrogen Sulphide (H_2S) 50 -2000 ppm and Ammonia (NH_2) 50-60 ppm. The biogas, by virtue of its high calorific value, has tremendous potential to be used as fuel for power generation through either internal combustion engines or gas turbines. (PURI)

Figure 4.37: Stages in Biomethanation plant

Stage I: Pre-Treatment
Separation of non-digestible material either through source segregation or through mechanical sorting at the biogas plant facility to remove undesirable or recyclable material such as glass, metals, stones, etc. The waste is shredded before it is fed into the digester for better fermentation.
Stage II: Anaerobic Fermentation
Happens in three steps brought about by different groups of microbes: hydrolysis (hydrolytic bacteria), acidogenesis (acidogenic bacteria), and finally biomethanation (methanogenic bacteria).
Stage III: Collection of Biogas and its Usage
The biogas obtained is stored and may be scrubbed to ensure automotive quality CNG-like gas (CO2 less than 5% and H2S less than 10 ppm). Biogas may also be used for generating electricity.
Stage IV: Residue Treatment
The digested sludge is dewatered and the liquid recycled for use in the dilution of incoming feed. The bio-solids are dewatered to 50%–55% total solids with a screw press, filter press, or other types of dewatering systems and aerobically cured to obtain a compost product.

Source: (CPHEEO, 2016)

Operating Parameters for Biomethanation

Raw material for anaerobic digestion comes from very different biomass sources and it must meet certain requirements such as: -

1. Solid wastes should contain only biodegradable organic matter;
2. **pH:** It should be maintained between 6.8 to 7.3. For biogas system in two stages, i.e. the hydrolytic step is separated from the methanogenic step, pH value for the first stage is between: 5.2 – 6.3, and for the second stage between: 6.7 – 7.5.
3. **C/N ratio:** C/N ratio should be 20-25. When the anaerobic digestion process is carried out in a single stage. When digester has double stage then for the first stage this ratio should be between 10-45 and for the 2nd stage- 20-30 Should not contain inhibitory substances for microorganisms (detergents, antibiotics, antiseptics, etc.).

4. **Temperature:** Temperature choice and control are critical to the development of anaerobic digestion process. The microorganisms participating in the process of anaerobic digestion (especially methanogenic ones), are divided into three large categories:
   a. Cryophiles (Psychrophiles), operating at temperatures from 12 to 24°C,
   b. Mesophiles, operating at temperatures between 22-40° C,
   c. Thermophiles, operating at temperatures between 50 – 60° C, characteristic area for thermophilic regime digestion.
5. **HRT.** The hydraulic retention time (HRT) it is the average range in which the substrate in the anaerobic digestion process is retained in the digester, in contact with biomass (bacterial mass). Optimum HRT varies with the atmospheric temperature of the area. In India most of the digesters are in mesophilic range. Where HRT is normally maintained at 30 days. In case of cryophilic digesters HRT is kept higher and for thermophilic digesters HRT is maintained at lower days. *Source: (MoHUA-SBM U, 2017)*

Design of digester

There are two basic designs of digesters approved by the Ministry of New and Renewable Energy Sources (MNRE), Government of India. These are:

1. **KVIC Model:** This design of biogas plant is most popular in India. It is applicable for household level, community level, institutional level and Industrial level. It is also called as floating gas holder type. In this case base of the biogas plant is fixed. Gas holder of the digester moves vertically upward when there is gas produced and downward when gas is consumed or there is no gas.

Figure 4.38:
Institutional KVIC biogas plant

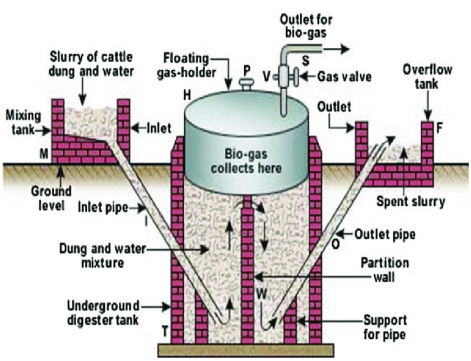
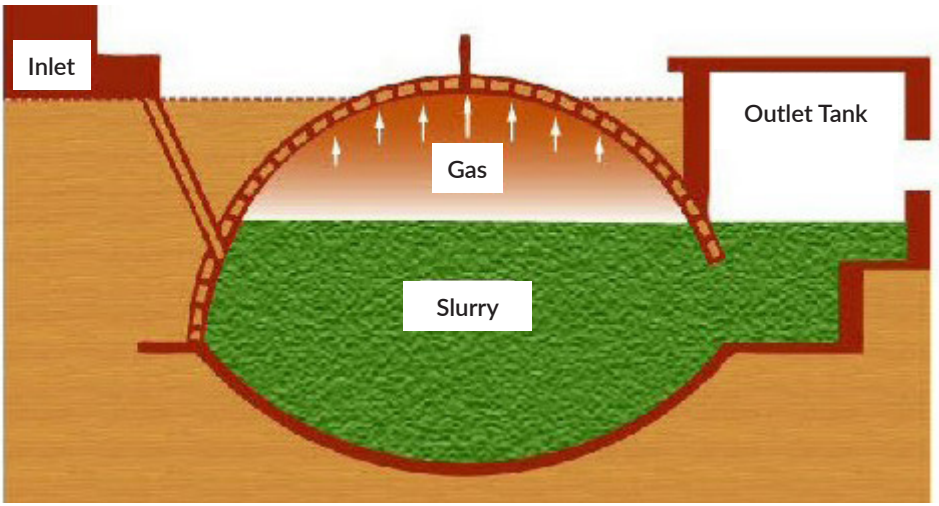


Figure 4.39:
Vertical section of a KVIC biogas plant

Source: (Anil Kumar, 2015)

2. **Deenbandhu Model:** It is also called fixed dome model. In this case brick, cement/ RCC structure. In this case biogas is fixed and produced biogas is stored inside plant through liquid displacement chamber.

Figure 4.40: Deenbandhu biogas plant



Source: (grassrootsindia, n.d.)

The table below enumerates the criteria required for selection of locations for biomethanation as an implementable technology.

Table 4.8: Selection criteria of some aspects of biomethanation plants

CRITERIA	
Facility Location	To be located as per the buffer zone criteria mentioned below.
Buffer Zone (No Development Zone)	500 m for facilities dealing with 100 TPD or more of MSW 400 m for facilities dealing with 75–100 TPD of MSW 300 m for facilities dealing with 50–75 TPD of MSW 200 m for facilities dealing with 10–50 TPD of MSW No buffer zone for facilities dealing upto 5 TPD of MSW No buffer zone for decentralised plants handling less than 1 TPD of MSW (but adequate environmental controls are required)
NATURAL ENVIRONMENT	
Land Requirement	For 300 TPD of segregated/ pre-sorted MSW: 2.5 ha of land is required
Waste Quantity which can be managed by a single facility.	1 TPD at small scale to 500 TPD at larger scale
Requirement for Segregation prior to technology	Very high
Technology Maturity	Feasibility for biodegradable waste is proven. In case of mixed waste, appropriate pre-sorting has to be carried out.

FINANCIAL CRITERIA	
Indicative Capital Investment	Typically 75-80 Cr for 500 TPD plant
Market for product/ By-Product	So far, there is no appropriate system for pricing biogas. The system of pricing according to kerosene equivalent puts biogas at a disadvantage. At present, there is lot of interest in conversion of biogas into automotive fuel by stripping CO_2. In this case, equivalent pricing with power/CNG again puts biogas at a disadvantage because of scale of economy.
MANAGERIAL CRITERIA	
Labour Requirement	Less labour intensive
Skills for Operation and Management	Technically qualified and experienced staff.
ENVIRONMENTAL CRITERIA	
Concerns for toxicity of product	The final product is generally applied to soil as a soil conditioner. Can contaminate the food chain if compost is not meeting FCO norms.
Leachate Pollution	High if not treated appropriately
Atmospheric pollution	Low. (Leakage of biogas, Odour issues)
Other	Fire and safety issues to be taken care of

Source: (CPHEEO, 2016)

Case study: Biomethanation plant with M-KVIC Floating Dome Technology, Ujjain

Highlights	
Type	Decentralised
Input capacity	5 TPD
Processing capacity	5 TPD
Output product	Manure and electricity
CAPEX	Rs 1.97 Crore
OPEX	Being borne by the contractor for 5 years

Source: (NIUA, 2020)

Ujjain, the ancient city, situated on the banks of River Kshipra in Madhya Pradesh. Ujjain city, as a municipal entity, spans an area of 92.68 sq. Km. The city is divided into 6 zones covering 54 wards. There are 4 daily markets and 3 weekly markets in the city which produce 25 – 30 MT of vegetable waste weekly. This plant is helping in the solid waste management of the city and is also a step towards reducing the burden on non-renewable resources by producing electricity.

Ujjain Smart City Limited with Aryan Associates (private contractor) has established a biomethanation plant of capacity 5TPD at Maksi Road, Sabzi Mandi to manage the wet waste generated in the vegetable markets. Approximately 600 kgs. of compost obtained per day as a by-product from the process is used in the city gardens. The plant also generates 225 units of electricity per day, which is used for street electrification.

Figure 4.41: Biomethanation Plant

Source: (NIUA, 2020)

The capital cost of the plant, which is Rs 1.97 Crore has been borne by the Ujjain Smart City Limited, while the O and M cost for 5 years is being borne by the contractor. Specifically marked bins are installed at daily vegetable markets for the collection of wet waste. The project has received multiple awards: Skotch Award, ITPO Green Energy Award, and Gurugram Smart Cities Award (NIUA, 2020). The project promoted the awareness of clean and green technologies and reduced greenhouse emissions onto the environment by 12,176 Kg/month

Replicability: ULBs can utilise the wet waste generated in markets like vegetable mandis to set up biomethanation plants. This can help produce electricity which can be used in street electrification. Post the implementation of the Biomethanation plant few technical issues were observed as there was no Net Metering Policy for the Biomethanation.

Case study: Bio CNG Technology Developed by Mahindra and Mahindra, Tirupati

Highlights	
Type	Decentralised
Input capacity	50 MTD
Processing capacity	NA
Output product	Bio gas
CAPEX	Rs 14.57 cr.
OPEX	NA

Source: (NIUA, 2020)

Figure 4.42: Biomethanation plant at Thukivakam

Source: (NIUA, 2020)

Tirupati is a vibrant pilgrimage town located in the Chittoor district of Andhra Pradesh. The city is famous for the shrine of Tirumala Venkateswara Temple and other historic temples. In the year 2012- 2013, India's Ministry of Tourism named Tirupati as the 'Best Heritage City. Tirupati has been selected as one of the hundred Indian cities to be developed as a smart city under Smart Cities Mission by the Government of India.

Tirupati Municipal Corporation (TMC) oversees the administration of the city. The Health Department of TMC is responsible for the management of solid waste in the city. The Bio-CNG Plant at Thukivakam has been established by the Tirupati Municipal Corporation (TMC) in Public Private Partnership (PPP) mode with Mahindra Waste-to-Energy Solutions Ltd. for a concession period of 20 years. Here, wet waste is being converted to methane rich biogas and high-quality manure in a specially designed digester. This facility has been developed in technical collaboration with IIT-Delhi.

At present, Mahindra has been supplying biogas to more than 10 hotels in Tirupati on a trial basis. TMC entered an MoU with Mahindra and Mahindra Ltd to generate gas from waste without financial burden over the civic body. The corporation is supplying 50 tonnes of wet waste the facility on a daily basis from Indira Priyadarshini Corporation vegetable market, Rythu Bazaar and other small vegetable markets apart from kitchen waste. Agricultural residues like straws and leaves would also be used as inputs for the facility. The TMC has provided land and water supply at Thukivakam for establishing and operating the facility. The facility has been spread over 6 acres of land and has a capital expenditure of 14.57 Crores. (NIUA, 2020)

Replicability: Such biomethanation plant can be set up in areas where the manure can be utilised in the nearby areas, for instance in large scale institutes, in commercial areas, etc. The biogas generated can be provided to nearby hotels for usage.

Case Study: Kitchen Waste Biogas Plant at Mysuru

Highlights	
Type	Decentralised
Input capacity	100 kg per day
Processing capacity	NA
Output product	Bio gas and manure
CAPEX	Rs. 5.50 lakh
OPEX	NA

Source: (NIUA, 2020)

Figure 4.43: Kitchen waste based Biogas unit

Source: (NIUA, 2020)

Mysuru (Previously known as Mysore) is the headquarters of Mysuru district which forms the southern-most district of Karnataka State. Mysuru district is noted for its rich history, monuments, forts, temples, art and culture.

NIE-CREST (Center for Renewable Energy and Sustainable Technologies) has come up with kitchen waste-based biogas plants (KWBP) to manage wet waste generated from their canteen. This plant digests rice starch, used rice water, used tea and coffee powder, leftover rice and sambhar, waste flour, over-ripened fruits, used edible oil, vegetable waste and other cooked waste from the kitchen. The plant produces biogas that is used for cooking purposes in the canteen itself. The slurry is used as manure for the kitchen garden. The plant is designed, established and maintained by NIE-CREST. (NIUA, 2020)

The biogas plant at NIE-CREST has an annual savings of Rs. 66,576 due to the replacement of LPG and Rs. 10,950 from the manure production. Thus, the total returns from the facility amounts to around Rs. 77,525 per year.

Replicability: This model can be replicated in small campuses like hostels, community kitchens, near canteens in special economic zones or institutional areas. This would help in the reduction of fuel usage from the establishments nearby and save cost as well.

Case study: Floating Dome Biomethanation Plant, Bhopal

Highlights	
Type	Decentralised
Input capacity	5 MTD
Processing capacity	5 MTD
Output product	Bio gas
CAPEX	NA

Source: (NIUA, 2020)

Figure 4.44: Biomethanation plant at vegetable market

Source: (NIUA, 2020)

The Bhopal is the capital of Madhya Pradesh and the administrative headquarters of Bhopal district and Bhopal division. There are 5 biomethanation plants installed across the city for wet waste in a decentralised manner. Their capacity is in the range of 5 each. One of the biomethanation plant located in Bittan market, has a capacity of 5 TPD of wet waste. The waste is collected from the vegetable market and to produce biogas. From this biogas; BMC has generated electricity, which is being used in the vegetable market itself. From this biogas; BMC has generated electricity, which is being used in the vegetable market itself. The model has helped in saving cost

Replicability: This model can be used for bulk waste generators like vegetable mandis, educational institutes, etc.

Case study: Nisarguna Technology Developed by BAARC, Chandigarh

Highlights	
Type	Decentralised
Input capacity	4.5 MTD
3.2 MTD	3.2 MTD
Output product	Biogas and weed free good quality manure
CAPEX	Rs 96 lakh (16 lakh for 0.9 MTD capacity)
OPEX	Approximately Rs. 1.6 lakh per month

Source: (NIUA, 2020)

Figure 4.45: Biomethanation-cum- electricity plant at Chandigarh

Source: (NIUA, 2020)

The Union Territory of Chandigarh is located in the foothills of the Shivalik hill ranges in the north. Chandigarh is the one of the earliest planned cities in post-independence India and is one of the best-planned city in India. As the capital of the states of Punjab and Haryana, and the Union Territory of Chandigarh holds a prestigious place among the capital cities of India

The Biomethanation-Cum-Electricity Generation Plant is located in the Industrial area, Phase-1 of Chandigarh. The plant was established by MCC, whereas the designing and execution was done by Avi Plast Garbage Treatment Projects, Mumbai. The project was commissioned in November, 2015 and inaugurated in November, 2016. The total area of this facility is 150x150 feet and processing area is 450 sq. ft. The plant has a daily intake capacity of 4.5MT per day of organic municipal garbage that comprises kitchen waste, paper, grass, gobar (cow dung), dry leaves etc.

NISARGRUNA technology offers a "Zero garbage, Zero effluent" method for waste management. Unlike conventional bio-gas plants that can handle only cow dung and/or human waste, BARC's NISARGRUNA technology has the capability to process almost any biodegradable waste, such as kitchen waste, paper, grass, cow dung, dry leaves etc. This makes, such bio-gas plants a good potential for energy generation in this biphasic-bio-methanation plant. The gas is used to generate electricity with the help of a generator set. The electricity so obtained is used to light the street lamps. Proper record of the materials taken in to the plant from all the sources is maintained through a register. (NIUA, 2020)

Replicability: This model can be replicated by choosing the NISARGUNA technology for biomethanation over any other. This can be replicated in areas having wet waste as the main waste composition, such as in hotels, mandis, academic institutions, etc.

Case study: Biogas Plant for Mule Dung, Jammu

Highlights	
Type	Decentralised
Input capacity	4 MTD
Processing capacity	NA
Output product	Bio gas
CAPEX	Rs 53 lakh
OPEX	Operated by shrine itself

Source: (NIUA, 2019)

Katra-Vaishno Devi is located at an altitude of 5200 ft in the foothills of Trikuta Mountains where the holy shrine of Vaishno Devi is located. Katra serves as the base camp for pilgrims who visit Vaishno Devi. Shri Mata Vaishno Devi Shrine Board (SMVDSB) is responsible for management, administration and governance of the Shri Mata Vaishno Devi Shrine and its endowments, including land and buildings attached to the Shrine. More than 10 million pilgrims visit the Vaishno Devi Temple every year. To reach the Vaishno Devi Temple, these pilgrims have to trek a total length of 20.5 km. Upto 15 km, horses or mules carry pilgrims from Katra. Managing the dung of more than 4600 horses and mules that ply on this 15 km trek is one of the major challenges for the Shrine Board. In the absence of proper disposal facility, the dung was either thrown into Banganga river or burnt or destroyed, causing water and air pollution. For appropriate disposal of waste, the Shrine Board has now set up a 24x7 mule dung based biogas plant for scientific processing of the waste.

Figure 4.46: Biogas plant at Banganga

Source: (NIUA, 2020)

For scientific disposal, a mule dung based biogas plant of 4 TPD capacity was commissioned in Banganga, Katra by the Shrine Board in April 2012 and the plant was first of its kind to run purely on mule dung. The project cost is approximately 53 lakh. The plant was installed and commissioned by M/s. Mailhem Engineers Pvt. Ltd., Pune. The company also carried out operation and maintenance of the plant for the next 5 years from 2012 to 2017. The plant is based on the principle of anaerobic digestion of cow dung. The biogas generated by this plant contains 65% methane which is suitable for cooking, it is being used in community kitchen to meet cooking energy requirements. The daily bio gas generation is 170-200 m3. The bio-manure being generated is used as soil conditioner in various greening project. The total manpower for this plant is 5 persons.

The mule dung is collected from the adjoining cattle shed from the treks. It is then fed into the digester for anaerobic digestion process. It is further heated to approximately 38-40 °C for fermentation. The substrate is decomposed by the micro-organisms under exclusion of light and oxygen. The final product of this fermentation process is biogas and methane acts as the main ingredient. Afterwards, the bio gas gets collected in the balloon, which holds the gas until the time of consumption. The gas pipeline carries the gas to the community kitchen. The remaining sludge is collected in sludge drying bed. In the first few hours, the liquid drains off after which drying occurs due to natural evaporation. The sludge completely dries within almost three weeks. The drying period may vary depending upon sunshine, rainfall, wind velocity, and relative humidity, apart from sludge characteristics. (NIUA, 2020)

Replicability: The same model can be replicated for Zoo, trekking, hilly areas, and dairy farms.

Case study: Biomethanation Plant by Mahindra and Mahindra, Indore

Highlights	
Type	Decentralised
Input capacity	20 MTD
Processing capacity	NA
Output product	Bio CNG and manure
CAPEX	Rs 15 Cr.
OPEX	NA

Source: (NIUA, 2020)

Indore, located on the Western region of Madhya Pradesh is one of the most important commercial centres of the state. It is also the most populous and the largest city of Madhya Pradesh. Indore has been part of Swachh Survekshan since its inception and had ranked 25th in 2016. It has been ranked as India's cleanest city four years in a row as per the Swachh Survekshan for the years 2017, 2018, 2019 and 2020. Solid Waste Management in Indore comes under the purview of the Indore Municipal Corporation (IMC).

Figure 4.47: Main digester and balloon

Source: (NIUA, 2020)

Approximately 20-25 MT per day of fruit and vegetable waste is generated in Choithram Mandi. Earlier, the waste was collected and transported to the centralized waste processing and disposal site of IMC. This incurred heavy transportation and manpower cost. Hence, IMC under its policy of promoting decentralized treatment of organic waste established a Bio-methanation plant (Bio-CNG Plant). Through tendering process; IMC appointed Mahindra and Mahindra Ltd., Mumbai to establish the plant, which was commissioned in December 2017. The concession period of the project is 15 years. Presently all the fruit and vegetable waste generated at Choithram Mandi is being collected and processed in the Bio-CNG plant.

