Solid waste treatment:

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Introduction:

Due to rapid increase in the production and consumption processes, societies generate as well as reject solid materials regularly from various sectors – agricultural, commercial, domestic, industrial and institutional. The considerable volume of wastes thus generated and rejected is called solid wastes. In other words, solid wastes are the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted. This inevitably places an enormous strain on natural resources and seriously undermines efficient and sustainable development. One of the ways to salvage the situation is through efficient management of solid wastes, and this is the focus of this Course, Management of Municipal Solid Waste. In the 10 Units that constitute this Course, we will discuss the processes involved in the management of solid wastes – from waste generation to final disposal.

CLASSIFICATION OF SOLID WASTES

Solid wastes are the organic and inorganic waste materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen refuse, paper, appliances, paint cans, batteries, etc., produced in a society, which do not generally carry any value to the first user(s). Solid wastes, thus, encompass both a heterogeneous mass of wastes from the urban community as well as a more homogeneous accumulation of agricultural, industrial and mineral wastes.

1.1.1 Source-based classification

(i) **Residential:**

(ii) **Commercial:**

(iii) **Institutional:**

(iv) **Municipal:**

(v) **Industrial:**

(vi) **Agricultural:**

1.1.2 Type-based classification

(i) **Garbage:**

(ii) **Ashes and residues:**

(iii) **Combustible and non-combustible wastes:**

(iv) **Bulky wastes:**

(v) **Street wastes:**

(vi) **Biodegradable and non-biodegradable wastes:**:

Table 1.1 Biodegradable and Non-Biodegradable Wastes: Degeneration Time

Category	Type of waste	Approximate time taken to degenerate
Biodegradable	Organic waste such as vegetable and fruit peels, leftover foodstuff, etc.	A week or two.
	Paper	10–30 days
	Cotton cloth	2–5 months
	Woollen items	1 year
	Wood	10–15 years
Non-biodegradable	Tin, aluminium, and other metal items such as cans	100–500 years
	Plastic bags	One million years
	Glass bottles	Undetermined

From Table 1.1, we can easily deduce the environmental consequences associated with non-biodegradable wastes such as plastics, glass, etc.

(vii) **Dead animals:**

(viii) **Abandoned vehicles:**

(ix) **Construction and demolition wastes:**

(x) **Farm wastes:**.

(xi) **Hazardous wastes:**

(xii) **Sewage wastes: Table 1.2 Classification of Solid Wastes**

1.2 SOLID WASTE MANAGEMENT (SWM)

Solid waste management (SWM) is associated with the control of waste generation, its storage, collection, transfer and transport, processing and disposal in a manner that is in accordance with the best principles of public health, economics, engineering, conservation, aesthetics, public attitude and other environmental consideration

1.2.1 SWM system

A SWM system refers to a combination of various functional elements associated with the management of solid wastes

(i) **Waste generation:**

(ii) **Waste storage:**

(iii) **Waste collection:**

(iv) **Transfer and transport:**

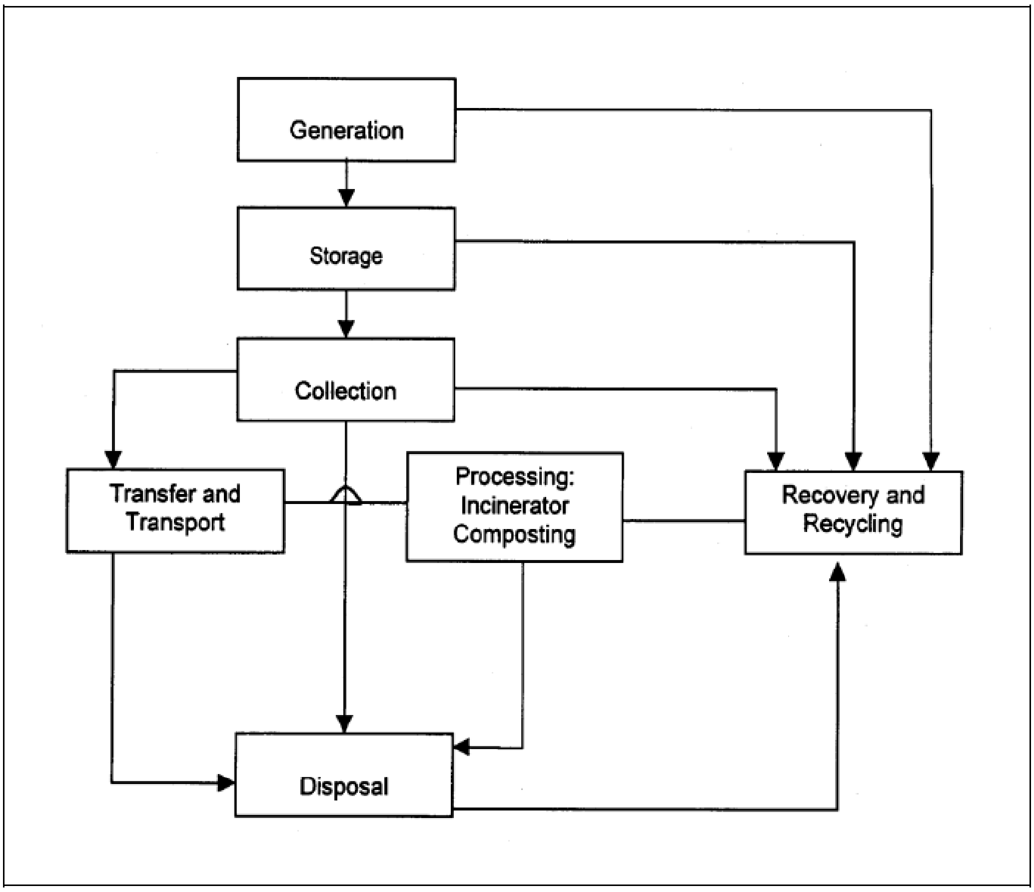
(v) **Processing:**

(vi) **Recovery and recycling:**

(vii) **Waste disposal:**

In Figure 1.1 below, we show you a typical SWM system with its functional elements and linkages:

Figure 1.1 Typical SWM System: Functional Elements



1.2.2 ESSWM and EST

We must recognize that each functional element discussed in Subsection 1.2.1 is closely interconnected to minimize adverse impact of wastes on the environment and to maximize the ecosystem carrying capacity

Environmentally sound solid waste management (ESSWM)

In any waste or resource management system, we must pay attention to the interaction between human activities and the ecosystem.

Environmentally sound technologies (EST)

EST refers to cost effective and energy efficient technologies, which generally perform better on the environment

Hard EST: This includes equipment, machines and other infrastructure with their material accessories to handle waste products and monitor/measure the quality of air, water and soil.

Soft EST: This supports and complements hard technologies and include *nature-based technologies and management tools*.

Affordability: This means low investment, reasonableness, maintenance-free and durability.

Validity: This refers to effectiveness, easy operation and maintenance.

Sustainability: This means low impact, energy saving and cultural acceptability.

Examples of EST for collection and transfer of Waste

Set-out container is one of the major factors that most collection system depends on. This is usually a paper or plastic bag,

1.2.3 Factors affecting SWM system

(i) **Quantities and characteristics of wastes:** The quantities of wastes generated generally depend on the income level of a family,

(ii) **Climate and seasonal variations:** There are regions in extreme north (> 70 N Latitude) and south (> 60 S Latitude), where temperatures are very low for much of the year.

(iii) **Physical characteristics of an urban area:** In urban areas (i.e., towns and cities), where the layout of streets and houses is such that access by vehicles is

(iv) **Financial and foreign exchange constraints:** Solid waste management accounts for sizeable proportions of the budgets of municipal corporations.

(v) **Cultural constraints:** In some regions, long-standing traditions preclude the intrusion of waste collection on the precincts of households, and therefore, influence the collection system.

(vi) **Management and technical resources:** Solid waste management, to be

Figure 1.7 below, gives an indication of sampling points along the waste management chain.

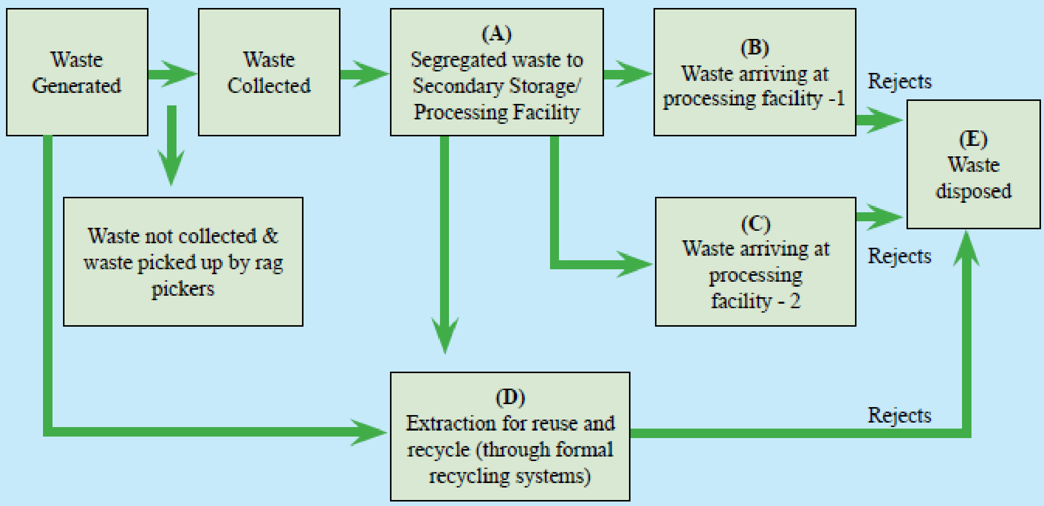


Figure 1.7: Waste Flow Diagram Depicting Points of Quantification[14]

Physical Characteristics of Municipal Waste

1. Density of Waste

Method for Bulk Density Measurement

Materials and Apparatus:

zz Wooden box of l m3 capacity

zz Wooden box of 1 ft3 capacity

Spring balance weighing up to 50 kg

Procedure: ------

2. Moisture Content

$$\text{Moisture Content (\%)} = \frac{\text{Wet weight} - \text{dry weight}}{\text{Wet weight}} \times 100$$

3. Calorific Value

Calorific value of waste is defined as the amount of heat generated from combustion of a unit weight of the waste, expressed as kJ/kg.

4. Bio-Chemical Characteristics

Chemical characteristics of waste are essential in determining the efficacy of any treatment process.

zz **Chemical characteristics:**

zz **Bio-Chemical characteristics:**

zz **Toxicity: Estimates of waste generation:**

It is essential to

zz **Households:** domestic waste generated per capita per day

zz **Non-residential premises:** waste generated by

zz **Bulk waste generators:** estimated waste generation from

(c) Estimates of the cost

An analysis

zz Collection

depreciation cost

Cost per Metric Ton of waste collected/day

zz Transportation

zz Processing

zz Disposal

zz Administrative overheads Day to day office/staff expenditure

(d) Determine service options

The service levels selected to

zz Consumers

a. Door-to door

b. For bulk waste generators

c. For vegetable & fruit market waste

zz Public Places

Step: 2 Norms of fee fixation

Key considerations for prescribing a fee structure for provision of SWM services:

zz Surveys have indicated

zz 50% O&M cost in beginning and 100% in 3 years – general households

zz 25% O&M cost in beginning and 50% in 3 years – poor households Norms for Tariff Determination for Door to Door Collection zz Tariff for non-residential premises based on the size of the premises. e.g.:

zz Bulk waste generators/vegetable

zz No fee may

Step: 3 Communication with Consumers

To gain popular acceptance of solid waste

Step 4: Mechanisms for Recovery of Solid Waste Management User Charges

Use of Fiscal Instruments:

MSW management in Baghdad

Baghdad the capital city

Fig 1: Base Map of Baghdad City

In Iraq; it is the responsibility of each municipality to provide free

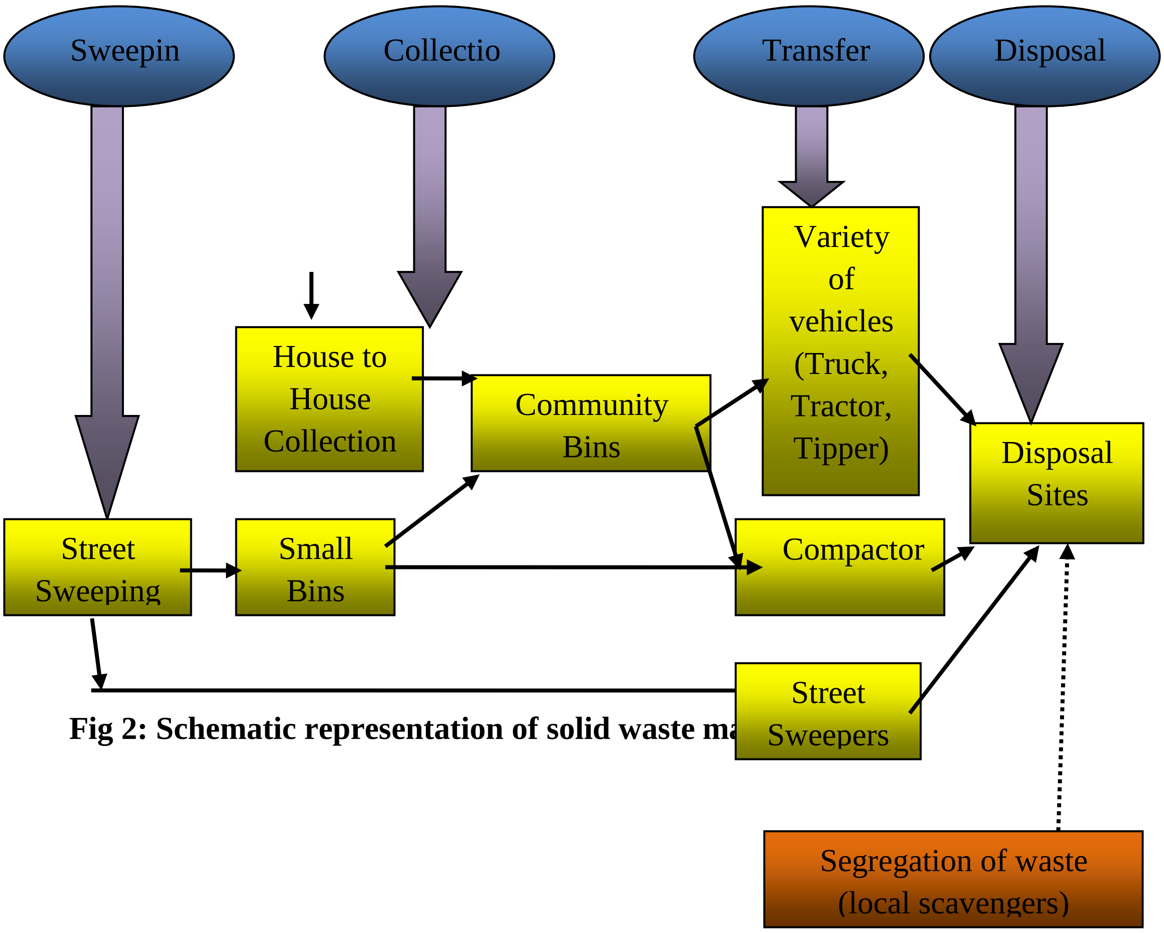


Fig 2: Schematic representation of solid waste ma

3.2 Waste generation

To plan a municipal solid waste (MSW) management strategy for a given region, it is essential to know the quantity of waste generated and its composition

Table 2: Sources and Types of MSW

Sources	Types of solid waste
Residential	Food wastes, paper, plastics, textiles, glass, iron metals, aluminum, garden waste (grass), wood, and special wastes (bulky items, consumer electronics, batteries, oil, tires).
Commercial	Paper, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes.
Institutional	Paper, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Municipal services	Street sweepings, landscape and tree trimmings, and general wastes from parks.

(i) **Waste quantum:** The per capita waste generation rate is about 500 g/day. This along with increased population

Table 1.4 Urban Waste Situation in Nine Major Indian Cities

Major Cities	Garbage Generated (Tonnes per Day)	Garbage Cleared (Tonnes per Day)	Annual Municipal Budget (Rs. in crores)*
Delhi	3880	2420	1016.28
Kolkata	3500	3150	250.00
Mumbai	5800	5000	2436.00
Bangalore	2130	1800	237.00
Chennai	2675	2140	145.00
Lucknow	1500	1000	48.00
Patna	1000	300	15.00
Ahmedabad	1500	1200	270.00
Surat	1250	1000	170.00

Source: Integrated Modeling of Solid Waste in India (March, 1999) CREED Working Paper Series no 26
** 1 crore = 10 million*

(ii) **Waste composition:** Studies reveal that the percentage of the organic matter has remained almost static at 41% in the past 3 decad

(iii) **Waste disposal methods:** Waste disposal is the final stage of the waste management cycle. About 90% of the municipal waste

Table 1.7 Waste Disposal Trends in Ind

As a result, leachate containing heavy metals finds its way to the underground water, rendering it unfit for drinking.

(iv) **Recycling:** This involves collection of recyclables from various sources, which ultimately reach recycling units.

(v) **Health impacts:** Due to the absence of standards and norms for handling municipal wastes, municipal

(vi) **Environmental impacts:** In addition to occupational health, injury issues and environmental health also need to

Model Answers to Learning Activities

LEARNING ACTIVITY 1.1

I reside in ward no. 89 of Bangalore (Karnataka, India), which is a residential area and has a population of 29,440. It has 2 colleges, 3 schools, 1 hospital and few commercial establishments. Based on source and type of wastes generated in my ward, they can be classified as follows:

(i) Based on source:

Residential: Consisting of single and multi-storied buildings (food leftovers, vegetable peels, plastics, clothes, etc.).

Commercial: Consisting of provision stores, hospital wastes and auto repair shops (food leftovers, glasses, metals, etc.).

Institutional: Consisting of schools and colleges (paper, plastics, glasses, etc.).

Municipal: Consisting of wastes from demolition and construction activities (dust, building debris, etc.).

(ii) Based on type:

Garbage (food wastes, vegetable peels, etc.).

Ashes and residue.

Combustible and noncombustible wastes (plastics, textiles, glass, etc.).

Bulky wastes (tires, trees, branches, crates, etc.).

Street wastes (dirt, leaves, etc.).

Dead animals (due to natural or accidental death, e.g., dogs, cats, cattle, etc.).

Construction and demolition wastes (rubber, concrete, plaster, bricks, etc.).

LEARNING ACTIVITY 1.2

Currently, the functional elements in my locality are waste generation, storage, collection and disposal.

Improvements can be made on the existing functional elements by the addition of transport and processing. Since our locality is mostly residential, the quantity of biodegradable waste generated is high. It is, therefore, important that wastes are collected at least three times a week. In order to combat the problems of narrow access ways, a transfer station can be set up, which could be a small area along the street, where collectors transfer wastes from smaller trucks or pushcarts to bigger vehicles. Segregation of wastes can be done at the transfer station, and depending on the waste, they can be disposed of in landfills.

LEARNING ACTIVITY 1.3

Environmentally sound management is an integrated approach for controlling and preserving the resources, both in quantity and quality. Its role is to ensure sustainable development of the ecosystem and human environment by minimizing the effects of human activities.

Environmental sound technologies (EST) are cost effective and energy efficient and they do not pollute the ecosystem's vital components such as air, land or water. EST can be categorized broadly as hard and soft. Hard ESTs include equipment, machines and other infrastructure with their material accessories, to handle waste products and monitor and measure environmental quality in the air, water and soil. Soft EST support and complement hard technologies and include nature-based technologies and management tools.

LEARNING ACTIVITY 1.4

Waste composition in our locality consists of wet waste and dry waste. Wet waste constitutes 60% of the solid waste generated, e.g., food wastes, vegetable peels, etc. Dry waste constitutes the remaining 40% of the solid wastes, i.e., paper 12%, plastics 14%, glass 4%, rubber 1%, battery and expired medicines 2%, iron 1%, dust 5% and cardboard boxes 1%.

There has been an increase in the number of residential dwellings in our locality. Due to the increase in population, the quantity of wet wastes (e.g., food leftovers, vegetable peels, etc.) and dry wastes (e.g., plastics, paper, etc.) have also increased, but the percentage of generation remains constant. The waste generated per person is 0.35 kg per capita per day

Management of industrial hazardous wastes

Industrial hazardous waste is managed through the **Hazardous Waste (Management and Handling) Fourth Amendment Rules 2010** and follows a regime different from the MSWM. Hazardous waste is typically identified with properties of ignitability, corrosively, reactivity and toxicity. Urban Local Bodies need to ensure that industrial hazardous wastes do not get mixed with the municipal solid waste stream. Wastes containing toxic components which are usually included in MSW, such as batteries,

Special Wastes.

technology developments and concepts for an integrated MSWM. In particular the Rules cover the following aspects:

zz list of authorities involved in MSWM and their corresponding duties;

zz mandatory MSWM Policy/Strategy to be prepared by the State or the Union Territory;

zz mandatory MSWM Plans to be prepared by the municipal authority;

zz specific requirements for the management of MSW including segregation into wet and dry waste, as well as restriction on material to be disposed in landfills; only nonreactive inert and pre-treated waste may be disposed;

zz levy of service fees by the municipal authority to make this service sustainable;

zz requirements for landfill sites including site selection and mandatory lining system;

zz requirement of environmental clearances for setting up MSW processing and disposal facilities including landfills;

zz standards for composting;

zz standards of treated leachate;

zz emission standards for incineration facilities;

zz mandatory annual reporting by the municipal authority on MSW operations; Municipal authorities and all stakeholders must carefully go through the above provisions of MSW Rules 2000 and the draft revised MSW Rules 2013 and make concerted efforts to improve SWM systems and services accordingly The preferred waste management strategies within the hierarchy include:

zz **At source reduction and reuse at source:** The most preferred option for waste management is to prevent the generation of waste at various stages including at product design stage, production, packaging, use and reuse stages of a product. Waste prevention helps reduce handling, treatment, and disposal costs and reduces various environmental impacts such as leachate, air emissions and generation of greenhouse gases.

zz **Waste recycling:** Recovery of recyclable material resources through a process of segregation, collection and re-processing to create new products is the next preferred alternative.

zz **Waste to composting:** The organic fraction of waste can be composted to improve soil health and agricultural production adhering to FCO norms.

zz **Waste-to-Energy:** Where material recovery from waste is not possible, energy recovery from waste through

zz **Waste Disposal:** Remaining residual wastes at the end of the hierarchy, which are ideally comprised of inerts

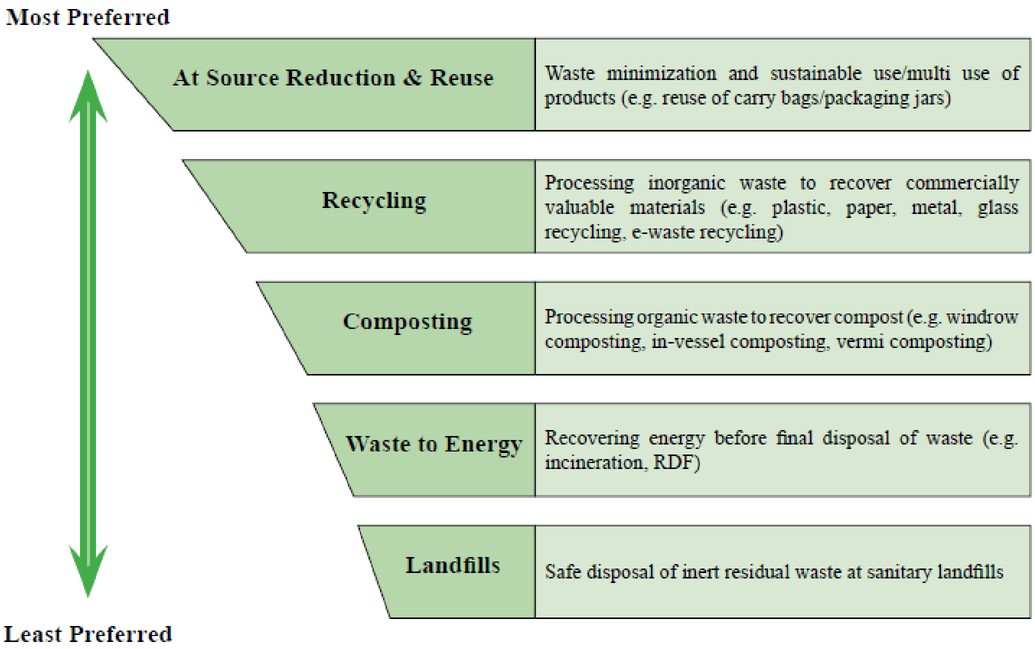


Figure 1.1: Integrated Solid Waste Management Hierarchy

Integrated solid waste management has also to reflect the following aspects:

zz **MSW and climate change:** MSW is related to climate change in several ways: (i) Integrated solid waste management reduces the emissions of greenhouse gases (mainly carbon **Gender equity aspects:** Women are involved in and affected by MSWM in multiple ways. They work in ULBs (e.g. many street sweepers and door step collectors

zz **Informal sector integration in MSWM:** An implication of the comprehensive understanding of ISWM is that it will involve

7-step process, which is illustrated below in figure 1.2.

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

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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

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STEP 3: STAKEHOLDER CONSULTATION FOR MSWM PLANNING

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STEP 4: PREPARATION OF DRAFT MSWM PLAN

Future Projections

- Population Forecast
- Anticipated Lifestyle Changes
- Change in Socio-economic Status

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/City Development Plan

Selection of Process & Best Available Technology for Processing & Disposal

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STEP 5: SCHEDULE FOR IMPLEMENTATION

- Timeline
- Manpower Requirement
- Financial Viability

↓

STEP 6: STAKEHOLDER CONSULTATION FOR MSWM PLAN VALIDATION

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STEP 7: CITY COUNCIL APPROVAL FOR MSWM PLAN

What To Do With 'Special Wastes'?

Special Waste includes any solid waste or combination of solid wastes that, because of its quantity, concentration and physical / chemical characteristics or biological properties, Wastes:

1. Plastics waste
2. Biomedical waste
3. Slaughterhouse waste
4. Electric and electronic waste (e-waste)
5. Waste Tires
6. Battery Waste

zz **Systems of Extended Producer Responsibility (EPR):** Batteries and certain types of e-waste can be collected and treated through return systems operated by producers or retailers of these products.

zz **Full responsibility of the private sector:** Some special wastes such as End-of-Life Vehicles are

zz **PPP:** Certain waste types can be handled within PPP schemes. This might be especially relevant for biomedical and slaughterhouse wastes.

zz **Integrated ULB operation:** Plastic waste is also a non-hazardous component of municipal solid waste. The ULB should establish special collection systems within their general MSWM operations.

Waste Minimization Initiatives Requiring UL B Support/Action

zz Promoting and implementing awareness and education programs that address different stakeholders: Residential, commercial and industrial educational programs that increase public awareness and participation in at source reduction programs.

zz Developing and promoting at source reduction programs in the community, e.g., domestic composting programs that reduce the volume of food waste, leaves and garden trimmings entering the collection system.

zz Campaigns for reducing the use of specific non-recyclable, non-reusable or toxic material. Practicing and promoting material substitution where possible. (Promoting the use of rechargeable batteries instead of single use batteries)

zz Bans within local authorities' jurisdiction (see also National / State level initiatives above): Replacing disposable materials and products with recyclables and reusable materials and products (e.g., banning the use of plastic bags).

zz Green Procurement & Take Back programs: Whereby the suppliers of a product to the municipality are responsible for providing a take back program and to promote the recycling of e.g., computer monitors, auto oil, batteries, paper etc. Procurement programs in the government and businesses should be designed to give preference to recyclable products.

zz Local businesses should be encouraged to reward consumers for returning recyclable products/ products which are toxic (e.g., batteries). EPR programs by manufacturers are a pre-requisite to these initiatives.

zz Educational and on-site business & industry assistance programs should be promoted that advise businesses how to use materials more efficiently and reduce waste generation.

Examples of Onsite Business Assistance Programmes

zz Reducing office paper waste by implementing a formal policy to duplex print all draft reports, and by making training manuals and personnel information available electronically.

zz Improving product design to use less material.

zz Redesigning packaging to eliminate excess material while maintaining strength.

zz Working with customers to design and implement a packaging return program.

zz Switching to reusable transport containers.

zz Purchasing products in bulk.

zz Promoting materials exchange and reuse programs that divert materials from the waste stream which will eventually go to the landfill, e.g.: Programs which link sellers of used furniture with potential second hand furniture buyers.

zz Establishing incentives for at- source reduction through the principle of "pay as you throw", supported by bye-laws. Urban local bodies can collect variable solid waste management charges, based on the quantities being disposed per household/ establishments. Variable rates can be fixed for pre-defined ranges of waste quantities, progressively increasing with waste generation rates. This would also imply that the ULB has the resources to record waste generation quantities. This system will function successfully only if the progressively increasing tariff is restrictive enough to prevent waste generation.

2.1.4 Developing A Waste Minimization Programme In Local Authorities

zz Waste minimization programs should be spearheaded by local authorities, not only to

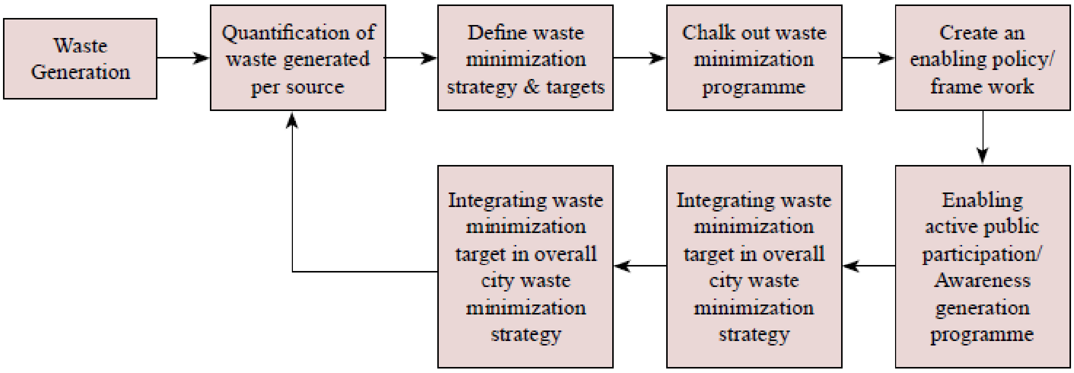


Figure 2.2: Developing a Waste Minimization Program

Technical Strategy:

zz Community bins were substituted by trolley bins as an intermediate stage of transfer.

zz Modifications were made in the hydraulic arm of the garbage trucks to enable transfer of waste from the trolley bin into the truck without manual intervention.

zz Segregation at source was initially introduced as wet and dry segregation, into in 2 bins.

zz Household bins with screw on lids were designed in order to prevent spillage of garbage by stray animals when households kept waste outside for collection.

Currently, segregation at source is undertaken in 8 clear streams of waste (wet, paper, plastic bags, metals/ glass, non- recyclable, tetra-packs, cardboard, plastic bottles) with designated colour coding for all the mentioned waste fractions.

Material Recycling Stations were established within colonies for further segregation of dry waste.

zz Decentralized Composting units were constructed for converting wet waste into manure for the community usage. Hotels were also asked to install decentralized composting units in their premises.

zz Tie-ups with various recycling units for selling bulk segregated waste.

zz Extended Producer Responsibility(EPR) initiatives through innovative measures Like:

— tie-ups with local dairies for paying residents a specified amount for returning washed empty plastic milk bags at the local dairy booths.

— tie-up with Tetrapak Company, for buy back of empty tetrapak containers.

zz Co-processing plastics and other dry fraction rejects in the cement industry:

— Two baling machines of the sizes 1ft x1ft and 1m x1m for bailing dry fractions/ plastic waste for different cement plants, were designed and bailed waste was sent to 4 different cement plants, located at distances varying from 250 to 600 km from CoP, for co-processing of plastic and other dry waste.

zz Hazardous waste like batteries and tube lights were segregated and once sufficient quantities obtained, are transported to the Hazardous waste - Treatment Storage and Disposal Facility (TSDF) site in Karnataka.

zz E-waste and thermocol are collected separately, but currently no tie-ups exist for them.

Institutional Strategy:

zz A Solid Waste Management Cell was formed in the CoP, headed by a Waste Management Officer.

zz The field services are headed by a Sanitary Inspector who is in-charge of 15 supervisors to oversee the collection and transportation of each zone.

zz Intensive monitoring by the Corporation staff. Centralized complaint redressal system established with a 24 hour helpline number to clear any uncollected/ unattended garbage. Quick response vehicle designated for the purpose.

zz Adequate health and safety measures provided to the sanitary workers.

Public Communication Strategy:

Financial Strategy:

zz User charges have been introduced by CoP and are collected by the supervisors. The supervisors maintain the ward wise accounts, are responsible for payment of cash incentives to the collection and transportation workers and deposit the surplus amount with the CoP.

zz Other revenue sources include:

— Sale of compost

— Sale of segregated waste for recycling like plastic bottles, cardboard boxes, etc.

— EPR initiatives – like Tetrapak

zz Costs are incurred by CoP for bailing and transporting waste for co-processing to cement plants. This acted as an incentive for increasing recycling tie-ups with other players in the market. 100% collection of segregated waste from the households as well as further sorting at the recycling stations in 8 streams of waste.

zz Active involvement of ragpickers, women volunteers/ SHGs in streamlining the waste management system.

zz Segregated waste transported to the recycling units and compost units for further processing.

zz Improved recycling efficiency through market creation and tie-ups for PET bottles, plastic bags, etc.

zz Minimized waste to landfill through effective management by co-processing waste fractions and sending hazardous waste to Treatment Storage & Disposal Facility (TSDF).

Success factors:

zz Clarity of vision for the city coupled with a strong and stable leadership

zz Institutional and managerial model within CoP established.

zz Technical innovations for segregation, minimal manual handling of waste, coprocessing, EPR, tie-ups.

zz Intensive campaigning, meetings with RWAs on the overall concept of segregation at source. Active involvement of youth, local celebrities, corporation staff, community for awareness generation activities. Including the waste segregation system in the school curricula from primary level onwards.

Overall Sustainability:

The expenditure on the solid waste program has been managed entirely from the corporations own sources.

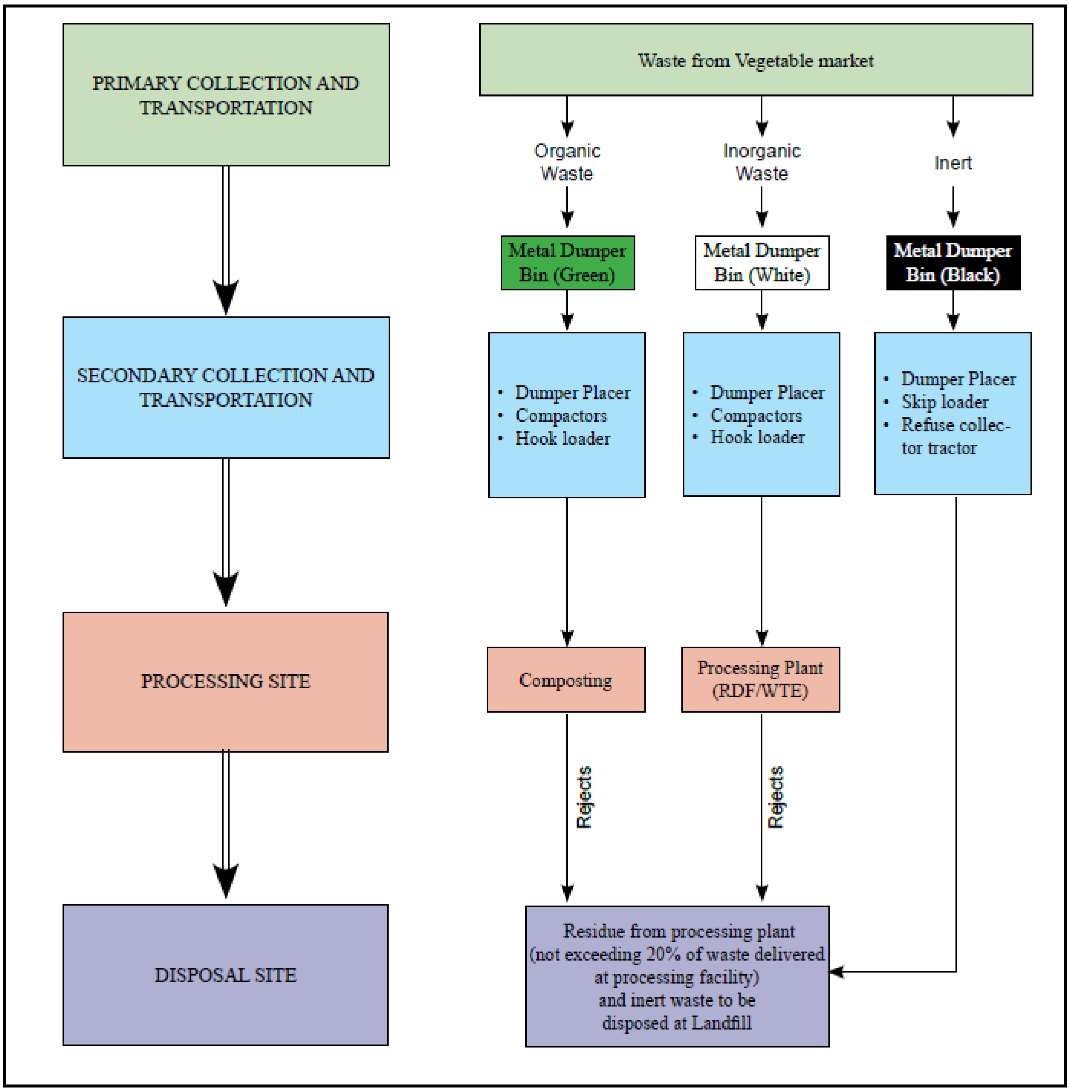


Figure 2.7: Flow chart for collection, transportation & disposal of vegetable market waste

3.1 Recycling & Recovery

Recycling is the process **3.1.1 Advantages of Recycling**

zz For the ULB

— Reduces waste volume

— Cost savings in collection, transport and disposal

— Longer life span for landfills

— Reduced environmental management efforts

zz For the economy:

— Reduction of imports of raw materials, fertilizers etc. and hence foreign currency required.

— Livelihood opportunities for recyclers in the recycling industry

zz For the environment

— Sustainable use of resources: less material and energy consumption and consequently lower pollution.

— Reduced amount of waste going to storage sites / reduced requirement of land.

— Reduced environmental impacts including impacts of climate change.

As per data received from CPCB, it is estimated that urban India generated 1, 27,486 metric tonnes of municipal solid waste per day in 2011-12. Of this waste 40-60% is organic and 10-20% is recyclables. This indicates a clear waste minimization potential of 12,750 metric tonne – 25,500 metric tonne per day through recycling and recovery. Figure 3.3 is indicative of the typical waste fractions in municipal solid waste generated in India:

Recyclables mainly consist of paper, plastic, metal, and glass— and can be retrieved from the waste stream for further recycling. Table 3.1 gives an overview of typical recycling material and their recycling potential.

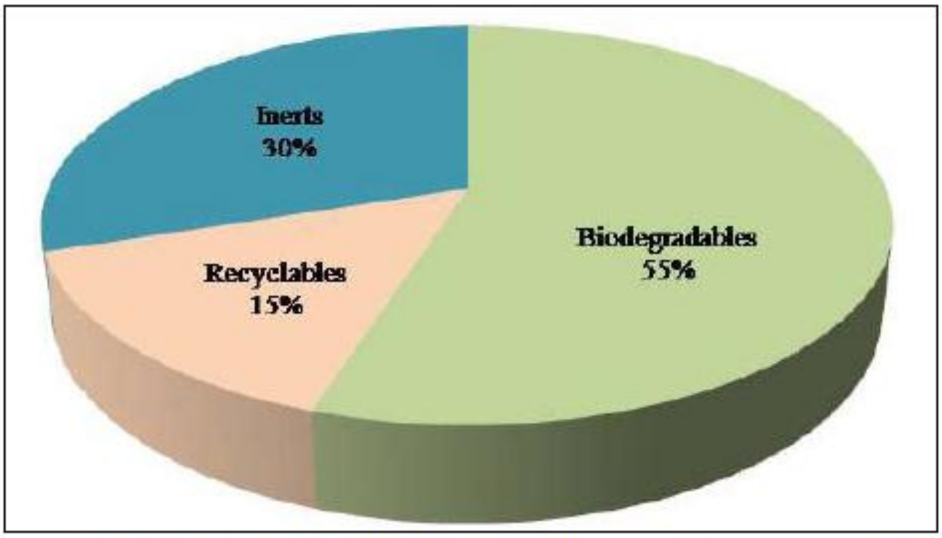


Figure 3.3: Municipal Solid Waste Characterization in India[2]

Table 3.1: Important Recycling Material: Recycling Potential & Special Conditions[2]

Material	Recycling Potential	Special Conditions
Aluminium	• High Market Value • Easily recycled by shredding and melting • