The dry waste from those establishment, would be transferred to the decentralized transfer station for compaction through stationary compactor. From the transfer station, the dry waste will be sent to the centralized material recovery facility.

The ULB also has a residential barrack from where dry waste will be collected and also sent to the MRF facility. The wet waste will be treated within the facility by means of organic waste converter. Below figure depicts the model:

Figure 41 SWM solution model for NDITA

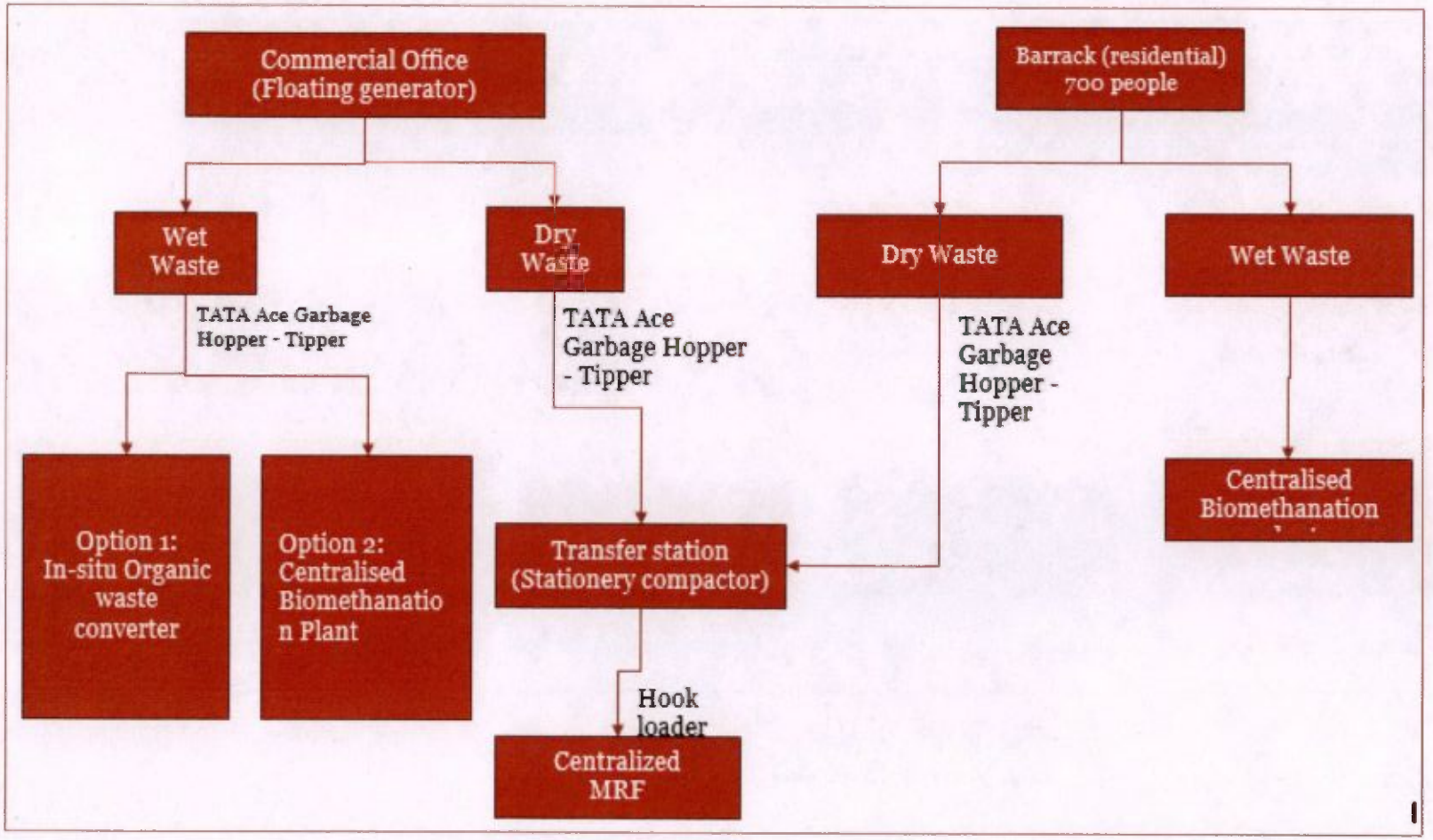


Figure 42 SWM solution model for NDITA - Mass balance

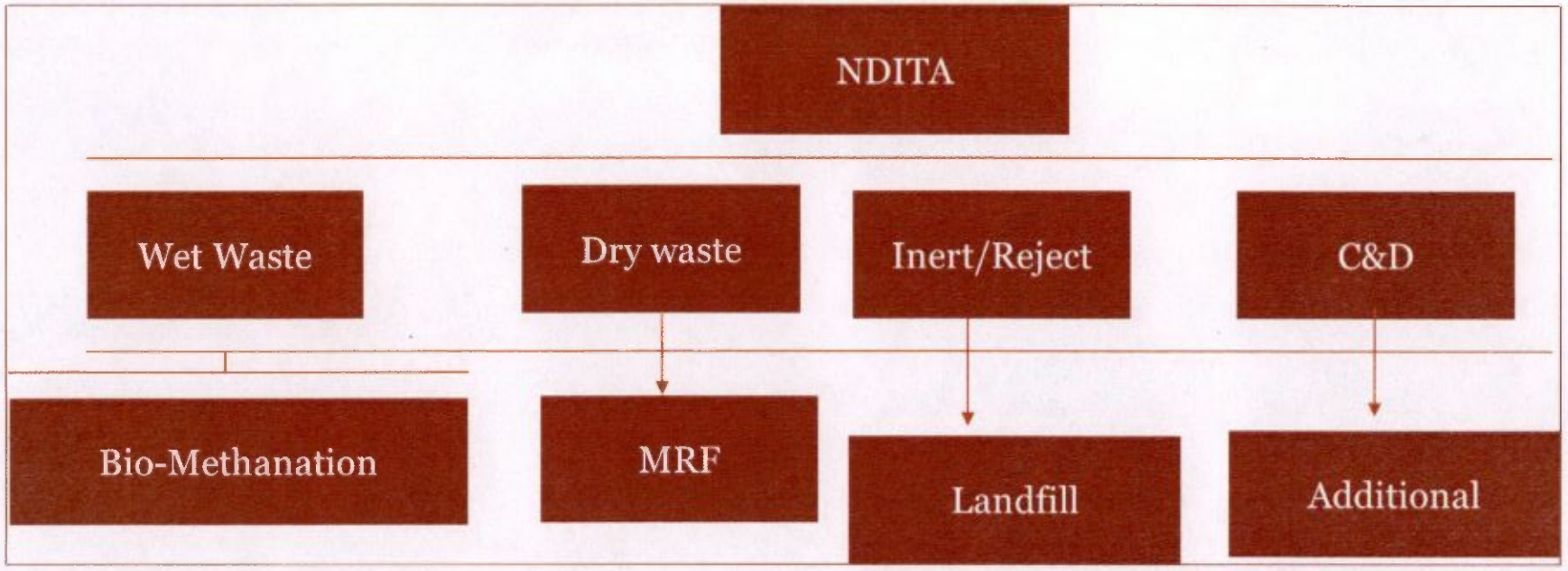


Table 41 Table for Mass Balance of NDITA

Decentralized System						Sharing of Centralized System by ULBs (20 years planning)				
5 TPD biomethanation Plant for bulk generators			In situ automatic organic waste composter (300 kg/day)			MRF	C&D	Biomethanation	Composting	SLF (TPD)
Location	Nos	Total TPD	Location	Nos	Total TPD	At 20-acre Patharghata site			At Bhangor	
NA	0	0		0	0	16	12	28	0	11

10.4. Processing, treatment & disposal model

A combination of centralized and decentralized system will be adopted for the proposed SWM scheme across the four ULBs. The table below, depicts the planning model for treatment and disposal facilities:

As per the analysis done it was recommended to install pilot level decentralized plant for bio-methanation and organic waste converters.

For centralized system such as landfill, MRF and C&D waste, short-term design period will be considered for installation. The first landfill cell should be designed for 5 years projected accumulation.

Table 42 Proposed treatment and disposal model

#	ULB	Decentralized Components			Centralized Components				
		at Respective ULB Levels			at 20-acre HIDCO land			Land for centralised disposal	
		In-situ Organic Converter	Biomethanation	Portable and/or Refuse Compactor	Biomethanation (if land is not available at ULB decentralized level)	C&D Plant	MRF	SLF	Composting
1	KMC	√		√	√		√	√	√
2	BMC	√	√	√	√	√	√	√	√
3	NKDA		√		√	√	√	√	
4	NDITA			√	√		√	√	

11. Design of Infrastructure and Facilities

This chapter discusses the project design, sizing, capacity of the plant and the numbers of different types of infrastructure required for this project. ULB specific infrastructure and equipment details are mentioned in the following sections:

11.1. Proposed Infrastructure Inventory for Different ULBs

11.1.1. Proposed infrastructure inventory for KMC

The details of infrastructure required for KMC is being furnished below:

Table 43 Infrastructure Requirement for KMC

• No of OWC unit	29
• No of 14 m3 Refused Compactor vehicle required for Patharghata & Bhangor for wet waste	12
• Refuse compactor 14 m3 to be procured for dry waste	6

11.1.2. Proposed infrastructure inventory for BMC

The details of infrastructure required for BMC is being furnished below:

Table 44 Infrastructure Requirement for BMC

• No of OWC unit	38
• No of 300 kg auto tipper vehicle required for Patharghata	107
• No of vehicle required for Decentralized biomethanation plant (for wet waste)	10
• No of new Refused compactor vehicle	14
• Refuse compactor 14 m3 to be procured for dry waste	3
• Nos of 1100 lit compactor bins required	653

11.1.3. Proposed infrastructure inventory for NKDA

The details of infrastructure required for NKDA is being furnished below:

Table 45 Infrastructure Requirement for NKDA

• No of 300 kg auto tipper vehicle required for Patharghata	5
• No of 300 kg auto tipper vehicle required for decentralized biomethanation plant	2
• No of compactor for dry waste	2
• No of 1100 lit Compactor Bins	39

11.1.4. Proposed inventory details for NDITA

The details of infrastructure required for NDITA is being furnished below:

Table 46 Infrastructure Requirement for NDITA

• No of 300 kg auto tipper for wet waste	30
• No of compactor required for dry waste (existing)	2
• Nos of 1100 lit compactor bins required	34

11.2. Proposed infrastructure inventory for processing & disposal system

The details of the centralized & decentralized facility and area requirement are given in the next page:

Table 47 Details of Capacity & Area of the Facilities

#	ULBs	Land requirement from ULBs for Decentralized Facilities				Central Facilities									
						At 20-acre HIDCO Land						Proposed land at Bhangor			
		Bio-methanation (Option I – if land is available with ULBs)		AOWC		Bio methanation		C&D		MRF		Sanitary Landfill Facility		Compost Plant	
		Capacity	Nos	Nos	Area	Capacity	Area	Capacity	Area	Capacity	Area	Capacity	Area	Capacity	Area
1	KMC	5 TPD (500 m² for each plant)	-	29 nos. (9 MT)	50 m²	400 TPD	8 acres	400 TPD	4 Acre	550 TPD	5 Acre	432 TPD 7 Lakh Ton *(5 years cell capacity)* 3 Million Ton *(20 years, till 2040 capacity)*	65.22 acre (with vehicle maintenance, storage, admin, office building, parking, green belt, roads and open space)	500 TPD	10 acres
2	BMC		4 Nos	38 nos.											
3	NKDA		1 No	-											
4	NDITA		-	-											

11.3. Design of Composting Facility

Compost plant is designed for the year 2030 with a provision of expansion for 2030. The land has been identified at the same place of the landfill site and the area for the compost plant has been calculated based upon the design waste quantity of 2030. However, at present the design, costing etc. has been done for the 2030 infrastructure requirement. The design capacity of the plant is 500 TPD (For 2020. 2030, and 2040 are 50 TPD, 70 TPD, and 90 TPD respectively).

Below different features and technical details of the process is described.

11.3.1. Basic steps

Wet waste would be delivered at the plant site regularly after arrival the material is unload at windrows for composting. The garbage will be stacked in the form of a windrow. Separate windrows will be formed for each day's wet waste. These windrows will be turned once in a week for proper aeration, so that aerobic process continues uninterrupted. First stage of composting will be completed within 30-35 days.

From here the digested garbage will be fed by a feeder into the course segregation section consists of series trammel which separate the digested garbage on the basis of size. Each trammel rejects are sent to temporary storage section for process rejects directly. The reject coming out of the second and third screen can be sent back to windrows for further digestion.

Material coming out of the last screen is transferred through a series of conveyor to curing area, where further curing of the digested garbage (compost) lakes place. Various nutrients such as rock phosphate etc. can be added to the compost therefore enhancing the quality of the finished product. This material is then fed into a drag chain feeder, which transfers it to a rotary screen through a bucket elevator, this rotary screen separates the material on the basis of size. So that the digested compost coming out of it is acceptable in the market.

Screened material coming out of the rotary screen is fed to a gravity separator, which separates materials such as Glass, metal etc. from the compost.

The reject material coming out of the rotary screen can be sent back to the curing area for further digestion, compost, free from all major external impurities will be lifted through another bucket elevator and discharged into an add- mixer and inoculums containing various useful microbes like Azetobactor, PSB, Rhizobium and micro nutrients etc. will be sprayed into the mixer inquired proportion for enriching the compost enriched organic manure, which will have 20 – 25% moisture, is then weighed and packed and distributed. Samples will be drawn at regular intervals from different stages for quality control.

Preferably as it is fast, exothermic and free form odor. Aerobic also help to eliminate Pathogenic bacteria weed seeds, larvas etc. as a result of high temperature developed during the process.

11.3.2. Process Description

There are four stages in the scientific treatment and processing of wet waste through controlled accelerated bioconversion technology. These stages are as following:

STAGE 1- SANITISATION:

Under hot weather organic waste rich in minerals, proteins and carbohydrates are quickly invaded by rot inducing pathogenic microorganisms and starts generation of mal-odors. These wastes are also great source for multiplication of flies, which becomes the carriers for pathogenic bacteria. Therefore, under the tropical and sub-tropical conditions municipal waste must be given a sanitization treatment with natural herbal extracts and bio-enzymes. Use of insecticides and chemical disinfectants is prohibited as these chemicals interfere with natural bioconversion process and may leave high levels of toxic residues.

Several preparations of herbal extracts are now available in the market as waste sanitizers and bio-stabilizers such as BIO-KLEEN, ECO-KLEEN, ECOLOGIC, CITRUS CLEAN, ECOLO, WASTE TREAT, RAPIDCOM. Spraying of these formulations as per the label direction ensures sanitary treatment of wastes and restricts the multiplication of pathogenic microorganisms.

STAGE 2- BIOCONVERSION:

This process involves generation of mesophilic [40°C] and thermophilic [>60°C] temperature by fast multiplication of desirable bacteria, fungi, and actinomycetes. The exothermic heat generated by introduced micro-organisms is useful to kill several pathogenic bacteria as well as speed up the bio-chemical breakdown of the complex organic matter to simpler forms of minerals, humus, growth promoting substances as well as food source for beneficial micro-organisms in the soil. The bioconversion process is compressed into 4 - 5 weeks' time cycle instead of usual 4 to 6 months. In this process waste volume is reduced by 45 to 50% and the stabilized biomass becomes usable compost after screening.

STAGE 3- FORTIFICATION & VALUE ENHANCEMENT:

Compost as some time misunderstood as refused derived product is not correct. In fact, it is the composted form of carbon energy as humus material and transferred nutrient elements in readily absorbable form by the crop plants.

Therefore, during the bio conversion process addition of enriching materials such as fibers, blood meal, slaughter house waste compost liquors, oil cakes, spoiled food grains, milk powders etc. These can ideally be combined in the first or second turning or sometimes even at the initial stage of windrow forming. Care is taken that such added materials are pressed through bio stabilization of 3 weeks.

Fortified batches can be separately processed as high value organic soil enricher or special grade organic fertilizer for a particular crop or soil conditions.

Total bioconversion cycle must last for 30 to 42 days.

STAGE 4- MECHANICAL PROCESSING:

After completion of the bio conversion cycle and bringing down moisture (around 20% level) for free flowing into machines, the material passes through 4 stage online screening system having series of conveying, rejection handling and rotary sieves / vibro sieves. The sieve size configurations are changeable as per the requirement of end product quality.

Usually a free-flowing coarse powder entirely passing through 3 mm sieve size (rules specify 90% material passing through 4 mm sieve size) is recovered. This powdery material can be furthered processed into granules or pelletized form for mechanized application in horticulture crops.

SEGREGATION PLANT:

Following are the basic component required for a Segregation plant:

i. Coarse Segregation plant – Consisting of standard equipment used in production of Organic Manure from Municipal Solid Waste such as Trommel, Chain Belt Conveyors, Hydraulic Power Pack etc.
   a. Design capacity of 15 Tons per day of digested municipal solid waste.
   b. Number of working days per annum – 300 days.

ii. Refinement plant - Consisting of standard equipment used in production of organic manure from municipal solid waste such as Vibro screen, Bulk density separator, Aspirator system, Bucket elevator etc.

11.3.3. *Factors Affecting Composting Process*

The factors affecting composting process are given in the table below:

Table 48 Factors affecting Compost process

SN	Driving Factors	Desirable ranges
1	Moisture content	50% to 60% optimum
2	Temperature	50 to 60 ^{o}C (for 5 to 7 days, pathogens get killed)
3	C/N ratio	Between 20- 40
4		If C/N ratio is less -straw, saw dust, paper to be added
5		If C/N ratio is more -sewage sludge, slaughter waste etc. to be added

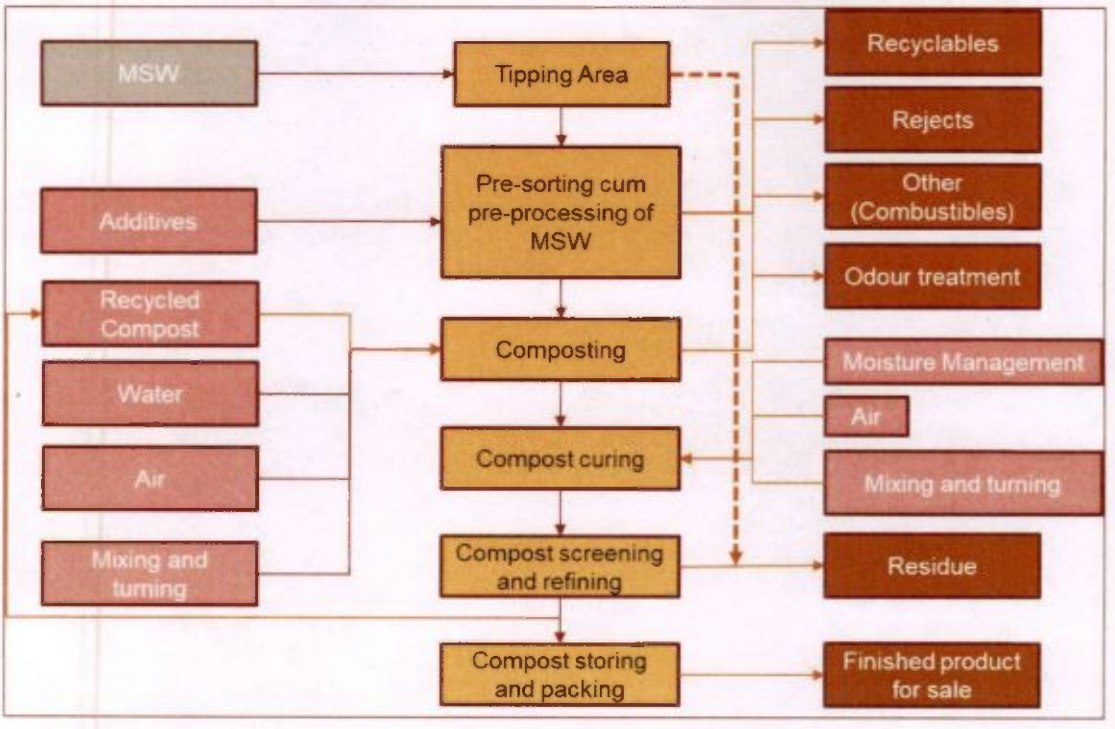
6		At the end of composting C/N =20. As per MSW regulations C/N permitted is 20-40
7	Aeration	Adequate oxygen throughout the mass-normally ensured by turning every 5-7 days

11.3.4. *Design Detail and Infrastructural Requirement*

Table 49 Required Infrastructure and Equipment for Compost plant

SN	Equipment	Qty	Purpose
1	***COARSE SEGREGATION PLANT***		
i)	Feeder	1 No.	For feeding material at controlled rate.
ii)	Dual Trommel 35/14	1 No.	For Screening
iii)	Process Conveyor	1 No.	For feeding material to next Trommel
iv)	Reject Conveyor	1 No.	For removal of rejection off-line.
2	***REFINEMENT PLANT***		
i)	Drag Chain Feeder	1 No.	For feeding material at controlled rate.
ii)	Bucket Elevator	1 No.	For lifting material & feeding it to rotary screen.
iii)	Vibro Screen	1 No.	For Screening
iv)	Gravity Separator with Aspirator	1 No.	For separation of heavy impurities.
v)	Packing Elevator	1 No.	For lifting material & feeding it to add-mixer.
vi)	Packing Spout	1 No.	Two-way for packing material.
3	***CONTROL PANEL***		
i)	Hydraulic Power Pack & Control Panel	1 Set	Push button station along with hydraulic system to improve efficiency and safety of equipment against continuously fluctuating load.

Figure 43 Composting process flow chart



11.3.5. Manual Segregation/ Pre-sorting of Dry Recyclables waste

Dry or recyclable waste would be sent to storage section for storage purpose. Recyclables form a separate stream of waste which can be further utilized and sold as source of revenues which is 90% of the recyclables.

The mixed dry waste separated into the following:

- Paper
- Plastic
- Glass
- Metals
- Others

The objective of separating the dry waste would be to remove the bulk inert material, recover the marketable products and produce a stream of waste with high organic content.

11.3.6. Plant Layout and Design

Windrow Platform

An impervious concrete platform scientifically designed with proper gradient to accommodate the garbage. The concrete platform is provided with peripheral drain to collect the Leachate and rainwater over flow.

Table 44 Details of Compost Plant

SN	Head	Unit	Details
1	Waste quantity	TPD	500
2	Design quantity considered	TPD	500
3	Volume	m3/day	1111
4	One cycle period	days	28
5	Total volume	m3	31111
6	Height of windrow	m	2.00
7	Area of windrow	m2	15556
8	Windrow heap length (each)	m	22.50
9	Windrow heap wifth (each)	m	4.50
10	No of windrow	Nos	154
11	Column	Nos	5
12	Row	Nos	31
13	Spacing between two heaps	m	3
14	Length of windrow (total)	m	176
15	Width of windrow (total)	m	123
16	Total area of the compost pad	m2	21648

Area Statement

The area statement for processing facility is given below:

SN	Head	Unit	Details
1	Windrow Pad	m2	21648
2	Machine Shed for Coarse Segregation Section	m2	600
3	Refinement Shed & Tower	m2	400
4	Finishing and begging Section Area	m2	400
5	By product Storage Shed	m2	400
6	Monitoring cum office room	m2	80
7	Monsson shed	m2	12300
8	Access, circulation, internal road etc (10%)	m2	3582.8

9	Total Area	39410.8

SN	Head	Unit	Details	length	width
1	Windrow Pad	m2	21648	112	44
2	Machine Shed for Coarse Segregation Section	m2	600	24	25
3	Refinement Shed & Tower	m2	400		
4	Finishing and begging Section Area	m2	400		
5	By product Storage Shed	m2	400		
6	Monitoring cum office room	m2	80		
7	Monsson shed	m2	12300		
8	Access, circulation, internal road etc (10%)	m2	3582.8		acre
9	Total Area		39410.8		9.740682

11.4. Design of Sanitary Landfill

The landfill design comprises of an active period and a closure and post closure period. For this site the active period is designed as 20 years.

Phasing: The landfilling activity will be under taken in a phased manner for 20 years. Each phase comprises 5 years from the base year 2020 until the year 2040 (i.e.) for 2020-2025, 2025-2030, 2030-2035, 2035-2040.

11.4.1. Landfill site setting criteria

While identification of land, following site setting criteria needs to be assessed and examined, as per MSW 2016 manual, CPHEEO, MoUD.

Table 50 Landfill Site Setting Criteria

SN	Criteria	CPHEEO Mandates
1	Lake/Pond	200 m away from the Lake/Pond
2	River/streams	100m away from the river/stream
3.	Flood plain	No land fill within a 100-year flood plain
4	Highway	Away from 200 m NHAI/State
5	Public parks	300 m away from public parks
6	Wet lands	No landfill within wet lands.
7	Habitation	500 m away from the notified habitation area
8	Ground water table	Ground water table > 2m.
9	Critical habitat area, reserve forest, protected area, ecologically sensitive area	No landfill within the Critical habitat area. It is defined as the area in which 1 or more endangered species live.
10	Air ports	No landfill within 20 km
11	Water supply schemes/ wells.	Minimum 500 m away

11.4.2. MoEFCC guidelines for landfill design

As per the Govt of India guideline, the sanitary landfill shall comply with the following,

- The sanitary landfill shall be provided with fence, security gate, approach and internal roads, waste inspection facility, weigh bridge, equipment and machinery, infrastructure like water supply, lighting, etc. and health inspection facilities.
- Waste shall be compacted adequately and provided with daily cover of minimum 10cm of soil inert debris.
- Prior to commencement of monsoon intermediate cover of thickness 45cm has to be provided with proper compaction and grading to prevent infiltration during monsoon. Proper drainage berms shall be provided to divert runoff from the active cell of the landfill.
- The minimum bottom layer specifications shall be a composite barrier having 1.5mm High Density Polyethylene (HDPE) geo-membrane overlying 90 cm of soil (clay/amended soil) having permeability coefficient not greater than 1 X 10^{-7}cm/sec. The highest level of water table shall be 2m below the clay/amended soil layer.
- The final cover shall have a barrier layer comprising of 60cm of clay/amended soil with permeability coefficient not greater than 1X10^{-7}cm/sec., on the top of the barrier soil layer there shall be a gas collection layer of 45cm and on the top there shall be a vegetative layer of 45cm thick.
- In order to prevent the pollution problems storm water diversion drains, leachate collection and treatment system and preventive measures for run – off from landfill area entering any stream, lake, river or pond shall be provided.
- Buffer zone around the landfill site and a vegetative cover over the completed site shall be provided.
- The post closure care of landfill site shall be conducted for at least fifteen years and long-term monitoring plan shall be prepared.

11.4.3. Sanitary landfill design concepts

Landfill design involves development of concept, adoption of suitable procedure and safety considerations. Landfill is a typical combination of different component and each of these components has to be designed separately. For this process standard design procedure by CPHEEO Manual on Municipal Solid Waste Management, United States Environmental Protection Agency's Manual on Solid Waste Management (Subpart – D, Design Criteria) etc. have been adopted. Design concepts for the following components have been developed.

- Assessment of landfill volume and area required
- Landfill life
- Evaluation of concept development plan – Foot Print of Landfill Site
- Design of leachate collection system
- Design of liner system
- Assessment of landfill gas generation
- Design of landfill gas collection system
- Design of final cover system.

11.4.4. Landfill volume

The volume of the landfill has been estimated based on the topography of the site and using the AutoCAD software. Before estimating the volume maximum height that can be achieved is estimated as 15m and depth has been considered as 4.5m. Thus, the basic cross section of the landfill considered is presented as below. Thus, the volume of the landfill (5 years cell) has been estimated as 975922 cum (waste including liner, cover and daily cover).

11.4.5. Landfill life

The landfill has been designed for a period of 5 years. Approximately 432 tons/day of inert matter comprising of silt, sand, rejects from each process line shall be disposed in the landfill.

11.4.6. Standard design requirements

The standard design of the sanitary landfill is furnished below:

Table 51 Standard Design Requirement for Sanitary Landfill

Landfill Component	Requirement
Bottom Liner / Composite Liner	• A 90cm thick compacted clay or amended soil (amended with bentonite) of permeability not greater than 1X10-7 cm/sec • A HDPE geo-membrane liner of thickness 1.5mm • A drainage layer of 300mm thick granular material of permeability not greater than 1X10-2 cm/sec.
Final Cover	• Vegetative layer of 450mm thick with good vegetation supporting soil • Barrier layer of 600mm thick clay/amended soil with permeability 1 X 10-7cm/sec • Gas venting layer of 450mm thick granular material with permeability 1 X 10-2cm/sec
Maximum Allowable Leachate Head with in Landfill	30 cm
Base Slope	2%
Cover Slope	Not steeper than 1:4

11.4.7. Bottom liner system

Leachate control by liner system within a landfill involves prevention of percolation of leachate from waste in landfill to the subsoil by a suitable protective system (liner system). The liner system is a combination of drainage layer and barrier layers. As per CPHEEO manual a competent liner system should have low permeability, should be robust and durable and should be resistant to chemical attack, puncture and rupture. A liner system comprises of combination of barrier materials such as natural clay, amended soils and flexible geomembrane.
As suggested by MoEF guidelines a composite liner of two barriers made of different materials, placed in immediate contact with each other provides a beneficial combined effect of both the barriers. The liner system suggested by MOEF is a geomembrane layer over clay or amended soil barrier. A drainage layer and leachate collection system is placed over the composite liner system.

The effectiveness of barrier layer basically depends on the hydraulic conductivity of the clay/amended soil liner and density of the geomembrane. The clay/amended soil liner is effective only if it is compacted properly and geomembrane liner is effective only if it has the density or mass per unit area (minimum thickness is specified) is sufficient enough against punctures. The landfill site composite liner of following specifications has been recommended:

- A 90cm thick compacted clay or amended soil (amended with bentonite) of permeability not greater than 1X10-7 cm/sec
- A HDPE geomembrane liner of thickness 1.5 mm
- A drainage layer of 300 mm thick granular material of permeability not greater than 10-2 cm/sec.

Main components of composite liner are clay/amended soil layer and geomembrane liner and performance of landfill largely depends on this liner system. Thus, it is incumbent to design the liner system very accurately and perfectly.

11.4.8. Landfill gas management

Landfill gas is generated as a product of waste biodegradation. In landfill sites organic waste is broken down by enzymes produced by bacteria in a manner comparable to food digestion. Considerable heat is generated by these reactions with methane, carbon dioxide, nitrogen, oxygen, hydrogen sulphite, carbon dioxide and other gases as the byproducts. Methane and carbon dioxide are the principle gases produced with almost 50 – 50 per cent share. When methane is present in the air in concentrations between 5 to 15 per cent, it is explosive. Landfills generate gases with a pressure sufficient enough to damage the final cover and largely have impact on vegetative cover. Also, because only limited amount of oxygen is present in a landfill, when methane concentration reaches this critical level, there is a little danger that the landfill will explode. As suggested by CPHEEO Manual the gas management strategies should follow the following three plans,

- Controlled Passive Venting
- Uncontrolled Release
- Controlled Collection and Treatment

Since the landfill in cluster II project is fundamentally and secured landfill and will receive inert only, gas generation is anticipated to be very less. Therefore, only a passive gas venting system is proposed for the landfill.

11.4.9. Design of final cover system

A final landfill cover is usually composed of several layers, each with a specific function. The surface cover system must enhance surface drainage, minimize infiltration, support vegetation and control the release of landfill gases. The landfill cover to be adopted will depend on the gas management system. As recommended by the MoEF and CPHEEO the final cover system must consist of a vegetative layer supported by a barrier layer and gas vent layer.

The final cover system proposed for landfill site is based on the recommendations of MoEF and CPHHEO Manual. The final cover consists of the following components,

- Vegetative layer of 450 mm thick with good vegetation supporting soil
- Barrier layer of 600mm thick clay/amended soil with permeability 1 X 10^{-7}cm/sec
- Gas venting layer of 450 mm thick granular material with permeability 1 X 10^{2} cm/sec

11.4.10. Inert waste volume and land fill capacity

The quantum of inert of the incoming waste at site will be filled in the proposed landfill. CPHEEO guidelines and MSW Rule 2016 norms have been adopted for assessing the waste volume. The detailed calculations for the estimated Landfill capacity and area have been given below.

Table 52Estimation of Volume and Design of Landfill for 20 Years Cell

S. L	Site Calculation by area Method	Qty	Unit
1	Average Waste Receipt	432.22	TPD
2	No of Years	20.00	yrs.
3	Total Waste Receipt during 20 years	3155217.15	tons
4	Achievable Waste Density in Landfill	0.85	tons/cum
5	Waste Characteristics -		
6	*% inert rejects to Landfill*	100.00	in %
7	Waste to Landfill (W) during the period	3155217	in tons
8	Volume of Waste	3712020.2	cum
9	Height of Landfill (H)	15	m
10	Depth of Landfill (D)	4.5	m
11	Slope above G.L (as 1: n1)	3	
12	Slope below G.L (as 1: n2)	2	
13	Area in hectare	26.40	hectare
14	Area in sq.m	264039	sq.m
15	Area in acre	65.22	Acre
16	Length	450.00	m
17	Width	587	m

Table 53 Estimation of Volume and Design of Landfill for5 Years Cell

S. No	Site Calculation by area Method	Qty	Unit
1	Average Waste Receipt	432.22	TPD
2	No of Years	5.00	yrs.
3	Total Waste Receipt during 5 years	788804.29	tons
4	Achievable Waste Density in Landfill	0.85	tons/cum
5	Waste Characteristics -		
6	*% inert rejects to Landfill*	100.00	in %
7	Waste to Landfill (W) during the period	788804	in tons
8	Volume of Waste	928005.0	cum
9	Height of Landfill (H)	15	m
10	Depth of Landfill (D)	4.5	m
11	Slope above G.L (as 1: n1)	3	
12	Slope below G.L (as 1: n2)	2	
13	Area in hectare	7.51	hectare
14	Area in sq.m	75119	sq.m
15	Area in acre	18.55	Acre
16	Length	300.00	m
17	Width	251	m

11.5. Design of Processing Facility ~ Biomethanation

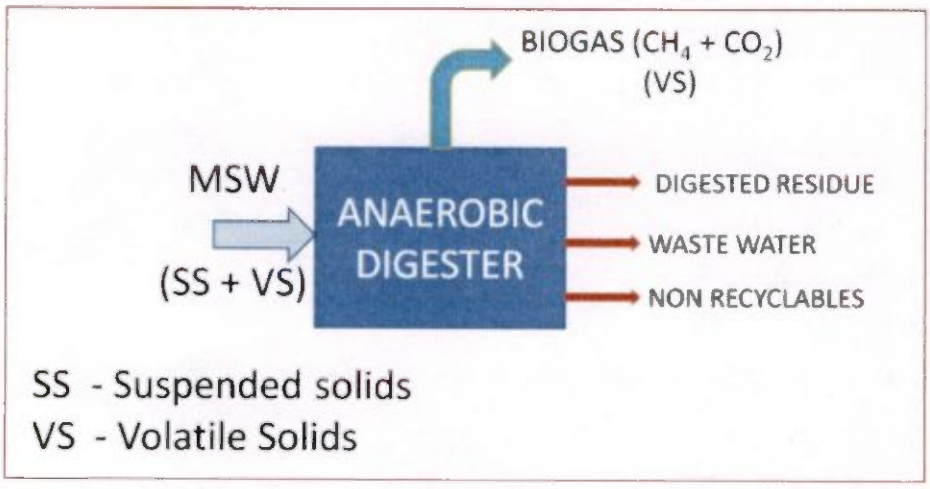
11.5.1. Process of anaerobic digestion

Anaerobic digestion (AD) is the biological breakdown of organic materials in the absence of oxygen. The process is carried out by anaerobic micro-organisms that convert organic material into three different end products.

- Biogas, which is a gas primarily consisting of methane (CH_4) and carbon dioxide (CO_2), with trace amounts of other gases;
- Digested residue, which is a partially stabilized organic material that can be used as a soil conditioner/ compost after proper curing and drying; and
- Nutrient rich liquid fraction, which in some cases can be used as liquid fertilizer if there is an agricultural user nearby or disposed of as wastewater

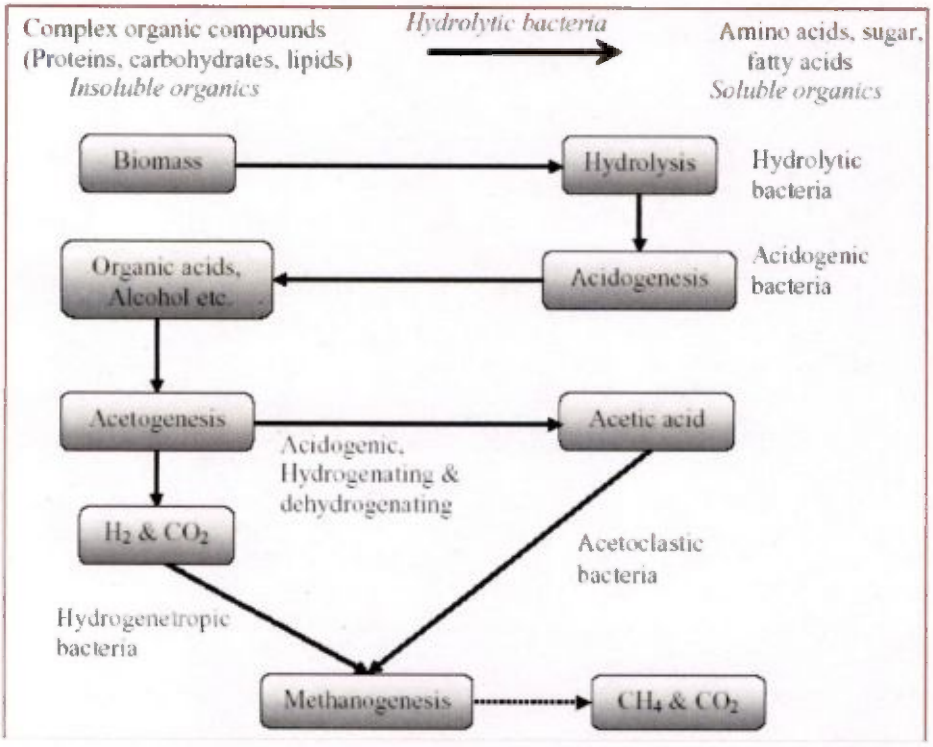
The rejects (inert content of MSW) separated during the pre-digestion process, are sent to the landfill for final disposal.