Approximately 800 kg of purified and compressed Bio-CNG, having 95% pure Methane gas is generated on a daily basis. The pressurized Bio-CNG gas is used as a fuel to operate approximately 15 city buses. Therefore, with the use of the Bio-CNG produced, there is a saving of Rs 4500 on the fuel expense of these buses, which would amount to a saving of about Rs. 1.35 lakh every month. The digested slurry is passed through solid liquid separation unit, filtered liquid is used in slurry making and the remaining solid are dried and converted into organic compost. (NIUA, 2020)

Replicability: This model can be replicated by utilising the vegetable Mandi waste and processing it through biomethanation. The obtained fuel can be put to use in city's public transportation or can be sold to private companies for their transportation of goods.

Case study: Thermophilic Anaerobic DigestionTechnology DRYADTM, Varanasi

Highlights	
Type	Decentralised
Input capacity	4.5 MTD
Processing capacity	NA
Output product	Manure
CAPEX	Rs 2 Cr.
OPEX	Rs. 2.15 lakhs

Source: (NIUA, 2019)

Varanasi, also regarded as one of the oldest cities in the world and lies in the state of Uttar Pradesh along the banks of the river Ganga. The solid waste management system of Varanasi city is being managed by Varanasi Municipal Corporation (VMC).

A decentralized waste to energy plant of 4.5 MT per day capacity was jointly commissioned in near I.D.H hospital by VMC and Indian Oil Corporation Ltd, (IOCL) in February 2018. The project was executed under the Corporate Social Responsibility scheme of IOCL. Approximately 400 sq.m. of land was allotted by the Corporation for the installation of plant. The total cost of the plant including the operational and maintenance cost was provided by IOCL through their CSR fund. IOCL has engaged M/s Organic Recycling Systems Pvt. Ltd (ORSPL) for designing, commissioning and operations of the plant.

Figure 4.48: Power generator

Source: (NIUA, 2020)

The plant comprises a small-scaled containerized unit called 'Yasasu Green' designed by ORSPL. The unit is designed to process the organic waste to obtain biogas and manure. It is based on continuous high solid thermophilic anaerobic digestion technology (DRYADTM), producing zero effluent and leachate in the process. The biogas produced on digestion is combusted through the gas engines to produce electricity which is used for captive use as well as lighting of the surrounding areas.

The digestion and composting period ranges from 14 to 21 days. The quality of compost obtained is better than the conventional product as all the inerts are removed during pre-treatment stage and the pathogens are completely absent as the digestion takes place at a high temperature. This plant produces nearly 800 Kwh (units) of energy per day from the feed of 4.5 MT of organic waste. After captive consumption, the unit is designed to ensure 400 units of energy per day to electrify the city's water treatment plant. This plant also produces 35 kg of manure per day in the process. (NIUA, 2020)

Replicability: This model can be replicated by utilising the vegetable mandi waste and processing it through biomethanation.

Case study: Double Digester Biomethanation (Aerobic and Anaerobic Biomethanation) Technology, Panchkula

Highlights	
Type	Decentralised
Input capacity	NA
Processing capacity	100kg
Output product	Biogas
CAPEX	NA
OPEX	NA

Source: (NIUA, 2020)

Figure 4.49: Biogas plant at Chandigarh

Source: (NIUA, 2020)

A biogas plant that has a treatment capacity of 100 kg has been installed by BEIL Research and Consultancy Private Limited at Nada Sahib Gurudwara. The plant is based on the Double Digester Biomethanation (Aerobic and Anaerobic Biomethanation) technology provided by Indian Institute of Chemical Technology, Hyderabad. The Gurudwara community kitchen caters to more than 2000 people per day. The organic waste from community kitchen is processed in the plant to convert it into biogas. The Gurudwara has employed one person to operate this plant. The 100 kg gas produced per day at this facility is being used for cooking purpose. The sludge and 35-40 litre leachate generated daily is used as manure and fertilizer for gardening within the premises. (NIUA, 2019)

Replicability: This model can be easily being replicated in similar religious places or canteens.

Composting (Aerobic Process)

Aerobic composting is the process of aerobic decomposition of biodegradable waste in a warm, moist environment by the action of bacteria, yeasts, fungi and other organisms. During aerobic composting, microorganisms oxidize organic compounds to compost (humus), carbon dioxide (CO_2) and water vapour with the release of energy (heat). The aerobic composting can be further divided into the following:

1. Conventional Windrow Composting
2. Rapid Composting
    a. Vermicomposting (using earthworms for composting) *
    b. Mechanical Composting (using mechanical equipment for composting) *

    *these models will be further discussed in detail

Composting involves the breakdown of organic waste by microorganisms in the presence of air, heat and moisture. This can be carried out on a small scale in households or on a large scale depending upon the quantity of waste to be processed and space available. Bacteria, fungi and actinomycetes act upon the waste to convert it into sugars, starch, and organic acids which in turn, are acted upon by high-temperature loving bacteria, resulting in a stable product called City Compost.

The SWM rules, 2016 mention provisions on composting under duties of waste generators and local authorities as discussed in chapter 2.

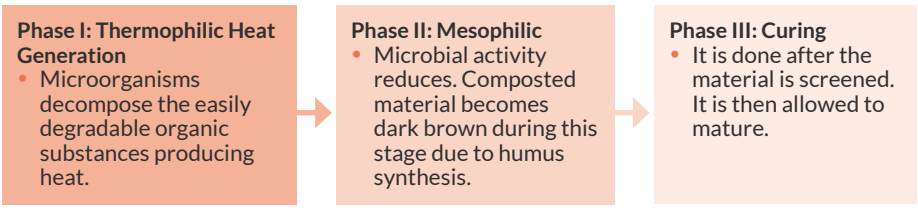
Merits of Composting

- Compost improves the quality of soil, and for this reason it is considered as a soil conditioner
- Compost improves the structure and texture of the soil enable them to retain nutrients, moisture, and air for the betterment of growth of plants
- In addition to, nitrogen, phosphorous, and potassium, certain micronutrients viz. manganese, copper, iron and zinc also found in compost which helps them to control diseases and insects
- It contains a variety of the basic nutrients required for healthy growth of plants

Phases of the Composting Process

Different organisms already present in MSW are known to play a predominant role in breaking down biodegradable constituents of MSW. A succession of microbial growth and activity among the bacteria, fungi, actinomycetes, yeasts, etc. takes place during the process, whereby the environment created by one community of microorganisms encourages the activity of a successor group. Different types of microorganisms are therefore active at different times and locations within the windrow depending upon the availability of substrate, oxygen supply, and moisture content of the organic matter. (MoHUA-SBM U, 2017)

Figure 4.50: Composting Process.



Source: (MoHUA-SBM U, 2017)

Initial decomposition is carried out by mesophilic microorganisms, which rapidly break down the soluble, readily degradable compounds. As the temperature rises above about 400C, the mesophilic are replaced by thermophilic. At temperature of 550°C and above, many microorganisms that are human or plant pathogens are destroyed. During the thermophilic phase, high temperature accelerates the breakdown of proteins, fats, and complex carbohydrates. Temperature gradually decreases and mesophilic microorganisms once again and take over for the final phase of "curing" or maturation of the remaining organic matter.

Speeding Up Composting – Alternative Sources of Culture/ Bioculum/ Inoculum (CPHEEO, 2018)

- **Cow dung:** Fresh cow dung may be used as an alternative to inoculum. The ratio of mixing varies with the characteristics of the waste material to be treated. However, care is to be taken to maintain the moisture content of the overall mixture at 45% to 55% by weight, for aerobic digestion. For 1000 kg microbial enriched compost production, the quantity of fresh waste material, cow dung and urea required will be 1600 kg, 320 kg and 21 kg, respectively.
- **Sour Buttermilk/Curd:** The ratio of sour buttermilk/curd to that of the waste varies with the characteristics and quantity of the waste material to be treated. Care is to be taken to maintain the moisture content of the overall mixture at 45% to 55% by weight, for aerobic digestion.

- **Panchagavya:** It is an organic concoction which has the potential to promote growth and provide immunity in plant systems. It consists of nine ingredients viz. cow dung, cow urine, milk, curd, jaggery, ghee, banana, tender coconut and water. Mix 7 kg Cow dung and 1 kg Cow ghee thoroughly both in morning and evening hours and keep it for 3 days. After 3 days, mix 10 L of cow urine and 10 L of water with the mixture and keep it for the next 15 days with regular mixing both in morning and evening. After 15 days, mix the following and panchagavya will be ready after another 30 days. (Cow milk - 3 litres, Cow curd - 2 litres, Tender coconut water - 3 litres, Jaggery - 3 kg, Well ripened banana – 12 nos).
- **Compost Inoculant developed by Indian Agricultural Research Institute (IARI), New Delhi:** The PUSA Institute has developed an inoculum of consortium of microbes (extracted from cow dung). This consortium can be used for small scale composting only. IARI also states that same microbes are present in air hence waste decomposition can happen even without the inoculum. (CPHEEO, 2016)

Compost Quality Standards

Following are the Compost Quality Standards as per Solid Waste Management Rules, 2016.

Table 4.9: Compost quality Standards

Sl. No.	Parameters	Organic Compost FCO 2009	Phosphate Rich Organic Manure FCO (PROM) 2013
1	Arsenic (mg/kg)	10.00	10.00
2	Cadmium (mg/kg)	5.00	5.00
3	Chromium (mg/kg)	50.00	50.00
4	Copper (mg/kg)	300.00	300.00
5	Lead (mg/kg)	100.00	100.00
6	Mercury (mg/kg)	0.15	0.15
7	Nickel (mg/kg)	50.00	50.00
8	Zinc (mg/kg)	1000.00	1000.00
9	C/N ratio	<20	less than 20:1
10	pH	6.5 - 7.5	(1:5 solution) maximum 6.7
11	Moisture, % by weight, maximum	15.0-25.0	25.0
12	Bulk density (g/cm^3)	<1.0	Less than 1.6
13	Total organic carbon, % by weight, minimum	12.0	7.9
14	Total nitrogen (N), % by weight, minimum	0.8	0.4
15	Total phosphate (P_2O_5), % by weight, minimum	0.4	10.4

Sl. No.	Parameters	Organic Compost FCO 2009	Phosphate Rich Organic Manure FCO (PROM) 2013
16	Total potassium (K_2O), % by weight, minimum	0.4	-
17	Colour	Dark brown to black	-
18	Odour	Absence of foul odour	-
19	Particle size	Minimum 90% material should pass through 4.0 mm IS sieve	Minimum 90% material should pass through 4.0 mm IS sieve
20	Conductivity (as dsm-1), not more than	4.0	8.2

Source: (CPHEEO, 2016)

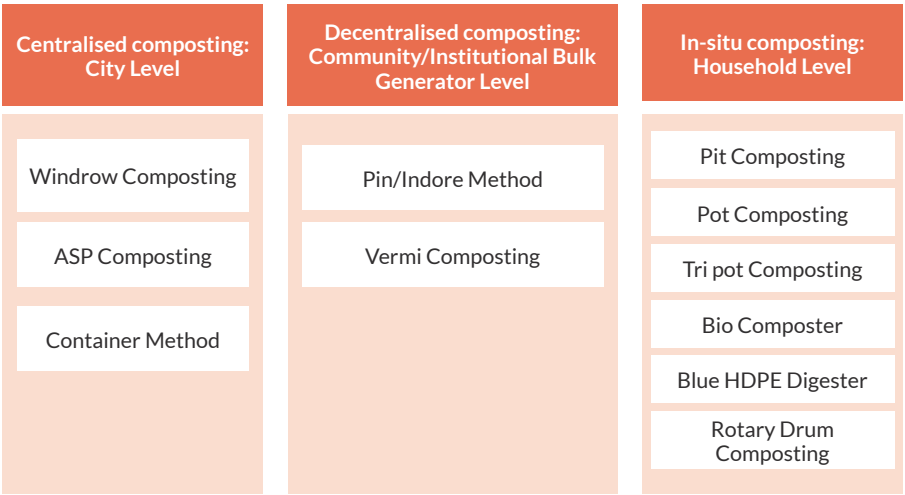
The Physical and Chemical parameters involved are enumerated below (CPHEEO, 2016)

- **Moisture:** Moisture is a critical factor in composting because the microbes need moisture for survival and growth. It tends to occupy the free air space between the decomposing particles. Hence, when the moisture content is too high, anaerobic conditions set in and composting is affected.
- **Aeration:** The composting process requires adequate supply of oxygen for biodegradation by microorganisms. Under aerobic conditions, the decomposition rate is 10–20 times faster than under limited oxygen supply or anaerobic conditions.
- **Carbon to Nitrogen Ratio:** MSW in India has a general carbon-to-nitrogen (C/N) ratio of around 30:1, which is ideal for decomposition. The organisms involved in stabilization of organic matter utilize about 30 parts of carbon for each part of nitrogen.
- **Temperature:** Under properly controlled conditions, temperatures are known to rise beyond 70°C in aerobic composting. This increased temperature results in increased rate of biological activity and faster stabilization of the material.
- **Particle Size:** The optimum particle size should have enough surface area for rapid microbial activity.

Conventional/Centralised composting system vs Decentralised composting system

In order to reduce the burden of handling of large volumes of MSW, the ULBs have to shift their focus from centralised composting system to a decentralised composting system. Based on the stream of waste and its generation, the appropriate method of treatment and the scale of treatment units (Home/Community/Ward/Division/ Zone/City level) have to be selected.

Figure 4.51: Types of composting methods



Source: Author

The onsite and decentralised organic waste treatment methods will bring several advantages as compared to the centralised system.

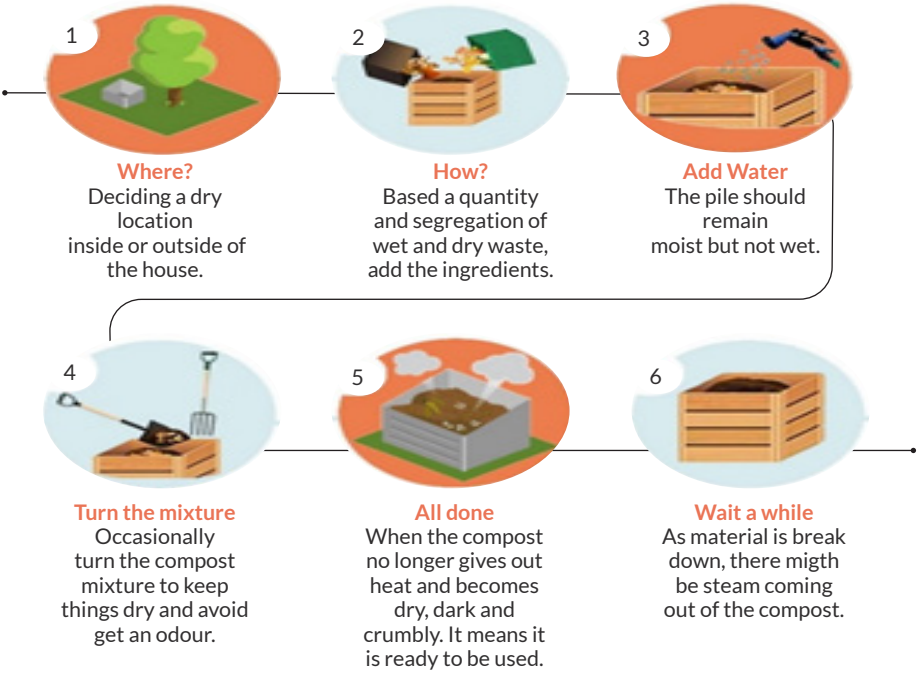
Merits of decentralised (wet waste) treatment methods

- Reduction in the collection and transportation chain of MSWM and costs thereof.
- Reduction in GHG emissions due to uncontrolled putrification /decay of biodegradable waste due to extended collection and transportation chains.
- Reduction in smell/bad odour at the premises / storage points and roads and streets.
- Elimination of uncontrolled leachate.
- Shorter the collection and transport chain, better the quality of city compost.
- Decentralised city compost producers are more likely to use the compost themselves or develop strong off-take arrangements.

Household Level Composting

Home composting (HC) is one of the composting techniques to manage domestic biodegradable waste at household level to get a high quality compost which is considered as black gold for gardens soil.

Figure 4.52: General steps involved in Home composting



Source: Author

Composting is a specialized recycling activity in which organic waste is biologically decomposed under controlled conditions to convert them into a product that can be applied to the land beneficially and without adverse environmental impact. The process of composting under controlled conditions destroys pathogens, weed seeds, insect eggs and other unwanted organisms.

This can be achieved by simple steps involving segregation of waste and collecting organic waste. Once the process starts, the waste is broken into humus naturally. The basic steps involved have been illustrated in figure. A very important part of the process is maintaining Carbon to Nitrogen ratio of the waste in the compost.

Biological agents like worms, insects, fungi, bacteria and other microorganisms consume and digest the materials releasing nutrients in the process.

Waste Segregation for Composting: Waste is classified in two types, namely, Organic dry waste (coconut shell, agricultural residues, wood, fibrous leaves, stems, seeds, paper and cartons) and wet waste (vegetables and fruits, food waste, cow dung, slaughter house waste).

The organic dry waste can be further classified into – brown organic material and green organic materials along with moisture and oxygen.

- **Brown organic materials:** Brown materials provide large amounts of carbon, one of the two main components of compost. Browns help slow the decomposition process to prevent rotting. Other materials in this group include dried grass, brown plant stalks, sawdust, straw and wood ash etc.
- **Green organic materials:** This group includes items typically thrown out in the kitchen. Green matter contains large amounts of nitrogen, which helps bacteria break down the ingredients.
- **Moisture and Oxygen:** For the organic materials to break down, compost needs moisture and oxygen. If the composting area does not receive rain regularly, the compost pile will need watering. To make sure that oxygen penetrates the pile and speeds the decomposition process, a shovel or a has to be used to turn it. Adding wood chips or another bulking material to a pile also helps aerate it.

Figure 4.53: Brown organic material: Aged hay, Wood chippings, Straw, Wood ash

Figure 4.54: Green organic material:
Vegetable trimming, Shrub pruning, Coffee ground waste, Used flowers

Pit Composting

Pit composting, also called trench composting. It is a traditional method of composting where a large pit is dug in the open and filled with organic waste for at least 6 months.

Table 4.10: Infrastructure requirement for Pit composting

Infrastructure requirement	Factors for Selection	Operation and Maintenance
Tarpaulin or PVC roofing sheets to cover the pits. Tools like shovel, hoe, etc.	Adequate space availability in the backyard, and located away from drinking water source, suitable for small to large families. Not suitable for areas with higher water table.	Pits should be located at elevated areas to prevent collection of rainwater. Follow the general process of composting till the pit is full. Close it with 15cm of earth.

Source: (CPHEEO, 2018)

Example

Figure 4.55: Pit Composting

Source: (NIUA, 2018)

The Defence Colony RWA in Delhi has managed their wet waste through pit composting. There are 4000 households in this colony, all of these are covered under the door-to-door collection. Each household gives about 0.3-0.5 kg of wet waste every day. The collected wet waste is managed through pit composting in a local park. A dedicated composting area has been assigned for this. There are about six composting pits, each pit having a size of 6x4x4 ft approximately. Effective Microbes (EM) solution is regularly sprayed on the compost at an interval of 2-3 days to maintain the moisture of the compost and reduce the odour. Each compost pit produces 200 kg to 300 kg of manure every three months. This manure is sold at a price of Rs.10 per kg to local people for gardening purposes

Steps for Pit Composting

Source: (CPHEEO, 2018)

Pot Composting

Pot composting is another variant to pit composting for household level. This method of composting is done in country burnt mud pots which are about 50 cm. in height and about 35 cm. in diameter at the centre with lid covers. A tri-pod stand is used as a pedestal made out of steel/ wood/ plastic/ steel for the pots. This composting also considers using leachate which is water that leaches out the solid waste and some of the constituents.

Table 4.11: Infrastructure requirements for Pot composting

Infrastructure requirement	Factors for Selection	Operation and Maintenance
A plastic vessel of 10cm height and 0.5 lt. capacity, for collection of leachate. 1 Trowel (small size) 1 brick cut in 2 pieces 1 Plastic cover	Requires less space, suitable for small families generating up to 2kg waste per day Should be kept away from rain.	This method can be used to treat 1-2 kg of waste per day. Salt powder can be sprinkled in the leachate collection vessel to avoid flies. Worms can be seen in the first week of composting; these are good for the process and die naturally within 2 weeks.

