Climate Centre for Cities

Ministry of Housing and Urban Affairs
Government of India

Counter MEASURE FOR PLASTIC FREE RIVERS

Scientific Landfill Remediation

TRAINING MANUAL

ClimateSmart Cities Assessment Framework

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Counter MEASURE FOR PLASTIC FREE RIVERS

Scientific Landfill Remediation
Training Module

Developed by:
Climate Centre for Cities, NIUA in association with UNEP under the Counter Measures (II) project

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Executive Summary

On one hand, cities are a significant contributor of carbon emissions aggravating climate change and on the other, cities are considerably impacted by climate disasters. The recently released Global Climate Risk Index 2021 ranks India as the 7th most affected country from climate related extreme weather events (storms, floods, heatwaves etc.). Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually.[1] Cities are increasingly at the forefront of addressing both urbanization and climate change and to strengthen climate-sensitive urban development, a holistic understanding of the urban development from a climate lens is crucial. The ClimateSmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (MoHUA), Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across 5 thematic areas helps cities to benchmark their development, understand the gaps and further prioritize climate relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach of conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that not only makes the cities climate resilient but also helps them progress across the assessment of CSCAF. This training focuses on the 'scientific landfill remediation' under the thematic area of waste management in the CSCAF. The training has been developed in association with UNEP under the CounterMEASURE (II) project.

Building on the phase 1 of the CounterMEASURE project which focused on identification of sources and pathways of major plastic leakage in India and along the Mekong River, the second project phase, "Promotion of action against marine plastic litter in Asia and

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[1] *Mani, M. et al., 2018. South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards, Washington*
D.C.: World Bank Group.

the Pacific (CounterMEASURE II) initiated in May 2020 aims to generate, share and disseminate scientific knowledge on plastic pollution in the Ganges, Mekong and selected rivers in Sri Lanka and Myanmar, to inform policy and decision-making processes at local, national, regional and global level.

Elaborate on objective of the module The objective of the module is to a provide a basic understanding of landfill design and operations as well as dumpsite remediation projects with an emphasis on its need & benefits required to unlock the large potential of land that is locked under the dumpsites especially in urban areas were the environmental pollution and the health hazards caused due to the landfills are also drastically increasing. The attendees in the training session will get an opportunity to gain knowledge on the various challenges in landfill management and dumpsite remediation as the technical capacity of the ULB officials and other stakeholders plays a important role in dealing the future landfill remediation needs.

key concepts covered in at least 2 paragraphs

The module is majorly developed in order to provide a wholesome understanding of the landfill remediation projects to the ULB officials. It covers the speciality areas such as landfill design and operation and landfill mining including feasibility, preliminary investigation, operation and management of landfill mining, and impact of landfill mining on sustainable waste management system.

The module also focuses on the bio remediation feasibility, technologies/various types of remediation practiced globally, suitable design based on the city requirement and technology availability over the traditional landfill capping which just covers the landfill with a layer of soil. Also the participants are given an insight of remediation impact on sustainable waste management system and the assessments tools used for analysing the environmental impact post remediation along with the various financial and operational models that can be followed by the ULBs.

Who is the training manual designed for?

What is the focus of the training manual?

How to make use of this manual?

What are the Learning outcomes of the training?

Scope and limitations of the training

The training manual has been designed for senior and mid-level ULB officials involved in the field of waste management and the urban planners involved in landfill remediation.

The manual provides a state-of-art knowledge of waste management majorly focusing on landfill remediation technologies, operational procedure as well technological and policy interventions in dumpsite remediation projects.

The manual is designed to guide readers to achieve a basic understanding of landfill remediation with an emphasis on its need & benefits, especially in urban areas were the environmental pollution and the health hazards are drastically increasing. Apart from the detailed information provided in the manual, a set of reference materials are indicated for additional reading. Case studies to demonstrate the theoretical concepts are also covered to demonstrate the practical application of concepts.

The participants would learn detailed step by step procedure for remediation process, technologies/various types of remediation practiced globally, suitable design based on the city requirement, technology availability, landfill capping, including feasibility, preliminary investigation, operation and management of landfill remediation, and its impact on sustainable waste management system and the assessments tools used for analysing the environmental impact post remediation. This manual covers the various financial and operational models that can be followed by the ULBs. The case studies outlined in the course would also help in learning best practices followed by other cities in the country and globally.

The manual is designed to guide readers to achieve basic understanding of landfill remediation. Detailed procedures to be followed for the current landfill remediation, financial models to be included in city action plan and development plan have not been included. However, additional reference materials indicated can support further understanding on these lines.

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Abbreviations

ACS	Automated trash Collection System
BMC	Brihanmumbai Municipal Corporation
CAA	Citizenship Amendment Act
CBO	Community-Based Organization
C&D	Construction & Demolition
CII	Confederation of Indian Industry
CH4	Methane
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO2	Carbon dioxide
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CSCAF	Climate Smart Cities Assessment Framework
DPR	Detailed Project Report
EAC	Expert Appraisal Committee
EfW	Energy from Waste
EPA	Environmental Protection Agency
EPC	Engineering Procurement and Construction
EPR	Extended Producer Responsibility
EU	European Union
EV	Electrical Vehicle
e-Waste	Electronic Waste
FICCI	Federation of Indian Chambers of Commerce & Industry
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Global System of Mobile
H2	Hydrogen
HDPE	High-Density PolyEthylene
IBA	Incinerator Bottom Ash
ICT	Information and communications technology
IEC	Information, Education and Communication
IoT	Internet of Things
ISWM	Integrated Solid Waste Management
IT	Information Technology
JNNURM	Jawaharlal Nehru National Urban Renewal Mission

LDPE	Low Density PolyEthylene
LFG	Landfill Gas
MoEFCC	Ministry of Environment, Forest and Climate Change
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NEERI	National Environmental Engineering Research Institute
NGO	Non-Governmental Organization
NOX	Nitrogen Oxides
OCC	Old Corrugated Cardboard
O&M	Operation & Maintenance
PET	Polyethylene terephthalate
PP	Polypropylene
PPE	Personal Protective Equipment
PPP	Public–Private Partnership
PRG	Preliminary Remediation Goals
PS	Polystyrene
PVC	Polyvinyl chloride
RDF	Refuse Derived Fuel
RS	Remote Sensing
SEAC	State Expert Appraisal Committee
SHG	Self Help Group
SO2	Sulfur dioxide
SPCB	State Pollution Control Board
SUP	Single Use Plastic
SVE	Soil Vapor Extraction
SWM	Solid Waste Management
ULB	Urban Local body
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VOC	Volatile organic compounds
WFH	Work From Home
WtE	Waste to Energy
3R	Reduce Reuse Recycle

1

Municipal Solid Waste Management Plan

India produces 277 million tonnes of municipal solid waste every year, according to a 2016 estimate. That's more than 80% of the 334 million tonnes of waste generated across South Asia and about 13% of the global waste generated every year. As per the 2016 survey, India generates the second-least waste per day at 0.5kg per person. However, India's per person per day average will increase based on the projection of 543 million tonnes of annual garbage by 2050 for the country. This means an average Indian an average Indian will be generating about 900gm of waste per day up from about 600gm now.

When looking forward, waste generated by India is expected to grow to 543.3 million tonnes by 2050, (i.e) India is projected to generate substantially the highest quantity of waste globally.[1]

MSWM is the management of waste generation, collection, storage, transfer and transportation, processing, and disposal in accordance with rules and regulations as well as best practises for public health, the environment, economics, and aesthetics.

MSW is defined as solid or semi-solid household waste, such as sanitary, commercial, institutional, catering, and market waste, as well as other non-residential wastes, such as street sweepings, silt removed or collected from surface drains, horticulture waste,

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[1]*India, T. o., 2020. Times of India. [Online] Available at: https://timesofindia.indiatimes.com/india/in-30-years-india-tipped-to-double-the-amount-of-waste-it-generates/articleshow/74454382.cms#:~:text=More%20than%20tenth%20of%20the,global%20waste%20generated%20every%20year. [Accessed December 2021].*

construction and demolition waste, and treated bio-medical waste, excluding industrial hazardous waste, bio-medical waste, and e-waste generated in an area under the jurisdiction of an urban local body. Commercial and domestic garbage generated in a notified municipal area are included in municipal solid waste.

To promote economic growth and a higher quality of life, solid waste management is crucial to decrease and eliminate the harmful effects of waste products on human health and the environment. To keep costs low and waste from accumulating, this must be done in the most efficient manner possible. The Waste Management System has six functional elements: generation, on-site handling, storage, and processing, collection, transportation, processing, and recovery, and disposal.

Institutional Structure

In the management of municipal solid waste, the government plays a significant role. Ministries, boards, and local governments all have duties and obligations in India.

The Ministry of Environment, Forestry, and Climate Change (MoEFCC), for example, is in responsible of MSW management in general, as well as drafting, directing, and enforcing waste management policy and regulations.

The Ministry of Housing and Urban Affairs is in charge of drafting the Municipal Solid Waste Management Manual for Urban Local Bodies in order to make municipal solid waste management easier and more environmentally friendly.

The Central Pollution Control Board (CPCB) is in charge of coordinating activities with the State Pollution Control Boards (SPCBs), providing technical help and training to people, disseminating waste management information or instructions, and completing government jobs.

The State Pollution Control Board must devise a comprehensive plan for the prevention and control of air and water pollution, inspect all realistic times, control equipment, and processes, and approve the construction of a landfill or incineration.

Municipal solid waste management services, such as waste collection from generation sources and road sweeping, transportation, treatment, and disposal of municipal solid waste at the local level, as well as operating disposal, recycling, or composting facilities, are the responsibility of local governments.

The Ministry of Chemicals and Fertilizers' Department of Fertilizers supports to the creation of an e-market for city compost and guarantees that compost co-marketing is promoted to enterprises.

The Ministry of Agriculture allows for more flexibility in fertiliser regulation for compost production and sale, as well as the circulation of compost in farms and the establishment of laboratories for testing compost prepared by local governments.

The Ministry of Power is in charge of determining the rate at which power is created from solid waste to energy facilities and ensuring that this power is purchased.

The Ministry of New and Renewable Energy Sources is responsible for supporting waste-to-energy plant infrastructure development as well as providing a subsidy or incentive.

Swachha Bharat Mission, Swachhata App, Swachhata Helpline, Swachha Survekshan, Municipal Solid Waste Management Manual are some of the Indian government's major initiatives and activities.

In waste management, institutional strengthening is critical, and it can be accomplished by decentralising administration effectively, delegating necessary authorities at the decentralised level, and giving adequate training to employees. In order to make the service competitive and efficient, NGOs and the private sector must be encouraged to participate.

At the levels below, the functions may be decentralised: Ward-level administration, zonal administration, and city-level administration are the three types of administration.

Challenges

The goal for waste management in India stresses the use of wastes as resources, with improved value extraction, recycling, recovery, and reuse. Waste management must be seen as a fundamental service in Indian civilization, requiring long-term commitment and the waste management business must be appealing and profitable.

Information about future waste amounts and characteristics determines the suitability of alternative waste management and treatment methods. To enable for considerably more efficient value extraction and recycling, waste management must include waste segregation at the source. Separating dry (inorganic) and moist (biodegradable) garbage would be beneficial, and it should be the waste producer's responsibility.

Long-term waste management planning necessitates the creation of bold projects by local governments, corporations, and non-profits. Setting roles and responsibilities, as well as tracking and assessing progress, are all crucial for delivering sustainable systems. It's crucial to share experiences from different parts of India and from different social groups. A number of academic institutes, organisations, non-governmental organisations (NGOs), and private sector firms are working on a comprehensive waste management strategy, and future trash management will require major participation from the informal sector across the country.

Data collection is necessary for keeping records, benchmarking, planning, justifying, and reporting against national standards.

At-source generation (segregated and non-segregated), waste for recycling, categories of waste, types and quantities of plastic, waste utilised for waste to energy, roadways, recycling programmes, and so on are examples of data.

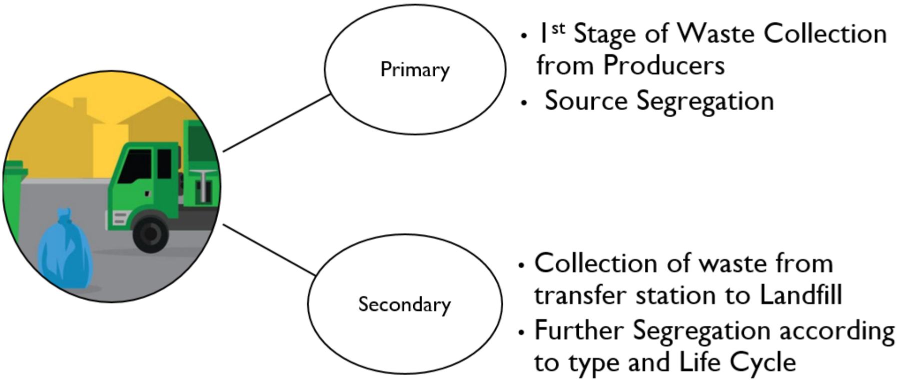
Quantification and Composition of Waste

Increased-income people purchase more packaged goods, resulting in higher volumes of plastics, paper, glass, metals, and textiles in the waste stream, which is influenced by the local economy. Changes in the content of garbage can have a significant impact on how we handle it.

Hazardous wastes like pesticides, paints, leftover medications, and batteries may be discovered in MSW in some places. All of the locations have fruits, veggies, and food waste.

Healthcare waste, such as disposable syringes, sanitary products, and blood-containing materials, is regulated by the Biomedical Waste (Management and Handling) Rules 1998 and the Amended Rules, 2003. Medical waste is not to be combined with MSW. Collection, segregation and transportation

Fig 1.1: Primary and secondary collection



Depending on the type of garbage collected, the trash collection process comprises gathering waste at its source and delivering it to either an intermediate collection facility or a landfill.

In India, the Municipal Authority is largely responsible for rubbish collection, which includes door-to-door collection, collection from communal bins, slums, hotels, restaurants, office complexes, commercial districts, markets, hospitals, and so on.

Segregation

Source segregation is a concept in which the waste generator divides garbage into pre-defined groups to enhance resource recovery through recycling and reuse. Source segregation increases the amount of recyclables recovered, reducing resource use and landfill space. Garbage that is separated at the source is also more sanitary for waste workers.

Reduce, Reuse, and Recycle is the source segregation thumb rule.

Storage

The storage of garbage at the source is the first step in solid waste management. Normally, trash should be kept at the source until it is collected and disposed of. Some examples of storage are as follows:

- Plastic buckets, containers, and totes
- Metal bins, either with or without lids

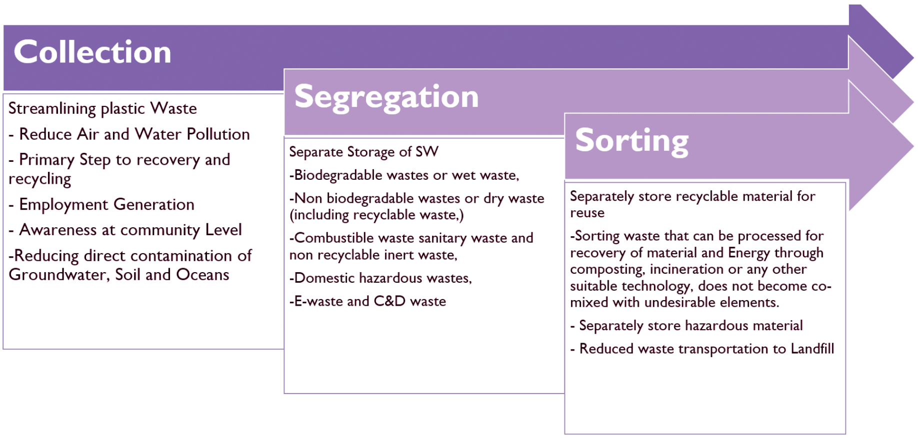
Waste has the potential to damage the environment and threaten human health if it is not properly handled and stored.

Transportation and Collection

The collection of segregated waste is the second step in the SWM process. To ensure that garbage generated at the source is collected on a regular basis and does not wind up in streets, drains, or water bodies, a waste collecting system is required.

Waste collection that is inefficient has a detrimental impact on public health, the environment, and aesthetics.

Fig 1.2: Steps in collection, segregation and sorting



Following collection, garbage transportation is the next phase. Transportation is critical to SWM services. Depending on the local conditions and location of the landfill site, ULBs collect and transport waste using a range of equipment, including pushcarts, auto tippers, tractors, tipper trucks, and compactors.

Processing and Treatment

Recycling

Recycling includes a wide range of benefits, including economic and social benefits, in addition to reducing garbage going to landfills. After they've served their purpose, the things and materials that can be used. Recycling is the process of sorting, collecting, and remanufacturing or converting discarded or waste materials into new resources.