Figure 45 Flow Diagram for Anaerobic Digestion Process



The digestion of organic waste takes place in two stages. In the first stage, generally referred to as hydrolysis and acidification, organic material is broken down by a group of microns called acid formers. One of the end products of this stage is the production of fatty acids that serves as a food source for different set of microbes. In the second stage, generally referred to as methanogenesis, a group of microbes called methane formers convert the acid produced in Stage 1 into simple products, which consist primarily of methane and carbon dioxide.

Figure 46 Anaerobic digestion process details



Anaerobic digestion systems, in a controlled environment, are now widely used throughout the world for treatment of MSW. Currently, the most popular AD technologies are available in Europe, with Germany and Denmark leading the field in terms of the number of successful plants in operation.

11.5.2. Acceptable feedstock

The feed or organics are defined as more than just food-scraps. The list below identifies the broad range of acceptable materials for processing:

Fruits, Vegetables	Dairy Products	Bakery Waste
Meat, Poultry, Fish	Frozen Food	Dry Goods
Paper Products Not Recycled	Milk, Juice, Beverage Cartons	Personal Hygiene Products
Disposable Diapers	Livestock Manures	Paper Based Packaging
Agricultural Wastes	Organic Sludges & Slurries	Glycol & Other Alcohols
Slaughterhouse Slurries	Food Plant Residues	Pet Wastes

11.5.3. Bio-methanation Technology details for Cluster II

Thermophilic Anaerobic Digestion Technology is an advanced biological process for processing of organic fraction of the waste. The process is suitable for high solids, accompanied with effective mixing and design of reactor.

Pre-treatment

The organic waste shall be fed to the Pulverizer / Homogenizer where the material shall get homogenized and sieved /shredded for size reduction < 10 mm material. After a retention time of few hours in the Pulverizer / Homogenizer, the waste is fed into the AD (Anaerobic Digestion) unit.

Digestion

The AD unit is provided with recirculation. During the anaerobic digestion process, the material passes through the AD unit. The digested residue is extracted from the AD unit from the bottom. The biogas generated is collected at the top.

Biogas Production

The bio-gas generated through Biomethanation process will be used for Power generation.

Power Generation from Bio-Gas

The gas stored in the gas holders is fed to Biogas engines to generate electricity. Necessary utilities, basic safety requirements and instrumentation are considered for proper operation, monitoring and control of the plant performance. The captive power will be utilized from the Gross generated power.

Slurry Dewatering

The residue left after the anaerobic digestion will be dewatered and dried. The dried solid can further be sold as organic compost.

Table 54 Overview of the Technology

SN	Item	Salient Features of the Technology
1.	Technology	**Thermophilic Anaerobic Digestion**
2.	Solid consistency	**Operates at higher solid consistency up to 40%.**
3.	Water requirement	**No water required**
4.	Retention time	**Around 14 days**
5.	Loading rate	**Requires small volumes of digesters because of higher loading rates.**
6.	Gas	**Faster recovery of biogas**
7.		**More production of biogas (100 –120 m3/ton/day)**
8.	Compost	**Produces better qualityorganic compost free of pathogens**

SN	Item	Salient Features of the Technology		
9.		**Complete dry compost**		
10.	Design	**Pre-engineered, Pre-fabricated Containerized/ movable, plug and play**		
11.	Flexibility	**Flexible for variable operating conditions like - Weather, Solid content (TS), Organic Content.**		
12.	**Construction**	**Less Civil works (Only Site foundation/shed), Less Execution time.**		

11.5.4. Advantage and benefits of the technology

Following are the advantage of the method:

- Gives green energy as its product.
- Practically no odors are observed in the system
- Produces better quality organic compost free of pathogens.
- No additional chemicals required to assist composting.
- Completely moveable.
- Pre-engineered, Pre-fabricated, hence less execution time at site.
- Reduced on-site commissioning & hook-up time thus minimal site disruption.
- Negligible O&M cost.

The major benefit of the biomethanation process is as per the following:

- Saving in Collection and transportation cost
- Saving in land due to reduction in the landfill requirement as organic fraction load reduced.
- Saving in O & M cost as captive power can be utilized from the generated power, so no addition cost for power.
- Revenue generation due to excess power (after captive consumption) and compost generation

11.5.5. Designed parameters

- Construction:
  - Fully prefabricated compact design.
  - Ready to install on foundation / level platform
  - Plug and play concept.
- Reliable process for optimum performance under varied conditions
- Modular design with flexibility to expand with minimum
  - Space
  - Time
  - Cost
  - Power requirement

11.5.6. Salient points

In this project 100 TPD Biomethanation plant has been proposed to be installed for four ULBs under cluster II, at 20-acre HIDCO land. The technical data of the plants are given below:

- Input material consideration
  - Total solids (TS) in segregated organic waste - 30 %
  - Organic content in Total solids – 70%
- Required boundary wall/ demarcated area, specified controlled land area
- Civil cost provided for foundations considering SBC of soil - 250 kn/Sqm & groundwater table. Civil cost may change as per site condition.
- The approach to the plot is by all-weather motorable roads.
- Land required to install the plant should be provided by the Client.

- Plot area to be leveled and would be around a rectangular in shape with flat ground /No undulations / Slopes.
- Any variation in the TS & Volatile Solids (VS) value will reflect in Biogas generation accordingly.
- The outputs are based on the Organic Waste characterization assumed on the general thumb rule basis considering that the waste to be processed is delivered at the site as per above assumptions.
- Actual Biogas yields may vary as per waste characterization.
- The outputs generated are Power and compost.

Although this project requires a Biomethanation plant of 400 TPD capacity, however it is recommended to first install a pilot plant of 5 TPD capacity for one of the ULB (possibly in Bidhannagar as a model city) and run it on pilot basis within first few months of project initiation. Based upon the success of the pilot plant 400 TPD plant at HIDCO land may be installed and commission on commercial scale.

11.5.7. Technical specification

The technical specification has been furnished in the table below:

Table 55 Technical Specification of the plant

SN	Specification Heads	Specification for 5 TPD
1	Product Category	**Bio Methanation Plant of 5 TPD Capacity**
3	Maximum capacity of Plant	**5 TPD – Organic Waste Processing Plant (Biomethanation)**
4	Area Requirement during operation	**500 Sq.m (in case of 1 TPD, 150 sqm)**
	Type of Plant	**Containerized, Compact & Modular and Plug & Play Model & transferrable Unit suitable for all climatic conditions**
6	Declaration about Technology	**open to bidders**
7	Type of Waste processed	**Biodegradable**
8	Service Water Requirement	**250 Ltrs. /day**
9	No contact Part of the Entire Plant/ Unit shall be of Mild Steel	**Yes**
10	Net Electricity Production per day after Auxiliary consumption	**250-500 Units/day (max.)**
11	Shredder/Crusher capacity	**800 Kg/hr**
12	Shredder Feed Pump capacity	**5 m^3/hr**
13	Containerized Main Digester with mixing arrangement and Temperature Maintaining Arrangement	**Yes**
14	Main Digester Material	**Stainless Steel Grade 304 (Contact Parts)**
15	No. of Days of Anaerobic Digestion	**20**
16	Type of Anaerobic Digestion	**Thermophilic Digestion**
17	Capacity of Digester	**100 m^3**
18	Thermal Insulation of Digester with Glass Wool & Aluminium Panel Cladding	**Yes**
19	Purification Unit with H_2S Scrubber	**Yes**
	Gas Storage Unit- Balloon with Bio-gas flow	

20	meters with complete Accessories,	Yes
21	Biogas generation per day	500-600 Nm^3/Day
22	Total Power generation per day	750-900 kWh/Day
23	Net Power generation per day =Total Power generation – captive power consumption	380-530 kWh/Day
24	Compost	700 kg/day

- The Calorific value of Bio gas would be approx. 4000 to 5000 Kcal/m3
- Inlet: Plant Premises.
- Rejects: Plant Premises
- Output Power Supply: 415 V AC, 3 Phase, 50 Hz at engine panel.
- Input Power Supply: 415 V AC, 3 Phase, 50 Hz at incomer of the panel.
- Service water: 1-meter flange connection from plant boundary.

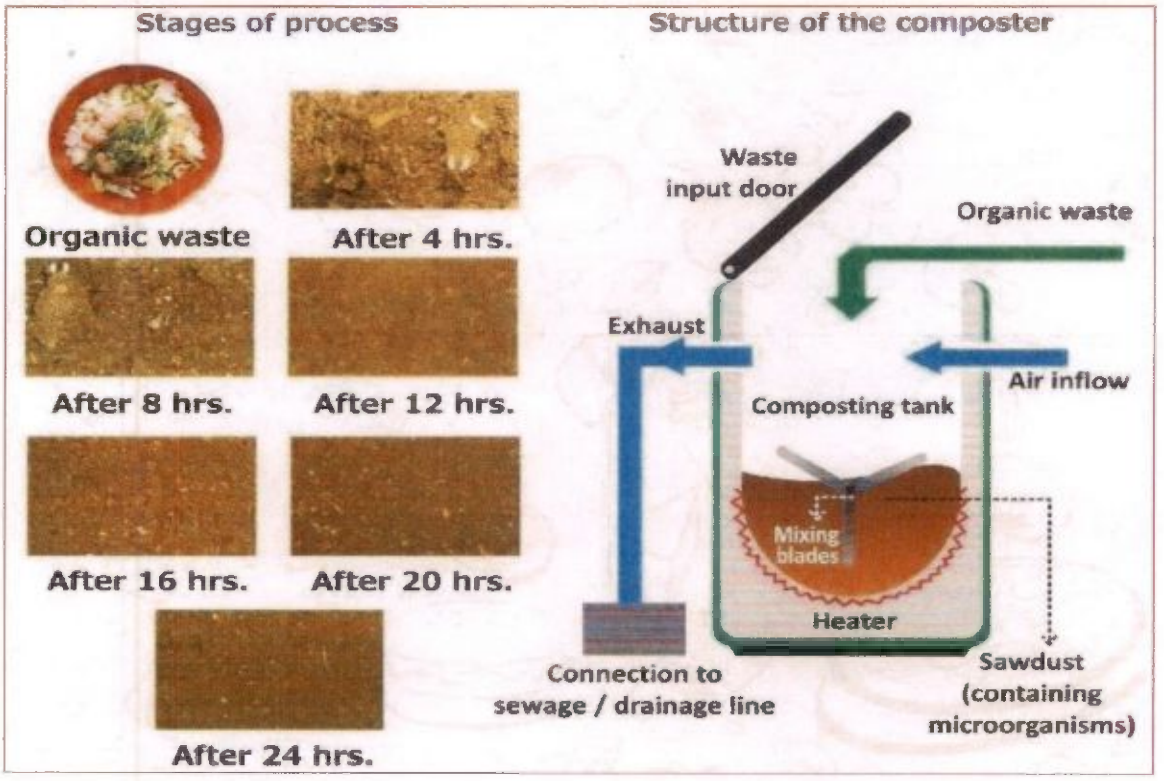
11.6. Design of in-situ organic wet waste treatment plant

Organic food waste generally fosters infectious diseases and attracts rodents, pests and insects leading to unhygienic living conditions. In order to address the organic waste, especially the food waste at the source of generation organic waste converter at domestic or residential society level is being proposed, which would degrade the waste biologically through composting process.

11.6.1. The process

- The entire composting process is natural & biological. The decomposition is done by microbes / micro-organisms which thrive in high temperature as well as in high acidic or salty atmosphere.
- When Food Waste is put in, moisture in the waste is sensed & the tank is heated from below. Due to this the water present in the food is evaporated and sent out to the atmosphere.
- As any food waste contains 75-80% moisture we achieve 75-80% volume reduction due to evaporation. Also, there is no smell of any sort.
- Thereafter, the microbes are activated due to high temperature & they decompose the remaining food. That's how we achieve a volume reduction of 85-90% i.e. 100% waste to 10-15% of compost.
- There is no crushing or grinding taking place in the machine & hence no wear-and-tear which contributes to the long-life span of our machine. The blades in the machine are only for stirring and mixing of waste.
- The compost that is formed as a result of the above process has to be removed once in a month, which can be used for the plants in the garden. Thus, this process completes an ecological loop. The process diagram is depicted below.

Figure 47 Schematic of In-Situ Organic Waste Treatment Process



11.6.2. Design specification

As a model city project, it is recommended to install 350 kg/day organic waste treatment plant at pilot level for domestic purpose. The technical specification of the plant is mentioned below:

Table 56 Indicative Specification of the Organic Waste Converter plant - Module

SN	Head	Details
1	Waste processing capacity per day	**350 Kg**
2	Approx. Dimension	**13 ft (L) X 5.5 ft (W) X 5.5 ft (H)**
3	Input	**All types of organic wastes**
4	Output	**Soil additive**
5	Volume reduction	**85 – 90%**
6	Power rating	**9.0 Kw**
7	Voltage	**440V/50Hz**
8	Control system	**Electronic control**
	Operation	**Fully Automatic**
	Heating system	**Oil bath/Master & slave heating system**

11.6.3. Technical features and technological benefits

The technical features of the process and the details of the plant are described below:

Table 57 Technical Features of the Organic Waste Converter Plant

SN	Key Technical Features	Benefits Over Other Technologies
1	Inner Tank made of SS 304	Main organic waste holding tank is made of 4mm thick inner circular high-grade stainless-steel SS- 304 which guarantees

		no corrosion and hence life of the machine is enhanced. Inner blades attached to the shaft are designed for mixing, hammering and shredding.
2	Outer Body	Outer body is made up of MS Powder coated
3	Oil bath heating system	A) Since the heaters are immersed in oil there is no contact with the atmosphere and hence the climate does not affect the heaters. The heaters life expectancy is much higher. B) The oil uniformly heats the inner tank and retains the heat for a long period of time, resulting in lower power bills and better energy Management.
4	Master &Slave-heating system	Prevents downtime if a heater failure occurs. The slave heaters come on in case of the master heater failure. There is no need to shut down the machine when a heater failure occurs, resulting in a better uptime.
5	Direct Drive technology	The machine uses a direct drive technology wherein the main shaft of the machine on which the mixing blades are fixed is directly coupled to the geared motor by a perfectly matched planetary gearbox. The shaft with the mixing blades is balanced with precision, resulting in better load distribution to main shaft and better mixing. It also prevents main shaft breakage due to metal fatigue and stress.
6	Odor Management	The ODS ensures odour removal from the hot air that is let out through the machine ventilation system.
7	Motors and controls	All motors and control equipment are of International quality, resulting in better efficiency and durability.

11.7. Design of Material Recovery Facility

It has been proposed to develop a centralized material recovery facility at 20-acre HIDCO land of capacity around 550 TPD. The design basis and other features of the MRF is being discussed below.

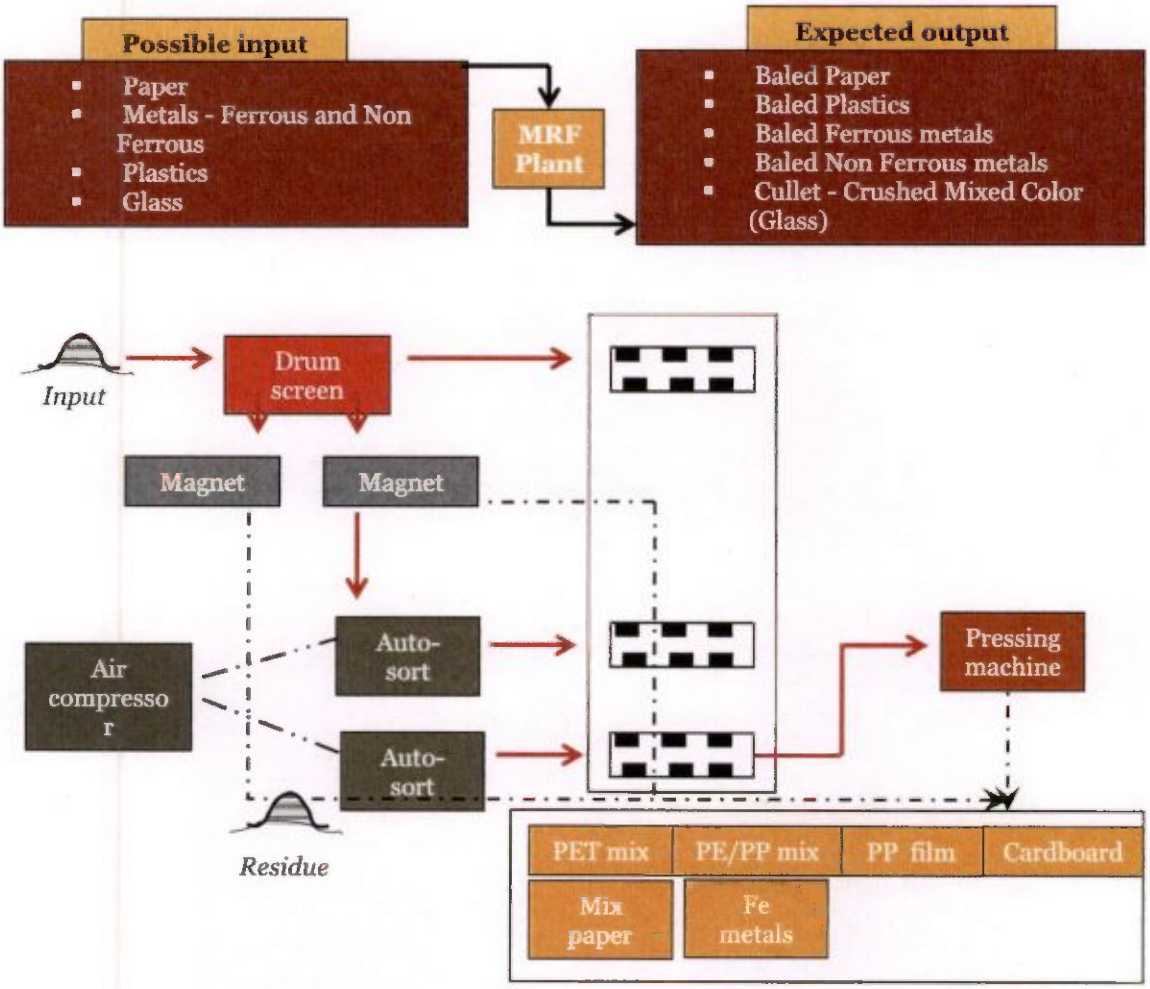
11.7.1. Design basis of MRF facility

A typical MRF is sited within a warehouse-type building with concrete flooring and enclosed by a perimeter fence for security. It will have the following components: (i) receiving or tipping area, (ii) sorting/processing area, (iii) storage area for recyclables, (iv) residuals storage area, (v) equipment area, (vi) space for an office, and (vii) loading area for residuals and processed recyclables. It should also be provided with the basic connections for water and electricity and adequate space for the entry and exit of waste trucks. Provisions for washing and a septic tank must be included. The warehouse design will minimize the placement of columns that could interfere with the efficient movement of materials and equipment and facilitate the installation of higher ceilings. Receiving areas should have the capacity to receive at least 2 days' worth of the MRF's processing capacity in anticipation of equipment breakdown and to provide materials for the second-shift operation, if required. The process flow diagram of the facility is being furnished below.

11.7.2. Process flow diagram

The process flow diagram of an automatic MRF facility is given below:

Figure 48 Process Flow Diagram of MRF



11.7.3. Technical details and area statement

The technical details and area statement of the MRF facility is given in the table below:

Table 58 Technical Details of the MRF Plant

SN	Head	Unit	Details
1	Design waste quantity (dry)	TPD	550 500
2	No of regular shifts	No	1
3	Duration of shift	hr	8
4	Plant capacity	TPH	~ 70
5	Processing Facility (including tipping floor, processing equipment, residue transfer area, and storage)	m^2	7027
6	Scales, Truck Queuing and Outdoor Vehicle	m^2	4260
7	Parking for Rolling Stock	m^2	10892
8	Employee Parking (combined with SLF)	m2	1000
9	Site Buffer Allowance (combined	m2	4650

SN	Head	Unit	Details
	with SLF)		
10	**Total Site area Requirement**	**acre**	**10 Acre**

11.8. Design of Construction and Demolition waste plant

11.8.1. Typical constituent of C&D Waste

The typical constituents of C&D waste are as per the followings:

- Wood
- Bricks, Concrete and Other Masonry Products
  - *Crushed and used for Fill, New Roads, Under lament for Concrete Applications*
- Metals (Ferrous and Non-Ferrous)
  - *Melted into New Products*
- Roofing Shingles
  - *Asphalt Roads*
- Cardboard
  - *Processed used New Cardboard Products*
- Plastic
  - *Made into bottles, floor tile, paneling, plastic lumber, etc.*

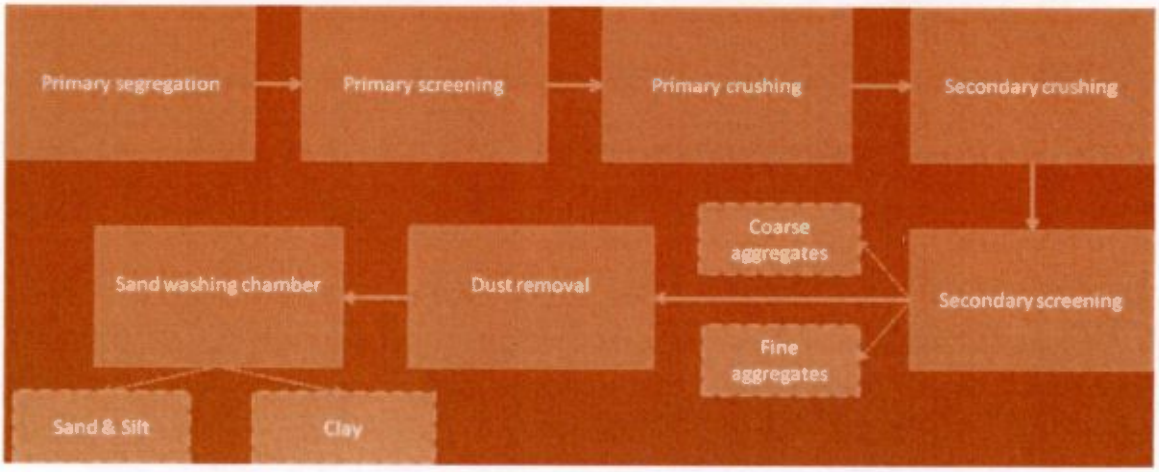
11.8.2. Plant equipment and process flow

The C&D plant at 20-acre HIDCO area shall be comprising of the following components:

1 Feed Hopper with Vibrating Grizzly Feeder
2 Evo Screen – Pre-Screen
3 RotoMax - Log Washer for Aggregate cleaning
4 Trash Screen for removal of light weights
5 ProGrade - Sizing Screen for washed Aggregate
6 EvoWash - Dual Pass Hydro cyclone system for Sand washing
7 AquaCycle - Water Management system for recycling of process water

The process flow of the plant is shown in the below figure:

Figure 49 Process Flow Diagram of C&D Plant



The proposed C&D plant will be a stationery plant with an assembly of crushing, sieving and washing machinery interconnected by conveyer belts for material movement. The machinery will be housed on steel/concrete platforms on a permanent basis. The crushing units will also have dust control systems,

noise control systems, magnetic separator devices and other additional devices based on requirements. The systems are either semi-automated or completely automated units.

11.8.3. Plant capacity and area

The Plant Capacity and area for the C&D waste treatment will be as per the following:

Table 59 Technical Details of the C&D Plant

SN	Head	Unit	Details
1	Capacity of C&D plant	TPD	400
2	Capacity of C&D plant	TPH	50
3	**Area requirement**	**Acre**	4

12. Rehabilitation & Closure of Legacy Site

12.1. Primary considerations

In this chapter, various options for site reclamation and closure of Mollar Bheri disposal site will be discussed including bio-mining, landfill gas capture and waste relocation with reduced footprint. The option of utilization of closed landfill area for solar power generation will also be discussed, here. An assessment to recommend the best feasible option of closure in order to maximize the utilization of land for reclamation has also been provided in this chapter.

12.2. Different closure alternatives

In this section, different closure alternatives will be discussed and based upon the current waste disposal pattern and condition, the suitable option will be recommended. Options, which have been considered & examined while formulating the closure of Mollar Bheri dumpsite, are as follows:

12.2.1. Option 1 - Simple Closure

This option is the simplest option and does not involve any potential recovery of materials, area, or energy. The existing accumulated waste would be levelled and will be capped with top cover. Then the entire area would be vegetated after closure. This option is a least preferable option.

Figure 50 A typical Example of Simple Closure

The above figure depicts closure of a dumpsite without disturbing the position of waste. It does not involve any land reclamation and hence entire area is closed with vegetative cover at top.

12.2.2. Option 2 – Closure with land recovery

It may be mentioned that, Mollar Bheri disposal site has entered the city limits. In other words, the city has been extended to the site periphery. Therefore, the cost of the land has become a prominent

priority of SUDA/ ULBs. Keeping this consideration in view, the maximum recovery of the land from the disposal site is a key criterion of the project.

In this option the entire waste volume will be compacted for volume reduction. It has been observed in section below that there is a potential scope of volume reduction by effective compaction, and thereby achieving the bulk density up to 0.85 gm/cc. Then the waste will be shifted and moved to a particular place. It is estimated that by doing this significant portion of the land could be reclaimed. Then the shifted waste will be covered and capped.

Based upon the volume of waste and a considering a slope of 1:3.5 (recommended side slope as per SWM rules, 2016), the foot print of the waste area & height of closure shall be evaluated. This option could be considered as one of the preferable options. However, it may be noted that although simple closure gives a flat surface, but due to un-compacted loose waste material, it does not support the civil foundation to stand. Hence, from construction point of view also, the shifting of waste and reclamation of land with base soil is seen to be a desirable proposition. Figure below depicts the closure activity with land reclamation option.

Figure 51 A Typical Example of Waste Shifting & Land Reclamation

12.2.3. Option 3 – Closure with landfill gas recovery

This option can be exercised wherever there are potential of landfill gas extraction and utilization. Slope reformation is done along with closure of dumpsite with HDPE liners and thick layer of clay. Vertical or horizontal gas collection wells are connected to the gas collection network i.e. consisting of HDPE pipe, blower and flare. The landfill gas after purification can be utilized in a gas engine for power generation or for steam generation.

Although this option evolves methane gas with a conversion potential into fuel, but it has certain demerits. The LFG recovery option is feasible only in the cases where there is significant quantum of underlying unburned waste in the waste pile of at-least more than 7-8m with minimal disturbance and regular soil cover to prevent unabated escape/destruction of the landfill gas into the open atmosphere. However, in case of Mollar Bheri dumpsite, there has been many incidents of frequent burning of

waste and shifting/spreading of waste heaps in the past. This option, further, does not guarantee potential recovery of land, which is one of the priorities of ULB, from economic point of view. A typical pictorial view of landfill gas recovery from old dumpsite is shown in below figure.

Figure 52 A Typical Example of Landfill Gas Recovery

12.2.4. Option 4 – Closure with bio mining and land reclamation

Bio mining and land reclamation is a process whereby solid wastes, which have previously been landfilled, are excavated and processed. Processing typically involves a series of mechanical processing operations designed to recover one or all of the following: recyclable materials, a combustible fraction, soil, and landfill space. In this option, material will be recovered from the landfill, which is technically termed as bio-mining, followed by compaction, shifting of waste and reclamation of the available land.

In addition, LFMR can be used as a measure to remediate poorly designed or improperly operated landfills and to upgrade landfills that do not meet environmental and public health specifications. Material recovery operations associated with LFMR activities undertaken to-date have primarily comprised soil and metals removal, and, on occasion, the preparation of a refused derived fuel and the replacement and compaction of residual materials back in to the landfill.

Typical equipment used in simple LFMR operations includes excavators, screens, and conveyors. An adequate working area equipped with a leachate, odor and gas management system is needed for carrying out the sorting & segregation of the excavated waste. A storage go-down is further needed to store the recovered material

Many projects of landfill mining have been taken up in developed economies where the value of the materials in the sites is expected to be high, where the value of the land if it could be reused is high and where the engineering of landfill sites since the 1970s makes them most suited to mining activities. There are more than 100 documented projects of LFMR undertaken worldwide since the first recorded project in Israel in the 1950s.

From commercial point of view this option is the most appealing, as it reclaims land as well as recovers the usable materials. The below figure depicts waste movement & shifting activities in the waste disposal site, as well as the trommel which is recovering usable materials from waste stream.

However, one of the key barriers to LFMR is the difficulty in understanding the composition of the waste that has been landfilled. In the cases where there are no past records of waste quantity & composition, there could be an issue regarding the quality of recovered. The quality of materials from a landfill is likely to be poor when compared to wastes being processed from 'new' or 'fresh' waste and materials are likely to be contaminated with soils, leachate and other materials, resulting in increased difficulties in obtaining quality recyclable materials. As such, market values for recovered plastics, metals etc. may be lower, and this could undermine the business case for landfill mining operations.

Figure 53 A Typical Example of Waste Shifting & Material Recovery

From the previous discussions, the following advantage and disadvantages could be summarized for all four options:

#	Closure Options	Advantages	Disadvantages
1	Top capping and covering with vegetative layer	• Simple to implement • Less cost • Less f manpower and machinery requirement • No need of significant waste compaction • No need of slope stabilization	• Does not reclaim any land • No material recovery from the landfill • No potential gas recovery • The site cannot be used for any other purpose
2	Closure with waste shifting only	• Maximum reclamation of land is possible • Optimized economic appeal	• Involves more equipment and time • No usable material recovery

3	Closure with Landfill Gas (LFG) recovery	• Simple process of covering • No compaction required • Option for generation of fuel	• Requires skilled technology • No material recovery from the landfill • No land reclamation • The site cannot be used for any other purpose • More O&M cost • Expensive, most cost involvement
4	Closure with waste shifting and material recovery	• Land reclamation is possible • Usable material is recovered • Has high economic revenue	• Proper waste compaction is required • Waste slope stabilization is required • More manpower and equipment involvement

12.2.5. Solar power generation

Closed dumpsites can also be used for generation of solar power.

There are many persuasive commercial arguments in favor of extending the role of former landfill sites to include the generation of solar power. The first and most obvious arises from the fact that many former landfill sites had a connection to the electricity grid. The availability and capacity of an existing grid connection is normally a significant factor in the development of a large-scale solar PV facility and could therefore considerably reduce both cost and timescale. The connection could potentially be optimized by using the solar farm to generate and export electricity during daylight hours.

The natural attributes of a closed dumpsite i.e. being a tall structure, out of the shadows of the tree line - gives it a unique advantage as a solar project. Installing the solar panels is initially more expensive than the usual method of closing landfills, but the solar liner pays off with lower maintenance costs.

The major issues in solar park project on dumpsite are wind loads, site slope, panel weight, foundation design considerations, landfill settlement, control of leachate and gas, shading effects, economic and environmental. Differential settlement occurs at varying rates across an area because of the variations in the depth, type, method of waste disposal and decomposition rate within the underlying landfill. Its effects would in the past normally have resulted in damage to solar panel frames and foundations, ultimately leading to failure of the panels themselves as well as creating an unsightly layout. It would previously also have been hard to anchor the structures, since an engineered cap often covers former landfill sites in order to prevent the ingress of water and the escape of landfill gas.

However, new technological advances in panel mounting and framing systems give landfill operators a way around these problems.

12.3. Selection of technology

From the above discussions and comparative analysis option 4, vis-à-vis, closure with waste shifting and material recovery through Bio-mining process may be selected for the proposed reclamation project. The reasons are:

- Dumpsite reclamation results in recovery of land for further use, e.g., construction of saleable buildings by ULB or any other purpose.

- Revenue is generated from the sale of recovered combustible material.
- Reclaimed soil can also be used as filling material after excavation, during any construction work taken place in the reclaimed land. Thus, the cost of filling soil could be reduced
- Combustible waste from the landfill, if any, can be used for the production of refuse-derived fuel (RDF) and sold to cement or power plants for co-processing or co-incineration.
- Dumpsite reclamation reduces costs of dumpsite closure and post-closure care and monitoring.

Based upon the analyses mentioned in this chapter the option of land fill closure by means of – ***waste shifting, compacting, usable material recovery and thereby reclaiming the utilisable land, free from waste, has been selected. The shifted and moved waste shall be capped & covered at top with vegetative layer.***

In the following chapters the technical details of this selected closure options have been discussed.

12.4. Status of waste accumulation at Mollar Bheri

As of 2019, around 1250 TPD of waste is being generated from four ULBs under the project. Presently from BMC, NKDA & NDITA MSW is reaching to Mollar Bheri in tune of 600 TPD. Mollar Bheri is spread over an area of about 25 acres, out of which entire area is covered with waste. This site is operating since last couple of decades. The present dumpsite falls under the category of uncontrolled solid waste disposal facility. Due to this scenario, anaerobic decomposition of organic content of the waste is leading to landfill gas generation, comprising mainly of methane. As, this site is not scientifically managed, there is no control over the escape of the landfill gas into the atmosphere.

12.5. Planning of closure of existing dumpsite for land reclamation

Reclamation of land is a relatively new approach used to expand municipal solid waste (MSW) capacity and avoid the high cost of acquiring additional land. Once it gets filled, the landfill must be closed, and no solid waste should be received at the site. To utilize the available space optimally, Bio-mining of significant quantity of waste is recommended, followed by slope stabilization and waste relocation and compaction with its capping, which would subsequently help to reclaim some useful land at site, as well.

12.5.1. Quantity assessment &design parameters

As discussed earlier, Mollar Bheri is an unscientific disposal site where the mixed municipal solid waste is being dumped since last couple of decades. The total area of the said site is about 55 acres out of which, active dumping has happened in more than 45% area. As of now, the waste confined area of the site is around 25 acres with a height of around 12-15 ft.

In order to comply the environmental norms and to mitigate the social & environmental hazard due to this dumpsite, a reclamation process of the site through Biomining process has been conceptualized/ initiated. Under this process, major part of the accumulated portion of area (say A, about 65% of 25 acre) has been proposed to be reclaimed. The reclamation process will comprise segregation of combustible part and inert part from the mixed legacy waste and then to separate out them from the site. After reclamation, a portion small piece of area (say B, about 10% of 25 acre) within the same legacy site would be utilized for deposition of the rejects, generated through this Biomining process. And another part of the land (say C, about 25% of 25 acre) shall be utilized as a confined active area, which could be utilized (in controlled manner) for disposal of incoming fresh waste (till the time any alternative disposal site is identified).


Google Earth
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Image © 2019 Maxar Technologies
200 m
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Table 60 Design parameters

SN	Head	%	Acre
1	Total Area (acre)	100%	25
2	Reclamation area	65%	16.25
3	Inert disposal	10%	2.5
4	Active disposal	25%	6.25

SN	Head	Unit	Details
1	Accumulated waste quantity as on June,2019 (topo survey 25 acre)	Cum	155853
2	Additional waste during the project period @ 508 TPD	Ton	185420
3	Density of fresh waste, as per survey	t/m3	0.496
4	Compaction reduction during operational phase, achievable density	t/m3	0.7
5	Volume of incoming waste	m3	264885.7143
6	Total waste to be handled in biomining process	m3	420739
7	Rate of biomining	Rs per m3	500
8	Project cost	Rs Cr	21.036936
9	Consider GST (for sanctioning purpose), 12%	Rs Cr	2.524
10	Total Project cost	Rs Cr	23.561368

12.5.2. Reclamation and reuse plan

Mechanism or Approach

This flow is only for guidance, the process may change according to the site requirement and composition of the waste when actually work at site starts:

- Identify and earmark the area required for establishing the new facilities on the 25 acres layout.
- Volume of waste to be determined through contour survey and site measurements. Weighment of heaps is difficult and problematic as gaseous emissions could endanger operators especially when no treatment is done. Hence initial Contour level survey of the site has been done. Final Contour level survey shall be done before completion of the work.
- Bioremediation treatment should be done by dividing the site into suitable blocks of 100 sq.m to 200 sq.m.
- With the help of Back Hoe loader, the waste in the demarcated area will be loosened up. Usually the top layer has several materials in the active biological state. This layer is to be stabilized through herbal/biological sanitizers and water.
- Raking of garbage layer through long spike harrow operating in cross directions is to be done regularly to pull out rags, plastic, rubber, textiles etc. big size of rags, plastic, rubber, textiles etc. will be taken out with help of laborer's by manual means.
- This waste shall be accumulated by the laborer's at a designated place on the site. Initial cleaning of recyclable & combustible waste may be required before it is bundled for transportation for sale or disposal.
- The left-over waste shall be formed into open windrows of suitable height and length with help of back hoe loader.
- Additives like bio culture, raw compost or cattle dung to be added as desirable microbial substrates for speedy fermentation of waste and achieving of thermophilic temperature range of 55 to 65-degree C.

- Since the waste is old garbage most of the organic matter has already been decomposed. After 7-10 days of stabilization the waste shall be taken up for screening.
- Coarsely material and garbage shall be screened through rotary/horizontal screens.
- The recovered earth can be used for ground levelling, bund making of the landfill closure, base filling of the road, landscaping, gardening. Authority in consultation with other concerned departments should also find out a green area where this "soil enricher" can be spread. This soil enricher shall be tested intermittently about the ingredients before use.
- The stone, bricks, ceramics which are removed while screening and raking should be used as landfilling cover material preparation.
- The recyclables like plastic glass metal rugs cloth recovered from the waste during screening shall be sort out manually. The waste thus collected shall be bundled. This waste may be used in cement plant refractory of for making fuel or can be directly sold.
- A part of site shall be clearly ear marked for storage of recyclable and reusable materials, which will be recovered from bioremediation process of accumulated waste.
- Identify the area where the excavated waste from the above site is to be trans-ported and dumped. The locations suggested by us are the opposite side of flyover and then profile the entire dump into a single contagious mass with slopes of 1:3.5.
- Heap up the transported waste to as high as possible in those portions and also over the existing dumps Excavators and JCBs should be deployed to transfer excavated waste into trucks/conveyors. This dumping of the trans-shipped material will be in accordance to the finalized levels of both top and slopes. The trans-shipped material shall also be subjected to a regular consolidation with spiked & vibratory compactors.
- Once the total relocation of waste is completed, the dump will be brought to its final shape. Requisite soil layer will be laid over the final profile. Above the soil covers vegetative soil will be laid to support vegetation.
- Gas collection and venting system will also be provided to collect the LFG gas generated. If the gas quantities are large the same will be sent to the power plant and if the quantities are less LFG will be vented out or connected to flaring system
- The capped portions of this landfill should be maintained throughout the cooperation period.
- It is proposed to excavate and biomine around 30% of the accumulated waste. The idea is to make use of the top lying waste of the dumpsite which must be having some useful material. The dumpsite being so old, the waste beneath the top layers of 3-4 m, especially lying in the inner sides of the dumpsite, must be already fully decomposed and would already be in compacted form. Hence, should not be disturbed.