Source: (CPHEEO, 2018)

Example

Ujjain is a city in Madhya Pradesh with a total population of 5,15,215, residing in 54 wards. The city has achieved 100% door-to-door waste collection and source segregation. The city transformed one of its wards into a 'smart ward,' which has adopted a zero-waste model. All the ward residents practice pot composting at the household level. The compost produced is utilized in nearby parks, while the excess is handed over to SHG, which sells it locally. This treatment at source practice has reduced the transportation cost and burden on centralized facilities.

Figure 4.56: Pot Composting

Source: (NIUA, 2020)

Steps for Pot Composting

Source: (CPHEEO, 2018)

Tri Pot Composting

Tri pot composting involves a set of pots locally moulded together vertically, with clay/ terracotta and oven dried. This model has a lid at the top and the bottom open portion of the middle pot is provided with weaved plastic wires. The bottom most pot is closed.

Table 4.12: Infrastructure requirements for Tri pot composting

Infrastructure requirement	Factors for Selection	Operation and Maintenance
3 Clay pots of 30 cm diameter and height. 1 earthen lid cover. Hand pump (sprayer)	Requires less space, suitable for small families generating Should be kept away from rain.	The bio platform should be 1-inch-thick to be used as starter material. The top and middle pots have a wire mesh at the bottom.

Source: (CPHEEO, 2018)

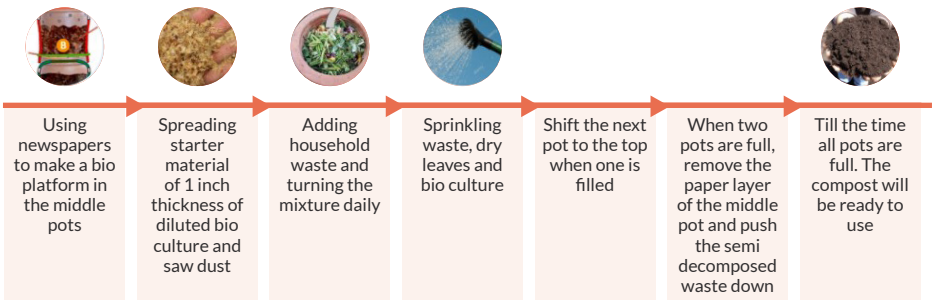
Example

Panchkula is a town in Haryana having a population of 2,11,355 spread over an area of 33 sq. km. Solid waste management comes under the purview of the Panchkula Municipal Corporation. As a part of the SWM plan, 100% door-to-door collection has been practiced in the city. Sector-12, Panchkula has adopted the tri-pot composting method. Nearly 250 households, few apartments, 80 parks, and a temple are practicing on-site composting. The compost is being used for horticulture purposes.

Figure 4.57: Tripot Composting

Source: (NIUA, 2019)

Steps for Tripot Composting



Source: (CPHEEO, 2018)

Bio Composter

Bio composter is used for composting organic kitchen waste generated on daily basis at household level. The process of bio composting is the aerobic decomposition of organic material into simpler compounds.

Table 4.13: Infrastructure requirements for Bio composter

Infrastructure requirement	Factors for Selection	Operation and Maintenance
3 perforated bins mounted on one another.	Requires less space, suitable for small families generating Should be kept away from rain.	The coconut pith bio-clean inoculum should be 2 inches thick. Omit gravy and liquid waste or dried before composting.

Source: (CPHEEO, 2018)

Example

Thiruvananthapuram has an area of 214 sq. km, having 100 wards with a total population of 7,43,691. It is estimated that the total waste generated in the city per day is 350 tonnes. For improving the waste management mechanism, home composting is being promoted in the city. The local authority distributed three-layered bio-composter kitchen bins to every household to encourage this.

Figure 4.58: Bio Composter

Source: (CPHEEO, 2018)

Steps for Bio Composter

Source: (CPHEEO, 2018)

Blue HDPE Digester

The High-Density Polyethylene (HDPE) is a strong and durable plastic. The compost drums made from HDPE can hold waste of 10 households (approximately 6kg per day).

Table 4.14: Infrastructure requirements for Blue HDPE digester

Infrastructure requirement	Operation and Maintenance
HDPE drum Small fork	Ensure this is well segregated waste and is evenly layered Neem powder once a week can help reduce flies. Cow dung, Cow urine, panchagavya or sour curd if available, can be added to increase the natural microbial activity and reduce foul smell and insects

Source: (CPHEEO, 2018)

Example

Bruhat Bengaluru Mahanagar Palike has 198 wards with a total population of 84,43,675. The city generates 5760 MT of waste daily. Singapore layout is a residential colony in the city, 50-60 kg of biodegradable waste is treated every day. The compost production is 5 -10 kgs per day, which is utilized within the campus for landscaping

Figure 4.59: Blue HDPE Composter

Source: (CPHEEO, 2018)

Steps for Blue HDPE Digester

Source: (CPHEEO, 2018)

Rotary Drum Composting (Small)

Composting is usually done in an enclosed vessel, such as a large diameter drum. The material is typically agitated, turned and force-aerated on a daily basis or multiple time each day, depending on the size of the unit and how it is operated. Due to this daily turning and aeration, the composting process starts quicker and progresses faster in rotary drum than with static-bin.

Table 4.15: Infrastructure requirement for Rotary Drum composting

Infrastructure requirement	Operation and Maintenance
Rotary drum of 250 L capacity **Machine description:** The drum is mounted on four rubber rollers and attached to metal stand. The drum is rotated manually by the 40mm long angles that are welded longitudinally inside the drum. Two adjacent holes are made on top of the drum to drain excess water.	Waste mixture should be finely shredded (1 cm.) For proper mixing, drum should be turned clockwise everyday. Primary stabilized compost is achieved within 15-20 days.

Source: (CPHEEO, 2018)

Example

Nirvana Country is a large township in Gurgaon, Haryana. It is spread over 135 acres with 900 households and 16 community parks. All the wet waste generated in the colony is treated through rotary composters. About 30 tonnes of compost is produced annually. Most of the compost is used in the 16 public parks all over the township. The residents are also given 12 kg of compost free every year to use in their home gardens. The total capital cost of this facility is Rs 10 lakh.

Figure 4.60: Rotary Drum Composting

Source: (Gulati, 2019)

Steps for Rotary Drum Composting

Source: (CPHEEO, 2018)

MARC technology

Mesophilic Aerobic Rapid Composting (MARC) is an innovative technology for composting of biodegradable wastes, suitable for households and community level. The technology is based on aerobic and mesophilic conditions. It operates on continuous basis. The composter is a prefabricated, cylindrical structure having two chambers with separate openings. There are perforations on the outer portion of the cylinder. It is fitted with balls and bearings on a stand. It is rotated easily and during this action air passes into the chamber making aerobic condition inside. Both the chambers are alternately filled with wastes (60-70% of volume). After the first chamber is filled, the second chamber is used. By the time, the second chamber fills, wastes from first chamber turns into pathogen free, odourless manure within 15 - 20 days. This is suitable to be used in agriculture. In case of community scale, it is fitted with a motor to rotate it.

Figure 4.61: March Composter

Merits of Marc Composter

- Collection and transportation costs of wastes are minimized
- Effective composting time is only 15-20 days.
- There is no smell during composting.
- It operates on continuous basis.
- It requires much less space and can be installed even in balcony or on roof top of house
- There is no recurring expense to maintain the system.

Decentralised Composting

Decentralized composting is the composting of organic household waste at neighbourhood or ward levels. Also known as community composting, the involvement of local residents ensures the segregation of waste at source. The operation and maintenance of this facility creates employment opportunity for waste pickers. Such a decentralized approach reduces transportation, operation and maintenance cost. These models are appropriate for processing 1 to 3 tons of organic waste per day at a slightly larger level. At the ward level 3 to 10 tons of organic waste can be processed through decentralised models.

Pit composting method

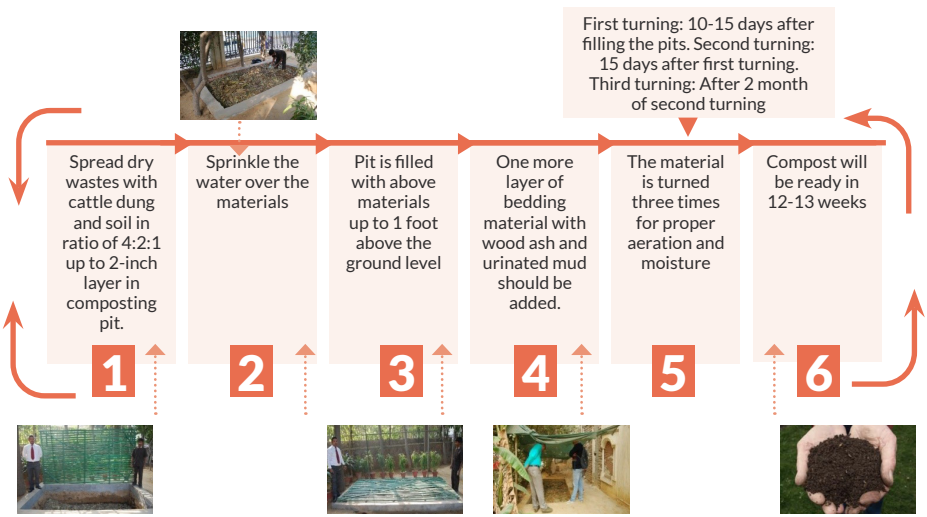
The pit composting method is a cost effective approach. It involves less labour for preparing organic manure or compost. The table below enumerates the details of infrastructure requirements for setting up this facility.

Table 4.16: Infrastructure requirement for Pit composting method

Infrastructure requirement	Description
Size of the pit	Breadth 6-8 feet, Depth 2-3 feet (not more than 3 feet), Length 10 feet or more as per requirement
Materials	Plant residues, weeds, leaves, grass, wood ashes, cow dung, urine soaked mud, wood ashes, bran etc.

Source: (CPHEEO, 2018)

Figure 4.62: Process involved in Pit composting



Source: (CPHEEO, 2018)

Below are some examples of pit composting being adopted by cities across India

Case study: Decentralized (pit composting) facility, Panchkula

Highlights	
Waste processed	8 MT
Compost produced	2MT
CAPEX	Rs. 15 lakhs
OPEX	NA
Revenue generated	Compost supply to Panchkula Municipal Coporation (PMC)
Manpower	7

Source: (NIUA, 2019)

Panchkula generates 70 MT of wet waste and 40 MT of dry waste. Out of the total wet waste generated, 15 MT is processed through onsite composting in 80 parks and 10 MT by composting at various levels (such as household, community and Bulk waste generators (BGG). The community composting facility at sector 12 consists of 18 composting pits of size 3ftx4ftx7ft approximately, processing around 8 MT waste comprising dried leaves, grass, vegetables, fruit peels, rice, leftover food, bread and curd etc.

Waste pickers not only collect waste but are also trained to carryout composting. They are responsible for the overall functioning of the community composting facility at sector 12.

The manure thus produced is used by the PMC for horticultural purposes.

Figure 4.63: Composting pits

Source: (NIUA, 2019)

Replicability: This type of model can be replicated in city parks or community level gardens.

Composting facility, Nawanshahr

Highlights	
Waste processed	7.2 – 9 MT
Compost produced	1.8 MT
CAPEX	NA
OPEX	NA
Revenue generated	NA
Area of the facility	865 sq.m.

Source: (NIUA, 2019)

Nawanshahr administration took steps to undertake a complete makeover of the dumpsite and constructed an aerobic honeycomb composting pit within the same premises. This was done to effectively treat the collected bio-degradable waste to marketable compost. The pits are constructed with latticework walls to facilitate proper aeration and avoid foul odour. There are approximately 100 composting pits that are spread over an area of around 526 sq. m.

The compost is prepared in 90 days. After 90 days, the compost thus formed is taken out and dried in the sun. Larger chunks are broken into small pieces and then sieved to collect the fine compost. A locally engineered legacy separator machine is additionally used to segregate legacy waste. The capital expenditure is based on donations by various organizations. 6 workers carry out operation and maintenance.

Figure 4.64: Composting pits

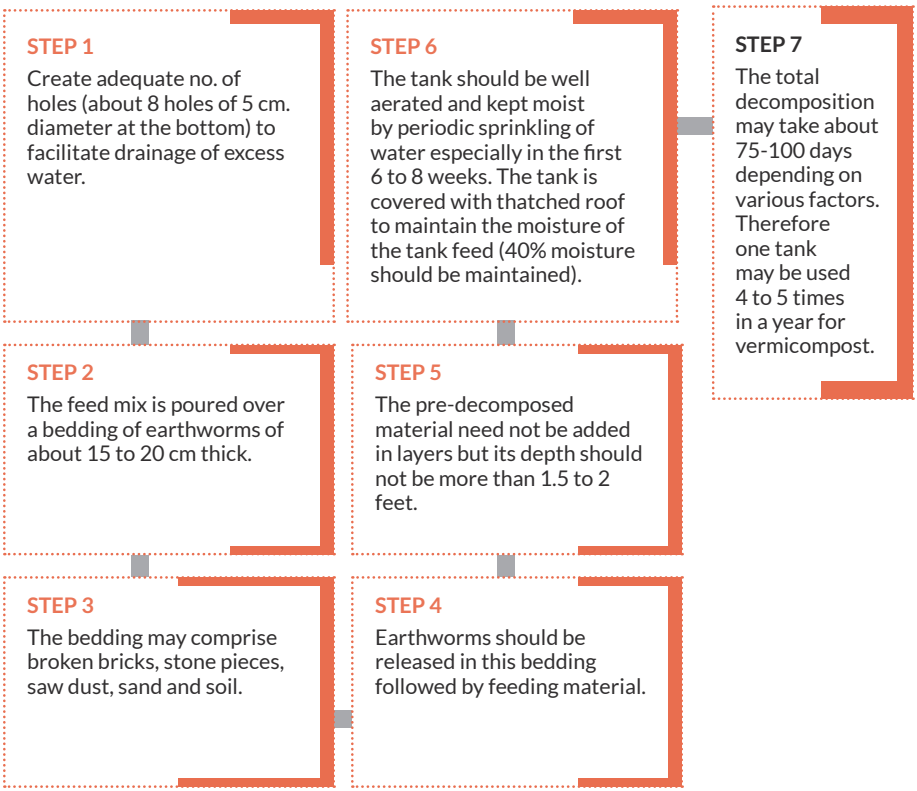
Source: (NIUA, 2019)

Replicability: This model is appropriate for cities with population less than 50,000

Vermi Composting

Vermicomposting is the processing of organic wastes through earthworms. It is a natural, odourless and aerobic process. Earthworms ingest waste and excrete casts (dark, odourless, nutrient and organically rich, soil or mud granules) that make an excellent soil conditioner. Earthworm casts are a ready-to-use fertilizer that can be used at a higher rate of application than compost, since nutrients are released at rates that growing plants prefer. Vermicomposting can be done on a small scale by individual household, on a large-scale by ULBs or by bulk waste generators (hotels, academic institutions, canteens). One kg. of worms numbering about 600 to 1000 can convert 25 to 45 kg. of wet waste per week. The compost recovery would be around 25 kg. per week under well managed conditions. (MoHUA-SBM U, 2017)

Figure 4.65: Steps involved in the process of vermicomposting



Source: (CPHEEO, 2016)

Merits of Vermicomposting

- Vermicomposting is free flowing, easy to apply, handle and store. It does not have bad odour
- It improves soil textures, aeration and water holding capacity and prevents soil erosion.
- It enhances the decomposition of organic matter in soil
- It provides essential effect on overall plant growth

Figure 4.66: (a) Vermi composting pits (b) Earthworms

The table below enumerates the criteria required for selection of vermicomposting as an implementable technology.

Table 4.17: Criteria for selection of Vermi composting facility

Criteria	Vermiculture
Facility Location	To be located as per the buffer zone criteria mentioned below.
Buffer Zone (No Development Zone)	• 500 m for facilities dealing with 100 TPD or more of MSW • 400 m for facilities dealing with 75–100 TPD of MSW • 300 m for facilities dealing with 50–75 TPD of MSW • 200 m for facilities dealing with 10–50 TPD of MSW • No buffer zone for facilities dealing upto 5 TPD of MSW • No buffer zone for decentralised plants handling less than 1 TPD of MSW (but adequate environmental controls are required)
Natural environment	Composting in coastal/high rainfall areas should have a shed to prevent waste from becoming excessively wet and thereby to control leachate generation.
Land Requirement	For 20 TPD of segregated/ pre-sorted: the land required is 1.25 ha.
Waste Quantity which can be managed by a single facility.	1 TPD to 20 TPD; Higher capacities can also be planned if adequate land is available along with other necessary arrangements.
Requirement for Segregation prior to technology	Very high
Technology Maturity	Community scale projects are successful

Financial Criteria	
Indicative Capital Investment	1 Cr. per 20 TPD (approximately)
Market for product/ By-Product	Good market potential in urban and rural areas. However it is not adequately explored for bulk marketing.
Managerial Criteria	
Labour Requirement	Labour intensive
Predominant skills for Operation and Management	Technically qualified, experienced, and semi-skilled staff.
Environmental Criteria	
Concerns for toxicity of product	The product is generally safe as worms cannot endure significant contamination of raw materials. FCO Standards are to be met with.
Leachate Pollution	Insignificant quantities at low waste volumes per vermi-pit.
Atmospheric pollution	Low. Odour issues.
Other	Fire and safety issues to be taken care of

Source: (CPHEEO, 2016)

Table 4.18: Vermi-Compost Standards as Per Fertilizer Control Order, 2009

Sl. No.	Criteria	Value
1	Moisture % by weight	15.0–25.0
2	Colour	Dark brown to black
3	Odour	Absence of foul odour
4	Particle size	Minimum 90% material should pass through 4.0 mm IS sieve
5	Bulk density	0.7–0.9
6	Total Organic carbon, minimum % by weight,	18.0
7	Total Nitrogen (N), minimum % by weight,	1.0
8	Total Phosphates (P_2O_5), minimum % by weight,	0.8
9	Total Potash (K_2O), minimum % by weight,	0.8
10	Heavy metal content (mg/kg) maximum by weight,	
	a. Cadmium (Cd)	5.00
	b. Chromium (Cr)	50.0
	c. Nickel (Ni)	50.0
	d. Lead (Pb)	100.0

Source: (CPHEEO, 2018)

Case study: Vermi compost plant, Nagpur

Highlights	
Waste processed	1 MT
Compost produced	5 MT per month
CAPEX	Rs. 20 lakhs
OPEX	Rs. 10,000 per month
Revenue generated	NA
Manpower	4

Source: (NIUA, 2019)

Figure 4.67: Vermi compost plant

Source: (NIUA, 2019)

The waste generated from Nagpur's vegetable market, fruit market, hotels and restaurants is processed in a vermicomposting plant at Bhandewadi. This plant is operational since 2008 and is being operated and maintained by the health department of Nagpur Municipal Corporation (NMC). The total capacity of this plant is 2 MT but presently runs at its 50% operational capacity. Around 5 MT compost is produced on a monthly basis. The total plant cost is Rs. 20 lakh and the recurring cost of earthworms is around Rs. 800 per kg. The plant produces fine quality compost which is used in the gardens of NMC.

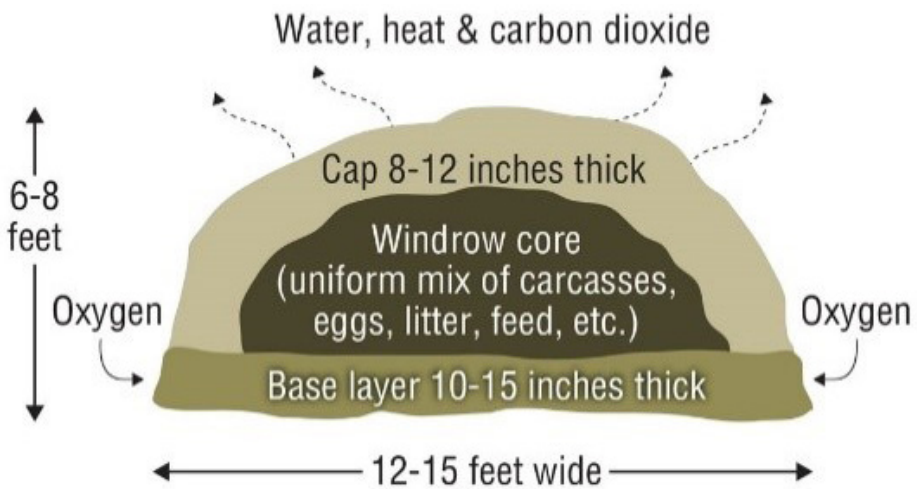
In the vermicomposting plant, preparation of appropriate bed is done in the tank by using straw, husk and earthworms. The food waste and fruits are mixed with cow dung reconstituted water (1:1 ratio). Approximately 10 litres of this reconstituted mixture is required for waste of 2 to 3 kg. The layering of organic waste is done daily and is mixed with the reconstituted water by sprinkling it over the layer. The tank is left undisturbed for around 45-60 days and then transferred to another empty tank. The compost is passed through the machine where fine and coarse compost is separated from the worms. The worms are reused, and the compost is sent for use to NMC. NMC uses the vermicomposting for enriching the garden soil.

