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Integrated Solid Waste Management: Principles, Disposal Methods, Public Health Implications, and Current Challenges—A Narrative Review

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ABSTRACT

Solid waste management (SWM) is an essential component of environmental sanitation and public health. Rapid urbanization, industrialization, population growth, and changing consumption patterns have led to a substantial increase in the quantity and complexity of solid waste generated worldwide. Inadequate waste management practices contribute to environmental pollution, contamination of water resources, greenhouse gas emissions, and the spread of communicable diseases. Integrated Solid Waste Management (ISWM) provides a systematic approach encompassing waste generation, segregation, collection, transportation, processing, recycling, treatment, resource recovery, and environmentally safe disposal. This narrative review discusses the classification and functional elements of solid waste management, conventional methods of waste treatment and disposal, and their environmental and public health implications. The review also highlights the current status of solid waste management in India, major regulatory initiatives, and existing challenges in achieving sustainable waste management. Strengthening waste segregation, improving recycling infrastructure, promoting public participation, and adopting scientific waste management practices are essential for protecting public health and ensuring environmental sustainability.

Keywords: Solid waste management; Integrated solid waste management; Municipal solid waste; Public health; Recycling; Sanitary landfill

1. INTRODUCTION

Solid waste management is an indispensable element of environmental health and sustainable development. The accelerated pace of urbanization, industrialization, population growth, and evolving lifestyles has led to a continuous increase in both the volume and complexity of solid waste generated globally. Inefficient waste management practices, such as open dumping and uncontrolled burning, significantly contribute to environmental pollution, greenhouse gas emissions, water resource contamination, and heightened risks of communicable and vector-borne diseases.

Solid waste encompasses discarded materials originating from residential, commercial, industrial, agricultural, healthcare, and institutional activities. Its constituents include biodegradable waste, recyclable materials, hazardous waste, construction debris, electronic waste, and biomedical waste. Effective management of these diverse waste streams is crucial for safeguarding public health, conserving natural resources, and maintaining environmental sustainability. ISWM emphasizes waste reduction, source segregation, collection, transportation, recycling, treatment, resource recovery, and environmentally safe disposal through an interdisciplinary approach.

India faces substantial challenges in municipal waste management owing to increasing urbanization, escalating waste generation, inadequate source segregation, and limited treatment infrastructure. Initiatives such as the Solid Waste Management Rules, 2016, and the Swachh Bharat Mission have improved waste management practices; however, increased public participation, technological innovation, and efficacious implementation are vital for sustainable management.

This review provides a comprehensive overview of ISWM, including waste classification, functional components, treatment and disposal technologies, public health implications, government policies, and emerging technological solutions for sustainable waste management.

2. DEFINITION AND OBJECTIVES OF SOLID WASTE MANAGEMENT

Solid waste refers to unwanted or discarded materials produced by human and animal activities that are no longer deemed useful. It includes household refuse, commercial waste, industrial waste, agricultural residues, biomedical waste, electronic waste, and construction debris. Waste management is defined as the systematic process of waste generation, segregation, storage, collection, transportation, processing, recycling, treatment, and final disposal, aimed at protecting human health and the environment while promoting sustainable resource utilization.

The principal goal of solid waste management is to safeguard human health and the environment through the secure collection, treatment, recycling, and disposal of waste materials. It seeks to minimize waste production, conserve natural resources, mitigate pollution, facilitate resource recovery, and support environmental sustainability via responsible waste management practices.

3. CLASSIFICATION OF SOLID WASTE

Solid waste is categorized according to its source and characteristics. Municipal solid waste (MSW) includes waste generated from households, commercial entities, institutions, and public spaces, comprising food waste, paper, plastics, glass, metals, and textiles. Industrial waste originates from manufacturing processes and may contain hazardous chemicals, heavy metals, and industrial sludge. Biomedical waste is produced during diagnosis, treatment, or immunization procedures and requires specialized handling due to its infectious potential. Hazardous waste includes toxic, corrosive, flammable, or reactive substances, while electronic waste (e-waste) consists of discarded electrical and electronic equipment containing both valuable recyclable materials and hazardous constituents.

4. FUNCTIONAL ELEMENTS OF INTEGRATED SOLID WASTE MANAGEMENT (ISWM):

ISWM comprises six functional components that facilitate the systematic management of waste from its inception to final disposal.

4.1 Waste Generation

Waste generation pertains to the production of solid waste originating from residential, commercial, industrial, agricultural, and healthcare activities. The volume and composition of waste are influenced by factors such as population growth, urbanization, economic development, and consumption patterns. Source reduction remains the most effective strategy for sustainable waste management.

4.2 On-site Handling, Segregation, and Storage

Waste should be segregated at the source into biodegradable, recyclable, hazardous, and sanitary fractions to enhance recycling efficiency and reduce environmental impact. Proper storage in covered, color-coded containers minimizes odors, vector breeding, and occupational hazards.

4.3 Collection

The collection process involves the regular removal of segregated waste from households and institutions. Door-to-door collection is considered the most effective approach, as it promotes source segregation, improves collection efficiency, and curtails indiscriminate dumping.

4.4 Transfer and Transportation

Collected waste is transported to treatment or disposal facilities using covered vehicles to prevent littering, odors, and environmental contamination. Modern logistics increasingly employ GPS and GIS-based route optimization to enhance operational efficiency.

4.5 Processing and Resource Recovery

Processing includes the recovery of recyclable materials and the treatment of biodegradable waste through composting, anaerobic digestion, and other methods. Resource recovery reduces landfill burden, conserves natural resources, and advances a circular economy.

4.6 Final Disposal

Residual waste that cannot be recycled or recovered is disposed of in engineered sanitary landfills designed to minimize environmental pollution through leachate management, landfill gas control, and continuous environmental monitoring.

Image 1: AI-modified image depicting of the solid waste management cycle

5. METHODS OF SOLID WASTE DISPOSAL AND MANAGEMENT

5.1 Dumping:

Refuse dumped in low-lying areas is often used to reclaim land or, more commonly, as a quick, inexpensive way to dispose of dry waste. Bacterial activity reduces waste volume and slowly transforms it into humus, but this method has faced strong criticism. The WHO Expert Committee (1967) called dumping "a most insanitary method that creates public health hazards, a nuisance, and severe environmental pollution." The issues are complex: exposed waste attracts flies and rodents, foul odour and unsightly heaps cause community discomfort, loose refuse can be blown away by wind, and drainage from dumps pollutes surface and groundwater. Although dumping may seem convenient, it harms environmental balance and public health, making it an unsuitable practice for modern waste management.

5.2Sanitary Landfills/ Controlled Tipping:

Landfilling involves the controlled disposal of solid waste on or in the upper layer of the earth's mantle. It's a Simple, cheap, and effective method of disposal of waste. The principal methods used for landfilling in dry areas may be classified as (1) Area, (2) Trench, (3) Depression.

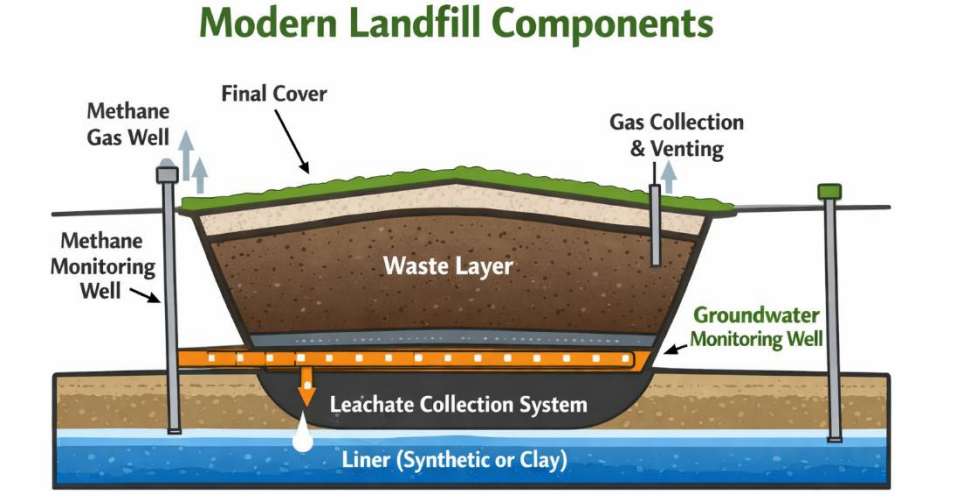

Image 2: AI- modified image depicting of Modern Landfill Components

The **area method of sanitary landfilling** is applied in regions where the terrain does not permit trench excavation. The process begins with the construction of an earthen bund, against which solid waste is deposited in successive thin layers and compacted until it reaches a height of about 2–3 m. At the end of each working day, the compacted waste is covered with a 150–300 mm layer of soil to control odor, litter, insects, rodents, and fire hazards. The cover material is

usually transported from nearby land or borrow pits using trucks or earth-moving equipment. Once the landfill attains its planned elevation, a final soil cover is placed to seal the surface, stabilize the site, and prepare it for future land use.

Trench Method: A deep trench, typically 3 to 5 meters deep, is excavated. Refuse is then laid in layers within the trench. Each layer is compacted using mechanical equipment and covered with earth, which is leveled and further compacted. Over time, the fill settles as microorganisms act on the organic matter, breaking it down. The decomposition process is similar to composting. Facultative bacteria hydrolyze complex organic matter into simpler, water-soluble compounds. These diffuse through the soil, where fungi and other bacteria convert them into carbon dioxide and water under aerobic conditions. Aerobic methanogenic bacteria use some of the methane generated, while the remainder escapes into the atmosphere. The depth of refuse is generally limited to 2 meters; exceeding 3 meters can lead to dangerous combustion due to compression of the bottom layers and should be avoided. During the initial stages of decomposition, temperatures can reach as high as 70°C before dropping. Eventually, reclaimed areas may be used for other purposes.

Depression Method: At sites where natural or artificial depressions exist, such as canyons, ravines, borrow pits, or quarries, these areas can be effectively utilized for landfilling operations. The method of placing and compacting solid waste in depression landfills depends on the site's geometry, the properties of the cover material, local hydrology and geology, and accessibility.

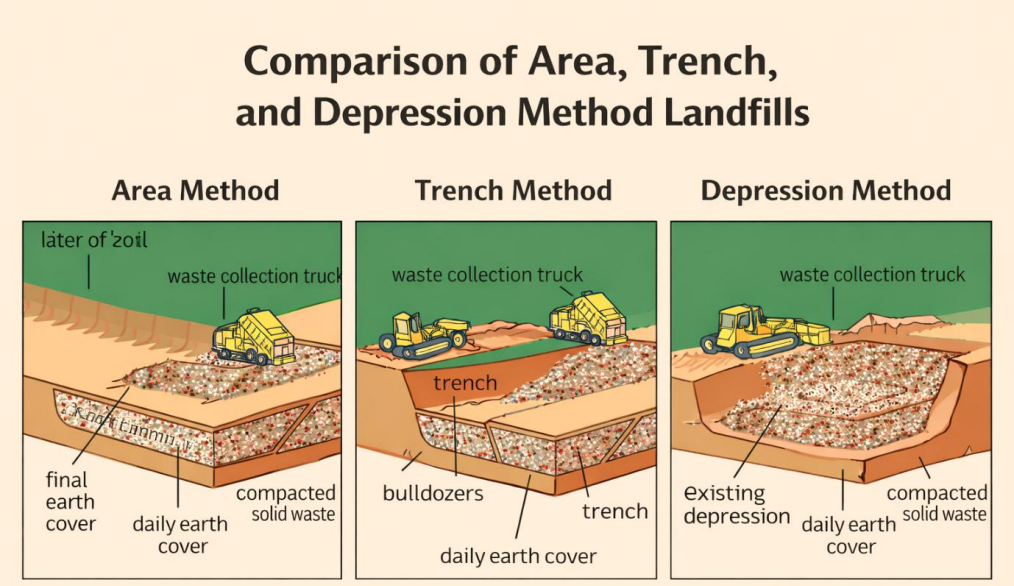

Image 3: AI- modified image depicting modern landfill methods

5.3 Incineration:

- It is a method of choice where suitable land is not available.
- particularly dangerous Hospital refuse is best disposed of by this method.
- It is not a popular method in India because the refuse contains a fair proportion of fine ash which makes the burning difficult. A preliminary separation of dust or ash is needed.

- All this involves heavy outlay and expenditure, besides manipulative difficulties in the incinerator.
- Further, disposal of refuse by burning is a loss to the community in terms of much needed manure.
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5.4 Composting

- Composting is defined as a process in which organic matter of the solid waste is decomposed and converted to humus and stable mineral compounds.
- The end product of composting process is called compost which is rich fertilizer.
- Popular method in developing countries
- There are three methods of composting:
  (1) Composting by Trenching
  (2) Open window composting
  (3) Mechanical Composting

1) Composting By Trenching:

- In this method, trenches of 3 to 12 m long, 2 to 3 m wide and 1 to 2 m deep are excavated with clear spacing of 2 m. The trenches are then filled up with dry solid waste in layers of 15 cm.
- On top of each layer 5 cm thick sandwiching layer of night soil, animal dung is spread in semi liquid form.
- On the top layer which is protruding about 30 cm above the surrounding ground layer, a layer of earth having thickness of around 10 cm is laid so that there is no problem of flies.
- Intensive biological action starts in 2 to 3 days and organic matter decomposition starts. In this process considerable heat is generated and temperature of the composting mass rises upto 70 C. Due to this fly breeding does not take place.
- The solid waste stabilizes in 4 to 6 months and get changed into a brown coloured, odourless, innocuous powdery form known as humus having high manure value because of nitrogen content.
- The stabilized mass is then removed from trenches screened to remove coarse inert materials like stones brick bats, glass pieces plastic articles

Indore Method

- In this method, solid waste, night soil and animal dung etc. are placed in brick lined pits 3 m x 3 m x 1 m deep in alternate layers of 7.5 to 10 cm height, till the total height becomes 1.5 m.
- Chemical insecticides are added to prevent fly breeding.
- The material is turned regularly for a period of about 8 to 12 weeks and then stored on ground for 4 to 6 weeks. In about 6 to 8 turnings and period of 4 months time compost becomes ready for use as manure.
- Insecticide used in Indore method was DDT but now because of very high half life of DDT in nature other suitable insecticide is recommended, e.g. Gamaxine.

Banglore Method

- The solid waste is stabilized anaerobically.
- Earthen trenches of size 10 x 1.5 x 1.5 m deep are filled up in alternate layers of solid waste and night soil/cow dung. The material is covered with 15 cm earthen layer and left for biodegradation.
- In about 4-5 months the compost becomes ready to use

2) Open Window Composting:

- Refuse is placed in piles, about 1.5m high and 2.5m wide at about 60% moisture content.
- The piles are then covered with night soil, animal dung to supply necessary organisms for biodegradation.
- Heat build up in the refuse piles due to biological activity – temperature rises to about 70 degree C because of biological activities in the waste piles and microbial action shift from mesophilic to thermophilic stage.
- After this, pile is turned up for cooling and aeration to avoid anaerobic decomposition.
- The temperature of pile again rises to 70degree C and process of turning cooling and aeration are repeated.

3) Mechanical Composting

- Process of stabilization is expedited by mechanical devices of turning the compost.

- Mechanical devices are employed in turning the solid waste undergoing composting. The stabilization of the wastes takes only about 3 to 6 days.
- The operation involves:

(1) Reception and refuse
(2) segregation
(3) Shredding
(4) Stabilization
(5) Marketing the humus.

5.5 Vermicomposting

Vermicomposting is ideal for biodegradable wastes from kitchens, hotels, and similar sources. At the household level, a vessel or tray measuring about 1 × 0.60 m with a depth greater than 45 cm is sufficient. A hole should be provided at one end of the bottom to drain leachate into a tray or vessel. The base of the tray is first lined with a thick layer of gravel, followed by an old gunny bag or piece of thick cloth. On top of this, place coconut husk upside down, then add a thick layer of dry leaves and powdered cow dung. Biodegradable waste is laid over this bedding, and good-quality earthworms are introduced (approximately 10 g for a 0.6 × 0.45 × 0.45 m box). If the waste is dry, water should be sprinkled daily, while rainwater must be prevented from entering by keeping the box closed. Under bright sunlight, earthworms move downward, allowing compost to be collected from the top. The compost can be dried and stored, and waste should continue to be added regularly with small amounts of cow dung at intervals. Vermiwash, the liquid fertilizer obtained, should not be used directly but diluted in a 1:10 ratio before application

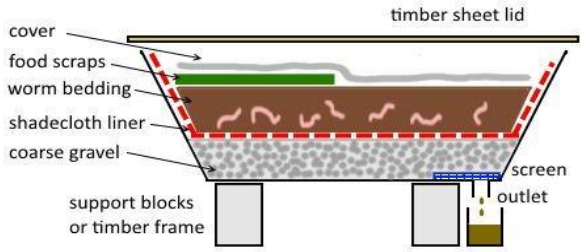

Image 7: Depicting vermicomposting

5.6 Salvaging

- Materials like paper, metal, glass, rags, certain types of plastic etc. can be salvaged, recycled, and reused

5.7 Manure Pits:

- In rural areas, where there is no system for collection and disposal of refuse, ‘manure pits’ can be digged by the individual householders.

- The garbage, cattle dung, straw and leaves should be dumped into the manure pits and covered with earth after each day's dumping.
- Two such pits will be needed, when one is closed, the other will be in use.
- In 5-6 month's time, the refuse is converted into manure which can be returned to the field.

5.8 Burial:

- This method is suitable for small camps.
- A trench 1.5 m wide and 2 m deep is excavated, and at the end of each day the refuse is covered with 20-30 cm of earth.
- When the level in the trench is 40 cm from the ground level, the trench is filled with earth and compacted, and a new trench is dug out. The contents may be taken out after 4-6 monthsand used on the fields.

6. WASTE AUDIT

- A waste audit is a method for analyzing an organization's waste stream.

Goal

- The goal is to discover what types and quantities of waste (paper, plastic, food etc.) you produce within a given timeframe—usually a week. Auditing also measures how much waste is recycled vs. thrown out

Steps To Conduct A Waste Audit

Step 1. Assemble A Team & Set A Date

- Find a volunteer from each department to form your waste auditing team. Aim for at least five people. Deirdre Fitzgerald of Badger Balm, a certified B Corp that holds audits every quarter, recommends making this group an ongoing "Sustainability Committee" who can oversee any changes you want to make as a result of your audit.
- Next, pick a week for the audit. You want a clear picture of your normal trash output, so choose a week without any special events and when most of your staff will be in the office. If you have outside custodial staff, make sure they know to hold off on emptying the trash that week

.

1. Determine Your Waste Categories

Before "Waste Audit Week" rolls around, make a list of the most common trash types your business produces. This list can be general for now—if the audit reveals different categories, you can always add them to the list as you go.

Common Waste Audit Categories:

- Paper
- Cardboard
- Plastic bottles
- Other plastic
- Aluminum cans
- Glass
- Food waste
- Materials packaging
- Signage
- Display materials

2. Gather Your Tools

Before the main event, you'll need to stock up on a few supplies to make sure your team can work safely.

Tools Needed for a Waste Audit:

- An open area for sorting the trash.
- Rubber gloves for each volunteer.

- Face masks for each volunteer.
- Labelled boxes for sorting each waste category.
- A bathroom scale for weighing each category.
- Clipboards for recording your findings.
- Trash bags for re-bagging your waste after the audit.

ANALYZE YOUR RESULTS

Now that you've recorded all weights, you can use this data for a waste stream analysis.

1. Calculate and record your waste diversion rate using this process:

- Divide the weight of your recyclables by the combined weight of all your waste (trash + recyclables).
- Multiply the result by 100.
- This gives you the percentage of waste you divert from the landfill each week.

2. Look at the weights you recorded for individual waste categories.

- Which categories are highest?
- Did the highest categories differ between departments?
- Did you find any recyclables mixed in with the trash?
- Were there categories you didn't realize you had?

3. Sort Your Trash

1. At the end of the week, round up all the trash and recycling from your building.
2. If you'd like to gather department-specific data, label each trash bag with the department it came from.
3. Weigh all the trash to get a baseline for how much you throw out each week.
4. Weigh all the recyclables to establish how much you recycle each week.
5. Wearing gloves, sort all materials into the boxes for their categories. If you labelled your trash by department, make sure each has separate boxes.
6. As you work, note any recyclables mixed in with trash.
7. Once everything has been sorted, weigh each category.

Public Health Aspect

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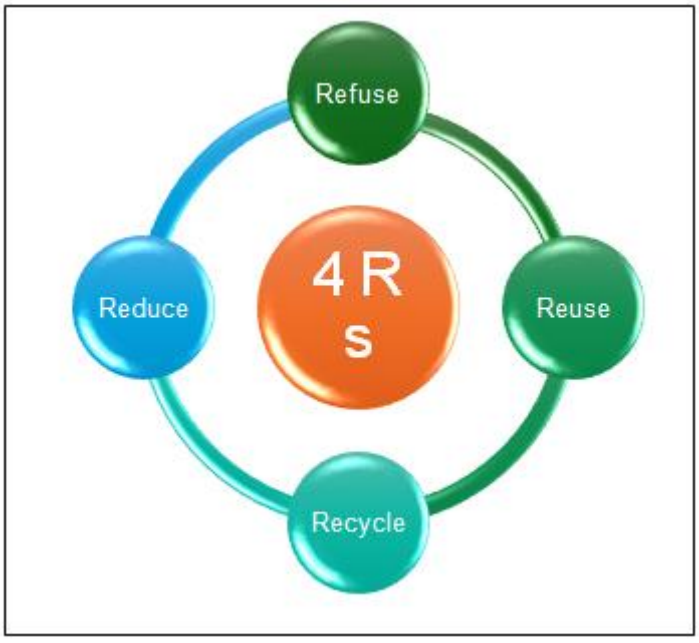
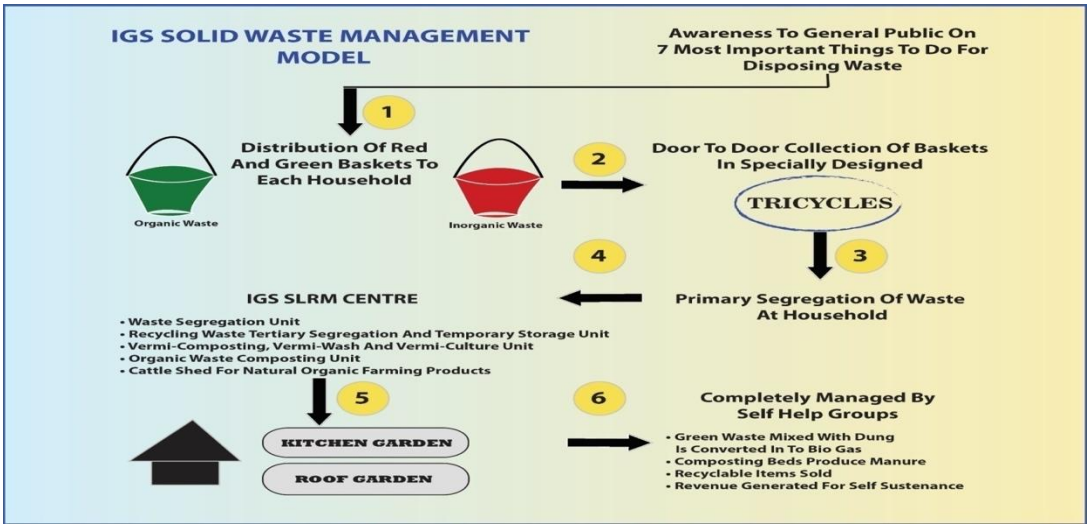


- **Refuse**
  - Refuse to buy new items
  - e.g. instead of buying new containers from the market use the ones that are in the house.
- **Reuse**
  - Do not throw away the soft drink cans or the bottles and use them as pencil stands or small vases.
- **Recycle**
  - Use shopping bags made of cloth or jute, which can be used over and over again.
  - Segregate your waste to make sure that it is collected and taken for recycling.

- **Reduce**
  - Reduce the generation of unnecessary waste.
  - e.g. carry your own shopping bag to the market and put all your purchases directly into it.

ZERO WASTE SYSTEM



CHALLENGES OF MSW OF INDIA

(1) Awareness to enhance segregation:

- Ecological awareness and citizen participation to segregate waste at source, door-to-door collection, and disposal in appropriate collecting bin is imperative.
- The awareness plays an important role in MSWM and augments the efficiency of waste management stream. It is the most critical phase in the whole process of MSWM, which helps in handling solid waste leading to ultimate success.

However, in India, the present scenario reveals that there is almost no segregation of garbage at source which leads to various environmental problems and it becomes very difficult to segregate waste at transfer station or in landfill or treatment site

(2) Characterization of municipal solid waste:

- India is a vast country divided into different climatic zone, different food habits, and different living standard thereby producing waste of different types.
- The policy-makers rely on the limited source of information available from few places thereby are unable to provide appropriate solutions for the kind of waste produced for a particular region

(3) Urbanization and lack of appropriate level funding:

- With the population growth, challenge to provide adequate infrastructure in urban area and new landfill site selection is important.
- Most of the landfill sites are running beyond their capacity in metropolitan cities. Inadequate financial support to cater to waste management problem aggravates it.

(4) Implementation of rules at ground level:

- ULBs hasnt implemented MSWR adequately as revealed by various government reports.

(5) Resistance for notification of new landfill site:

- There is resistance of local citizen for notification of landfill site in their locality and therefore selection of new site is difficult and all the existing landfill sites are running beyond their capacity

(6) Lack of coordination among Centre and State:

- There is less dialogue between Central and State government. Delay in submission of information from State to Central delays appropriate level implementation at ground level. Such lack of coordination for specific action plan and poor strategy at implementation level by ULBs are main hindrance.

(8) Appropriate technological solution, Outsourcing and PPP:

- Lack of competency and insufficient financial support are major threats to ULBs for development of MSW infrastructure. There is need for PPP to implement management and handling with the latest technology/know-how with the subject experts firms and companies.
- Establishment of the good public governance in compliance with secured regulatory framework and appropriate financial support and strict contract implementation is required for the success of PPP
- (9) Involvement of organized sector:
- For improving MSW collection efficiency and source segregations, rag-pickers can be engaged through organized sector. However, due to lack of recycling industries and acceptance of society this vast potential has been ignored.

GOVERNMENT RULES AND POLICIES FOR SWM

The MoEFCC revised and notified the SWM Rules in April 2016, which replaces the Municipal Solid Waste (Management and Handling) Rules, 2000. The new rules have extended beyond the municipal jurisdiction.

It provides for waste generators to segregate waste at source and allocate dry waste such as paper, plastic, glass and metal for recycling and reuse, as well as utilize wet waste from the kitchen for composting or biomethanation.

- The local authorities are responsible for setting up "the material recovery facilities or secondary storage facilities with sufficient space for sorting of recyclable materials to enable informal or authorized waste-pickers and waste-collectors to separate recyclables from the waste and provide easy access to waste-pickers and recyclers for collection of segregated recyclable waste such as paper, plastic, metal, glass, textile from the source of generation or from material recovery facilities.
- The new rules prohibit waste generators from throwing, burning or burying solid waste in open public spaces, outside premises, or in drains and water bodies.
- Waste generators now have to pay a "user fee" to the waste-collector and a "spot fine" in case of littering and non-segregation. The rules enable ulbs to frame by-laws and prescribe the criteria for levying spot fines. The 2016 SWM rules further recommend biodegradable waste to be processed, treated and disposed of within the premises, through composting or biomethanation.

Swachh Bharat Mission (URBAN)

- The Swachh Bharat Mission (SBM) was launched by the Indian government on 2 October 2014 for five years (2014–19), aimed at creating a "Clean India" with an emphasis on eliminating open defecation by October 2019. The SBM addresses the growing problems of open defecation, sanitation, and SWM. It seeks people's participation in creating a trash-free environment, providing sanitation facilities and paving a way for Swachh Bharat.
- The Mission Directorate has taken several steps to help cities accelerate their progress of implementation. Some of the important initiatives under this are discussed below:

Conducting Swachh Survekshan:

Various rounds of Swachh Survekshan (SS) were conducted by the MoHUA to encourage citizen participation, ensure sustainability of initiatives taken towards garbage-free and open-defecation-free cities, institutionalise existing systems through online processes, and create awareness amongst all sections of society. The first round of the annual cleanliness survey was conducted in January 2016 across 73 cities; the second round was conducted in January–February 2017 across 434 cities. The third round was conducted in 2018 across 4,203 cities in 66 days, and became the largest-ever Pan-India Sanitation Survey in the world, impacting around 40 crore people. The fourth survey, SS-19, covered 4,237 cities in a record time of 28 days and was a fully digitised and paperless

Star Rating of Garbage-Free Cities:

To ensure continued scientific management of solid waste and motivate cities to achieve increased cleanliness, the MoHUA launched the Star-Rating Protocol of Garbage-Free Cities on 20 January 2018. The rating protocol is an outcome-based tool, not a process-based one. The single metric rating system, based on 12 parameters,[3] builds on the spirit of healthy competition amongst cities and the aspirations of cities to progress towards higher standards of "Swachhata" and sustainability.[xlviii] The most significant feature of the rating protocol is that it provides stakeholders with a single metric to rate a city's overall cleanliness.

Swachhata Hi Sewa Campaign:

The "Swachhata Hi Sewa" Campaign was launched on 15 September 2017, with the aim of ensuring cleanliness through the various stakeholders in the "*Jan Andolan*" (National Movement).

WASTE MANAGEMENT AGENCIES IN INDIA

1. Attero

- Attero is an E-waste management company. They spin around the unwanted electronics into sustainable resources. End of life electronics are recycled at their recycling units using disruptive technology. Attero recovers nearly 98% of high-quality minerals through its cutting edge technology. And they are India's largest producers of Tin.
- Their services are data security, take back action, recycling, upcycling, reverse logistics, and extended producer responsibility compliance. Some of their clients are LG, Acer, Whirlpool, OPPO, Nexcharge, etc.

2. Synergy Waste Management Pvt. Ltd.

- Synergy Waste Management is one of the best biomedical **waste management companies in India**. With twenty years of experience, they are serving more than 8,000 hospitals in India with economically sustainable structural models. They have set up eight Common Bio-medical Waste Treatment and Disposal Facilities (CBWTF) in different states across India with their resources and capabilities. Their projects are set up in Hisar, Meerut, Barabanki, Bhagalpur, Gaya.

3. Eco-Wise Waste Management Pvt. Ltd.

- Eco-Wise Waste Management offers commercial waste management, industrial waste management, residential Waste Management, document destruction, product destruction, and purchase of scrap. They have offices in Greater Noida, Bangalore, and Mewat.

4. Sampurn (E)Arth Environment Solutions Pvt. Ltd.

- Sampurn (e)arth Environment Solutions Pvt. Ltd. provides solid waste management services to housing societies, corporate, educational campuses, and municipal corporations. Some of their clients include the Tata Group Companies, Coca Cola, Unilever, Bhabha Atomic Research Centre, and even the Mumbai Railway Vikas Corp.

5 Greenobin Recycling Pvt. Ltd.

- Greenobin Recycling Pvt. Ltd. is a leading paper **waste management company in India**. They offer a wide range of services like waste audits, training programs, recycling bins, eco fair, recycled paper products etc.

6 Namo Ewaste Management Ltd.

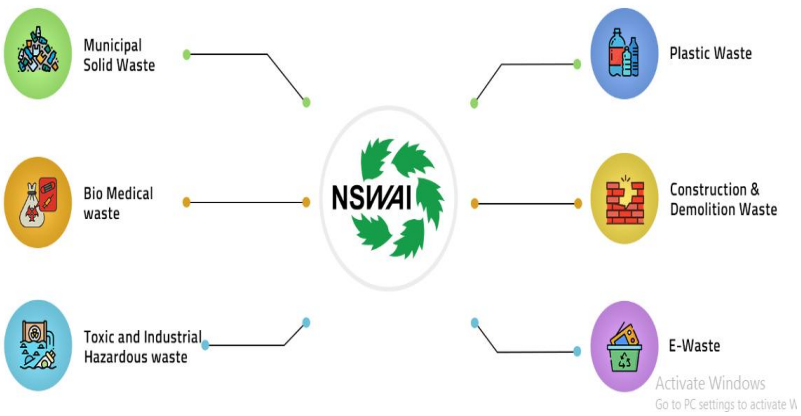
- Namo eWaste Management Ltd. is on a mission to make e-waste disposal sustainable and clean across the country. They provide door-to-door services to collect and transport the e-waste to their recycling facility.

NSWAI

Established in the year 1996, the National Solid Waste Association of India (NSWAI) is one of its kind and the only leading organization in India in the field of Solid Waste Management.

NSWAI was envisioned by Dr Amiya Kumar Sahu to address the pervasive deep-rooted problems and challenges associated with Solid Waste Management.

NSWAI's contributions have been recognized across international institutions such as UNEP, United Nations Development Program (UNDP) and several national systems such as the Bureau of Indian Standard, Planning Commission of India (now known as Niti Aayog) to name a few. The range of topics covered in years included waste management, waste-to-energy, waste management rules and guidelines, monetizing garbage and climate change.



EMERGING CHALLENGES FOR SWM

1. Data on the quantum of waste generation in India is conflicting, since there is no system of periodic data collection on waste generation. Consequently, the estimations and projections of solid waste vary wildly from one agency to the other.
2. SWM Rules 2016 mandate the segregation of waste at the household level, i.e. waste generators must segregate the waste into the three categories: biodegradable, non-biodegradable and hazardous waste. Thereafter, the segregated waste must be handed over to the authorised waste-collectors.
3. Research has shown that waste collection efficiency is low in India, due to non-uniformity in the collection system. Waste collection efficiency is 100 percent only in those areas where private contractors and non-governmental organisations are actively involved.
4. Most cities and towns in India dispose of their waste by depositing it in low-lying areas outside the city, without taking adequate precautions. Research shows that there is no land available for landfill. Since ULBs do not have the resources to acquire new land, finding new land becomes a major challenge.

ANNUAL REPORT 2020-21 ON IMPLEMENTATION OF SOLID WASTE MANAGEMENT RULES, 2016

BACKGROUND:

- In accordance with the Provision of the Solid Wastes Management Rules, 2016, the Central Pollution Control Board (CPCB) is required to prepare a Consolidated Annual Report (CAR) and forward it to the Central Government (Ministry of Environment, Forests and Climate Change) along with suggestions/ recommendations.
- During 2020-21, 35 SPCBs/PCCs have submitted Annual Reports in compliance of Solid Waste Management Rules, 2016.

  OVERALL SOLID WASTE MANAGEMENT STATUS :
- The total quantity of Solid waste generated in the country is 160038.9 TPD of which 152749.5 TPD of waste is collected at a collection efficiency of 95.4%. 79956.3 TPD (50 %) of waste is treated and 29427.2 (18.4%) TPD is landfilled. 50655.4 TPD which is 31.7 % of the total waste generated remains un-accounted

Table 1.0: OVERALL SOLID WASTE MANAGEMENT STATUS

Sl. No.	State	Solid waste generated (TPD)	Collected (TPD)	Treated (TPD)	Landfilled (TPD)
1.	Andhra Pradesh	6898	6829	1133	205
2.	Arunachal Pradesh	236.51	202.11	Nil	27.5
3.	Assam	1199	1091	41.4	0
4.	Bihar	4281.27	4013.55	Not provided	No
5.	Chhattisgarh	1650	1650	1650	0
6.	Goa	226.87	218.87	197.47	22.05
7.	Gujarat	10373.79	10332	6946	3385.82
8.	Haryana	5352.12	5291.41	3123.9	2167.51
9.	Himachal Pradesh	346	332	221	111
10.	Jammu & Kashmir	1463.23	1437.28	547.5	376

(A) Trends In Solid Waste Management

- Per capita solid waste generation has been calculated for the last six years and is given in Table 2.0.

Table 2.0: SOLID WASTE GENERATION PER CAPITA

Year	Solid Waste Generation Per Capita(gm/day)
2015-16	118.68
2016-17	132.78
2017-18	98.79
2018-19	121.54
2019-20	119.26
2020-21	119.07

The trend in per capita waste generation is illustrated in Figure 1. Marginal decreasing trend is observed in per capita solid waste generation over the last six year

(B) Solid Waste Processing

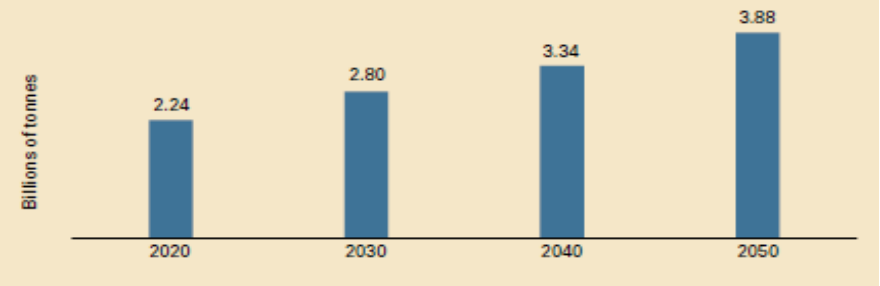
Trend of percentage solid waste processed during the last 2015-21is illustrated in Figure 2. Increasing trend in percentage of solid waste processed has been observed during the last five years wherein percentage of solid waste processed has increased from 19% in 2015-16 to 49.96% in 2020-21.

C. Trend In Solid Waste Landfilled:

Trend of percentage solid waste landfilled during 2015-21is illustrated in Figure 3. Decreasing trend in solid waste landfilled has been observed during the last six years wherein solid waste landfilled has decreased from 54% in 2015-16 to 18.4% in 2020-21.

WHAT A WASTE 2.0: A GLOBAL SNAPSHOT OF SOLID WASTE MANAGEMENT TO 2050

- What a Waste is a global project to aggregate data on solid waste management at the national and urban levels around the world. This database features the statistics collected through the effort, covering nearly all countries and over 330 cities.
- By 2050, the world is expected to generate 3.40 billion tons of waste annually, increasing drastically from today's 2.01 billion tons.
- It estimates and projects waste generation to 2030 and 2050
- Beyond the core data metrics from waste generation to disposal, the report provides information on waste management costs, revenues, and tariffs; special wastes; regulations; public communication; administrative and operational models and the informal sector.
- In 2020, the world was estimated to generate **0.79** kg of waste per capita per day, with volumes generally correlated with income levels, and varying drastically across regions.
- figure has risen from the **0.74** kg/capita/ day reported in *What a Waste 2.0* for 2016, reflecting growth in generation as well as updated data.
- Across the world, an estimated **2.24** billion metric tons (tonnes) of municipal solid waste was expected to be generated in 2020. The residual fraction – which includes waste that is landfilled, incinerated or otherwise ultimately disposed – is estimated to be **1.86** billion tonnes.
- The total amount of waste generated is expected to grow to **3.88** billion tonnes by 2050 under a business-as-usual scenario, which represents a **73%** increase from 2020 or **93%** compared to the waste generations estimates in 2016 in *What a Waste 2.0*. By 2050, global waste generation is expected to stand at **1.09** kg of waste per capita per day, on average.



Economics And Finance

- It refuse disposal is to be carried out efficiently, hygienically and economically, heavy capital outlay will be needed whatever system of disposal is adopted.
- In the highly industrialized countries up to 20% of municipal budgets are spent on the collection and disposal of solid wastes, and even more will be required if the job is to be done adequately.

International Cooperation

- An organization was formed- the International Solid Wastes and Public Cleansing Association (ISWA) in 1970, to assist countries in the general endeavor to improve sanitary services.
- A WHO International Reference Centre has also been set up in Switzerland to collect, evaluate and disseminate information on wastes- disposal practices and to foster research.

SUMMARY & CONCLUSION

- Public awareness should be created.
- Littering of solid waste should be prohibited.
- House to house collection of solid wastes should be done.
- The collection bins must have a large enough capacity to accommodate 20% more than the expected waste generation in the area.
- Municipal authorities should maintain the storage facilities to avoid unhygienic and unsanitary condition.

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