Technical Steps at Site

Pre-stabilization – The disposal site is converted into equal sized windrows and turned frequently along with spraying of bio-culture and de-odouriser. This would ensure removal of stench, reduction of flies, and elimination of pathogenic activities, complete biodegradation and reduction of moisture.

Sorting and segregation – In this stage, mobile equipment separates and excavate waste into soil, stones and combustibles.

Disposal – In this stage soil, inert and non-combustible are disposed as construction material/ earth filling material/ soil enricher etc. and the combustible part as refused derived fuel.

Table 61 Timeline

Head	Unit	Value
Operational capacity	Tons/ day	1500
Total waste	Tons	340494
Days required	Day	226.9958233
Months	Month	7
Erection period	Month	3
Total months	Month	10

13. Environmental Management and Monitoring Plans

The proposed project Solid Waste Management, comprising development of landfill and closure of Mollar Bheri, which in itself, is a project for environmental and social betterment of the local urban area. However, any activity aimed at development, will have repercussions on the environment, on both positive and negative ways. This chapter will essentially highlight the potential impacts that are likely to occur due to closure and post closure operations. The contents of this chapter are focuses on the same specifically the EMP related to the project

Environment Management Plan (EMP) plays a vital role in safeguarding the environment largely through reducing the negative impacts of the project. The proposed project has positive and few negative impacts during closure and post closure phase for which mitigation measures are suggested.

13.1. Environmental Management Plan

13.1.1. Air environment management plan

EMP for Closure Phase

During closure phase, the main air emission anticipated is dust. The most cost-effective dust suppressant is water. Water can be applied using water trucks, handheld sprays and automatic sprinkler systems. The following procedural changes in the construction activities are suggested to reduce dust emission:

Idling Time Reduction - Equipment are generally left idling most of the time while the operators are on break or waiting for the completion of another task. Emissions from idling equipment tend to be high, since catalytic converters cool down, thus reducing the efficiency of hydrocarbon and carbon monoxide oxidation. Existing idling control technologies, which automatically shut the engine off after a pre-set time can reduce emissions, without intervention from the operators.

Improved Maintenance - Recognizing that significant emission reductions can be achieved through regular equipment maintenance, contractors will be asked to provide maintenance records for their fleet as part of the contract bid and at regular intervals throughout the duration of the contract.

Reduction of On-site Construction Time - Rapid on-site construction would reduce the duration of the project as well as reduce the emissions. Off-site fabrication of structural components can also enhance the quality of work, as the production takes place in controlled settings and external factors such as weather and traffic do not interfere.

Other measures to control dust emissions include reducing the vehicular speed limit on the landfills and working on a smaller area at one point of time.

EMP for Post-closure Phase

During this phase, the main issue is involved with the landfill gas management system. However, for this closed site, where rejects are mostly soil in nature due to bio-mining activities, this issue may be minimally envisaged. However, detailed management plan is described in landfill gas management plan section.

13.1.2. Odor control &management plan

Significant odour will be generated from Mollar Bheri disposal site, during the closure phase of the project. Following mitigation measures have been suggested to control odour:

- Excavation for slope reformation shall be done on a smaller area at one time and levelling and covering of the open patch shall be done as early as possible to avoid odour emanating from the waste
- High odour producing activities (e.g., drying & segregation) will be limited to specific times of the day, temperature or wind conditions
- Odour neutralizing solutions shall be used
- Excavation of odour producing waste may be suspended during the times when winds are blowing towards residential areas, warm weather and / or during the time of the day when there is a higher public presence in the vicinity of the landfill.

13.1.3. Noise management plan

EMP for Closure Phase

To mitigate the impact of noise from vehicle & equipment during the closure phase the following measures are recommended for implementation:

Noise Shields - Construction equipment producing the maximum noise level should be fitted with noise shields.

Time of Operation - Noisy construction equipment should not be permitted during night hours.

Job Rotation and Hearing Protection - Workers employed in high noise areas will be rotated. Earplugs/muffs, or other hearing protective wear will be provided to those working very close to the noise generating machinery.

EMP for Post-closure Phase

During the post closure phase of the project, sources of noise pollution from landfill include mainly the DG set & vehicles. To mitigate the impacts of noise arising during closure phase the following measures are recommended:

- Acoustic DG set with enclosure should be used
- Routine maintenance of the DG set should be done to keep noise level within prescribed limits.
- Use of personal protective devices such as ear-muffs, ear-plugs etc. should be strictly enforced for the workers engaged in high noise areas,
- It would be ensured that low noise equipment is procured wherever feasible
- Development of peripheral green belt is expected to reduce noise impacts from the project activities. Species such as Tectona grandis (Teak), Butea monosperma (Palash), Leucana leucocephala (Subabual), Mangifera indica (Aam) and Dalbergia Sissoo (Shisham) have been proposed for greenbelt development.
- To control noise pollution due to vibrations, necessary spacing between individual vibration producing equipment shall be provided to subside the vibrations generated at individual units
- Vibration generating sources and their platforms would be maintained properly to mitigate vibrations.

13.1.4. Leachate management plan

Leachate is a generated from storm water and moisture. Leachate is considered to be a contaminated liquid, since it contains many dissolved and suspended materials. The fundamental approach in controlling leachate is first to confine leachate to the limits of the landfill, and then to collect and dispose it safely. The leachate shall be collected through a system of collection pipes and provision may be made for on-site leachate treatment using solar evaporation ponds. Evaporation ponds rely on solar energy to evaporate water from the leachate, leaving behind precipitated salts.

The main components of leachate collection system are drainage layer and conveyance system. Leachate conveyance system is a network of pipes by which the leachate is collected through perforated HDPE pipes and collected in a sump.

The leachate collection system is a network consisting, 100 mm diameter feeder pipes @ 20 m spacing, connected to 150 mm diameter header pipe. The pipes are HDPE perforated pipes with sufficient strength (minimum 6 kgf) and are safe from particulate and biological clogging and deflections. The main header pipe of 250 mm dia. is connected to leachate collection sump. The purpose of leachate collection sump is to collect the leachate from entire landfill on daily basis. Generated leachate will be managed by leachate collection sump.
Leachate collection network face major operational problems due to clogging and choking of pipes. Some of the common causes and preventive measures have been discussed below:

Management Plan against Clogging of Leachate Pipes

Leachate pipes can be susceptible to particulate and biological clogging similar to drainage layer material. Proper maintenance and design of pipe systems can mitigate these effects and provide systems that function properly. Leachate trench provide better collection efficiency to the collection system. Leachate pipe back-flushing or break through water after leachate head builds up are some of the options needed to be explored under operations. Listed are some of the corrective actions that can be taken as a safeguard strategy to proper leachate management mechanism:

Table 62 Leachate Management Checklist

SN	Rationale	Description
1	Protective Mechanism for Leachate Pipes	A wrap of geo-membrane layer around the collection pipe helps reduce pipe clogging.
5	Infiltration Control	Using state-of-the-art cover design and surface and subsurface water interception systems.
7	Ease of Access	Providing easy access to pipes for inspection and maintenance through the use of specialty pipe connectors, sweep bends. 6-in. or larger pipes. Cleanouts at strategic locations, etc.
8	Covers for Manholes	Preventing wind-blown debris from entering lines
9	Traffic on Pipes	Minimizing potential for pipe collapse through design/operation which would eliminate or reduce traffic on pipes.
11	Side Slopes	Using suitable side slopes and protective cover to prevent erosion washing of clay from side slopes.
12	Construction QA/QC	Supervising construction to ensure conformance with design specs.
14	Preventive Maintenance	Periodically inspecting and cleaning lines and cover maintenances.

13.1.5. Storm-water management plan

Surface water management is required to ensure that rainwater run-off does not drain into the landfill area from surrounding areas and that there is no water-logging / ponding on covers of landfills.

To develop a model for the drainage network, the entire site would be laid with a number of nodal networks. Each segment (node to node distance) shall cater the storm water of the adjoined area. Each segment shall also carry the storm water of all previous segments. The slope of the segment has been tried to keep as per the Finished Natural Gradient, wherever possible.

The design scheme should be formulated to cater all the storm water that would be accumulated during the precipitation in the entire waste management facility. For this purpose, peripheral drains along the road and internal drain adjoined to the different individual facilities shall be constructed. The drains will be with respect to the finished ground level wherever possible and/ or provided with sufficient longitudinal slopes in order to enable the gravity flow of water. The water will be conveyed to the lowest gradient area of the site and will be disposed off to the existing nallah at the north-western side of the site.

In order to achieve that, following management plan shall be adopted:

- Rainwater running off slopes above and outside the landfill area should be intercepted and channeled to water courses without entering the operational area of the site. A low permeability lining shall be provided to prevent leakage into the closed landfill.
- Rain falling on active waste handling area (during closure period) should be collected separately and managed as leachate through the leachate collection drain and leachate collection sumps.
- Rainfall on final covers should be diverted away in drainage channels and directed through a settling pond to remove suspended silt, prior to discharge.
- Any drainage channels or drains constructed on the resorted landfill surface should be able to accommodate settlement, resist erosion and cope with localized storm conditions.

13.1.6. Landfill Gas (LFG) management plan

Landfill gas is generated as a product of waste biodegradation. In landfill sites organic waste is broken down by enzymes produced by bacteria in a manner comparable to food digestion. Considerable heat is generated by these reactions with methane, carbon dioxide, nitrogen, oxygen, hydrogen sulphite, carbon dioxide and other gases as the by-products. Methane and carbon dioxide are the principle gases produced with almost 50 – 50 per cent share.

When methane is present in the air in concentrations between 5 to 15 per cent, it is explosive. Landfills generate gases with a pressure sufficient enough to damage the final cover and largely have impact on vegetative cover. Also, because only limited amount of oxygen is present in a landfill, when methane concentration reaches this critical level, there is a little danger that the landfill will explode. As suggested by CPHEEO Manual the gas management strategies should follow the following three plans,

- Controlled Passive Venting
- Uncontrolled Release
- Controlled Collection and Treatment

Since Mollar Bheri disposal site is going to be a closed and reclaimed landfill, the gas generation is anticipated to be very less. The principal components of landfill gas are Methane (CH_4) and Carbon dioxide (CO_2) and USEPA has identified another 47 type of toxicants and carcinogens liberate from the landfill. For closed landfill site at Mollar Bheri, a passive gas venting system is proposed. Passive gas venting systems shall be provided over the site for LFG management. Passive gas collection systems use existing variations in landfill pressure and gas concentrations to vent landfill gas into the atmosphere. Shallow gas venting pipes shall be installed within the landfill and vented to the atmosphere, to allow gas from interior regions of the closed landfill to escape. In passive venting, gas is released to the atmosphere without treatment.

13.1.7. Landscaping plan

During the closure of Mollar Bheri disposal site, plantation shall be done for three specific reasons –

- *Plantation for beautification of the area*
- *Plantation to absorb air pollutant*
- *Re-plantation, pertaining to the cutting of trees, if any*

During the operational phase, air emissions will be from the vehicular traffic and operation of the DG sets. Based on the location, suitable type of trees and plants will be recommended as a part of the greenbelt development plan to mitigate the impact and to restore the damaged habitat of the region.

13.1.8. Guideline for plantation & landscaping

Selection of plant species is to be done on the basis of their adaptability to the existing geographical conditions and the vegetation composition of the topography of the region.

Also, the selection of plant species will be done carefully, as such they are of fast-growing variety, perennial and evergreen with thick canopy cover, large leaf area index (LAI) and a high pollution attenuation factor (PAF) for effective dry deposition of particles and fibers.

In order to assure proper greenbelt development, following management plan will be adopted:

- Healthy and established sapling having 1m height should be selected for planting in greenbelt to avoid mortality
- Pit measurements of 0.6 m x 0.6 m x 0.6 m are to be dug up at desired point in triangular pattern
- The tall shrubs and dwarf trees with 3 m spacing between plants and rows is sufficient while medium and tall trees in middle and rear rows are to be planted at a distance of 6-7m and 8-10m apart respectively depending upon the space available.
- Close plantation is recommended for accommodating a greater number of trees per unit area resulting in more leaf surface
- The pit should be filled with mixture of cow dung manure and soil in ratio of 1: 4. 10 gm BHC of 10% concentration should be properly mixed with the soil and manure to kill the termites and insect.
- Close plantation with three tiers system keeping dwarf trees with round canopy exposed to the source of emission followed by medium and tall trees with cylindrical canopy is ideal design for the polluted area, because all plants are exposed to the pollutants.
- Close plantation also results in tall trees with deeper roots and ultimately yield more bio-mass per unit area and more efficient absorption of pollutants. Plantation of trees in staging arrangement in multiple rows across the direction of the wind is recommended for better trapping and absorption of the pollutants.

13.1.9. Recommendation of species for plantation

Following is a suggestive list of the plants, which could be considered for pollution abatement:

Table 63 Suggestive List of the Species for Dust pollution abatements

SN	Scientific Name	Height	Duct collection Index
1	Albizzia lebbeck	Tall	Moderate
2	Azadirachta indica	Tall	Fair
3	Pithecolobium dulce	Tall	Moderate
4	Ficus glomerata	Tall	Moderate
5	Ficus infectoria	Tall	Moderate
6	Polyalthia longifolia	Tall	Moderate
7	Tectona grandis	Tall	Moderate
8	Terminalia arjuna	Tall	Moderate
9	Bauhinalia purpurea	Medium	Good
10	Cassia fistula	Medium	Fair
11	Lagerstroemia flosreginae	Medium	Fair
12	Saraca indica	Medium	Fair
13	Thesperia populrea	Medium	Moderate
14	Acacia Arabica	Dwarf	Good
15	Diospyros embryopteris	Dwarf	Moderate
16	Parkinson aculeter	Dwarf	Good

13.1.10. Summary of environment mitigation measures

Environment mitigation measure addresses all the adverse environmental impacts of the proposed facility. This would also include the social and health and safety issues.

Table 64 Environmental Impact & Mitigation Measures

Service	Risk Involved	Mitigation Plan
Collection	Waste spillage by stray animals	Covered bins
	Removal of recyclables by rag pickers	Waste collected by primary collection vehicles directly transferred to refuse compactors, which transfer the waste to the landfill site, thus ensuring minimum ground touch during the collection and transportation.
	E-waste, hazardous waste getting mixed with household waste	Separate collection vehicles for e-waste and hazardous waste
	Huge emissions while operating the vehicles in highly dense areas	Rickshaws will operate in highly dense areas and hence contribute to emission reduction
	Spillage of waste around collection bins	Waste will be majorly collected from each household and the collection bins will only be used for waste collected from street sweeping as well as pedestrian waste
	No door-to-door collection of waste	Propose a plan for door-to-door collection of municipal solid waste by also charging user-fees and penalty for irresponsible disposal of waste
	Nuisance due to location of waste collection bins. During the monsoon the waste may mix with the runoff and may potentially create unhygienic conditions around the site	Covered collection bins are proposed and are placed on a slightly elevated impervious area
Storage at Satellite Stations	Spillage of waste during unloading and loading	Solid and covered platform must be made, and proper equipment should be provided to handle the waste
	Delay in tertiary transportation due to some unavoidable issues	Provisions must be made at the satellite station to store the waste for a few more days in any emergency, especially for wet waste
Transportation	Waste Spillage while transportation	Transportation in covered vehicles
	Non-collection of waste in a particular region due to non-functioning of any vehicle	Centralized GPS monitoring as well as stand-by vehicles will ensure that the waste is collected as schedules
	Spillage of waste while transferring waste to refuse compactors manually	Auto-tippers will transfer the waste to the refuse compactors
Segregation	Poor segregation resulting in poor collection of recyclables	Automatic segregator will ensure efficient segregation
	Theft of recyclables from segregation unit	Segregation unit has been planned in the centralized landfill site with proper boundary walls
	Odour nuisance	De-odorizers in place to maintain
Disposal & Landfilling	Landfill site being accessed by stray animals	Landfill site provided by boundaries to prevent this
	Leachate contaminating the ground water as well as downstream water courses	Proper leachate collection system is planned; further landfill site not close to any water body
	Landfill site prone to	Gas collection system provided to reduce the

Service	Risk Involved	Mitigation Plan
	frequent fires	leakage of methane and hence prevent fires; further fire hydrants provided at the landfill site
	Contaminated air at the landfill site	Ambient air quality in and around the landfill site to be maintained
	Loss of amenity, aesthetics, property values to neighbors	Landfill site lies at more than 250 meters from any residential establishments
	Odor Nuisance	Adequate buffer in the form of green belt to be provided
Safety of manpower involved in operations	Health and safety hazards to workers during waste collection, transportation and at compost and disposal site	Occupational Safety Plan shall be prepared. This shall include: (i) provision of personal protection equipment such as gloves, boots, (ii) Eliminating manual handling of waste; and (iii) Training of workers on safe handling of waste

13.2. Post-Closure Environmental Monitoring Plan

Environmental monitoring plan represents a guideline to assess the quality of different physico-chemical parameters in and around the Mollar Bheri disposal site, such as – groundwater, soil, ambient air quality, noise etc., and thereby indicates the requirement of taking necessary measures to ensure the safe & acceptable condition of the same.

Below the following monitoring plans have been discussed:

- Groundwater monitoring plan
- Surface water monitoring plan
- Ambient Air Quality (AAQ) monitoring plan
- Soil quality monitoring plan
- Quantity and Quality of Gas Generated
- Quality of Leachate after treatment

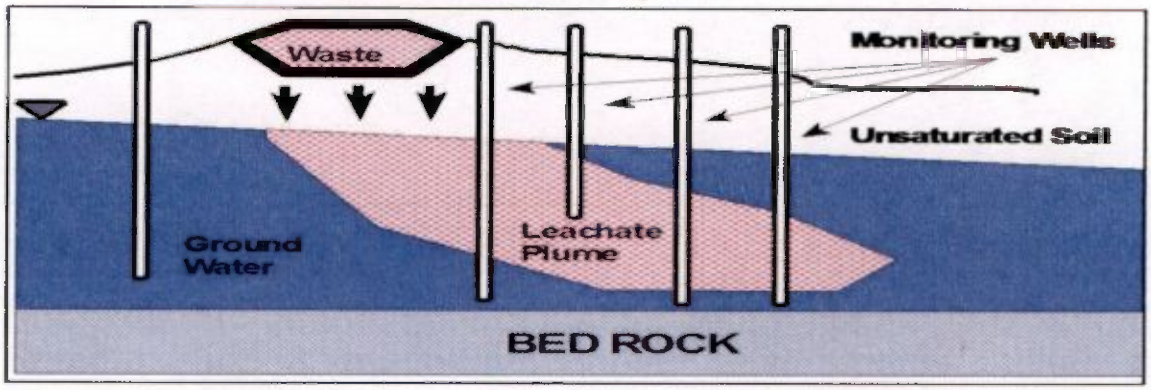
Table 65 Sampling Specification for Environmental Monitoring

SN	Description	Sampling Specifications
1	Quality of Leachate after treatment	One grab Sampling at out let of the treatment plant every month
2	Surface Water Quality	One grab sample at upstream side and one grab sample at downstream side for water body near the landfill site monthly
3	Ground Water Quality	One sample at up-gradient side and three samples at down-gradient side of the closed landfill site every month
4	Quantity and Quality of Gas Generated	24 hours continuous stack monitoring at selected vent on every month
5	Ambient Air Quality	48 hours continuous ambient air quality monitoring at one location in upwind and three locations in downwind directions every month

13.2.1. Ground water monitoring plan

After closure and reclamation of Mollar Bheri disposal site, it shall be monitored for ground water quality as per requirements laid down under MSW 2016. The ground-water monitoring system (monitoring wells) will be installed at all landfill disposal facilities which have the potential for generating leachate. A schematic model is presented in figure above, depicting the concept of installing groundwater monitoring wells.

Figure 54 Conceptual Model of Groundwater Monitoring Well



Ground water wells shall confirm to following standards of drinking water quality wherever it is used for direct consumption.

Table 66 Ground Water Quality Standards in monitoring wells

SN	Parameters	IS 10500: 1991 Desirable limit (mg/l except for pH)
1	Arsenic	0.05
2	Cadmium	0.01
3	Chromium	0.05
4	Copper	0.05
5	Cyanide	0.05
6	Lead	0.05
7	Mercury	0.001
8	Nickel	-
9	Nitrate as NO3	45
10	PH	6.5-8.5
11	Iron	0.3
12	Total hardness (as CaCO3)	300
13	Chlorides	250
14	Dissolved solids	500
15	Phenolic compounds (as C6H5OH)	0.001
16	Zinc	5
17	Sulphate (as SO4)	200

13.2.2. Surface water monitoring plan

Surface water monitoring system will be installed at the landfill site to test if there is any contamination resulting from the surface run-off from the landfill. Provision should be made at landfill sites for collection of surface runoff at sump and then their final drainage. In no case shall the run-off water come in contact with landfill waste and get contaminated. This will lead to further contamination of the surface water source in its downstream. The storm water drain will be operative only in rainy seasons, hence it is very important to keep the drains clean to accommodate the rainwater to avoid flooding and dispose it to the proposed site. All effort should be made to avoid any kind of failure in the drainage system due to choking of the drains by earth, plastic bags, dry leaves and other foreign matters. The system should be properly maintained and inspected throughout the year. Storm water parameters need to be monitored on a regular basis. Parameter to be monitored on regular basis is as per below table.

Table 67 Surface Water Quality Parameters

SN	Parameters	IS 10500: 1991 Desirable limit (mg/l except for pH)
1	Arsenic	0.05
2	Cadmium	0.01
3	Chromium	0.05
4	Copper	0.05

SN	Parameters	IS 10500: 1991 Desirable limit (mg/l except for pH)
5	Cyanide	0.05
6	Lead	0.05
7	Mercury	0.001
8	Nickel	-
9	Nitrate as NO3	45
10	pH	6.5-8.5
11	Iron	0.3
12	Total hardness (as CaCO3)	300
13	Chlorides	250
14	Dissolved solids	500
15	Phenolic compounds (as C6H5OH)	0.001
16	Zinc	5
17	Sulphate (as SO4)	200

13.2.3. Air quality monitoring plan

Monitoring of Ambient Air Quality is required in the vicinity of closed disposal site. Ambient air shall be monitored regularly.

Table 68 Ambient Air Monitoring Parameters and Limits

Pollutants	Time- weighted average	Concentration in Ambient Air Industrial Areas	Residential, Rural & other Areas	Sensitive Areas
Sulphur Dioxide (SO_2)	Annual Average*	80 µg/m³	60 µg/m³	15 µg/m³
	24 hours**	120 µg/m³	80 µg/m³	30 µg/m³
Oxides of Nitrogen as NO_2	Annual Average*	80 µg/m³	60 µg/m³	15 µg/m³
	24 hours**	120 µg/m³	80 µg/m³	30 µg/m³
Suspended Particulate Matter (SPM)	Annual Average*	360 µg/m³	140 µg/m³	70 µg/m³
	24 hours**	500 µg/m³	200 µg/m³	100 µg/m³
Respirable Particulate Matter (RPM) (size less than 10 microns)	Annual Average*	120 µg/m³	60 µg/m³	50 µg/m³
	24 hours**	150 µg/m³	100 µg/m³	75 µg/m³
Lead (Pb)	Annual Average*	1.0 µg/m³	0.75 µg/m³	0.50 µg/m³
	24 hours**	1.5 µg/m³	1.00 µg/m³	0.75 µg/m³
Ammonia	Annual Average*	0.1 mg/m³	0.1 mg/m³	0.1 mg/m³
	24 hours**	0.4 mg/m³	0.4 mg/m³	0.4 mg/m³
Carbon Monoxide (CO)	8 hours*	5.0 mg/m³	2.0 mg/m³	1.0 mg/m³
	1 hour**	10.0 mg/m³	4.0 mg/m³	2.0 mg/m³

13.2.4. Treated leachate monitoring plan

The leachate quality after treatment should meet the standards recommended by MoEF in Municipal Soil Waste (Management and Handling) Rules, 2016 and presented in Table 5-5.

Table 69 Disposal standards for treated leachate

SN	Parameter	Standards (Mode of Disposal)		
		Surface Water	Sewers	Land
1	Suspended solids, mg/1, Max	100	600	200
2	Dissolved solids (inorganic) mg/1	2100	2100	2100

SN	Parameter	Standards (Mode of Disposal)		
		Surface Water	Sewers	Land
3	pH	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
4	Ammonical nitrogen (as N), mg/1	50	50	-
5	Total Kjeldahl nitorgen as N, mg/1	100	-	-
6	BOD in mg/1 (3 days @ 27°C)	30	350	100
7	Chemical oxygen demand, mg/1	250	-	-
8	Arsenic (as as), mg/1 max	0.2	0.2	0.2
9	Mercury (as Hg) mg/1, max	0.01	0.01	
10	Lead (as Pb), mg/1, max	0.1	1.0	
11	Cadmium (as Cd) mg/1 max	2.0	1.0	
12	Total chromium as Cr, mg/1	2.0	2.0	
13	Copper as Cu, mg/1	3.0	3.0	
14	Zinc A as Zn, mg/1	5.0	15	
15	Nickel as Ni, mg/1	3.0	3.0	
16	Cyanide as CN, mg/1	0.2	2.0	0.2
17	Chloride as CI, mg/1	1000	1000	600
18	Fluoride as F, mg/1	2.0	1.5	-
19	Phenolic compounds (C_6H_5OH), mg/1	1.0	5.0	-

13.2.5. Ambient noise level

The limit of ambient noise quality is shown in Table 5-6 below.

Table 70 Ambient Noise Quality Standard

Area Code	Category of Area	Limits in dB(A) Leq	
		Day Time (0600 hrs. – 2200 hrs.)	Night Time (2200 hrs. – 0600 hrs.)
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

Note: -

1. *Day time shall mean from 6.00 a.m. to 10.00 p.m.*
2. *Night time shall mean from 10.00 p.m. to 6.00 a.m.*

13.3. Environment Health & Safety Measures (EHS)

13.3.1. Associated risks

- The organization shall identify the occupational health and safety (OHS) hazards and the associated risk on ongoing basis, to facilitate setting of OHS objective and targets, control risk and to keep this information up to date.
- While identifying occupational health and safety (OH&S) hazards and risk during initial OH&S review the following criteria should be considered.
  - *All activities where previous records of incidents, accident occurred.*
  - *Inputs from regular Plant visit and meetings.*
  - *All activities routine and non-routine, where substantial hazards and risk share involved including contracted & company own activities / facilities.*
  - *Evaluation of feedback from investigation of previous incidents/accidents*
  - *Examination of all existing OH&S procedure and practice.*
- While identifying significant OH&S risks consideration shall also be given to
  - *Chemical hazards.*
  - *Physical hazards, Biological hazards.*
  - *Monotonous work.*
  - *Hazard Due to layout and design deficiency.*

Preparing a Register of OH&S hazards and associated risks, which shall include the departments & facility layout chart.

13.3.2. EHS & social roles and responsibility

- Define and communicate role, responsibilities and authority for effective functioning of EHS & Social management systems:
- Organization shall comply with the relevant applicable policies such as environmental, quality and fund standard guidelines.
- Shall define roles, responsibilities and authorities w.r.t EHS and applicable social guidelines from statutory bodies.
- Monitoring of effective implementation, Compliance to rules/acts.
- Initial training needs to be addressed and provide awareness and competence.
- Calibration and Maintenance of EHS equipment.
- Maintenance of updated on – Site Emergency Plan.
- Handling and investigation of incidents/ accidents, non-conformities, taking action to mitigate impacts and completing corrective and preventive actions.
- Conduct internal EHS & social compliance audits

13.3.3. Training & awareness

To lay down the procedure for identification of training needs and providing appropriate training to all employees and contract employees to ensure effective implementation of EHS &social management systems at all levels and functions. The organization shall do the necessary training need identification at all level and functions.

13.3.4. Emergency preparedness & response plan

To establish and maintain procedures in order to identify potential foreseeable accidents/ emergency situations and to prevent, control and mitigate the associated environmental impacts and Occupational Health & Safety risks and to test effectiveness of such procedure. If required review/revise such procedures periodically.

Some of the key measures include:

- Maintain all fire extinguishers in working condition. Provide training to employees on fire fighting.
- Explosion prevention.
- Explosive mitigation.
- Corrective and preventive action.
- Avoidance of major Spillage of any chemical.

Some of the general measures:

- Vehicle speed will be restricted to 15 km/hour at site to minimize potential for dust generated in the surroundings.
- Appropriate measures will be employed to minimize windblown litter and dust during transportation by either covering trucks or transporting wastes in enclosed containers.
- Heavy Goods Vehicles holding areas to be provided for vehicles waiting to deliver loads at work sites so as to avoid queuing on other connecting roads.
- Fixed noise sources to be located away more than 50 m away from the site fencing.
- Site workers working near high noise equipment to use personal protective devices like ear muff/plugs to minimize their exposure to high noise levels.
- Maintain clearance between electric lines and work spaces / nearest service lines, ensure enough space for maintenance.
- Adequate precautions shall be taken to prevent the accidents and from the machineries. All machines used shall confirm to the relevant Indian standards.

- Protective footwear and protective goggles to all workers employed on mixing of materials like cement, concrete etc.
- Welder's protective eye shields shall be provided to workers who are engaged in welding works.
- Earplugs shall be provided to workers exposed to loud noise, and workers working in crushing, compaction, or concrete mixing operation.
- The contractor shall supply all necessary safety appliances such as safety goggles, helmets, safety belts, earplugs, mask etc. to workers and staffs.
- For safety of people occupying the site, regulations concerning fire safety to be followed. Some of the requirements include:
- Installation of fire extinguishers.
- Provision of water sprinklers for unpaved roads and Emergency exit.
- Proper labeling of exit and place of fire protective system installation;
- Trained personal to use fire control systems.
- Display of phone numbers of the city/local fire services, nearest hospital, ambulance facility, etc.
- A readily available first aid unit including an adequate supply of sterilized dressing materials and appliances as per the Factories Rules in every work zone.
- Availability of suitable transport at all times to take injured or sick per-son(s) to the nearest hospital.

Apart from providing a sustainable solution to waste management, this system has many direct as well as indirect social, health and environmental benefits.

Table 71 Environmental health & safety aspects

Aspects	Description
Environmental Health	
Environmental Improvement	• No dumping of waste on ground and open areas • Covered waste handling, to prevent spreading of foul odour at collection points • No open burning of MSW • Recycling of MSW • Composting of biodegradable waste • Development of sanitary landfill • In the long run, lower pollution levels would ensure cleaner environment and improve the ambiance of the cluster
Improvement in soil fertility	• Composting provides the dual benefits of generation of revenue for the system and restoring fertility to the soil • Does not carry harmful chemicals
Pollution Reduction	• Based on 4R principle (Reduce, Reuse, Recycle and Recover)
Health and Safety Aspects	
Improved Health	• Workers are trained in the appropriate techniques of waste handling • Reduction in spread of diseases, lower emissions, improved ground water quality and soil fertility • Reduced exposure to waste • Segregation of wastes and inspection prior to land filling will ensure that hazardous waste is not mixed with the MSW • Elimination of road side disposal would reduce the health hazards caused due to open decomposition
Safety Measures	• Implementation of the proposed strategy would result in safe disposal of MSW. Safety standards implemented at multiple levels, would result in safer working conditions for the waste collectors • Providing protective gear to waste collectors would prevent injuries when in contact with unsafe waste disposed

14. Environmental Benefits and Sustainability

The chapter focuses on highlighting the aspects of the environmental sustainability, which would form part of the project. It will lend a robust platform to the project towards achieving the principles of sustainability during operations.

14.1. Environmental & social aspects of the project

The main focus areas of consideration are as follows:

1. To create an efficient and effective collection, storage, transportation, treatment, disposal and recycling system for MSW Management in four ULBs, and thereby creating an aesthetically improved and environmentally sound waste management system.
2. To find robust solutions for waste management, through community participation in establishing environmentally, socially and economically sustainable waste management systems with the help of NGOs, CBOs and RWAs.
3. To ensure that lessons learned provide useful inputs in formulating the overall strategy for the city.
4. To change the people's perceptions towards solid waste management problems and encourage them to participate in effective solid waste management
5. To create an IEC / awareness campaign among the public for social consciousness on waste management.

14.2. Environmental impact and benefits of the project

In the following sections, the details of the project components and its environmental benefits are being discussed.

14.2.1. Environmental benefit of door to door (D2D) household collection

Door to door collection is one of the important aspects of the project. Lifting of waste on daily basis from individual households reduces the load on disposal site, and subsequently enables to get rid of emission of methane gas and burning of waste. Moreover, on daily basis the source of waste generation remains clean, and thereby turning the domestic environment hygienically safe and healthy.

14.2.2. Environmental benefit of source segregation

Segregation of waste at source isolates the waste into two different waste streams - biodegradable and non-biodegradable. This waste segregation process increases the efficiency of processing and treatment, thereby increasing the effectiveness of the environmental status of the waste management system.

More precisely, a properly segregated waste into organic part would increase the efficiency of composting process and thereby it would evolve more good quality manure which is rich in N, P, K. This will increase the natural enrichment of the crops in terms of nutrient contents.

14.2.3. Environmental benefit of road sweeping

Road sweeping of waste improves the aesthetic condition of the neighborhoods, as well as maintains the environmental cleanliness of the road. Daily street sweeping removes the dust particles and

fugitive pollutants from the road, clears the path for a healthy walking for pedestrians and overall increases the hygienic status of the pathway. Daily cleaning and street sweeping keeps the road free from any obnoxious smell, littering, etc., thereby turning the entire social condition of the road good.

14.2.4. Environmental impact of drain cleaning

De-silting of drain and cleaning is one of the important tasks under this project. Drains are very critical part in the city of Kolkata. Blocking & choking of drains with plastic, grits etc causes overflow of the liquid, causing environmental degradation of the condition and status of the road. Moreover, it spreads potential diseases from the bacteria and pathogens that the drain water carries with it.

Due to regular cleaning and de-silting of drains, the chances of bacteriological contamination within the community due to overflow of waste water could be substantially controlled, and thereby the health & hygiene condition of the community get improved.

14.2.5. Environmental impact of transportation in a closed container

With the present project, transportation of waste in open truck and dumpers has been controlled and all transportation vehicles, being used are closed containers. Due to this change in practice - the odor, flies, unaesthetic condition of the environment have been effectively altered and an environmental improved status of waste transportation has been achieved. It reduces – a) flying of waste materials from the vehicles, b) emission of dust particles, c) bad smell and odor due to generation of methane gas, d) menace of flying birds and breeding of houseflies and mobility of stray dogs in the city.

14.2.6. Reduction of fossil fuel consumption through route optimization

The collection & transportation route would be optimized in this project due to decentralization of facilitated, thereby reducing the hauling time and maximizing the time utilization, i.e., efficiency of the C&T process. This change in operational procedure, has substantially contributed in saving of fuel consumption and thereby reducing the carbon emission from the transportation vehicles.

14.2.7. Monitoring and periodical checks

Through the service level agreement, a number of clauses have been set in order to ensure effectiveness of the waste management implementation. Through introduction of pictorial views, forms, GPS tracking system, complaint handling system etc. it is being ensured that the C&T system shall evolved 100% of effectiveness to maintain the clean and aesthetic condition of the environment.

14.2.8. Statutory &regulatory environmental compliances

During the conceptualization stage of the project, different prevailing environmental laws and guidelines have been reviewed. Thereafter, the project has been designed adhering all prevailing guidelines as per MSW Rule 2016 as well as other norms of pollution control board. Therefore, it may be mentioned that the overall environmental due diligence of the cluster II waste management project for four ULBs has been satisfied as far as possible, with respect to the national and international standard of waste management.

14.3. Social sustainability and benefits of the project

In the following sections, the details of the project components and its social benefits are being discussed.

14.3.1. Community benefit as a whole

With the introduction of the proper collection & transportation system there is an overall benefit to the community. Around 28 lakhs of people in four ULBs will be directly benefitted due to the improved environmental condition of the city through a scientific waste management system.

14.3.2. Improvement of the occupational safety as a social benefit

Earlier the waste management practices, especially collection & transportation strategy was not as per the SWM Rule 2016 in many of the wards. With introduction of the service level agreement in this present projects, waste handler and conservancy team are bound to use the PPE, and rigorous monitoring has been introduced into the system. Therefore, with implementation of this project, it can be said that the chances of health hazard of the workers have been substantially reduced.

14.3.3. Employment opportunities for informal sector as a social benefit

The employment opportunity of the local citizen has been increased, in terms of temporary task force in the conservancy, driving job for the new vehicles, door to door collection etc. There is also potential scope of engagement of different NGOs in the city to assist ULBs in household level collection, awareness campaigning and also for engagement in different IEC activities. This will induce a positive social impact in terms of generating employment opportunities.

Linking of informal recycling sector in the current waste collection & transportation system is one of the important social aspects of this project. Rag pickers play an important role in any city in waste management system. Due to segregation at source, thereafter recovery of utilizable material at plant practically leaves no window for rag pickers to pick revenue generating materials at the dumpsite. Therefore, bringing this taskforce into present collection & transportation system (especially into source segregation and household collection system) will upgrade the livelihood of the rag pickers in the city.

14.3.4. Awareness creation in the society

The project involves community participation through rigorous IEC activities to be undertaken by the implementing agency. With introduction of awareness campaign, nukkads, street plays, posters, pamphlets etc., the overall consciousness and understanding of the importance of scientific waste management are spread among the citizens and society. Networking with the citizens and development of their knowledge towards the waste management, understanding the benefit of waste segregation etc. are few of the important goals of this project. The overall social acceptability and motivation towards the waste management thereby get enhanced in the society, which in turn, brings a positive social impact for the community.