Replicability: The model can be replicated in areas producing upto 2MT per day of wet waste.

Centralised Windrow Composting method

Windrow composting is the production of compost by piling biodegradable waste, in long rows (windrows). This method is suited to produce large volumes of compost. These rows are regularly turned over to improve porosity/voids and oxygen content, remove moisture and redistribute cooler and hotter portions of the pile. Windrow composting is a commonly used composting method (MoHUA-SBM U, 2017). The ideal pile height is between four and eight feet with a width of 14 to 16 feet. This size pile is large enough to generate enough heat and maintain temperatures. It is small enough to allow oxygen flow to the windrow's core.

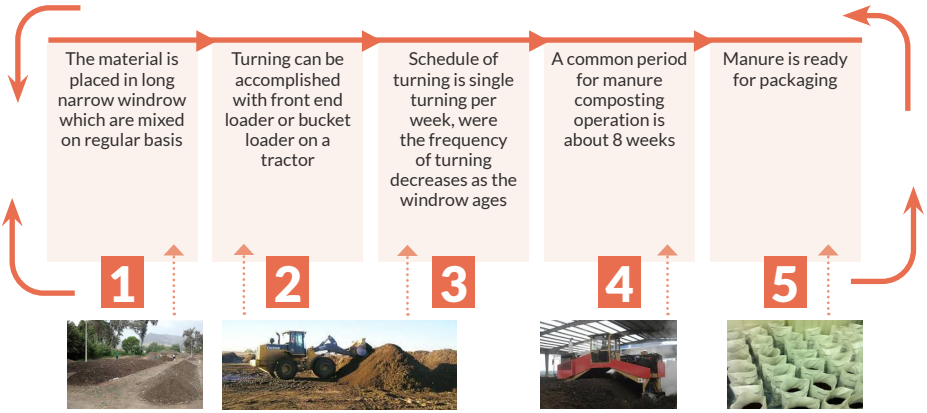
Figure 4.68: Cross-section of Windrow



Source: (Peer, 2016)

Replicability: Large volumes of waste such as yard trimmings, grease, liquids, and animal by-products (such as fish and poultry waste) can be composted through this method.

Figure 4.69: Steps involved in Windrow composting



Source: (CPHEEO, 2016)

The table below enumerates the criteria required for selection of windrow composting as an implementable method.

Table 4.19: Criteria for selection of windrow composting

Technical Criteria	
Facility Location	To be located as per the buffer zone criteria mentioned below
Buffer Zone (No Development Zone)	• 500 m for facilities dealing with 100 TPD or more of MSW • 400 m for facilities dealing with 75–100 TPD of MSW • 300 m for facilities dealing with 50–75 TPD of MSW • 200 m for facilities dealing with 10–50 TPD of MSW • No buffer zone for facilities dealing upto 5 TPD of MSW • No buffer zone for decentralised plants handling less than 1 TPD of MSW (but adequate environmental controls are required)
Natural environment	Composting in coastal/high rainfall areas should have a shed to prevent waste from becoming excessively wet and thereby to control leachate generation.
Land Requirement	For 300 TPD of segregated/pre-sorted MSW: 5 ha of land including buffer zone is required.
Waste Quantity which can be managed by a single facility.	500 TPD
Requirement for Segregation prior to technology	High
Technology Maturity	Windrow composting technique is well established
Financial Criteria	
Indicative Capital Investment	Typically 15-20 Cr for 500 TPD plant

Technical Criteria	
Market for product/ By-Product	Quality compost compliant with FCO 2013 has a good market. IPNM Task Force (vetted by Supreme Court, 1 Sep 2006); Recommended co-marketing of 3-4 bags of compost with 6-7 bags of inorganic fertiliser
Managerial Criteria	
Labour Requirement	Labour intensive
Predominant skills for Operation and Management	Technically qualified and experienced and semi-skilled staff.
Environmental Criteria	
Concerns for toxicity of product	The final product is generally applied to soil and used as manure. Can contaminate the food chain if compost is not meeting FCO norms.
Leachate Pollution	Potential exists; Varies with the climate of area and seasonal variation. In relatively dry seasons, leachate can be recirculated into the windrow to contain loss of nutrients and also pollution potential. In high rainfall areas, the windrows need to be covered either temporarily or permanently to control leachate generation. However, the design of the shed should be such that good natural ventilation is maintained.
Atmospheric pollution	Low (dust, aerosol etc.); Odour issues.
Other	Fire and safety issues to be taken care of.

Source: (CPHEEO, 2016)

Case study: Centralised Windrow composting plant, Nashik

Technology Highlights	
Compost produced	50 MT
CAPEX	Part of centralised plant
OPEX	NA
Revenue generated	Rs. 3 per kg

Source: (NIUA, 2019)

Nashik has an integrated solid waste management facility that also includes windrow method aerobic composting facility. In this method, there are three stages of treatment - pre-sorting, composting and mechanical composting. After applying the necessary quantity of microbial inoculant and slurry along with sufficient moisture, windrows are formed to facilitate composting. The width at the bottom of the windrow is 3 to 4 meter and height is up to 2 meter. The moisture content of the windrows is maintained as 45 to 55%. Once in every week, the windrows are turned and mixed thoroughly to homogenize the material using excavators.

After three turnings during a period of three weeks, the partially composted garbage is then subjected to mechanical processing. The mechanical processing system consists of different types of automated trommel screens with sieve sizes of 35 mm and 16 mm. In this process majority of the inorganic and inert materials get removed and the sieved organic materials below 16 mm size is kept for curing process. Later the compost is refined through a trommel screen followed by gravity separators. In these stages, material above 4 mm size (e.g. sand, silt, etc.) are removed. The remaining powdery compost is then stored in batches for quality check. The plant prepares 50 MT of compost per day which is being sold in the market at Rs 3 per kg.

Replicability: This model is replicable for large volumes of organic waste generated by entire cities. Such a facility can be set up within cities having ample land area.

Figure 4.70: Windrow composting at Centralized plant

Source: (NIUA, 2020)

Aerated Static Pile (ASP) Composting

Aerated Static Pile (ASP) composting refers to the system in which organic material is biodegraded without physical turning during composting. The blended waste is usually placed on perforated piping, providing air circulation for controlled aeration. It may be in windrows (open or covered), or in closed containers. This composting process is suitable for rapid biodegradation and for processing saturated wet waste in large volumes.

Figure 4.71: Static piles below windrow

Source: (NIUA, 2019)

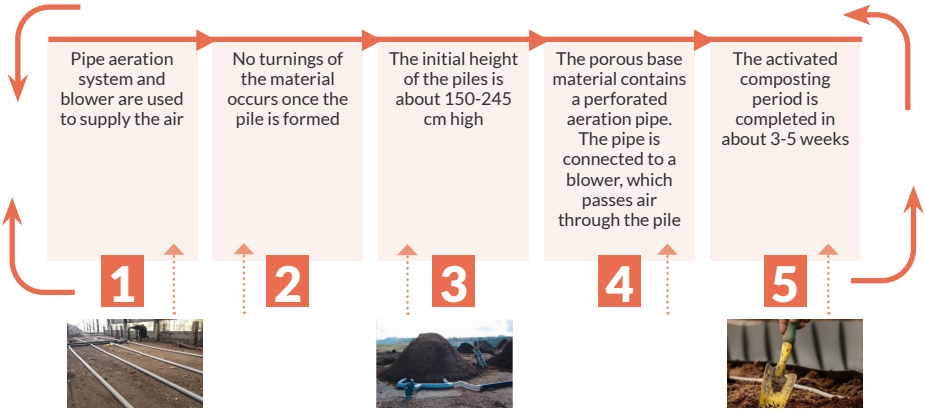
Case study: Smart Covered Composting Technology, Vishakhapatnam

Highlights	
Waste processed	20 MT
Technology	Smart Covered Composting Technology
Facility managed by	Environ Systems Pvt. Ltd.
Facility developed under	Smart city mission

Source: (NIUA, 2020)

Smart Cover Composting technology has been implemented under Greater Visakhapatnam Smart City Corporation Limited for processing decentralized organic waste by using smart covered composting technology. The facility is conceived as a part of Smart City initiative and it is being managed by Smart Enviro Systems Private Limited, Pune. The facility capacity is 20 MT per day.

Figure 4.72: Steps involved in Aerated static pile composting



Source: (CPHEEO, 2016)

Figure 4.73: Covered Aerated Static Pile Composting at Gajuwaka

Source: (NIUA, 2019)

The technology is cost effective and is an efficient solution. It is processing organic waste by applying Covered Aerated Static Pile (ASP) composting systems utilizing compost cover. The 'Compost Cover System' leads the way in no smell, no noise, no negative visual appearance and no air or water quality issues. An enclosed heap composting with membrane covered, pressure-aerated, oxygen-controlled decomposition technology is maintained at 40°C under enclosed cover through air blower.

Replicability: ASP Composting model is well-suited for all varieties of feedstock, including food waste, horticulture waste and all varieties of animal manure.

In-vessel Composting

In-vessel composting is a method that confines the composting materials within a building, container or vessel. This system consists of metal or plastic tanks or concrete bunkers in which air flow and temperature can be controlled. Using the principles of a "bioreactor" the air circulation is metered in via buried tubes that allow fresh air to be injected under pressure. Exhaust air is extracted through a bio-filter to allow maintenance of optimum aerobic decomposition conditions. This technique is generally used for large scale organic waste processing, including final treatment of sewage bio-solids. (MoHUA-SBM U, 2017)

Figure 4.74: In vessel composter

Source: (MoHUA-SBM U, 2017)

Table 4.20: Merits and Constraints of In vessel composting

Merits	Constraints
Requires the least amount of land	Most capital intensive
Most rapid production of compost – highest control of composting parameter	Requires extensive training of staff
Odour can be controlled reasonably well inside a building in most cases	Higher maintenance and operational costs
Control release of leachate	

Source: Ripley, S., and Mackenzie, K. 2008

Bioreactor composting system, Panaji, Goa

These 3 Bioreactors are part of a comprehensive solid organic processing facility in Goa. The Bioreactor Composting System by XACT Systems Inc. handles all the wet waste management

Figure 4.75: In vessel composting drums, compost screens

Figure 4.76: Screw press for dewatering

Figure 4.77: Fully enclosed compost shed

Source: (SFC Environmental Technology)

Dry Waste processing techniques

Dry waste includes waste that cannot be bio-degraded. This comprises recyclable waste, non-recyclable waste and inert material.

Recyclable waste includes paper, plastic, metal, glass, aluminium cans, etc. Recyclables also constitute plastics that are processed in plastic recycling units or as an ingredient in strengthening roads.

Construction and demolition waste is also recyclable. However, they need to be separated from household municipal waste. A significant amount of construction waste can be recycled and reused in the construction industry. The details regarding this are mentioned in the C and D Waste Management Rules, 2016.

Non-recyclable waste includes multi-layered plastics, thermocol, etc. These have to be processed through thermal processing (waste to energy) which includes incineration, gasification and pyrolysis. The output of this is electricity. This can be sold to electricity distribution companies at a certain tariff.

Inerts includes sweeping dust, residue from processing plants, ashes, etc. Inerts cannot be treated and are disposed in sanitary landfills

Apart from the above-mentioned municipal solid waste, it also contains domestic hazardous waste, sanitary waste and electronic waste (E-waste).

Domestic hazardous waste constitutes used batteries, CFLs and tube lights; chemical, paint, and insecticide containers etc. Such waste should be handed over separately to the waste collectors for safe disposal as specified by the municipal authority or through the relevant retail trade.

Sanitary waste (e.g. diapers and sanitary napkins) should be wrapped securely in pouches and handed over separately to the waste collectors on a daily basis. Upon collection of sanitary waste, it should be preferably disposed along with biomedical waste or incinerators, as applicable to the local context or as directed by the State Pollution Control Board (SPCB).

In case of E-waste management, the manufacturers are responsible for its collection, recycling and disposal at the time of its manufacturing. Additionally, every manufacturer, producer, bulk consumer, refurbisher, dismantler and recycler may store the e-waste and maintain a record of collection, sale, transfer and storage of wastes and make these records available for inspection. These aspects are detailed out in the E-waste management rules, 2016.

As per Biomedical Waste Management Rules, 2016, biomedical waste generated in households during healthcare activities shall be segregated as per rules and handed over in separate bags or containers to waste collectors. ULBs should have tie ups with the common biomedical waste treatment and disposal facility to pick up this waste from the Material Recovery Facility (MRF) or from the house hold directly, for final disposal.

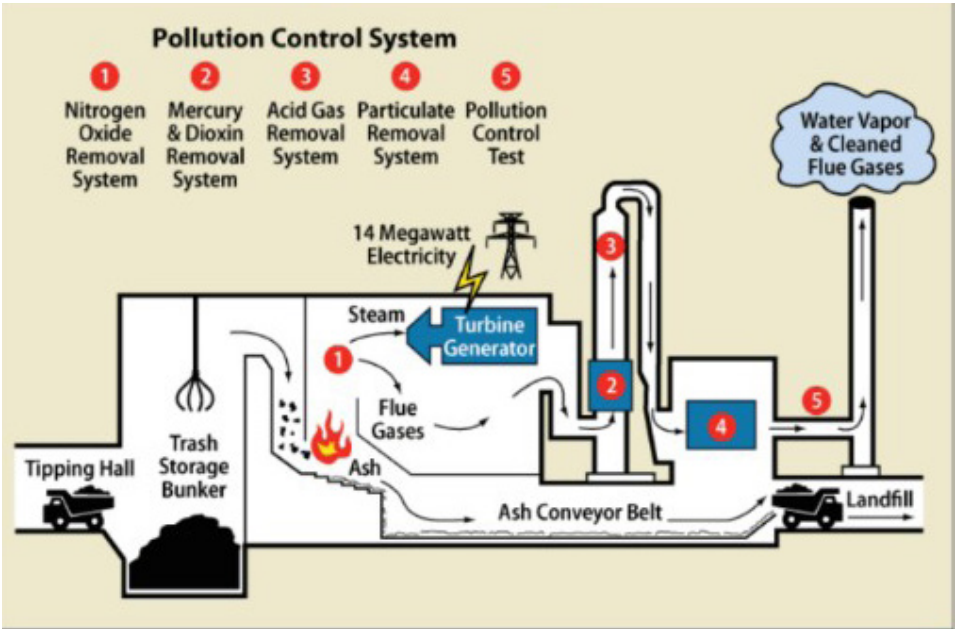
Combustible waste processing technologies

The SWM rules, 2016 specifies that the "residual combustible wastes shall be utilized for supplying as a feedstock for preparing RDF or for generating energy or power from the waste by adopting proven waste to energy (WtE) technologies for which emission standards as well as standards for dioxins and furans have been prescribed by the CPCB." (MoHUA-SBM U, 2017)

Direct Combustion (Incineration) technology

Incineration is a waste treatment process that involves combustion of waste at very high temperatures in the presence of oxygen and results in the production of ash, flue gas, and heat. Incineration is a feasible technology for combustion of unprocessed or minimum processed refuse and for the segregated fraction of high calorific value waste. In some cases, the heat generated by incineration can be used to generate electric power. Incineration with energy recovery is one of several waste-to-energy (WTE) technologies such as gasification, pyrolysis and anaerobic digestion. *(CPHEEO, 2016)*

Figure 4.78: Process involved in Incineration technology



Source: (CPHEEO, 2016)

Constraints of Incineration technology in the Indian context

- Setting up incineration plants have not been economically viable
- Indian waste is not suitable for incineration because it has too high a moisture content, leading to low calorific value
- Incineration technologies require a continuous supply of waste with a sufficiently high calorific value and low moisture content

The table below enumerates the criteria required for selection of incineration as an implementable technology.

Table 4.21: Criteria for Selection of Incineration technology

CRITERIA	
Facility Location	To be located as per the buffer zone criteria mentioned below.
Buffer Zone (No Development Zone)	• 500 m for facilities dealing with 100 TPD or more of MSW • 400 m for facilities dealing with 75–100 TPD of MSW • 300 m for facilities dealing with 50–75 TPD of MSW • 200 m for facilities dealing with 10–50 TPD of MSW • No buffer zone for facilities dealing up to 5 TPD of MSW No buffer zone for decentralised plants handling less than 1 TPD of MSW (but adequate environmental controls are required)
Natural environment	For 1000 TPD of waste: 5 ha of land including buffer zone
Waste Quantity which can be managed by a single facility.	1000 TPD and above waste (smaller plants are not techno economically viable, given the cost of required environmental control equipment and boiler technology
Requirement for Segregation prior to technology	High – Feed stock should be free from Inerts and low on moisture content
Rejects	Around 15%
Potential for Direct Energy Recovery	Yes
Technology Maturity	Technology is available. However constraints of low calorific value, high moisture content and high proportion of inert waste should be considered while undertaking the project commercially.
FINANCIAL CRITERIA	
Indicative Capital Investment	Very high capital, operating and maintenance costs. 15 Cr. per MW power production
Market for product/ By- Product	Good potential of energy generation if power purchase agreements are made reflecting true cost of production including O and M costs
MANAGERIAL CRITERIA	
Labour Requirement	Non labour intensive but requires considerable technical capacity,
Predominant skills for Operation and Management	Technically qualified and experienced staff.
ENVIRONMENTAL CRITERIA	
Leachate Pollution	High potential of leachate at the receiving pit
Atmospheric pollution	Very high if emissions not managed properly. Fly ash should be disposed safely in an engineered landfill. (Emissions due to incomplete combustion of municipal refuse contain a number of toxic compounds, dioxins and furans, requiring appropriate emissions control systems)
Other	Disposal of bottom ash/ slag. Fire and safety issues to be taken care of.

Source: (CPHEEO, 2016)

Standards for Incineration

Table 4.22: Stack Emission Standards (CPCB) for Treatment and Utilisation of Municipal Solid Waste using Incinerator or Thermal Technologies

Parameter	Emission standard	
Particulates	50 mg/Nm^3	Standard refers to half hourly average value.
HCl	50 mg/Nm^3	
SO_2	200 mg/Nm^3	
CO	100 mg/Nm^3	
Total Organic Carbon (TOC)	20 mg/Nm^3	
HF	4 mg/Nm^3	
NOx (NO and NO_2 expressed as NO_2)	400 mg/Nm^3	
Total dioxins and furans	0.1 ng TEQ/Nm^3	Standard refers to 6–8 hours sampling.
Cd + Th + their compounds	0.05 mg/Nm^3	Standard refers to sampling time anywhere between 30 minutes and 8 hours.
Hg and its compounds	0.05 mg/Nm^3	
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V + their compounds	0.5 mg/Nm^3	

Source: (CPHEEO, 2016)

Case study: Waste to Energy Plant (Mass Incineration Technology), Jabalpur

Technology highlights	
Plant capacity	11.5 MW
Operational Capacity	600 Tons per day
Technology	Grate combustion system by Hitachi Zosen's thermal waste processing solution
Power supplied	18000 households

Source: (NIUA, 2019)

This plant is developed on 65 acres land by Essel Infra projects limited and Hitachi Zosen Corporation for a cost of 17.3 million US dollars. The plant is currently operated on (public private partnership) PPP model by Essel Infra with Madhya Pradesh government for 15 years. The plant generates 11.5 mw energy by recycling 600 tonnes of municipal solid waste per day and reduces over 37,000 tonnes of carbon emission annually, which can power 18,000 households. This plant deploys Hitachi Zosen's customized thermal waste processing technology. Its Grate Combustion System is one of the best waste treatment technology with regard to environment friendliness, operating reliability, flexibility and cost-effectiveness The other salient features of this plant include Flue Gas Treatment, water and ash treatment, which ensures that all the waste generates as part of the processes are also treated before emission.

