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सत्यमेव जयते
Ministry of Housing and Urban Affairs
Government of India

CounterMEASURE FOR PLASTIC FREE RIVERS

Scientific Landfill Availability and Operations

TRAINING MANUAL

ClimateSmart Cities Assessment Framework

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Scientific Landfill Availability and Operations
Training Manual

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 - (i) Energy and Green Buildings, (ii) Urban Planning, Green Cover & Biodiversity, (iii) Mobility and Air Quality, (iv) Water Management, and (v) 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 availability and operations' 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

[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.

Unlined and poorly built landfills, often known as dumpsites, pose irreversible environmental and health risks, including long-term concerns about greenhouse gas emissions, groundwater and surface water contamination, air pollution, and surface fires. The training's objective is to build the technical capacity of the ULB officials and other stakeholders in dealing the future landfill needs by delivering up-to-date information on landfill design and operations, as well as technological aspects.

The module is majorly developed in order to provide a wholesome understanding of the scientific landfills and it's needs to the ULB officials. It covers the speciality areas such as landfill design and operation including feasibility, preliminary investigation, operation and management of scientific landfills, and its impact on sustainable waste management system.

The module also focuses on the various conditions for the scientific landfill construction such as design criteria and site conditions, feasibility, technologies practiced globally. Also the participants are given an insight of scientific landfill impact on sustainable waste management system and the assessments tools used for analysing the environmental impact 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 solid waste management majorly focusing on the landfill scenario, landfill design, its availability and operational procedures & issues in the Indian cities as well technological and policy interventions, that can be followed and assessment to be conducted for determining the suitable land and design for scientific landfill.

The manual is designed to guide readers to achieve a basic understanding of scientific landfill with an emphasis on its need & benefits, especially in urban areas where 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 will learn the detailed approach, various site selection criteria, suitable design based on the city requirement, land & technology availability, landfill gas & leachate management and the assessments tools used for identifying the capacity of landfill, suitable site and technology to implement the scientific landfill. The case studies outlined in the course would also help in learning best practices of followed by other ULBs and countries, their approach, benefits and financial models.

The manual is designed to guide readers to achieve basic understanding of scientific landfill. Detailed procedures to follow for the construction of landfill, 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 Waste 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
EAC	Expert Appraisal Committee
EPR	Extended Producer Responsibility
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
PS	Polystyrene
PVC	Polyvinyl chloride
RS	Remote Sensing
SEAC	State Expert Appraisal Committee
SHG	Self Help Group
SO2	Sulfur dioxide
SPCB	State Pollution Control Board
SUP	Single Use Plastic
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

The world generates 2.01 billion tonnes of municipal solid waste annually, with at least 33 percent of that—extremely conservatively—not managed in an environmentally safe manner. Worldwide, waste generated per person per day averages 0.74 kilogram but ranges widely, from 0.11 to 4.54 kilograms. Though they only account for 16 percent of the world's population, high-income countries generate about 34 percent, or 683 million tonnes, of the world's waste.[1]

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 in 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.

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.

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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.*

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, 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, Mahatma Gandhi Swachhata 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

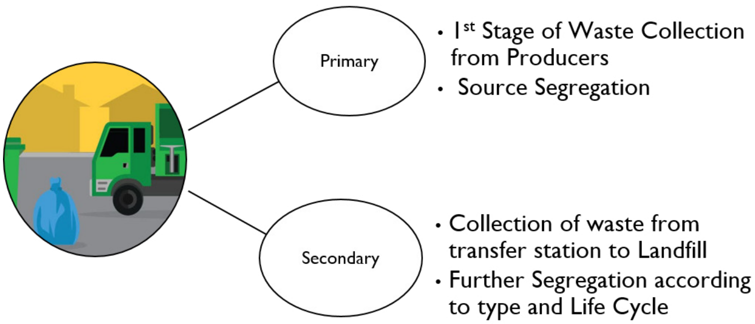
Increased-income people purchase more packaged goods, resulting in higher volumes of plastics, paper, glass, metals, and textiles in the waste stream, which is influenced by the local economy. Changes in the content of garbage can have a significant impact on how we handle it.

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



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

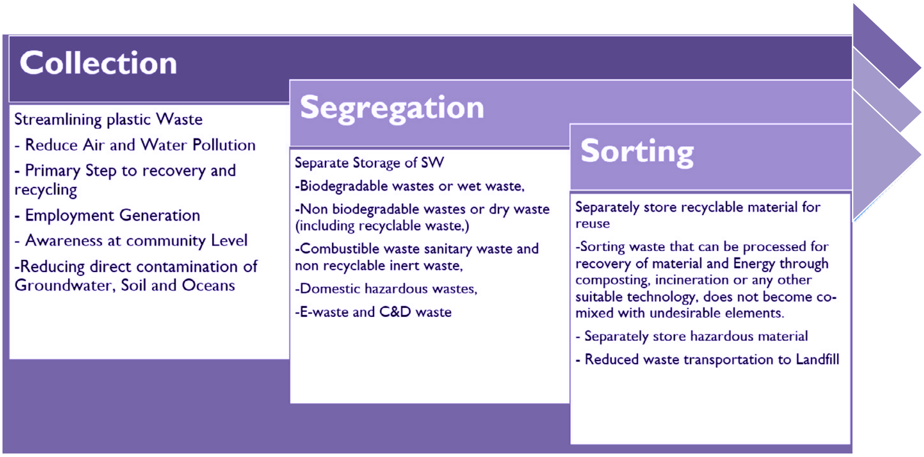
Waste has the potential to damage the environment and threaten human health if it is not properly handled and stored.

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, reparability, 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 . 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

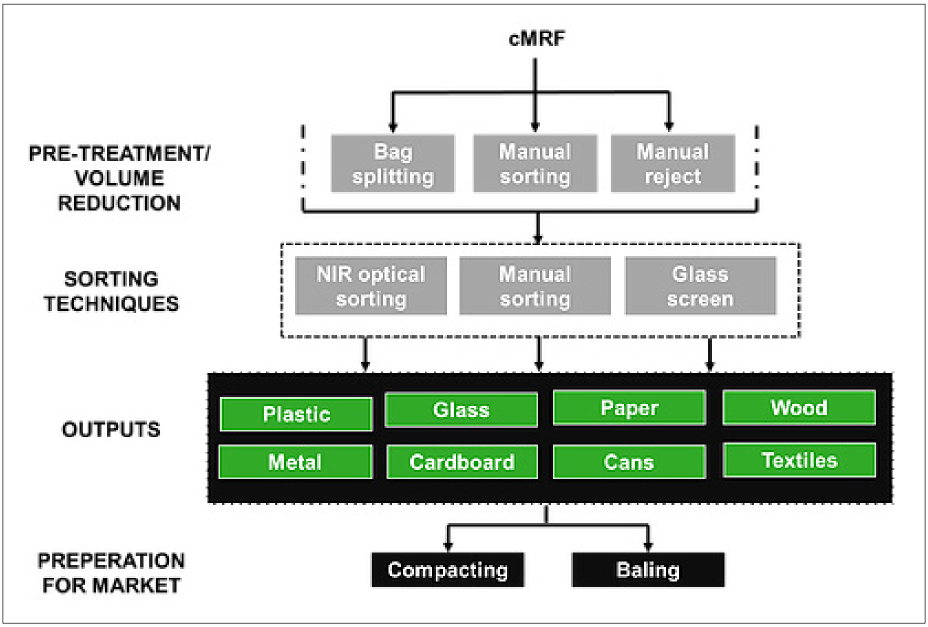


Fig 1.4: Pictures of a MRF Plant

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 scientific landfill availability and operations is covered in this module. The indicator focuses on capturing the amount of collectable waste which is going to the landfill and ensures whether the operations and management of landfill are according to the guidelines.

Fig 1.5: Climate Smart Cities Assessment Framework

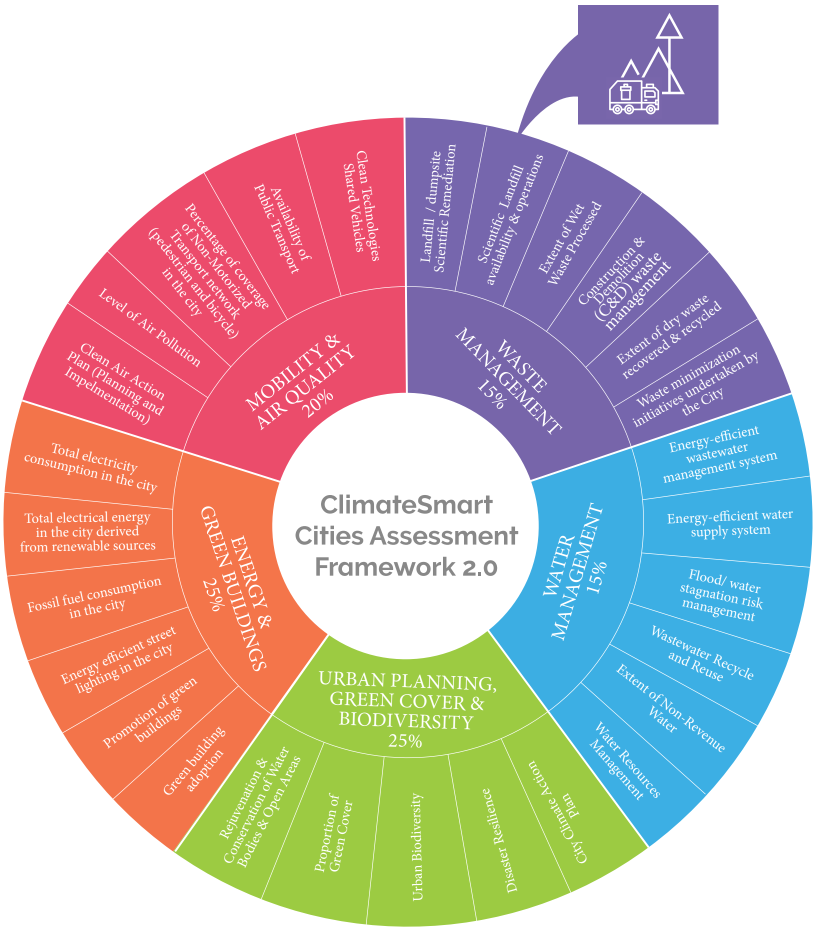
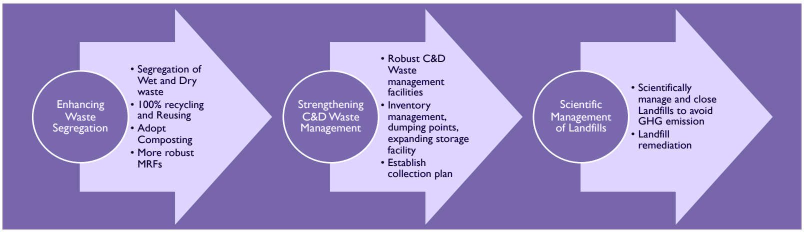
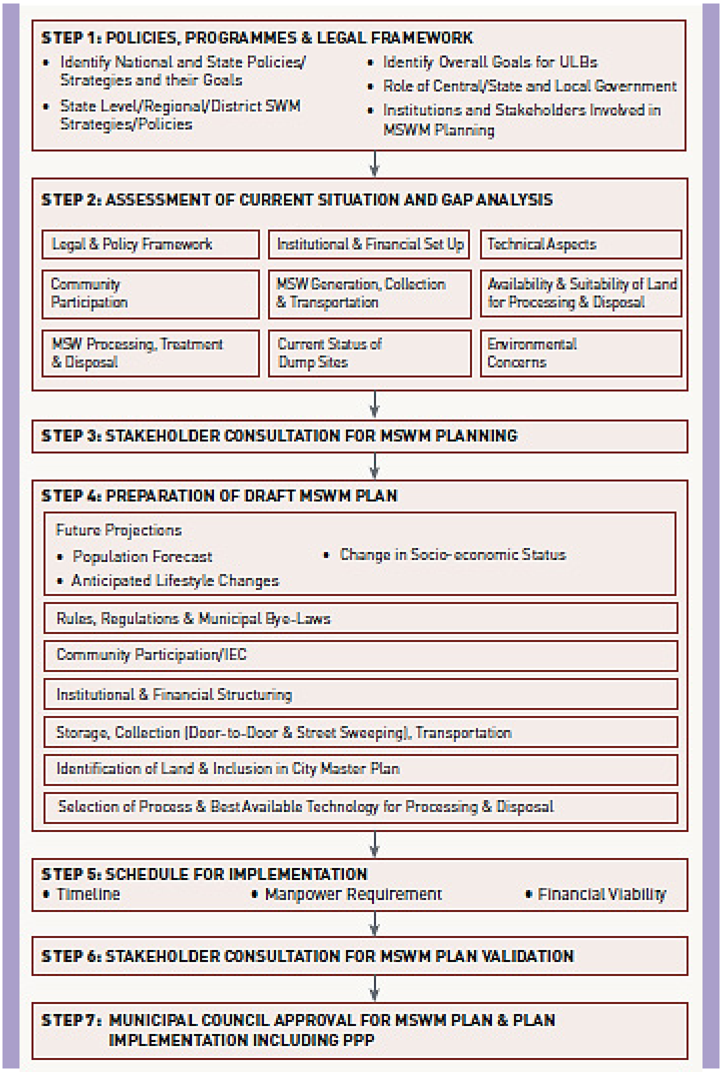


Fig 1.6: Progressive level in landfill bioremediation, CSCAF





Municipal Solid Waste Management Plan

ULBs should systematically develop their MSWM systems including carefully accessing their requirements of tools, equipment, vehicles, and processing and disposal facilities in a way and at a pace that is locally doable, meets the long term needs of the ULB, and is also financially sustainable. It is imperative to take stock of the situation and develop a Municipal Solid Waste Management plan.