14.3.5. Mitigating health hazard as a social benefit

Currently, the process of scientific waste collection & transportation system, segregation is of one of the important mandates to be performed by the Nagar Nigam. In the segregation process different mixed domestic biomedical and hazardous waste components, such as – blades, broken glasses, batteries, syringes etc. are removed from the waste stream and separately collected as dry waste. With the reduction of manual handling of waste as well as use of PPE, reduces the chances of occupational health hazards of safai karmchari and other task force engaged in collection & transportation system.

14.3.6. Periodical health check-up for C&T workers

Under this project, periodical health check-up for the workers engaged in collection & transportation process will be done. This will identify any sort of health issues due to their occupation and necessary medical measures will be taken immediately for the worker(s), as and when required.

14.3.7. Improving quality of life

A proper collection & transportation procedure in a waste management system has a big role in change in the quality of the life of the citizen of Kolkata. The overall change or improvement in the environmental condition of the city brings a big impact on the quality of life of the citizens. It improves the living condition, change in behaviors of citizens, enhances aesthetic quality and keeps

the city clean and beautiful for the people of KMC, BMC, NKDA & NDITA, as well as for the floating populations.

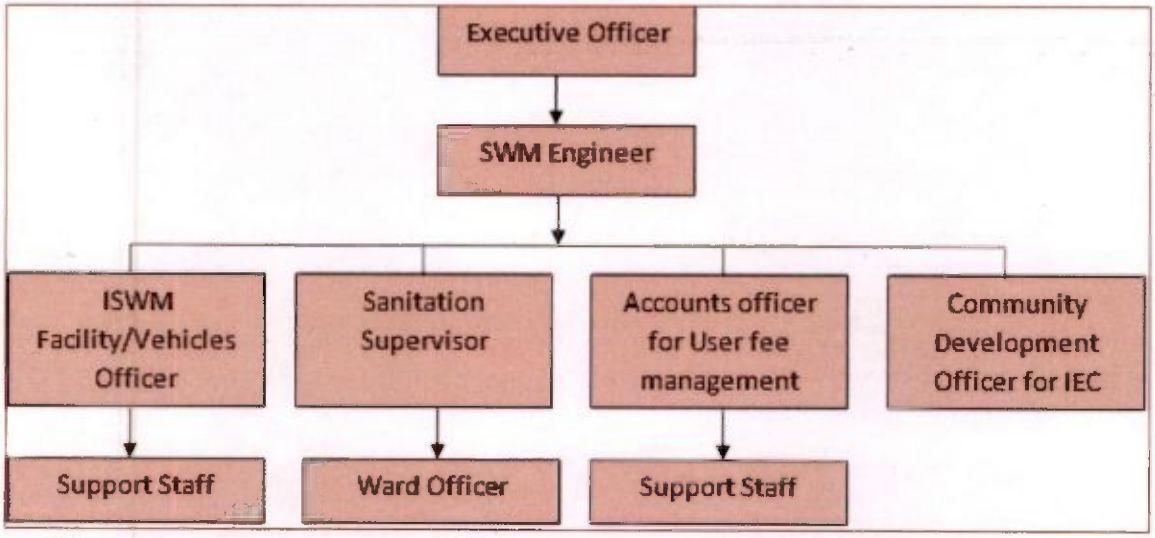
15. Institutional Aspects and Capacity Building

15.1. Introduction

The subject of solid waste management has remained neglected for the past several decades with the result that the level of service is highly inadequate and inefficient. For improving the solid waste management services, it is essential to adopt modern methods of waste management, having a proper choice of technology, which can work in the given area successfully. Simultaneously, measures must be taken for institutional strengthening and internal capacity building so that the efforts made can be sustained over a period of time and the proposed system can be well managed. Institutional strengthening can be done by adequately decentralizing the administration, delegating adequate powers at the decentralized level, by including professionals into the administration and providing adequate training to the existing staff. NGO/private sector participation also needs to be encouraged to make the SWM services competitive and efficient.

15.2. Proposed organizational set-up

Figure 55 Proposed organization set-up



15.3. Decentralization of Administration

Based on the analysis done and the interventions proposed, the SWM services may be proposed to perform effectively in a decentralized manner at the ward level.

15.3.1. Ward level administration

The ward level administration should be fully responsible for ensuring storage of segregated waste at source, primary collection of waste, street sweeping and transferring the waste to the designated auto tippers. The cleaning of each street, lane by lane, markets and public space should be regularly supervised by the ward level supervisors. The presence of all SWM officers of the ward in the field during and morning hours is most essential. A grievance redressal system should be put in place in each ward. Ward level efforts could be made in the following:

- Creating public awareness at the ward level.
- Formation of Residents Association/ Neighborhood Committees to ensure public participation in source segregation of recyclable waste and deposition of domestic waste in the handcarts on time during primary collection.

- Involving school children to be watchdogs in preventing littering of streets by the people
- Interfacing with the people, officials, and help in redressal of public grievances on SWM at the ward level.
- Supporting the effort of cost recovery for the services rendered
- Encouraging NGO participation.

15.3.2. City level administration

The respective ULBs (BMC, KMC, NKDA, NDITA) should supervise and support the ward level administration. The SWM Department should be responsible for upkeep of vehicles, setting up and maintenance of processing plants as well as for managing the disposal sites in an environmentally acceptable manner.

The SWM department should also be responsible for the procurement of vehicles, equipment, and land for processing and disposal of waste. As a Head office it should take policy decisions and co-ordinate the activities of all the wards and be answerable to the chief executive officer and elected body for the efficient functioning of the department. It should look after the recruitment of manpower, human resources development and training, etc.

15.4. Training & Capacity Building

Human resources development is very essential for internal capacity building for any organization. Training, motivation, incentives for outstanding service and disincentives for those who fail to perform are essential for human resources development.

Concerted efforts should be made by the Corporations and authorities to inculcate among its officers and staff a sense of pride in the work they do and to motivate them to perform and give their optimum output to improve the level of services of the city and the image of the Municipal Council.

15.4.1. Special training to unqualified staff

Unqualified supervisory staff should be given service training to qualify for supervising sanitation works.

15.4.2. Refresher courses for supervisory staff

Refresher courses should be conducted for the supervisory staff at least every 5 years or they should be sent for training to get an exposure to advance in this field.

15.4.3. Work norms (SOP)

The sweepers may be assigned "Pin point" individual work assignments to the density of the area to be swept.

Similarly work norms or Standard Operating Procedure may be prescribed for variety of vehicles used depending upon the distance to be travelled and the places to be covered. These norms may be prescribed after conducting time and motion study. The norms of work for the supervisor may also be prescribed and monitored by the ULBs, for the extent of sweeping areas and the number of garbage collection points to be inspected watch day by the various levels of supervisors and inspection of processing and disposal sites etc. to ensure adequate output of the supervisory staff.

For capacity building of the department, senior officials should be frequently exposed to developments taking place in various parts of the State and Country by sending them out on city visits and to attend seminars, workshops and training courses. They should also be involved in all decision-making processes.

15.4.4. Course Content for training to staff/officers

Based on the experience in Capacity building exercises across the country we fell the following robust module in the following form can be effective in addressing the same as mentioned below, the content of the same can be developed based on involving NGOs and other civil and community organizations.

A. Training to sanitation workers

1. Importance of sanitation in urban areas.
2. Present scenario of solid waste management system in the urban areas, deficiency in the system etc.
3. Impact of inefficient SWM services on health and environment
4. Impact of inefficient SWM services on the health of sanitation workers.
5. Inefficiency of tools and equipment used and loss of manpower productivity.
6. Need for modernization of solid waste management practices.
7. Options available for improving the services.
8. Advantages of using improved tools and equipment for primary collection of waste and street sweeping.

B. **Training to Sanitation Supervisors of Various levels**

1 to 8 as per A above

9. Transportation of waste on day to day basis
10. Waste processing & disposal options, advantages & disadvantages of various technologies.
11. Sanitary land filling.
12. Public and NGO participation in waste management.
13. Building public awareness.
14. Enforcement

C. Training for the Officers at SWM Department

1 to 14 as per A & B above

15. SWM practices prevalent in other parts of the country and in the developed countries
16. Institutional strengthening, internal capacity building and human resources development.
17. Private sector participation in SWM
18. Management information system
19. Financial aspects
20. Health aspects
21. Legal aspects.

16. Community Awareness and Public Participation

16.1. Introduction

The success of any solid waste management scheme can be measured through the extent of co–operation of people, effectiveness of the proposed system and operational efficiency. The effectiveness of the system and operational efficiency can be improved through HRD and capacity building, the co–operation of people can achieve through Information, Education and Communication (IEC) techniques. During such campaigns, strategies for waste reduction, Reuse and Recycling (R – & – R) may also be propagated for deriving long-term benefits.

16.2. Status of Public Participation in SWM

Solid waste management is not on the priority list for general public. The general approach to SWM has been 'Out of Sight, Out of Mind' and 'Not in my backyard' attitude. Community participation is not very active. Segregation of waste at source is not practiced religiously by all public. Waste is burnt in the open to get rid of the smell and junk. Public participation can be considered negligible when it comes to Solid Waste Management.

Waste is disposed off carelessly into the environment. The afterthought of waste processing is not considered. Thus, waste often ends up on fertile soil and water bodies contaminating our environment. There are cases where waste ends up in our drains and clogs the drain resulting in an ample amount of wastage of resources and energy.

Also, waste management is not considered as a dignified job and there is lack of leadership in taking the system of waste management to a higher level. Thus, there are many loopholes in the system that needs to be corrected and catered to.

16.3. Essential steps of Public Participation

The success of SWM depends on building meaningful partnership with the stakeholders. Active involvement of the following community groups is essential especially in primary collection:

- Resident Welfare Associations
- Hotel owners Association
- Merchants union
- Restaurant and commercial Association

The ULB may organize the above groups through a series of interactive meetings with the office bearers before a phased program for community awareness is launched.

NGOs can provide support in:

- Awareness creation programmes
- In developing pilot programmes
- In organizing door – to – door collection systems
- In setting up local processing units

Community awareness program have to focus on:

- Awareness of the perils of the present practice, their role in keeping the surroundings clean.
- Not to litter on streets
- Storage of waste at source in two bins in a segregated manner
- Primary collection from doorstep
- Popularizing 4R strategy – Reduce, Reuse, Recycle, Recovery
- Discourage use of plastics
- Developing methodology for reaching schools to create awareness among children.

Public Information, Education, Communication Programs (IEC)

For the successful implementation of any program involving public at large in SWM system, it is essential to spell out clearly and make them known the manner in which local body proposes to tackle the problem of waste management and extent to which public participation in Solid Waste Management is expected to keep the city clean and improve the quality of life in the city.

Based on the recommendations by the various government agencies, and the SWM Rule, 2016, the approach to an IEC plan could include the following aspects:

- Organize the sanitary workers, train them for providing professional services in field of Solid Waste Management.
- Provide training and other capacity development to guarantee efficient, quality and timely waste management services including door to door collection of waste.
- Mobilize resident communities and bring awareness to segregate the waste and not to throw or dump waste in back-lanes and open plots
- Execute Awareness and information campaigns, organize SBM thematic drives, meetings etc. as instructed by officials and Consultant
- Training of field staff by convergence with NULM, also focusing on the organization of the rag-pickers of the ULB in solid waste management and door to door collection, route rationalizing of vehicles and it's planning and get it approved from officials and consultant.
- Awareness and training for segregation of waste at source to the citizens and staff of the ULB, organize meeting in consultation with Ward Councilor (elected representative), resort and hotel association, and RWA on weekly basis.
- Promote primary collection, secondary collection of waste and cleaning of entire ward area i.e. door to door collection in assign wards, collection and removal of roadside waste dumps, collection and cleaning of waste bins, cleaning of drains and nallahs and cleaning of entire ward area and back-lanes.
- Identification of open defecation points in the wards, creating awareness involving RWA, local residents, female groups, children and helping ULB to make the wards clean, identification of locations for constructing new community /public toilets, suggest up gradation if required in existing community /public toilets. Filling up of application forms for constructing house hold toilets in the wards.
- Report weekly to the ULB officials and TA

Table 72 Awareness activities and components

SN	Activity	Sub Activity
1	**Preparation and Designing promotional materials**	Designing of SWM Flex and hoardings
		Designing of SWM Pamphlets
		SWM Voice Recording Based on local theme
		Designing of SWM Uniform
		Designing of SWM Small Hording and promotional material
		Perform SWM Street Play, beach play
		Vehicle Route Planning as per MSW rules
		Logo Designing
		Share with the ULB Team and get approval for the same
2	**Meeting with all stakeholder of Solid Waste Management activities**	Meeting with citizens to organize SWM campaign
		Meeting with hotel and resort association and organize SWM campaign
		Meeting with school and colleges and organize SWM campaign
		Meeting with market associations and organize SWM campaign
		Meeting with municipal staff and organize SWM campaign
		Share and promote waste management video/best practices
		Organize rally with RWA for SWM weekly
		Meeting with women's group and self-help groups
		Pamphlet distribution at HH level and performing street play
3	**Door to Door Waste**	HH/Shops and Public awareness for uses of two/three dustbin for segregation of MSW

SN	Activity	Sub Activity
	Collection	HH /shops and other common places information collection
		HH Awareness for waste segregation
		Promote D to D waste collection with segregation
		Training of waste collectors for Door to Door waste collection
		Feedback and Suggestion from Stakeholder
		Report Preparation and sharing with the ULB weekly
4	**Street Cleaning**	Information collection of all Roads/Markets areas
		Study of present system
		Design route map for proper cleaning in consultation with the ULB
		Training of Sanitary workers for street cleaning. Help in Assigning responsibility to Sanitary workers with time scheduling
		Promote sanitary workers for street cleaning on daily basis
		Training of Sanitary workers for Nallah and Drain cleaning
		Assign responsibility to Sanitary workers
		Street Drain Cleaning on daily basis
		Proper collection of nali and drain waste. Assign responsibility to Sanitary workers
		Take 2 persons signatures daily from HH in each row / lane of every ward
5	**Preparation of Progress report and submission to SUDA**	Preparation of Qualitative report for each ward on monthly basis and its submission to the ULB
		Preparation of Quantitative report for each ward on monthly basis and its submission to the ULB
		Preparation of Budget Utilization report for each ward on monthly basis and its submission to the ULB
6	**Making Wards Open Defecation Free**	Identification of open defecation points in the wards
		Creating awareness involving RWA, local residents, female groups, children and helping the ULB
		Identification of locations for constructing new community /public toilets, suggest up gradation if required in existing community /public toilets
		Filling up of application forms for constructing house hold toilets in the wards.

Prohibition of land filling or dumping of mixed waste soon after the timeline as specified in Rule for setting up and Citizens co-operation is vital to reduce, reuse and recycling of waste and in keeping garbage off the streets, by keeping biodegradable "wet" kitchen and food wastes unmixed and separate from recyclable "dry" wastes and other hazardous wastes. Their participation in primary collection of waste, using community bins for storage of waste generated in multistoried buildings, societies, commercial complexes and slums is also essential. If the reasons for doing so are explained, public participation is bound to improve.

16.4. IEC Approaches

The communication material developed should be utilized in public awareness programs through variety of approaches as under:

Group Education: This may be done through:

i. Group meetings in the community
ii. Workshops
iii. Exhibitions
iv. Lecture series
v. Panel Discussions, etc.

Mass Education: This is very essential to cover the entire population, as it is not possible to reach all the people through group education programs.

Mass Education programs can be planned using following methods of communication.

i. Use of Print Media
ii. Use of TV / Cable TV / Radio/Web Site
iii. Street Plays, Puppet Shows, beach play etc.
iv. Posters
v. Pamphlets
vi. Use of Hoardings
vii. Use of Public Transport System
viii. Use of School Children
ix. Primary School Curriculum to cover the subject

According to SWM Rules, 2016, all manufacturers of disposable products such as tin, glass, plastics packaging, etc., brand owners or marketing companies shall educate the masses for wrapping and disposal of their products.

16.5. Stakeholders Analysis

Stakeholder Analysis (SA) is a tool used to identify and analyze the interest and influences of the Stakeholders. This analysis can develop an action plan for your project.
SA is one of the most crucial elements of the project planning process as it provides answers to important questions such as:

- What is our present status (i.e. what are the problems and what are the possible solutions)?
- What do we want (i.e. what are our objectives and what are our options)?
- What and how supports can be evoked from each of the stakeholders?

Stakeholders Analysis would identify primary stakeholder groups, their stake, roles and interests with a view to:

- Identify the problem to be addressed and its cause (s) and effect (s).
- Identify who should be encouraged and helped to participate (e.g. Students, Home-makers, Housekeeping staffs, Shop keepers, Garbage collectors, employees of the department, citizens other primary beneficiaries who are directly impacted by the services).
- Improve project sensitivity of those affected
- Enable useful alliances which can be built upon (e.g. with funding organizations, private organizations willing to participate in the project, community-based groups, etc.)

The steps to be followed while undertaking a stakeholder analysis are:

Undertake stakeholder meetings/ workshops, etc. to freeze the following:

- List all primary stakeholders
- Problem w.r.t what the SWM Project is proposing to address Causes and effects of the problem
- would identify each stakeholders' interests, roles and responsibilities in relation to the project
- would consider the potential impact of the project on the identified stakeholders and vice-versa (i.e. level of influence of each stakeholder)
- would decide degree of importance to be placed on the interests of each stakeholder
- would decide when and how to engage each stakeholder groups
- would classify stakeholders based on their level of interest and influence in context of the project and develop an engagement strategy.

Major steps taken for generating awareness and education will be:

1. Stakeholder identification and assessment
2. Need based assessment and data analysis
3. IEC development after analysis focusing on customized stakeholder plans focusing on the short, medium and the long term.

4. Delivering IEC programs for waste segregation
5. Monitoring and evaluation of waste segregation
6. Developing local leaders from existing community for future monitoring.

17. Operation & Maintenance Aspects of the Project

17.1. Management Information System

Collection and analysis of data related to MSWM is required to assess the existing situation and propose adequate measures for improving service delivery. Management information system (MIS) is a computerized system which can help capture, store, and retrieve data or information for decision makers. MIS can manage large amounts of data such as waste collection points, location of bins, designated secondary storage points, ward level vehicle movement, information on transportation of waste and its weighment. MIS helps in establishing a strong and reliable information database necessary to facilitate planning, midcourse corrections, and decision making. It enhances transparency and accountability of officials in the MSWM system. Information is the foundation of an MIS system. Therefore, for any ULB to have a sound MIS on solid waste management, it should have a good compilation of basic information ranging from a ward to a city level. Essentially all the information that was earlier kept and updated manually in the ULB has to be now available electronically. Creation and maintenance of such information and database is not very resource intensive and requires basic technical expertise at the ULB level.

ULB needs to maintain a basic MIS system either through manual records or electronically. Once this system has been established, level two is to connect this basic database on solid waste to be analyzed through map-based tools and applications. The use of integrated technologies over the basic MIS system such as geographic information systems (GIS), global positioning system (GPS), radio frequency identification (RFID), and general packet radio services (GPRS) have resulted in the development of integrated and comprehensive solutions for MSWM. GIS and remote sensing imageries (visual capture of information using cameras) are now being integrated with MIS to provide spatial and visual validation for provision of services. A GIS system is actually a visual representation of information (attributes) on maps which are geo-referenced (show location coordinates). Data collected for monitoring and evaluation (M&E) of MSWM systems can thus be linked to the geographical locations on a map created in the GIS system. Data on maps can be used to analyse the spatial information and identify patterns, trends, and relationships in the existing information. GIS systems are useful in planning for door-to-door collection, waste transportation routes, location for waste collection bins, etc.

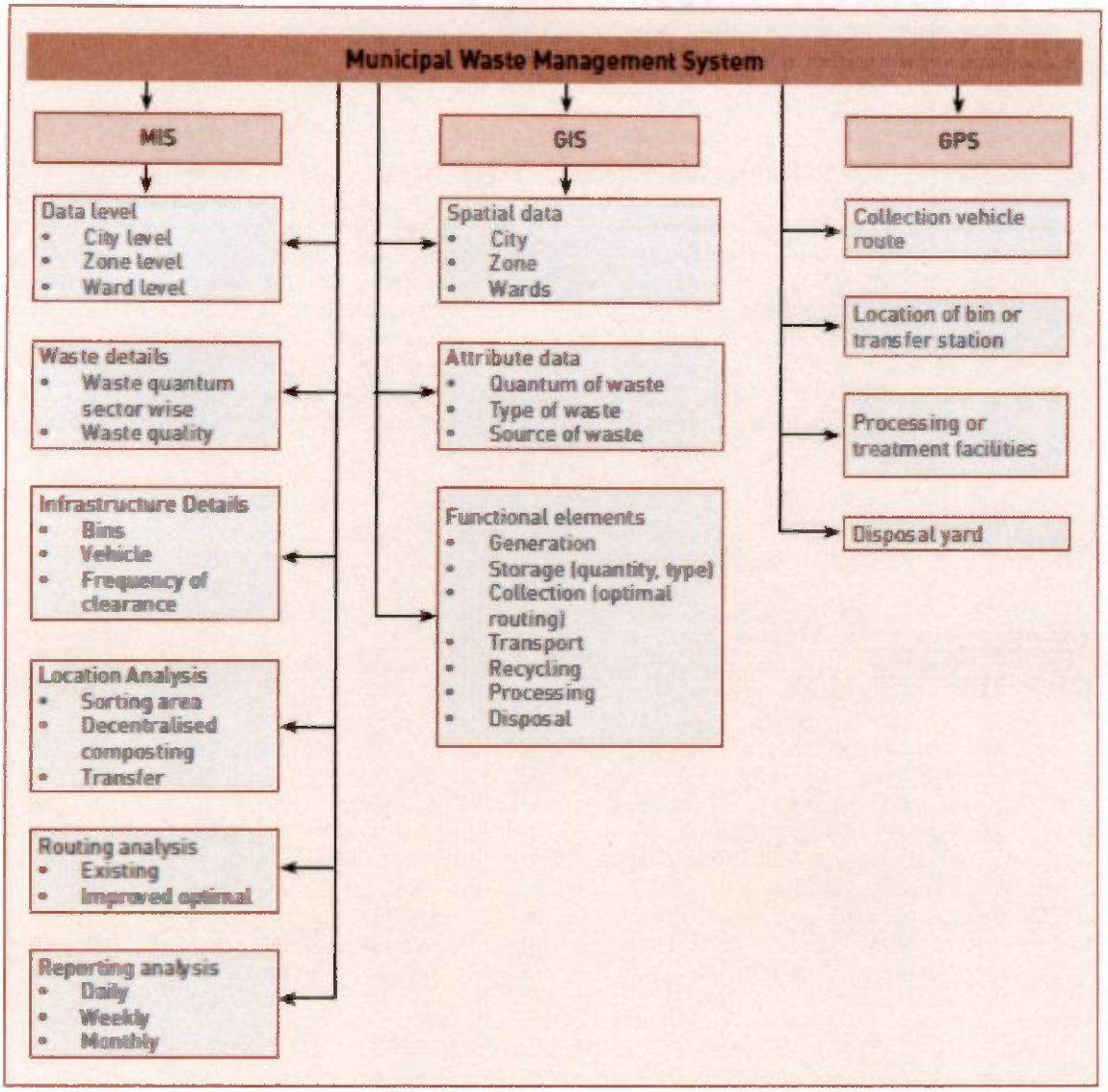
Once the GIS has been linked to the MIS, the system can be further advanced to show real-time spatial information captured through a global positioning system (GPS), e.g., real-time data regarding vehicle movement, secondary collection bin pickup, and transportation to processing and disposal sites can also be linked to the GIS system. Waste transport vehicles may be fitted with a GPS linked to the GIS system to enable real-time monitoring of vehicle movement.

In several advanced MIS systems, radio frequency identification (RFID) tags are used to identify equipment. These are electronic tags which can carry preloaded information specific to the equipment they are tagged to, e.g., secondary collection bins. Electronic scanners equipped with the general packet radio services (GPRS) technology can scan these tags and relay information to the GIS system, whereby all necessary information fed into the GPRS unit with regard to the equipment is updated automatically. GIS is then used to check the location.

Once linked with GPRS or RFID systems, GIS provides real-time data on vehicles, collection of waste, bin pickup, and transportation of waste to treatment or disposal facilities.

These systems are now being suitably adopted by cities to improve service efficiency of MSWM. Minimum data requirements for an effective MIS–GIS–GPS system are shown in figure in the next page.

Figure 56 A Screenshot of MIS, GIS & GPS System



17.2. Benefits of these systems include the following

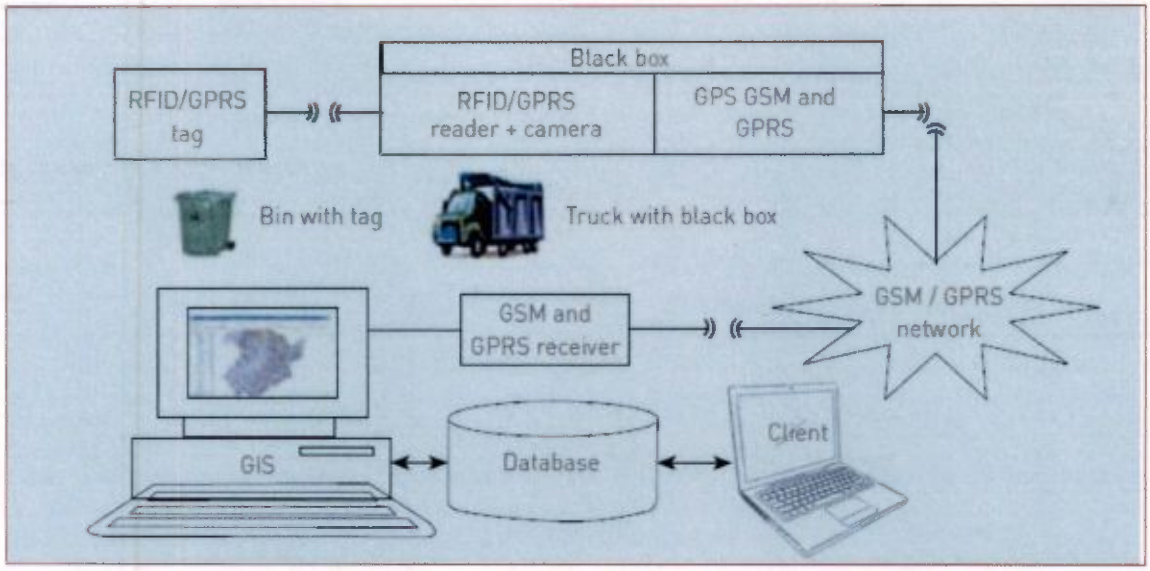
Data aggregation and process monitoring are managed electronically, avoiding daily human intervention, thereby increasing reliability and transparency of information and helping in resolution of disputes among citizens, contractors, and officials.

Effective and timely complaint redressal of grievances is generated through online monitoring system.

Movement of vehicles and tracking of average stoppage time may be monitored in real time by using a surveillance system based on GIS and or GPS technologies, thereby reducing noncompliance and enhancing efficiency.

Status of evacuation of bins on a daily basis can be monitored through RFID and or GPRS, facilitating increase in service efficiency and decrease in customer complaints.

Figure 57 Monitoring Skelton



17.3. Complaint Handling System

A complaint redressal system creates a platform for citizens to voice their complaints and grievances regarding provision of MSWM services and also helps in promoting efficiency and transparency at the ULB level. The ULB, through an analysis of the complaints or grievances it receives, is able to identify lacunae and bridge gaps in service delivery. The time taken for resolution of grievances and the action taken are also monitored and recorded through this system. Typically, ULBs have a common complaint redressal system for all municipal services.

A complaint redressal system is effectively supported through the introduction of a citizen charter. The citizen's charter is a written voluntary declaration by a ULB with the basic objective to empower the citizens to get public service in a given time frame.

The Citizen's Charter includes:

- information on municipal services and expected outcomes,
- municipal service delivery standards,
- response time for rendering services or redressing grievances,
- information dissemination process on the complaint redressal process, and
- Contact details of officers responsible for provision of the various municipal services.

The citizen's charter should be prepared by the ULB and officially adopted by the municipal council and widely publicized. Urban development or local government departments may prepare a model citizen's charter to be adopted by all ULBs in the state after preparing city-specific citizen's charters for their own city.

17.3.1. Elements of a Complaint Redressal System

Typical elements of a complaint redressal system include the following:

1. Complaint management system: A computerized central complaint management system should be networked, and the complaints could be recorded through a register. A grievance redressal officer from the MSWM department or cell at senior level should be responsible for recording and monitoring the complaints and also for taking necessary actions for redressal.

2. Medium of complaint registration: Multiple channels or a combination of different channels may be adopted for receiving complaints, e.g., phone calls to a centralized customer service or complaint number, SMS messages to notified mobile numbers, automated generated complaints sent to commissioners for their records, walk-in complaint registration, and online complaint registration.

3. Complaint registration and recording system: This system should

- assign a unique ID to each complaint generated;
- record contact details of the complainant;
- record details of the physical location (zone, ward, area) relevant to the complaint;
- assign the complaint to the concerned official in the MSWM department or cell;
- record the stipulated time within which the complaint shall be redressed;
- provide an acknowledgement receipt to the complainant with all the above details, in case the complaint is registered manually or online; and
- Provide a complaint reference number with an SMS of registration to telephone-based complainants.

4. Resolution certificate: Field officers, after resolving the complaint, should take resolution certificate from the complainant and subsequently inform the complaint cell. The complaint shall thereafter be treated as resolved.

5. Complaint resolution and feedback: The designated official for complaint resolution in the MSWM department or cell shall be made aware of received complaints on a daily basis. Feedback could be taken through telephone, internet, SMS.

6. Pending complaints: Complaints which are not resolved in stipulated time shall be deemed pending. The reason for the pending complaint should be recorded and the designated officer and the complainant should be duly informed. Such pending complaints should automatically be escalated to higher officials for monitoring and directions.

7. Reporting and complaint analysis: A daily status report of complaint redressal should be prepared by an officer and submitted to the higher officer-in-charge for further directions. The complaint management system should generate periodic, area-wise reports on number of complaints received, nature of complaints, time taken for resolution, etc. The report should highlight the critical issues such as most frequently received complaints, frequently delayed responses, repetition of complaints (if any), time for resolution of complaints, etc. The weekly analysis of all complaints received should be reported to the Head of Municipal Council. Status of the complaints should be put in public domain and updated on a daily basis for ensuring transparency of the system.

18. Implementation mechanism

The time line for the implementation mechanism of the proposed project could be as per the following :

Table 73 Implementation model

SN	Activities	Duration
1	Procurement, supply, operation & maintenance of C&T system	5 years (renewable)
2	Construction, procurement & installation of treatment & disposal facilities	7 months
3	Operation and maintenance of treatment and disposal facilities	20 Years
4	Bioremediation of the Mollar Bheri	7 months
5	Erection of reclamation machineries and equipment	3 months

Based up on this feasibility study report and the concept plan proposed in this report, the implementation mechanism of the project will be discussed with the ULBs and SUDA and the contract model will be decided in due consultation with SUDA.

19. Project cost estimates[16]

19.1. Introduction

In this chapter, the project cost details for SWM system for the following components has been discussed. The cost components are worked out as per the following:

19.1.1. ULBs

- Cost estimation for KMC selected wards
- Cost estimation for BMC
- Cost estimation for NKDA
- Cost estimation for NDITA

19.1.2. Cost components

- Collection and transportation
- Decentralized system
- Centralized system
- Pilot projects

19.2. Collection & Transportation System

In this section cost estimated for collection and transportation vehicle and equipment has been presented. It should be noted that, the cost has been estimated only for the items which are to be procured newly, and the cost if existing infrastructure which could be utilizable have been has been excluded from costing. A substantial number of existing collection & transportation infrastructure will be clubbed in the proposed system, thereby reducing the capital cost for the project as much as possible.

However, it is to be mentioned that the present project does not include the scope of collection & transportation and shall not be undertaken by SUDA. The collection and transportation shall be managed and financed by respective ULBs and will be taken up separately by them. The infrastructure estimation and financial part have been worked out here in to assist ULBs with C&T infrastructure planning for future.

The cost estimate for collection & transportation system is given in the following tables:

Table 74 Cost estimates of C&T system for KMC

SN	Infrastructure	Specification	Total (Rs Lakh)
1	Refuse compactor (wet waste)	14 m3 capacity	451.87
2	Refuse compactor (dry waste)	14 m3 capacity	231.08
3	Compactor bins	1100 lit	22.79
4	Total		705.75

Table 75 Cost estimates of C&T system for BMC

SN	Infrastructure	Specification	Cost
1	Tata Ace CNG Garbage Hopper tipper	310 kg	267.34
2	Refuse compactor for wet waste	14 m3	524.51
3	Compactor bin for wet waste	1100 Lit	170.31
4	Refuse compactor for dry waste	14 m3	110

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[16] These estimates have been arrived in consultation with SUDA, based on established govt rates for similar items

5	Compactor bin for dry waste	1100 Lit	169.78
6	**Total**		**1242**

Table 76 Cost estimates of C&T system for NKDA

SN	Infrastructure	Cost (INR Lakh)
1	Auto tippers (310 kg)	15.995
2	Refuse compactors (14 m3)	77
3	Compactor bins	10.14
4	**Total**	**103.135**

Table 77 Cost estimates of C&T system for NDITA

SN	Infrastructure	Cost (INR Lakh)
1	Auto tippers (310 kg)	68.55
2	Compactor bins	8.84
3	**Total**	**77.39**

19.3. Capital cost of decentralized treatment facility

Total cost for Decentralized System and Pilot Level Cost for Decentralized System is being furnished below:

Table 78 Total cost estimates for Decentralized System

SN	ULB	OWC (300 kg)			Biomethanation (5 TPD)			Total (Rs lakh)
		Nos	Unit Rate (Rs lakh)	Subtotal (Rs lakh)	Nos	Unit rate (Rs lakh)	Subtotal (Rs lakh)	
1	**KMC**	29	11.6	336.4	0	251.24	0	336.4
2	**BMC**	38		440.8	4		1004.96	1445.76
3	**NKDA**	0		0	1		251.24	251.24
4	**NDITA**	0		0	0		0	0
5	**Total (Rs lakh)**	67		777.2	5		1256.2	**2033.4**

Table 79 Pilot scale cost estimates for Decentralized System

Item	Cost of one number Organic waste pilot treatment plant (300 kg/day) at community level (Rs lakh)	Cost of one number 5 TPD Biomethanation Pilot Plant at one market (INR Lakh)
Cost	11.6	251.24

[171] These estimates have been arrived in consultation with SUDA, based on established govt rates for similar items.

19.4. Capital cost of centralized treatment facility

Total cost for Decentralized System and Pilot Level Cost for Decentralized System is being furnished below:

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Table 80 Cleaning and rehabilitation cost of Mollar Bheri

SN	Head	Rate (Rs/ m3)	Quantity(m3)	Total (INR Cr)
1	Biomining of legacy waste	500	420739	21.0369
	GST (12%)			2.524
	Total Project Cost including GST			23.5613

Table 81 Cost of 550 TPD Capacity Material Recovery Facility

SN	Item	Cost (INR Lakh)
1	Drum screen	738.80
2	Sorting cabin	68.74
3	Magnetic separator (line 1)	343.69
4	Magnet separator (line 2)	343.69
5	Auto sort 1000mm (line 1)	893.58
6	Auto sort 1000mm (line 2)	893.58
7	Air compressor	343.69
	Contingency	178.72
8	**Total cost**	3804.48

Table 82 Cost of Centralized Biomethanation Plant

SN	Head	Rate (Rs lakh/ no)	Quantity (No)	Total (INR lakh)
1	400 TPD Biomethanation plant	6500	1	6400

Table 83 Cost of Construction & Demolition Waste Plant[18]

SN	Head	Total (INR lakh)
1	400 TPD C&D waste treatment plant	1151.7

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[18] These estimates have been arrived in consultation with SUDA, based on established govt rates for similar items

Table 84 Cost of Centralized Compost Plant Facility

SN	Head	Total (INR lakh)
1	500 TPD Windrow composting plant	2000.00

Table 85Cost of Centralized Sanitary Landfill Facility (for 20 years design period)

SN	Head	Total (INR lakh)
1	Cost of 432 TPD SLF for 20 years design period	107.54

19.5. Summary of Capital Cost for Treatment & Disposal Facility

The table below depicts the summary of the cost for the proposed project:

Table 86 Summary of Cost[19]

SN	Head	Total (INR lakh)
1	**Cost for Decentralized Facility**	
A	*- Decentralized Bio-methanation Plant for bulk generators*	1256.2
B	*- Decentralized wet waste converter at community level*	777.2
	Total Cost for Decentralized facilities	**2033.4**
2	**Cost for Centralized Facility**	
A	*Centralized Biomethanation Plant*	6400.00
B	*- Material recovery facility*	3804.48
C	*- Construction & demolition waste treatment plant*	1151.7
D	- Other upgradation work for the 20-acre land (approach road and water supply line), 10%	1135.618
E	- Compost plant	2000
F	*Construction of sanitary landfill for 20 years*	10753.92
	Total Cost for Centralized facilities	**25245.71**
3	***Rehabilitation & cleaning of Mollar Bheri***	**2103.69**
	Total Project Cost	**29382.81**
	GST @ 12%	3525.93682
	Project Cost including GST	32908.74

19.6. Summary of Annual Operation and Maintenance Cost

The table below depicts the summary of the O&M cost for the proposed project:

Table 87 Summary of O&M Cost (without GST)

SN	Item	Unit	Amount
1	Landfill	Lakh Rs/annum	374.4
2	Compost plant		547.5
3	400 TPD C&D Waste plant (5% considered of capex)	Lakh Rs/annum	57.585
4	MRF (5% considered of capex)	Lakh Rs/annum	190.22
5	Centralized bio-methanation plant (400 TPD)	Lakh Rs/annum	146

[19] These estimates have been arrived in consultation with SUDA, based on established govt rates for similar items

SN	Item	Unit	Amount
6	Decentralized 5 TPD bio-methanation plant	Lakh Rs/annum/unit	20.1
7	Decentralized 300 kg organic waste converter	Lakh Rs/annum/unit	1.8

Cost of IEC is not included in the O&M cost and in the financial model, as this would be a separate assignment for sectoral agencies. It shall not be taken care by the O&M contractors. A separate proposal may be submitted.

The cost of IEC activity would be around Rs 186/- per population per year. [20]

19.7. Assumptions and way forward

In this report, we have proposed the broad conceptual framework for managing municipal solid waste in Cluster 2 ULBs. At this stage, we await a) concurrence from stakeholder ULBs on the proposed treatment options and b) identification of requisite land parcel (meeting minimum area requirement as well as siting pre-conditions as per PCB guidelines) for sanitary landfill. Upon concurrence from the stakeholder ULBs in Cluster 2 on the proposed management options for the solid waste being generated within their jurisdictions, we would finalize the treatment options, and accordingly proceed with the financial feasibility analysis inclusive of the O&M costs and revenue estimations to be added for the finalized management options.

Similarly, details of the centralized treatment and disposal facility, associated capital, O&M costs and financial feasibility will be provided based on the final land parcel identified by SUDA for Cluster 2. These will be duly incorporated in our final feasibility report.

Way forward:

- In the immediate term, SUDA to expedite land acquisition process for centralized SLF at Bhangor and obtain necessary clearances for permissible land-use.
- Consultation with technology providers, if necessary, may be organized to enable informed discussions around techno-commercial feasibility of SWM options
- Financial modelling, cost recovery plan etc. will be finalized based on receiving concurrence from ULBs and SUDA

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[20] These estimates have been arrived in consultation with SUDA, based on established govt rates for similar items

Appendix A. - Appendices

A.1. Minutes of meetings

A.1.1. SUDA

Date: 17th May 2019

PwC apprised SUDA regarding current development of the project and subsequently the following takeaways from their meeting with Cluster 2 stakeholders:

- Meetings with waste processing agencies such as Vital Waste (process both wet and dry waste), Tesla Energy "MBFT" (process mixed waste), NETEL, etc. revealed these agencies are keen on bidding for waste processing opportunities for this cluster
- Discussions were held with IEC agencies such as SAFE (NGO), Srimitram (private agency) who are already engaged in SWM related IEC in Kolkata and New Town area and have proven experience in the same
- Meetings with stakeholder ULBs revealed the following primary concerns of each ULB in this context:
    - KMC: The 20-acre HIDCO land, which has been identified for the whole cluster 2 under this present project, was earlier originally handed over to KMC with the intention of setting up a 600 TPD WTE unit only for KMC. Therefore, KMC has requested PwC to consider at least 600 TPD of exclusive KMC waste for the proposed treatment/ processing unit under this particular project.
    - BMC: We verbally understand that BMC is already on the process of secondary segregation followed by recycling of dry waste, and for that purpose they have identified a space/ land. However, this will be officially confirmed from BMC on 20th May during the proposed meeting with BMC officials. It was also understood that earlier they had initiated the procurement of 3 nos. of 100 TPD waste treatment unit, based upon MBFT technology from Tesla Energy, which is kept on hold as of now. BMC is also planning to mandate source segregation.
    - NKDA: Their primary concern is C&D waste. Also, since the identified 20-acre land is located within NKDA, they would expect it to cater to their waste as well.
    - Pollution control board: PWC team has discussed the implication of landfill site setting criteria as per Clause No 1.4.5.11 of MSWM Manual 2016. As per the discussions with PCB, there would be requirement for EC/ NOC from statutory authority while implementing landfill construction at the site. However, as this land falls within 10 km distance from airport and lots of habitations are already in place within 500 m periphery of the proposed 20-acre HIDCO land, identification of an alternative land may be initiated. The size and other criteria for this land shall be communicated to SUDA by PwC soon.

SUDA also mentioned BMC has been planning requirements for introducing source segregation, including bins and vehicles, and suggested BMC get these vetted by PwC so that it is in line with the DFR plan for BMC.

A.1.2. BMC

Date – 20-05-2019

The meeting commenced with the consultants explaining the officials about the analysis done by them and the progress made on the study till date. The objective of the meeting was to discuss with BMC on PWC's planning on the project concept and obtaining BMC view through a brainstorming session.

In addition to these, some of the points that were discussed are as follows:

- The plan for Mollar Bheri and its bio-mining/remediation has been discussed. BMC showed their concerns regarding how the huge quantum of fresh waste will be generated without Mollar Bheri. PWC team appraised BMC that Mollar Bheri will be closed, only once the new alternative waste processing & disposal system would get functional.
- Value chain of SWM, holistically in this project in line with a combination of centralized & decentralized SWM scenarios was discussed.
- Land constraints and the role of aerial distance in feasibility of SLF as the distance is less than 10 kms from the airport was also shared with them for (HIDCO land). The distance becomes paramount in case of obtaining clearances from AAI, which might be an issue.
- The constraints of availability of alternate land within BMC for decentralized MRF and composting facilities was understood from BMC. However, in ward no 36 some utilizable land has been identified by BMC, which could be made available for waste processing, exclusively for the waste generated within BMC premises. However, land in general is a constrained resource and BMC cannot provide the same within its limits.
- In wards 1, 2,3,4,5 and in wards 12, 16, 13, 14 there are waste processing system, in practice
- BMC had already initiated the required action to adopt zero waste solution through black hole technology. For that purpose, 2 nos. of 100 TPD MBFT at Mollar Bheri and one of same capacity at Kestopur have already been proposed earlier.
- BMC is implementing household level pilot project of source treatment of wet waste in some of the housings.
- Interventions in the form of 200 VATS to be built and locations are being identified.
- BMC is planning to create pilot projects of 1-2 TPD compost plants for decentralized approach in identified residential complexes. AOWC's have been given to some of them for implementation.
- BMC currently faces problems in SLWM and e-waste, industrial and domestic hazardous as MSME's pertaining to Jeans, Biscuits, Candy are present.
- BMC is also on the process of SWM plan on their own capacity, which they will be implementing on pilot scale basis. The infrastructure, manpower, asset etc. are being prepared by themselves. This is in accordance with the mandate of 10 identified model towns, in which SWM system will be implemented within the period of next 6 months.

A.1.3. KMC

Date -20/05/2019

The meeting began with the team of consultants briefing the Assistant Director about the project and the current level of progress. The Assistant director then briefed the team about the situation in Borough VII and gave them insights pertaining to the following:

- The entire area including the details of the wards that come under the Borough. Borough VII consists of 9 wards of which in 7 wards Islamic population is dominant.
- Location of collection points.
- Collection mechanisms being employed in Borough VII, 100% door to door collection happens in all wards
- Level of segregation in various wards and the mechanism for the same.
- Vehicles used for collection and transportation of waste such as Auto tippers, BOHD and push carts.

- Major issues pertaining to solid waste management in that area were also discussed, the assistant director informed the team about the constraints the municipal corporation faces in order to efficiently collect the generated waste and process the same.
- The problem of the Muslim population objecting to early morning collection of waste in Tiljala, Topsia, Tangra and BB Bagan areas and the issue with the mindset of the people in that region was also discussed.
- Another issue which was highlighted was the dumping of garbage on the street in Broad Street and Tiljala Road.
- KMC had undertaken IEC campaigns but they have not been that effective and wanted a firm to be hired for the same.
- The issue pertaining to mounting garbage bins on auto tippers has not yet been solved.
- The team was then briefed about the waste management scenario in the markets that come under the borough. The Assistant Director explained about the dry waste generated by hawkers in the market and explained the challenges associated with management of that waste. A compactor station is located right behind the market in spite of which waste is not being dumped properly. The problem of alcoholism and absenteeism of workers was also cited as a reason for ineffective waste management in that area.
- The team was given examples of a few outlets which are generating high amount of waste and details pertaining to areas like Tiljala and Topsia which are considered to be critical waste management sites in Borough VII.
- The tanneries present in the area produce two kinds of wastes, processed leather waste and unprocessed leather waste. The waste from both the processed & unprocessed sources go to the open vats, drains and roadside low land areas, along the ward canal.

  It is strongly recommended to segregate the waste at source in three categories from those specific leather product manufacturing establishments/ ward areas. Those streams should be – domestic wet waste, dry waste and leather waste. Leather waste should be stored, handled and collected separately by dedicated agencies and shall be diverted to the industrial hazardous waste disposal pathway.
- Segregation of waste happens in ward number 64 only. 20 workers visit every establishment in the ward every alternate day and collect wet waste from green bins and dry waste from white bins, but the level and extent of segregation is not very satisfactory.
- The team was then explained about the SWM process followed in the wards in the borough. Waste is collected through push carts and auto tippers, which work from 6AM in the morning to 6PM in the evening, which is then transferred to compactor station (95%) and RC station (5%). From there it is transferred to the Dumping ground in Dhapa.
- The team was then given a demo of the working of a BOHD and the technical details of the vehicle was shared with the team.

- Following which the locations of a few key dumping sites/VATS was shared with the team. The team visited the sites and observed the situation at the ground level to gain an understanding of how waste is being dumped at those locations

A.2. Model case studies &suitable technology options

Based on our understanding of the various models prevalent in the area of study, we have identified the best practices from across the country for exploring the replicability of the same in the context of the present cluster. Understanding the key-takeaways from the same would help the authority in understanding various models for effective administration.

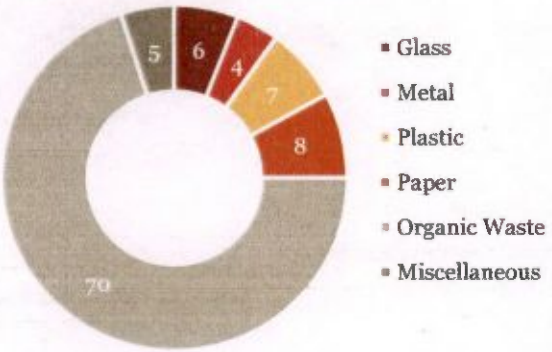
Model case studies

Pune

Overview

Pune is an Indian City located in the state of Maharashtra. The city spans across an area of 244 sq. Km and has a population of 3.5 million people. The city is divided into 41 wards and all the wards are governed by PMC. The city generates around 1600 MT of waste per day. According to projections, Pune is expected to generate around 3600 tons of waste by 2031.

Figure 58 Percentage composition of Municipal Solid Waste in Pune

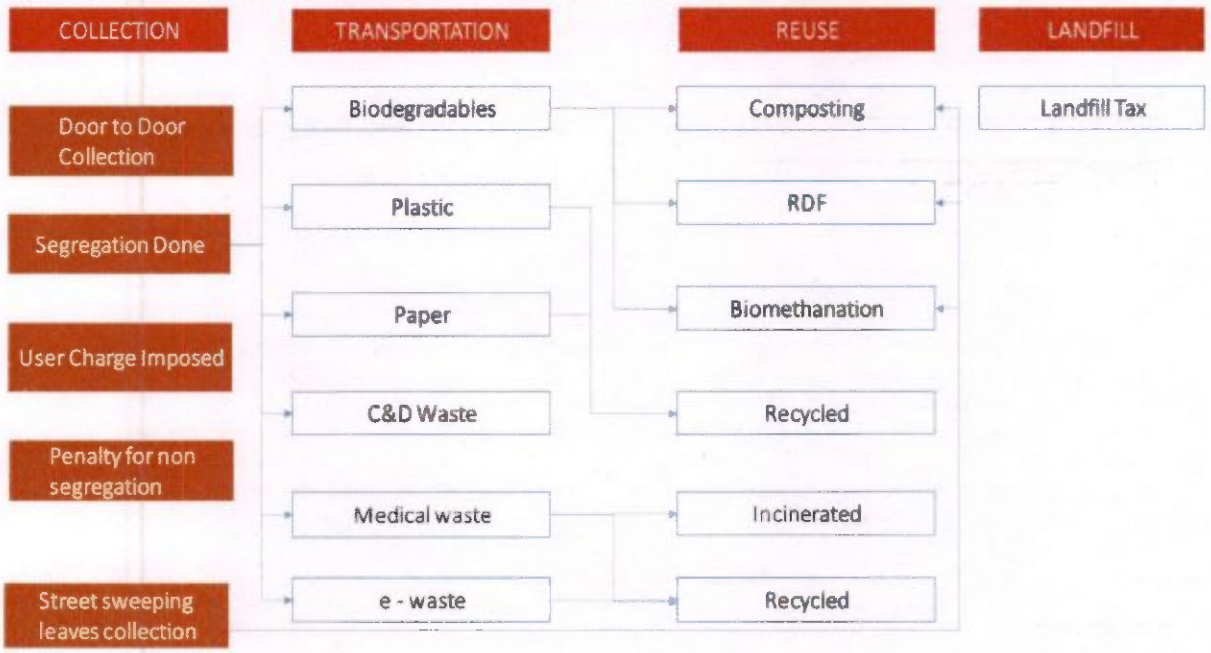


Source – Not in My Backyard

Solid Waste Management System

The SWM mechanism of Pune is as follows:

Figure 59Waste collection process of Pune Municipal Corporation



Collection, segregation and transportation

Door-to-Door collection is undertaken by an NGO called SwaCH, following which waste collection is done from households through Ghantagadis, which start collection from 6:30 AM onwards and have separate partitions for dry and wet waste. However, the level of segregation is only 50%. The Ghantagadis transport the waste to transfer stations where the waste is compacted and sent to respective processing sites using bulk refuse carriers.

Apart from this, there are households that process waste at their complexes itself. More than 10000 households have installed vermicomposting arrays at their buildings itself, PMC has offered a property tax rebate to all those households.

Figure 60 Vehicle used for waste collection in Pune

Source http://swm.punecorporation.org/

Infrastructure

VTS System

All garbage collection vehicles are GPS enabled and are monitored from a control room. The VTS system has been designed by Bio Enable systems. The Vehicles are monitored through a virtual dashboard which displays the status of the garbage bins, garbage collection vehicles and estimated time of clearance. This data can be accessed by citizens through the PMC's official website. The PMC authorities monitor the system from a control room.[21]

Table 88 List of assets of the PMC for waste collection

Existing Vehicles	Ghantagadi	Dumper Placer	Compactor	BRC	Mechanical Sweeper	Other	Total
	160	85	24	59	2	119	449

Source – SWM_Plan_2025_2017-PMC

IEC activities

The PMC has prepared an action plan for involving the citizens in the SWM value chain. As part of the IEC activities, PMC has planned outreach programs through special groups like schools & colleges, Corporates, Lions and Rotary Clubs and SHGs. It has also planned to conduct ward level rallies, exhibitions to generate awareness on a door-to-door basis. Social media campaigns through Facebook, Twitter and Whatsapp along with advertisements through print media have been planned to spread awareness about source segregation, waste disposal and waste processing at source. The budget outlay for the proposed IEC activities was 1.72 Cr in 2017 mainly towards awareness spreading activities. For 2018, a budget of 17 Cr has been proposed towards ensuring compliance.

[21]https://www.pwc.in/assets/pdfs/publications/2017/waste-management-in-india-shifting-gears.pdf

Source – http://swm.punecorporation.org/

Figure 61 Monitoring of Garbage Vehicles by the Pune Municipal Corporation

Waste processing

The city possesses centralized and decentralized composting and vermicomposting facilities, a waste recycling plant using RDF and a waste to electricity plant. Pune also has a biogas plant, which can process 5TPD waste in the form of vegetable, fruit rejects and stale food waste. The processing plants in Pune are as follows:

Table 89 Number of processing plants under PMC

	Biogas	Composting	Bio CNG	Thermal Composting	Mixed Waste	Other	Total
Processing Plants	25	5	1	7	5	0	43
Transfer Stations	7	NA	NA	NA	NA	NA	7

Source – Solid Waste Management Strategy Plan 2017 – 2025, PMC

Summary

Table 90 Summary of the current SWM practices in Pune

City	Waste Generated	C&T Mechanism	Source Segregation	Processing capacity
Pune	1600 MT/Day	1. D2D by Swach workers 2. Gate collection by Ghantagadis 3. Compactor stations 4. Processing plant using BRC 5. Scientific Disposal	50%	A total of 43 processing plants which include biogas, composting, bio CNG and mixed waste processing plants.

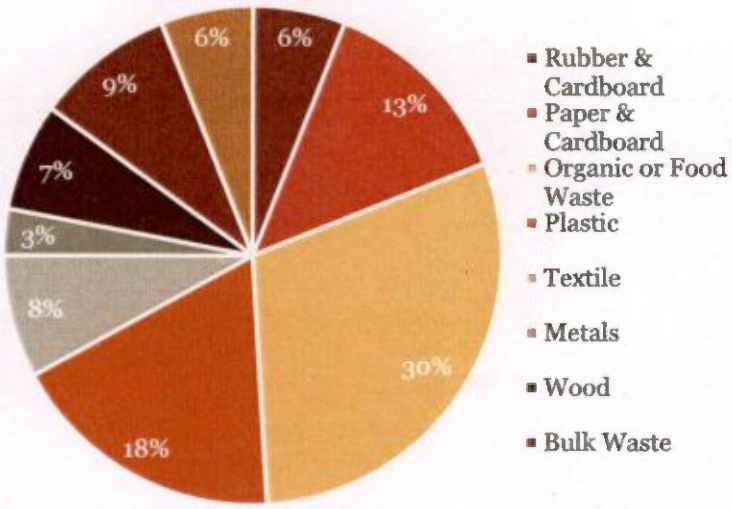
Source – Solid Waste Management Strategy Plan 2017 – 2025, PMC

Varanasi

Overview

Varanasi is a city on the banks of the river Ganga in Uttar Pradesh. It is a pilgrimage place and a holy site for sacred baths in the river Ganga. As per census 2011, there are 1.91 lakh households in Varanasi with nearly 11.98 lakh population. Daily flow of tourists and pilgrims from all over the world to the city is constantly increasing city population from decade to decade. Varanasi Municipal Corporation (VMC) is managing the solid waste management system of Varanasi city. The municipal area of VMC is 82.1 km², which is divided in 90 administrative wards for management of basic services to citizens. The city at present generates 645 MT of waste per day at the rate of 0.50 Kg per capita per day and decadal population growth of 10%.[22] The solid waste generation in 2041 is expected to be 1206 TPD. This has been calculated for the projected population, with waste per capita increasing from 400 grams in 2013 to 420 grams in 2041.[23]

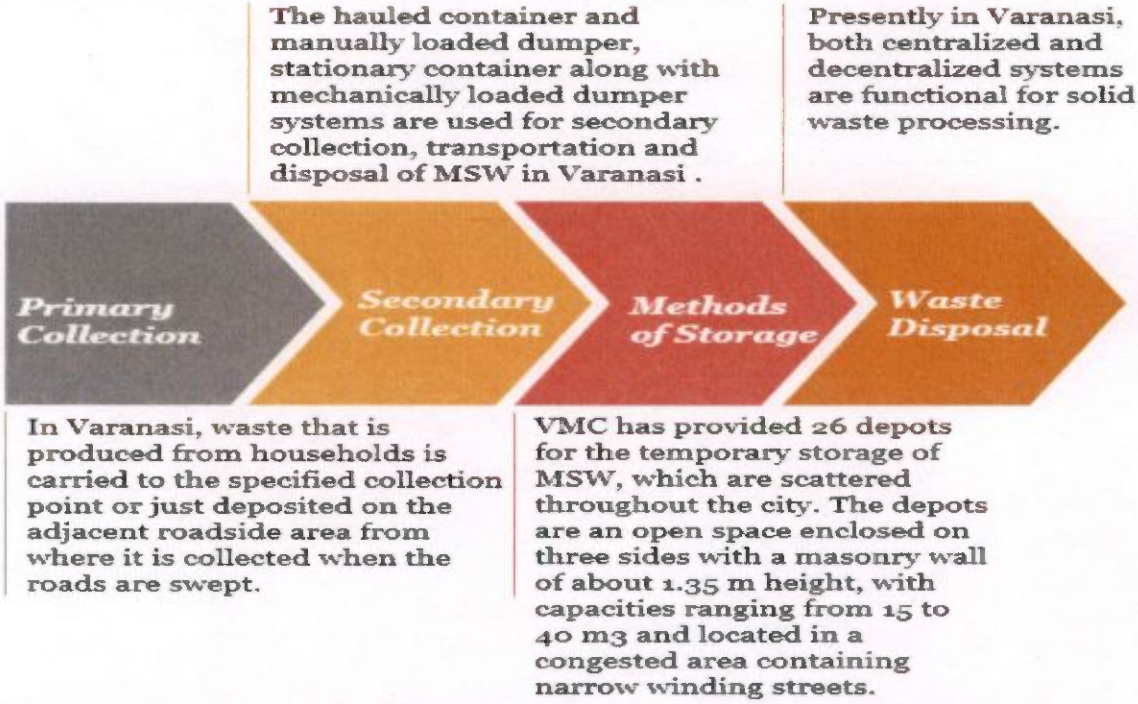
Figure 62 Composition of Municipal Solid Waste



Source: Municipal Solid Waste and its Management (A Study on Varanasi City), 2018

Solid Waste Management System

Figure 63 Waste Collection process of Varanasi Municipal Corporation



Source: Municipal Solid Waste and its Management (A Study on Varanasi City), 2018

[22]http://ijtimes.com/papers/finished_papers/150531034102.pdf(Municipal solid waste management in Varanasi, India)
[23]http://nnvns.org/data/Final%20CDP%20Varanasi.pdf(City Development Plan for Varanasi, 2041)

The SWM mechanism of Varanasi is as follows:

Collection, segregation and transportation

Door-to-Door waste collection is functional in all 90 wards of Varanasi using handcarts, and rickshaws, auto trippers and four wheelers Tata Ace. Waste collected from total 2,13,450 households are transferred to roadside bins or nearby secondary storage point. Waste from roadside bins are collected by refuse compacter and transported to disposal site. Similarly waste from secondary storage points are collected by dumper placer and transported to disposal site. Presently 30 secondary waste storage points are operational in Varanasi.[24]

Infrastructure

Table 91Types of Vehicles used for Waste Collection

Details of vehicles used for waste transportation in Varanasi	Refuse Compactor	Tata Ace	Dumper	Dumper placer	Tractor
	24	72	28	8	27

Source – Municipal solid waste management in Varanasi, India, 2018

Waste processing

Varanasi does not have many industries that produce hazardous products; hence, the presence of industrial hazardous waste is low. However household hazardous waste like detergents, pesticides, medicines which have crossed expiry date, cleaning products, automobile wastes, batteries, etc. were seen in plenty. Presently in Varanasi both centralized and decentralized system is functional for solid waste processing.[25]

Table 92Number of processing plants under VMC

Location of processing facility	Processing capacity	Category of waste process	Processing technology
Karsada	600 TPD	Mixed Waste	Windrows Composting
Bhawaniya Pokhari	5 TPD	Organic Waste	Biomethanization
Pahariya mandi	5 TPD	Organic Waste	Biomethanization
Near IDH hospital	5 TPD	Organic Waste	Biomethanization
Ram Ghat	1 TPD	Flower Waste	Composting

Source – Municipal solid waste management in Varanasi, India, 2018

Summary

City	Waste Generated	C & T Mechanism	Source Segregation	Processing Capacity
Varanasi	600 TPD	• Household & waste generated from other sources discarded on the roadside collected by the VMC appointed sweepers. • The hauled container and manually loaded dumper, stationary container along with mechanically loaded dumper systems are used for secondary collection, transportation and disposal of MSW in Varanasi.	0%	5 Processing Plants are there- • 1 Windrows Composting in Karsada for Mixed Waste; • 3 Biomethanization plants in Bhawaniya Pokhari, Pahariya mandi & Near IDH hospital for Organic Waste; and • 1 Composting plant in Ram Ghat for Flower Waste.

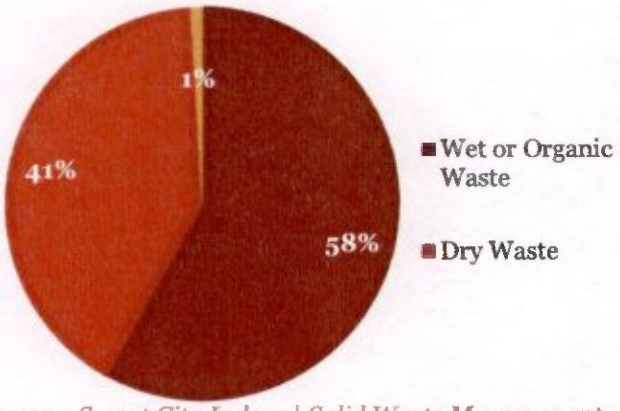
[24]http://ijtimes.com/papers/finished_papers/150531034102.pdf
[25]https://www.ijtsrd.com/papers/ijtsrd14494.pdf

Indore

Overview

According to the 2011 census, the population of the city of Indore was about 2.17 million, which represents an increase of nearly 47% since the last census of 2001.[26] The rapid population growth, the industrialization, urbanization and economic growth of the city generates over 1,115 MT of municipal solid waste per day. Out of the total waste 58.25% is the wet or organic waste, 41.75% is dry waste ando.5% is household hazardous and sanitary waste. The total wet waste generation is 650MTPD (Approximately) and dry waste generation is 465 MTPD (approximately).[27]

Figure 64Composition of Municipal Solid Waste in Indore



Source – Smart City Indore | Solid Waste Management, 2019

Solid Waste Management System

Indore today generates over 1,115 MT of garbage a day and all of it is collected from the source whether it is a household or commercial establishment. The door-to-door service was started in January 2016 as a pilot projects in two of the 84 wards in the city. It took almost a year to achieve 100% door-to-door garbage collection. Indore through its commendable collaborative efforts has achieved segregation of waste at source at 100% of its household's and commercial units.

Citizens of Indore played a significant role in making the city neat and clean. The cleanliness scenario of Indore was changed by improved habits of its people. Within a span of one year, the Municipal Corporation successfully sensitized citizens for segregation at source and not dumping garbage in open areas.
The SWM mechanism of Indore is as follows:

Figure 65 Waste Collection Process of Indore Municipal Corporation

Source – Smart City Indore | Solid Waste Management, 2019

[26]https://www.irjet.net/archives/V4/i11/IRJET-V4I11344.pdf(SOLID WASTE MANGEMENT OF INDORE CITY: A REVIEW, 2017)
[27]https://www.smartcityindore.org/solid-waste/

Collection, segregation and transportation

Indore has been divided into 19 zones and 85 wards. Each ward has on an average 6,000households and 600 commercial establishments (part of 88 notified commercial areas). In Indore, waste is generated from various sources including households, commercial areas and other institutions like RWAs, hospitals, hotels among others. The households or residential complexes are covered by the door-to-door collection system while the semi bulk and bulk generators are covered by the bulk collection system. Indore ensures the 100%coverage of wards through its door-to-door collection system.

Figure 66 The waste in Indore is collected through partitioned vehicles known as 'Tippers'

Source – Smart City Indore | Solid Waste Management, 2019

VTS system

The door-to-door collection is done through the use of partitioned vehicles. There are three separate collection bins for wet, dry and domestic hazardous waste in each tipper. The tippers have a predefined collection route, which has been defined in their deployment plan. The tippers on completing their collection routes, move to their designated GTS and offload their waste in the designated compactor. These tippers carry the waste from households to the transfer station, from where the waste is transported to the trenching ground in hook loaders. All vehicles used in the collection and transportation system are monitored by a GPS enabled tracking system. The GPS system is constantly monitored by the monitoring cell.

IEC activities

IMC adopted and undertook a range of IEC activities ranging from traditional to audiovisual to print and electronic media to social/digital media to change the behavior of different segments of population and those who associated with different sectors viz. hotel and restaurants, hospitals, industry, transportation, commercial complex, park and entertainment, etc.

IEC was aimed at educating citizens on whom to reach out for availing services as well as articulate issues. The success of Swachh Indore depended on the nature of collaboration between service providers (community associations, citizen volunteers, NGOs) and IMC official machinery (CSI, Zonal officers and core IMC officials). While certain IEC media, such as nukkad nataks, rallies, swachhata samitis connected citizens with service providers – on the other hand technologies such as 311 App and walkie- talkies helped in directly connecting with the IMC official machinery.

Some of the novel IEC measures taken up by IMC for behavioral change in Indore were- Grassroots innovations street plays, Wall paintings, FM radio constantly upgraded its content itself through incorporating new thematic messages to be communicated and utilizing creative ways of undertaking the same. Cultural events such as Ganesh festival, Dusshera, Gandhi Jayanti were also utilized as events to spread the Swachhata message.

Waste processing

To strengthen and reduce the cost of the Secondary Collection and Transportation System, IMC has constructed eight ultra-modern transfer stations of three types of models such as Ramp based static GTS, portable Compactors based GTS and semi portable Compactors based GTS installed by Hyva and TPS at different locations mentioned below within the city-

1) Star Square
2) Kabitkhedi
3) F-sector, Sanwer Road
4) Sangam Nagar
5) Sirpur, Dhar Road
6) Lalbagh
7) Crystal IT Park
8) Rajshahi, DakkanwalaKua

Summary

City	Waste Generated	C & T Mechanism	Source Segregation	Processing Capacity
Indore	1,115 MT	• In Indore, waste is collected in segregated manner i.e. the waste is segregated at source by the generators. • The collected waste is transported by the Tri-partioned garbage tippers deployed in all 85 wards to the designated Garbage transfer station (GTS). • The segregated MSW is compressed into respective containers. • When the containers are filled to capacity, they are lifted by dedicated hook loader and sent to disposal site in a segregated manner.	100%	• Wet Waste offloaded at the Centralized Composting Unit. • Dry Waste offloaded at the Material Recovery Facility 1 / Material Recovery Facility 2 at the disposal site. • Domestic Hazardous Waste is offloaded at the Common Biomedical Waste Facility (CBWTF).

Key takeaways:

1. IEC was aimed at educating citizens on whom to reach out for availing services as well as articulate issues. The success of Swachh Indore depended on the nature of collaboration between service providers (community associations, citizen volunteers, NGOs) and IMC official machinery (CSI, Zonal officers and core IMC officials). While certain IEC media, such as nukkad nataks, rallies, swachhata samitis connected citizens with service providers – on the other hand technologies such as 311 App and walkie- talkies helped in directly connecting with the IMC official machinery.

2. Domestic hazardous waste is treated in modular bio-medical vans, which operate across the city.

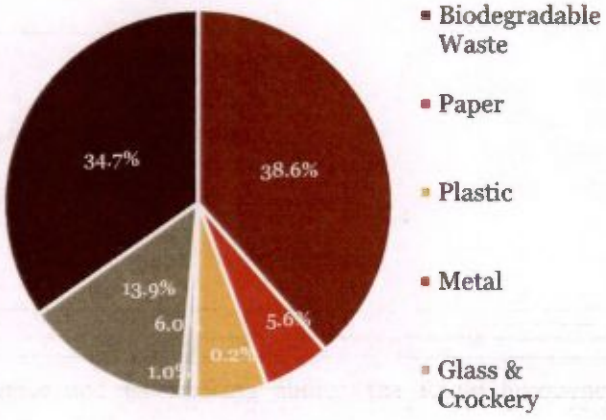
Delhi

Overview

Delhi, officially the National Capital Territory (NCT) of Delhi, is the capital of India. It has a population of about 16.3 million, making it the second most populous city and second most populous urban agglomeration in India and third largest urban area in the world (Census of India, 2011; UNSD, 2015). The NCT includes the neighboring cities of Gurgaon, Noida, Greater Noida, Faridabad, Neharpar (Greater Faridabad), Ghaziabad, Bahadurgarh, Sonepat, Panipat, Karnal, Rohtak, Alwar, Bharatpur, Bhiwani, Rewari, Baghpat, Meerut, and other nearby towns.[28]

Delhi is a commercial and administrative hub, providing employment opportunities that has accelerated the pace of urbanization, resulting in a corresponding increase in Municipal Solid Waste (MSW) generation.[29]Five municipal authorities are responsible for solid waste management in the city—the North Delhi Municipal Corporation (North DMC), South Delhi Municipal Corporation (SDMC), East Delhi Municipal Corporation (EDMC) the New Delhi Municipal Council and the Delhi Cantonment Board (DCB). The three corporations--North, East and South—alone manage 96 per cent of the total area of the city. As per information provided by MCDs, 10050 TPD of municipal solid waste is collected in Delhi.[30]Delhi, have a per capita waste generation in the range of 0.22-0.62 kg.[31]

Figure 67Physical Characteristics of waste in Delhi

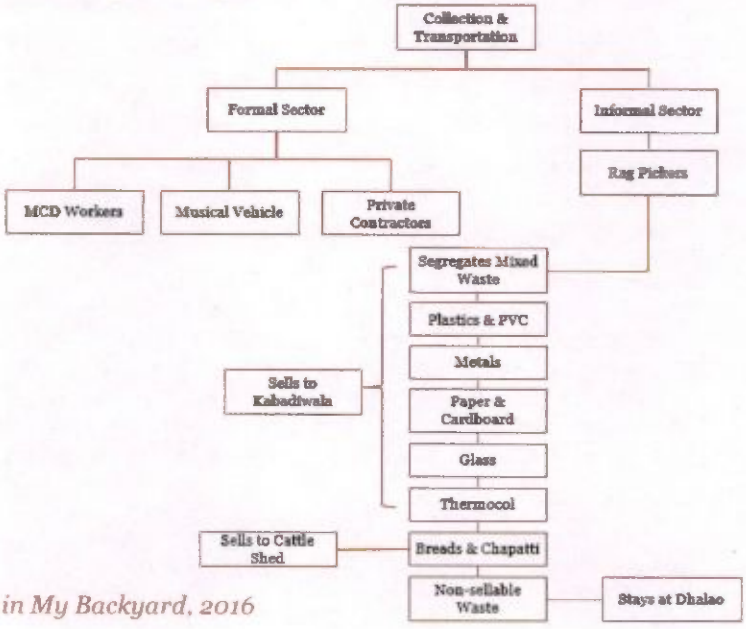


Source – Study on the Municipal Solid Waste Generated in the Delhi City, 2018

Solid Waste Management System

The SWM mechanism of Delhi is as follows:

Figure 68 Waste collection process of Delhi



Source – Not in My Backyard, 2016

[28]A study on management of municipal solid waste in Delhi, Journal of Environment and Waste Management, 2018

[29]http://www.duac.org/site_content/attachments/SWM%20CR%20Park.pdf, SOLID WASTE MANAGEMENT, Chittaranjan Park (Ward Number 190), Delhi.

[30] Recommendations for Long Term Action Plan for Solid Waste Management in Delhi, 2017.

[31] NIMBY, Not In My Backyard, 2016.

Collection, segregation and transportation

As per information provided by MCDs, there are two waste collection systems running in Delhi. Under one system, collection is done through formal sector by the municipal staff or by an authorized party or private concessionaire. Under the other, the informal sector is responsible for door-to-door collection of garbage, which is further transported to dhalaos after the waste picker takes up the recyclable fraction. The informal sector is integrated into the collection systems by an informal contractor. As documented in CSE's report, 'Not in My Backyard', 2016, there are about 300,000-400,000 ragpickers in Delhi, who play a critical role in the recycling industry and help prevent tons of recyclable waste from reaching the dumpsites. There is an urgent need to integrate (upscale) the two collection systems and incentivize the collector to collect segregated waste.

MSW is collected daily from storage /receptacles /collection centers/ (dhalaos/dustbins/) existing at different places in all statutory bodies of Delhi. This MSW does not include segregated waste picked up by waste pickers / kabariwala at the doorstep and Collection Centers. This waste generated by the citizens is deposited in the receptacles either by the citizens themselves or through private waste pickers and the same is taken to various facilities for processing/disposal. NDMC is carrying out door-to-door collection and segregation of MSW in its jurisdiction.

Infrastructure

Table 93 Vehicles for Solid Waste Management.

Name of the Vehicle	Number of Vehicles				
	MCD			DCB	NDMC
	NDMC	SDMC	EDMC		
Truck - Tipper having capacity 8 m3	101	138	140	15	14
Tractor - Trailer	Nil	40	Nil	Nil	Nil
Refuse collector/ compactor having capacity 14 m3	58	26	Nil	11	15
Dumper - placers/Bins having capacity 1100ltrs.	222	1151	Nil	Nil	Nil
Front end loaders	22	30	26	Nil	Nil
Auto Tipper	398	256	302	Nil	26
PVC Bins having capacity 200ltrs.	Nil	800	Nil	Nil	Nil
Tricycle	Nil	Nil	1000	Nil	144

Source – A study on management of municipal solid waste in Delhi, 2016

GPS tracking for the waste management vehicles[32]

EDMC and SDMC have started GPS /Radio-frequency identification (RFID) based tracking system to locate the position of its refuse removal trucks and other vehicles to increase their efficiency and productivity. This also ensures regular and timely collection of garbage and deportation to the Ghazipur SLF. 232 GPS have been installed on auto tippers and around 450 RFIDs are fixed on waste storage depot, tipper trucks, and workshop and landfill sites. In EDMC area, the vehicles deployed in Rohini Zone and Civil Line Zone (about 248 no. of vehicles) are equipped with GPS. In SDMC, this work has been outsourced to DIMTS (Delhi Integrated Multi-Modals Transit System).

IEC activities[33]

In North Delhi Municipal Corporation, distribution of pamphlets, meetings with RWAs, market associations, public representatives, nukkad-nataks, children education program, etc. are being done for public awareness in the locality. As for Delhi Cantonment Board- public, hoardings and posters have been put up for creating public awareness.

Whereas for South Delhi Municipal Corporation, a public notice was issued in the leading newspapers for public awareness. Moreover, pamphlets were distributed apart from other publicity measures such

[32]Final Solid Waste Management Of EDMC, 2017
[33]Long term action plan for solid waste management in Delhi

as through radio jingles etc. Other activities such as nukkad-natak's etc., education in schools, interaction with RWAs etc. highlighting the importance of segregation and adherence to Solid Waste Management Rules, are being done.

Waste processing

Table 94 Existing infrastructure for waste disposal

Waste Processing Units	Area of Establishment
Composting Sites	• Okhla (200 tons) • Bawana (1000 tons)
Waste to Energy	• Okhla (2000 tons, 16MW) • Gazipur (1300 tons, 14MW) • Narela- Bawana (2000 tons, 24MW)
C&D Facility	• Shastri Park (500 ton) • Burari (2000 ton)
Landfills/Dumpsites for waste disposal	• Ghazipur (70Acres, oversaturated) • Okhla (56Acres, oversaturated) • Bhlasawa (40Acres, oversaturated) • Bawana (Integrated waste management plant in 100 acres)

Source – Recommendations for Long Term Action Plan for Solid Waste Management in Delhi, 2017

Greater Mumbai

Overview

Mumbai has garbage production of around 6500 tons per day and around 2500 tons of construction and demolition (C&D) waste per day. MCGM operates a huge fleet of 1,234 municipal and private vehicles for collection of waste, making approx. 1,396 number of trips each day.

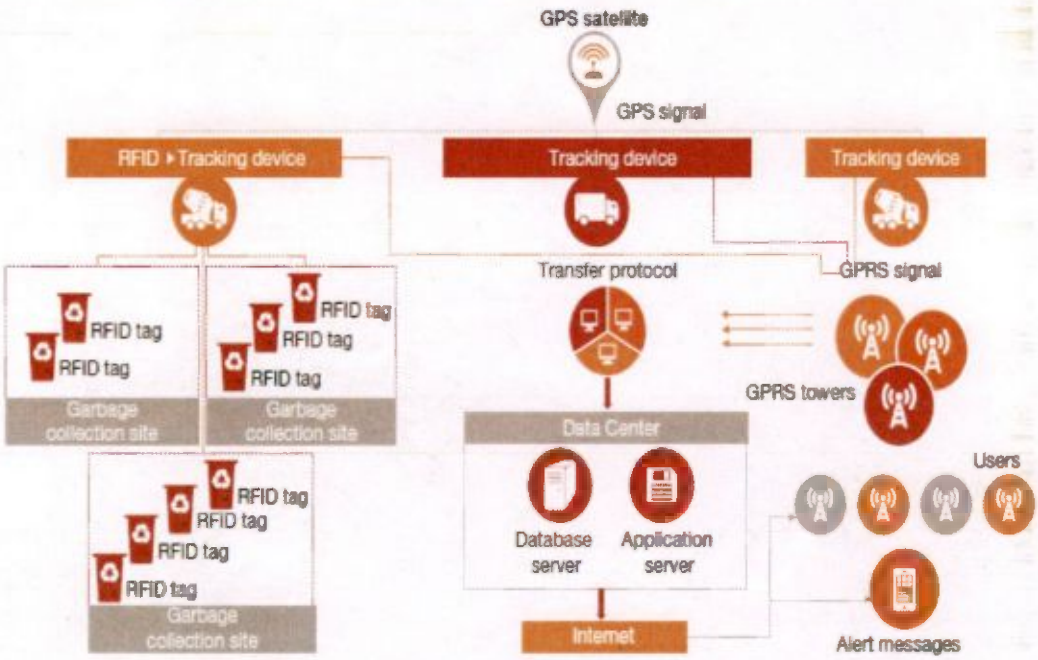
ICT-enabled waste management for Municipal Corporation of Greater Mumbai (MCGM)

The benefits of using ICT in waste management systems are:

- Real-time bin clearing status
- Viewing vehicles on duty
- Monitoring bins, vehicles and staff
- Tracking bin clearing efficiency
- Monitoring SWM disposal quantity
- Monitoring citizen complaints
- Monitoring trips by vehicles in km

MCGM, under one of its IT initiatives started ICT enabled waste management project called GPS based Vehicle Tracking and Monitoring System (VTMS). The system is a web based automatic vehicle tracking and telemetric fleet management incorporating Global Positioning System (GPS), combined with GPRS/GSM and digital map technology. The key components of the solution are GPS based navigation device and its tracking ability, the Radio Frequency Identification (RFID) and few electronic sensors to monitor the activities carried out by the vehicle and department personnel using the vehicle. The vehicles attached with GPS devices for location tracking, RFID readers to sense and verify the refuse bin pickups, fuel sensors to keep a track on the fuel used, and weight sensors to get information of weight collected at each garbage pickup location. The garbage bins are also fitted with RFID tag (passive tags) which are read by the garbage vehicle readers each time the bin is picked. The system is completely monitored by a central monitoring cell and is also integrated with other systems like weighbridges at the dumping grounds, Fleet Management system of the MCGM ERP and GIS system for map-based module.

Figure 69Vehicle Tracking and Monitoring System (VTMS) used by MCGM



Source – Waste Management in India - Shifting Gears, March 2017

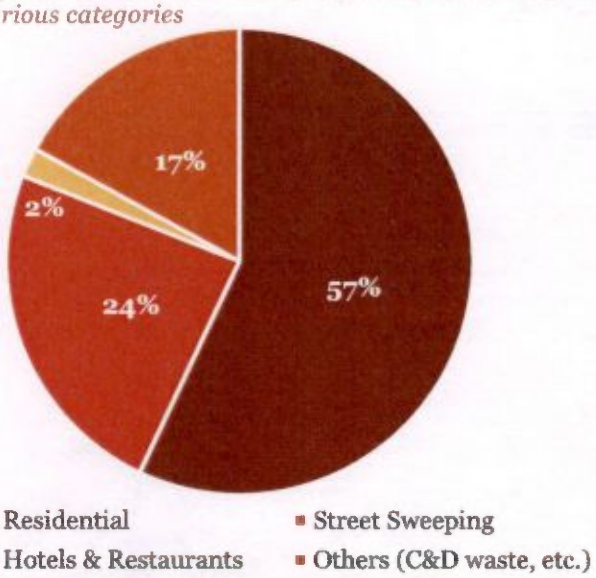
Ahmedabad

Overview

Ahmedabad is the 7th largest metropolis in India, having a population of more than 63 lakhs and spread over an area of 466 Sq. Km. The Ahmedabad Municipal Corporation (AMC) provides all basic services to citizens of Ahmedabad such as water supply, collection of sewage, solid waste management, building roads and transportation, street lighting, providing medical and educational facilities are some of the key services. For effective service provision and smooth administration to all citizens, AMC has divided its activities into 6 zones and 48 wards. Budget allocated and spent in the year 2015-16 was Rs 410 crore.

Moreover, the city is witnessing a major construction / infrastructure boom as well as a steady population increase. It is a growing hub of education, information technology and scientific Industries. Hence, almost, 4000 metric tons of solid waste (including 300 tons of C&D waste) is generated from the city on a daily basis.[34]

Figure 70A detailed break up of MSW generated by various categories

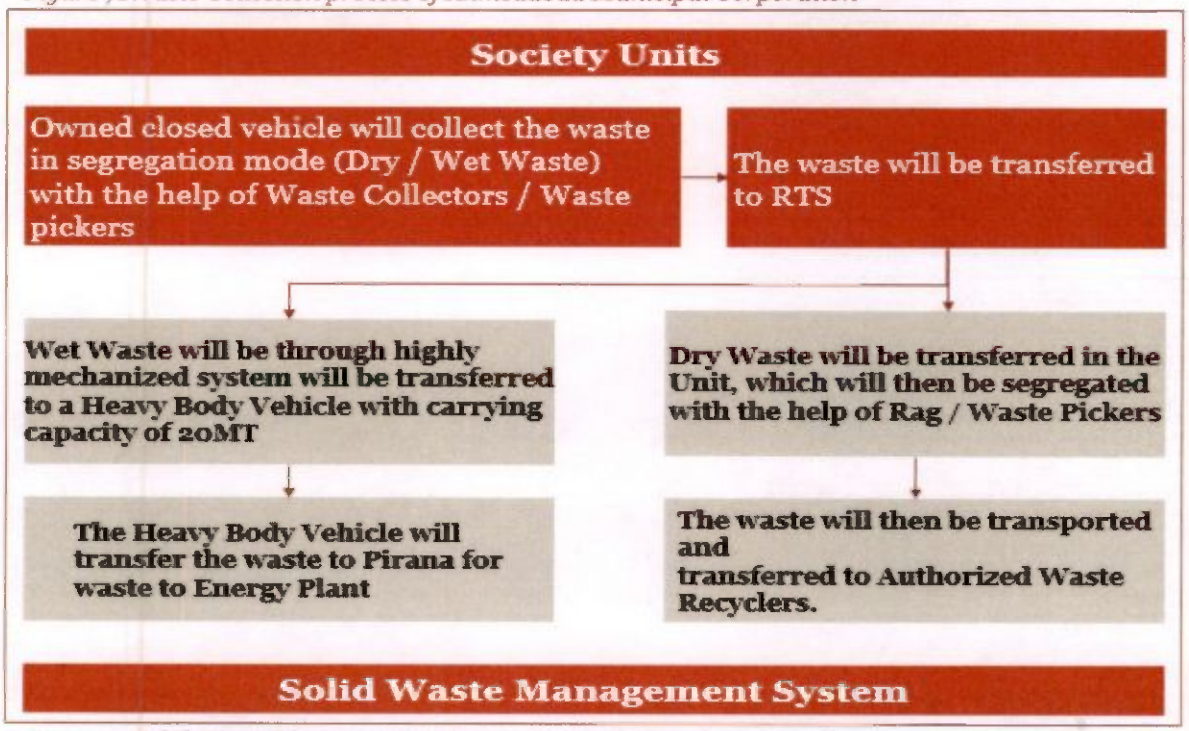


Source – Integrated Solid Waste Management System of Ahmedabad City, 2018

SWM system

The SWM mechanism of Ahmedabad is as follows:

Figure 71Waste Collection process of Ahmedabad Municipal Corporation



Source – Solid Waste Management: A Case Study of Ahmedabad, 2016

Collection, segregation and transportation

AMC has identified more than 934 locations as waste collection points, where 1051 closed body M.S. Community storage bins have been provided for waste collection. These containers are lifted

[34] *Solid Waste Management: Ahmedabad*. Ahmedabad Municipal Corporation, 2018.

minimum once in a day and if required, then twice a day. Nearly 50 percent of the entire waste is collected from municipal bins and from street sweeping. Street Sweeping is carried out on all 365 days by more than 12,500 workers from the morning 6:30 am to 11:30 am and 3.00 pm to 6.00 pm on all roads of the city.

AMC introduced a new concept of Door/Gate to Dump since July 2009, in which the AMC appointed contractor to collect waste from residential units in the morning hours and from commercial units in the evening in closed Hydraulic Euro III vehicles. The waste from these vehicles is transferred to transfer stations from each ward to the treatment plants. Currently, more than 1300 metric tons of waste is collected from more than 14, 33,000 residences and almost 1, 50,000 commercial units in this manner and transported to the processing plants through Refuse Transfer Stations. This work is monitored through GPS system.

Notably, AMC has developed a fully mechanized transportation system that ensures handling of waste only once. Further AMC has also outsourced the secondary waste transportation system & ensure timely & efficient removal of waste from its collection point.

Figure 72 The new vehicle, for waste collection, introduced by AMC with closed body having different compartments with tipping agreement for collection of segregated waste from citizens

Source – Integrated Solid Waste Management System of Ahmedabad City, 2018

Infrastructure

AMC has developed a fully mechanized transportation system that ensures handling of waste only once. Further, AMC has also outsourced the secondary waste transportation system to ensure timely & efficient removal of waste from its collection point.

Table 95 Types of Vehicles used by AMC for waste collection

Types of Vehicles	Number of Vehicles
Tipper Trucks	89
JCB Machines	40
Bobcat type machines	33
Hydraulic Dumper Placers	120
Skip Lifters	11
Compactors	54
Dead Animal Vans	4
Nuisance Tankers	14
Mobile Court	1
Tractors	60
Excavators	3
Bull dozers	5
Wheel Dozers	3
Road Vacuum Sweepers	20
Mini Vans	24

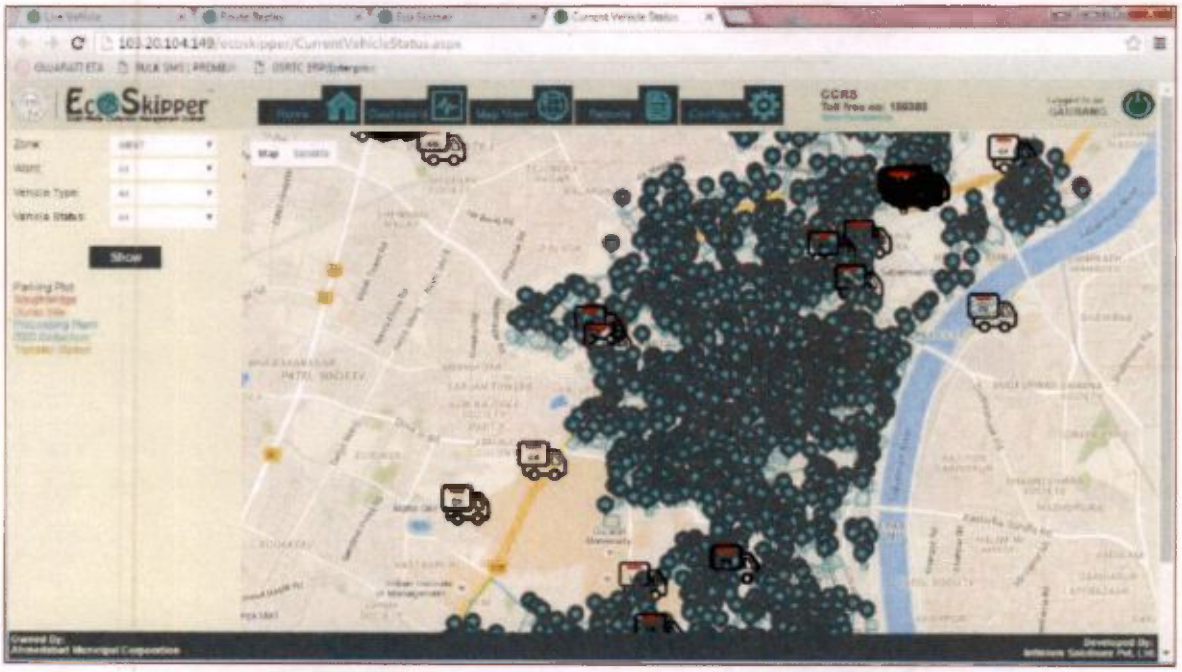
Source – Solid Waste Management System of Ahmedabad City, 2018

GPS & RFID based monitoring system

Current status of project for the implementation of GPS enabled waste collection vehicles in Ahmedabad is as follows:

- Zone wise Bin Lifter vehicle details and Bin locations is provided to the computer system.
- GPS device is installed in each Bin Lifter vehicle.
- RFID Tag is mounted on each Bin.
- RFID readers are installed at ward offices, Transfer stations, dumpsite weighbridges.
- One supervisor for each zone is deployed by the contractor for effective monitoring from 8 am to 6 pm.

Figure 73 Live status of the location of the MSW vehicles showing on the map



Source – Integrated Solid Waste Management System of Ahmedabad City, 2018

IEC activities

AMC has initiated IEC (Information, Education and Communication) activities for generating awareness among the general public towards cleanliness, waste treatment & waste disposal. Activities include formation of committees, conducting group meetings in the wards, short films, publicity through television channels / local cable network, advertisement in newspapers, distribution of pamphlets, erecting of Banners, Slides in cinema theatres, conducting street plays, organizing of rallies involving school & college students. Imparting awareness training to municipal staff and councilors has also been included.

Figure 74 Engineered Landfill Site, Gyaspur

Source – Solid Waste Management System of Ahmedabad City, 2018

Waste processing

AMC has secured engineered landfill site in operation and made provision for another five scientific landfill sites for disposal of inert/post process solid waste at Gyaspur.

Summary

City	Waste Generated	C & T Mechanism	Source Segregation	Processing Capacity
Ahmedabad	4,000 MT	• AMC has identified more than 934 locations as waste collection points, where 1051 closed body M.S. Community storage bins have been provided for waste collection. • These containers are lifted minimum once in a day and if required, then twice a day and carried to the disposal site.	AMC prepared Public Health Bye-laws for effective enforcement	• Secured engineered landfill site in Gyaspur.

Key takeaways:

1. Planning for five scientific landfills by identifying landfill sites in advance in conjunction with the projected population and corresponding waste growth.
2. Established centralized composting facility with focus on hub and spoke model with six new similar facilities in the future.

Mysore

Overview

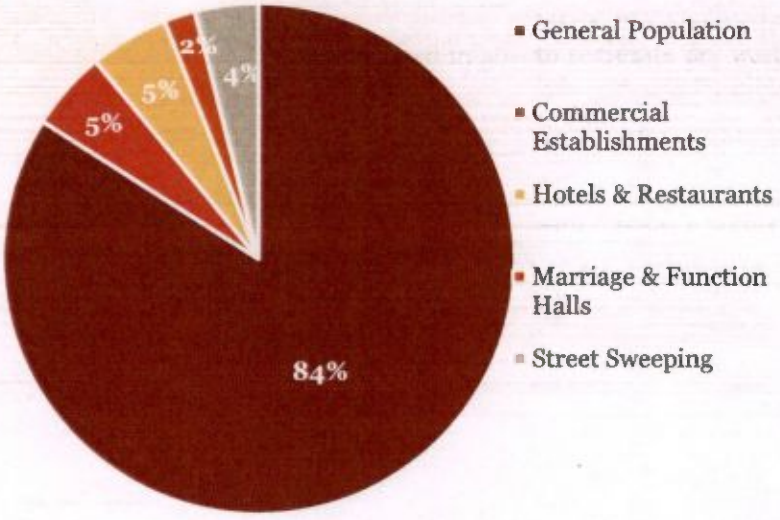
The Mysore City is located at 76°12' (East) longitude and 12°18' (North) latitude. It is the second largest city in the state of Karnataka.

It was the capital of the former princely state of Mysore and is now a divisional headquarters having a population of about 9.95 lakhs, as per provisional population table of Mysore 2011.

The total estimated quantity of Municipal Solid waste generated per day in Mysore City is 402MT. The residents of Mysore City, at an average generates 360 grams of MSW every day which accounts for a total of 338MT. Mysore City has 20,329 commercial establishments generating 20MT of MSW per day.

Hotels and Restaurants in Mysore city generate 21MT of MSW at an average per day. 124 Marriage and function halls generate 6MT of MSW per day. Street sweeping throughout the city accounts for an average 17MT of waste.

Figure 75 Composition of Municipal Solid Waste in Mysore

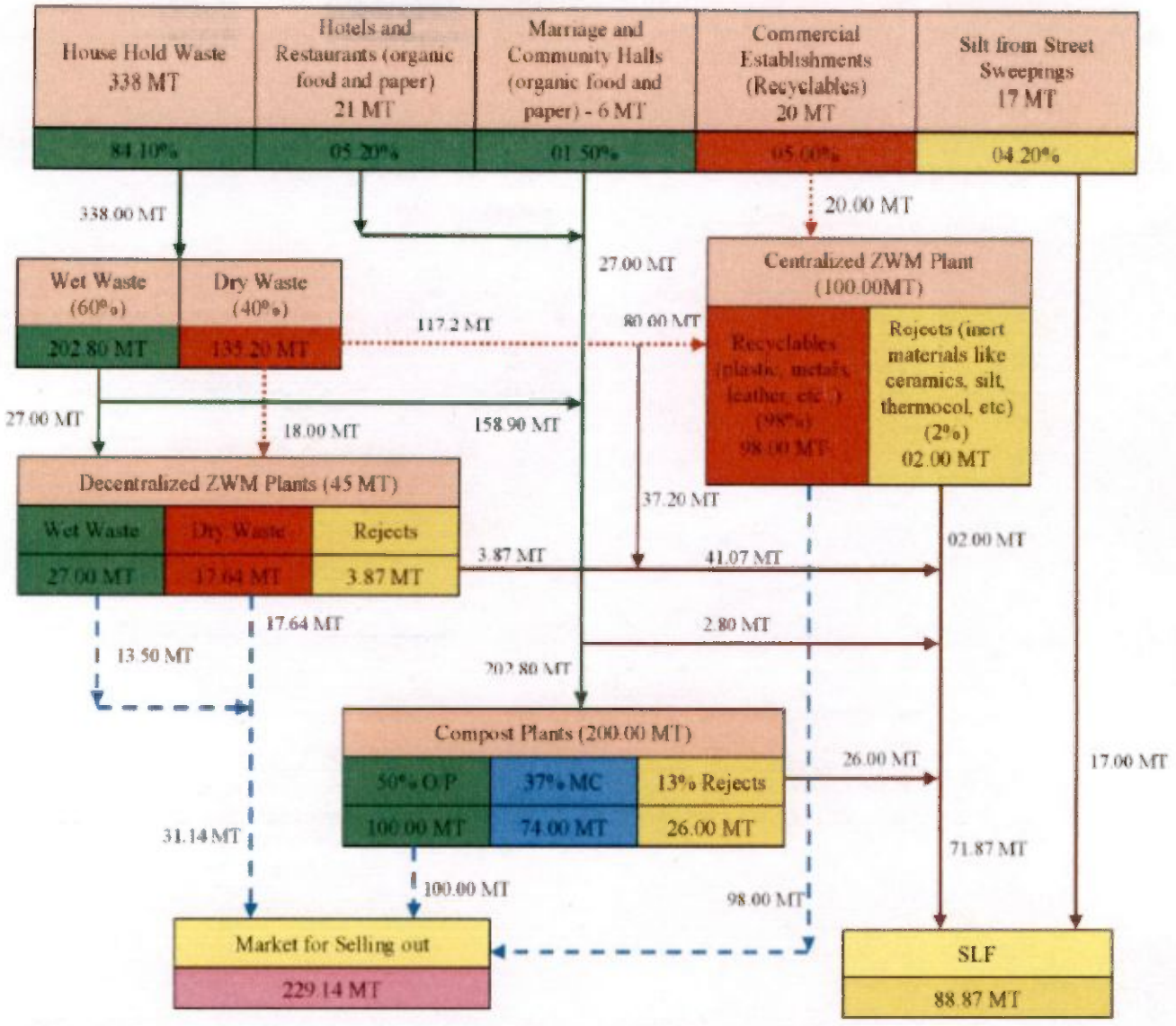


Source – Mysore City Corporation

SWM system

The SWM mechanism of Mysore is as follows and is depicted in the figure below in the next page:

Figure 76 Integrated SWM Strategy of Mysore City



Source – Assessment of Municipal Solid Waste Management in Mysore City, 2014

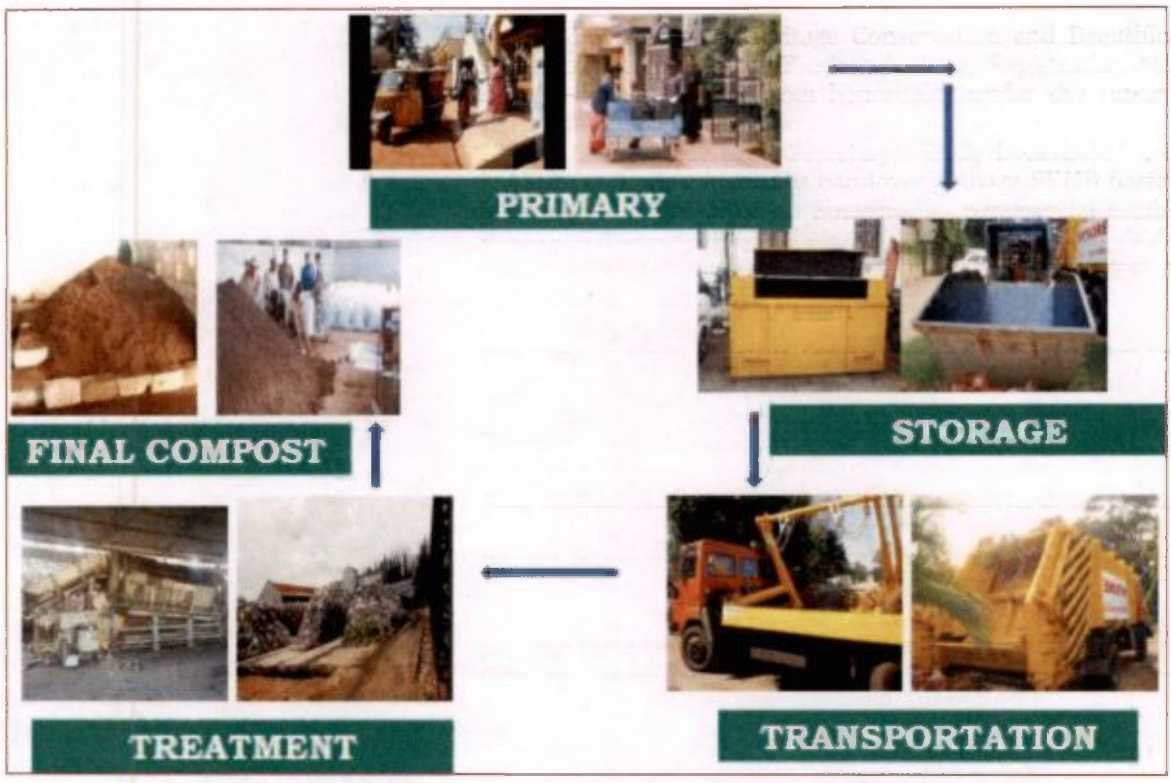
Collection, segregation and transportation

The Mysore City Corporation carries out Door to door collection of solid waste from all the 65 wards within its limit. Out of which, 62 wards are handled by Outsourced labors and three wards are handled by federation of Mysore City Wards Parliament. MCC has deployed 240 auto tippers and 396 pushcarts for the collection of waste throughout the city. One auto tipper is allotted to 1000 houses to collect wet waste and dry waste from the localities and one pushcart for 250 houses, which dump them at the Zero Waste Management units. Five Auto tippers and one canter are collecting the chicken and mutton market wastes separately.[35]

The Mysore City Corporation is engaged in Street sweeping activities for all the 65 wards of Mysore city every day. Out of which, 17 wards are handled by MCC Pourakarmikas (sanitary workers), one ward is handled by federation of Mysore City Wards Parliament (Ward No. 28) and rest of the 47 wards are handled by outsourced labors. The street sweepings and the silt collected from the road side drains are temporarily stored in small heaps on the road sides or are collected in the bins and transferred to tractor placers for disposal.[36]

[35] NIMBY, Not In My Backyard, 2016.
[36] Assessment of Municipal Solid Waste Management in Mysore City, 2014.

Figure 77 Solid Waste Management- A bird's eye view of the process



Source – Integrated Solid Waste Management Strategy in Mysore City, Mysore City Corporation

VTS System[37]

The corporation has installed GPS units to track the movement of these vehicles. The device sends signals to the control room about the exact location of these vehicles, which displays the status of the garbage bins, garbage collection vehicles and estimated time of clearance. The MCC authorities monitor the system from a control room.

Waste processing[38]

200-ton capacity compost plant located near Vidyaranyapuram was established in 2001 under ADB project & is outsourced to M/s IL & FS Company. To reduce the smell, a barricade of about 26 Ft is erected around the compost plant. To avoid accidental burning of waste the accumulated waste of about 4 lakhs cum is capped. 6700 saplings are planted around entire sewage farm to reduce the smell emanating from the compost plant.

3 acres of land is developed for landfill and is operational since July 2012, about 90-125 TPD of rejects from Compost plant and Zero Waste Management plant is land filled every day, and at the end of the day, it is covered by soil. Vidyaranyapuram sewage farm, Gokulam, Kumbar Koppal and Old Kesesre are the functional ZWM plants.

Moreover, the Mysore City Corporation and Mysore Pinjarapole Society, Mysore has jointly implemented the Solid and Liquid Resource Management Project for the production and sale of Eco-friendly Vessel Washing Powder and Eco- friendly Toilet/ Floor Cleaning Powder from Citrus fruit peels, cow dung ash, Shikakai and soap nut and Cattle Dung & Urine related products (Panchagavyam and Amritpani).

[37] Assessment of Municipal Solid Waste Management in Mysore City, 2014.
[38] NIMBY, Not In My Backyard, 2016.

Summary

City	Waste Generated	C & T Mechanism	Source Segregation	Processing Capacity
Mysore	402 MT	• Door to door collection of solid waste implemented in all 65 Wards. • The collected waste is to secondary manual segregation points. • After which the waste is transported to the disposal/landfill sites.	New initiative by MCC- distributing bins to the households to segregate dry waste (plastics, paper, glass, metals, tetra packs, aluminum foils, etc.) and wet waste (vegetables, fruits, flowers, leaves, wood, kitchen waste, etc) at homes.	• 200-ton capacity compost plant located near Vidyaranyapuram. • 3 acres of land developed for Compost plant and Zero Waste Management in- Vidyaranyapuram sewage farm, Gokulam, Kumbar Koppal and Old Kesesre. • Reuse of waste- MCC implemented the Solid and Liquid Resource Management Project.

Key takeaways:

1. The BBMP has assigned the primary and secondary collection and transportation activity to Self Help Groups (SHG's) which are basically below poverty women's groups and landfill sites are operated by the private sector based on public-private partnership (PPP).
2. Established centralized composting facility with focus on hub and spoke model with six new similar facilities in the future.

Shimla

Overview

As per Census (2011), Shimla is the only Class I City in the State of Himachal Pradesh with total population of 1, 69, 758 persons. The total area under the jurisdiction of MC Shimla also has increased after merger of New Shimla, Totu (including some parts of Jutog) and Dhalli areas to 35.00 sq. km. At present, Municipal Corporation of Shimla (MCS) is divided into 25 wards covering urban core and urban fringes. The daily waste generation in Shimla City is approximately 93.0 MT. This depicts that waste generation per capita per day is 350 gm/capita/day in the city.[39]

Table 96 Population growth and SWM generation in SMC area

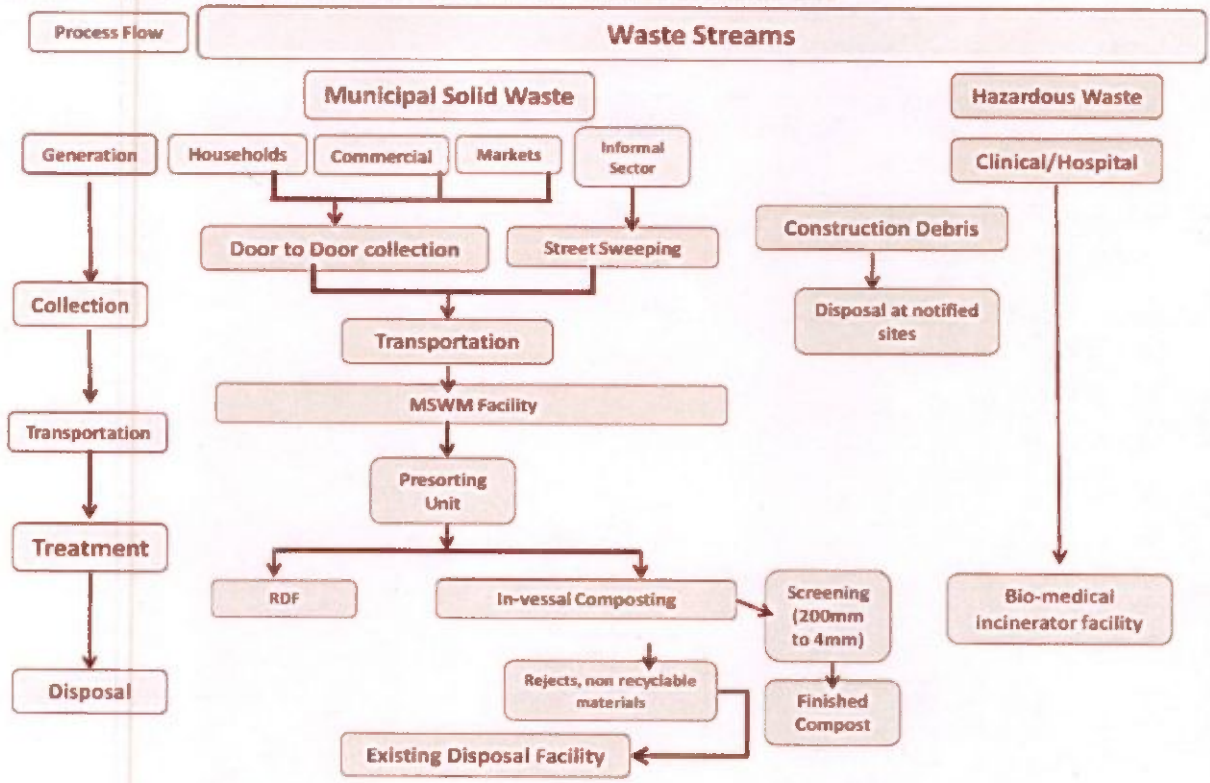
Head/Years	2011	2021	2031	2041
Resident Population	1,69,758	2,56,883	3,49,361	4,18,296
Floating Population	76,000	1,00,000	1,25,000	1,50,000
Solid Waste Generation (MT)	86.01	124.91	166.03	198.90

Source – City Sanitation Plan of Shimla, 2011

Solid Waste Management System

Figure 29 is a schematic representation of the Municipal Solid Waste Management system within the boundary limits of Municipal Corporation of Shimla. The left column depicts the process flow for waste and the right column shows how the municipal and hazardous waste is being handled within the

Figure 78 Flow Chart for Current SWM Practices followed in Shimla City



Source – Municipal Solid Waste Management Plan for Municipal Corporation Shimla, 2012

[39] Effective Municipal Solid Waste Management Practices: A Case study of Shimla, Himachal Pradesh, India, 2014

Collection, segregation and transportation

Shimla Environment, Heritage Conservation and Beautification (SEHB) Society was registered in 2009 under the Himachal Pradesh Societies Registration Act 2006. This society is responsible for the door-to-door collection from households under the supervision of Commissioner (President) and Corporation.
Health Officer (Member Secretary). Each household/ commercial establishment or educational institute and other institutes handover garbage SEHB Society. The society has provided two colored bins – yellow and green to households/ commercial establishments/ institutions, etc. for primary storage and segregation of garbage. As per MCS record, 86 % of the residential population is covered under door-to-door waste collection system, followed by 14% population dependent on the community bins for waste disposal.

The community bin system comprising of 8 concrete dust bins 148 numbers of dumper containers of 4.5 cum capacity and 54 numbers of dumper containers of 3.5 cum capacity. The frequency of clearing of these bins varies from daily, alternate day, twice a week or even once a week depending on the area. These concrete bins and dumper containers are placed at convenient locations for the residents to access and dispose their waste in an appropriate manner. MCS efforts to extend 100% ward level door-to-door garbage collection are supported by declaring the ward as dumper free.

Moreover, the ward level routing and loading plan has been developed by MC Shimla with help of GIZ. The collection vehicles run on a predefined and optimized route. The routing and loading plan for waste transportation is shared with each vehicle and exercised in coherence with door-to-door garbage collection. Manual loading is practiced at primary level. MCS also plan to set up a waste transfer station at Darni ka Bagicha where discharged treatment facility was in operational earlier.

Infrastructure

Transportation of waste from the secondary collection points to the treatment plant and landfill is the operated and managed by MC Shimla. The entire city's waste is collected and transported through 40 different vehicles with varying capacities.

Table 97 Details of Solid Waste Transportation Vehicles

Type of Vehicles	Quantity	Capacity (in Tonnes)
Pick-Ups (Hydraulic)	25	1-1.5
Pick-Ups (Non-Hydraulic Inspection vehicle)	1	-
Dumper Placer	5	Single
Dumper Placer	2	Twinned
Auto Tipper	3	1
Auto Tipper	3	5
Compactors	2	8
Backhoe-Loader	1	-

Source – Effective Municipal Solid Waste Management Practices: A Case study of Shimla, Himachal Pradesh, India, 2014

For further improving the overall solid waste management system and providing satisfactory services to the citizens, MC Shimla is in process of procuring 2 compactors and 1 mechanical sweeping machine.

Waste processing

Municipal Corporation Shimla established its first scientific waste processing and treatment unit with Norwegian assistance in 2001 at the Darni-ka-Baghicha at foothill of the central Shimla which later created nuisance for the public and tourists. After intervention of the HP High Court, the Government decided to set up a new treatment and disposal facility outside the municipal limits on Public Private Partnership (PPP) model. Hence, MC Shimla is in the process of relocating the waste processing unit from Darni ka Bagicha (100 MT capacity) to Bharial.

Key takeaways:

1. NGOs involved in waste collection (Door to Door)
2. Bins placed across the city at major commercial and transit nodes.
3. Established its first scientific waste processing and treatment unit with foreign assistance on PPP mode.

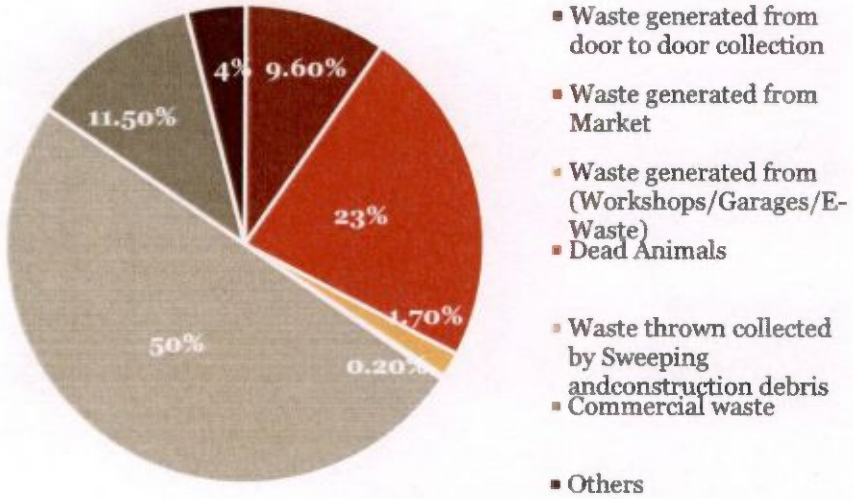
Agartala

Overview

Agartala is the Capital & Main City of Tripura State and the hub of all administrative, Business, industrial, Educational & Health Centre, and is well connected with Airport and Railway with rest of India.

As per 2011 census, population of this city was 399,688 with density of 6,251/Sq. km. Around 260 MT (metric ton) urban solid waste is generated every day from more than 90,000 households.[40]

Figure 79Estimated waste generation of Agartala

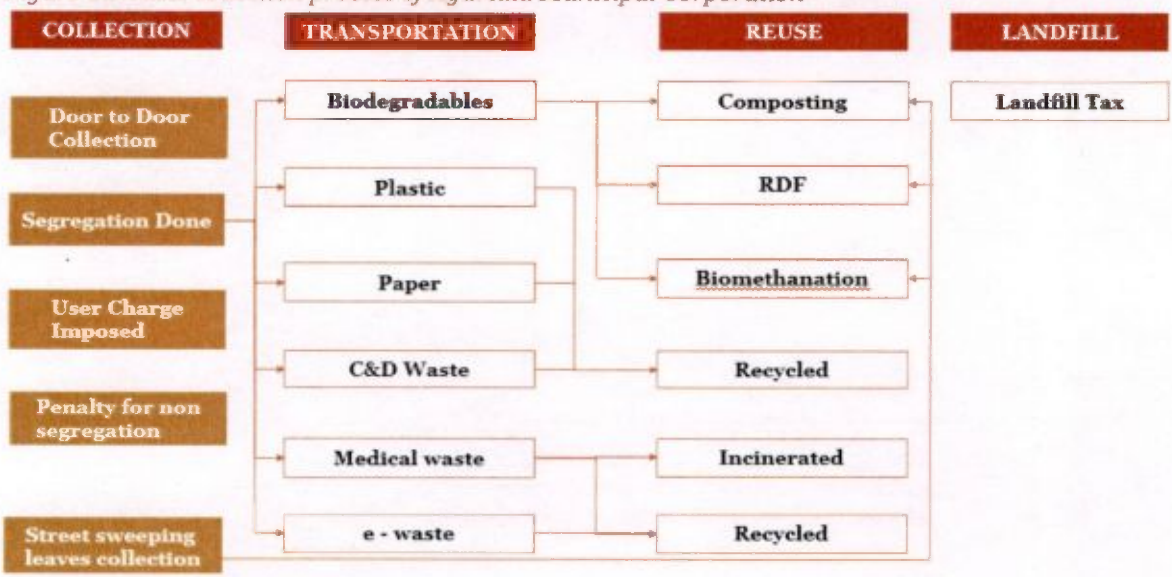


, India, 2014

Solid Waste Management System

The prevalent system of SWM existing in the city can be seen in the next section:

Figure 80Waste collection process of Agartala Municipal Corporation



Source – Not in My Backyard, 2016

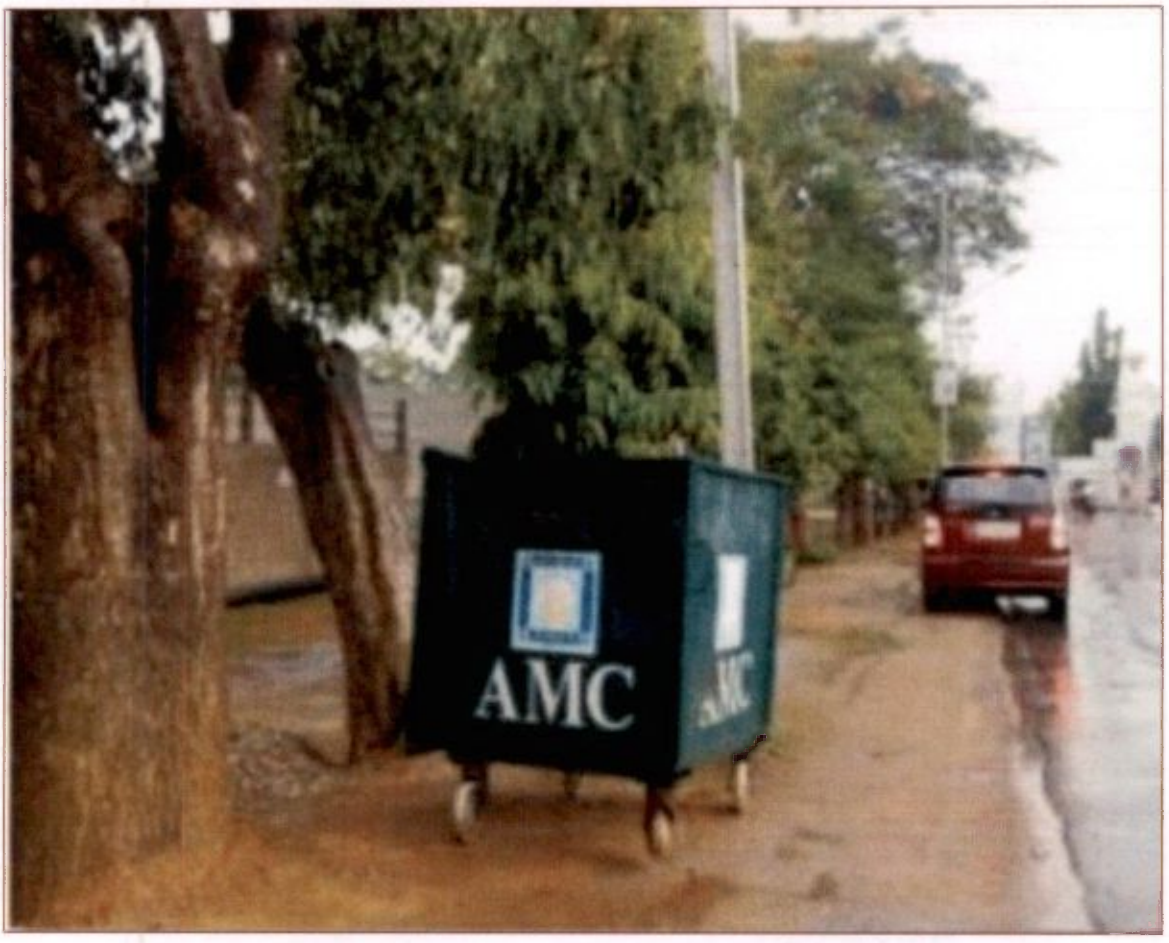
[40]Trends of Urban Solid Waste Management in Agartala City, Tripura, India, 2014.

The SWM mechanism of Agartala is as follows:

Collection, segregation and transportation

The process of waste collection done by AMC is generally from the source of generation that comprises of waste collection from house to house. Proper storage bins or centers are placed at different location of the city, which is widely used for throwing wastes of nearby localities. NGOs are involved in collection process, as in every ward one NGO is involved for collection of waste.

Figure 81 Bin/containers used for waste collection in AMC



Source – Trends of Urban Solid Waste Management in Agartala City, Tripura, India, 2014

Every day more than 400 numbers of sweeping employees sweeps the major places and accumulate the wastes in the container/bin. Around 500 numbers of medium and large size bins/containers are placed in different parts of city mainly in the major market areas, roads and commercial areas etc. Stationary container manually loaded trucks and mechanically loaded trucks are used during secondary collection, transportation and disposal of waste.

Solid Wastes generated by Agartala city is transported to the dumping site by both covered and uncovered trucks and other modern vehicles. The dumping site is situated about 15 km away from the main city Agartala known as Debendra Chandra Nagar. There are around 25 vehicles, and all these are managed by AMC which are working daily by rotation of twice or thrice to the dumping site for disposal process.

Infrastructure

Table 98 Vehicles involved in the complete MSW process

Types of Vehicles	Number of Vehicles
14 Meter Refuge Compactors	3
8 Meter Refuge Compact powerful de-silting machines ors	10
Skid steer loaders	4
Powerful de-silting machines	2
Sweeping machines	1
Auto trucks for biomedical waste collection	5

Source – Trends of Urban Solid Waste Management in Agartala City, Tripura, India, 2014

Waste processing

At present all the wastes from the city Agartala is being dumped in open dumping ground as a landfill site which is situated outside form the city about 15 km and known as "Debendra Chandra Nagar" where total waste of city generally dumped in site which is not found scientifically improved. Though AMC has already started waste manure recycle plant but, it is not possible to manage 260MT of wastes with one single plant. The wastes of entire city include both biodegradable and non-biodegradable waste products that create problem in recycling process and conversion in to manure.

Whereas, Bio-Medical wastes is being collected almost from all the Government, private hospitals, nursing homes, medical colleges, pathology laboratories on daily basis as per guideline given by Government of India rule 1998(Biomedical waste handling rule 1998). The bio-Medical wastes which are being collect regularly and send for incineration in the Diesel incinerator which is situated at "Hapania area".

Key takeaways:

1. NGOs involved in waste collection (Door to Door)
2. Bins placed across the city at major commercial and transit nodes.
3. AMC is thrusting on the composting process for which decentralized approach being considered.

Surat

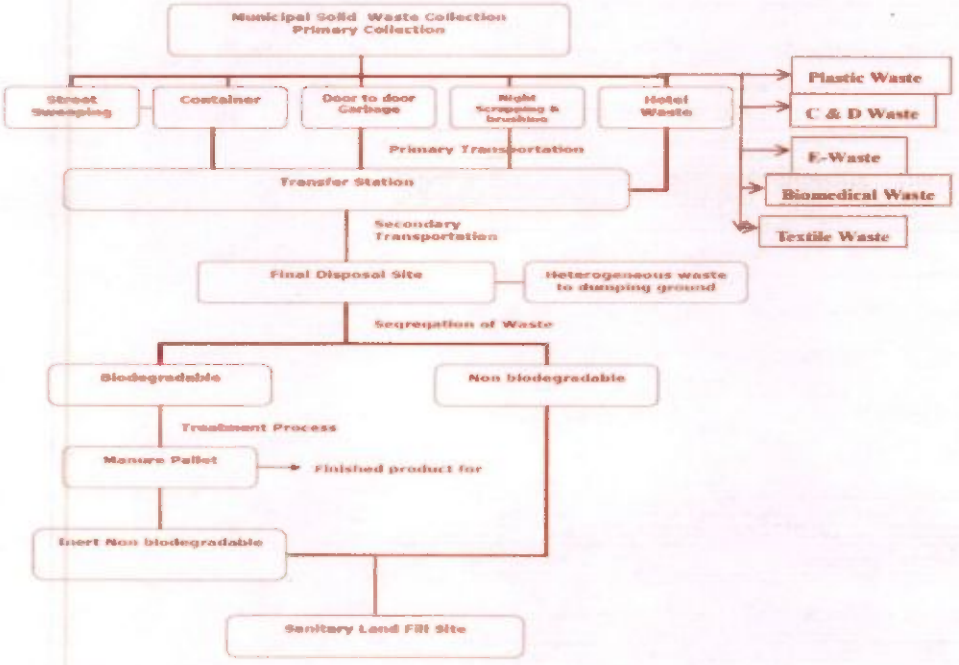
Overview

Surat, the economic capital of Gujarat and home to India's textile and diamond industry, is one of the fastest growing cities in India. Over 4.8 lac tons of Municipal Solid Waste (MSW) is generated in City of Surat annually with less than 30% being processed.[41] Surat is a city with more than 45 lacs generates about 2200 TPD of MSW at the rate of 450 gpcd. The Municipal Corporation of Surat has opted for integrated Municipal Solid Waste (MSW) Management scheme starting from collection of MSW till its treatment and disposal of inert at end.[42]

Solid Waste Management System:

The SWM mechanism of Surat is as follows:

Figure 82 Proposed Waste collection process for Surat Municipal Corporation



Source – Waste smart cities: A survey by the Centre for Science and Environment shows how Indian cities are turning over a new leaf in solid waste management, 2016. (Down To Earth)

Collection, segregation and transportation

More than 70 percent of Surat city area is covered with Door-to Door collection system. At present there are 4503 sweepers engaged in the Door-to-Door collection of waste across the seven zones of the city. But there are still some areas which are having conventional bin system for their solid waste collection. The total number of waste collection bins is 1170. These are mainly 4.5 cu.m in size with a capacity of 1.5 tons (4.5 cu. m)/ dustbin and cover the entire population of the city. The spacing between waste storage depots is about 100 m. M.S.W. transported from the transfer stations reaches to the final disposal site at Khajod whereat M.S.W. is dumped and leveled by the heavy machineries. Daily cover of soil is also laid on the leveled M.S.W.

[41]Surat Municipal Corporation, SWM Plan.
[42]Surat Municipal Corporation, SWM-RTI DISCLOSURE, 2019.

SMC has also introduced an Anudan Scheme under which it pays residential societies to collect their waste and clean their premises. It has been noticed that around 600 societies are part of this scheme and a minimum of Rs 1,500 is paid to every society every month.[43]

There are total six numbers of transfer stations in Surat located at Katargam, Pal, Bhatar, Varacha, Bhestan and Anjana. Surat is administratively divided in seven zones from which, south zone generates the highest amount of daily solid waste. Surat is maintaining Door-to-Door collection on PPP (Public Private Partnership) model basis.

Table 99 Zone wise solid waste generation for Surat city

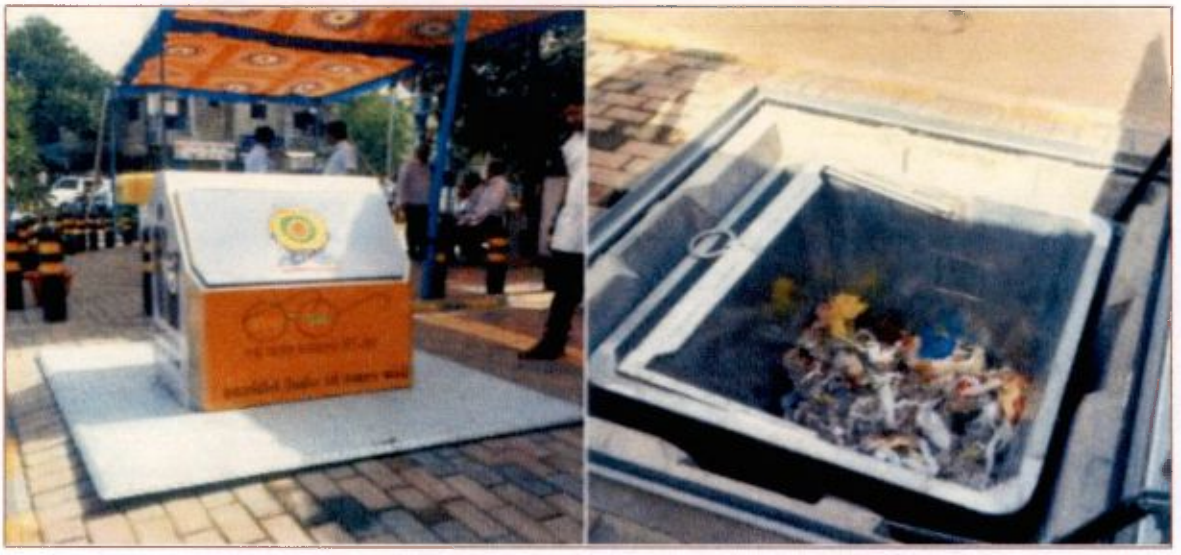
Zone	Area (Sq. Km)	Population as per 2011 Census	Solid Waste Generation		
			2001	2011	2015
Central	8.18	408760	150.1	139.5	116.2
North	36.363	705163	121.7	179.1	220.6
East	37.525	1137138	210.7	295.9	337.7
West	51.279	424986	90.9	166.3	224.5
South	61.764	695028	177.6	291.45	383.1
South East	19.492	748304	59.2	97.15	127.7
South West	111.912	347447	73.2	108.7	139.9

Notably, as part of the Smart City Mission, the Surat Municipal Corporation (SMC) had proposed installation of 75 underground garbage bins across the city last year of which 43 have been installed in public areas. A total of R 456 crore was spent by the SMC to install the bins. All the bins are equipped with two compartments – one for the general public to discard their litter and the other one for municipal workers who collect waste from that area. To ensure efficient waste segregation, the bins are further divided into dry and wet waste. The size of the underground dustbin is 3 cubic meters and each bin can hold up to 1.5 tons of garbage.[44]

VTS SYSTEM

The corporation has installed GPS units to track the movement of these vehicles. The device sends signals to the control room about the exact location of these vehicles, which displays the status of the garbage bins, garbage collection vehicles and estimated time of clearance. The MCC authorities monitor the system from a control room.

Figure 83 Underground garbage bins installed in Surat



[43]Surat Municipal Corporation, SWM-RTI DISCLOSURE, 2019.
[44] Surat Smart City.

Waste processing

1. *600 TPD Waste Processing Treatment Plant:* Operational from January 2016, the integrated MSW treatment process of Surat Municipal Corporation is to find the best possible technology and scientific solution for the perennial garbage disposal problem for the city through Public Private Partnership. The quantity agreed for agency is minimum 600MT per day subjected to maximum treatment of 5, 00,000.00 MT for treatment.
2. *Waste to RDF to Energy 1200 TPD:* City has been expanding very fast and to meet the future demand and to meet current Challengers, Surat Municipal Corporation has issued work order for 1200 TPD Waste to RDF to Energy as per Gujarat Waste to Energy Policy to M/s. Abbellon Clean Energy Pvt. Ltd. The plant will be developed at Bamroli.
3. *Centralized Waste Processing Plant (PPP/EPC Basis):* In order to meet future challenges SMC is planning to Implement the MSW processing plant with new Methodology and Consultation work for preparing tender documents is under Progress.
4. *Treatment and final disposal of Bio Medical Waste:* Concession Agreement Signed by Surat Municipal Corporation with Agency named En-Vision Enviro Engineers –Surat to establish, operate and maintain the centralized Biomedical waste treatment facility, Now it is named as En-cler Bio Medical Waste Pvt. Ltd.
5. *Centralized Plastic Waste Management Plant:* Concession Agreement Signed by Surat Municipal Corporation with Agency named Eco Vision resources L.L.P for 15 years concession period. SMC has provided 2 acre land on token rent at Bhatar. Agency is producing at moment. Minimum one collection center per zone has been established and operated by agency. Tie-up with rag pickers and NGO has F:\05 RTI\Year 2019\05 May\14-05-2019\Solid Waste Management\PROACTIVE SWM.doc been done by agency to lift street level plastic. Neither SMC is paying tipping fee to agency nor the agency is paying any royalty to SMC. Plant is commissioned & operational from June-2017 with capacity of 20 TPD.
    - *E- Waste Management:* Project mode is on PPP mode with 15 years concession period and Overall 5 TPD Plant has to be Set up by SPV named Pruthvi E-wate Recyclers Pvt. Ltd. SMC has provided 1-acre land on token rent at Unn. Agency has to establish primary level Treatment in Surat Agency will be authorized to setup collection centers for collection of e-Waste from various sources Model will be worked out based on producer's responsibility and their involvement.
    - *C & D Waste Management:* Project mode is on PPP mode with 20 years concession period and Overall 100 TPD Plant Set up by SPV named Surat Precast Green Pvt. Ltd. SMC provided 3-acre land on token rent at Kosad. Agency is producing various construction material such sand, block, Paver block etc. Agency is collecting collection charges directly from Users/ Generator Agency has deploy GPS based vehicles for efficient monitoring. SMC will make compulsory for utilization of 20% recycle products in all of the tenders as per the guideline of SBM. Plant is commissioned & operational from Feb-2019 with capacity of 200 TPD.
    - *Industrial Waste Management:* SMC has invited EOI from agency who has established facility for treatment of Waste. SMC to authorize agency for Collection of Non-Hazardous waste from Surat City and to collect monthly charges from units as per rates approved by SMC. Agency will treat collected waste to their unit and

Figure 84 Location of Bins in Surat

Source – Prospects and Perspectives of Integrated Solid Waste Management in Smart Cities (Surat)

produce energy in form of Steam, which shall be utilized for various industrial applications for the units in Sachin GIDC. Presently work is pending in approval stage.

- *Scientific Land Filling:* SMC was the first to develop scientific land fill site in the country with a capacity of 1.25 lac cu.mt. with cost of Rs. 131 lacs whose capacity exhausted in 2011, and the same SLF is been extended for capacity of 8,25,000 m3 at cost of 21 Cr under Swachh Bharat Mission. Meanwhile since 2011, 2nd SLF cell capacity of 6,25,000 cu.mt. is constructed under JnNURM scheme. This SLF cell also in underutilization.

6. *Dumpsite Remediation:* SMC has started the work for scientific closure of accumulated waste at cost of Approximately Rs. 52 Cr under Swachh Bharat Mission, which was dumped open by SMC during the period of year 2001-2014.

Summary

City	Waste Generated	C & T Mechanism	Source Segregation	Processing Capacity
Surat	2200 MT	• The SMC has engaged five private agencies for door-to-door collection. The swm workers empty the bins in the closed body vehicle and continue blowing the whistle until every house hands their bins to them. • The collected waste is transported first to transfer stations: Surat has six refuse transfer stations. At the transfer stations, the trucks and closed body vehicles transporting waste are weighed on a weighbridge—a sanitary inspector records their 'gross weight' (weight of the truck including the garbage). • Waste collected all over the city is transported to the processing and disposal site by 450 laborers and 104 drivers. A fleet of 162 vehicles available for the purpose includes dumper placers, trucks, tractor trailers, market vans and heavy machines. • The SMC has also made provisions for cleaning the roads and streets during the	• 100%	• At the Khajod disposal site, which is around 10 km from the city, 41 laborers are involved in processing and disposing of the waste. Khajod houses two secure landfill (six) sites, spread over an area of 200 hectares. • 600 TPD Waste Processing Treatment Plant • Scientific Land Filling • Centralized Plastic Waste Management Plant • C & D Waste Management

night to avoid traffic and passerby.

Key takeaways:

1. SMC has also introduced an Anudan Scheme under which it pays residential societies to collect their waste and clean their premises. It has been noticed that around 600 societies are part of this scheme and a minimum of Rs 1,500 is paid to every society every month – Community involvement through incentivization.

2. Plastic waste, Biomedical waste and C&D waste management vendor on PPP for period of 15/20 years respectively across the SMC jurisdiction through the SPV route.

3. *Dumpsite Remediation:* SMC has started the work for scientific closure of accumulated waste at cost of Approximately Rs. 52 Cr under Swachh Bharat Mission, which was dumped open by SMC during the period of year 2001-2014.

4. Privatization of centralized waste processing facility on PPP/EPC mode for effective management of the assets for enhanced service delivery.

Suitable technology options[45]

This section assesses different technologies across the cities and tries to encapsulate all the parameters as deemed in alignment with the current project. Technology options tabulated in the main section of the report have been further discussed below.

Waste to Energy Technology

Overview

Waste to Energy Technologies recover energy by processing non-recyclable waste using either biochemical or thermo-chemical processes, in this process waste is converted into non-leachable ash while generating energy. This technology addresses the problem of overfilling of landfill sites which is a major issue in many cities across the country due to increasing urbanization. Also, untreated waste emits products like methane, dioxins and leachate which can lead to contamination of soil. Waste to Energy systems use waste as fuel and generate energy, this leads to a reduction in the volume of waste by 90%.

The commonly used technologies being:

1. Incineration
2. Gasification

Figure 85 Technology setup of a Waste to Energy plant

Process flow of the system

The following diagram shows the technology setup of a waste to energy plant (Incineration Plant)

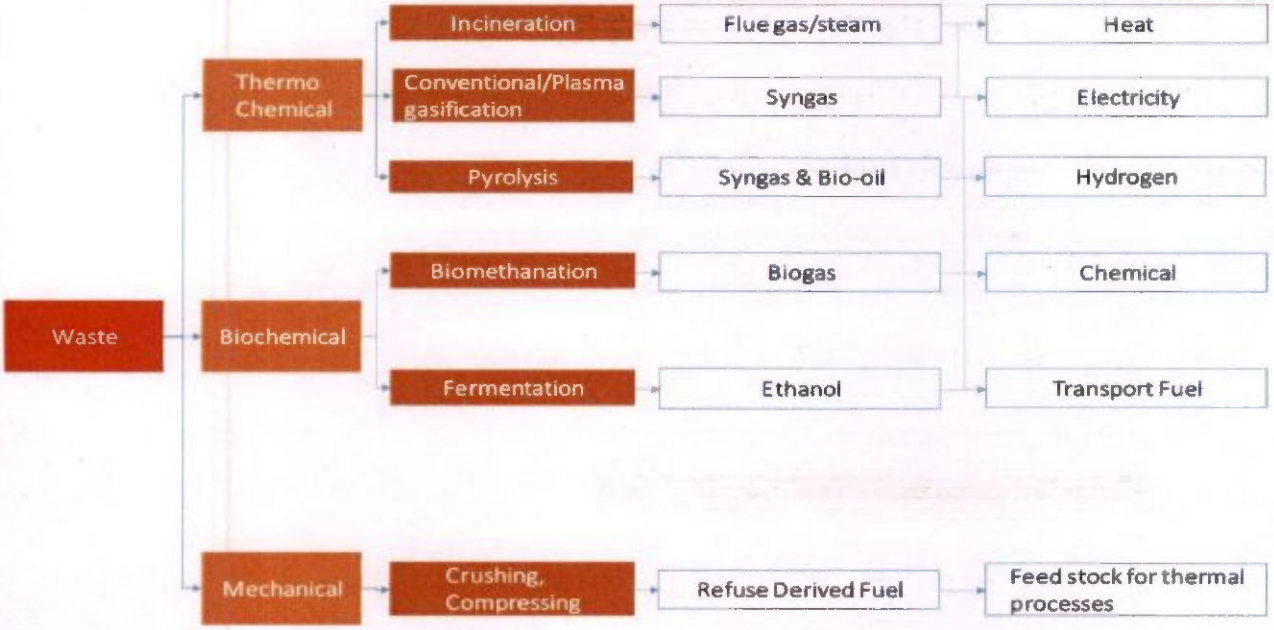
The process flow of the system and its integration with the SWM value chain has been captured in the following diagram. Waste from various sources is brought to the plant through trucks, hook loaders and other Bulk waste carriers. Waste is dumped at the plant, following which it is processed, and the outputs are used for various purposes.

[45] Waste to Wealth 2016, Vendor consultations.

Techniques, inputs and outputs

The different waste conversion techniques employed in a waste to energy plant is shown in the following infographic. The input to the system is waste collected from different collection points, the outputs obtained can be used for various purposes as shown:

Figure 86 Techniques, Inputs and Outputs in the Waste to Energy process



The final outputs can be used for domestic and industrial purposes. The outputs generated can be used for producing Bio fuels, fertilizers and feedstock in many industries.

Requirements for setting up a plant

The capital expenditure, operational expenditure and other requirements vary with the technology used to convert waste to energy. The following table summarizes the requirements of different technologies:

Table 100 Requirements for setting up various forms of W2E plant

Parameters	Incineration	Gasification	RDF
Type of waste	Mixed co-combustible waste	Mixed combustible waste	Mixed co- combustible waste
Waste Capacity	300-2000 Tones	500-1000 Tones	0.5-150 tons
Area Requirement	90000 - 600000 Sqm	150000-300000 Sqm	100-1000 Sqm
Capital Requirement	4350-29000 Lakhs	7750-15100 Lakhs	15-1500 Lakhs
Operational cost	261-1740 Lakhs	465-906 Lakhs	3.5-18 Lakhs
Output Generated	3-20 MW Power	8.33 MW-16.67 MW Power	0.25-75 MTPD RDF
Project Life	15 years	15 years	15 Years
Reduction in waste volume	90%	95%	50%

Incineration

Overview

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.

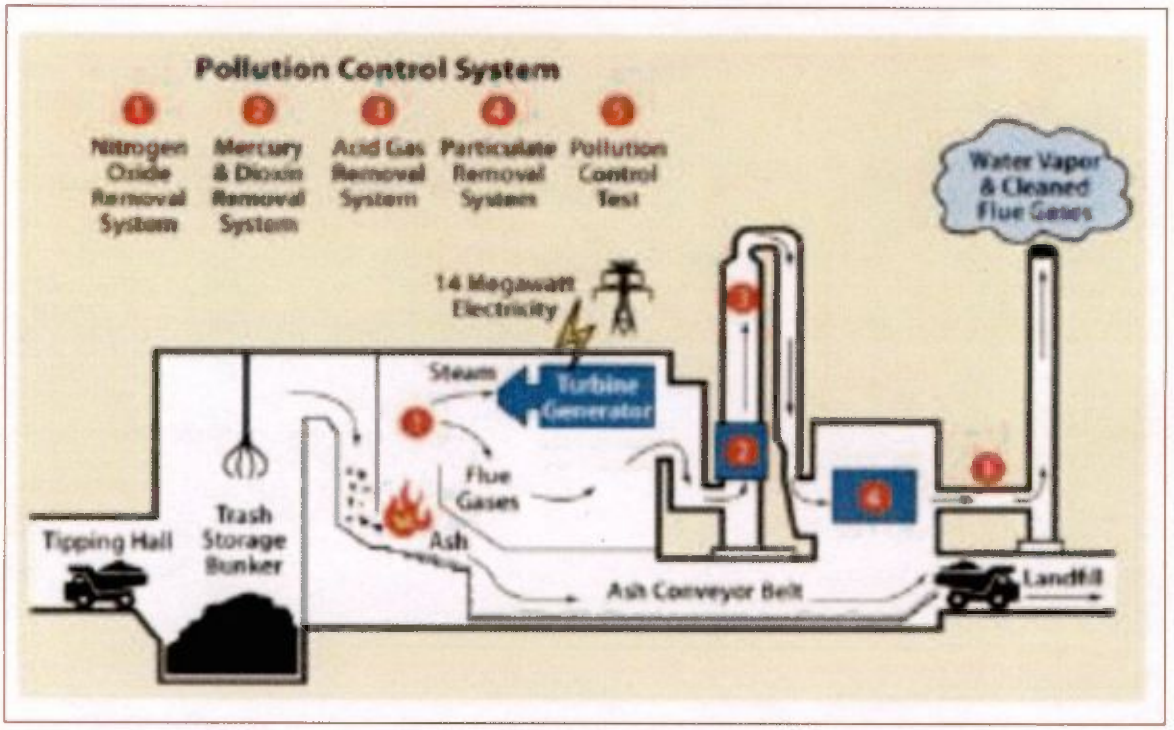
Incineration Plant

The following general description of an incineration plant includes the crucial processing steps and aspects:

- Siting of an incineration plant;
- Waste reception and handling (storage, on-site pre-treatment facilities);
- Combustion and steam generation system;
- Flue gas cleaning system;
- Energy generation system (steam turbine and generator in case the unit is equipped for WTE recovery);
- Residual hauling and disposal system; and
- Monitoring and controlling incineration conditions.

The figure below shows the schematic diagram of an Incineration Plant.

Figure 87 Working of an Incineration Plant



Source: Waste to Wealth

Criteria's for Incineration projects

MSW incineration projects are appropriate only if the following overall criteria are fulfilled:

- A mature and well-functioning waste management system has been in place for a number of years;
- Incineration is especially relevant for the dry bin content in a two-bin system. For unsegregated waste, pre-treatment is necessary;

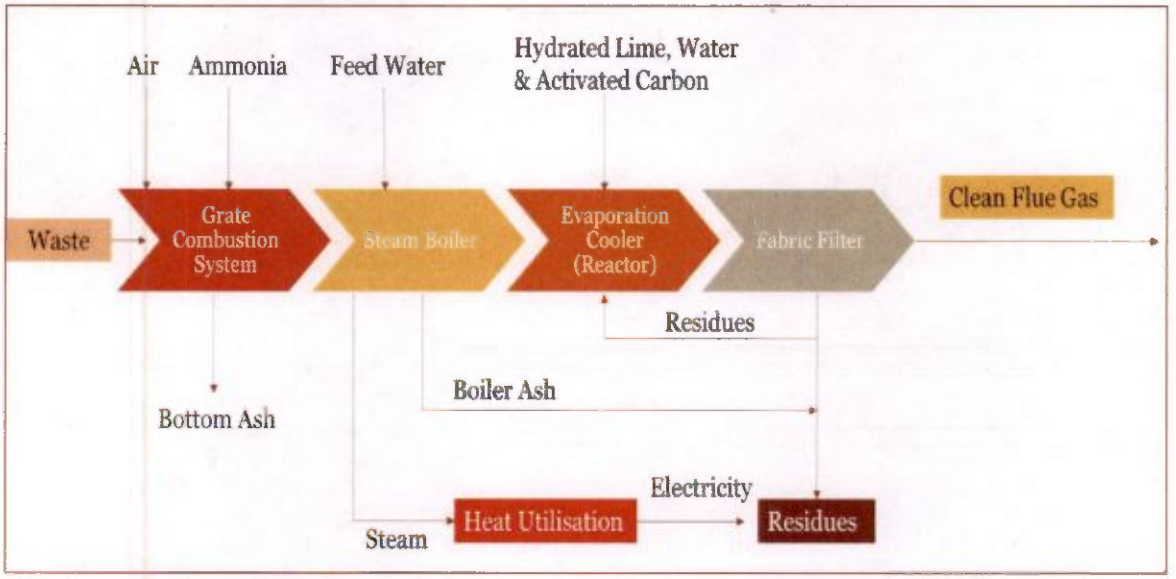
- The lower calorific value (LCV) of waste must be at least 1,500 kcal/kg.
- The furnace must be designed in line with best available technologies to ensure stable and continuous operation and complete burnout of the waste and flue gases. MSW is usually incinerated in a grate incinerator. Uniform combustion of waste is dependent on the grate design.
- Produced electricity or steam can be sold on a sustainable basis (e.g., feeding into the general grid at adequate tariffs).
- Since the capital investment is very high, the planning framework of the community should be stable enough to allow a planning horizon of 25 years or more.
- Pre-feasibility study for the technology leads to positive conclusions for the respective community.
- Strict monitoring systems are to be proposed and to be followed.

Processes involved

Some Technological Highlights/Processes involved for the functioning of an Incineration Plant are:

- Grate based system
- The optimized secondary combustion chamber with tangential secondary air-injection and specifically chosen refractory which results in low emission
- DeNOx SNCR system ensuring minimum emissions and simultaneously guarantees maximum efficiency as well as the lowest amount of residues
- The combustion control system (CCS) ensuring operations a requested thermal load. Constant steam production, flue gas oxygen content and flue gas flow are achieved even at varying waste.

Figure 88 Process flow of an Incineration Plant



Source: Waste to Wealth

Requirements for setting up a plant

The capital expenditure, operational expenditure and other requirements vary with the technology used to convert waste to energy. The following table summarizes the different requirements of different technologies:

Table 101 General requirements for setting up an Incineration Plant

Parameters	
Type of Waste	Mixed Combustible Waste
Suitability (Tones/day)	Min: 300 Tones and Max: 2000 Tones
Area Requirement	Min: 90,000 m2 and Max: 600,000 m2

Capital Investment	Min: 4350 Lakhs and Max: 29000 Lakhs
Operational Costs	Min: 261 Lakhs and Max: 1740 Lakhs
Energy/Resource Generation	Resource: Syngas/ Power; Min: 3.06MW and Max: 20.41MW
Production costs	4.50 per unit electricity
Life Duration	15 years
Handling Expertise	Skilled+ Semi Skilled+ Unskilled
Reduction in Waste Volume	90%

Case Studies for of the Incineration plant

1 **Narela-Bawana Plant:** Considered as the country's biggest such plant, it can process 2,000 MT of waste and generate up to 24MW energy. The capacity of Narela-Bawana plant would be expanded to process about 3,000 MT waste in future. Narela-Bawana plant, has come up on a private-public partnership model with Ramky Group at a cost of Rs. 458 crores are the biggest such facility in the country.

Figure 90 A sample incineration plant

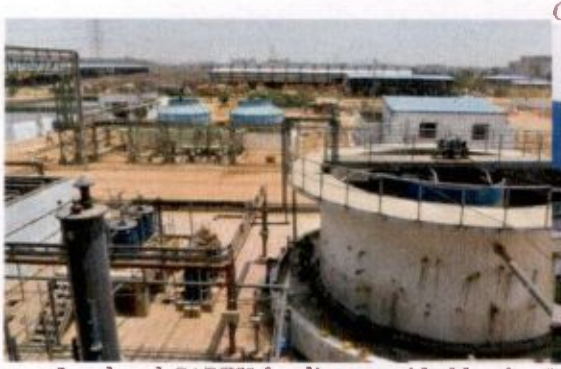


Figure 89 South Delhi Municipal Corporation along with JITF set up the Waste Incineration Plant in Okhla

2 Land and CAPEX funding provided by the Government on revenue sharing basis to set up the Incineration Plant

3 **Timarpur Okhla Waste Incineration Plant:** Timarpur-Okhla Waste Management Co Pvt Ltd is an initiative of M/s Jindal ITF Ecopolis. JITF Urban Infrastructure Ltd won the bid to develop the project on a Built Own Operate and Transfer (BOOT) basis, in a Public private partnership with the Delhi Government as legal Entity: Timarpur Okhla Waste Management Co Pvt Ltd. The incineration plant was commissioned in January 2012 and is processing 2,000 tons per day (TPD) and generating 16 MW. No tipping fee but waste is to be provided by MCD at plant site. The project is the first and largest integrated waste management project ever being set up in the country. The project is CDM registered with United Nations Framework Convention on Climate Change (UNFCCC) for earning carbon credits.

Gasification

Overview

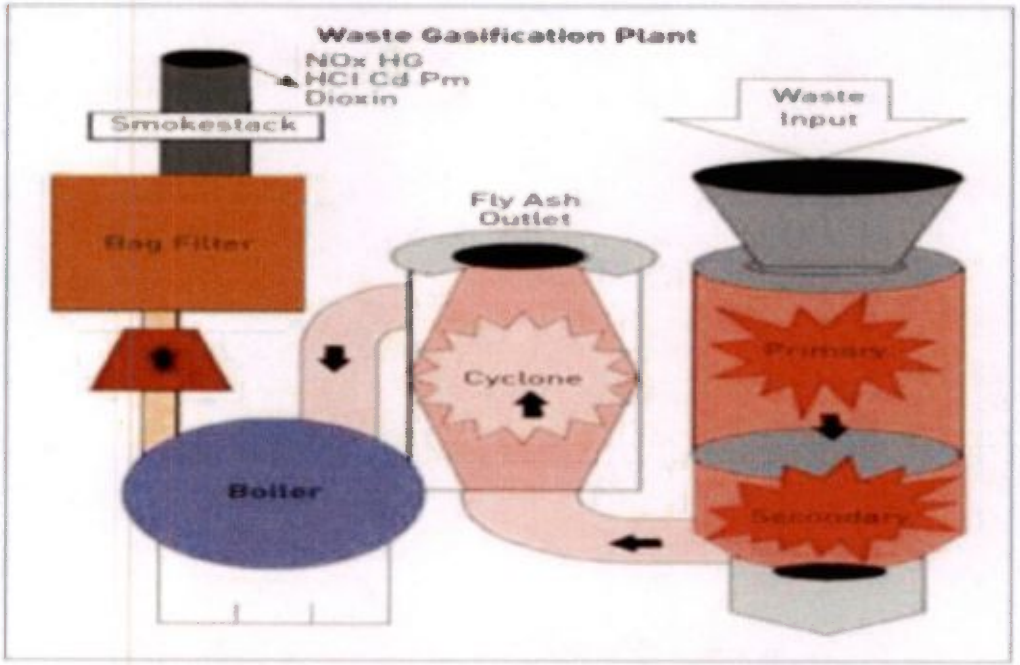
Gasification is the partial combustion of organic or fossil-based carbonaceous material, plastics, etc. into carbon monoxide, hydrogen, carbon dioxide, and methane. This is achieved at high temperature (650°C and above), with controlled amount of air, oxygen, or steam.

Types of Gasification: Gasification technology is selected on the basis of available waste quality, capacity range, and gas quality conditions. The main reactors used for gasification of MSW are fixed beds and fluidized beds. Larger capacity gasifiers are preferable for treatment of MSW because they allow for variable fuel feed, uniform process temperatures due to highly turbulent flow through the bed, good interaction between gases and solids, and high levels of carbon conversion.

Gasification process

The process of Gasification is largely exothermic, and the main product is syngas, which contains carbon monoxide, hydrogen, and methane. Typically, the gas generated from gasification will have an NCV of 4–10 MJ/Nm3. The other main product is a solid residue of non-combustible material (ash).

Figure 91 Waste Gasification Plant



Source: Waste to Wealth

Processes Involved

MSW should be pre-processed before it can be fed into the gasification process. The pre-processing comprises of manual and mechanical sorting, grinding, blending with other material, drying, and palletization, is to produce a feed material with consistent physical characteristics and chemical properties. Carbonaceous material of municipal waste stream is the most important feedstock for gasification.

Gasification of MSW in the waste gasification plant is accomplished in two chambers:

(i) The primary chamber is operated with less air than required for combustion and

(ii) The secondary chamber is operated with excess air conditions.

The waste is fed into the primary chamber and semi-pyrolyzed, releasing moisture and volatile components. The heat is provided by the controlled combustion of fixed carbon within the waste. The syngas that is driven off has a high calorific value becomes feedstock for the secondary chamber. Combustion air is then added to the syngas, and the combined gases are combusted in the secondary chamber.

Requirements for Setting up a plant

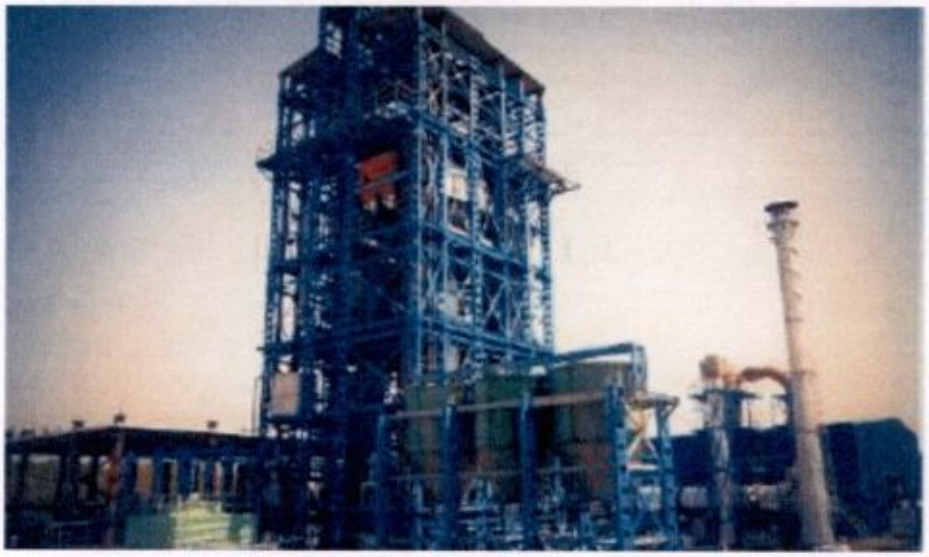
The following summarizes the capital expenditure, operational expenditure and other requirements for setting up a Gasification Plant:

Table 102 General requirements for setting up a Gasification Plant

Parameters	
Type of waste	Mixed Combustible Waste
Suitability (Tones/day)	Min: 500 Tones and Max: 1000 Tones
Area Requirement	Min: 1,50,000 m2 and Max: 3,00,000 m2
Capital Investment	Min: 7750 Lakhs and Max: 15100 Lakhs
Operational Costs	Min: 465 Lakhs and Max: 906 Lakhs
Energy/Resource Generation	Resource: Syngas/Power Min: 8.33 MW and Max: 16.67 MW
Production costs	7.20 per unit electricity
Life Duration	15 Years
Handling Expertise	Skilled+ Semi Skilled+ Unskilled
Reduction in Waste Volume	95%

Case Studies of Successful Implementation of Gasification

Figure 92 Pune Municipal Corporation along with ROCHEM Technologies set up the Waste Gasification Plant



Source: Waste to Wealth

Gasification Plant set up in Pune Municipal Corporation: The technology is based on Gasification which has a processing capacity of 700 tons of MSW per day. The plant is capable of producing 10 MW electricity per day. The plant is set up on DBOOT basis between Pune Municipal Corporation and ROCHEM Technologies Private Limited.

The space requirement for the plant is about 10,000 Sq. meters Currently the plant is producing 0.78 MW to 1 MW of power per day by processing around 250 metric ton of waste per day. It is consumed within plant. Commercialization is proposed.

Refuse Derived Fuel (RDF)

Overview

RDF typically consists of the residual dry combustible fraction of the MSW including paper, textile, rags, leather, rubber, non-recyclable plastic, jute, multilayered 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 or resource is dependent on certain parameters of the constituent waste:

- Calorific value;
- Water content;
- Ash content;
- Sulphur content; and
- Chlorine content.

The required specific composition and characteristics of RDF for fuel or co-processing is determined by the kind of boiler/furnace, temperatures achieved in the furnace, and the associated flue gas management systems.

Figure 93 Refuse Derived Fuel Plant

Source: Waste to Wealth

Processes involved

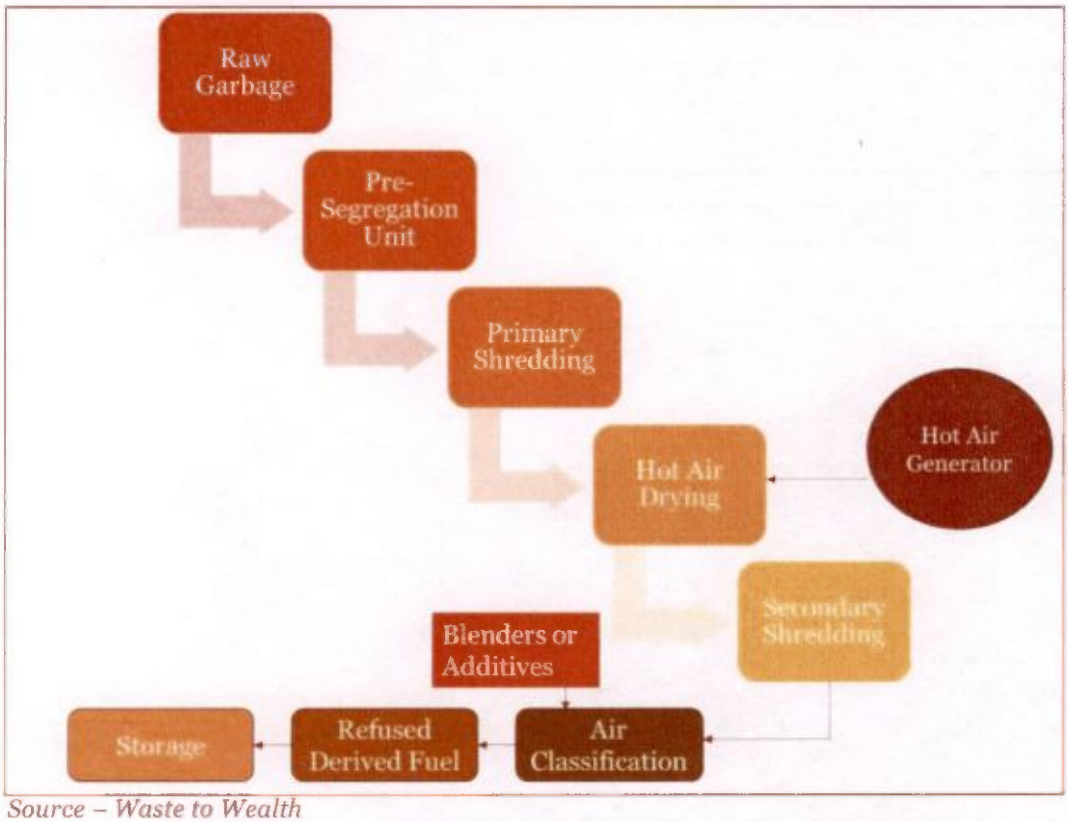
The RDF production line consists of several unit operations in series to separate unwanted components and condition the combustible matter to obtain required RDF characteristics. In general, segregation and processing may include:

1. Sorting or mechanical separation
2. Size reduction (shredding, chipping, and milling);
3. Drying (where required);
4. Separation;
5. Screening;
6. Air density separation (for removing fine inert material);
7. Blending;
8. Packaging; and
9. Storage

The type and configuration of unit operations required depend on the end use of the RDF determines the necessary characteristics of RDF (size, moisture, ash content, calorific value, chloride, heavy metals, etc.).

Requirements for Setting up a plant

Figure 94 Process in RDF



Source – Waste to Wealth

The following summarizes the capital expenditure, operational expenditure and other requirements for setting up an RDF Plant:

Table 103 General requirements for setting up a RDF Plant

Parameters	
Type of waste	Mixed Combustible Waste
Suitability (Tones/day)	Min: 0.50 and Max: 150.00
Area Requirement	Min: 100m2 and Max: 1000m2
Capital Investment	Min: 15.0Lac and Max: 15.0Cr
Operational Costs	Min: 3.50Lac PA and Max: 18.0Lac PA
Energy/Resource Generation	Resource: RDF Min: 0.25 MTPD and Max: 75.0 MTPD
Production costs	Rs. 2000 TPD
Life Duration	15 Years
Handling Expertise	Skilled + Semi Skilled + Unskilled
Reduction in Waste Volume	50 %

Source: Waste to Wealth

Case Studies of Successful Implementation of RDF plant

Co-processing of Segregated Plastic Waste (an Initiative of Jabalpur Municipal Corporation and ACC–Holcim)

1. Out of 340 tons of MSW generated in Jabalpur Municipal limits, 5% was plastic and other combustible fractions (approximately 15–20 tons of waste per day), which was sent to the cement plant.
2. JMC introduced door-to-door waste collection service from households in 6–7 colonies as a pilot service wherein waste pickers collect the waste.
3. Self-help groups (SHGs) of over 200 waste pickers were formed for collection and segregation of waste.
4. JMC initiated a process of issuing identification numbers followed by issuing identification cards to the waste collectors or waste pickers to formally integrate them into the system.
5. Non-recyclable fractions of waste—e.g., double coated plastic, torn paper, jute, tetra-packs, thermocol, waste tires, etc.—were segregated and transported to cement plants.
6. Until 2013, ACC–Kymore Cement Works had successfully co-processed 1,622 tons of segregated waste, and the initiative is being replicated in other locations as well.

Figure 95 Jabalpur Municipal Corporation along with ACC Holcim set up the RDF Plant

Source – Waste to Wealth

To demonstrate the co-processing methodology, ACC had conducted co-processing trial of plastic waste at Kymore Cement Works plant, with support from CPCB and MPPCB. The results of the trial run demonstrated that there are no negative influences of the stack emissions on product quality. The presence of high temperature and long residence time of the kiln ensures complete destruction, thus making co-processing in cement kiln a safer and greener way of management of segregated plastic waste.

Considering the importance and benefits of the co-processing technology and based on the experience of various successful trial runs for hazardous and non-hazardous waste across the country, CPCB formulated the "Guidelines on Co-processing in Cement or Power or Steel Industry." In these guidelines, CPCB has included plastic as a nonhazardous fraction that can be co-processed.

Windrow Composting

Overview

Windrow composting is the production of compost by piling biodegradable waste, in long rows (windrows). This method is suited to producing large volumes of compost. These rows are regularly turned over to improve porosity/voids and oxygen content, mix in or remove moisture, and redistribute cooler and hotter portions of the pile. Windrow composting is a commonly used composting method.

Windrow composting is the most common technology implemented in most of the ULBs in India. Windrows are defined as regularly turned elongated piles, trapezoidal in cross section and up to a hundred meters or more in length. The cross-sectional dimensions vary with feedstock and turning equipment, but most municipal solid waste (MSW) windrows are 1.5 to 2 meters high and 3 to 6 meters wide.

Processes involved

Windrow composting involves aerobic bioconversion of organic matter to stable compost with release of heat, water vapor and CO_2.

In which the pile composting can be used only for small quantities of input materials. However, the windrow composting allows large quantities of materials to be composted. Having a geometrical shape ranging from 2 to 4 m wide and 2 to 3 m high at the starting of composting process.

These types of systems usually acquire a trapezoidal shape. Depending on the nature of raw material used for composting. Before forming the windrow, the material is shredded and screened to 3 to 9 cm, with moisture content adjusted to 50-60%. Usually.

The windrows are turned twice in a week so that temperature is maintained at 55°C and the process is accomplished in 3-4 weeks. Furthermore, for curing, the compost is left without turning for another 3-4 weeks for the degradation of residual organics.

•Materials Delivering •Materials Piling •Regularly Turning •Generated Compost

Source: Waste to Wealth

Requirements for setting up a plant

The capital expenditure, operational expenditure and other requirements vary with the technology used to convert waste to energy. The following table summarizes the different requirements of different technologies:

Table 104 -General requirements for setting up a Windrow Composting plant

Parameters	
Type of Waste	Organic Waste (All type of Wet-Biodegradable Waste)
Suitability (Tons/day)	Min: 100 Tones and Max: 1000 Tones
Approx. Area Requirement (m2)	Min: 12500 m2 and Max: 185000 m2
Approx. Capital Investment (Rs.)	Min: 650 Lakhs and Max: 5500 Lakhs
Approx. Operational Costs (PA)	Min: 70 Lakhs and Max: 250 Lakhs

Compost Generation	Resource: Compost Min: 15 TPD Max: 175 TPD
Approx. Operational costs (Rs.)	750 INR per ton of compost
Processing Period	60Days
Type of Labor Requirement	Skilled + Semi Skilled + Unskilled
Suitability	1 Large Quantity of Waste 2 Large piece of land 3 Agriculture and Horticulture activity in surrounding

Case studies of successful implementation of the Windrow composting plant

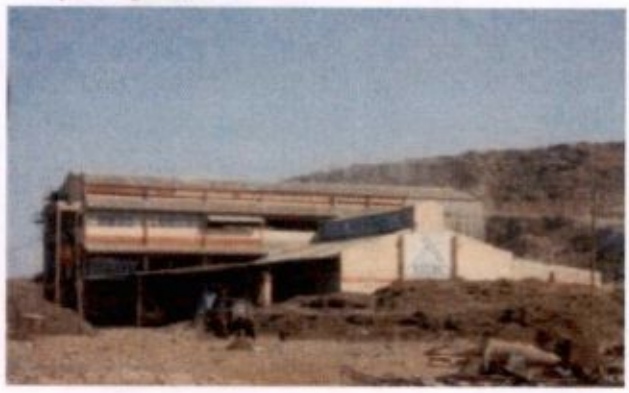
1. **Okhla Waste to Compost Plant:** The Okhla compost plant was set up on Public Private Partnership (PPP) in association with South Delhi Municipal Corporation of Delhi (SDMC). Today the plant processes 200 Tonnes of MSW each day and produces 30 TPD of organic compost.
2. **Ahmedabad Municipal Corporation**: Ahmedabad the capital of Gujarat covers 500 km2 area in the heart of the state. Population of the city is around 7.5 million. City collects and transports approx. 4000 Tonnes of garbage every day.
    - A private composting agencysigned 30-year agreement with Ahmedabad Municipal Corporation (AMC) in 1997 for 500 TPD MSW processing for converting it into compost. AMC has given 25-acre land on 1 rupee/sq. mtr rent basis. This is the oldest & largest surviving MSW treatment compost plant in India.
    - As per the original agreement, the agency is giving 2.5% royalty to AMC on realization price of compost. The plant is one of the highest producers of good quality City Compost in India.

We are not proposing open any composting like windrow or vermicomposting. It is a primitive method having environmental and aesthetic nuisance.

Figure 96 South Delhi Municipal Corporation along with a private agency set up the Okhla Compost Plant

Source: Waste to Wealth

Figure 97 Ahmedabad Municipal Corporation along with a private agency set up the Windrow Composting Plant



Bioremediation

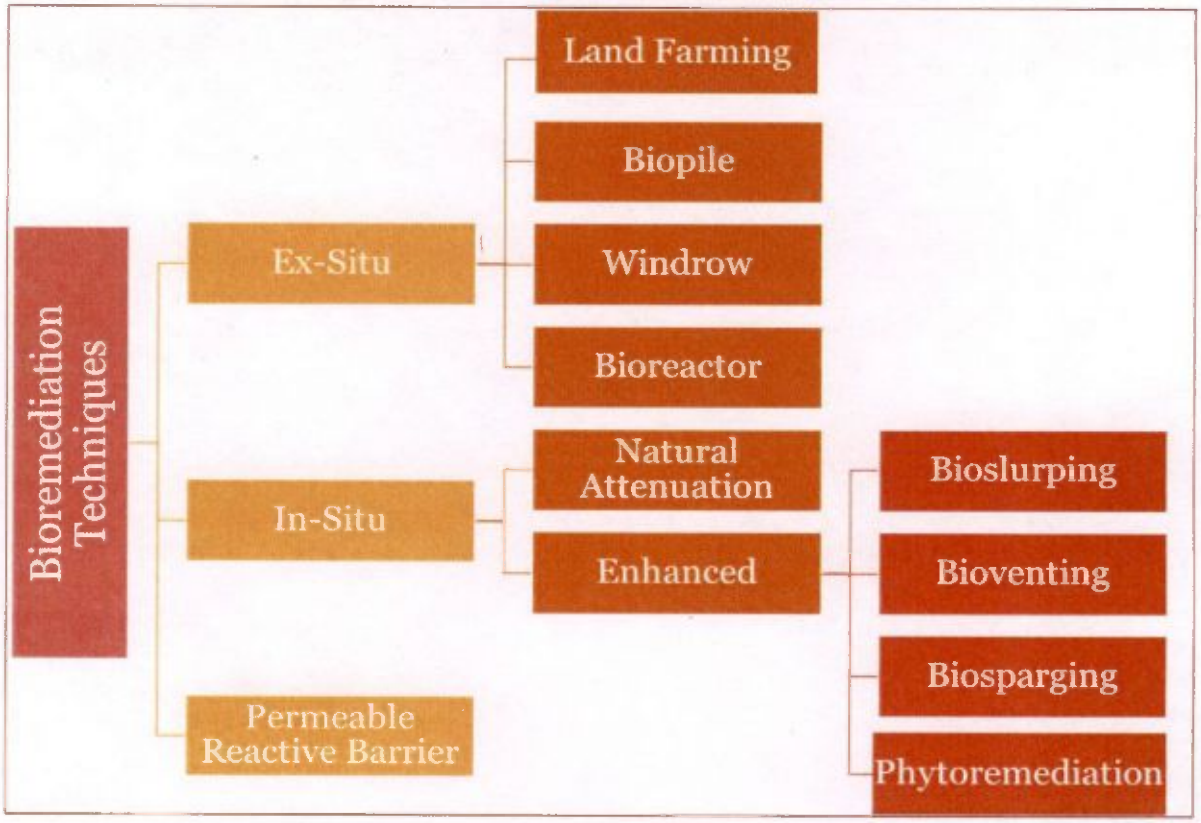
Overview

Bioremediation is a means of cleaning up contaminated environments by exploiting the diverse metabolic abilities of microorganisms to convert contaminants to harmless products by mineralization, generation of carbon (IV) oxide and water, or by conversion into microbial biomass.[46]

The figure below represents the techniques used under Bioremediation:

Figure 98 Bioremediation plant

Figure 99 Techniques of Bioremediation



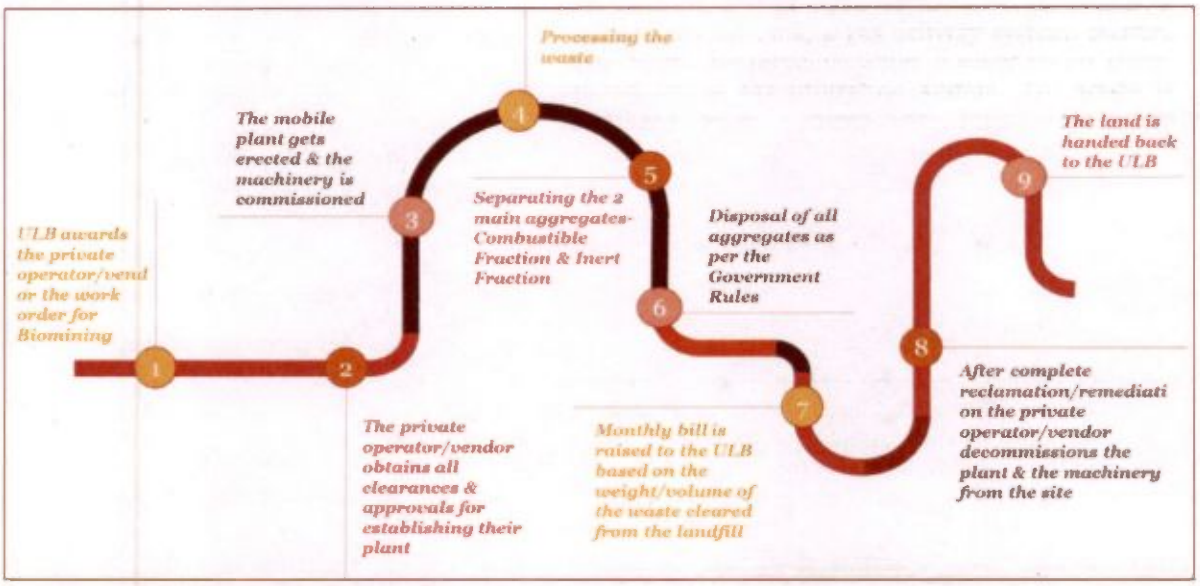
Source – A private agency

[46] An Introduction to Bioremediation, 2013

Processes involved

The figure below shows the process involved in setting up a Bioremediation Plant:

Figure 100 Processes involved in setting up a Bioremediation Plant



Source: An Introduction to Bioremediation, 2013

Requirements for setting up a plant

Depending upon the bid parameter of the private operator the cost revolves around Rs. 600-700/ton of waste.

Case Studies of successful implementation of the Bioremediation plant

Noida Bioremediation Plant: The area coverage of the plant is about 6, 96,000 Sq. Ft. where it can hold 1, 50, 000 MT of waste. Currently, for this site plant erection is in process.

Figure 101 Noida Bioremediation Plant

Source: Private agency

Biomethanation (DRYAD)

Overview[47]

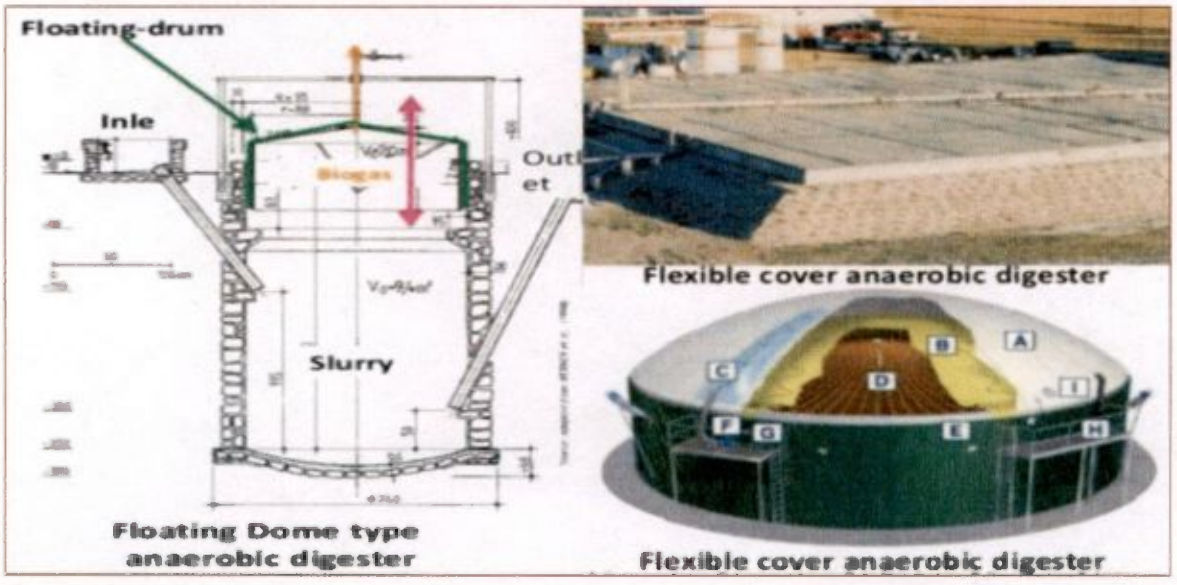
Bio-methanation is the anaerobic (in the absence of free oxygen) fermentation of biodegradable matter in an enclosed space under controlled conditions of temperature, moisture, pH, etc. The waste mass undergoes decomposition due to microbial activity, thereby generating biogas comprising mainly of methane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

Operating Parameters for Bio-methanation plant

1. **Temperature:** Temperature affects bacterial growth and hence the amount of biogas produced. Treatment of waste in anaerobic reactors is normally carried out within two ranges: around 25°C–40°C (ideally 35°C–37°C) known as mesophilic range, and higher than 45°C (ideally 55°C–60°C) known as thermophilic range
2. **pH:** The anaerobic digestion process is limited to a relatively narrow pH band from 6.0 pH to 8.5 pH approximately, especially that the methanogenic bacteria are very sensitive to pH (close to neutral pH around 7.0)
3. **Toxicity:** A number of compounds are toxic to anaerobic microorganisms. Methanogens are commonly considered to be the most sensitive to toxicity
4. **Carbon-to-nitrogen ratio:** Optimum carbon-to-nitrogen (C/N) ratio in anaerobic digesters is 20:30. Optimum C/N ratios of the digester materials can be achieved by mixing material of high and low C/N ratios, such as organic solid waste (high in carbon) and sewage or animal manure (high in nitrogen).
5. **Organic loading rate:** Organic loading rate is the frequency and speed at which the substrate is added to the digester. For each plant of a particular size, there is an optimal rate at which the substrate should be loaded.
6. **Retention time:** The required retention time for completion of the reactions varies with differing technologies, process temperature, and waste composition. The retention time for waste treated in a mesophilic digester ranges from 20 to 30 days. A high solids reactor operating in the thermophilic range has a retention time of about 14 days.

A schematic showcasing the same is depicted in the next section.

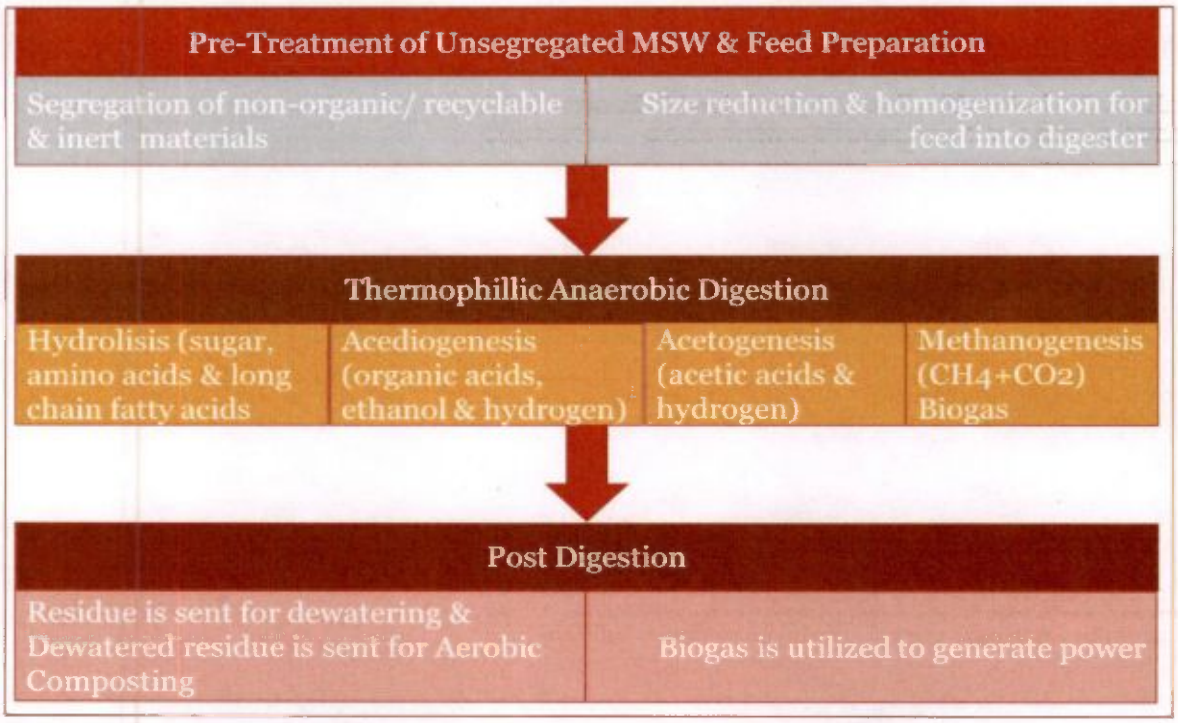
Figure 102 Bio-methanation Plant



[47] Waste to Wealth

Processes Involved

The Process (for DRYAD) involves 3 Steps:



Source: CAPEX, DRYAD™.

Requirement for Setting up a plant

The following summarizes the capital expenditure, operational expenditure and other requirements for setting up a Bio-methanation plant:

Table 105 General requirements for setting up a Bio-methanation plant

Parameters	
Type of waste	Mixed Combustible Waste
Suitability (Tones/day)	Min: 0.50Tonnes and Max: 300 Tones
Area Requirement	Min: 350 m2 and Max: 37,000 m2
Capital Investment	Min: 15.0 Lakhs and Max: 9000 Lakhs
Operational Costs	Min: 1.5 Lakhs and Max: 90 Lakhs
Energy/Resource Generation	Power + Compost Min: 0.2MW and Max: 3.0MW
Production costs	4.50 per unit electricity
Life Duration	15 Years
Handling Expertise	Skilled+ Semi Skilled+ Unskilled
Reduction in Waste Volume	40%

Case Studies of successful implementation of the Bio-methanation plant

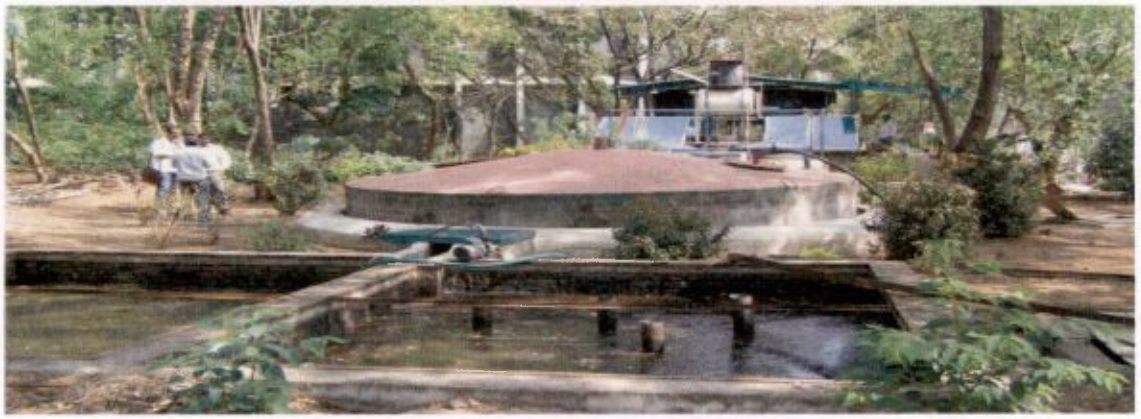
1. 400 TPD Solapur Project: 400 TPD Solapur Project on Mixed MSW is completed & is under stabilization. It is 'FIRST OF ITS KIND' operational plant based on biomethanation process in the country. Once stabilized, the plant will generate over 3.00 MW of electricity and 60-80 TPD of organic compost. The electricity will be sold to Maharashtra State Electricity Distribution Company Limited (MSEDCL) for which PPA has already been signed. The compost & carbon credits will be sold in open market. (The project was completed at a cost of 60 cr. in 2 years timeframe.)

2. Nisargruna Plant, Shatabdi Hospital Site at Govandi, Mumbai: Technical details of the plant Major components of BARC's a Nisarguna plant include a mixture/pulper with 5 HP motor for crushing solid waste, a pre-mix tank, a pre-digester tank, an air compressor, a slow water heater or solar panels, a main digestion tank, a gas delivery system, manure pits, a tank for recycling water, a water pump, slurry pump and a gas utilization system. The waste is homogenized in a mixer using water. This slurry enters the pre-digester tank where aerobic thermophilic bacteria proliferate and convert part of this waste into organic acids like acetic acid, butyric acid, propionic acid and formic acid.

Figure 103 Biomethanation Plant in Solapur

Source: CAPEX, DRYAD™.

Figure 104 Shatabdi Hospital Site at Govandi, Mumbai



Automatic Organic Waste Converter (AOWC)

Overview

Processes all types of organic waste like curry, roti, bread, egg-shells, chicken bones, mutton bones, fish, fish bones, fruit, fruit peels, vegetables, vegetable peels, left-overs of kitchen waste, garden waste like dry leaves and small twigs etc.[48]

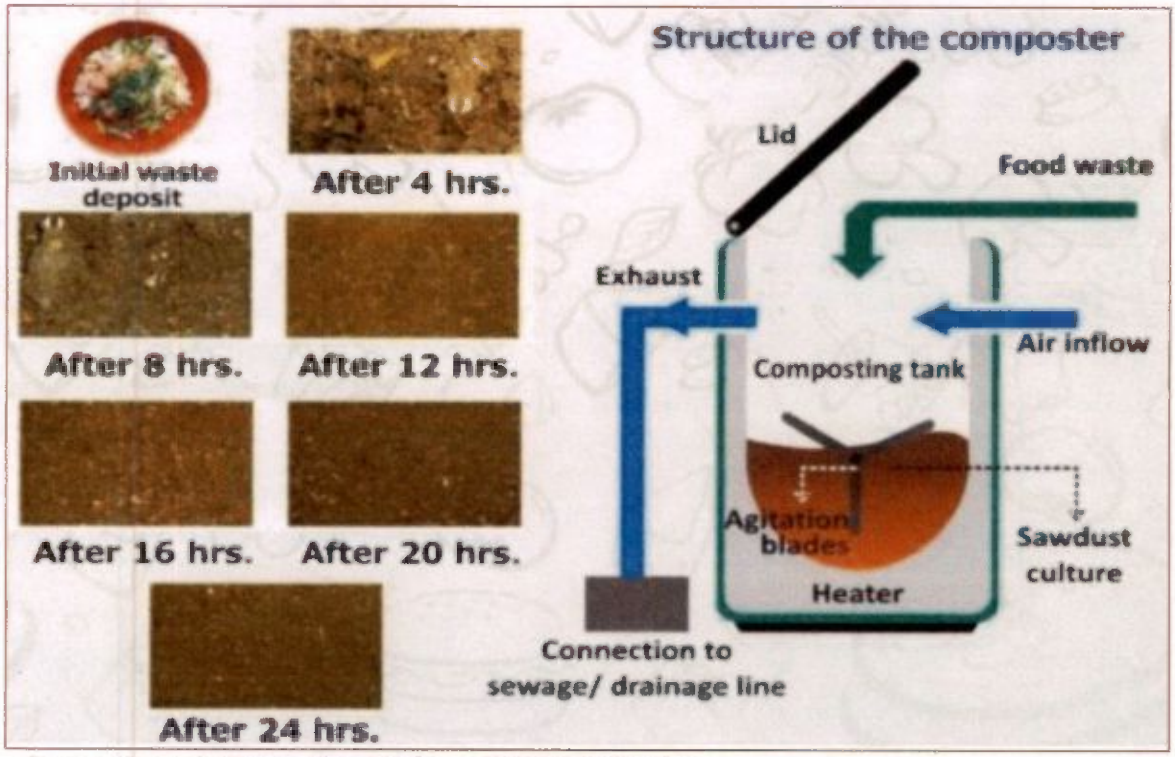
Some of the unique features of the plant are:

- Fully Automatic & compact in size
- Processes waste to compost in 24 hours
- Processes all types of organic waste like curry, roti, bread, egg-shells, chicken bones, mutton bones, fish, fish bones, fruit, fruit peels, vegetables, vegetable peels, left-overs of kitchen waste, garden waste like dry leaves and small twigs etc.
- 85-90% volume reduction of organic waste into high quality compost.
- Removal of compost only once in 10 days. • No addition of any micro-organisms or anything else for composting ever.
- Noiseless,
- Odorless,
- Maintenance-free and no harmful gases
- No pathogens

Processes Involved

The figure below represents how an AOWC system works:

Figure 105 Processes involved in AOWC



Source: Organic Composting Machine, SHUDHHI Brochure

[48]ORGANIC COMPOSTING MACHINE (SHUDHHI COMPOSTER)

Requirements for setting up a plant

Depending upon the bid price of the private operator the cost revolves around Rs. 13, 00000-57, 13,000 per unit.[49]

Case studies of Automatic Organic Waste Treatment plant

Sawantwadi Municipal Council, Mumbai (Installation of automatic organic waste converter – 2000 with a Processing Capacity: 2 Tons per day): Tons of municipal solid and organic wastes can be treated and reduced to 85 – 90% of its weight which will produce odorless dry soil enricher which can be used for agricultural purposes. Due to reduction of wastes, areas for landfills can be put to better use. Constant fires and emissions of toxic fumes will reduce thereby a decrease in health hazards caused due to pollution.

Figure 106 Installation of AOWC

Source: Case Study on Automatic Organic Waste Converter Machine Installed At Narkhed Municipal Council & Sawantwadi Municipal Council Situated In Maharashtra

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