Figure 4.79: Jabalpur WtE plant

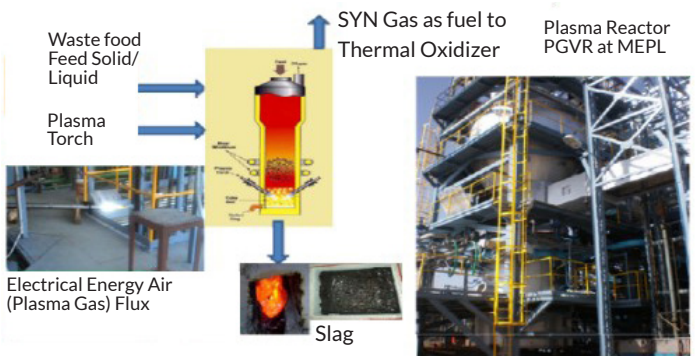
Source: (NIUA, 2019)

Gasification technology

Gasification is the partial combustion of fossil based carbonaceous material, plastics, etc. into carbon monoxide, hydrogen, carbon dioxide, and methane. This is achieved at high temperature (650°C and above), with controlled amount of air, oxygen or steam. The process is largely exothermic, and the main product is syngas, which contains carbon monoxide, hydrogen, and methane. The syngas generated from gasification will have a net calorific value of 4–10 MJ/Nm3. The other main product is a solid residue of non-combustible material (ash) (MoHUA-SBM U, 2017). This syngas can be used in the following ways:

- Burnt in a boiler to generate steam which may be used for power generation or industrial heating.
- Used as a fuel in a dedicated gas engine.
- Suitable for use in a gas turbine after reform.
- Used as a chemical feedstock.

Figure: 4.80: Gasification Technology



Source: (environmentclearance, 2017)

Constraints in gasification technology in the Indian context

- High calorific value waste, which may otherwise be processed in more sustainable processes, is required as feedstock; Organics can be converted into compost in a much more cost-effective and environmentally safe process, as against using them as feedstock for these processes.
- Setting up gasification plants have not been economically viable. *(MoHUA-SBM U, 2017)*

Case Study: Plasma Gasification Facility for Disposal of Incinerable Hazardous Waste, Pune

Technology Highlights	
Technology	Plasma Gasification Vitrification Reactor (PGVR) technology
Processing Capacity	72 TPD

Source: (environmentclearance, 2017)

This project uses the proprietary Plasma Gasification Vitrification Reactor (PGVR) technology from Westinghouse Plasma Corporation, USA for processing of industrial hazardous waste. The technology uses the ultra high thermal energy from a plasma generation system (e.g. plasma torches). The present plant processing capacity is 72 TPD of industrial hazardous waste. In this plant, Synthesis gas generated from the plasma gasification process is further destructed in Thermal Oxidizer. Flue gas from thermal oxidizer is taken to waste heat recovery system for generation of steam. This steam is used to generate electricity. *(environmentclearance, 2017)*

Figure 4.81: Plasma Gasification Facility

Source: (environmentclearance, 2017)

Refuse Derived Fuel (RDF) Plants

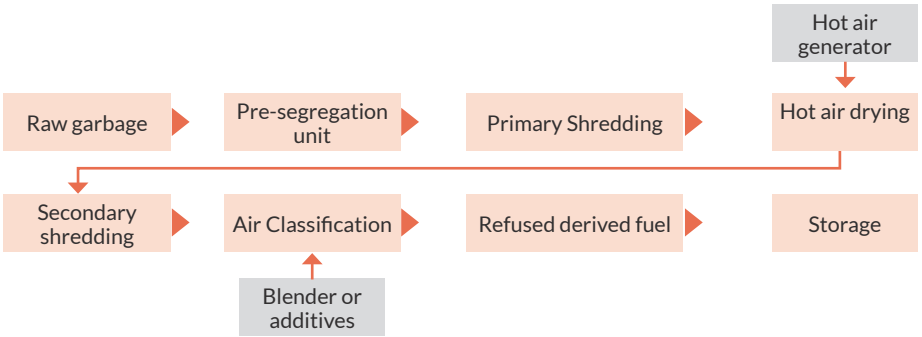
RDF consists of the residual dry combustible fraction of the MSW including paper, textile, rags, leather, rubber, non-recyclable plastic, jute, multi-layered packaging and other compound packaging, cellophane, thermocol, melamine, coconut shells, and other high calorific fractions of MSW. The suitability of RDF for use as a fuel is dependent on certain parameters of the constituent waste: calorific value, water content, ash content, sulphur content and chlorine content.

Figure 4.82: RDF fractions for co-processing

The required specific composition and characteristics of RDF for co-processing will be determined by the kind of furnace, temperatures achieved in the furnace and the associated flue gas management systems. RDF may be utilised in the following manner:

- Co-processing in cement kilns;
- Co-combustion in coal fired power plants
- On-site or off-site in an appropriately designed waste incinerator for power generation. (CPHEEO, 2016)

Figure 4.83: Refuse Derived Fuel Production Line (Pelletization)



Source: SWM Manual Part II (CPHEEO)

Criteria for Selection of RDF Plants

The selection of technology should be based on defined selection criteria and local conditions. The criteria for selection of RDF plants is listed in the table below.

Table 4.23: Refuse Derived Fuel Production Line (Pelletization)

CRITERIA	
Facility Location	To be located as per the buffer zone criteria mentioned below.
Land Requirement	For 300 TPD of segregated/ pre-sorted MSW: 2 ha of land is required.
Waste Quantity which can be managed by a single facility.	100 TPD of segregated waste and above
Requirement for Segregation prior to technology	High
Technology Maturity	• Quality of RDF should be based on end use, no clear consensus on quality requirements. • Burning of RDF below 850°C for less than 2 seconds residence time can pose serious problems of health and environment. • Rules regulating characteristics of RDF and guidelines for appropriate use not prescribed by concerned authority.
FINANCIAL CRITERIA	
Indicative Capital Investment	Typically 17-20 Cr for 500 TPD plant (approximately)
Market for product/ By-Product	Good market potential for RDF; In small cities, RDF plants only become feeders of RDF to large RDF based power plants and cement plants.

MANAGERIAL CRITERIA	
Labour Requirement	Labour intensive (based on current practice).
Predominant skills forOperation and Management	Technically qualified and experienced staff.
ENVIRONMENTAL CRITERIA	
Leachate Pollution	Low
Atmospheric pollution	Low to moderate (dust, aerosols); Very high if RDF is not burnt at required temperature. Odour issues
Other	Presence of inappropriate material in the RDF (chlorinated plastics); Fire and safety issues to be taken care of.

Source: (CPHEEO, 2016)

Enabling Policy Framework for RDF Co-Processing

- The Solid Waste Management Rules, 2016 recommended that high calorific wastes shall be used for co-processing in cement or thermal power plants or waste to energy plants. This is also applicable in all industrial units using fuel and located within 100 km from a solid waste-based RDF plant. Such industries shall make arrangements within six months from the date of notification of the rules to replace at least 5% of their fuel requirement by RDF so produced.
- Under the umbrella of 'Hazardous and Other waste (Management and Transboundary Movement Rules, 2016) [H and OW (M and TBM)] CPCB has drafted guidelines for pre-processing and co-processing of waste. This also includes use of MSW based RDF with enabling conditions by regulators for trans boundary movement of RDF. It also defines the related emission standards.
- Preferential Tariff for Waste to Energy Plants and Grants by Ministry of New and Renewable Energy (MNRE): A preferential tariff for Waste to Energy plants was issued by Central Electricity Regulatory Authority (CERC) of INR 7.04 per unit for MSW and NR 7.90 for RDF based projects. In addition, a grant of INR 20 million per MW has been provided for setting up waste to energy plants.
- Swachh Bharat Mission (SBM): As per SBM guidelines, grants are available for processing and disposal of Municipal Solid Waste and therefore can be utilized for setting up RDF facilities.

Comparative feasibility of RDF use in various Industries

The SWM Rules, 2016 suggest the possible usage of RDF in various industries. The usage of RDF translates into potential cost savings and reduces fossil fuel consumption. A comparative analysis of cement kilns, thermal power plants, iron and steel manufacturing units and brick kilns is detailed below. *(CPHEEO, 2018)*

Table 4.24: Comparative feasibility of RDF usage

Criteria for implementation	Cement Plants	Thermal Power	Iron and Steel processing plants
RDF size Specifications	RDF size is acceptable (<50mm)	Additional shredding Required (<2 mm)	RDF cannot be used as fuel for steelmaking as the process is autogenous. The usage of RDF as fuel in other processes like sinter making or in reheating furnaces was also explored by Steel Authority of India (SAIL)
Impact on Final Output	Negligible impact on final product	RDF contaminants like Silica and Chlorides corrode the heating surface, thereby affecting the boiler	Burning RDF affects forward reaction rate which leads to lower production of pure iron from the ore
Environmental Impact	None if proper safeguards are in place; additionally, it leads to net reduction in GHG emissions	Toxic emissions like dioxins and furans	Toxic emissions like dioxins and furans
Residue Disposal	None, as it becomes part of the clinker	Higher generation of fly ash and clinker formation on grate	Higher generation of slag, which is difficult to manage

Source: (CPHEEO, 2018)

Case study: UltraTech RDF Plant, Jaipur

Highlights	
Technology	MSW to RDF production
Processing capacity	150 TPD
Plant area	25 acres
Ownership	PPP between UltraTech and Jaipur Municipal Corporation

Source: (NIUA, 2019)

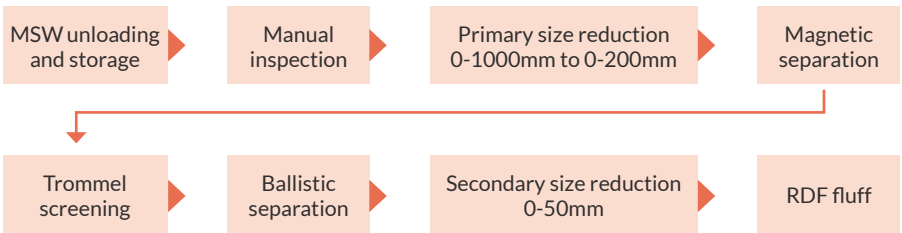
UltraTech has been developed a RDF plant from Municipal solid waste on public-private partnership with Jaipur Municipal Corporation in 2007. Spread over an area 25 acres, the plant is based on German technology that converts MSW into refuse-derived fuels (RDF). The plant is capable of extracting 150 tonnes of RDF per day from 500 tonnes of municipal waste, which is supplied by the Jaipur Municipal Corporation daily. The overall process is briefly described below:

Figure 4.84: RDF facility by Ultra Tech, Jaipur

Source: (NIUA, 2019)

- **Stage 1 Pre-sorting and Shredding:** The process starts with manual sorting of mixed municipal solid waste followed by size reduction through shredding. The waste is shredded to ensure certain degree of size uniformity and homogeneity of RDF with high-calorific value.
- **Stage 2 Magnetic Separator:** In the second stage, electromagnets are used for separating heavy ferrous metals from mixed waste.
- **Stage 3 Trommel Separator and Ballistic Separator:** Trommel separator is used to separate wastes which are less than 40 mm size. Then the waste is passed through ballistic separator which performs separation of waste according to its physical characteristics. It separates waste such as stones from textile, paper and cardboard.
- **Stage 4 Fine shredding of final product:** Final products are then shredded into 6 mm, 10mm and 12 mm size.

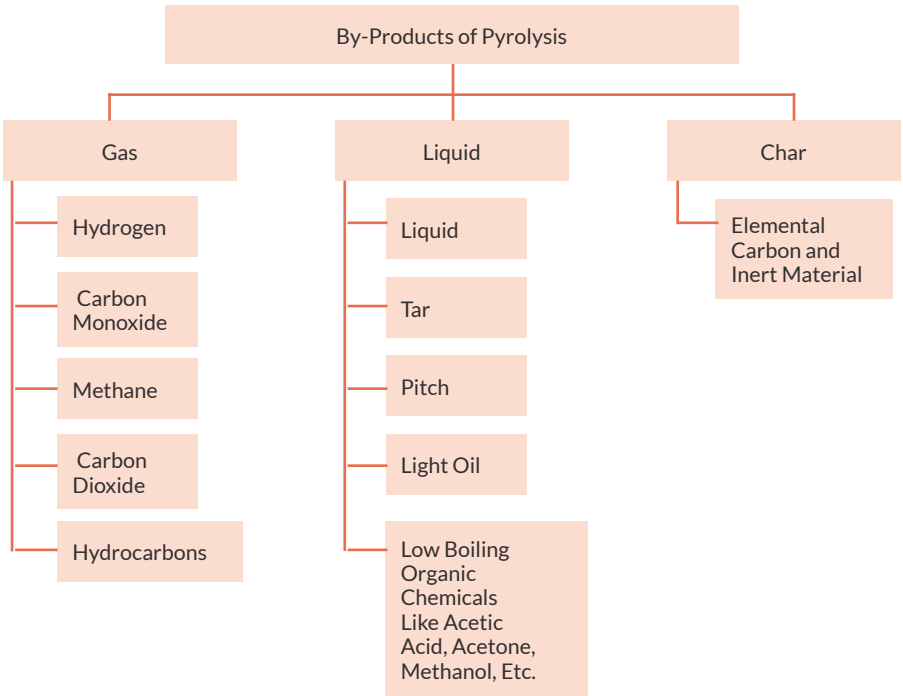
Figure 4.85: Process of RDF production at UltraTech RDF facility



Pyrolysis

Pyrolysis is an endothermic reaction in which heat is applied to waste to refine volatile components. This process is used for converting plastic to fuels (CPHEEO, 2016). Feedstock for pyrolysis should have high calorific value with very less moisture content and should be homogenous in nature. Many plastics, particularly the polyolefin, which have high calorific values and simple chemical constitutions of primarily carbon and hydrogen, are usually used as a feedstock in pyrolysis. Sorted and pre-treated feedstock is supplied to the pyrolysis reactor. Rotary kilns, rotary hearth furnaces, and fluidised bed furnaces are commonly used as MSW pyrolysis reactors, where partial combustion of material occurs at 500°C-800°C. As a result of combustion of organic matter in an oxygen-deficient environment, various products such as char (ash), pyrolysis oil and syngas are produced.

Figure 4.86: By-products of Pyrolysis process



Plastic Waste Recycling

"Recycling" means the process of transforming segregated plastic waste into a new product or raw material for producing new products. Recycling and re-utilization of waste plastics have several advantages. It leads to a reduction of the use of virgin materials and of the use of energy. This leads to the reduction of carbon dioxide emissions. (MoHUA-SBM U, 2017)

Table 4.25: Merits and Constraints in Recycling

Merits	Constraints
Reduces environmental pollution	Hard to separate from non-plastics (no 'magnet'equivalent)
Energy savings : 40 - 100 MJ/kg (depends on the polymer)	Differing composition of plastic resins means they are largely incompatible
Economic Benefits	Degradation of polymer chains on recycling
Reduces demand for virgin polymer	Recycled polymer is of lower quality than virgin polymer
Preferred to land filling	Most waste plastics films especially thin plastics films have limited market value, therefore effort is not spent in collecting them
Generates Employment	Identification of reuse and recycling opportunities
Reduces depletion of Fossil fuel reserves	Markets for Plastics; Lack of Infrastructure
	Low value of recovered Plastics

In plastic recycling segregation of waste at source is also a very important step. Some cities have set up segregation centres in the city to facilitate secondary segregation of plastic waste into 25- 27 categories and assist in recycling of plastic. Below are some of the plastic waste management and recycling models adopted by Indian cities.

Case Study: Decentralised Plastic Waste Management Facility, Bhopal

Highlights	
Area	Approximately 1.0 Acres
Land ownership	Bhopal Municipal Corporation
Owner of the facility	Sarthak
Input capacity	07 MT
Processing capacity	07 MT
Total manpower	10

Source: (NIUA, 2020)

The plastic waste facility was initiated in the year 2018 and has a capacity of 15 TPD. It is on an area of 1 acre. This facility recycles dry waste. Plastic recycling refers to the process of recovering waste or scrap plastic and reprocessing the materials into functional and useful products. A bailing machine is used to compress and cut the waste. A fatka machine is used to remove any particle left in the plastic waste before processing in the granular machine. The granular machine makes granules of plastic waste for recycling purposes. The granules of plastic waste are then supplied to vendors who make plastic products.

Currently, only Polyethylene terephthalate (PET), High Density Polyethylene (HDPE), and Poly Vinyl Chloride (PVC) plastic products are recycled under this unit. Polystyrene (PS), Polypropylene (PP), and Low Density Polyethylene (LDPE) are not recycled because these plastic materials get stuck in the sorting equipment. Most plastic recycling facilities use the following two-step process:

Figure 4.87: Plastic management facility

Source: (NIUA, 2020)

- Step One: Sorting plastics automatically or with a manual sort to make sure all the contaminants are removed from the plastic waste stream
- Step Two: Melting down plastics directly into a new shape or shredding into flakes then melting down before being finally processed into granulate. The granules are then supplied to vendors who manufactured plastic products.

Case Study: Plastic Waste Management Facility, Imphal

S. J. Plastic Industries has established a successful operation of plastic waste recycling programme in Imphal in the year 2007. The plant collects 2 MT of plastic waste from the city and segregates it into 30 categories.

Figure 4.88: Plastic Granular machine

Source: (NIUA, 2020)

Segregated plastics are then shredded, washed with water, dried and granulated for making flower pots, bins, pipes, etc. These products are sold in the market.

Case Study: Non-Recyclable Multi-layered Plastic Waste Recycling, Guwahati

Highlights	
CAPEX	Rs. 50 lakhs
OPEX	Rs. 10 lakhs per month
Revenue	Rs. 15 lakhs per month
Manpower	4
Plastic waste processing	600 kg per day

Figure 4.89: Zerund bricks

Source: (NIUA, 2019)

Zerund Bricks Manufacturing Pvt. Ltd. has setup a plant with initial capital expenditure of Rs 50 lakhs. The enterprise makes patented Plastic Embedded Light Weight Brick using the multi-layered plastic waste derived from plastic carry bags, biscuits and chips packs and different wrappers which create a lot of environmental problems. The enterprise helps in managing 600 kg per day of plastic waste by utilizing them to create the bricks. As the brick is light-weight, total dead load of the structure reduces up to 40% in comparison to the red clay bricks, hence the cost of the whole structure decreases. The brick has been developed in larger size. The larger size reduces the total number of mortar joints in the walls which leads to the less consumption of cement and sand in the joints and hence cost of infrastructure development decreases

Table 4.26: Specification of bricks

Parameters	Zerund Brick	Red Clay Brick
Size of Brick (in mm)	500 X 200 X 100	225 X 100 X 75
Compressive Strength (kg/cm^2)	38-45	30-35
Fire Resistance (in hours)	6-7	2-3
Water Absorption (in %)	7	30

Source: (NIUA, 2019)

Case Study: Plastic Waste to Road Construction, Jamshedpur

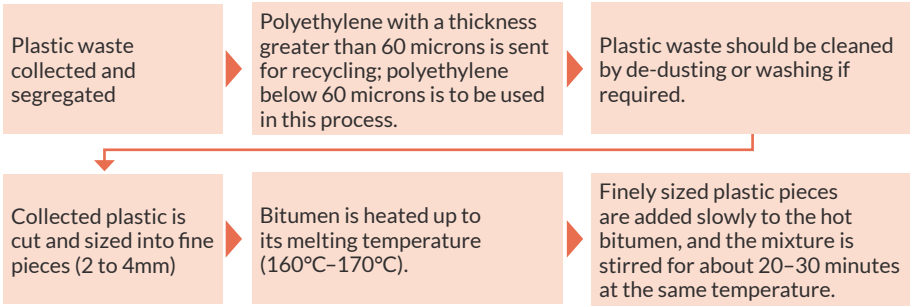
Highlights	
Road length	12-15 km
Total cost saved (1 km length and 4 m width)	Rs 50,000
Reducing use of bitumen	7% per km

Source: (NIUA, 2019)

Figure 4.90 Road made up of plastic waste

The disposed plastic ranging from polybags to biscuit packets are used for constructing roads in the city using bitumen technology. Jamshedpur Utilities and Services Company (JUSCO) has constructed 12-15 km roads in the steel city, as well as widened 22 roads using the environmentally-friendly technology. Bitumen, also commonly known as Asphalt, is a sticky, black and highly viscous liquid form of petroleum. The primary use of bitumen is in road construction where it is used as the glue or binder mixed with aggregate. The initiative is helping in reducing the use of bitumen by 7% in construction. For every stretch of such one km long and four-metre-wide road, one ton of bitumen costing Rs 50,000 is saved. The quality and longevity of roads made of waste plastic-aggregate-bitumen is two times better than bitumen road.

Figure 4.91: Application of plastic waste in construction of bituminous roads



Source: (NIUA, 2019)

4.9 Disposal of Solid Waste

Disposal is the final step in the SWM value chain. As per SWM rules, 2016 only the non-usable, inerts, pre-processing rejects and residues from waste processing facilities should be disposed in sanitary landfills. This facility reduces the negative impact on environment, public health, contamination of ground water and soil. In addition, all the legacy waste should be bio-remediated or bio-mined. In the absence of bio mining and bioremediation, it should be scientifically capped as per landfill capping norms.