Fig 1.7: Seven step approach for developing a MSW plan

STEP 1: POLICIES, PROGRAMMES & LEGAL FRAMEWORK	• Identify National and State Policies/ Strategies and their Goals • State Level/Regional/District SWM Strategies/Policies • Identify Overall Goals for ULBs • Role of Central/State and Local Government • Institutions and Stakeholders Involved in MSWM Planning
STEP 2: ASSESSMENT OF CURRENT SITUATION AND GAP ANALYSIS	•Legal & Policy Framework • Institutional & Financial Set Up • Technical Aspects • Community Participation • MSW Generation, , Collection & Transportation • Availability & Suitability of Land for Processing & Disposal • MSW Processing, Treatment & Disposal • Current Status of Dump Sites • Environmental Concerns
STEP 3: STAKEHOLDER CONSULTATION FOR MSWM PLANNING	• Number of institutions and stakeholders involvement • Bridging the gaps or improve the level of service • Consultative process. • Stakeholders' views and their willingness to participate and pay for the service
STEP 4: PREPARATION OF DRAFT MSWM PLAN	•Future Projections •Rules, Regulations & Municipal Bye-Laws •Community Participation/IEC •Institutional & Financial Structuring •Storage, Collection (Door-to-Door & Street Sweeping), Transportation •Identification of Land & Inclusion in City Master Plan •Selection of Process & Best Available Technology for Processing & Disposal
STEP 5: SCHEDULE FOR IMPLEMENTATION	• Timeline • Manpower Requirement • Financial Viability
STEP 6: STAKEHOLDER CONSULTATION FOR MSWM PLAN VALIDATION	• Dependent on community behavior and practices. • Consultation before finalization of the MSWM plan.
STEP 7: Municipal COUNCIL APPROVAL FOR MSWM PLAN & PLAN IMPLEMENTATION INCLUDING PPP	• Final MSWM plan presented to elected body of the local authority • Approval and official formalization the plan. • Defining short term and long term actions • Financial planning and institutional strengthening for implementation • Contracting models should be transparent and performance based. • Both the ULB and PPP operator should be accountable for their roles to ensure successful and sustainable project implementation.

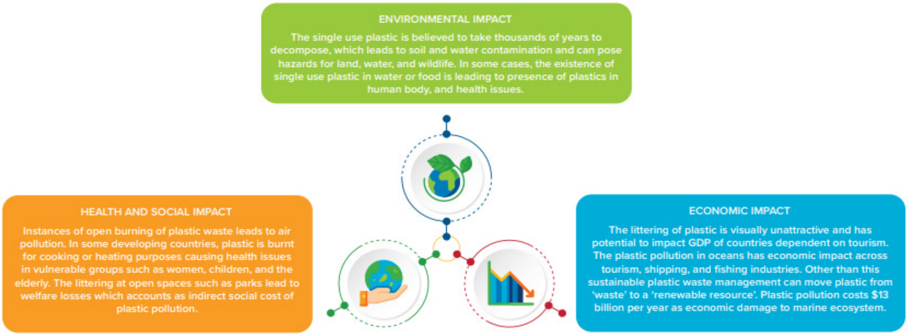
2

Plastic Waste Management

Plastic products have become an indispensable element of our daily lives. Packaging films, wrapping materials, shopping and litter bags, fluid containers, apparel, toys, home and industrial products, and building materials are among its many uses. There are growing concerns about non-biodegradability and the production of hazardous gases during burning. Packaging, agriculture, vehicles, and biomedical applications are all growing in popularity because to the ability to fabricate desired shapes, colours, and -specifications that are easy for customers.

Plastic waste management is a critical issue. Over 300 million metric tons of plastics are produced in the world annually and about fifty percent of this volume is for disposal applications, product that are discarded within a year of their purchase.[1] There is a need to manage the amount of plastic we use in our daily lives and look for more sustainable alternatives.

Fig 2.1: Impacts of plastics



[1]*Singh, P. & Sharma, V. P., 2016. Integrated Plastic Waste Management: Environmental and Improved Health Approaches. Procedia Environmental Sciences, Volume 36, pp. 692-700*

Plastic Waste Management Rules

The Ministry of Environment, Forests and Climate Change is in charge of waste management in India. Plastic Waste Management Rules were originally introduced in 2011, and they were updated in 2016 and 2021.[2]

Plastic has been overused in large quantities, and it is now making up a considerable amount of the waste stream. In some parts of the world, there has been a suggestion that we need a distinct set of rules focused solely on plastic since plastic is becoming a problem or, to put it another way, a catastrophe. Some highlights of the rules are:

- ***To reduce, reuse, recycle and educate:*** The plastic waste generated should be reduced, reused and handled by utilising it in various applications that will aid in the plastic recycling process. This shall also include educating all the stakeholders for alternatives.
- ***Pre-registration fee collection from producers and importers***: According to the rules, a payment shall be collected through the pre-registration procedure of producers, importers of plastic carry bags and multilayered packaging, as well as vendors for selling plastic in the market, to assist in the establishment of a waste management system.
- ***Responsibility of waste generator, Extended Producer Responsibility and collect back system***: Within six months of the date of publication of the notification of these Rules, all producers, importers, and brands who have introduced plastic carry bags, multilayered plastic sachets, pouches, or packings in the market must implement a waste collection procedure to collect the plastic waste generated by them. Individuals and bulk generators such as commercial establishments, offices, industries, and event organisers must segregate plastic garbage at the source, hand it over, and pay a user charge as defined by the ULB (Urban Local Bodies) as well as a spot fine if the laws are broken. The goal of EPR is to provide funding to companies that can come up with a new way to manage plastic waste. All of these companies that sell products

[2] *NITI Aayog, U., n.d. Sustainable Urban Plastic Waste Management, s.l.: s.n*

that cause plastic waste can be asked to pay a certain amount of money based on the volume of those products that they sell, and that money can be put into a pool of money where a company, which specialises in waste management, can come in and help the government pool such money, resulting in better waste management rather than expecting other countries or companies to manage it.

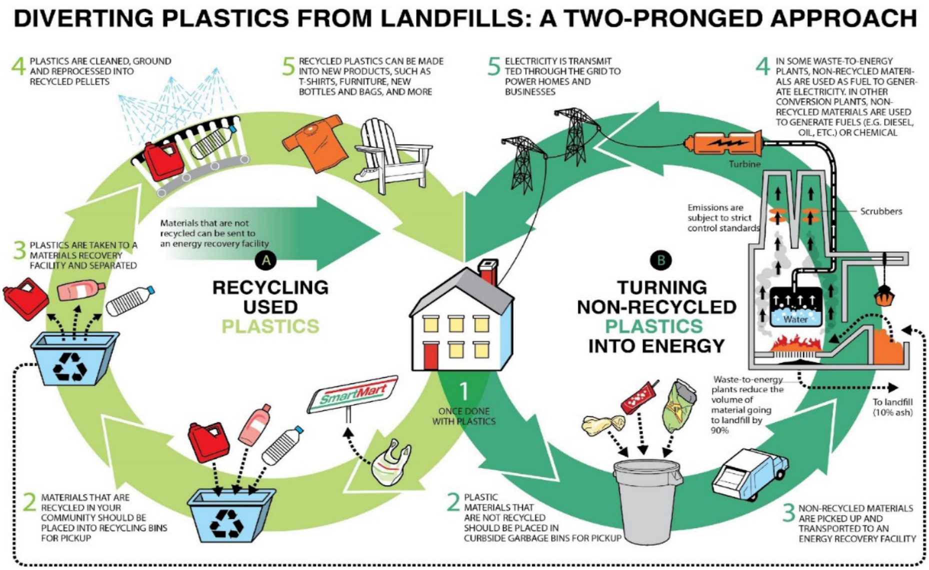
- ***Utilizing the plastic waste***: The rules encouraged people to come up with new ideas and ways to profitably use waste and address the country's waste disposal problem, such as using plastic waste for road and construction, energy recovery, or waste conversion to oil, and to come up with new ideas and ways to profitably use waste and address the country's waste disposal problem.
- ***Probation of 40 microns' plastic sheets and carry bags:*** The rules also request that the thickness of carrying bags and plastic sheets be increased from 40 micron to 50 micron. This will eventually assist to reduce plastic trash since the price of plastic bags will rise in the market, and people will be hesitant to buy and sell them due to their high prices.
- ***Borden the scope of applicability from urban areas to rural areas:*** Local bodies and Gram panchayats are advised by the Rules to act responsibly in creating and organising a waste management system within their villages and populations.
- ***Responsibility of retailers, street vendors, etc:*** The laws also imposed a punishment on shops or street sellers that sell or give commodities in plastic bags, plastic sheets, multilayered packaging, or plastic covers that were not manufactured, tagged, or labelled in accordance with the rules.

The objectives of the rule are as follow:

- Increase the minimum thickness of the carry bags made of plastic to 50 microns instead of 40 microns and also further specify the minimum thickness to be 50 microns for the plastic sheets to aid the better collection and recycling of the plastic waste.
- To broaden the scope of the applicability from urban areas to rural areas as plastic waste has made its way towards the rural areas too.
- To introduce the role of Producers and generators to act responsibly towards the waste management system and to further introduce the collect back system of plastic waste by the different brands, producers and owners according to the extended producers' responsibility system brought into light via these rules.
- Through introducing the pre-registration system the government aims at collecting the plastic waste management fee from the producers and importers from selling these plastic bags in the market and contributing towards the plastic waste for establishing a better waste management system.

- It further encouraged the use of plastic for the construction of roads as per the guidelines issued by the Indian Road Congress or energy recovery or conversion of waste to oil etc. Better utilization of the waste produced.

Fig 2.2: Divergence of Plastic from Landfill[3]



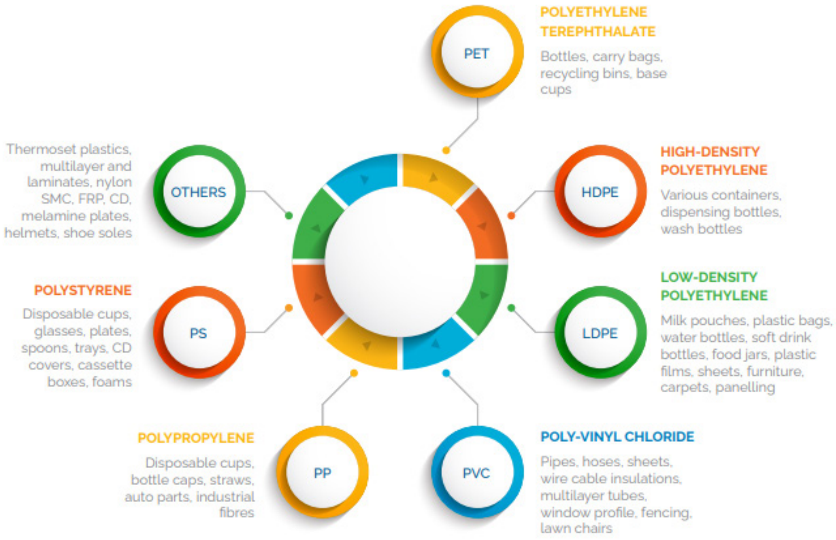
Divergence of plastic from landfills can be accomplished using the age-old 3Rs concept: Reduce>Reuse> Recycle. However, the addition of another "**R**"- Recovery (energy) is also beneficial when it comes to diverging plastic from landfills. Energy recovery facilities divert a significant amount of garbage from landfills. Modern energy recovery facilities are more environmentally friendly than ever before. With today's technology, contemporary energy recovery facilities can process waste with lower emissions than some conventional fuels used in most power plants. Plastics improve the efficiency of energy recovery equipment for municipal solid garbage. Plastics have a higher energy value than other components of municipal waste, thus they help the energy recovery process run more efficiently and produce less ash for disposal.

[3] *NITI Aayog, U., n.d. Sustainable Urban Plastic Waste Management, s.l.: s.n*

Recycling

Different forms of plastic are utilized for a variety of purposes in our daily lives.

Fig 2.3: Types of plastics and their applications[1]



There are various advantages to recycling and reusing waste plastics. It results in a decrease in the use of virgin materials and energy, as well as a decrease in carbon dioxide emissions.