Recycling has the following advantages: It reduces the amount of waste sent to landfills and incinerators; it conserves natural resources such as timber, water, and minerals; it improves economic security by utilising waste; it reduces the need for additional raw materials, which reduces pollution; it conserves energy; and it helps to create jobs in the recycling and manufacturing industries.

Recovery

Resource recovery is the process of using trash as an input material to create valuable items as new outputs. The goal is to reduce waste generation, reducing the requirement for landfill space and increasing the value generated from garbage.

More than waste management is involved in resource recovery. A circular economy is one in which natural resource extraction and waste generation are reduced, and materials and products are intended for durability, reuse, repairability, remanufacturing, and recycling in a more sustainable way.

Composting

Composting is the process of microbes like bacteria and fungi breaking down organic wastes into simpler forms. The microorganisms use the carbon in the waste as an energy source. As the nitrogen-containing compounds decay, the original constituents break down into a much more homogeneous product that can be utilised as a soil amendment. Composting is a long-term waste management strategy that converts any amount of organic waste into a product that can be used.

When microorganisms decompose organic waste in a heat-generating environment, the waste volume is reduced, many harmful organisms are eliminated, and a valuable, possibly marketable product is produced.

Waste to Energy

Waste-to-energy (WtE) or energy-from-waste is the process of generating energy in the form of electricity and/or heat from the primary treatment of rubbish, or the processing of waste into a fuel source (EfW). WtE is a technique for reclaiming energy. Most WtE processes either generate electricity and/or heat directly through burning, or produce a combustible fuel commodity, such as methane, methanol, ethanol, or synthetic fuels.

MRF

A material recovery facility (MRF) is a facility that accepts, sorts, and prepares recyclables for sale to a third party. Recycling facilities sift a wide variety of materials, including but not limited to: Cardboard Plastics

- Plastics
- Papers
- Glass
- Metal containers
- Cartons, and other materials

MRF works on principle of sorting, processing, storage, and load-out. The complete packages must include below equipment,

- Conveyors & material handling equipment to move material through the system
- Screening equipment to sort material by size,
- Magnetic separation to remove ferrous metals
- Eddy current separation to remove non-ferrous metals
- Air classifiers to sort materials by density
- Bag openers
- Optical sorting equipment to separate plastics or glass by material composition
- Interim Storage containers
- Baling equipment to prepare recovered material for market.
- Weighing scale

Fig 1.3: Process flow of a MRF

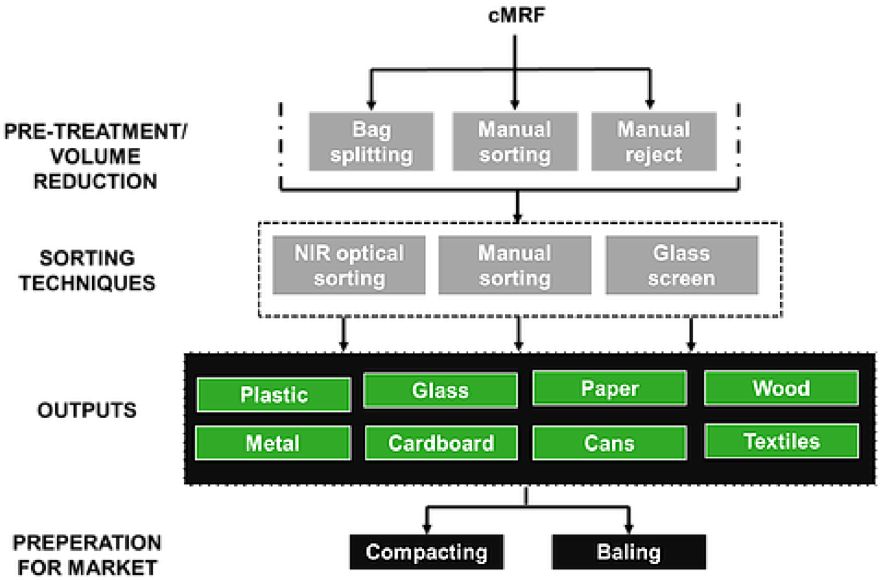
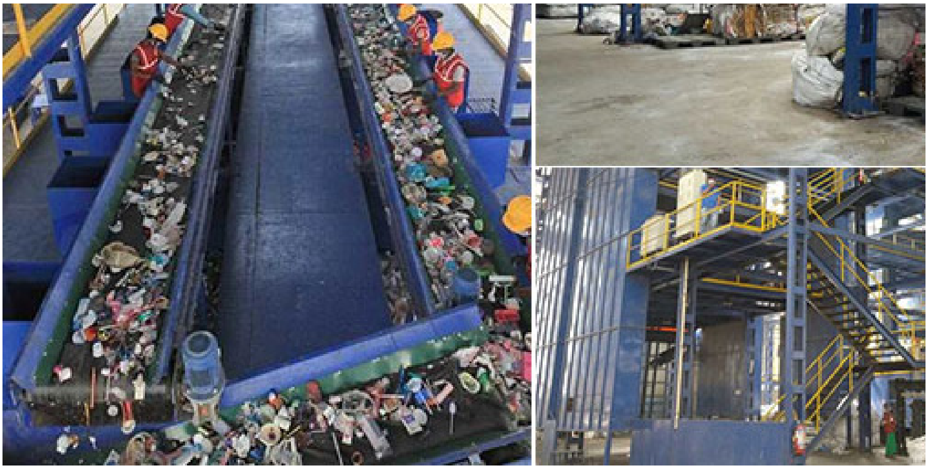


Fig 1.4: Pictures of a MRF Plant



Climate Smart Cities Assessment Framework

Understanding the losses and damages from the disasters, identifying the vulnerability hotspots, safeguarding urban assets, development of city level action plan, monitoring and performance evaluation of the same is the need of the hour in order to build the disaster resilience and also to adapt climate change. Considering the same CSCAF 2.0 has formulated five themes capturing both mitigation and adaptation aspects of various sectors in the city. Waste management being one of themes, indicator focusing on landfill/dumpsite scientific remediation is covered in this module. The indicator focuses on evaluating the city's readiness to scientifically manage the landfill emphasizing on bio-remediation and bio mining over traditional landfill capping.

Fig 1.5: Progressive level in landfill bioremediation, CSCAF

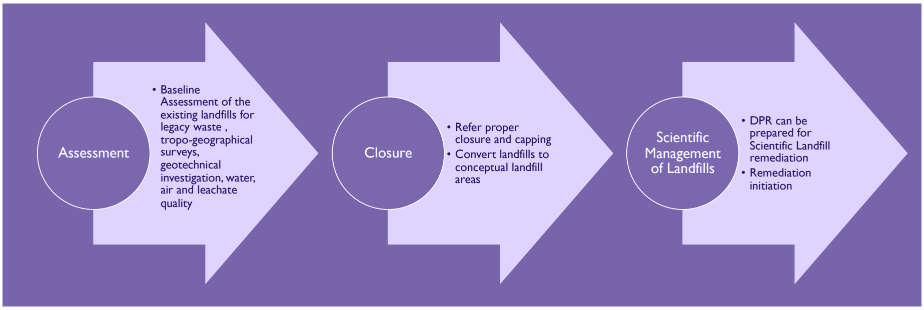
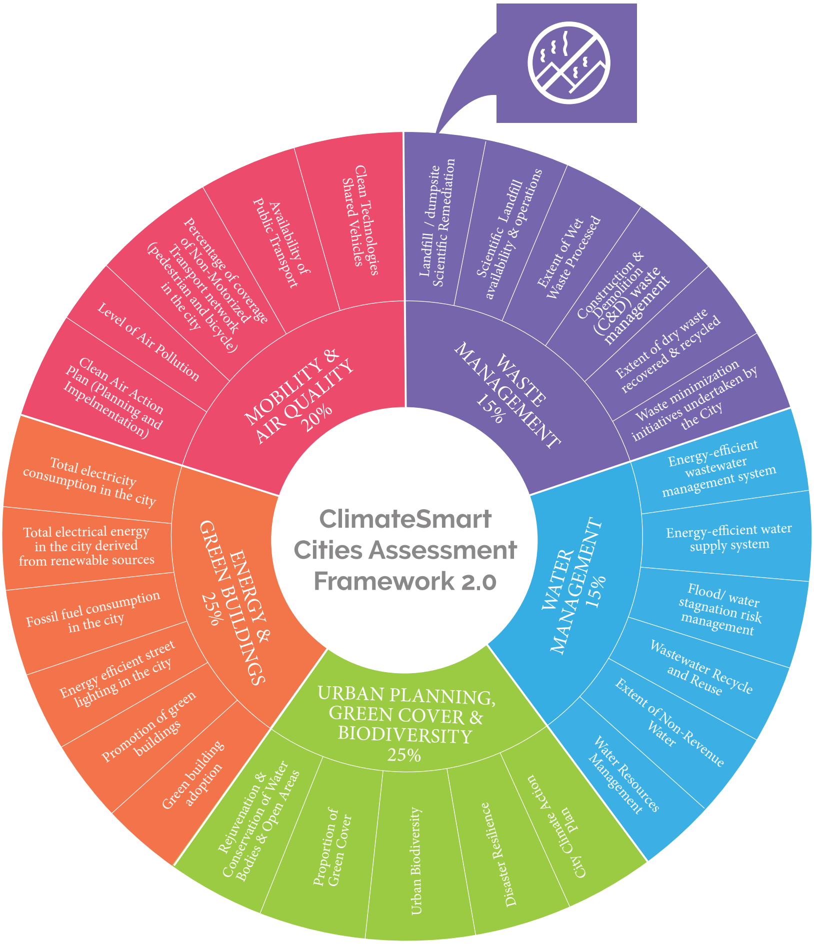


Fig 1.6: ClimateSmart Cities Assessment Framework



2

Landfill

A conventional landfill is a man-made system for storing trash in specially constructed and protected cells on the ground's surface or in underground excavations. Despite the fact that more rubbish is being reused, repurposed, or energetically valorized, landfills remain an important aspect of waste management. During the degradation of waste in landfills, leachate and gases are created. These emissions have the potential to threaten human health as well as the quality of the environment. The most common greenhouse gases found in landfill gas are methane and CO_2 (carbon dioxide). Landfills account approximately 20% of all anthropogenic methane emissions worldwide.[1]

Much of the potential risk from MSW dumps is accounted for by the migration of toxic leachate and landfill gas, as well as the environmental ramifications of the many landfills that exist around the world. When MSW is dumped without being pre-treated, biological processes in the landfill have a considerable impact on main emissions (leachates and biogas). Emissions are created during the landfill's operation and continue to be produced long after it is closed.

The migration of gas and leachate from the landfill body into the environment is a serious environmental concern, posing a threat to groundwater, air quality, and climate change via methane emissions, as well as significant health risks.

The following are some of the factors that have an impact on the environment:

- Landfills provide a long-term threat to ground water and surface water that are hydrologically related by generating a deadly soup of industrial and domestic cleaning chemicals.

[1] *Kumar, C., Mishra, P., Pathnak, A. K. & Pathak, A. K., 2020. Landfill Emissions and Their Impact on the Environment. INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT), Volume 09(Issue 08 (August 2020)).*

- Almost a third of landfill garbage is biodegradable; as it rots and decomposes, harmful gases (CO_2 and methane) are released, both of which contribute to global warming. Landfills contaminate the surrounding environment, particularly the water and soil.
- Landfills are one way that humans change the development of soil by changing factors including climate, exposure, and soil organisms.
- Landfills can produce unpleasant odours, and landfill gas can migrate through the soil and settle in nearby structures. The most harmful gases produced in landfills include ammonia, sulphide, methane, and carbon dioxide.
- Ammonia and hydrogen sulphide are the most common orders at landfills.

Residents living near five kilometres (5km) of a landfill are at risk. Lung cancer and death, as well as respiratory disease-related death and hospitalisation (used as a surrogate for all pollutants co-emitted from landfills). When the capacity of a landfill is reached, the trash is covered with clay and a second plastic shield. The soil and plants are then placed on top of several feet of dirt fill.

The term “landfill” refers to a unit operation for the final disposal of “Municipal Solid Waste” on land that has been created and constructed with the purpose of minimising environmental impact by integrating critical components.

Landfills come in a variety of shapes and sizes.

- Landfills for sanitary waste
- Landfill for Municipal Solid Waste (MSW)
- Landfills for construction and demolition waste
- Landfills that are well-managed
- Landfills for industrial waste
- Landfills for Hazardous Waste

Scientific Landfills

A scientific dump is so titled because it was built using a scientific design and approach. The seepage of solid waste leachate into the underlying soil and water, contaminating both, is one of the most critical problems with traditional landfills. Because the base layer of clay in scientific landfills successfully eliminates any seepage or leaking within the landfill, there is no possibility of garbage seeping underground. A soil drainage layer and a vegetative layer are placed on top of the base layer to avoid soil erosion. Leachate is collected before it seeps underground due to the presence of these layers.

Fig 2.1: Landfill Type – Based On Waste Type

Municipal Solid Waste	Industrial waste (C&D)	Hazardous waste	Green waste

Scientific landfills act as degassing systems by reducing methane production. Methane is produced at a slower rate than in typical landfills because the layers soak up the majority of the contaminants in the rubbish. In scientific landfills, vertical wells aid in the regular extraction of methane, which can then be used to generate energy and heat.

Components of Scientific Landfill

The following are the seven fundamental components of an MSW landfill:

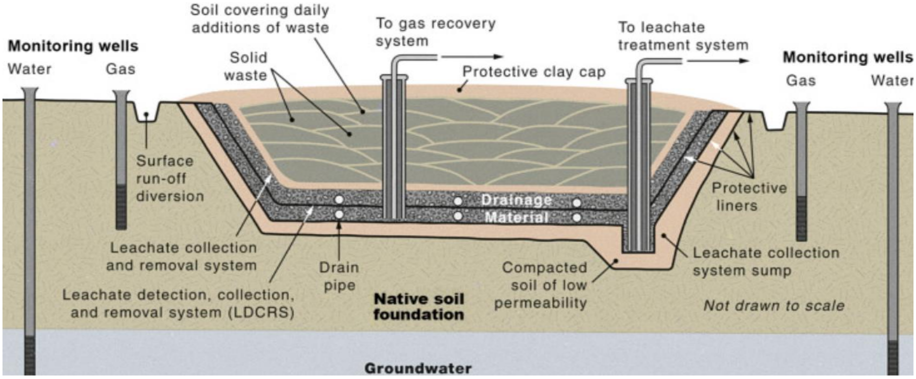
1. A liner system that prevents leachate or gas from seeping into the surrounding soil at the landfill's base and sidewalls.
2. A leachate collection and control facility that collects and removes leachate from the inside and outside of the landfill before treating it.
3. A gas collection and control facility (optional for small landfills) that collects and eliminates gas from within and on top of waste before treating or recycling it.
4. A final cover system that improves surface drainage, prevents infiltration, and maintains surface vegetation at the top of the landfill.
5. A drainage system for surface water that collects and transfers all surface runoff away from the landfill.
6. An environmental monitoring system based on a landfill that collects and analyses air, surface water, soil gas, and groundwater samples on a regular basis.
7. A closure and post-closure plan that includes the methods for closing and securing a landfill once it has been filled, as well as the activities for long-term monitoring, management, and maintenance of the closed landfill.

Planning and Design

The design of a landfill consists of 3 phases:

- Active
- Pre-closure
- Closure

Fig 2.2: Typical section of a scientific landfill[2]



The volume of waste to be disposed of in a landfill will be calculated for the 'active' period of the landfill, taking into account. (a) Current yearly water generation; (b) Expected increase in waste generation rate based on historical data or population growth.

The volume occupied by the liner system and cover material (daily, intermediate, and final cover), as well as the waste's compacted density, determine the landfill's real capacity.

Layout of the Landfill: It is critical to define the layout prior to construction, and the following should be taken into account when planning the landfill:

- Access roads;
- Equipment shelters;
- Weighing scales;
- Office space;
- Location of waste inspection and transfer station;
- Temporary waste storage and/or disposal sites for special wastes;
- Waste processing areas (e.g. shredding);
- Demarcation of landfill areas and areas for stockpiling cover and liner material
- Drainage facilities;
- Location of landfill gas management facilities;
- Location of leachate treatment facilities; and
- Location of monitoring wells.

Depending on the topography, geography of the area, depth of the water table, and availability of daily cover material, several sections of a landfill exist.

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[2] *Government, S. M., 2015. Seoul Soultion. [Online] Available at: https://seoulsolution.kr/en/content/landfill-recovery-project-transformation-landfill-ecological-park [Accessed 2021]*

The Phases is a landfill sub-area. Along with the landfill layout, a phase plan should be drawn up that includes cells, lifts, daily cover, intermediate cover, liner and leachate collection facility, gas control facility, and final cover.

The use of a liner system in a landfill is critical for containing leachate and protecting ground trash and soil. Controlling leachate at a landfill entails the following steps:

- Use of an appropriate liner system to prevent leachate migration from the landfill sides and base to the subsoil; and
- Drainage of leachate collected at the base of a landfill to the sides of the landfill and removal of the leachate from within the landfill.

Scientific Landfill Availability and Operations

Landfills in metropolitan India were traditionally envisioned as large plots of land far from residential areas, with garbage disposed of on a regular basis and recycled to keep the landfill from being depleted. Landfills, on the other hand, have become dump yards as cities have increased in population, with no regard for their capacity or lifespan.

Due to their haphazard design and indiscriminate trash disposal, landfills in India offer a number of problems. The release of methane gas as a result of rubbish accumulation is one of the most serious threats that landfills pose.

Most landfills in India have reached the end of their useful lives and are spewing harmful gases like methane. Scientific landfills have the ability to treat garbage while it is being disposed of, making them valuable in urban waste management. Landfills in India were merely considered as dumpsites, that are located far away from the city limits. But the rapid urbanization has brought the landfills to the end of their life causing innumerable stress to the environment and also created a need to unlock the potential of land. The newly inaugurated landfill at Narela-Bawana is India's first scientific landfill. At 150 acres, the Narela-Bawana landfill is situated on an area more than double of Ghazipur at 70 acres. The scientific landfill has the capacity to treat 2,000 tonnes of waste every day, generating 24 megawatts of electricity. Given the Central Pollution Control Board's estimate of Delhi projected to generate 15,000 tonnes of garbage daily by 2021, the new plant is welcome to change the waste management scenario in capital. Sadly, Narela-Bawana remains the only scientific landfill in India."[3]

Implementation plan and strategy

The implementation plan and strategy for a scientific landfill begins at the point of generation. Implementing Integrated Solid Waste Management (ISWM) is crucial. Rather of relying just on technical methods, integrated solid waste management relies on a

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[3]Dutta, S., 2019. NDTV. [Online] Available at: https://swachhindia.ndtv.com/disposing-waste-scientifically-how-scientific-landfills-can-change-the-waste-disposal-scenario-in-india-8159/ [Accessed 2021].

wide range of complementary solutions and a holistic strategy. This integrated waste management technique includes every stakeholder involved in and affected by waste management. When constructing an integrated waste management strategy, social, environmental, and economic restrictions are all taken into account.

Local government, central governing authorities, the commercial sector, local inhabitants, and all other stakeholders must work together to improve ISWM from a system perspective. ISWM has been praised and advocated by Ministries, Central Pollution Control Boards, and other regulating bodies as a long-term solution. ISWM includes waste avoidance, reduction, reuse, and recovery, as well as recycling, composting, incineration with and without energy recovery, and disposal in sanitary landfills.

Management support, quality assurance, collective labour, better training programmes, and appreciation ratings are all required for strategy implementation and strategy execution. The participation and ownership of citizens is critical to achieving better results.

Adequate funding from the municipality for garbage collection, MRF facility, and landfill operations will ensure the use of new technologies to improve waste management efficiency.

3

Scientific Landfill Remediation

Open dumping sites are concerning as they have environmental, health, and livelihood risks. Most landfill sites are dumping grounds that were once low-lying areas that were filled with waste, hence the name "land-fill." These dumping grounds create severe ground water pollution, methane gas emissions, fire dangers, and vermin, which is the polar opposite of a scientific landfill site. To address this, it is critical to reclaim these areas in order to construct new scientific landfills for the disposal of inerts and residual solid waste, as well as to extend the life of existing landfills (a process known as 'landfill capacity extension'). In addition, legacy garbage buried in dumpsites must be handled and recycled for profit-generating purposes.

Scientific Remediation is a process in which contaminants are removed or neutralized scientifically so that they cannot cause further harm to the environment.

On-site clean-up is a tried-and-true strategy for reducing environmental concerns from abandoned landfills and eventually reclaiming the area for public use.

Remediation of Scientific Landfill

Landfills pose a number of risks due to their poor design and indiscriminate waste disposal. One of the most serious concern is the release of methane gas as a result of garbage accumulation. Methane is the most common cause of landfill fires, which result in rubbish burning and severe air pollution. Landfills also represent significant health risks since they are a repository for viruses and bacteria that cause cardiovascular and respiratory ailments.

Threats possessed by Landfills:

- Uncontrolled Fires
- Methane Emission
- Cardiovascular and Lung Disease

In non-scientific words, remediation is the process of covering existing landfill cells with dirt and potentially a membrane to lessen the risk of fires, leachate, storm water runoff, vermin, windblown dust, and other undesired impurities.

On-site clean-up is a tried-and-true strategy for reducing environmental concerns from abandoned landfills and eventually reclaiming the area for public use. Another plus is that any new waste management facility would include adequately lined landfill cells and, ideally, the option to include features like sorting, recycling, and even waste-to-energy technology if its installation is financially feasible and its long-term operation is viable.

There are various remediation guidelines in place around the world, like,
The Environmental Protection Agency (EPA) Region 9 has the most comprehensive list of Preliminary Remediation Goals (PRGs) in the United States. There is a set of European standards that is commonly referred to as the Dutch standards. Although most of Europe's industrialised nations have their own standards, the European Union (EU) is gradually heading toward Europe-wide standards. The majority of remediation standards in Canada are defined by individual provinces, however the Canadian Council of Ministers of the Environment provides federal advice in the form of the Canadian Environmental Quality Guidelines and the Canada-Wide Standards| 3.2 Petroleum Hydrocarbons in Soil: A Canada-Wide Standard.

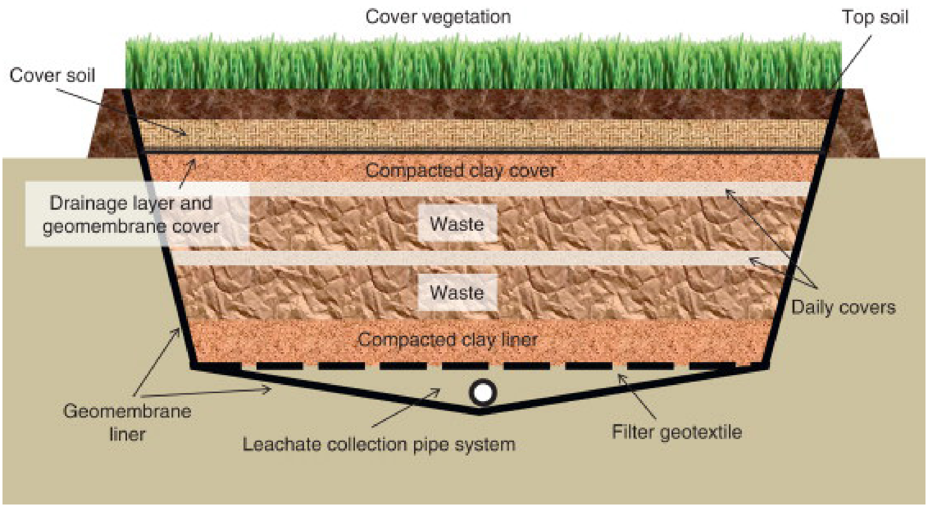
Guidelines to adopt landfill remediation in India
All existing and old landfills will be inspected and boreholes will be drilled for (i) recovery of leachate samples from the base of the landfill, (ii) recovery of subsoil samples beneath the base of the landfill for evaluation of permeability and soil properties and (iii) recovery of waste samples for waste characterisation. A minimum of 3 boreholes will be drilled with atleast one borehole for each acre of landfill area. The quality of leachate samples will be compared with (a) the ground water quality in existing borewells 2 km away

from the landfill and (b) the Central Pollution Control Board (CPCB) norms for limits of contaminants in leachate. If the leachate quality and the permeability of the subsoil strata is observed to be satisfactory, the existing landfill can continue to operate with bi-annual monitoring of leachate quality in the drilled boreholes. (f) If the leachate quality is observed to be of poor quality with respect to the local ground water quality or with respect to the CPCB norms, steps will be taken to close the existing landfill site and remedial measures adopted. (http://cpheeo.gov.in/upload/uploadfiles/files/chap17(1).pdf)

Post Closure MSW rules 2016

1. The post-closure care of landfill site shall be conducted for at least fifteen years and long term monitoring or care plan shall consist of the following, namely:-'
   i. Maintaining the integrity and effectiveness of final cover, making repairs and preventing run-on and run-off from eroding or otherwise damaging the final cover;
   ii. Monitoring leachate collection system in accordance with the requirement;
   iii. Monitoring of ground water in and around landfill;
   iv. Maintaining and operating the landfill gas collection system to meet the standards.
2. Use of closed landfill sites after fifteen years of post-closure monitoring can be considered for human settlement or otherwise only after ensuring that gaseous emission and leachate quality analysis complies with the specified standards and the soil stability is ensured.

Fig 3.1 Typical section of a remediated landfill



Overview of Remediation waste

To safeguard human health and the environment, remediation waste is regulated. The specifications are determined by the pollutants found in the trash. As a result, you must be able to classify your remediation waste in order to comply with the standards that apply during garbage removal and disposal.

Remediation waste is a type of trash that is formed during the remediation process and typically consists of polluted soil, water, or demolition debris. Hazardous and/or non-hazardous waste can be found in remediation waste. Before generating any remediation trash, you must classify the waste as hazardous or non-hazardous and devise a management, treatment, or disposal strategy. The clean-up waste must be addressed immediately after it has been generated.

Important waste characterization concepts include the following:

- Point of Generation.
- Listed vs. Characteristic waste.
- "Contained-in" Policy for Contaminated Environmental Media.
- "Area of Contamination" Policy.
- Requirements for treatment.
- Land Disposal Restrictions

Waste characterization should be an integral part of site-wide project management:

- Tempting to focus on clean-up and worry about characterization later.
- Allows Law of Unintended Consequences to kick in.
- Opportunities to minimize disposal cost can be missed.
- Timing of "Contained-in" determinations.
- Contaminated soil management and staging.
- In-situ treatment vs. ex-situ.
- Can result in a need for unexpected approvals/permits, causing delays and cost overruns.

Remediation technologies

1. Bioremediation (Excavation/landfill mining)
2. Landfill capping
3. Landfill surcharging
4. Soil vapor extraction and air sparging
5. Co-treatment of landfill leachate
    i. Landfill leachate with sewage in a wastewater treatment plant
    ii. Bioreactor landfills

Landfill capping:

In this method, the dumpsite is initially levelled, covered with soil by providing the surface drainage system, leachate management and gas collection systems and then capped. By doing these the landfill site is converted into a green space having an environmental monitoring systems as well. This is used in absence of viable reclamation options where bioremediation becomes highly expensive, high levels of contamination or unpredictable material that would come out of the legacy dumpsite. Capping a landfill involves three layers: an upper vegetative (top soil) layer, a drainage layer and a low permeability layer comprised of a synthetic material overlaying two feet of compacted clay. Capping has a 50-100 years of lifetime, although the cap's performance depends on the site's environmental conditions. Caps can crack and erode as a result of changes in air temperatures and precipitation, as well as if the region is prone to subsidence and earthquakes. To prevent frost, the top must be thick enough to accommodate vegetative roots and burrowing animals.

Fig 3.2: Landfill remediation technology

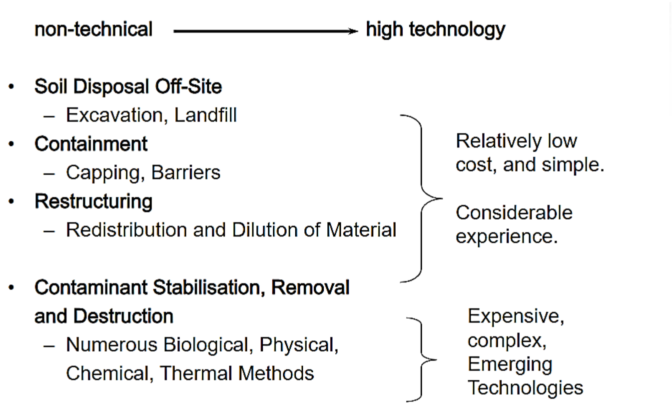


Fig 3.3: Partial land reclamation and capping project in Nashik[1]

Before *After*

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[1]*Source: Swachh Bharat Mission – Advisory on Land reclamation*

Landfill Surcharging:

Surcharging is the process of putting additional weight on the landfill. Usually this is done with soil stockpiles (clean soil so that it can be reused). The heavier the stockpile and the longer it stays in-place, resulting in noticeable settlements. The settlement can also be improved by placing the green/wood waste operation on top of the landfill. Surcharging usually carried out when a landfill reaches its final elevation levels.

Soil vapor extraction and air sparging:

In-situ remediation procedure such as Soil vapor extraction (SVE) and air sparging are used to remove vapors from polluted soil and plume, respectively. These procedures, SVE and air sparging are used in site parallely. This removes solvents, fuels and volatile organic compounds readily. The procedure involves with the construction of two types of wells around the landfill, (i.e.) extraction wells and air injection wells. The vacuum is created in the extraction well to draw the vapors to the surface, while an air injection well pumps air into the ground. The injected air promotes the growth of aerobic bacteria which aid in the microbial decomposition. The evaporation of the compounds is enhanced if the injected air is heated. SVE and air sparging are both safe, although full remediation can take years, depending on the amount and depth of the pollution, the type of soil, and the chemical concentrations in the soil and groundwater. These solutions, on the other hand, are faster than relying solely on natural processes.

Co-treatment:

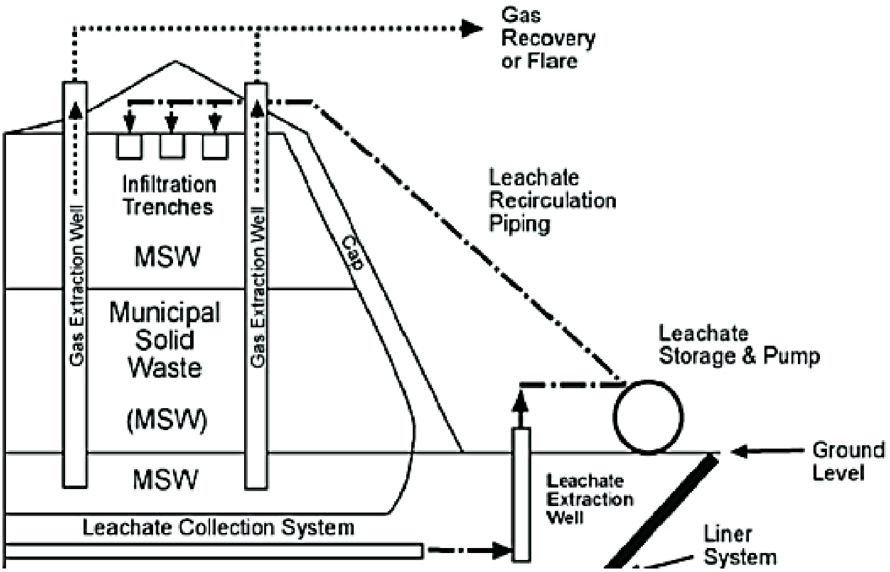
A. Landfill leachate with sewage in a wastewater treatment plant

In this the leachate is usually discharged to a wastewater treatment plant. Pre-treatment is done before discharging to a wastewater treatment plant, or treatment onsite followed by discharge to a nearby stream are all options for leachate management. The most typical approach is to connect to a local sewer line. The majority of municipal wastewater treatment plants employ aerobic biological treatment (e.g., the activated sludge process), which is created specifically to target biodegradable organic matter and suspended solids in sewage. As a result, refractory organics and emergent contaminants may be inadequately removed from leachate. Although a lot of big sewage can dilute the persistent pollutants in leachate, it's important to remember that these pollutants aren't really removed or eradicated. Furthermore, harmful compounds in leachate (such as ammonia and heavy metals) might disrupt microbial activity and cause atypical wastewater treatment plant operation. Additionally, sewer lines may be inaccessible, have insufficient capacity, or be prohibited for certain reasons for connection to nearby treatment plants.

B. Bioreactor landfills

In a bioreactor landfill, the microbial activity is purposely increased by cycling of leachate back into filled cells. Leachate recirculation provides moisture and/or oxygen to encourage microbial breakdown of solid wastes while also reducing the amount of leachate required for treatment. To reclaim landfill space, a bioreactor landfill can be either aerobic or anaerobic. Anaerobic bioreactor landfills just inject leachate, whereas aerobic bioreactor landfills pump both air and leachate into the garbage. In comparison to anaerobic bioreactor landfills, the aerobic bioreactor enhances microbial digestion rates, resulting in faster waste settlement. Anaerobic bioreactor landfills, on the other hand, produce more methane gas. As a result, it's a good option for energy recovery initiatives.

Fig 3.4: Schematic of a bioreactor landfill using leachate recirculation[2]



[2]*Bendere, R., Šmigins, R. & Teibe, I., 2012. WASTE PRE-TREATMENT METHOD – STARTING STATEMENTS, MAINTENANCE, FINAL RECOVERY AND LANDFILLING. Linnaeus ECO-TECH 2012 , Issue November 26-28, 2012.*

Fig 3.5: Approaches to Landfill Remediation

Quantity of the waste to be remedied on the basis of area and surveys

↓

Reaching the Lowest Ground Level

↓

Garbage Layer Ranking

↓

Coarse Material and Garbage are screening

↓

Valuable Land recovered by Bio-Remediation

↓

C&D Waste- sent to C&D Processing Facility

↓

Recovered Soil is used for refilling Grounds

↓

Post Screening, useful waste is sent to further processing (recycle/ selling) and C&D waste may be used for filling low-lying areas

↓

Respective machinery and tools deployment

↓

Regular Monitoring

Site characterization and Preparation

There are 10 steps to for site preparation and characterization, mentioned below:

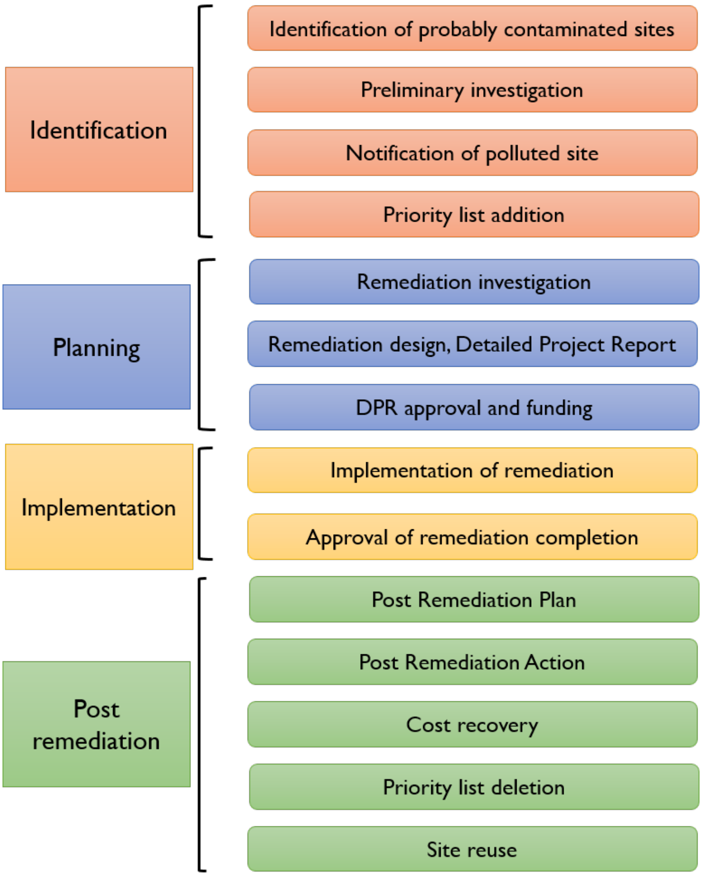
- Quality of groundwater
- Surrounding Land
- Local Landscape
- Operational Timeline
- Waste Disposal Type
- Disposal Procedure
- Depth and Volume of Waste
- Site Location
- Local Geology
- Depth of Ground & Surface Water, and nearby water channels.

The first step in the landfill repair procedure is to assess the contamination. Environmental Site Assessment is frequently the first step in the process. The evaluation technique and type of sample and chemical analysis to be performed will be guided by the site's use and the materials placed there. Even though the current land use appears to be harmless, surrounding sites held by the same corporation or nearby sites that have been reclaimed, levelled, or filled are frequently contaminated. Off-site pollution of surrounding locations, frequently caused by decades of emissions to soil, groundwater, and air, is also vital to address. Before and after any repair, the ceiling dust, topsoil, surface water, and groundwater of surrounding properties should all be evaluated.

The final criteria is that the environmental impact, social acceptance, and transportation and remediation costs are to considered.

Remediation principles and process

Fig 3.6: Fourteen Steps remediation process



Models for Implementing Dumpsite Remediation (Swachh Bharat Mission – Urban, Advisory on Landfill Reclamation) are

Execution Methods

- 100% Reclamation: Design Finance Own and Operate and Transfer with near-zero residues. All work must be carried out in compliance with SWM Rules 2016 and CPCB Guidelines for the disposal of legacy waste 2019. (Tamil Nadu Model)- Maximum processing cost & no operating costs
- 100% Capping (Minimum operating/ processing cost) e.g. Gorai Dumpsite in Mumbai
- 60-70% Reclamation, rest with inert capping - Part Capping, (Nashik Model, EPC)- Processing & Operating cost lying between the first two models

Working Models

- 100% work to outsourced to selected private contractor • 100% by ULB with rented equipment and manpower
- Part by private operator (processing only) and rest by ULB (utilization, transportation and disposal)

The reference scope and qualification criteria for each model mentioned above is elaborated in the annexure for general understanding and reference.

Leachate and Gas

Landfill gas (LFG) is a natural byproduct of the decomposition of organic material in landfills. LFG is composed of roughly 50 percent methane (the primary component of natural gas), 50 percent carbon dioxide (CO^2) and a small amount of non-methane organic compounds.

Collecting and Treating Landfill Gas:

Landfill gas can be caught, processed, and used as a renewable energy resource instead of escaping into the atmosphere. Landfill Gas is used to eliminate odours and other risks associated with Landfill Gas emissions, as well as to prevent methane from migrating into the atmosphere and contributing to local smog and global climate change. Landfill Gas energy projects also produce revenue and career opportunities in the community and beyond.

Fig 3.7:Landfill collection system[3]

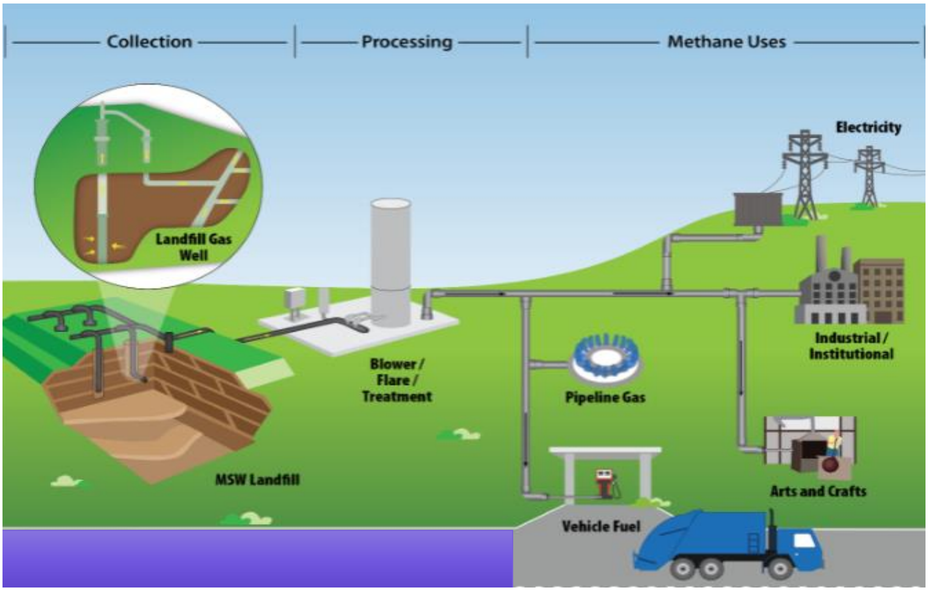
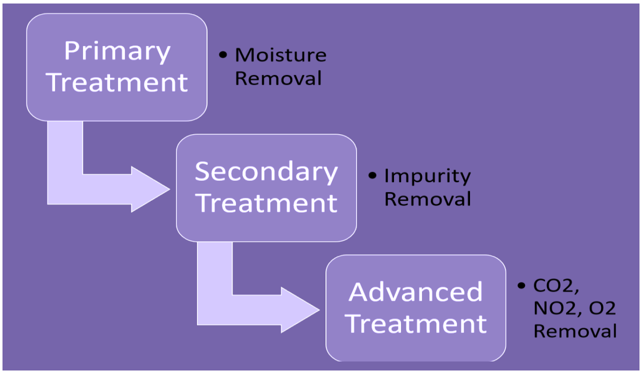
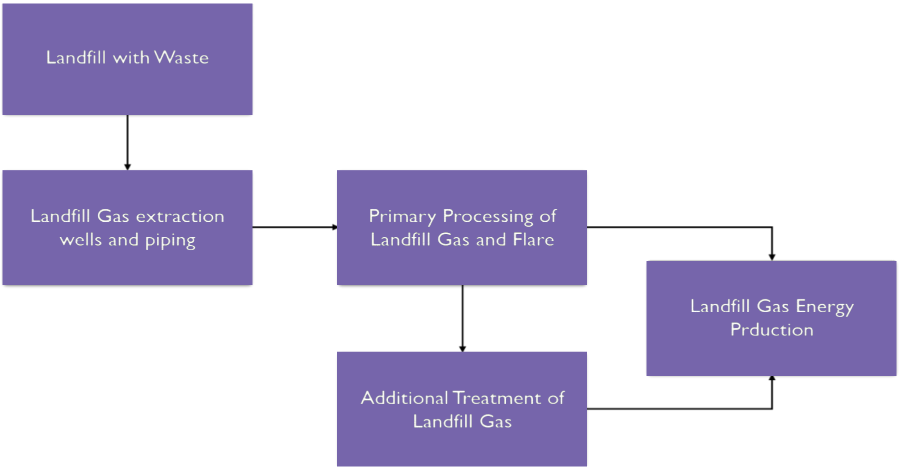


Fig 3.8: Three stages of landfill gas treatment



[3]*(USEPA), U. S. E. P. A., n.d. EPA. [Online] Available at: https://www.epa.gov/lmop/basic-information-about-landfill-gas*

Fig 3.9: Flowchart of a Basic LFG Collection and Processing System



Closure of Remediation Landfill:

- Compacting of land for Waste
- Before the waste processing, the waste shall be sent to the sanitary landfill.
- Before monsoon season, an intermediate cover of 40-65 cm thickness of soil shall be placed on the landfill with proper compaction and grading.
- Final cover shall be designed to minimize infiltration and erosion after completion of landfill.
- The final cover shall have a barrier soil layer comprising of 60 cm of clay with proper drainage layer of 15cm on top of it vegetative layer of 45 cm to support natural plant growth and to minimize erosion.

The post-closure care of landfill site shall be conducted for at least fifteen years and long term monitoring or care plan shall consist of the following

- Maintaining the integrity and effectiveness of final cover, making repairs and preventing run-on and run-off from eroding or otherwise damaging the final cover;
- Monitoring leachate collection system in accordance with the requirement;
- Monitoring of ground water in and around landfill;
- Maintaining and operating the landfill gas collection system to meet the standards.

Use of closed landfill sites after fifteen years of post-closure monitoring can be considered for human settlement or otherwise only after ensuring that gaseous emission and leachate quality analysis complies with the specified standards and the soil stability is ensured.

Fig 3.10: Benefits and challenges of remediation

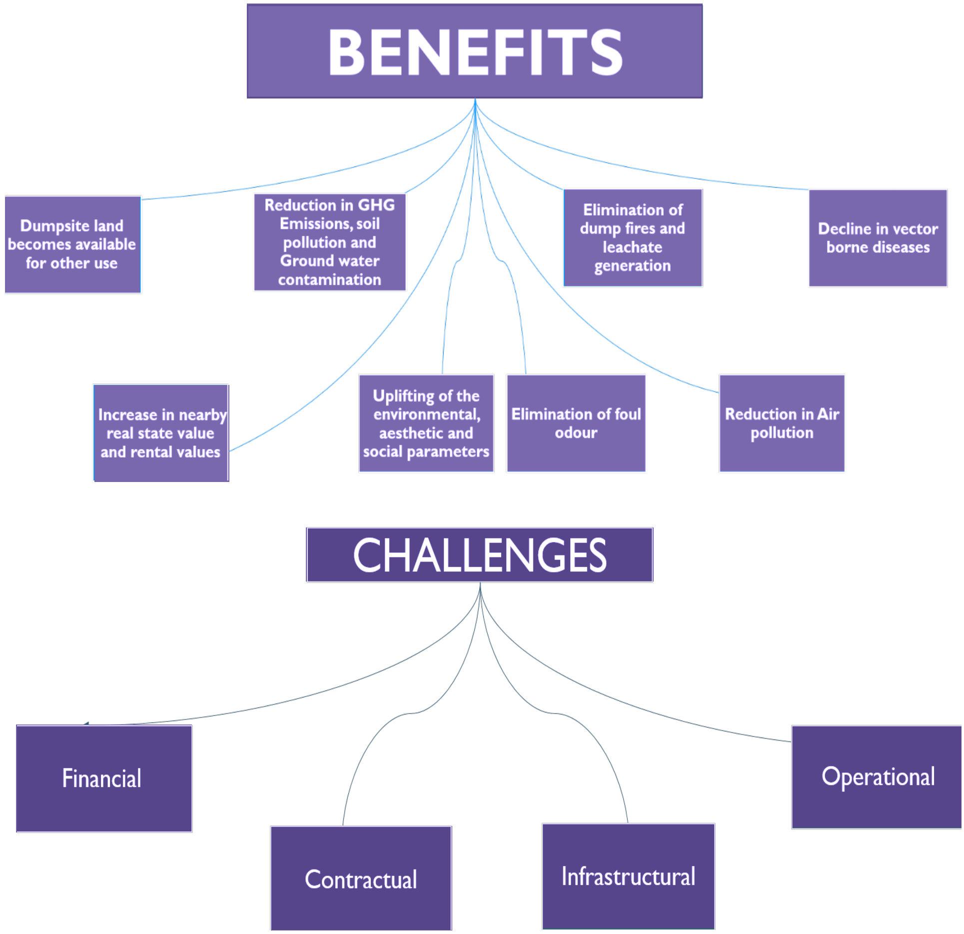
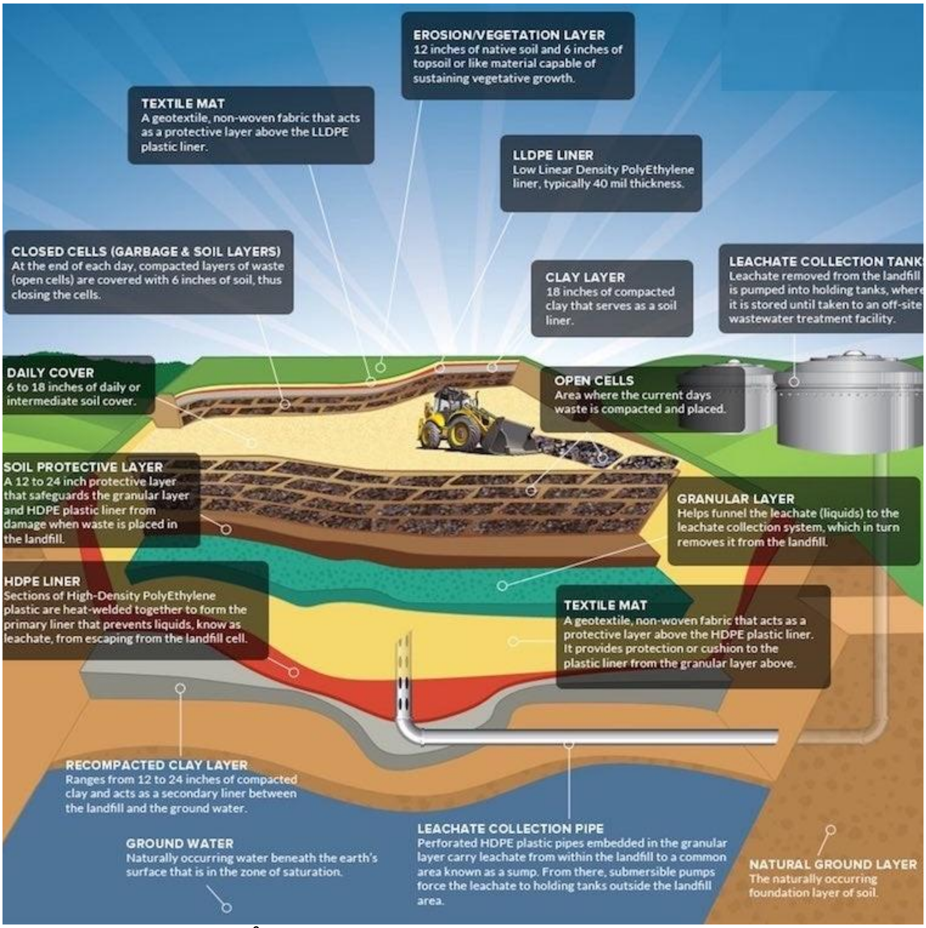


Fig 3.11: Landfill Closure[4]



[4]Anon., n.d. *Plastic Smart Cities is an initiative by WWF - World Wide Fund For Nature. [Online] Available at: https://plasticsmartcities.org/products/sanitary-landfilling [Accessed 2021]*

Action Plan

States and Union territories are required to prepare action plans for cities and towns based on the population and waste generation. Steps/action need to be taken could be indicated in a phased manner. An

Fig 3.12: Indicative action plan based on city population

<table>
<tr><th>MSW Generation-> (T/day)</th><th>>500</th><th>100-500</th><th>50 -100</th></tr>
<tr><td>Authorization</td><td colspan="2">Should apply for authorization and seek from SPCBs/PCCs</td><td>SPCBs/PCCs to prioritize based on State/ UT- specific requirement</td></tr>
<tr><td>Collection of Waste</td><td colspan="3">Comply with Schedule- II of the Rules and comply within six months</td></tr>
<tr><td>Segregation of waste</td><td colspan="3">Launch mass awareness programme</td></tr>
<tr><td>Storage of Waste Or MRF</td><td colspan="2">Set up waste storage facilities which would be combination of conventional as well as mechanized system</td><td>Set up conventional bin system and maintaining them in hygienic manner</td></tr>
<tr><td>Transportation of waste</td><td colspan="2">• Vehicles used for transportation of waste.
• Storage facilities should synchronize with transportation system.
• Strict compliance with Schedule-II to be ensured</td><td>• Vehicles of smaller size and easy to maintain be used</td></tr>
<tr><td>Processing of waste Schedule II & IV</td><td colspan="2">• ·Adopt combination of waste processing technologies, as single technology may not take care of such quantities of waste.
• Processing plants should be set up as per Schedule-I</td><td>• Considering technical capabilities of local bodies and garbage quantities upto 100 t/d, aerobic process could be feasible solution with better segregation, bio-gas plants can be set up.</td></tr>
<tr><td>Disposal of waste (Schedule-III)</td><td colspan="2">• Rejects of waste processing plants to be disposed off as per Schedule-III of the Rules.
• In case of mixed waste, landfilling may be continued following specifications laid down in Schedule III of the Rules.</td><td>• Simpler-easy to operate landfills be preferred</td></tr>
</table>

4

Scientific Landfill Monitoring

Monitoring helps to inform the design and implementation of a functional and efficient landfill, providing for a precise assessment of the landfill's impact on the environment. A well-designed monitoring system can aid in the early detection of detrimental environmental effects and rapid remediation.

The following are the major phases of monitoring:

1. Baseline (before to the landfill), which comprises site study, environmental impact assessment, and planning.
2. Compliance/Assessment during the dump's operation to guarantee that the landfill runs smoothly.
3. Compliance/Assessment follow-up and landfill rehabilitation for proper closure.

The objectives of a monitoring are:

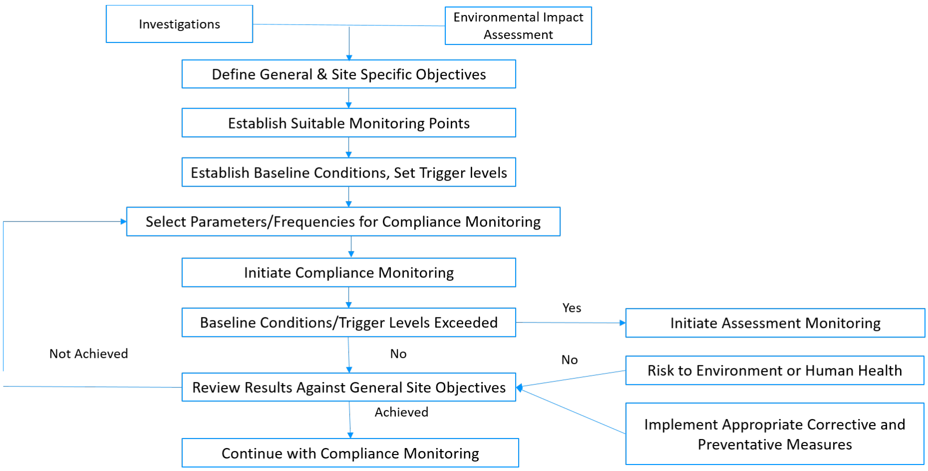
- To establish baseline environmental conditions;
- To detect adverse environmental impacts from the landfilling of waste;
- To demonstrate that the environmental control measures are operating as designed;
- To assist in the evaluation of the processes occurring within the landfill;
- To demonstrate compliance with the conditions;
- To provide data for emission records;
- To provide data to inform the public;
- To provide data for the improvement and updating of monitoring;
- To assist in an investigation in the event of a trigger level or emission limit value being breached

What to Monitor?

- Surface Water
- Groundwater
- Leachate
- Landfill Gas & Landfill Gas Combustion Products

- Odours
- Noise
- Meteorological Conditions
- Dust/Particulate Matter
- Topography and Stability
- Ecology
- Archaeology

Fig 4.1: Monitoring Flow and Process



Some of the key technologies relevant to achieve objectives of Swachh Bharat Mission includes: [1]

Online platforms: Online platforms give users options and alternatives for repurposing outdated items. Before dumping the product as waste, the existing user is encouraged to explore for ways to sell it and recoup some of its value.

Analytics: Accurate estimates of total waste created, waste type, and high waste generation locations allow for successful solid waste management service planning and management.

Crowd-sourcing: Citizens can be encouraged to report waste-related actions that require immediate attention from authorities (through web/mobile/social channels).

Sensor-based waste collection: Sensor-based waste bins assess the status of waste bins, such as whether they are empty or full, allowing the waste collection schedule to be customised accordingly and saving money.

Automated trash collection system (ACS) is a long-term solution that can handle traditional waste collection techniques such as door-to-door, curb-side, block, communal bins, and transportation through chute system from high-rise buildings.

GPS devices and sensors on waste trucks: Waste collection vans are routed using GPS technology to maximise collection efficiency and guarantee contractors deposit waste in designated areas. It will also show how much rubbish is generated every ward.

Sensor-based sorting: Using sensor technology to separate waste material aids in smart sorting. The sensor technology may detect materials using the visible spectrum or infrared colour.

Pollution sensors: Use pollution sensors to determine the degree of pollution at landfills.

E**nergy simulation (waste to energy):** Using energy simulation software and analytics, precise estimates of waste generation and waste-to-energy production may be made.

Landfill management based on analytics: Accurate garbage generation and collection estimates, as well as a breakdown of waste types, can help with smart landfill management.

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[1] *Prabhakar , V. & Mehrotra, R., 2015.* ***The Economics Times.*** *[Online] Available at: https://economictimes.indiatimes.com/news/science/how-to-transform-waste-management-using-ict-to-enable-swachh-bharat-mission/articleshow/47957702.cms?from=mdr [Accessed 2021].*

Integrated asset management solutions: Integrated asset management of all waste infrastructure assets, including the data, procedures, information systems, and governance associated with them, enabling more controllable operations and improved sustainability.

Business process automation: Using a business process management solution, reengineer, optimise, and automate business processes to create a fully integrated and policy-driven set of automated business processes that boost productivity.

Workforce and resource management: Improve workforce engagement and task management by utilising workforce and resource management solutions. Staff management solutions such as planning, forecasting, and scheduling, shift management, mobile apps for job execution, and effective performance management tools can help you optimise your workforce.

City performance management: Using digital technology, track the performance of city subsystems.

Integrated command and operations centre: Use an integrated command and operations centre to keep a real-time eye on city services. To reduce downtime and improve maintenance effectiveness, improve/synchronize maintenance activities.

Geospatial dashboard: Bin locations, landfill locations, and waste management assets must all be mapped using a geospatial system.

5

Data and visualization

Collecting and analysing data

The importance of waste generation data availability, dependability, and comparability is emphasised in an effective solid waste management system. Furthermore, trustworthy statistics on garbage creation per capita can be used to compare waste management in different cities and nations. When calculating waste creation, it is necessary to take into account the diverse geographic and climatic characteristics.

Primary data on per capita trash generation and related characteristics is unavailable. Furthermore, the influence of the informal sector is not taken into account.

Data Handling and utilization

Waste and recycling data is increasingly being collected by local governments in order to report on national waste minimization efforts. It has the potential to be a helpful tool in the effort to minimise the amount of rubbish hauled to landfills each year if the data collected is comprehensive, consistent, and accurate.

Apart from the need to collect this information for reporting and analysis, there are a number of other explanations and advantages to collecting accurate waste data.

- Benchmarking: It allows local governments, the private and public sectors, and the federal government to compare performance and identify areas of success. This enables progress to be tracked in relation to specific waste reduction targets and objectives.
- Troubleshooting: Accurate waste data can aid in the detection of potential problem areas as well as the identification of areas of accomplishment. Potential liabilities such as rubbish accumulating at recycling depots or inappropriate payments and levies may go undetected if this monitoring is not in place.

- Planning: By analysing existing performance across the sector, it is possible to determine the optimal way for streamlining systems and processes to be the most effective. These kinds of breakthroughs are crucial for developing successful waste minimization approaches and developing future legislation.
- Justification: Good statistics can also be used to support and justify financing for a new recycling programme or project.
- Aids in the prevention of levy evasion: Unfortunately, some waste management and recycling facilities participate in fee avoidance activities. To avoid paying disposal fees, some businesses, for example, will stockpile materials on site. Some regulators are collecting trash data and statistics to keep track of how much and what kind of waste facilities are storing to combat this problem. The collecting of this information helps to increase transparency and allows authorities to track waste amounts across multiple locations. In other words, authorities can prohibit excessive stockpiling and stimulate material flow throughout the waste management process.

IT intervention and tools

Due to the increasing demand for automatic data processing, identification, connectivity, storage, and analysis concerning quick and parallel computation, information and communications technology (ICTs) are becoming increasingly valuable in order to handle the developing challenges in SWM. Information and communication technology (ICT) is widely acknowledged as a tool for data collecting, processing, and communication. Due to its capacity to provide quick access to information from any remote place, ICT is a convenient solution to address SWM concerns. Communities will be able to accomplish sustainable urban development if there is a clear motivation to use ICTs to fulfil the broad SWM objectives. Even under the smart city paradigm, information and communication technology (ICT) plays a critical role in establishing, implementing, and empowering a sustainable growth environment. Because of the increasing demands on SWM, ICTs are becoming increasingly important. Due to the increasing demand for autonomous data processing, identification, connectivity, storage, and analysis concerning quick and parallel computation, information and communication technologies (ICTs) are becoming increasingly valuable in order to handle the developing difficulties in SWM.

In practise, various types of technologies include:

- **Geo-Spatial:** Based on the findings, geo-spatial technology is the first ICT technology to be applied in the SWM to track trash collection and generation. We analysed the use of geospatial technology for several SWM applications with constraints in this technology.
  For example, a mobile application was designed under Project of UNEP, Counter Measure for Plastic Free Rivers, where the main objective was to map plastic waste leakage density using multi-source geospatial data. Result will be used for monitoring and assessment of plastic waste and pollution reduction.
  For achieving this objective, National Productivity Council (NPC) developed a mobile survey application for the collection of data by local partners.
- **Wireless Data Acquisition:** As materials technology advances, the size of electronics materials shrinks to the micro and nano scale. As a result of this breakthrough, data collecting techniques such as sensors were developed. Sensors capture quantities of chemical, biological, or physical qualities and turn them into readable signals, which is how data gathering technology works. The many forms of data acquisition technologies that have been deployed in SWM with function have been assessed.
- **Wireless Data Communication:** Wireless data communication is critical in any application that requires data to be transmitted from one location to another. We analysed different types of communication protocols that are used in SWM to transfer sensor data in this study. In the SWM, we also examined the constraints and benefits of the various communication protocols.
- **Internet of Things (IoT):** IoT is widely used in a variety of applications to provide real-time monitoring. We examined the deployment of IoT for several SWM functions in this study. In addition to IoT research, this review considers IoT experiments with cloud servers to see how real-time SWM implementation works.
- **Blockchain:** Blockchain is a new technology being used in the SWM to improve digital documentation and the circular economy. In this paper, we looked at how blockchain can be used in the SWM.

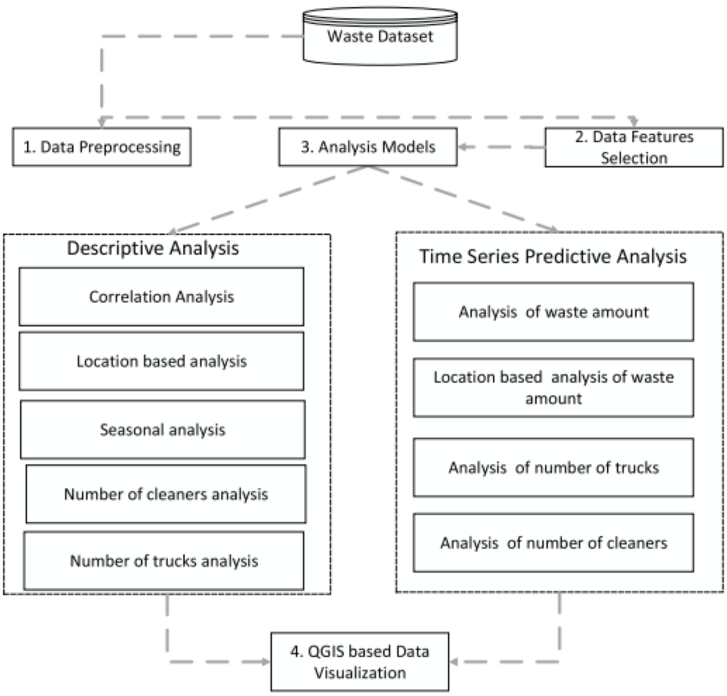
Visualization tools and GIS

GIS (geographic information systems) are one of the most advanced current technologies for capturing, storing, manipulating, analysing, and displaying spatial data. In the form of digital maps, these data are frequently arranged into themed layers. The use of GIS in conjunction with advanced related technologies (e.g., GPS and Remote Sensing – RS) aids in the recording of spatial data as well as the direct use of these data for analysis and graphical depiction.

As previously stated, the most common use of GIS-assisted modelling in waste management is in the areas of landfill siting and garbage collection and transportation optimization. Furthermore, GIS technology has been used to successfully locate recycling drop-off centres,optimise waste management in coastal areas,estimate solid waste generation using local demographic and socioeconomic data and forecast waste generation at the local level.

Since routing models make extensive use of spatial data, GIS can provide effective handling, displaying and manipulation of such geographical and spatial information.

Fig 5.1: Data analysis model



Other important datasets from landfill operations include:

- Environmental Factors (landfill gas concentrations, leachate, run off, odour/other air emissions);
- Greenhouse Gas Emissions (transport emissions, GHG capture, carbon storage, anaerobic windrow operations);
- Landfill Capacity (population, waste to landfill and recycling, landfill capacity data, waste to inert landfills)
- Sustainability data (recycling / diversion rates, composting, future landfill capacity).

6

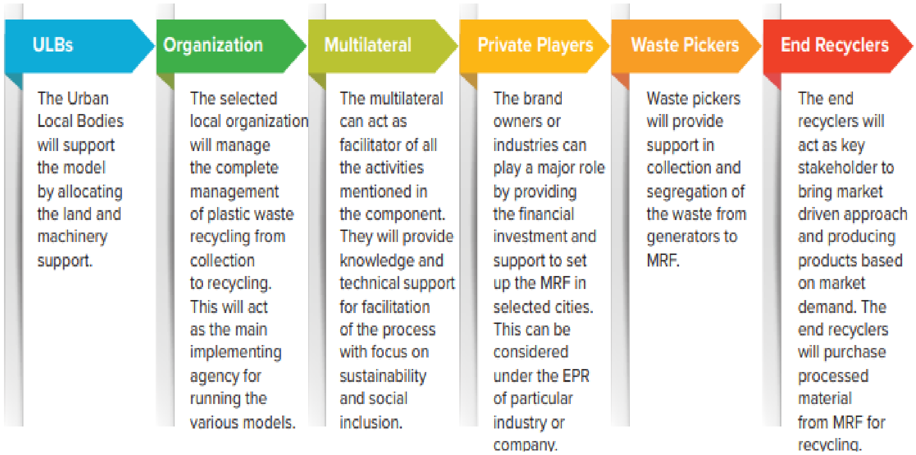
Stakeholders and financial plans

All stakeholders—waste processors (formal and informal recyclers), waste generators (households, industries, and agriculture), and government institutions—are involved and participating (regulators, waste managers and urban planners). The engagement of different actors/stakeholders can help to solve many of the city's environmental concerns.

The stakeholders involved are:

- Public and Households
- Private sector participation
- Policy and institutional support
- ULB Officials
- SWM Department Executives
- Engineers
- Town Planners
- Officials of Water Supply, public health, sewage Department
- Account and Financing
- Businesses
- Industries
- Informal Sectors
- NGOs
- CBOs
- SHGs etc.

Fig 6.1: Role of Stakeholders



Community Engagement

SWM (solid waste management) is an example of an activity that strongly relies on public engagement. Solid waste management comprises a number of processes, some of which necessitate people's active participation. Participation is required in the following areas:

- Waste reduction, reuse, and recycling; and not littering streets, drains, open spaces, and water bodies, among other locations.
- At the point of generation, separate storage of organic/biodegradable and recyclable garbage.
- Waste collection and storage in apartments, multi-story buildings, societies, commercial complexes, and other communities
- Managing the excrement of pet dogs and cats properly.
- Make suitable remuneration for the services rendered (optional) • Community-based trash processing and disposal

Public Private Partnership

In terms of product design and waste separation, both the public and commercial sectors must assume greater responsibility for waste generation and disposal. Formalizing these responsibilities through well-structured public-private partnerships (PPPs) can result in significant improvements in the efficiency and quality of solid waste management.

As public-private partnerships (PPPs) grow more widespread, investments in the trash business have risen as governments seek private capital and technical expertise to build, operate, and manage waste projects. The most prevalent types of programmes include waste incineration, waste treatment, recycling, and electricity from waste initiatives.

With programmes ranging from waste collection and transportation to waste disposal and treatment, the private sector has been encouraged to participate in solid waste management.

Informal Sector

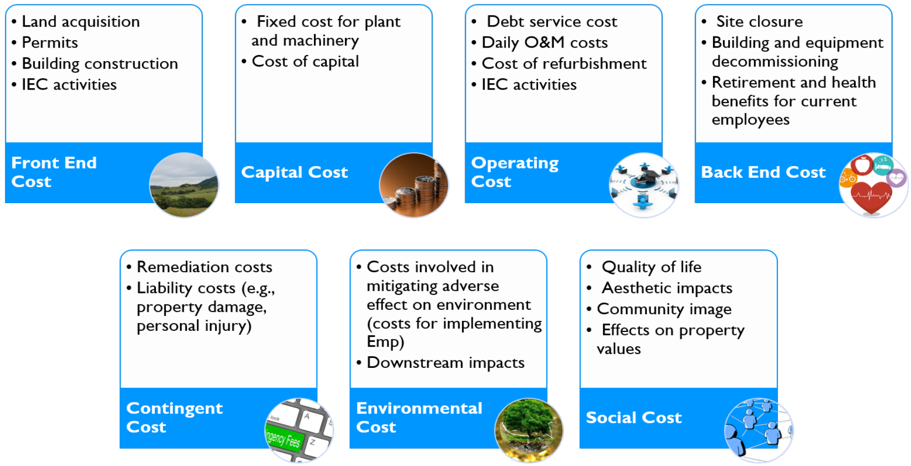
Without the cooperation of rubbish pickers, scrap collectors, merchants, and recyclers, many cities' formal waste management systems would not be effective. Organically grown informal sector operations are exceptionally adaptable, agile, and quick to change to market conditions. The integration of informal players improves the waste management system's efficiency. In many cities, integrative and decentralized techniques offer economic, environmental, and social benefits, and are consequently considered as the best sustainable future option.

Cost and finances

The development of a sophisticated MSWM system should be based on precise financial calculations that account for all relevant costs, including hidden costs and revenues. This crucial duty in the planning process is to assure the MSWM system's financial feasibility and long-term sustainability.

Government grants and internal income from property tax and non-tax revenues are used to fund MSWM activities in most ULBs and some ULBs use public-private partnership (PPP) arrangements to finance projects.

Fig 6.2: Various cost component involved in the remediation project



7

Trends and Impact of COVID 19

During the COVID-19 pandemic, plastic goods were crucial in keeping people safe. The increased usage of personal protection equipment disrupted the supply chain and waste disposal system significantly.

Fig 8.1: Plastic based bio-medical products

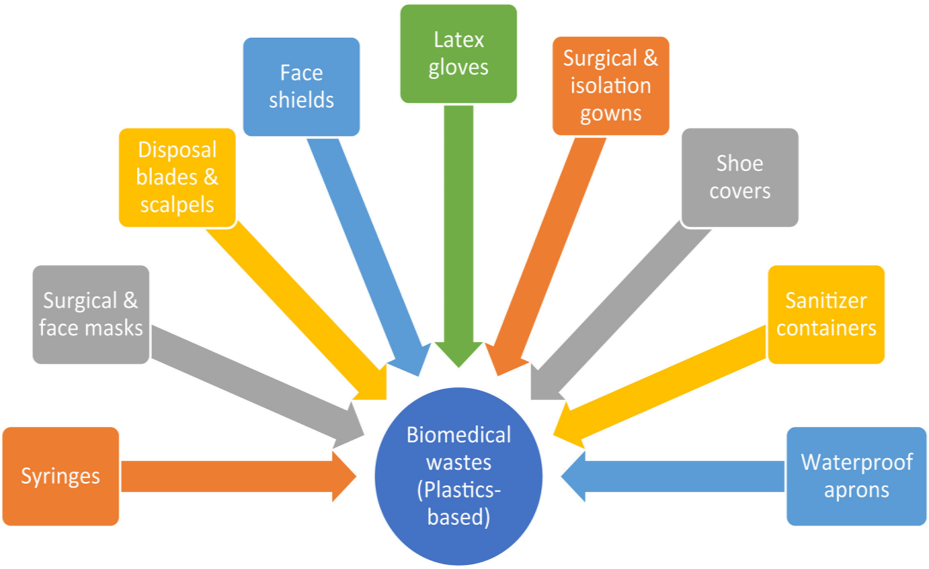
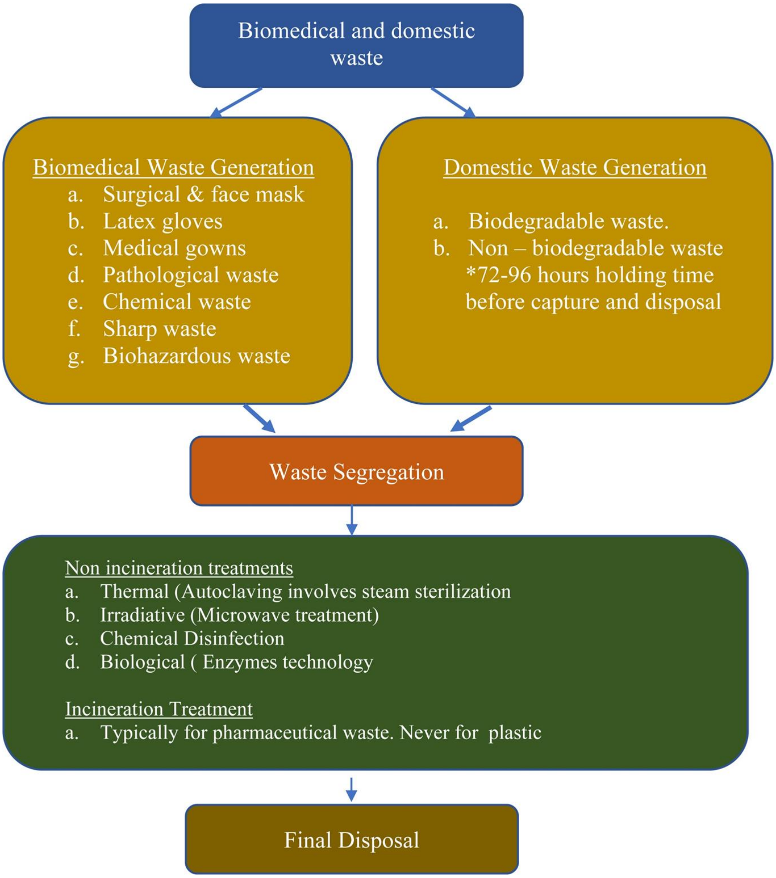


Fig 8.2: Biomedical & domestic waste processing



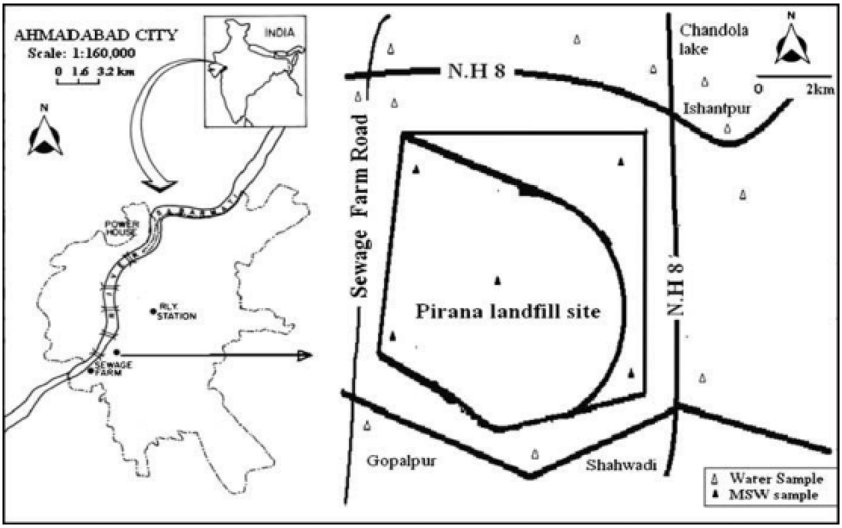
8

Case Study

Pirana Dumpsite Biomining Project, Ahmedabad, Gujarat[1]

Ahmedabad is the first largest metropolis in Gujarat with a population of 55.7 lakh and spread over an area of 464 Sq Km. Solid waste production in Ahmedabad city is almost 4200 tonnes/day. As estimated 13.5% of today's waste is recycled and 5.5%is composted.

Fig 8.1: Layout of Pirana landfill site, Ahmedabad



[1]*Case Study: Pirana Landfill, Ahmedabad, India-An Assessment of the Potential for Methane Gas Recovery and its Industrial Applications (n.d.) UMC Projects India (P) Ltd.*

Pirana is the main landfill site present in Ahmedabad city with 84 sections of land of land which gets metropolitan strong waste for around 35 years. At present, the community body gathers 4000 metric huge amounts of strong waste day by day(Source: Supervisor Ahmadabad Municipal Corporation). Of which around 1900 metric ton gets reused at various plants, with around 100 metric huge amounts of material being recuperated at the decline move station once a day (Mukesh Gandhvi, Deputy Municipal Commissioner AMC).

As per AMC there 10 lac Ton of Legacy waste is accumulated at Pirana dump site. Of the entire waste collected the ULBs were able to compost only 660TPD waste and rest is openly dumped.

Materials and Methods

The samples of solid waste, leachate and groundwater were taken in June, 2018. The wastes dumped into this site are largely from domestic and commercial sources. Nearly 75-80% of the accumulated waste is collected from municipal bins and street sweeping.

Fig 8.2: Characteristics of MSW

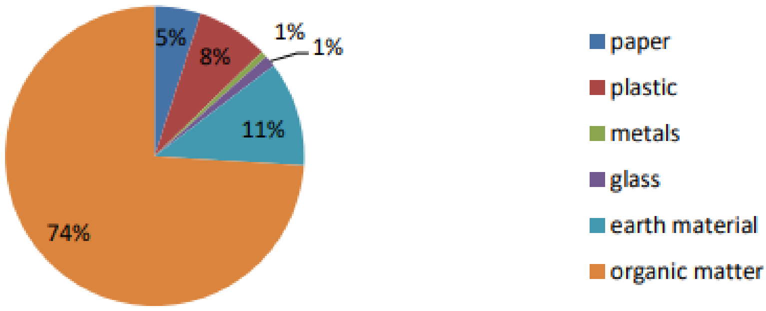


Table 8.1: Characteristics of the landfill leachate

Sr. No.	Parameters	Sample 1	Sample 2	Sample 3
1	pH	6.8	7.3	7.1
2	TDS	2103	1873	1813
3	Total Hardness	743	703	683
4	Calcium Hardness	493	473	450
5	Magnesium Hardness	253	233	233
6	Sulphates	433	393	473
7	Chlorides	203	293	313
8	Acidity	103	123	103
9	Calcium	199	191	183
10	Magnesium	103	95	95

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2	TDS	2103	1873	1813
3	Total Hardness	743	703	683
4	Calcium Hardness	493	473	450
5	Magnesium Hardness	253	233	233
6	Sulphates	433	393	473
7	Chlorides	203	293	313
8	Acidity	103	123	103
9	Calcium	199	191	183
10	Magnesium	103	95	95

The solid waste samples (up to depth 0–25 cm) were collected with help of quadrate area 1×1 m. Five MSW samples were taken, i.e. one sample from each corner and one from the center of landfill site. The results of the tests are listed in table.

Dumpsite Closure Method

To close the Pirana Dumpsite various technology/practices of dumpsite closure around the world were studied.

Technology Options

A. Biomining (Legacy Waste)

For the Bio Mining option a cost of 400 rs/MT was required which will leads to land reclaim and giving back to public/private allocation. With the Bio mining option land will be remediated & environment impact will be minimized. Only issue with Bio mining option is that it is time consuming. land requirement for the waste Cost:600/MT

B. Capping (Legacy Waste)

For the Bio Mining option a cost of 415 rs/MT was required which includes O&M cost fro15 years. The entire dump hill will be capped & used as post closure as green closure.

This will cause damaged to environment in future as the trapped leachate and Bio methane gas will leaked to atmosphere. Although this is cheaper, easy and faster solution but having a major impact on environment in future.

C. Bio reactor (For incoming waste)

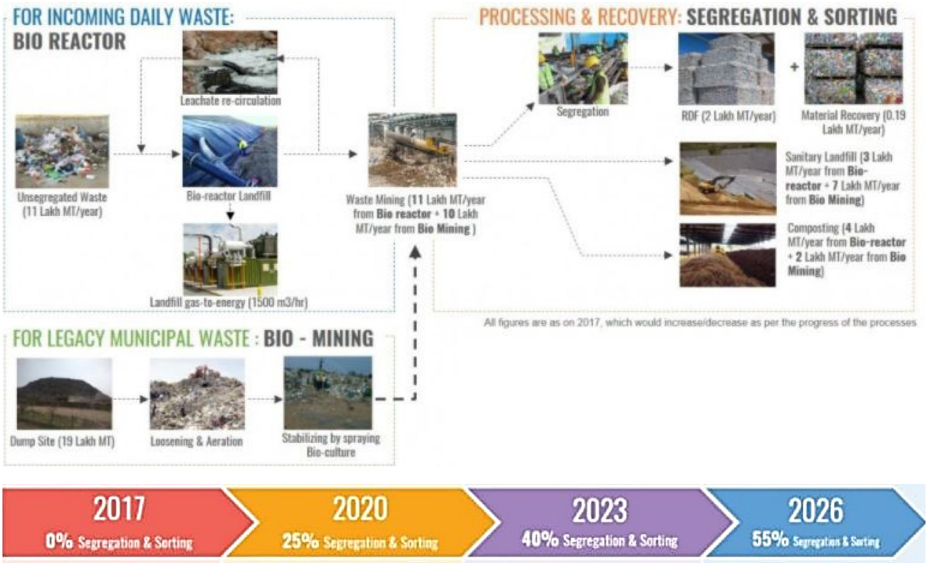
Bio reactor option is much better and high-end technology which provides better solution to the incoming waste that the dumpsite.

- Faster composting than other method
- Lower toxicity
- Reduced leachate disposal cost
- Increase LFG generation
- Selected Technology: Bio reactor & Bio Mining

After comparison Bio-Mining of the legacy waste V/S the capping of the dump site, it can be concluded that Biomining is more feasible and efficient for the Pirana dumpsite closure, as it is permanent solution with overall positive impact on the environment.

Also, parallelly Bio reactor will be used for the mixed incoming waste to avoid mixing with legacy waste.

Fig 8.3: Process followed



Dumpsite Closure Process

In case of Biomining, first the legacy waste is loosened with bulldozers. Then the Bio culture is sprayed in order to sanitize the waste. Then it is segregated and sorted out in order to recover various aggregates. The Organic aggregates was composted, then the aggregates like plastics, rubber ,wood etc. Are removed and converted to Refused derived fuel(RDF).And recyclable materials like Glass, plastic etc. are recovered and sold to various recyclers.

While the legacy waste is mined like this the incoming waste shall be missed with a portion of legacy waste and covered with soil layer and converted into Bioreactor. The bio reactor functions by recirculating leachate and air into the composting to catalyze the composting process & its later opened to recover the RDF & recyclables.

End products & By-products

After Remediation of Legacy waste, mainly four outputs are derived namely:

1. **Refuse Derived Fuel (RDF) -** RDF to Abellon Clean Energy free of cost; they are utilizing it as a fuel in their Bio-mass Gasification and also to 3 other Plants of similar type
2. **Construction & Demolition Waste -** The C & D waste has been transported to the C & D plant to reuse and produce paver blocks, precast walls, manhole covers and many more products,

3. **Semi Compost** - transferred to the existing MSW compost plants namely Excel Industries and BEIL to treat further and for sale to farmers
4. **Inert -** The Semi-compost has been transferred to the existing Landfill Site at Gyaspur 3.0 Km away from the Dump Site

Overall Benefits of PIRANA Dumpsite Closure

Fig 8.4: Overall Benefits

- Reduction of 23 lacu.mt/year of Global Methane emissions.
- Preventing the ground water contamination due to the seepage of leachate
- 10 Lakh MT Material recovery
- Revenue Generation of 33 crore(approx.)
- Job creation around 5000 nos.
- Affordable living place of around100,000 people

Landfill remediation of six New Jersey projects[2]

New Jersey has a legacy of improperly closed landfills. The New Jersey Department of Environmental Protection (NJDEP) had historically registered 387 landfills, most of which are currently closed. The State estimates that the total number of landfills registered and unregistered) may approach 600. Most of the unregistered landfills were never properly closed, a handful of those landfills were properly closed and received a Closure and Post Closure Plan Approval.

This case study represents a model for both redevelopment potentials of old landfills and proper remediation to meet the strictest environmental standards. Six projects including residential, commercial and institutional uses were taken up. Table summarizes the key features of the projects including name allocation, waste acreage, end use,

[2]*Redevelopment potential of landfills. A case study of six New Jersey Projects (2002) J.B. Wiley, III& B, Asadi, Sadat Associates, Inc, United States of America.*

remediation techniques, remedial costs, value of land uses constructed and beneficial use of recyclables.

Table 8.2: Summary of Six Landfill redevelopment projects

Project Name	Location	Owner/ Developer	Acres	End Use Type	Remediation Technique	Value of Development	Use of Recyclables/ Dredge
Jersey Gardens Mall	Elizabeth, NJ	OENJ Corporation	166	Mall, Hotels, Commercial, Ferry Service	L,V.C,H,G	$700M Constructed $300M Planned	2.5 MCY
Bayonne Golf Course	Bayonne, NJ	OENJ-Cherokee Corporation	120	Golf Course	L,S,C.H,G	$10M Planned	5.0MCY+
Seaboard Point Resort	North Wildwood, NJ	Seaboard Development	12	Residential Condominiums	C, G	$50M+	50,000 cy
Passaic County Comm. College	Wanaque, NJ	Passaic County Community College	12	Community College	L,C,W,G	$10M	--
Ashbrook Farm	Edison, NJ	W&F Developers	30	Residential	W,C,L,G	$3M	--
Federal Business Center	Woodbridge, NJ	Federal Business Centers	38	Office/ Warehouse Development	W,C,L,G	$9M	--
Totals			378			$1 Billion+	7.5 MCY+

L = Leachate Collection & Treatment C = Capping S = Slurry Wall H = Hazardous Waste Removal
V = Vertical Membrane Wall W = Waste Relocation G = Landfill Gas Controls

Remediation techniques

A wide variety of remediation techniques were utilized. In the simplest case, waste was capped in place with one foot of silty, clayey material and one and one-half feet soil cover. In the most complex case, a slurry wall/sheet pile wall was used to contain leachate from outflow from the site and an interior leachate system was installed. The degree of capping, containment and leachate collection was influenced by the underlying geology, leachate strength and site- specific cap design.

Remedial costs

Remedial costs ranged from $0.3 to $11 million, the cost per acre of closure/remediation ranged from $10,000 to $100,000, In addition to remedial costs, additional costs were incurred for the Elizabeth and Passaic projects for improving the geotechnical conditions of the waste to make it possible to build parking areas on the closed waste.

End uses

The end uses varied widely. In another projects, the waste was moved, consolidated and capped so that the end use could be built on remediated areas of the site. In the recent project, involves the construction of elevated residential units on pile structures over the capped waste.

Value of end uses

The value of the constructed end uses varied from $3 million to over $500 million. The value of the end uses reflected in Table only represents the approximate investment costs for building the end use and does not include the value of the property after remediation. All the cases, the development project was profitable.

Uses of recyclable

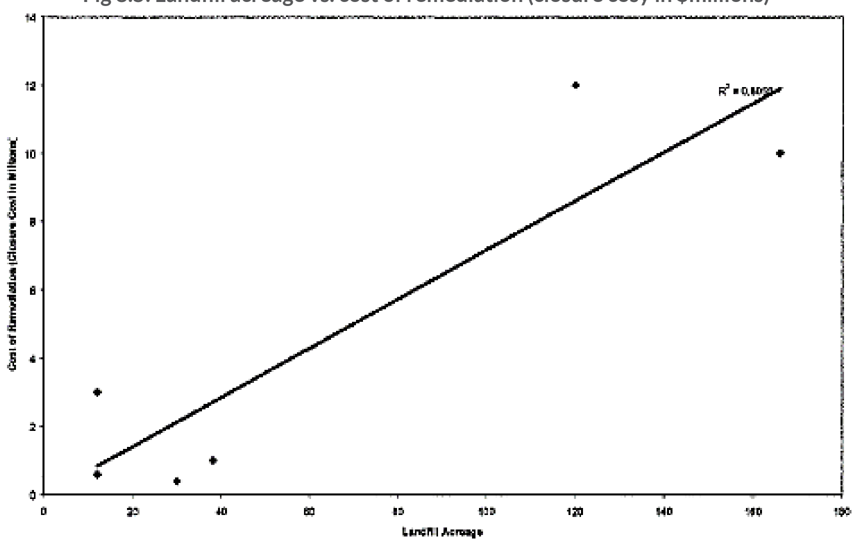
Two of the projects utilized large amounts of recyclable materials to prepare the land for end use development. In one, approximately 2.2 million cubic yards of contaminated dredge spoils and recyclable were used to recontour the site for development and surcharge the old waste to provide adequate foundation conditions.

In the other, over 5 million cubic yards of contaminated dredge spoils and recyclable are being used to create a rolling topography for use in golf course construction.

Financial incentives

Several significant financial incentives are available in New Jersey for landfill redevelopment. Up to 75% in state tax credits (1996, the Gormley Bill) for remediation costs for qualified landfill redevelopment projects.

Fig 8.5: Landfill acreage vs. cost of remediation (closure cosy in $millions)



Remedial action

For the six cases that are considered here, some or all of the landfill remediation elements were implemented to prepare the sites for redevelopment. The least remedial action involved: capping, landfill gas management, and maintenance and monitoring program (North Wildwood), The earliest remediated site (Edison) involved: partial relocation of waste to accommodate redevelopment, capping the relocated waste with one foot of clay and one and a half foot of soil to promote vegetative growth, landfill gas control and venting system leachate collection and disposal system. The second earliest remediated site (Woodbridge) involved: excavation and relocation of the entire waste, the construction of a state-of-the-art small landfill on a two-acre lot (clay liner, leachate collection and disposal system, passive gas venting system).

Result

Thirty-six acres of this thirty-eight-acre site became available for development after implementing the remedial action/closure, the closed and capped two-acre new landfill has also been used for parking purposes.

Tokyo Bay Side – Landfill[3]

Background

One of the biggest challenges for a mega city is securing space for final disposal sites. As the concentration of urban functions has progressed, the degree of difficulty becomes more serious. Tokyo has been facing the same challenges and found the answer in bay-side disposal sites.

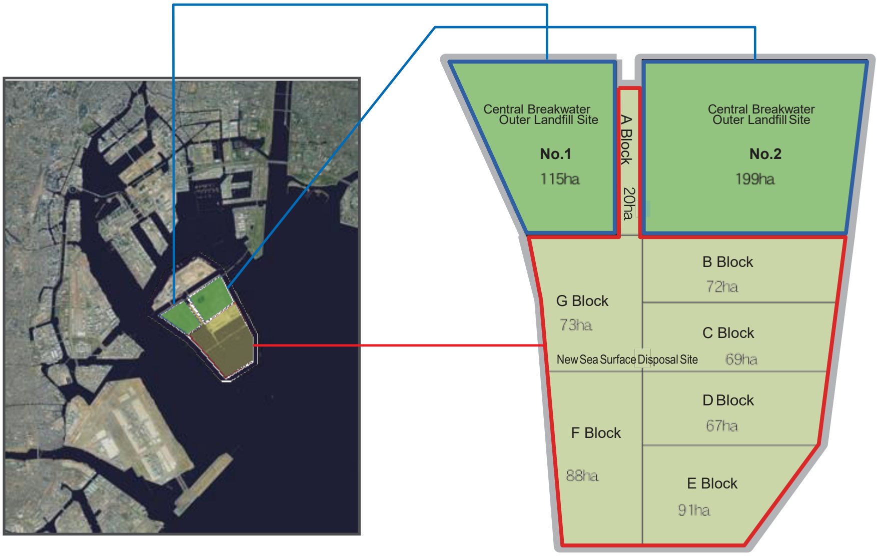
Bay-side disposal sites create the potential of new city development in addition to appropriate disposal of waste. Meanwhile, the bay-side is an extremely valuable natural resource it is necessary to pay utmost concern to the conservation of the environment.

Basic information of Tokyo bay-side disposal sites

The Tokyo Metropolitan Government is now installing and managing two bay side disposal sites in the Port of Tokyo. These disposal sites receive incineration ash and incombustible residue from municipal solid waste in the 23-ward area of Tokyo, sludge from water and sewerage, and industrial waste* after intermediate treatments such as incineration and pulverization. The Tokyo Metropolitan Government Bureau of Port and Harbor is responsible for the construction of the disposal sites while the Bureau of Environment is responsible for the landfilling of waste.

[3] *Tokyo Bay Side – Landfill (n.d.) Tokyo Metropolitan Government*

Fig 8.6 Aerial of Tokyo's bay side landfill



** Composed of combustion residue, sludge, metal scraps, and the like discharged from small and medium enterprises located in Tokyo.*

Waste landfill and maintenance

The municipal solid waste from the 23 wards of Tokyo is currently buried at the Central Breakwater Outer Landfill Site and the New Sea Surface Disposal Site. These bay-side disposal sites are crucial facilities as Tokyo's final disposal sites are in the Port of Tokyo and these finite disposal are valuable for as long as possible to hand over ownership of the irreplaceable global environment to the next generation, various e⁇orts are being made at the landfill disposal sites.

In the past, organic waste was buried without intermediate treatment and led to problems such as bad odors and outbreaks of flies. At present, however, all the waste is processed by intermediate treatments (e.g. incineration or pulverization); therefore, the waste received at the disposal sites mainly consists of incineration ash and pulverized residue. This system contributes to extending the service life of the final disposal sites and reduces the operational expenses of wastewater treatment.

Landfill disposal plan for waste

The current landfill disposal sites, which assume the very last space in the Port of Tokyo, need to be used for as long as possible. With this goal in mind, the Tokyo Metropolitan Government has been creating plans to define the categories of waste separation and also project landfill waste volume with the goal of extending the service life of the landfill disposal sites. The current plan has a 15-year overall design covering 2012 to 2026, and undergoes review every five years

Fig 8.7 Landfill disposal plan for waste (unit in ten thousand Cu.m)

	2012– 2016	2017-2021	2022-2026	Total
Waste	207	195	195	597
Soil-covering	42	39	39	120
Dredge soil	465	510	390	1365
Soil from construction	245	200	200	645
Total	959	944	824	2727

9

Interactive Exercise

In the above exercise, the facilitator need to ask the participants to place the dots in the relevant box. The facilitator can prompt the question, such as, “make the interventions in your city or mark the interventions adopted in your city”.

The facilitator can also explain the heading of all the boxes, like, the meaning of reuse, disposal, recycle, energy recovery, prevention, and waste minimization.

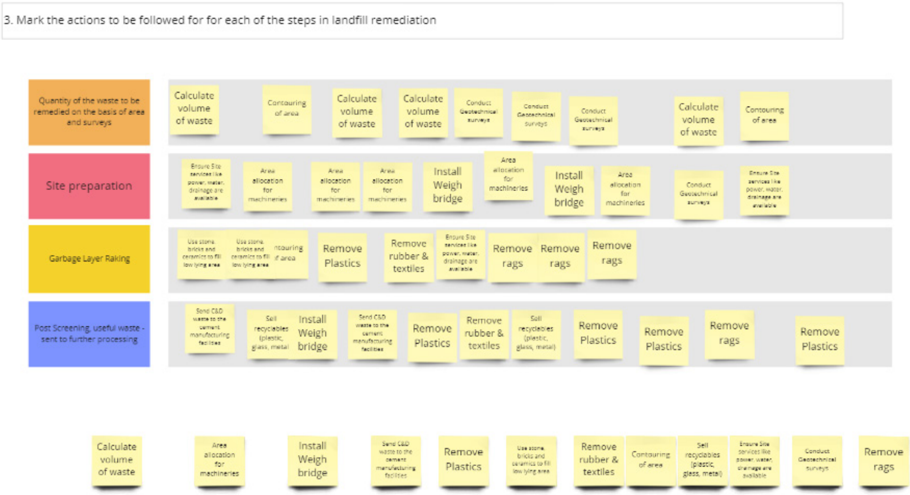
Encourage the participants to do the exercise and prompt any question, should they have.

2. Mark the steps to be followed for initiating landfill remediation

	Jamshedpur	Bangalore	Prayagarj	City name	Nakul	Jamshedpur
Step 1	Quantity of the waste to be remedied on the basis of area and surveys	Quantity of the waste to be remedied on the basis of area and surveys	Quantity of the waste to be remedied on the basis of area and surveys	Recovered Soil is used for refilling Grounds	Quantity of the waste to be remedied on the basis of area and surveys	
Step 2	Site preparation & Reaching the Lowest Ground Level	Site preparation & Reaching the Lowest Ground Level	Respective machinery and tools deployment	Site preparation & Reaching the Lowest Ground Level	Site preparation & Reaching the Lowest Ground Level	
Step 3	Respective machinery and tools deployment	Garbage Layer Raking	Garbage Layer Raking	Coarse Material and Garbage are screening	Garbage Layer Raking	
Step 4	Garbage Layer Raking	Coarse Material and Garbage are screening	Coarse Material and Garbage are screening	Garbage Layer Raking	Coarse Material and Garbage are screening	
Step 5	C&D Waste- sent to C&D Processing Facility	C&D Waste- sent to C&D Processing Facility	Post Screening, useful waste - sent to further processing and C&D waste - filling low lying areas	Respective machinery and tools deployment	Post Screening, useful waste - sent to further processing and C&D waste - filling low lying areas	
Step 6	Coarse Material and Garbage are screening	Respective machinery and tools deployment	C&D Waste- sent to C&D Processing Facility	Post Screening, useful waste - sent to further processing and C&D waste - filling low lying areas	Recovered Soil is used for refilling Grounds	
Step 7	Post Screening, useful waste - sent to further processing and C&D waste - filling low lying areas	Valuable Land recovered by Bio-Remediation	Site preparation & Reaching the Lowest Ground Level	Respective machinery and tools deployment	C&D Waste- sent to C&D Processing Facility	
Step 8	Valuable Land recovered by Bio-Remediation	Recovered Soil is used for refilling Grounds	Recovered Soil is used for refilling Grounds	Quantity of the waste to be remedied on the basis of area and surveys	Valuable Land recovered by Bio-Remediation	
Step 9	Recovered Soil is used for refilling Grounds	Post Screening, useful waste - sent to further processing and C&D waste - filling low lying areas	Valuable Land recovered by Bio-Remediation	Valuable Land recovered by Bio-Remediation	Respective machinery and tools deployment	
Step 10	Regular Monitoring	Regular Monitoring	Regular Monitoring	Regular Monitoring	Regular Monitoring	

In the above exercise, the facilitator need to ask the participants to place the post-its in front of relevant step for landfill remediation. The facilitator can prompt the question, such as, "mark the steps to be followed for initiating a landfill remediation."

The facilitator can also explain the post-its one-by-one to all the participants. Encourage the participants to do the exercise and prompt any question, should they have.



In the above exercise, the facilitator need to ask the participants to place the post-its which represents actions in front of the relevant steps for landfill remediation.

The facilitator can also explain the post-its one-by-one to all the participants. Encourage the participants to do the exercise and prompt any question, should they have.

10

List of additional materials

- Municipal Solid Waste Management Manual 2016 (Part I - Overview, II - Manual, III – Compendium) published by Central Public Health and Environmental Engineering Organization (CPHEEO) - Government of India along with German International cooperation.
  http://cpheeo.gov.in/upload/uploadfiles/files/Part1%281%29.pdf http://cpheeo.gov.in/upload/uploadfiles/files/Part2.pdf http://cpheeo.gov.in/upload/uploadfiles/files/Part3.pdf
- Plastic Waste Management Rules 2016, [Published in the Gazette of India, Part-II, Section-3, Sub-section (i)] Ministry of Environment, Forest and Climate Change, dated 18th March 2016.
  https://cpcb.nic.in/displaypdf.php?id=cGxhc3RpY3dhc3RlL1BXTV9HYXpldHRlLnBkZg==
- Smart City Mission Statement and Guidelines published by Ministry of Urban Development Government of India on June 2015.
  http://smartcityrajkot.in/Docs/SmartCityGuidelines.pdf
- Climate Smart Cities Assessment Framework developed by Ministry of Housing and Urban Affairs, Government of India in the year 2020.
  https://www.niua.org/csc/assets/pdf/CSCAF_2_Booklet.pdf
- Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic, authored by Kumar Raja Vanapalli, Hari Bhakta Sharma, Ved Prakash Ranjan, Biswajit Samal, Jayanta Bhattacharya, Brajesh K. Dubey, Sudha Goel, published on Elsevier and Science of the Total Environment dated 1st January 2021.
  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7399665/
- Remediation Techniques, for Open Dump Sites, used for the Disposal of Municipal Solid Waste in India authored by Mayurika Chakrabarti and Amit Dubey, published on Journal of Basic and Applied Engineering Research on July-September 2015.
  https://cyberleninka.org/article/n/659471https://cyberleninka.org/article/n/659471

- Landfill mining as a remediation technique for open dumpsites in India authored by A. Dubey M. Chakrabarti, D. Pandit published on Elsevier B.V in the year 2016. https://www.sciencedirect.com/science/article/pii/S1878029616301013
- Advisory on Landfill Reclamation under Swachh Bharat Mission published by the Central Public Health and Environmental Engineering Organisation (CPHEEO) under Ministry of Housing and Urban Affairs, Government of India in June 2020. https://www.suratmunicipal.gov.in/CleanSurat/Documents/SOP/SBMAdvisoryOnLandfillReclamation.pdf
- India's answer to the mounting landfill problem: Bio-mining and Bio-remediation published by The Week Magazine. https://www.theweek.in/news/biz-tech/2021/01/09/india_s-answer-to-the-mounting-landfill-problem--bio-mining-and-.html
- Reclamation of landfills and dumps of municipal solid waste in an energy efficient waste management system: methodology and practice authored by Tatyana Orlova, Aleksandr Melnichuk, Kseniya Klimenko, Valentina Vitvitskaya, Valentina Popovych, Ielizaveta Dunaieva, Vitaly Terleev, Aleksandr Nikonorov, Issa Togo, Yulia Volkova, Wilfried Mirschel and Vitaly Garmanov published under licence by IOP Publishing Ltd.
  https://iopscience.iop.org/article/10.1088/1755-1315/90/1/012110
- A study of reclamation of Bandhwari landfill site, Gurgaon, Haryana authored by Neeraj Khatri, Dr. S. K. Singh, Dr. Joginder Kairo published by International Journal For Technological Research In Engineering.
  https://ijtre.com/images/scripts/16106.pdf

Annexure

100% Outsourced Model

ULB shall assess the quantity of waste and hand over the land for setting up of the plant contractor to set up the plant at his own cost. Electricity connection to be provided by ULB for the plant. Electricity charges for the usage of the plant to be paid by contractor ULB shall facilitate the disposal arrangements with their processing facilities.

Responsibility for disposal of RDF, recyclables and aggregates. ULB to appoint academic institution as Third party to verify the activities. Biomining to be carried out as per SWM rules 2016 and CPCB guidelines- Payment shall be made for the quantity of waste removed subject to verification by Third\party Contractor shall make all investment for machineries and daily operational cost in advance

Suggested Scope of Work:

- Set up bioremediation facility with all the required infrastructure and equipment and manpower
- Excavate the existing mixed compacted garbage and bioremediate the waste through mechanical sieving/ segregation/ other machines like shredders, separators, / any other equipment at the cost of the Developer/Contractor
- The Contractor shall ensure processing of the Legacy Waste in accordance with CPCB guidelines for handling Legacy Waste (Old Municipal Solid Waste dated Feb 2019) along with SWM Rules 2016 (as amended from time to time).
- The Contractor shall take necessary steps and processes to minimize environmental pollution while carrying out remediation/ reclamation of legacy waste at the Dumpsite. The Contractor shall take all reasonable steps to ensure that there is control of odour, dust and treatment generated leachate, flies, rodents and bird menace and fire hazards in and around the Dumpsite during the period of remediation work.
- Set up a processing system flexible enough and convenient for segregation of dumped material;
- Segregate the excavated garbage in the land portion earmarked into as many categories as possible in compliance with CPCB guidelines. Maximize the separation of recyclables viz. glass, metal etc. from the Dumpsite. Maximize the separation of components for generation of Refuse Derived Fuel ("RDF") from the Dumpsite.
- Set up an eco-friendly and non-polluting processing system in order to reduce the impact of the dumping site on the adjacent areas.
- Carry out necessary geotechnical surveys for considering the hydrological and flooding potential at site, in order to mitigate any effect on the activities during Bioremediation
- Carry out soil, air, ground water and noise baseline studies so that the same will be available to evaluate post Remediation/ Reclamation of the Dumpsite from authorized laboratories/agencies and submit the reports.

- Monitor and measure noise levels at the site, at the facility with plant boundary and surrounding area.
- Provide on-site storage facility for various fractions of processed Waste.
- Deal with processing outputs such as RDF, soil enricher, recyclables and inert from component of the Waste at the Dumpsite.
- While reclaiming and excavating MSW from the present open dumpsite following aspects must be handled carefully
- Exposure to hazardous material, leachate, gases, odour etc.
- Contaminated wastes that maybe uncovered during reclamation operations require special handling and disposal requirements as per CPCB guidelines.
- Precautions must be taken while excavating as it releases gases like methane, Sulphur dioxide and other gases which causes explosion and fire
- The Contractor shall explore the possibility of minimizing the disposal of inert/ processing rejects and maximize the usage of such inert waste including but not limited to making of curb side blocks, filling of low lying areas, construction of roads etc.
- Be responsible for the sale and marketing of all recovered materials to appropriate vendors.
- Be responsible for creation and maintenance of infrastructure, facilities and amenities for sieving the excavated garbage and storing the segregated materials etc. at their own risk and cost. Provide adequate number of processing machines for achieving its daily target of handling Waste per day based on the estimated quantum of waste at Dumpsite; Provide weighbridge to measure the quantity of various components of waste at dumpsite, processed in terms of sorting and segregated materials, RDF, soil enricher, and inert going out of the Dumpsite.
- Carry out levelling of the earth surface by bulldozers or any other earth moving equipment.
- Deploy the necessary manpower, materials, equipment, tools and construction of plants and sheds and creation of facilities for handling, separating, segregating and storing for the operation of the plant.
- Provide security arrangements for the planned project site, machineries, equipment etc. at the cost of the Developer / Contractor.
- Legacy C&D waste if found during excavation, sorting/segregation and final disposal of such legacy C&D Waste shall be the sole responsibility of the Contractor. The Contractor shall be free to explore alternate uses for C&D waste as per the C&D Waste Rules, 2016. Further, if the said C&D Waste is found to be lying around the Dumpsite or found to be not properly disposed of, the Contractor shall be liable to be penalized for the same in accordance with the terms of the Draft Contract.
- Hazardous waste such as physical, chemical, biological, reactive, toxic, flammable, explosive or corrosive waste, if found, during excavation, sorting or segregation shall be handled as per the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016.

- Handover any domestic hazardous waste/ biomedical waste if found during excavation, sorting/segregation to the nearest biomedical/ hazardous waste facility. This waste shall be handled as per Biomedical Waste Management Rules, 2016.
- Access to the Project Site provided by Municipal Corporation shall have to be maintained by the Developer/Contractor to have easy movement of vehicles and etc. from outside.
- Provide fire protection measures and safety equipment for all workers at the site.
- Ensure total stabilization of the waste dump so that it releases no offensive odors and generates no leachates, so as to have the stabilized material fit for application to farmland, parks, road dividers control of soil erosion and soil remediation.
- All the necessary regulatory approvals should be taken prior to the commencement of reclamation and remediation work.
- The ULB will earmark the legacy waste area at all times during the contract period.
- The ULB will provide an alternative site for the disposal of fresh waste.
- If the alternative site is not available, then the ULB, in consultation with selected contracted, must specifically earmark the area of legacy waste and the disposal area for fresh waste. In any circumstances, the contractor will not be held responsible for the environmental degradation caused by fresh waste.
- Method of quantification of waste: (Metric tonne/cubic meter)
- Stage of quantification/ measurement must be clearly specified
- All payment conditions must be clearly mentioned (rate, schedule, mode, etc.)

Suggested Qualification Criteria:

- Bidding entity can be a Joint Venture with a maximum of 3 entities. Lead Member must own 51% equity for the duration of the project and other members must own minimum 10% each.
- Bidder must have a minimum net worth as well as minimum turnover of 20% of the estimated project 36 Advisory on Landfill Reclamation cost.

Technical Capacity:

- At least 02 (Two) years of Satisfactory experience in last 05 (Five) years in solid waste management projects/ Remediation of a MSW Dumpsite/ Landfill Mining/ Bio-Mining/ Mining/ Material Handling and
- Satisfactory Experience of Operating 01 (One) project of Remediation of a MSW Dumpsite/ Landfill Mining/ Bio-Mining in India or abroad having 40 % (Seventy percent) capacity of the Estimated Capacity, during the last 5 (five) years preceding the Bid Due Date Or
- Satisfactory Experience of operating 01 (One) Solid Waste Management Project 40 % (Sixty percent) of Estimated Capacity in India or abroad during the last 5 (five) years preceding the Bid Due Date. Or
- Satisfactory Experience of operating 2 (Two) projects of Remediation of a MSW Dumpsite / Landfill Mining/ Bio-Mining in India or in abroad, Each having 30% (fifty percent) of the Estimated Capacity, during the last 5 (five) years preceding the Bid Due Date Or

- Satisfactory Experience of operating of 02 (Two) Solid Waste Management project each having capacity of 30% (fifty percent) of Estimated capacity in India or abroad during the last 5 (five) years preceding the Bid Due Date.

100% Work done by ULB with Rental Equipment Suggested Scope of Work:

- To rent machines (trommel, separators, and other required processing equipment as per DPR/ Technical feasibility report for setting up bioremediation facility.
- To arrange manpower (manager, supervisors, technical support staff, labourers, etc.) to operate provided machinery and manage the entire process as per CPCB guidelines for reclamation of said landfill site.
- To arrange operational and maintenance support for the machinery to keep them operational during the remediation period at their own cost and efforts for processing the legacy waste.
- The contractor will process the waste at their processing site. The excavation and subsequent transportation of waste will be carried out by the Urban Local Body (ULB)
- The ULB itself shall ensure processing of the Legacy Waste in accordance with CPCB guidelines for handling Legacy Waste (Old Municipal Solid Waste dated Feb 2019) along with SWM Rules 2016 (as amended time to time).
- Set up a processing system flexible enough and convenient for segregation of dumped material;
- Selected contractor will segregate the excavated garbage in the land portion earmarked, into as many kinds and categories as possible in compliance with CPCB guidelines at the rental cost finalized by ULB through competitive bid process. Maximize the separation of recyclables viz. glass, metal etc. from the Dumpsite. Maximize the separation of components for generation of Refuse Derived Fuel ("RDF") from the Dumpsite.
- Set up an eco-friendly and non-polluting processing system in order to reduce the impact of the dumping site on the adjacent areas.
- Monitor and measure noise levels at the site and interface of the facility with plant boundary and surrounding area.
- Store the processing outputs such as RDF, soil enricher, recyclables and inert from component of the Waste at the Dumpsite at the space provided by ULB.
- The contractor shall provide fractions like soil enricher, RDF/ combustible fraction, C&D waste and recyclables to ULB at the processing site
- Contractor has no responsibility for the disposal of such segregated fractions.
- The Contractor shall explore the possibility of minimizing the disposal of inert/ processing rejects and maximize the usage of such inert waste including but not limited to making of curb side blocks, filling of low-lying areas, construction of roads etc.
- Be responsible for Supply of machines, their operations & maintenance by the manpower provided for the reclamation work at their own risk and cost. Provide adequate number of processing machines for achieving its daily target of Waste per day based on the estimated quantum of waste at Dumpsite;

- Provide weighbridge to measure the quantity of various components of waste at dumpsite, processed in terms of sorting and segregated materials, RDF, soil enricher, and inert going out of the Dumpsite.
- Provide security arrangements for the planned project site, machineries, equipment etc. at the cost of the Contractor.
- Provide fire protection measures and safety equipment for all workers at the site.
- Ensure total stabilization of the waste dump so that it releases no offensive odors and generates no leachates, so as to have the stabilized material fit for application to farmland, parks, road dividers control of soil erosion and soil remediation.
- Excavation and transportation of the legacy waste will be in the scope of ULB.
- ULB will carry out the transportation of the by-products at its own cost.
- The ULB will earmark the legacy waste area at all times during the contract period.
- The ULB will develop an alternative site for the disposal of fresh waste as required
- If the alternative site is not available, then the ULB, in consultation with selected contracted, must specifically earmark the area of legacy waste and the disposal area for fresh waste. In any circumstances, the contractor will not be held responsible for the environmental degradation caused by fresh waste.
- Method of quantification of waste: (Metric tonne/ cubic meter)
- Stage of quantification/ measurement must be clearly specified
- All payment conditions must be clearly mentioned (rate, schedule, mode, etc

Suggested Qualification Criteria:

- Bidding entity can be a Joint Venture with a maximum of 3 entities. Lead Member must own 51% equity for the duration of the project and other members must own minimum 10% each.
- Bidder must have a minimum net worth as well as minimum turnover of 20% of the estimated project cost.

Technical Capacity:

- Supply of machinery, manpower and O&M services in last 05 (Five) years in solid waste management projects/ Remediation of an MSW Dumpsite/ Landfill Mining/ Bio-Mining/ Mining/ Material Handling and
- Satisfactory supplying of machinery, manpower and O&M services for 01 (One) project of Solid waste processing facility/ Remediation of an MSW Dumpsite/ Landfill Mining/ Bio-Mining in India or abroad having 70% (Seventy percent) capacity of the Estimated Capacity, during the last 5 (five) years preceding the Bid Due Date (or)
- Satisfactory supplying of machinery, manpower and O&M for 2 (Two) projects of Solid waste processing facility/ Remediation of an MSW Dumpsite / Landfill Mining/ Bio-Mining in India or in abroad, each having 50% (fifty percent) of the Estimated Capacity, during the last 5 (five) years preceding the Bid Due Date.

Combination of private operator and ULB Suggested Scope of Work for contractor/ private operator:

- To provide machines (trommel, separators, and other required processing equipment as per DPR/ Technical feasibility report for setting up bioremediation facility at the cost of ULB.
- To provide operational and maintenance support for the machinery to keep them operational during the contract period at their own cost and efforts for processing the legacy waste.
- Be responsible for Supply of machines, their operations & maintenance of the supplied equipment for the reclamation work by the ULB at their own risk and cost.
- Contractor has no responsibility for the disposal of such segregated fractions.
- Ensure that provided machinery in an operational condition at all times. Any breakdown in the machinery will be informed to contractor for repair and maintenance.
- Contractor will repair and maintain the machines within the stipulated time as informed by the site supervisor. All the machines will be maintained by the contractor as per the standard operating procedures of original equipment manufacturer.
- Manpower for the processing and other related works related to legacy waste remediation shall be provided by the ULB
- Operations related to processing shall be carried out by the ULB
- The respective sale and disposal of by-products shall be carried out by the ULB.
- Contractor will provide replacements for damaged components at the cost of ULB for that equipment which is not covered under warranty.
- All the consumables for the regular maintenance purpose will be provided by the ULB.
- The ULB will earmark the legacy waste area at all times during the contract period.
- The ULB will develop an alternative site for the disposal of fresh waste as required
- If the alternative site is not available, then the ULB, in consultation with selected contracted, must specifically earmark the area of legacy waste and the disposal area for fresh waste. In any circumstances, the contractor will not be held responsible for the environmental degradation caused by fresh waste.
- Method of quantification of waste: (Metric tonne/ cubic meter)
- Stage of quantification/ measurement must be clearly specified
- All payment conditions must be clearly mentioned (rate, schedule, mode, etc.

Suggested Qualification Criteria:

- Bidding entity can be a Joint Venture with a maximum of 3 entities. Lead Member must own 51% equity for the duration of the project and other members must own minimum 10% each.
- Bidder must have a minimum net worth as well as minimum turnover of 20% of the estimated project cost.

Technical Capacity:

- Supply of machinery, manpower and O&M services in last 05 (Five) years in solid waste management projects/ Remediation of a MSW Dumpsite/ Landfill Mining/ Bio-Mining/ Mining/ Material Handling And
- Satisfactory supplying of machinery and O&M services for 01 (One) project of Remediation of an MSW Dumpsite/ Landfill Mining/ Bio-Mining in India or abroad having 70 % (Seventy percent) capacity of the Estimated Capacity, during the last 5 (five) years preceding the Bid Due Date Or
- Satisfactory supplying of machinery and O&M for 2 (Two) projects of Remediation of MSW Dumpsite / Landfill Mining/ Bio-Mining in India or in abroad, Each having 50% (fifty percent) of the Estimated Capacity, during the last 5 (five) years preceding the Bid Due Date.

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Ministry of Housing and Urban Affairs
Government of India