Following are the criteria for identification of suitable landfill site

Table 4.27: Criteria for identification of suitable landfill site

Sl. No.	Place	Minimum siting distance
1	Coastal regulation, wetland, critical habitat areas, sensitive Eco fragile areas, and flood plains as recorded for the last 100 years	Sanitary landfill site not permitted within these identified areas
2	Rivers	100 m away
3	Pond, lakes, water bodies	200 m
4	Non-meandering water channel (canal, drainage, etc.)	30 m
5	Highway or railway line, water supply wells	500 m from the centre line
6	Habitation	All landfill facilities 500m
7	Earthquake zone	500 m from fault line fracture*
8	Flood prone area	Sanitary landfill site not permitted
9	Water table (highest level)	The bottom liner of the landfill should be above 2 m from the highest water table
10	Airport	20 km**

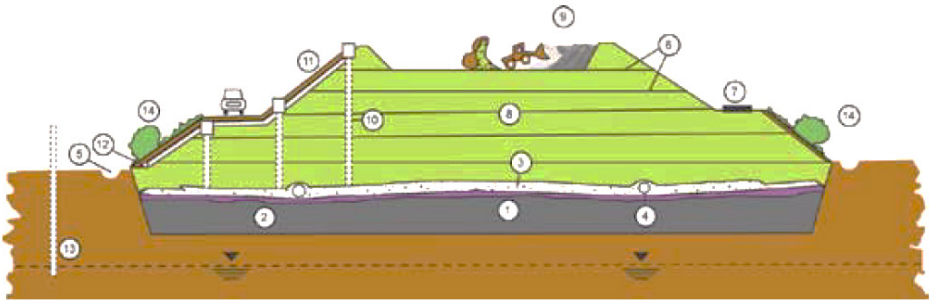
** The urban local bodies(ULBs) located in seismic zone 4 and zone 5 should consult the seismic fault map before finalizing the site for the sanitary landfill.*

*** In a special case, a landfill site may be set up within 10-20 km away from the airport or airbase if there is no objection certificate from the civil aviation authority or air force as the case may be*

Source: (CPHEEO, 2016)

Essential components of Sanitary Landfill

Figure 4.92 Essential components of municipal sanitary landfill



1. Geological barrier
2. Impermeable base liner
3. Drainage layer
4. Leachate collection system
5. Storm - water drain ditch
6. Bordering dams
7. Circulation roads
8. Landfill body
9. Filling and compacting in layers
10. Gas venting system
11. Protective cover system
12. Gas collectors
13. Groundwater control
14. Re-planting

Source: (CPHEEO, 2016)

The above figure illustrates the essential components of a sanitary landfill. It includes the following:

1. **Geological barrier:** a mineral layer to protect from contamination of groundwater and surface water in the long-term.
2. **Impermeable base liner:** a synthetic plastic (polyethylene, high-density polyethylene, polyvinylchloride). It prevents the trash from coming in contact with the outside soil, particularly the groundwater.
3. **Drainage layer:** a drainage layer of coarse sand or fine gravel to collect the infiltrating precipitation.
4. **Leachate collection system:** a leachate treatment facility to collect leachate from the base of the sanitary landfill.
5. **Storm-water drain ditch:** This is very crucial. It helps to keep the landfill dry and reduce the amount of leachate. This can be done in the following ways: It is critical to any landfill to reduce the amount of leachate. This can be done in two ways:
    - **Separation of liquids from solid waste:** before any solid waste enters a landfill it must be tested for amount of liquids. This is usually done by straining off the waste samples with the help of standard paint filters. The waste is only accepted into the landfill when after observing the waste for 10 minutes. There is no liquid observed.

- **No rainwater should seep into the landfill:** In order to do this, there has to be a provision for a storm water drainage system. This is done by laying plastic drain pipes and storm water liners that can collect water from the landfill. This has to be channelized to drainage ditches that surround the base of the landfill. Such ditches can be either made of concrete or gravel-lined. They are capable of carrying water to collection ponds located near the landfill. Suspended particles are allowed to settle in collection ponds. This water is usually tested for chemicals in the leachate. Once the water has passed the tests it can be pumped or permitted to flow away from the site.

6. Bordering dams: the surface that defines the grading laterally is called the slope. In cuts, the slope is included between the chamfer and the bottom of the channel. In embankments, the slope is included between the chamfer (foot of the embankment) and the edge of the berm. Taking into account that for the construction of a manual sanitary landfill it is recommended that the terrain be of a relatively impermeable material (fine sand mixed with silt, clay).
7. Circulation roads: There has to be adequate arrangement for comfortable movement of vehicle. This can be done by ensuring that internal circulation space is available.
8. Landfill body: The main purpose of landfills are to store waste. However, waste does decompose progressively in an anaerobic and sealed environment.
9. Filling and compacting in layers: the volume of material that is put in a landfill in one operating period is called a cell. One complete layer of cell in a landfill is called a lift. In the last part of each operating period, alternative material like compost is applied to the working face of the landfill. This is called the intermediate cover. Once all landfill operations are done, a final cover is added.
10. Gas venting system: The gas from interior parts of the landfill needs to escape. This is facilitated through venting trenches or venting pipes. They are installed within the landfill and are usually equipped with flares. This enables to burn the gas and avoid bad odour.
11. Protective cover system: It helps to support and maintain the growth of vegetation by retaining moisture and providing nutrients.
12. Gas collectors: It collects and extracts gas from sanitary landfill and uses it for energy recovery.
13. Groundwater control: It is a liner system designed to prevent the escape of liquids and to prevent the contamination of groundwater by waste. Generally, the foundation of this liner system is a thick layer of compacted clay. Above this is a synthetic "geomembrane" liner, usually in the form of a high-density polyethylene sheet.
14. Replanting: The landfill sites produce greenhouse gases, methane and carbon dioxide, as putrescible waste decays. Growing plants and trees on top of a landfill, a process known as 'Phytocapping', could reduce the production and release of these gases.

Following steps are adopted to estimate the capacity, height and area of sanitary landfill site.

Table 4.28: Estimation of capacity, height and area of sanitary landfill

Sl. No.	Parameters	Formula for calculation
1	Current waste generation per year	= W (tons per year)
2	Estimated rate of increase (or decrease) of waste generation per year (*use rate of population growth where waste generation growth rate estimates not available*)	= x (percent)
3	Proposed life of landfill (in years)	= n (years)
4	Waste generation after n years	=)^{n} (tons per year)
5	Total waste generation in n years (T) in tons	T =
6	Total volume of waste in n years (V_w) (*on the assumption of 0.85 t/cu.m density of waste*)	V_w = T/0.85 (cu.m.)
7	Total volume of daily cover in n years (V_{dc}) (on the basis of 15 cm soil cover on top and sides for lift height of 1.5 to 2 m)	V_{dc} = 0.1 V_w (cu.m.)
8	Total volume required for components of liner system and of cover system (on the assumption of 1.5m thick liner system (including leachate collection layer) and 1.0 m thick cover system (including gas collection layer)	V_c = k V_w (cu.m.) (*k = 0.25 for 10 m high landfill* *k = 0.125 for 20 m high landfill* *k = 0.08 for 30 m high landfill.* *This is valid for landfills where width of landfill is significantly larger than the height*)
9	Volume likely to become available within 10 years due to settlement / biodegradation of waste	Vs = m V_w (*m = 0.10 for biodegradable waste; m will for less than 0.05 for incinerated/inert waste*)
10	First estimate of landfill capacity (Ci)	Ci = V_w + V_d + V_c - V_s (cu.m.)
11	Likely shape of landfill in plan and section (To be based on topography of area, depth to ground water table and other factors) : Area type, trench type, slope type, valley type, combination	
12	First estimate of landfill height and area (a) Restricted area available	= A_r (sq.m.)
	Area required for infrastructural facilities	= 0.15 A_r
	Area available for landfilling	= 0.85 A_r
	Average landfill height required (first estimate) above base level H_i	= C_i / 0.9 A_r (m) (valid for area type landfill)
	(b) No limitation on area	
	Possible maximum average landfill	= H_i (typically between height (first estimate) 10 to 20 m, rarely above 30 m)
	Area required for landfilling separations	A_i = C_i / H_i (sq.m.) (valid for area type landfill)
	Total area required (including infrastructural facilities) (first estimate) A_i = 1.15 A_i	

Sl. No.	Parameters	Formula for calculation
13	Refinement in estimates of landfill capacities, height and area: After obtaining the initial estimates, the volume of daily cover as well as volume of liner system and cover system can be revised keeping in view the shape of the landfill as well as on the basis of whether materials of daily cover, liner system and cover system will be excavated from within the landfill site. Taking these revised values into account, refined estimates of landfill capacity, height and area can be made. The final and precise estimates will be arrived at after topographical survey results (0.30 m contour interval) become available. It may be noted that landfill capacity values will undergo revision during operation of the landfill when waste quantities delivered at the site vary from the generation rates estimated prior to the start of landfill operations.	

Source: (CPHEEO, 2016)

Case study: Sanitary landfill, Pimpri Chinchwad

Highlights	
Total area	7.4 acres (includes two capped landfill and two active landfill)
CAPEX	Rs 35 crores (including mechanical composting and Sanitary landfill)
Managed by	BVG India Pvt. Ltd.

Source: (NIUA, 2019)

Figure 4.93: Sanitary landfill, Pimpri

Source: (NIUA, 2019)

This sanitary landfill is spread over an area of 7.4 acres (two capped landfills and two active landfill. Approximately 295 MT per day of waste generated is brought to the landfill site. This facility is managed by BVG India Pvt. Ltd.

4.10. Further Readings

- Guidance on Efficient Collection and Transportation of MSW, July 2020, formulated by Ministry of Environment and Forests, Govt. of India, available at https://www.niua.org/csc/assets/pdf/key-documents/phase-2/Waste/SBM-Guidance-on-Efficient-Collection-and-Transportation-of-MSW.pdf
- 'Toolkit for Solid Waste Management' - Jawaharlal Nehru National Urban Renewal Mission (JnNURM), 2012, Ministry of Housing and Urban Affairs (MoHUA), Government of India, New Delhi November available at http://www.hpccc.gov.in/PDF/Solid_Waste/SWMtoolkit.pdf
- The High Powered Expert Committee (HPEC) for Estimating the Investment Requirements for Urban Infrastructure Services: Report on Indian Urban Infrastructure and Services, 2011, Ministry of Housing and Urban Affairs (MoHUA) , Government of India, available at http://cpheeo.gov.in/upload/uploadfiles/files/FinalReport_hpec09.pdf
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Quick Assessment

1. The process of burning municipal solid wastes under suitable temperature and conditions in a specific furnace is called....
   a. Landfill
   b. Incineration
   c. Recycling
   d. Vermicomposting
2. When the organic matter present in the sanitary landfill decomposes, it generates
   a. Methane
   b. Nitrogen
   c. Hydrogen
   d. All of the above
3. Which of the following can be recycled many times?
   a. Wood
   b. Plastic
   c. Aluminium
   d. Organic materials
4. Which of the following gas is produced from landfill wastes?
   a. Biogas
   b. Natural gas
   c. Liquefied petroleum gas
   d. All of the above

5. The average person living in the India produces about..... of solid waste per day
6. Reducing the amount of solid waste that we generate or make is called...
    a. Recycling
    b. Composting
    c. Source reduction
    d. Incineration
7. Which of the following is not a factor that affects composting?
    a. Temperature
    b. Particle size
    c. Air circulation
    d. Colour
8. What are the special facilities to separate recyclables into various streams?
    a. Shredding
    b. Compaction
    c. Screens
    d. Mechanical separators
9. Why aeration is required in composting process?
    a. To reduce temperature
    b. To maintain aerobic activity
    c. To increase the rate of decomposition
    d. All the above

** For answers please refer annexure II*

Awareness Campaign, Indore, Madhya Pradesh
Source: Indore Municipal Corporation

Chapter
5

Role of Information, Education and Communication (IEC) in SWM

Recap

After understanding the elements of SWM value chain, it is necessary to get an idea of the IEC tools for behaviour change, to take necessary actions.

Training Objectives

- Understand the role of Information, Education and Communication (IEC) in solid waste management
- Explore various methods and tools that can be used to implement behavioral changes among the citizens
- Gain knowledge of best practices that have been implemented in Indian cities

Training Outcomes

- Knowledge of tools to communicate strategies of solid waste management.
- Effective and comprehensive approach to implementation, operation and management of SWM process.

Chapter Contents

5.1 Introduction
5.2 Effective IEC plan
5.3 Communication tools
5.4 Funding pattern of IEC
5.5 Further reading
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Quick Assessment

5.1 Introduction

Information, Education and Communication (IEC) is simply a process of working with individuals and communities to develop a communication strategy to bring about behavioral change according to the need of the situation. IEC consists of strategies, approaches and methods that enable individuals, families and groups to attain awareness and actively participate in the development activity.

Solid Waste Management is an activity in which community engagement and public participation are the keys to success. It is not only the technology but community behaviour that will make the difference. In SWM, Information, Education and Communication (IEC) plays an essential role in creating awareness and sustaining change in communities.

IEC combines strategies, approaches and methods that enable individuals, groups, organizations and communities to play an active role in achieving sustainable waste management. The aim is to achieve the "SMART" objectives mentioned below:

- **S** Specific and sustainable (what and who)
- **M** Measurable and manageable (something which is visible)
- **A** Area specific and applicable (where)
- **R** Realistic and replicable (achievable)
- **T** Time-bound and transparent (when)

Pre-testing of the IEC material should be done on a small group belonging to the targeted population. It is a method of analysing whether the intention of the message can be achieved or not.

After the identification of the target population, the key messages are chosen with the selection of media and combination of information channels. Each channel has its own strength and weakness that depends on what kind of role the information channel has to play in IEC.

Different messages should be made for different media like radio, stories, poems, songs, posters according to the need. The persons using the material should be properly trained so as to ensure that the envisaged goal is achieved.

The key pillars to solid waste management are volunteerism and public participation. Along with technology, public attitude and behaviour can make a difference. An IEC plan for SWM should focus on the following:

- Ensure clear understanding of 4-R concept i.e. reduce, reuse, recycle and recover the waste.
- Focus on storage and segregation at source.
- Assimilate the civic sense of keeping the locality clean.
- Motivate willingness of the citizen to accept civic responsibilities.
- Ensure buy-in to eradicate unscientific solid waste disposal.

Awareness should be created on the positive and negative effects of unscientific waste management. This includes the following:

- Health hazards
- Aesthetic damage
- Environmental issues
- Creation of awareness on the different technical options available of solid waste management that explores the possibility of converting waste into a valuable source.
- Proximity theory of SWM. (Scientific disposal of waste at the nearest point of source. For example, biogas plant at a market; composting at households etc.)
- Willingness to pay for services.

The communication technique may include both mass communication and inter personal communication. The techniques adopted will vary from place to place based on the local barriers to efficient waste management system. Some of these barriers and ways to covercome them is summarized below:

Table 5.1: Level Barriers of Communication Techniques

Barrier	Way to overcome the barrier
Knowledge level barrier	To adopt right waste management practices and make citizens realize their roles, responsibilities and benefits of effective SWM practices.
Attitude level barrier	To bring motivation, awareness and empowerment in communities.
Practice level barrier	To create awareness, sensitization and motivation of communities to follow right waste handling practices and hygiene.

5.2 Effective IEC Plan

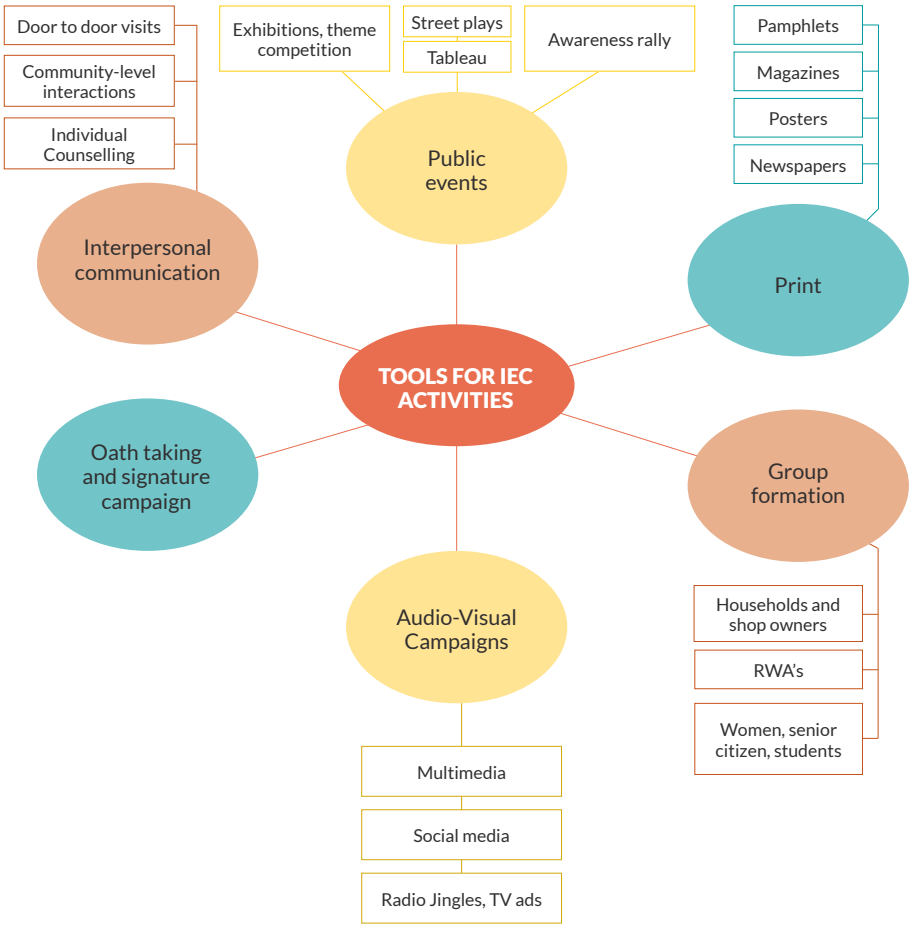
For effective implementation of the IEC campaign, a strategic and planned approach is critical. It is important to understand what communities already know and do in terms of solid waste management. An IEC plan of ULBs should focus on the following

- Creating awareness on waste minimisation, source segragation into wet waste, dry waste, sanitary waste and domestic hazardous; Storing segregated waste at source in different bins
- Practicing home composting or community level composting
- Creating behavioural change for adoption of the 3R concept-reduce, reuse, recycle
- Handing over e-waste to authorized recylers or submit at waste collection centres
- Paying monthly user fee or charges to ULBs or any other authorised person.

Before commencing the IEC campaign, it is important to understand whose behaviour needs are to be changed and in which direction. The IEC shall:

- Build the integrated communication on community participation, consistency and transparency.
- Communicate in simple and direct medium, keeping the local cultural context in mind.
- Aid to allocate adequate funds to each intervention.
- Help to follow a top down approach involving elected representatives, RWA presidents, religious leaders, youth clubs and citizens.
- Assist to reach out to all stakeholders and communities in a city including schools, colleges, hospitals, hotels, offices, market places, malls, residential colonies and all age groups including children, women, men, youth, and elderly persons.
- Make sure to Focus on children and youth as agents of change. Make extensive use of influencers and city leaders.

Figure 5.1: Communication tools for IEC activities



Source: (IMC, 2020)

5.3 Communication tools

For effective implementation of an IEC plan, the use of print media, audio-visual, social media and interpersonal communications needs to be undertaken in spreading awareness. Some of the commonly used communication tools are as follows:

Table 5.2: Communication tools with respect to target groups

Target groups	Important responsibilities	IEC focus areas	Use of communication options
Households	-100% source segregation -Pay user charges	-Waste minimization -At source segregation -Home composting	Poster, leaflet, brochure, social media, individual counselling; Use of school children and waste collectors in creating awareness
Community (RWAs, Housing Societies)	-100% source segregation -Pay user charges -recyclables are being sent to processing facilities	-treatment of wet waste at community level -Benefits of composting -No littering -Use of separate bins for waste segregation -Benefits of 3R (Reduce, Reuse and Recycle)	Hoardings, trainings , community- level interactions and group meetings.
Mass level (Shopping centres, vegetable markets, railway stations)	-No littering -No waste burning -Keep work place clean -No use of single-use plastic bags	-Promotion of reusable bags -Change in shopping habits to reduce packaging waste.	Street plays, tableau, print media (newspaper), social media, poster, hoardings, use of public transport, TV-ads, radio jingles, exhibitions
Institutions (Schools, Colleges, etc.)	-100% source segregation -Pay user charges -recyclables are being sent to processing facilities	-Orientation on the 3R principle (Reduce, Reuse and Recycle)	Rallies, exhibitions, quiz and essay competition, debate, lectures on SWM, oath taking and signature campaigns, Hackathons
NGO's, CSO's	-Conduct awareness campaigns -Mobilise community -Training and capacity building of ULB officials and sanitary workers	-Mobilise communities, conduct awareness campaigns and capacity building workshops	Workshops, trainings, panel discussions

Source: Author

5.4 Funding pattern of IEC

The case of the Swachh Bharat Mission (SBM) is taken here to explain the funding pattern of IEC. In SBM, IEC consists of 15% of the central allocation. Out of this 15%, 12% was earmarked for States to conduct campaigns on public awareness on issues like public health, hygiene and the environment by different means like short films, radio, social media, plays, workshops. 3% was earmarked for the MoHUA to run a national media campaign and develop standardized methods for campaigning. Newspaper and TV were excluded item from this component for the State government or for the ULB's as it is under the purview of different ministries of Government of India. States were mandated to make an action plan with all the details of state funding. State High Powered Committee (HPC) approved the Public Awareness and IEC plan. A minimum of 50% of the IEC fund in each annual plan were given to the urban local bodies for IEC activities. The authority to give power to use state level funds was HPEC under the approved plan. The Urban local bodies spent a minimum 50% part of the ULB level funds, as per approved plan. It was further mentioned that this fund cannot be use for any other purpose like purchase of vehicles, construction and maintenance of buildings, payment of salary etc. It was mandated that a minimum of 25% for the states contribution towards IEC and Public awareness should match 75% Central share (10% for the North Eastern states and states with special category in each annual plan). A few good practices are narrated below for better understanding of IEC activities implemented in Indian cities, as part of SBM.

Case study: IEC model, Indore

Highlights	
Total Population	1,990,000
Total area	275 sq. km
Number of households	6.20 lakh

Indore is the largest and most populous city of Madhya Pradesh. It is also one of the 100 smart cities under the national Smart Cities Mission. Solid Waste Management in Indore comes under the purview of the Indore Municipal Corporation (IMC). The city generates over 980 MT of garbage per day, and all of it is collected from each household and commercial establishment. Indore ensures 100% coverage of all wards through door to door collection system. 100% segregation at source is being practiced in the city. All waste collecting vehicles have separate wet and dry waste collection partition in vehicles besides a separate container for domestic hazardous waste.

IMC engaged NGO's for IEC activities which focuses on source segregation and plastic waste management. At first IMC identified the stakeholders. The city management has used many IEC tools such as hoardings, swachhata newsletter, cultural events, radio jingles, public transport panel advertising, social media campaign, pole banner advertisements, etc.

IEC activities performed by Indore Municipal Corporation

- 188 road rallies with 26,100 participants
- 408 street plays with 16,876 audience
- 476 RWA meetings with 11,785 participants
- Dustbin distribution to approximately 1 lakh residents
- Meetings with all Bulk waste generators (hotels, institutions, business associations and shop owners)
- 225 Oath taking ceremonies with 15,860 school children and staff
- Training of nearly 6200 Safaimitras

Figure 5.2: IEC activities for awareness

(a) Door to door source segregation awareness campaign

(b) Street plays on waste segregation

(c) Wall Paintings

(d) Installation of Murals

(e) Wall art in slums

(f) Wall paint in slums

(g) Awareness on Indore 311 app for complaint redressal

(h) Student rallies

(i) Awareness and training on Home composting

(j) Campaign on use of litter bins in commercial areas

Source: (IMC, 2020)

IEC activities conducted by IMC were very engaging and were recognized by GoI. Presented below are some of the key results/achievements.

- Indore has won the title of cleanest city of India in Swachh Survekshan for four consecutive years (2017, 2018 ,2019, 2020)
- An opinion study conducted by IMC has indicated that 95% of the respondents believed that there is a significant change in awareness level; 84% agreed that IEC approaches resulted in successfully bringing behaviour change and habits of citizens (MoHUA, 2019)
- There was a significant reduction in communicable diseases
- Indore has also emerged as the first ODF++ city in India

Case study: Haritha Karma Sena Spreading awareness on Decentralised waste management

Highlights	
State Population	33,387,677
Wards covered	13,000
Population outreach	77,16,370
Households covered by intervention	38 lakh households

Source: (MoHUA, 2019)

In Kerala, the Local Self Government Institutions (LSGIs) constitute the system for field level waste management. The ''Haritha Karma Sena (HKS)'' or Green Task Force is a Self Help Group (SHG) of women responsible for field level management. The women were recruited from Kudumbashree, a women empowerment and poverty eradication program (by the State Poverty Eradication Mission, Government of Kerala). Each member gets a 3-day training on waste management practices and welfare schemes. Daily, a team of two HKS visits around 250 households in a ward. Harithasahayasthapanams (technical support agency) is deployed on cluster basis to provide technical assistance to HKS. They also developed IEC material such as hoardings, pamphlets, stickers, radio jingles, songs, videos messages, etc. in local language. The mechanism to address all the grievances in 24 hours is managed by HKS.

Figure 5.3: Flowchart of HKS functions

Source: (MoHUA, 2019)

Figure 5.4: Haritha Karma Sena

(a) Dry waste collection from a household,

(b) HKS team operating the mobile waste converter

(c) Managing Resource Recovery centre

(d) Secondary Segregation at Resource Recovery Centre

(e) HKS at decentralised composting facility

(f) Members of HKS team

Source: (MoHUA, 2019)

Case study: Alag Karo, Gurugram

Alag Karo is a source segregation program in Gurugram. It is implemented by a non-profit organization, Saahas with support of GIZ, Coca-Cola and Tetra Pak. This programme was conceived with the premise that the most important step to achieve a circular economy is to segregate waste at its source.

Alag Karo, Har Din Teen Bin is an endeavour towards efficient management of the Municipal Solid Waste in Gurugram. The objective of the project is to establish and sustain segregation at source and develop capacities of the waste collectors (formal and informal) to ensure high recycling rates in Gurugram. The program is a collaborative initiative involving government, private sector and civil society members. The program works in close coordination with the Municipal Corporation of Gurugram (MCG) under its "Open Waste Free' initiative. Through the program, MCG has started source segregation in many apartment complexes and gated communities. Schools and commercial establishments are also part of the program coverage.

Figure 5.5: Awareness campaign on waste segregation

Figure 5.6: Awareness rally by sanitation workers

Figure 5.7: Sanitation fest


SWACHH SURVEKSHAN

SANITATION FEST
स्वच्छता उत्सव

'Swachhata Guru', a Mascot Launch

To encourage and engage more people to contribute to the Swachhata of Gurugram, 'Swachhta Guru', a mascot was launched.

A lot of children and citizens were seen clicking selfies with it. Launched with the intention that 'Swachhata Guru', will act as a role model and encourage citizens to start small.

Like Waste Segregation into 4 bins (Green, Blue, Black and Yellow), composting at home, to not use and replace single use plastic products with reusable and biodegradable solutions like cloth/paper bag, metal/wood cutlery, metal/glass water bottles and so on.

Together we can achieve #GarbageFreeGurugram.
कचरा मुक्त, गुरुग्राम अनुभव |

Figure 5.8: Swachhata Guru

Figure 5.9: IEC pamphlets

Source: (Alagkaro, 2021)

Public events and workshops involving all the stakeholders are being held throughout the program duration to spread awareness and facilitate direct public interaction.

'Swachhata Guru', a role model, a mascot, was launched to encourage and engage more citizens to be ''SwachhataSuperstars'' themselves at Sanitation Fest on 28-Feb-21, at Sec-29.

5.5 Further Readings

- Compendium on ''Transforming Urban Landscapes of India Success Stories in Information, Education and Communication (IEC) and Behaviour Change'', Swachh Bharat Mission (Urban) by Ministry of Housing and Urban Affairs, Government of India, available at http://164.100.228.143:8080/sbm/content/writereaddata/SBM%20IEC%20Coffee%20Table%20Book.pdf
- CPHEEO manual on Solid Waste Management 2016, Ministry of Housing and Urban Affairs, Government of India available at http://cpheeo.gov.in/cms/manual-on-municipal-solid-waste-management-2016.php
- Solid Waste Management Advocacy and Communication Strategy (SWACS) prepared by Directorate of Urban Development, Shimla, Himachal Pradesh available at https://ud.hp.gov.in/schemes-projectsswachh-bharat-missioncomponentsolid-waste-management/solid-waste-management

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Quick Assessment

1. How long does it take plastic to degrade?
   a. 500-1000 years
   b. 200 years
   c. 150 years
   d. 50 years

2. ____are major agents of societal change and are primary targets of IEC campaigns
   a. School children
   b. Rotary clubs
   c. Resident Welfare associations
   d. Self-help groups

3. Which of the following statements is true about zero waste management?
   a. Separate collection of each kind of waste
   b. Segregation of garbage at the source
   c. Community involvement
   d. All of the above

4. What is the order of waste management hierarchy, from most to least favoured?
   a. Prevention- Recycle-Reuse- Disposal
   b. Prevention-Reuse-Disposal-Recycle
   c. Prevention-Disposal -Reuse-Recycle
   d. Prevention-Reuse-Recycle-Disposal

5. Which of the following is impact of solid waste on environment?
   a. Ground water contamination
   b. Bad odour and air pollution
   c. Diseases spread (Epidemic condition)
   d. All the above

** For answers please refer annexure II*

Annexure-I

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Aspects under various components of a DPR

1. Executive Summary

A concise summary of the DPR including a short brief of city and its MSW situation, proposed schemes, economics and timelines and contract methodology for implementation

2. Introduction to the Project

- 2.1 **Definition of MSWM**
- 2.2 **Status and issues of MSWM**
- 2.3 **Provisions of MSWM plan – long term and short term**
- 2.4 **Project background and link to the MSWM plan**
- 2.5 **Project formulation justification (need for the project**

3. City Profile

History and importance of the project town, City formation year, Introduction to the City including importance eg. – Religious significance, industrial town, tourist hub, etc.

3.1 Geographical and climatic conditions

Physiography of the city, Temperature, rainfall, wind directions etc

3.2 Location and extent

Latitude, Longitude, elevation, area of the city, extent of project area, number of zones and wards, Map of the city, Distance of the city from major towns, Transportation facility in the city.

3.3 Population

Population growth trend 1991-2011, Ward wise population, slum population

- 3.3.1. Population projections

  Decadal growth rate, population projection for 30 years
- 3.3.2. Population density

  Average size of houses in the city
- 3.3.3. Floating Population

  Average monthly floating population, peak seasons

3.4 Settlements in city

- 3.4.1. Number of households, shops, commercial establishments and institutions
- 3.4.2. Number of hotels, restaurants, banquet halls
- 3.4.3. Number of large markets (vegetables, meat and fish)

3.4.4. Slums and other informal settlements

3.4.5. Slum Map

3.4.6. Industries and their profile

3.4.7. Health care establishments

3.4.8. Slaughterhouses

3.5 Land use plan

Land use map, percentage breakup of land use in the city

3.6 Physical infrastructure

3.6.1. Roads

Length and width of roads

3.6.2. Storm water management length and width

3.6.3. Sewage management

Number of public toilets, Septage management

3.6.4. Water supply system

3.6.5. Electricity

Voltage, Substation capacity near proposed processing disposal site, tariffs

3.6.6. Urban economy

Tourism/ agricultural/ industrial/ etc. focus of the city and related information. Average income, over view of different industries (small-scale/ medium or large scale) present in the city. Prevalent occupation base of the city.

3.6.7. Information about the ULB

Political Setup

Year of city formation, governing body

Administrative setup of ULB

Both executive and administrative wings – overview organogram with all departments and staff working. Number of zones and wards, head of ULB, Organizational hierarchy of ULB.

Administrative setup of Sanitation Department of the ULB

Brief note on Sanitation Department of the city, organization hierarchy of MSW department, Number of Workers (including higher officers to safai karamcharis), Roles and responsibilities of each Workers (including higher officers to safai karamcharis), Number of SWM workers involved in Door to Door collection and Street cleaning, Ward wise number of workers for different SWM activities, Number of informal/Contractual waste collectors (Elakdaars) and their duties and the fee they collect.

Financial status of ULB

Sources of funds, central, state and revenue taxes

Administrative and financial aspects of MSWM

Cost heads, salaries and wages, cost of MSW management

4. Status of Existing Solid Waste Management System in City

4.1 Waste generation (based on primary information)

Total Quantity of Waste Generated in the city, ward wise solid waste generation, Projection of waste generation in the city, segregation of waste at source. Composition of MSW, Chemical Composition of the waste.

4.1.1. Sampling of waste

Methodology of sampling, selection of sample size, strata, recording and analysis of data.

4.1.2. Physio-chemical characteristic of MSW

Characteristics of municipal solid waste generated at different categories of users from a laboratory accredited by State Pollution Control Board/ State Govt./ MoEF and design the components accordingly, as per SWM Rules, 2016.

4.1.3. Waste Forecast

Waste generation is projected for future years in blocks of 5 years. The waste growth rate is also assumed in line with the CPHEEO manual to account for life style changes.

4.2 Existing MSW collection system

4.2.1. Primary waste collection system

Door to door collection details, number of houses and wards covered number of non- domestic such as institutional, commercial, markets, hospitals, slums and informal settlements, etc. Served, frequency of door to door collection, average trips, type of vehicles used (hand carts, autos, etc). Segregation of waste into wet, dry and domestic hazardous waste. Involvement of SHGs, NGOs, waste pickers, informal sector in primary collection system.

4.2.2. Primary Waste Storage at Generation

Residential, Market (Vegetable, Meat and Fish), Institutional, Commercial Establishments, Hotels and Restaurants, Hospitals, Industries, slums and informal settlements. Segregated/ not-segregated storage of waste

4.2.3. Secondary waste collection system

Storage bins, transfer points, sorting areas. Segregated/ not-segregated storage of waste. Involvement of SHGs, NGOs, waste pickers, informal sector in primary collection system.

4.3 Street sweeping and drain cleaning

Total Area covered, area covered by one sweeper, frequency, quantity of solid waste generated, Composition of road sweeping waste, Chemical Composition of road sweeping waste. Length of roads, streets, lanes, bye-lanes in the city that need to be cleaned, frequency of street sweepings and percentage of population covered, Manual/Mechanical sweeping

4.4 MSW secondary storage system

4.4.1. Transfer Station Details

Transfer Station Details, Location, Number of transfer stations, weigh bridge details, segregation at the transfer station

4.4.2. Waste Storage Depots and secondary storage bins

Total number of bins, where is the solid waste stored, Zone wise allocation of storage bins with capacities, Spatial Distribution of Bins on a map, ward wise open dumping points, Bin/ population ratio, total waste actually stored at the waste storage depots daily, give frequency of collection of waste from the depots, number of bins cleared, whether storage depots have facility for storage of segregated waste in green, white and black bins. Segregation at the transfer station.

4.5 MSW transportation system

Total number of vehicles in the city used for MSW collection- tractors, compactors, etc.

4.6 Existing MSW processing system

Details, waste treatment technology, Map showing processing/ treatment site, quantity of solid waste processed, Land(s) available with the local body for waste processing, Land and area currently utilized for waste processing, Solid waste processing facilities under construction, Distance of processing facilities from city/town boundary, Details of technologies adopted.

4.6.1. Recyclable waste

Quantity of segregated recyclables and final utilization.

4.6.2. Biodegradable waste

Technology used quantity and quality of incoming waste and quantity of final product produced. Utilization and sale of products. Land allotted for facility, Photos.

4.6.3. Non-biodegradable waste

RDF production, quantity and final utilization and sale of products. Any other Land allocated for facility, photos

4.6.4. Construction and Demolition waste

Quantity generated, practice adopted for utilization of C and D waste, and products manufactured and utilized. Land allotted for facility, photos

4.6.5. Any other waste (domestic hazardous waste, sanitary waste)

Quantity generated, current practice followed

4.7 Infrastructure existing for SWM

From collection till final disposal existing manpower details. ULB staff and contractual workers.

4.7.1. Equipment's/Vehicles

Vehicle details with their capacity and average trips. From collection till final disposal existing Vehicle details.

4.7.2. Equipment repair facility

4.8 **Status of present disposal and proposed landfill site**

Details, Map showing dumping area, Photos of dumping site, quantity of solid waste disposed, No. of dumpsites sites and no. of sanitary landfill sites available with the local body, Area of each such sites available for waste disposal, total unutilized land for disposal available with the ULB, distance of site/ sites from town/city, airport, wetland, railway station, Layout plan of existing landfill.

4.9 **Overall compliance of SWM Rules, 2016**

5. Project Definition

5.1 **Project objectives**

5.2 **Scope of project**

5.3 **Approach and methodology**

6. Gap Analysis

6.1 **Manpower and vehicle requirement for Door-to-Door Collection, Street sweeping and Drain Cleaning**

Total number of present manpower and vehicle details and requirement of manpower and vehicle details.

6.2 **Sufficiency of Secondary Collection Bins**

Total number of bins and their capacities to check whether bins are excess or insufficient. Whether bins are required or should be totally removed.

6.3 **Sufficiency of Secondary Collection Vehicles**

Total number of vehicles and their capacities to check whether bins are excess or insufficient/ not required.

6.4 **Sufficiency in treatment, processing and disposal facilities**

Current treatment, processing and disposal is sufficient or else any up gradation is needed.

6.5 **Gaps in Awareness among City Residents and Civic Authorities**

Details on lack of awareness of duties of citizens as well as civic authorities.

6.6 **Gaps in Institutional structure**

6.7 **Gaps in Capacity Building for ULB**

Details on capacity building gaps for MSW staff at different levels and and contractual workers.

7. Proposed Municipal Solid Waste Management Systems

7.1 **Segregated Storage of waste at source**

Plan for segregation of waste at source in three separate streams namely bio-degradable, non- biodegradable and domestic hazardous wastes.

7.2 **Street sweeping and drain cleaning**

Separate collection and separate transportation to processing site or disposal site

7.3 Segregated Waste collection

Plan for door to door collection of segregated solid waste from all households including slums and informal in 3 streams. As far as possible, separate collection of sanitary waste. Plan for establishment of a system for integration of authorized waste-pickers and waste collectors: Registration of association of waste pickers or Self Help Groups or Cooperatives; document the total number of waste pickers working in the town, Plan for engaging of waste pickers in door to door collection activities and total number to be engaged

7.4 Segregated MSW transport system and secondary storage

Plan to set up material recovery facilities or secondary storage facilities with sufficient space for sorting of recyclable materials to enable informal or authorized waste pickers and waste collectors to separate recyclables from the waste. Waste segregation in wet, dry, domestic hazardous waste, sanitary waste. Plan for separate waste deposition centres for domestic hazardous waste, as per city requirements

7.5 Transfer Station if required

Assessing requirement of transfer station, number and type

7.6 Processing of MSW

Processing technologies according to quantities and characterization of different waste material in the city (Design and Operation Requirements)

7.6.1. Criteria for selection of processing technology

7.6.2. Availability of land and siting guidelines

7.6.3. Design of processing plant

7.6.4. Required infrastructure and equipment

Detailed drawing, estimation and detailed BOQ for main and ancillary works such as boundary wall / fencing, approach and internal road, electrification, buildings, water supply and drainage, site development / landscaping etc.

7.6.5. Environmental monitoring and control

a. Clearance / consent from the State Pollution Control Board, Airport / Airfield Authorities, Flood Control/Ground water Management Authorities etc. for setting up MSW treatment plants and landfill, regional facilities, as per the SWM Rules, CPHEEO manual.

b. Clearance for environmental impact assessment for proposed processing and sanitary landfill site – local or regional.

7.6.6. Socio-economic benefits

Benefits of proposed project for different aspects - social, environmental and financial.

7.6.7. Product utilization

Details of mechanism for marketing of compost/RDF/ power and tie-up with any agency including cement/ power plant and fertilizer production unit/ any other local market that has the capacity to utilize the saleable compost/ RDF/ power in market, etc.

7.7 Municipal sanitary landfill

7.7.1. Conceptual design of landfill

Inert estimation during the lifetime of the project, preliminary design of the landfill, layout to fit the land and existing contours, rainfall analysis and estimation of leachate, design of leachate collection system, leachate treatment plant.

7.7.2. Technical specification

Detailed drawing, estimation and detailed BOQ for main and ancillary works

7.7.3. Environmental monitoring and control (as in point 6.6.6 above)

7.7.4. Socio-economic benefit

7.7.5. Bio-mining and Bio-remediation plan for existing dumpsites

7.7.6. Capping of old Dumpsites

7.7.7. Staffing Requirements

7.7.8. Staffing requirements for the ULB for the proper management of municipal solid waste in the city.

8. Institutional Aspects and Capacity Building

8.1 Proposed organizational setup and staffing requirement

For the ULB and the operators

8.2 Training and capacity building of ULB

For the ULB and contractual workers for implementation monitoring, operation and maintenance

9. Other O and M Aspects

9.1 Management Information System

(Documentation and updating the information, maintain records) Objectives, Waste Generation Data, Waste Collection, Data (Primary and Secondary), Waste Transportation Data, Processing and Disposal, Performance Monitoring Indicators. GIS and GPRS requirements. Data requirements of the ULB and of the service provider and/ PPP operator.

9.2 Complaint Handling System

Essential features of a complaint handling system, General Rules for Handling Complaints, Complaint handling system for “City”.

9.3 Environmental Health and Safety Aspects

Measures to be taken to avoid sufferings due to improper solid waste handling.

10. Community Awareness and Public Participation

10.1 Objective

To create public awareness and induce good behavioural change

10.2 Community awareness and outreach strategies

Approach of IEC plan (Program communication, Social mobilization and Strategy for creating awareness) with support of NGOs, other welfare associations.

11. Cost Estimates

11.1 Cost Estimates for collection and transport

11.1.1. Capital Expenditure

This section summarizes the cost of infrastructure and other resources required for the waste collection and transportation. Cost element includes push carts, Tricycles, Auto tipper, Tractors, Skip trucks, Compactors etc used for primary collection and transportation and secondary transportation, transfer station, sweeping of roads, market places and other public places, drain cleaning, GPs tracking, SCADA, working capital expense, per operative expenses etc.

Summary of Operating Expenses WCTO				
Sl #	Description	Qty	Unit Rate (Rs)	Annual Rate (Rs)
1	Workers/Loaders/Sweepers			
2	Supervisor			
3	Driver			
4	Brooms			
5	Face Mask			
6	Ghamela			
7	Gum Boot			
8	Hand Gloves			
9	Metal Tray			
10	Uniform			
11	Fuel			
12	Veh. Maintenance Cost			
13	Hire Charges			
	Total (Rs)			

11.1.2. O and M Expenditure

This section summarizes the cost of operation and maintenance of collection and transportation infrastructure. Cost element includes Wages and Salaries, Fuel and lubricants and other consumables, hand tools, PPEs, Software subscription, GSM etc,

Estimated Capital Expenditure WCTO				
Sl #	Description	Total	Unit Rate	Amount
1	Pushcart Bins			
2	Push cart			
3	Tri Cycle			
4	Tricycle Bins			
5	Auto Tipper			
6	Metal Tray			
7	Tipper Trucks			
8	3.0 Cum Containers			
9	4.5 Cum Containers			
10	Twin Container Dumper Placer			
11	Compactors			
12	Drain Cleaning / Jetting M/c			
13	Mechanized Sweeper Trucks			
	Total			

11.2 Cost Estimates for Processing and Disposal

11.2.1. Capital Expenditure

This section summarizes the cost of infrastructure and other resources required for the adopted processing and disposal technology. Cost elements include building and machineries, mobile and stationary material handling equipment's, segregation, extrusion, generator, weigh bridge, laboratory, electrical and water supply infrastructure, Sanitary landfill, leachate collection and treatment plant etc.

Capital Expenditure For Infrastructure				
General (Building)	Unit	Qty	Unit Rate	Amount
Security				
Admin Cum Laboratory building				
Garage building				
Weighing bridge				
Interim Storage Facility				
Vehicle cleaning unit				
Pre-sorting section, process hall, curing shed, process tower and storage godown				

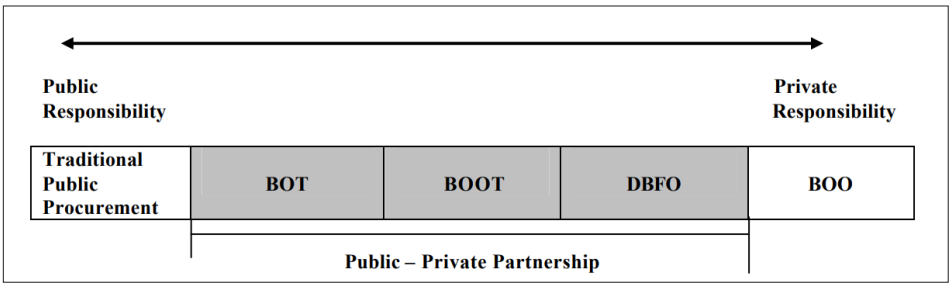
Watertank				
Fence (Boundary wall and Gate)				
Pumping accessories				
Distribution Transformer, yard and panels and electrification				
Water supply				
Sewage and Treatment				
Telecommunication and fire alarm supply				
Sanitary Landfill				
Cars (4wd,ac,)				
Leachate collection and treatment				
Utility Vehicle				
Tractor (45 kW)				
Dozer (15t, 130 kW)				
Tipper Trucks				
Excavator				
Front End Backhoe Loader				
Compactor				
Fork lift (3t, fork height -3.8m, diesel eng.)				
Tanker tractor (45 kW with pump attachment)				
Internal transportation vehicle (18t cap., ro-ro)				
Pre-sorting Equipment				
Process Equipment				
RDF Equipment Including Grab Crane				
Laboratory equipment				
Workshop equipment				
Office furniture including interiors				
Computers, server, Lan network, printers, etc.,				
GPS, IoT SCADA, Software				
Technical and Consultation Fee				
Contingency Expenses				
IDC				

11.2.2. O and M Expenditure

This section summarizes the cost of operation and maintenance of Processing and disposal plant. Cost element includes Wages and Salaries of Technical supervisory and unskilled staff, Electricity, Fuel and lubricants and other consumables, hand tools, PPEs, Software subscription, Laboratory chemicals and reagents, GSM etc,

Operational Expenditure For Processing and disposal				
General (Building)	Unit	Qty	Unit Rate	Amount
Description				
Wages and Salaries				
Packing Expenses				
Consumable Expenses				
Personal Protective Expenses				
Staff Welfare Expenses				
Repairs to machinery				
Repairs to vehicles				
Repairs to Buildings				
Fuel to vehicles				
Oil and Lubricants				
Electricity Charges				
Office , Admin and Licensing charges				
Laboratory / testing charges				
GPS tracking, IOT, SCADA				
Software				
Miscellaneous				
Total				

11.3 Total Revenues Generated



In the Engineering Procurement Construction EPC system, funds will be provided by the client based on the client's design and estimation. The contractor has to

execute the project as per the scope of the client.

The operation of a completed project may be carried out by the Client or outsourced through a Service Agreement

Build, own, operate and transfer (BOOT) model as per client design. the funds shall be of contractor's and based on project viability, the contractor shall implement, own it and manage the successful installation and commissioning of the plant. The contractor can collect predefined fee from the users for a specified period to get back his funds. After the contract period and the plant is transferred to the customer as per the agreed terms.

Design BOOT (DBOOT), contactor can do value engineering based on the scope of the project and can get back his investment as in the case of BOOT. When the whole funding is private sector, it is DFBOOT

11.3.1. Revenue generation from residential, commercial, institutional, industries, advertisement etc

11.3.2. Proposed tariff charges for different categories such as residential, commercial, establishments, hotels, restaurants, vegetable markets etc.

11.3.3. Revenue from sale of products eg. Compost, RDF, Electricity, Biogas

11.3.4. Revenues from user charges, taxes, etc.

12. Contract and Financial Aspects

12.1 Project implementation schedule

12.2 Public Private Partnership and Contract model

This section outlines the suggested model for delivering the SWM such as Service contract, EPC, BOOT, DBOOT and DFBOOT. It should highlight various options considered and recommend the most appropriate model for the City. Details would include the contract or concession period, scope of service, pricing model, etc

12.3 Project financial structuring including PPP decisions

The section details the financial structure of the project including the capital subsidy, viability gap funding, estimate of capex recovery etc

12.4 Estimate of fee for city sanitation and collection and transportation

The section details the projected fee required for financial sustainability of the different components after considering all the available funds.

12.5 Financial Analysis

The section summarizes the

Assumptions: this includes the costs of funds, bank guarantee, Insurances, contingencies, projected product revenue, wages and salaries, consumables etc.

Profitability, Cash flow, Balance sheet, Amortization, Depreciation, Loan repayment schedule, working capital estimation,

Ratio analysis including

Discounting factor DF = (1-(1/(1+Int rate/100)^concession period)))/(int rate/100)

- Payback period: (Total capex/ (Total Revenue- Total Opex))
- Discounted Cashflow DCF = (Total Revenue / DF)
- Net Present Value = (DCF- Total Capex)
- Equivalent annualized cost = (NPV/DF)
- Benefit Cost Ratio = DCF/ Capex
- Debt Service Coverage Ratio= (Profit after Tax+Depreciation+interest) / (Loan+Interest)
- Return on Investment= (Total revenue- Total expenses)/ Total Investment
- Return on Equity = (Total revenue- Total expenses)/ Total Equity
- Internal Rate of Return = The interest rate such that DCF = Total Capex, obtained by trial and error
- Break Even Point= Fixed Costs / (Revenue Per Unit – Variable Cost Per Unit)

Sensitivity analysis needs to be carried out to test the various assumptions. This section shall also highlight the impact of the project on the Municipal finance and suggest innovative ways to meet the challenges

Annexure-II

Answer Sheet - Quick Assessment

Chapter 1

Q. No.	Answer	Q. No.	Answer
1	d	5	d
2	d	6	0.57
3	b	7	c
4	d		

Chapter 2

Q. No.	Answer	Q. No.	Answer
1	a	5	Extended Producer Responsibility
2	d	6	Decentralized
3	d	7	c
4	d		

Chapter 3

Q. No.	Answer
1	Net Present Value
2	d
3	d
4	Viability Gap Funding

Chapter 4

Q. No.	Answer	Q. No.	Answer
1	b	5	c
2	a	6	d
3	c		
4	a		

Chapter 5

Q. No.	Answer
1	b
2	a
3	d
4	d
5	d

Glossary

Aerobic composting - A controlled process involving microbial decomposition of organic matter in the presence of oxygen.

Anaerobic digestion - A controlled process involving microbial decomposition of organic matter in absence of oxygen.

Bailing - A machine used to compress recyclables into bundles to reduce volume. Balers are often used for newspaper, plastics, and corrugated cardboard.

Biodegradable waste - Any organic material that can be degraded by micro- organisms into simpler stable compounds.

Bio-methanation - A process which entails enzymatic decomposition of the organic matter by microbial action to produce methane rich biogas.

Bulk waste generator - Includes buildings occupied by the Central government departments or undertakings, State government departments or undertakings, local bodies, public sector undertakings or private companies, hospitals, nursing homes, schools, colleges, universities, other educational institutions, hostels, hotels, commercial establishments, markets, places of worship, stadia and sports complexes having an average waste generation rate exceeding 100kg per day.

Bye-laws - A regulatory framework notified by local body, census town and notified area townships for facilitating the implementation of these rules effectively in their jurisdiction.

Capacity building - Enabling people, organizations, and societies to develop, strengthen, and expand their abilities to meet their goals or fulfill their mandates is referred to capacity building. It is a long-term and continuous process that focuses on developing human resources, organizational strength, technology know-how etc. involving all stakeholders and is strengthened through the transfer of knowledge and skills that enhance individual and collective abilities to deliver services and carry out programs that address challenges in a sustainable way.

Composting - A controlled process involving microbial decomposition of organic matter.

Compactor vehicle - A collection vehicle using high-power mechanical or hydraulic equipment to reduce the volume of solid waste.

Construction and demolition waste – The waste comprising of building materials debris and rubble resulting from construction, re-modelling, repair and demolition of any civil structure.

Conveyor belt-A wide belt made of rubber, textile, nylon or more commonly composite material, which moves on wide rollers. In compost industry chain drive is popular as the belt moves in a guided manner, directed by the chain sprockets. Conveyor belts are used for material movement in different stages.

Curing - Allowing partially composted materials to reside in a pile for a specified period of time as part of the maturing process in composting.

Decentralized processing - Establishment of dispersed facilities for maximizing the processing of biodegradable waste and recovery of recyclables closest to the source of generation so as to minimize transportation of waste for processing or disposal.

Disposal- The final and safe disposal of post processed residual solid waste and inert street sweepings and silt from surface drains on land as specified in Schedule I to prevent contamination of ground water, surface water, ambient air and attraction of animals or birds.

Domestic hazardous waste- Domestic hazardous wastes mean waste contaminated with hazardous chemicals or infectious waste such as discarded paint drums, pesticide cans, CFL bulbs, tube lights, expired medicines, broken mercury thermometers, used batteries, used needles, gauge and syringes, etc. generated at the household level.

Door to door collection - Collection of solid waste from the door step of households, shops, commercial establishments, offices, institutional or any other non-residential premises and includes collection of such waste from entry gate or a designated location on the ground floor in a housing society, multi storied building or apartments, large residential, commercial or institutional complex or premises.

Dry waste - Waste other than bio-degradable waste and inert street sweepings and includes recyclable and non-recyclable waste, combustible waste and sanitary napkin and diapers, etc.

Dump sites - A land utilized by local body for disposal of solid waste without following the principles of sanitary land filling.

E-waste - Means electrical and electronic equipment, whole or in part or rejects from their manufacturing and repair process, which are intended to be discarded as waste.

Extended Producer Responsibility (EPR) - Responsibility of any producer of packaging products such as plastic, tin, glass and corrugated boxes, etc., for environmentally sound management, till end-of-life of the packaging products.

Facility - Any establishment wherein the solid waste management processes namely segregation, recovery, storage, collection, recycling, processing, treatment or safe disposal are carried out.

Fine - Penalty imposed on waste generators or operators of waste processing and disposal facilities under the bye-laws for non-compliance of the directions contained in these rules and/or bye- laws.

Handling - Includes all activities relating to sorting, segregation, material recovery, collection, secondary storage, shredding, baling, crushing, loading, unloading, transportation, processing and disposal of solid wastes.

Inert - Wastes which are not bio-degradable, recyclable or combustible street sweeping or dust and silt removed from the surface drains.

Incineration- An engineered process involving burning or combustion of solid waste to thermally degrade waste materials at high temperatures.

Informal sector-The part of an economy that is characterized by private, usually small-scale, labor-intensive, largely unregulated, and unregistered manufacturing or provision of services.

Informal waste collector - includes individuals, associations or waste traders who are involved in sorting, sale and purchase of recyclable materials.

Integrated Solid Waste Management (ISWM) - ISWM refers to a strategic initiative for the sustained management of solid waste through the use of a comprehensive integrated format generated through sustained preventive and consultative approach to the complementary use of a variety of practices to handle solid waste in a safe and effective manner.

Leachate - The liquid that seeps through solid waste or other medium and has extracts of dissolved or suspended material from it.

Materials Recovery Facility (MRF) - A facility where non-compostable solid waste can be

temporarily stored by the local body or any other entity mentioned in rule 2 or any person or agency authorized by any of them to facilitate segregation, sorting and recovery of recyclables from various components of waste by authorized informal sector of waste pickers, informal recyclers or any other work force engaged by the local body or entity mentioned in rule 2for the purpose before the waste is delivered or taken up for its processing or disposal.

Municipal Solid Waste (MSW) - Includes the domestic waste, commercial waste, institutional waste, market waste and other non-residential wastes, street sweepings, silt removed/collected from the surface drains, horticulture waste, construction and demolition (C and D) waste and treated bio-medical waste excluding industrial hazardous waste, and e-waste generated in any municipal authority area in either solid or semi-solid form.

Non-biodegradable waste - Any waste that cannot be degraded by microorganisms into simpler stable compounds.

Operator of a facility - A person or entity, who owns or operates a facility for handling solid waste which includes the local body and any other entity or agency appointed by the local body.

Primary collection - Collecting, lifting and removal of segregated solid waste from source of its generation including households, shops, offices and any other non- residential premises or from any collection points or any other location specified by the local body.

Processing - Any scientific process by which segregated solid waste is handled for the purpose of reuse, recycling or transformation into new products.

Recycling - the process of transforming segregated non-biodegradable solid waste into new material or product or as raw material for producing new products which may or may not be similar to the original products.

Refuse Derived Fuel (RDF) - Segregated combustible fraction of solid waste other than chlorinated plastics in the form of pellets or fluff produced by drying, shredding, dehydrating and compacting combustible components of solid waste that can be used as fuel. Residual solid waste - And includes the waste and rejects from the solid waste processing facilities which are not suitable for recycling or further processing.

Sanitary land filling - The final and safe disposal of residual solid waste and inert wastes on land in a facility designed with protective measures against pollution of ground water, surface water and fugitive air dust, wind-blown litter, bad odour, fire hazard, animal menace, bird menace, pests or rodents, greenhouse gas emissions, persistent organic pollutants slope instability and erosion.

Sanitary waste - Wastes comprising of used diapers, sanitary towels or napkins, tampons, condoms, incontinence sheets and any other similar waste.

Secondary storage - The temporary containment of solid waste after collection at secondary waste storage depots or MRFs or bins for onward transportation of the waste to the processing or disposal facility.

Segregation - Sorting and separate storage of various components of solid waste namely biodegradable wastes including agriculture and dairy waste, non- biodegradable wastes including recyclable waste, non-recyclable combustible waste, sanitary waste and non-recyclable inert waste, domestic hazardous wastes, and construction and demolition wastes.

Sludge - A semi-liquid residue remaining from the treatment of municipal and industrial water and wastewater.

Sorting - Separating various components and categories of recyclables such as paper, plastic, cardboards, metal, glass, etc., from mixed waste as may be appropriate to facilitate recycling.

Stabilizing- the biological decomposition of biodegradable wastes to a stable state where it generates no leachate or offensive odours and is fit for application to farm land ,soil erosion control and soil remediation.

Street vendor - Any person engaged in vending of articles, goods, wares, food items or merchandise of everyday use or offering services to the general public, in a street, lane, side walk, footpath, pavement, public park or any other public place or private area, from a temporary built up structure or by moving from place to place and includes hawker, peddler, squatter and all other synonymous terms which may be local or region specific. and the words "street vending" with their grammatical variations and cognate expressions, shall be construed accordingly.

Tipping fee - A fee or support price determined by the local authorities or any state agency authorised by the State government to be paid to the concessionaire or operator of waste processing facility or for disposal of residual solid waste at the landfill.

Transfer station - A facility created to receive solid waste from collection areas and transport in bulk in covered vehicles or containers to waste processing and, or, disposal facilities.

Transportation - Conveyance of solid waste, either treated, partly treated or untreated from a location to another location in an environmentally sound manner through specially designed and covered transport system so as to prevent the foul odour, littering and unsightly conditions.

Treatment - The method, technique or process designed to modify physical, chemical or biological characteristics or composition of any waste so as to reduce its volume and potential to cause harm.

Trommel - An improved version of rotary screen, which is driven from outside, preferably using hydraulic power packs to keep the movement smooth, especially while starting after a power cut. The screen is covered from outside to control dust.

Urban Local body - Includes the municipal corporation, nagar nigam, municipal council, nagar palika, nagar palika parishad, municipal board, nagar panchayat, town panchayat, notified area committee or any other local body constituted under the relevant statutes where management of solid waste is entrusted to such agency including the body in notified industrial township, notified area, villages declared outgrowth in urban agglomeration by the Registrar General and Census Commissioner of India from time to time.

User fee - a fee imposed by the local body and any entity mentioned in rule 2 on the waste generator to cover full or part cost of providing solid waste collection, transportation, processing and disposal services.

Vermi-composting - The process of conversion of bio-degradable waste into compost using earth worms.

Waste generator - And includes every person or group of persons, every residential premises and non-residential establishments including Indian Railways, defense establishments, which generate solid waste.

Waste hierarchy - The priority order in which the solid waste is to should be managed by giving emphasis to prevention, reduction, reuse, recycling, recovery and disposal, with prevention being the most preferred option and the disposal at the landfill being the least.

Waste picker – A person or groups of persons informally engaged in collection and recovery of reusable and recyclable solid waste from the source of waste generation the streets, bins, material recovery facilities, processing and waste disposal facilities for sale to recyclers directly or through intermediaries to earn their livelihood.

Waste-to-Energy system (WTE) - A method of converting MSW into a usable form of energy, usually though combustion.

Windrow - Long trapezoidal heaps or piles. Long composting heaps are referred to as 'windrow'. The base is wider and the top is narrower.

Notes:

Notes:

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