Recycling's Advantages:

- Reduces pollution in the environment
- Energy savings range from 40 to 100 MJ/kg (depending on the polymer)
- Economic benefits
- Reduces demand for virgin polymer
- Preferable to land filling
- Creates jobs
- Helps to preserve fossil fuel reserves

Plastics recycling can be complicated by a number of issues, including waste collection, separation of different types of plastics, waste cleaning, and probable pollution of the plastics. Another complication is that most of the things that can be made from recycled plastics are of low value. Although reusing plastic is better to recycling because it consumes less energy and resources, recycling plastic consumes less energy than producing plastic from raw ingredients.

[1]*NITI Aayog, U., n.d. Sustainable Urban Plastic Waste Management, s.l.: s.n*

It has been discovered that recycling and reusing waste plastics in environmentally friendly ways is the best way to lessen the negative consequences of waste plastics. In addition to lowering the quantity of plastic waste that has to be disposed of, recycling and reusing plastic can have a number of other benefits, such as:

- Conservation of non-renewable fossil fuels – Plastic production uses 8% of the world's oil production, 4% as feedstock and 4% during manufacture[2]
- Reduced consumption of energy
- Reduced amounts of solid waste going to landfill
- Reduced emissions of carbon-dioxide (CO_2), nitrogen-oxides (NOx) and Sulphur-dioxide (SO_2).

Disposal of Plastic Waste

Plastic disposal is one of the least understood and most problematic aspects of plastic's environmental impact. One of plastic's most desired characteristics, its longevity and resistance to breakdown, is also one of its greatest liabilities when it comes to plastic disposal. Natural organisms have a hard time breaking down the manmade chemical bonds in plastic, which contributes to the material's long-term durability. Only a small percentage of total plastic manufacturing (less than 10%) is efficiently recycled; [3] the rest is disposed of in landfills, where it will rot for hundreds of thousands of years, or in incinerators, where poisonous compounds will be sprayed into the atmosphere and accumulated in biotic forms throughout the surrounding ecosystems.

Plastic usage has increased by 10% year on year, but plastic disposal options have not progressed, making the situation confusing for us. Multiple reasons contribute to the problem; for example, there is no trash segregation at the source, and many of us still use the same bin for all types of waste. According to the government, plastic accounts for around 8% of total solid waste in India, with the majority of this plastic coming from single-use items such as bags, cutlery, and straws. Approximately 80% of marine trash originates on land, and this mess ends up in landfills. However, it should be remembered that plastic isn't inherently harmful; it's how people use it that has a detrimental influence on the environment.[4]

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[2] *Karmakar, G. P., 2020. US National Library of Medical National Institute of Health- Elsevier Public Health Emergency Collection. [Online]*

Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7492070/

[3] *Koushal, V. et al., 2014. Plastics: Issues Challenges and Remediation. International Journal of Waste Resources*

[4] *Hopewell, J., Dvorak, R. & Kosior, E., 2009. Plastics recycling: challenges and opportunities. Philos Trans R Soc Lond B Biol Sci, 364(1526)(10.1098/rstb.2008.0311), p. 2115–2126.*

3

Landfill

In India we mostly have dumpsites. 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 CO2 (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 making the immediate need to focus on the scientific landfills.

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.

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[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)).*

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.
- 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 Landfill 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 3.1: 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.

Landfill site has design considerations for optimum usage:

- Infrastructural facilities
- Landfill capacity and life
- Development of operational plan
- Bottom and side liner system
- Cover system

- Leachate collection & Management
- Gas collection & Management
- Surface water drainage
- Slope stability
- Closure plan
- Environmental quality monitoring
- Post closure maintenance

Site selection criteria

- Responsibility of Development authorities to identify landfill sites and handover to concerned ULBs
- Near by waste processing facility.
- Soil conditions and topography.
- Surface waste hydrology.
- Large enough to last for 20-25 years
- No development zone around landfill area
- Temporary storage facility for solid waste shall be established in each landfill

Fig 3.2: Site selection criteria

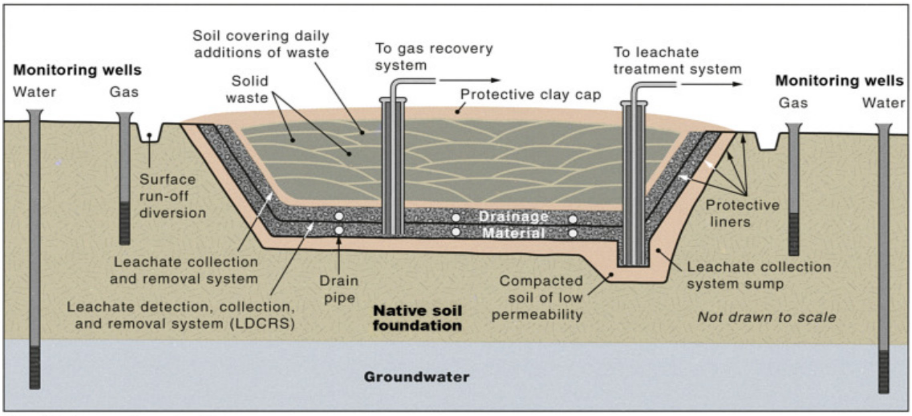
Place	Distance Parameters
Lake or Pond	• Maximum distance 200 m • Water monitoring system should be installed if the landfill site is less than 200 m from the lake/ pond • Site falling within Wetlands are avoided
River	• Maximum distance 100 m • The distance may be reduced in some instances for non-meandering rivers but a minimum of 30 m should be maintained
Flood Plains	No landfill should be constructed within a 100 m year-flood plain
Highway	Maximum distance 200 m
Habilitation	Maximum distance 200 m of notified habituated area Site falling within forest area and national park are avoided A distance of 100 m must be maintained from the residential areas.
Public Parks	Maximum distance 200 m
Ground Water Table	No landfill should be constructed in the area where water table is less than 2 m below ground surface
Airport	A distance of 20 km from the nearby airport must be maintained Can be set up between 10-20 km by obtaining NOC from the civil aviation authority/ Air Force

Planning and Design

The design of a landfill consists of 3 phases:

- Active
- Pre-closure
- Closure

Fig 3.3: 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.

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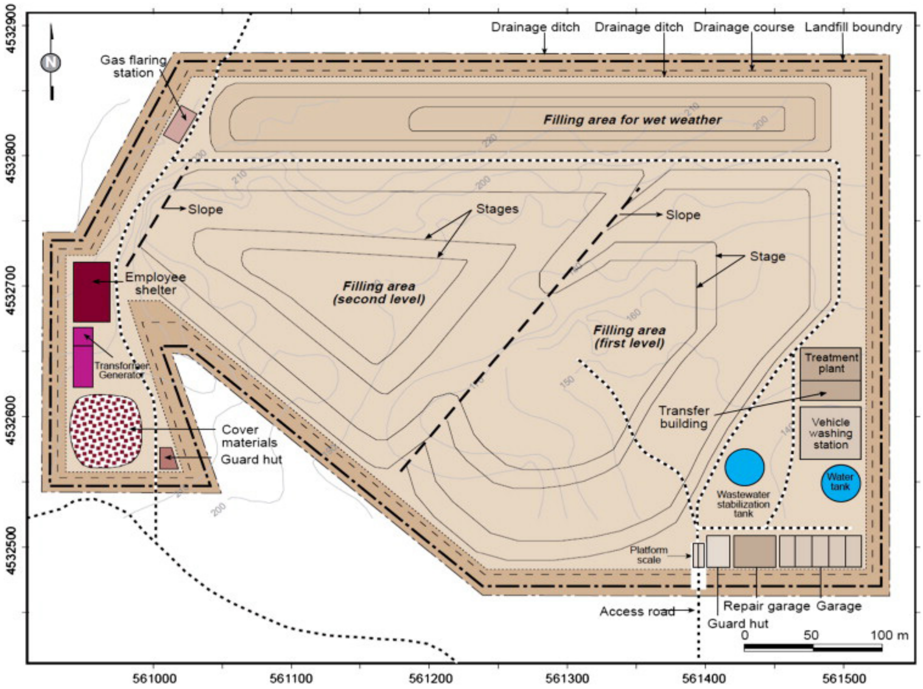
[2] *Government, S. M., 2015. Seoul Soultion. [Online]*
Available at: https://seoulsolution.kr/en/content/landfill-recovery-project-transformation-landfill-ecological-park [Accessed 2021]

Fig 3.4: Sample landfill layout[3]



There are different sections of a landfill depending on the topography, geography of the area, depth of the water table and availability of daily cover material.

The Phases is a sub-area of landfill. The phase plan which including cells, lifts, daily cover, intermediate cover, liner and leachate collection facility, gas control facility and final cover should be drawn out along with landfill layout.

Liner system is important to contain Leachate in the landfill and protect the ground waste and soil. Leachate control within a landfill involves the following steps:

- Prevention of migration of leachate from landfill sides and landfill base to the subsoil by a suitable liner system; 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.

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[3]*Ersoy, H., Buluta, F. & Berkünb, M., 2013. Landfill site requirements on the rock environment: A case study. Elsevier , 154(28 February), pp. Pages 20-35.*

Landfill – design principles

Fig 3.5: Landfill Type – Based On Technology

Landfill Type – Based on Technology

Engineered Landfill

Bioreactor Landfill

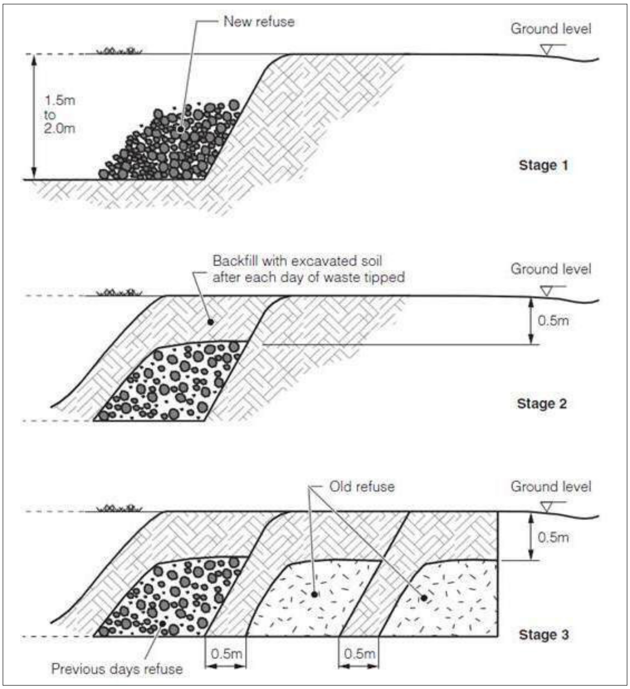
Basic Landfill

There are three basic landfill design principles

Basic Landfill (Emergency Landfill)

- Pit should be backfilled with excavated soil every day.
- Site should be agreed with local population and authorities.
- Site should be fenced. At least 1 km downwind from the nearest dwellings.

Fig 3.6: Basic Landfill[4]

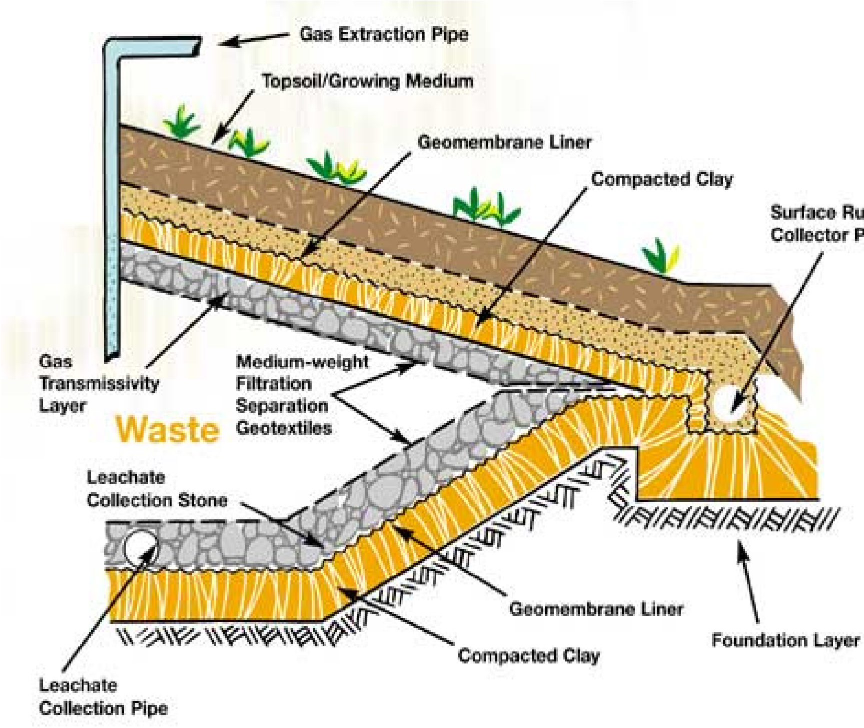


[4]*Reed, B. & Moreno, M., 2016. Solid Waste Management'. WASH in Emergencies | HIF Problem Exploration Report.. Research Gate*

Engineered Landfill

- The capacity is planned and the site is chosen based on an environmental risk assessment study.
- Gas is flared or used for energy production.

Fig 3.7 Engineered landfill[5]



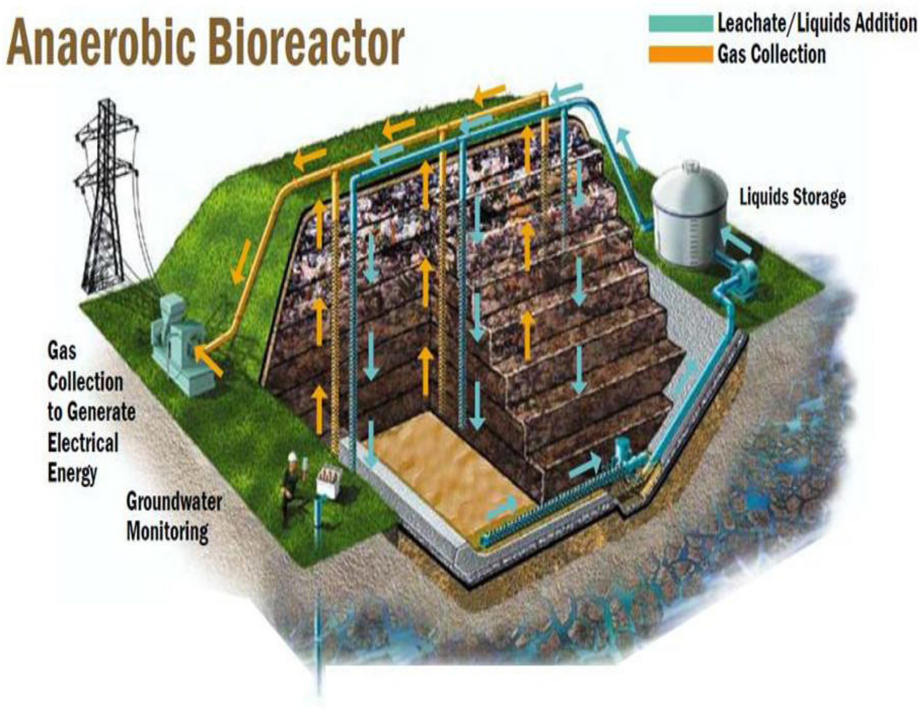
A cross-section of a best practice landfill cell

Bioreactor Landfill

- Acceleration of biologic decomposition (organic fraction).
- Promoting conditions necessary for the microorganisms (moisture content).
- Liquids must be added (leachate, stormwater, sewerage sludge).
- Systems: aerobic, anaerobic, aerobic-anaerobic, facultative (to control high ammonia concentration).

[5] *Anon., n.d. Landfill: A Waste Containment Faciity, s.l.: s.n.*

Fig 3.8: Anaerobic Bioreactor landfill[6]



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

[6]*Stauffer, B., n.d. SSWM. [Online]*

Available at: https://sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/solid-waste/landfills 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."[7]

Fig 3.9: Operational Procedure

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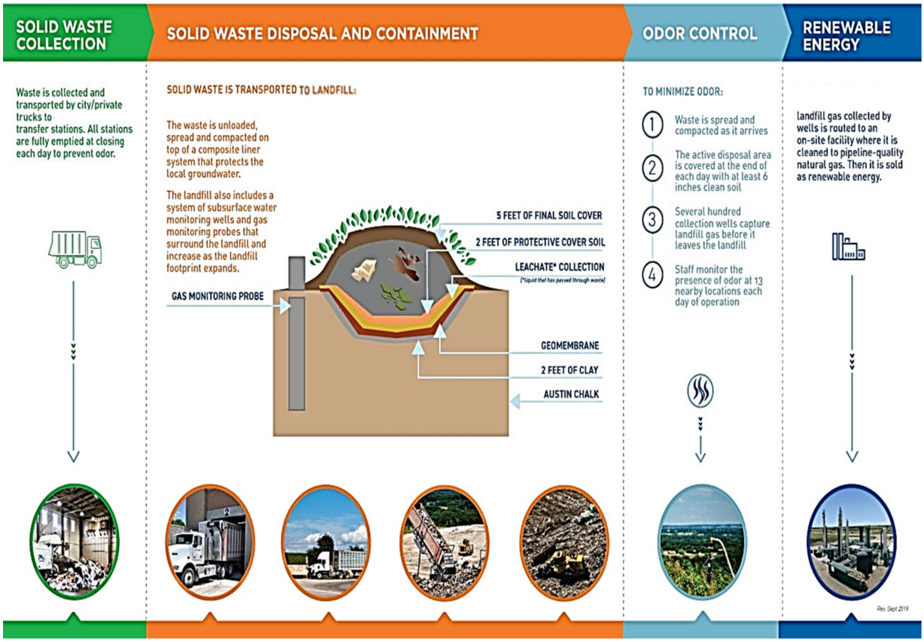
[7]*Dutta, S., 2019. NDTV. [Online]*
Available at: https://swachhindia.ndtv.com/disposing-waste-scientifically-how-scientific-landfills-can-change-the-waste-disposal-scenario-in-india-8159/
[Accessed 2021].

Fig 3.10: Overview of a Landfill operations & its by products



Leachate & Landfill Gas Management

Leachate collection systems are installed above the liner and consist of a perforated piping system which collects and carries leachate to a storage tank. Periodically, leachate removed from the storage tank and treated or disposed of. Most common leachate management methods are: discharge to waste water treatment plant, on site treatment & recirculation back into the landfill. Leachate recirculation accelerates decomposition, gas production & stabilization of organic matter.

A Landfill Gas Collection System is a network of landfill gas extraction wells, a suction pump or pumps, pipework, valves and gas flow control, condensate drainage, and monitoring devices installed in a landfill for the purpose of sucking landfill gas out of landfilled waste under a slight vacuum. These systems invariably deliver the landfill gas (LFG) to one point, a secure "Flare" compound area which may also include landfill gas utilization equipment. In the compound the suction pump (known as the "blower") expels the LFG into the flaring system or the LFG utilization plant.

Fig 3.11:Landfill gas collection system[8]

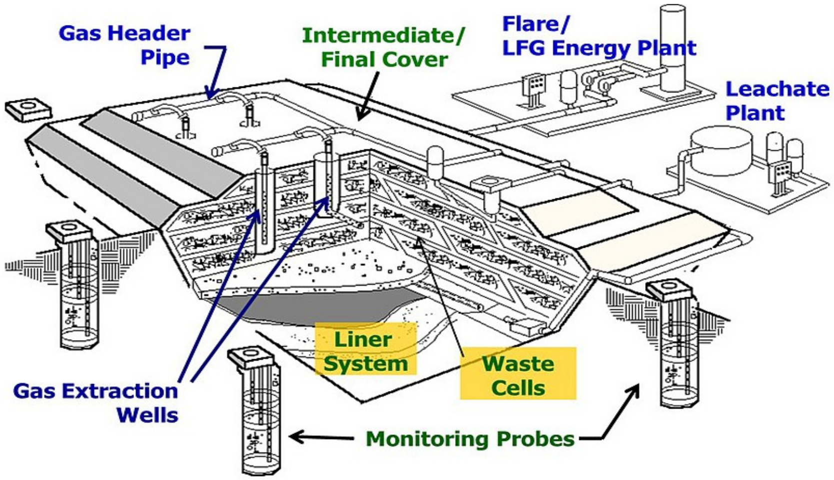
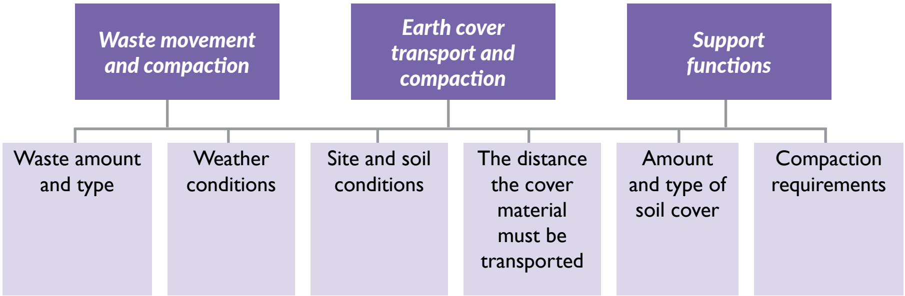


Fig 3.12: Landfill equipment



[8]*Anon., n.d. The Landfill Gas Expert. [Online]*
Available at: https://landfill-gas.com/landfill-gas-collection-systems-definition

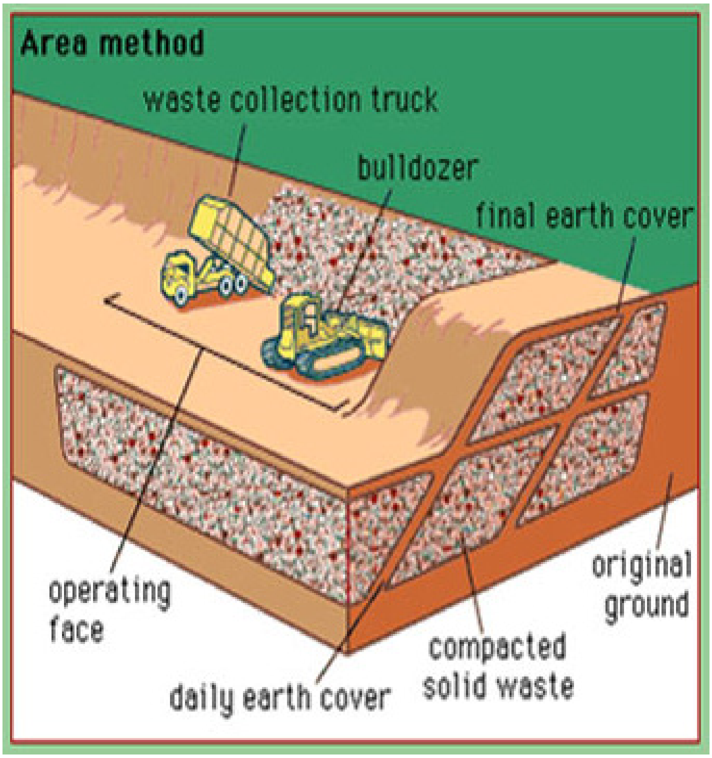
Scientific Landfill Methods – Based On Site Condition/Geography

Site condition and geography plays an important role in scientific landfill methods, described below:

Area Method (Above ground level)

- Used on flat ground.
- An earthen levee is constructed before landfilling against which wastes are placed in thin layers & compacted.
- Thickness of layer reaches a height of 200 to 300 cms
- Cover material of 15-30cm thickness is placed after each layer. Completed lift including the cover is called a cell.

Fig 3.13: Area method[9]

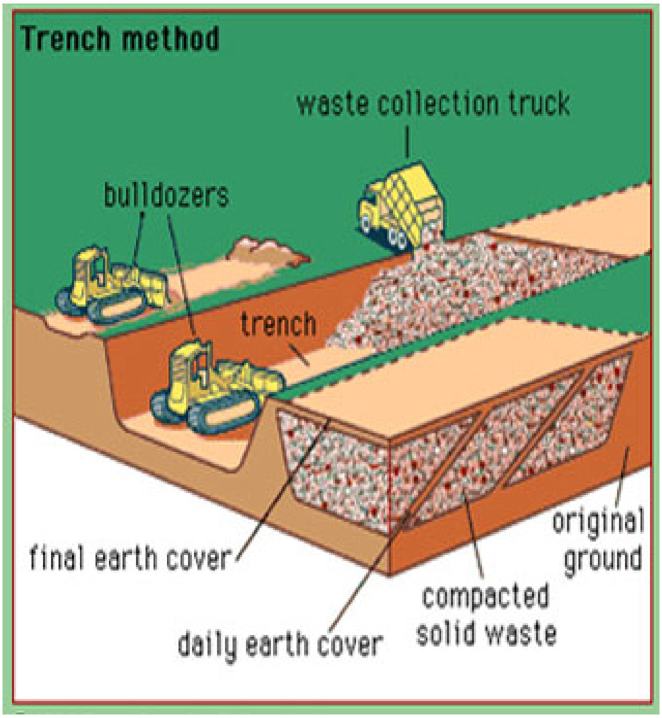


[9]*Nochian, A., Tahir, O. M. & Ding, R., June 2019. Towards Sustainable Development of a Landfill: Landfill to Landscape or Landscape Along with Landfill? A Review. Pertanika Journal of Social Science and Humanities, Volume Research Gate.*

Trench Method (Below ground level)

- Used where adequate cover material is available & water table is well below the surface.
- Waste are placed in trench & compacted in thin layers.
- After compacted height reaches design height, cover material is placed over the compacted layer.
- Same trench is then continued & filled similarly.

Fig 3.14: Trench method[10]



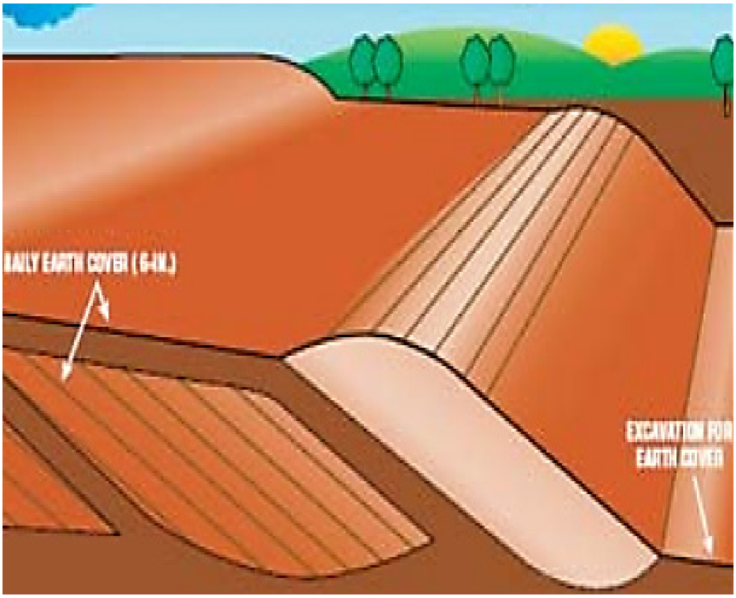
Ramp method

- Combination of area & trench method.
- Waste is spread and compacted on an existing slope.

[10]*Nochian, A., Tahir, O. M. & Ding, R., June 2019. Towards Sustainable Development of a Landfill: Landfill to Landscape or Landscape Along with Landfill? A Review. Pertanika Journal of Social Science and Humanities, Volume Research Gate.*

- Cover material is excavated directly in front of the waste. It is then spread over the waste and compacted.
- The excavated area becomes a part of the cell to be worked the following day. Ramp method is considered ideal by some operators because they do not have to haul in cover material

Fig 3.15: Ramp method[11]



Depression/Valley method

- Used where natural or artificial depressions exist.

Implementation plan and Strategy

The implementation plan and strategy towards Scientific landfill starts from the generation point itself. The key is to implement Integrated Solid Waste Management (ISWM). Integrated solid waste management is based on a variety of complementary solutions and a comprehensive approach, rather than just technical procedures. Every stakeholder involved and affected in waste management is brought into this integrated waste management method. Social, environmental, and economic constraints are all taken into account while designing an integrated waste management scheme.

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[11] *Anon., n.d. Govengr. [Online]*
Available at: https://sswm.info/sites/default/files/reference_attachments/GOVERNMENT%20 ENGINEERING%202006%20Landfill%20Design%20and%20Operation.pdf

Improving ISWM from a system viewpoint necessitates the collaboration of local government, central governing bodies, private sector, local citizens, and all other stakeholders. The Ministries, Central Pollution Control Boards, and other regulating authorities have praised and advocated ISWM as a long-term solution. Waste prevention, reduction, reuse, and recovery, recycling, composting, incineration with and without energy recovery, and disposal in sanitary landfills are all functional parts of ISWM.

The implementation and strategy execution would need support from management, quality assurance, collective work, better training programs and appreciation ratings. Citizen's involvement and ownership is a key to achieve better results.

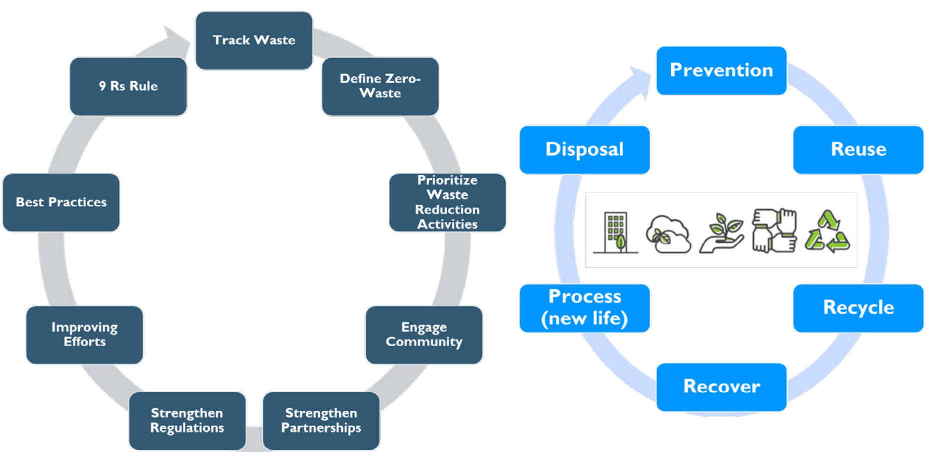
Adequate funds availability with the municipality for collection, MRF facility and landfill operations will ensure employment of advanced technologies in order to enhance efficiency of waste management activities.

Zero landfill

Zero Landfill' is the avoidance of disposal of waste to landfills. The avoidance of waste to the landfills can be achieved by :

- Reduction of waste generation
- Elimination of wastes
- Findings useful application of wastes in the process (reuse)
- Organization wastes can be a useful resource for other organization
- Recycling
- Recovering energy by anaerobic digestion
- Composting of bio-degradable material etc.

Fig 3.16: Zero Landfill



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:

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

The objectives of a monitoring are:

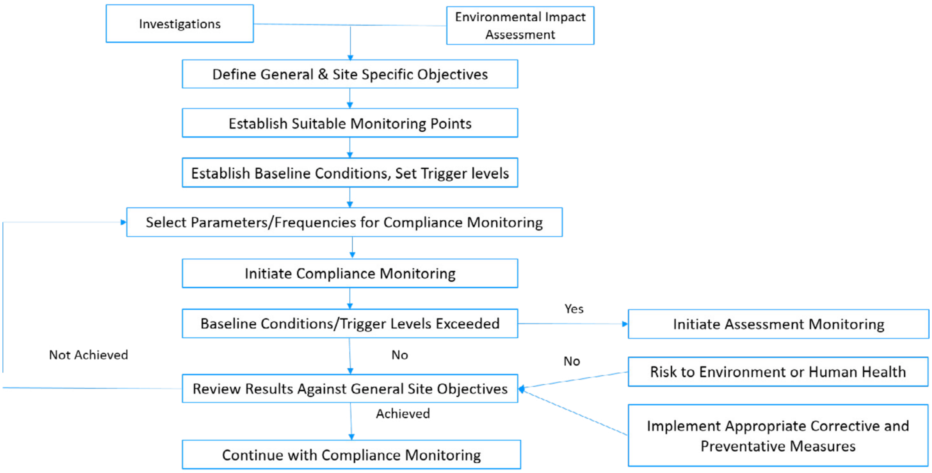
- To establish baseline environmental conditions;
- To detect adverse environmental impacts from the landfilling of waste;
- To demonstrate that the environmental control measures are operating as designed;
- To assist in the evaluation of the processes occurring within the landfill;
- To demonstrate 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

Figure 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.

Energy 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.

Environmental and Operational Hazards

A conventional landfill is an engineered system for storing waste in specifically constructed and protected cells on the surface of the land or in excavations into the ground.[2] Despite the fact that more trash is being reused, recycled, or energetically valorized, landfills continue to play a significant part in waste management methods. Leachate and gases are produced during the decomposition of trash in landfills. These emissions have the potential to endanger human health and the environment's quality. Methane and CO2 (carbon dioxide) are the most common greenhouse gases found in landfill gas. Landfills are responsible for 20% of global anthropogenic methane emissions[3].

Landfill as a potential source of pollution and effect on environment:

The migration of polluted leachate and landfill gas, as well as the environmental repercussions of the various landfills that exist around the world, account for much of the

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[2] *https://www.ijert.org/landfill-emissions-and-their-impact-on-the-environment*

[3] *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)).*

potential risk from MSW dumps. If MSW is placed on the landfill without pre-treatment, major emissions (leachates and biogas) are significantly affected by biological processes occurring in them. Emissions develop during the landfill operation period, and continue to be produced long after the landfill has been closed.

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

Below are some of points which are impacting the environment

- By generating a poisonous soup of industrial and household cleaning chemicals, landfills pose a long-term hazard to ground water and surface water that are hydrologically related.
- Almost a third of landfill waste is biodegradable; this waste rots and decomposes, emitting damaging gases (CO2 and methane), both of which are greenhouse gases that contribute to global warming. The nearby environment, particularly the water and soil, is also polluted by landfills.
- Landfills are one method that humans alter the formation of soil by altering soil forming elements such as climate, exposure, and soil organisms.
- Landfills can emit offensive odours, and landfill gas can travel through the soil and settle in surrounding structures. Ammonia, sulphide, methane, and carbon dioxide are the most dangerous gases produced in landfills.
- The most common orders at landfills are ammonia and hydrogen sulphide.
- Those who reside within five kilometers (5km) of a landfill site are at risk. Lung cancer and death, as well as death and hospitalization due to respiratory disease (used as a surrogate for all pollutants co-emitted from landfills). When a landfill's capacity is reached, the rubbish is covered with clay and a second plastic shield. Several feet of dirt fill are then topped with soil and plants.

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.

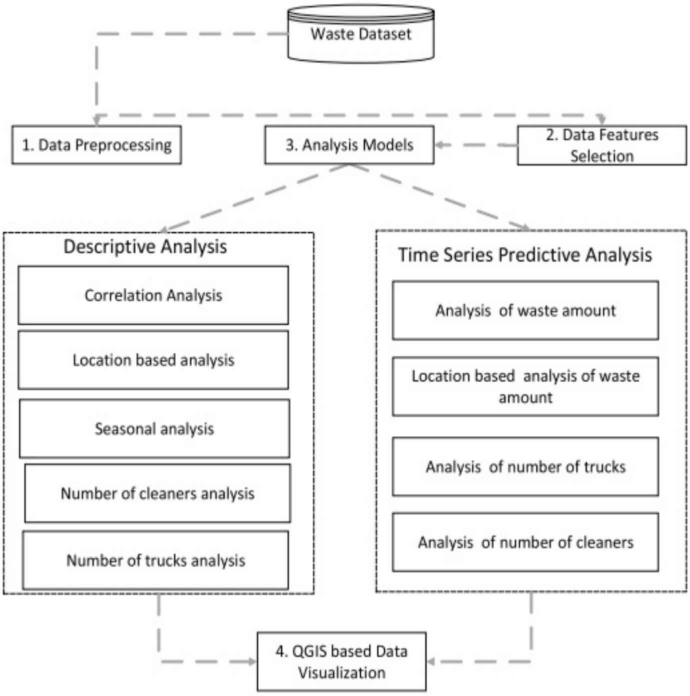
Visualization tools and GIS

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

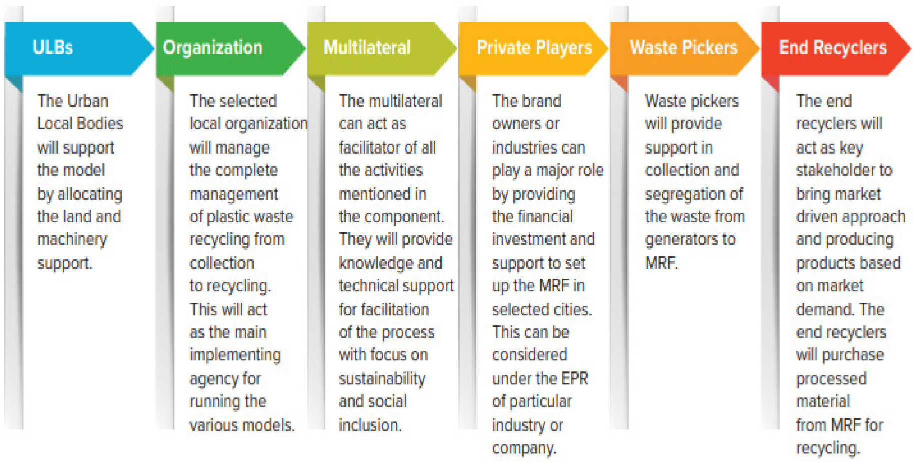
Stakeholders and financial plans

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

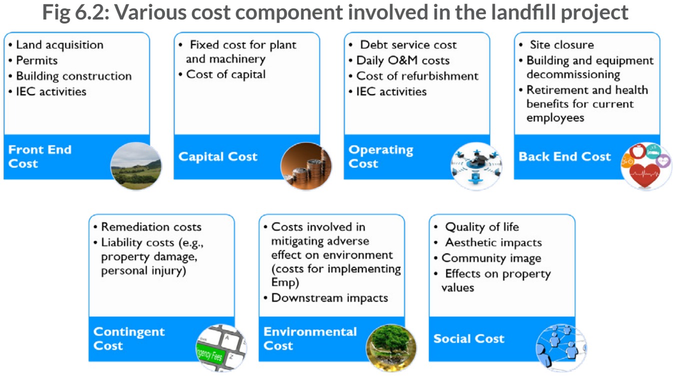
Without the cooperation of rubbish pickers, scrap collectors, merchants, and recyclers, many cities' formal waste management systems would not be effective. Organically grown informal sector operations are exceptionally adaptable, agile, and quick to change to market conditions. The integration of informal 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 landfill 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 7.1: Plastic based bio-medical products

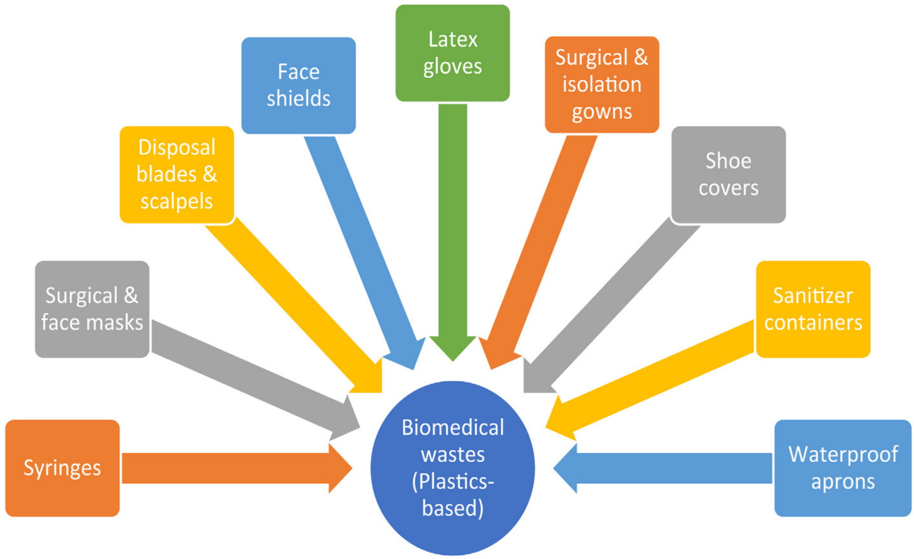
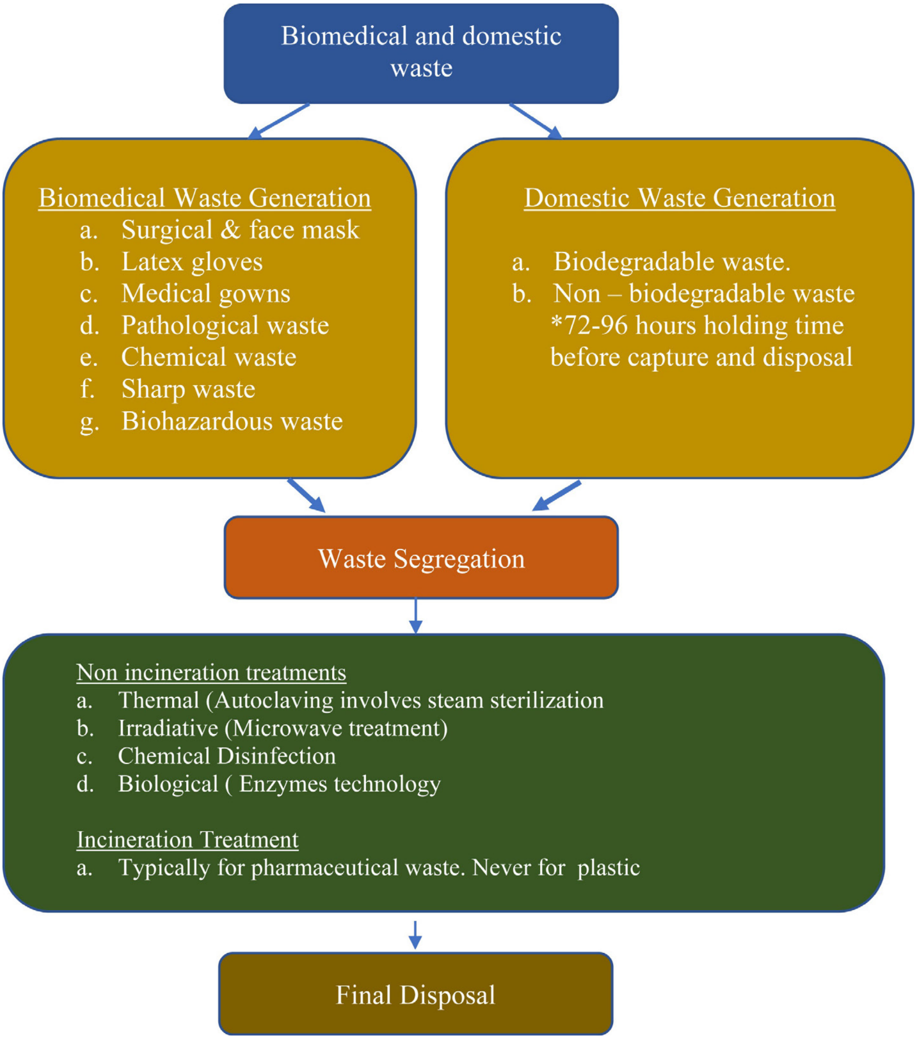


Fig 7.2: Biomedical & domestic waste processing



8

Recent Trends in Global Solid Waste Processing Technologies

Collection and transport

- Modern collection and transportation of municipal solid waste involve many technical steps and emerging technologies in integrated waste management system.
- The overlapping of information technology with waste management system give raise to many innovative technologies in the way of sustainable development.
- Latest technologies including underground collection system, Web based GIS technology, Waste bin monitoring system using GSM, and Waste compactors are being discussed further

Web based GIS (Geographic information system) technology

- Over the last few years, the GIS technology has gained popularity in almost every field of life. Coupling the GIS technology along with waste collecting became popular over the past few years in developed countries like Italy.
- Through this municipality can manage the entire waste cycle from production point to disposal areas, by optimizing and automating every step of cycle. According to the Italian and European case studies the implementation of web-based GIS technology optimized the waste collection and source separation for recycling had become efficient up to 80%.[1]
- As GIS can model the world landmarks and streets, it can play an important role in waste collection sector.
- GIS in combination of other software can give information regarding the most reliable routs, number of residents, number of contracts, their validation, and potential frauds.

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[1] *Anon., n.d. tumkuruniversity.ac.in. [Online]*
Available at: http://tumkuruniversity.ac.in/oc_pg/es/Recent%20trends%20in%20global%20solid%20 waste%20processing%20technologies..pdf

Waste bin monitoring technology using Global System of Mobile (GSM)

- GSM is a latest trend in the field of waste collection. In this technology sensors are placed in public garbage bins to detect a certain optimum level of waste.
- As the garbage reaches the threshold level, indication will be transferred to the controller which will further give indication to driver of collection truck for emptying the bin urgently.
- The indication will be sent to the driver through SMS using GSM

Compact garbage collection trucks

- In many developing countries, because of narrow and congested roads small garbage collection trucks are used. Latest technologies introduced garbage compactors in collector trucks in order to increase the collection capacity of vehicle. With continuous modification currently these trucks have achieved high compression rate as they can carry 1.5 times more waste as compare to flat pile trucks. [2]
- The technology does not only increase collection capacity, but also increases the fuel efficiency which is more environmentally and economically feasible. Researchers are been working to introduce electric motor drive and hybrid type collection trucks to overcome problems like greenhouse gas emissions and air pollution.

Segregation and sorting

- After collection the second step involved in MSW management system is sorting or segregation of different types of wastes for further processing.

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[2] *Anon., n.d. tumkuruniversity.ac.in. [Online]*

Available at: http://tumkuruniversity.ac.in/oc_pg/es/Recent%20trends%20in%20global%20solid%20 waste%20processing%20technologies..pdf

- Among all the steps sorting is the determining step for reuse and recycling. Latest technologies for municipal waste sorting includes optical sorting, Eddy current sorting, multi compartment bins, and optical sensor-based sorting technologies.

Automatic Bottle Sorting System

- This technology is widely used in Japan in recent years. It is comprised on sizing, aligning and clearing machine, along with color identification sensors.
- The role of sizing machine is to divide the bottles according to the size, after which bottles will send to color sensing machine and then conveyer belt.
- The bottles of each color are shredded and cullet is prepared. Through this volume of waste is reduced and cullet can be further used in different fields.

Recycling

- The best management practice is the implementation of 3Rs concept, developed countries had shifted to this concept decades back, while developing countries are still working on it.
- Municipal solid waste is a combination of components such as paper, plastic, glass and metal, which can be recycle and reuse certain times. Studies revealed that 28 to 48% of Thailand's MSW is comprised on such components. Further discussed are some latest recycling and reusing technologies.[3]

Incineration

- A thermal waste treatment process in which the unprocessed waste is burn at high temperature is commonly known as Incineration. Sufficient quantity of air is needed in order to oxidize the feedstock or the fuel. For combustion, waste has exposed to 850 ºC, and then it is converted to H2O, CO2, and the non-combustible material which is known as Incinerator Bottom Ash (IBA).
- Recently Japanese researchers are introducing pollution free incineration by recycling incinerated ash, and removal of acidic gases through control technology. Conventional stroke furnace is efficient and environment friendly incinerator reactor In the United Kingdom the most commonly used combustion reactor is moving grate.
- The combustion system gradually propels the waste into the combustion chamber by a mechanical actuated grate. The waste is continuously entering from one end of the furnace and the residual ash is being discharged from the other end.
- The processing conditions needs to be fully controlled in order to optimize the combustion, and also ensuring complete combustion of the feed
- Fixed grate reactor is a brick-lined cell which has a fixed metal grate above the ash pit, having two openings, one is at the top or on side for loading and the other one is on the parallel side for removing incombustible solids.

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[3] *Anon., n.d. tumkuruniversity.ac.in. [Online]*
Available at: http://tumkuruniversity.ac.in/oc_pg/es/Recent%20trends%20in%20global%20solid%20 waste%20processing%20technologies..pdf

Vermicomposting

- The latest technology which is being used in many developing countries as Japan and UK. In this process animal waste, pharmaceutical waste, food and sewage waste is processed through earthworms to give output known as vermiwash which is very rich in Nitrogen, Phosphate and Potassium. In this process specific species of earthworms have been fed on waste which give rise to new generations to feed on waste pile.
- The processing period ranges from 28-120 days. The temperature ranges between 18-67 oC with pH between 5.9 and 8.3 where the moisture content 80%. The vermiwash is used as bio fertilizer for crops of maize, soy bean, marigold and cow pea

Energy recovery

- The last step before disposal is energy recovery. All the waste residue after sorting, reuse, recycle and processing, is further inaugurated for energy recovery. In 2009-2010 UK generates 32millions of waste from which 48% was returned to landfills, 39% was recycled, and energy was produced from 13% of MSW.
- Studies reviled that energy from waste could account for 17% of UK's electriciy by 2020. Latest energy conversion technologies are categorized into two broad categories, including bioconversion and thermal conversion technologies. Waste to Energy (WTE) provides a renewable alternative of energy in the world, where we have limited fossil reservoirs.[4]

Advance Thermal Treatment Technologies

- Advance thermal treatment technologies have been introduced in recent years for efficient and pollution free WTE conversion. These technologies included pyrolysis, gasification and excluded incineration.
- Now-a-days incineration is used as a processing technology rather as energy generating technology. Because in such a mass burn system the organic content of municipal waste is converted to heat, with the emission of CO2 and H2O, which has no fuel value and emission of greenhouse gas is a real problem.
- Pyrolysis and gasification are not are not very new concepts they have been using since decade for the production charcoal, coke and producer gas. Recently these concepts are extensively been utilized for WTE conversion of solid waste.

Pyrolysis

Pyrolysis is the thermal degradation of substance in the absence of oxygen. As compare to incineration, pyrolysis is a conversion of waste to liquid or gaseous fuels along with residue char, which is a mixture of non-combustible material and carbon.

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[4]*Anon., n.d. tumkuruniversity.ac.in. [Online]*

Available at: http://tumkuruniversity.ac.in/oc_pg/es/Recent%20trends%20in%20global%20solid%20 waste%20processing%20technologies..pdf

The temperature requires for the process ranges between 300-800 C.

The product gas is known as syngas which is the combination of VOCs, CO, H2, and CH4. The volatilize gases and volatilize liquids are efficiently used to run a steam engine. Cooled syngas is widely used as liquid fuel.

Gasification

- Gasification involves partial oxidation of a substance; it lies between combustion and pyrolysis. The temperature required in above 750 C. The products are almost the same as pyrolysis; syngas and low C ash. Gasification is a reliable option as it meets the present emission standards and is helpful in maintaining the sustainability of landfill.
- The feedstock is fed into gasifiers along with limited amount of air. Many downstream gasification processes require syngas to be cleaned from trace level of impurities. The most common impurity is mercury. Carbon bed technology has been utilized for cleanup in recent years.
- The products of gasification are steam, chemicals, electricity, hydrogen, fertilizers, and natural gas. Different types of waste gasification methods are characterized on the basis of oxygen medium, two of them are steam gasification and plasma gasification. Recently many new technologies have been developed as plasma melting gasification.

Disposal

- The common and old methods of municipal solid waste disposal were open dumping, burning and incineration
- The process of open dumping leads to water and air pollution in the form of land litter, particulates and toxic gases. Methane gas and solid residues are also produced from burning process.
- American and European countries were famous for the incineration of waste with instant energy recovery, the technology became less common due to high operational cost.
- Disposal is the last step of MSWM, where the remaining trash after recycling, processing, and WTE is disposed.
- Disposal is the most technical step of waste management.
- Experts are encouraged to introduce technologies to lessen the amounts disposed of annually. In developing countries even today most of the disposal sites are open dumps, they have no proper leachate treatment and landfill gas utilization system
- Methods like open dumping were responsible for causing many aesthetic and other environmental issue.
- Two most common ways of disposing MSW are landfills and deep well injection slurry. Following are modern landfill technologies through which the experts can avoid issues regarding leachate leaking, water contamination, and landfill gas explosion

Sanitary Landfill

- Landfill is a professionally engineered depression in low population area, for the final disposal of left over after all the previous steps of integrated waste management.
- Waste is buried in that depression in order to avoid any hydraulic connection between trash and environment including air and water. Landfill is mostly preferred because it has the widest range of capabilities and is least expensive method of waste disposal.

Bioreactor Technology

- The latest technology to process disposed of waste rapidly is bioreactor technology.
- The basic aims of this technology are to enhance the rate of decomposition, circulation of leachate and increase in the growth of microbes, which decompose municipal waste.
- The waste is then dried by Conventional landfill technology.

Landfill gas recovery technologies

- The landfill gas emissions are greatly varied due to geological, hydrological and geotechnical properties which have environmental impacts. The biotic and abiotic factors lead to generation of gas at landfill which is the combination of CH4 and CO2. Which is known as biogas.
- Chemical International Journal of Advanced Science and Research 27 oxidation produces abiotic gas in the presence of water and metals like Aluminum. Al produces leachate which further undergoes redox reaction to produce of hydrogen gas. Metallic aluminum hydration and bottom ash results in gas production
- If mismanaged this gas can cause explosion of landfill or gradual leaking can cause global warming as both the gases (CH4 and CO2) are greenhouse gases. The voluntary program landfill methane outreach program is developed to reduce greenhouse gases which are causing climate change. This organization aware the public, stakeholders and local communities about the benefits and technologies of landfill gas recovery

Microturbine

- Technology Modern landfills have microturbines for generation of electricity from landfill gas. This technology is used to supply electricity to the small scale nearby projects.
- This technology is helpful in resolving the issue of air pollution and global warming due to the emission of landfill gas air.

Fuel cell

- Technology Energy from fuel is converted into electrical energy in an electrochemical cell is called fuel cell. Fuel supply and oxidizing agent react to generate electricity.
- Carbon dioxide, water vapors, heat and electricity are the end products of fuel reactions. Generation of transportation fuel for cars and buses without combustion is the application of fuel cell

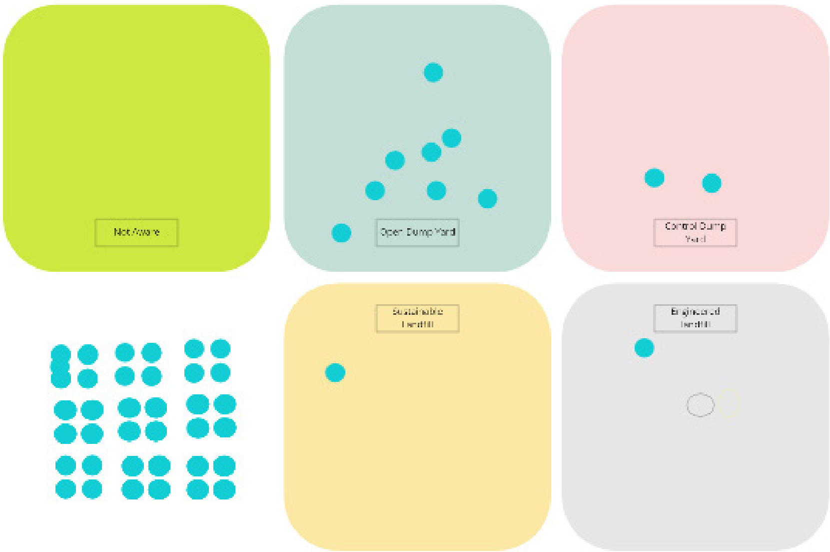
9

Interactive Exercise

Exercise Example 1-

Step 1: Read the MIRO Board carefully
Step 2: Mark the type of landfill available in your city.

Question : Indicate the type of landfill available in your city.



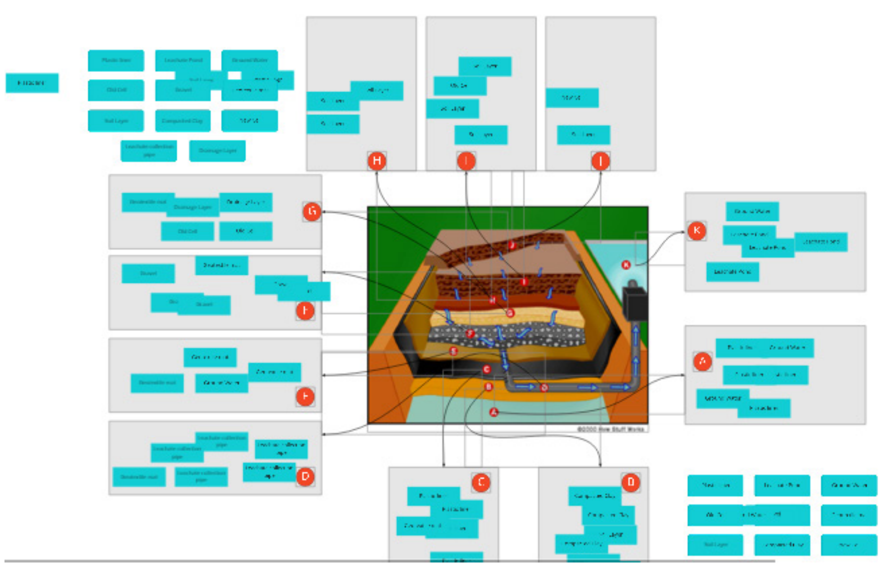
In the above exercise, participants are required to mark the type of landfill available in their city. The trainer can ask the participants to "indicate the type of landfill available in their city".

By doing this exercise, the trainer is creating a platform for all the participants to work together and understand the use of online board to perform the exercise.

While participants are working on the exercise, it is encouraged to the trainer to explain the components of the exercise for understanding.

Exercise Example 2-

Step 1: Read the MIRO Board carefully
Step 2: Arrange the landfill layers starting from bottom layer 'A'
Question: Arrange the below component as per scientific landfill layer starting from bottom layer

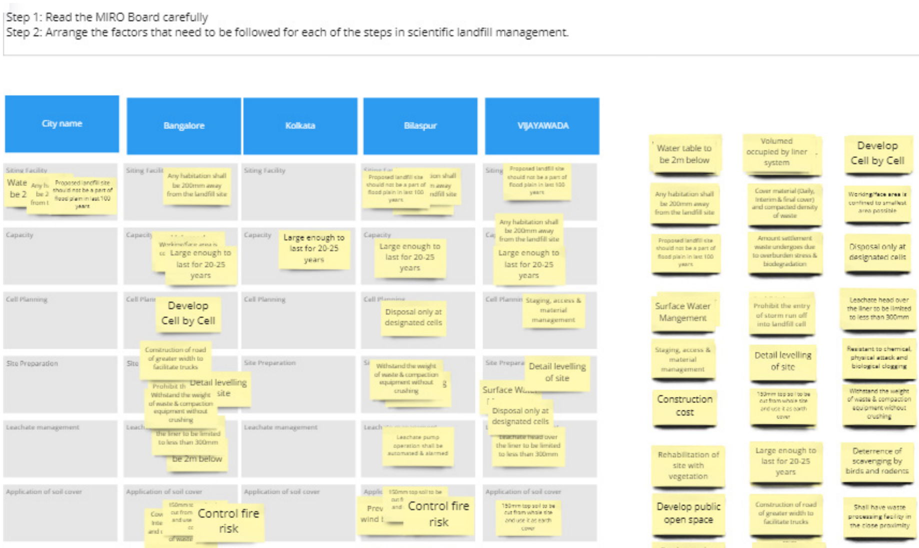


In the above exercise, participants are required to arrange the components of the scientific landfill form bottom to top layer (A-K).

By doing this exercise, the trainer is creating a platform for all the participants to work together and understand the layers of scientific landfill.

While participants are working on the exercise, it is encouraged to the trainer to explain the components of the exercise for understanding.

Exercise Example 3-



In the above exercise, participants are required to mark the factors against the criteria for a scientific landfill choosing from the post-its.

By doing this exercise, the trainer is creating a platform for all the participants to work together and understand the layers of scientific landfill.

While participants are working on the exercise, it is encouraged to the trainer to explain the components of the exercise for understanding.

10

Case Study

Landfill Design for Sustainable Waste Management in Pune, Maharastra.

Background

The city of Pune, located at 188310 N latitude and 738510 E longitudes, is situated in the western region. Pune is one of the fastest developing urban areas in Asia and ranks eighth at national level. The present growth is attributable to various factors such as industrialization, expanding educational. One of the negative impacts of the city's rapid development is the increase in MSW generation, resulting in environmental degradation. Many factors, such as spiraling urban population. Economic development, consumption patterns, climate and institutional framework, contribute to MSW generation and the composition of the waste.

Pune, with a population approaching 34, 00 000, is estimated to generate about 1200 metric tons of MSW daily. The per capita generation of MSW varies from 0.30 to 0.40 kg per day per person depending on the economic status of the community involved. MSW in Pune city has been predicted to increase from 1100 t per day in 2007 to 1800 t per day in 2011 and 2600 t per day in 2025. The annual rate of increase in solid waste generation has been forecasted to be 1.29% through 2025 (PMC, 2008).

Study Area

The earlier landfill site of Pune city covers an area of 64 ha (6.40_105m2) of which 15 ha were permanently sealed off as it was already landfilled. Landfill had been operational since 1983 and it mainly contains residential waste, market waste, institutional waste and waste from slaughterhouses and information technology (IT) industries. At present the total amount of landfill waste is about 0.438 million t per annum. Waste received at the landfill site was mostly of a mixed nature. The unsegregated waste and also Pune Municipal Corporation (PMC) used to dispose the unsegregated waste on the dumping site without any soil cover or leachate management. The height of waste dumped was 18 m. Recently PMC has agreed to allot 20 000m2 of land for an integrated solid waste management plant.

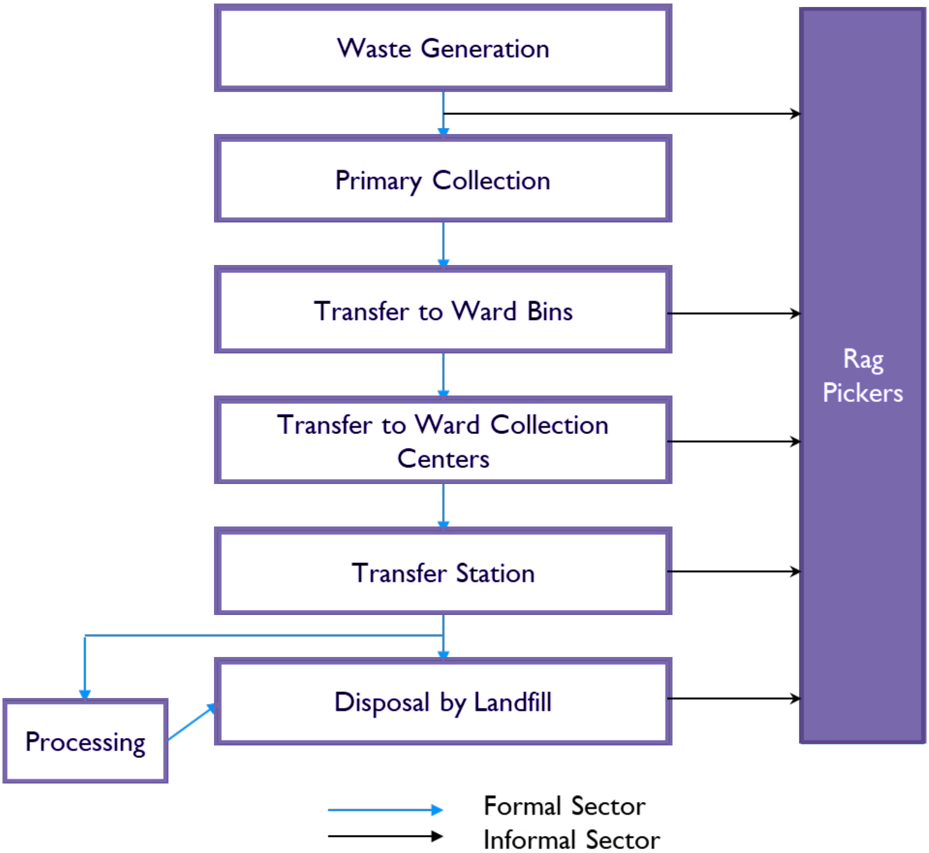
The present practice of solid waste disposal consists of biological decomposition of waste and landfilling.

Objectives

The objectives of the present study are the development of modified design methodology for landfill system.

- Gas recovery option and estimation of energy generation value for the case of Pune MSW.
- To characterization of MSW delivered to Pune city's landfill
- To studying the changing trends of waste characterization in the past 10 years and
- To suggest the appropriate MSW treatment plan

Fig 9.1: Schematic diagram of present municipal solid waste management in Pune



Significance of Study

- Pune city generates large amount of solid waste.
- Large amount of waste poorly disposed and untreated.
- The city does not have an engineered or scientific landfill site
- Capacity of existing dump site cannot cater the future demand of the waste generated.

So, there is an immediate need for designed scientific integrated solid waste management system using Geospatial tools like Remote Sensing, GIS and GPS to minimize adverse effects on environment, social and economic of solid waste management. Therefore the present research work focuses on understating effective waste management practices in study area.

Materials and Methods

1. Sample collection and segregation

Total of 25 samples were characterized for physical and chemical analysis of MSW.

2. Sorting and processing of samples

Manually sorting with the help of landfill workers into seven categories, namely plastic, paper, cloth (rubber, leather and synthetics), metals, stone, glass and organic matter.

Laboratory sample analysis

Various analysis done for MSW waste sample in lab.

- pH analysis MSW waste
- Organic matter
- Moisture content
- Total solids, volatile solids, fixed solids.
- Density (*By core cutter method*)
- Organic carbon
- Total Kjeldhal nitrogen

Proposed Methodology For Modified Design Of Landfills

Given the poor situation of waste management and landfills as also the failure of existing the following new methodology of landfill design is proposed and developed to attract private participation in waste management by providing economic gains.

The proposed design is based on an integrated approach to waste disposal and energy generation. This approach can be applied only to the proposed new landfills. It may not be applied to the existing landfills.

The following assumptions are made:

- Waste is segregated at source and should contain very little fraction of recyclable material when it reaches the landfill site.

- Direct shipment of waste is considered in most of the cases as the proposed landfills with modified designs could be located in different parts of the mainland leaving a wider scope for minimization of transportation cost and efficient waste collection.

In this modified design approach, in contrast to the conventional approach, land requirement is determined for the waste generation level and for a given life of landfill.

Research Methodology

The data collection involved collection of topographical maps, ward maps, satellite data and demographic details. The Survey of India topographical maps was used for the current study of the following features: drainage, water bodies, contours, roads and rail network and administrative boundaries. Other data sources are satellite images of Pune city, various maps collected from published materials and from related web sites.

The brief information about steps involved in implementation methodology for the present research work.

- Procurement of Satellite data and related attribute data
- Geo-correction of remote sensing data and topographical maps.
- Application of standard image processing techniques to identify the existing solid waste system of study area.
- Creation of GIS layers: digitization of contour lines, drainage, roads, railways, land use/ land cover area, location of smaller ramps, bio-gas plant and administrative boundary of study area from the topographical maps and Google images using GIS software's.
- Fieldwork would be carried out to survey by using GPS.
- Generation of base map and related database from topographical maps of Survey of India and satellite data.

Since the main objective of this research is to understand and assess the existing solid waste system of Pune city using Geospatial tools.

Conclusion

- The first step in waste management is to gain an understanding of the waste types being generated in order to design appropriate collection and disposal strategies.
- Characterization of MSW of the landfill site of Pune city shows that it contains a high percentage of organic matter (69.3%) and organic content in MSW to the tune of 32.83%, and average moisture content 48.08%, which confirms the viability of biological treatment.
- Effective management of solid waste at the landfill site of Pune city will reduce the environmental effects of landfill.
- The investigations of the present study will be useful for Pune city as well as for developing metropolitan cities

when making decisions regarding the integrated solid waste management strategy and for selection of treatment and disposal options.

Landfill Operation at Ghana

Background

The purpose of this study is to explore landfill operational activities in Ghana. Very little studies have been conducted on landfill operational practices in Ghana and this study therefore seeks to bridge that gap to help researchers, policy makers, landfill operators and the general public to improve upon existing landfill management. The types, operational practices and the challenges of the landfill management were the main areas touched upon in this study. Three (3) landfill strategies were identified as final disposal sites for collected Municipal Solid Waste. Kpone engineered landfill, Abokobi controlled dump and Nkanfoa open dump sites were the three main landfill sites that were selected.[1]

Objective

The most common way by which municipal solid waste is disposed in Ghana is through landfilling, and this according to the Environmental Protection Agency is due to its low cost and convenience. However, as a result of improper design and poor operational practices of these landfills, it has resulted in environmental problems such as surface and ground water pollution, bad odor and prevalence of disease vectors.

The main objective of this study is to assess current development and operational practices of landfills in Ghana are:

- Describe the types of landfills currently in operation
- Identify operational practices associated with the landfill types
- Determine operational cost of landfilling
- Identify the challenges of landfill operations

Types of Landfill Sites

In Ghana, landfills are grouped into four categories;

- **Open dumps** - Unimproved, inappropriate dump sites, often found in valleys
- **Improved dumps** - Usually fenced, have site drainage and separation of special or hazardous wastes
- **High Density Aerobic (HDA)** - Waste is spread out widely over site, with extra compaction and leachate recirculation
- **Sanitary landfills**- There is daily cover, impermeable liner, leachate treatment and gas management

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[1]*https://article.sciencepublishinggroup.com/html/10.11648.j.ijees.20160101.14.html*

Technical Activities at the Landfill Site

Municipal solid waste disposal practices in Ghana in the past have not been environmentally friendly. Landfills in Ghana are usually located in ecologically or hydrological sensitive areas. They are generally operated below the recommended standards of sanitary practice. Municipal and budgetary allocations for operation and maintenance are inadequate. The result is substandard and unsafe facilities which pose public health and aesthetic burdens to the citizens they are meant to serve. It is estimated that throughout the country only about 10% of solid wastes generated are properly disposed.

Operational Cost of Landfill Activities

Cost is a major driver and often a limitation for most landfill sites. The full cost of the site should be estimated by assessing the costs required for planning, operation, maintenance, administration, decommissioning and after care.

Landfill costs can be broken down into two (2) categories; capital costs and operating costs. Capital costs include land acquisition, professional services for design and the procurement of permits, machinery, and equipment purchases, site preparation and construction. Capital costs can range from 25% to 50% of the total lifetime costs of a landfill. Capital costs are usually paid by a public entity.

Operating costs are all costs associated with the day-to-day operation of the landfill. These range from salaries and wages to equipment maintenance and repairs. Ideally these costs should be covered through tipping fees from users of the landfill.

Capital cost is usually fixed cost, since it is set during the course of landfill operations. Operation cost on the other hand is a variable cost because it is a function of rate and magnitude of waste requiring disposal.

Methodology

Profile of Study Areas

The landfill sites serving three Metropolitan areas were used for this study. The Greater Accra Metropolitan Area (GAMA) with a total land area of 200 square km was the first metropolitan selected. With a population of four million, it is the second largest conglomeration in Ghana and the eleventh largest metropolitan area in Africa. Approximately 2000 metric tons of waste are generated daily in the city, however only 1200 to 1300 tons are properly collected and disposed.

The Team Metropolitan area, which is east of GAMA is the second metropolitan selected. Team, the biggest city in the metropolis, houses a lot of industries and factories, as well as a port being used as a hub for exports and imports. The total waste collected is 70% of the total generated waste in the metropolis.

The third metropolitan area, Cape Coast Metropolis has a population of 169,894. It covers an area of 122 square kilometers and it is the smallest metropolis in Ghana. Waste generation per day is about 250 tons with 138.6 tons collected and disposed.

Data Collection

Two kinds of data were collected for the study, although primary data was the main type used. The primary data were collected with the use of oral interviews, questionnaire, and site visits.

The researchers also contacted the Director of Waste Management and Municipal Environmental Health Officers within the project study areas to obtain information on the types of landfills currently in operation, waste generation rate and companies operating the landfills.

A questionnaire, targeting landfill managing companies, was designed to gather information on landfill management and operation. Acquired the list of companies managing landfills in their respective areas. Operational practices associated with the landfill types were obtained through site visits. In addition, secondary data regarding policies and landfill operational guidelines in Ghana were collected from written books and journal articles.

Study Sample Selection

Stratified random sampling technique was used to select landfills from the three metropolitan areas. The following characteristics were utilized for the sampling.

- Firstly, the landfills were chosen from three main types namely; engineered landfill, improved dump and open dump.
- After that, landfills were filtered out with diverse waste sources and different socio-economic groups utilizing it.
- Based on these criteria, three landfills were selected for the study. They were the Kpone engineered landfill, Abokobi improved dump and Nkanfoa open dump.

Data Analysis

Text, tables and graphs were used to describe the types of landfills and their operational practices and challenges of landfilling.

Results and Discussion

1. Types of Equipment Used at the Site
2. Waste Reception
3. Waste Deposition
4. General Site Management and Control
   i. Litter Control
   ii. Dust Control

iii. Surface Water and Leachate Management
iv. Landfill Gas Management
v. Landfill Fires
vi. Scavenging Activities
vii. Environmental Monitoring
viii. Recordkeeping
ix. Operational Cost

Challenges

Below challenges are faced at various level during landfill operational management.

Challenges faced by operators of engineered landfills.

- Frequent breakdown of equipment
- Lack of funds to run a more efficient operations
- Inability of government to pay contractors
- Daily covering of refuse
- Lack of technically skilled landfill workers

Challenges faced by operators of controlled and open dumps.

- Frequent breakdown of equipment
- Inaccessible roads in wet seasons
- Smoke from burning waste at the site
- Encroachment due to absence of fence
- Lack of lighting system to aid in night operations
- Uncontrolled leachate flow
- Dumping of liquid waste at the site

Conclusion

The study provides insight on operational practices of landfills in Ghana. The study identified open dumps, improved dumps and engineered landfills as the three landfill types in operation in Ghana. The following conclusions were drawn from the study:

- Most communities in municipalities and districts resort to open dumps for disposing their Municipal Solid Waste. It is predominant because it is convenient and less expensive to operate. Engineered landfills are operated only in Metropolitan areas.
- The location of landfill sites is a major concern. The study revealed that the landfills are sited close to water bodies, highways and schools.
- Operation and maintenance procedures were strongly adhered to in engineered landfills sites albeit the same cannot be said for open and improved dumps.
- Among the three landfill types, engineered landfills has the highest operational cost.
- Lack of funds to pay contractors and repair broken down vehicles, impassable roads and encroachment due to absence of fence are some of the challenges facing landfill operations in Ghana.

Based on the findings of this study, the following recommendations are made;

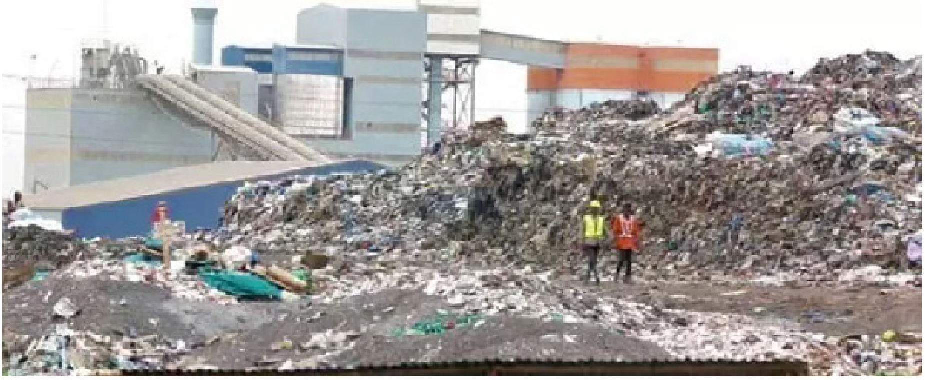
- The development of new landfills should be sited not too close to natural features, residential areas and institutions in order to have minimal negative impact on them.
- Waste streams must be sorted to encourage recycling and recovery of materials before being sent to the landfills as this practice would increase the life span of landfills.
- Public private partnerships schemes such as BOT etc. should be adopted to increase private sector involvement in the acquisition and developments of landfills as government alone cannot shoulder all the cost of building new landfills.
- The Environmental Protection Agency (EPA) should enforce the landfill operational guidelines to the latter by prosecuting MMDAs who have been flaunting the policy with impunity.
- Monitoring of landfills by MMDAs should be intensified to check private companies operating the landfills.
- Government should pay promptly management fees due private landfill contractors in order to adhere to basic operational controls and standards.
- Operators and mechanics of landfills should be trained to be abreast with modern trends of machine usage and repair and maintenance issues in order to reduce landfill operational cost.
- Compliant from the public on the operations of landfills should be taken seriously by the regulators in order to reduce "NIMBY syndrome" with regards to acquisition and development of new landfills.

Fig 9.2.Anaerobic pond for leachate treatment & gas extracting structure at Kpone dumpsite

Fig 9.3. Occurrence of fire at Abokobi dumpsite

Fig 9.4 Sampling of ground water wells for analysis

Fig 9.4. Kpone Landfill[2]



[2]*https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Waste-pickers-at-Kpone-landfill-site-cry-over-economic-challenges-1192840*

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List of Additional Materials

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Ministry of Housing and Urban Affairs
Government of India

SCIENTIFIC LANDFILL AVAILABILITY AND OPERATIONS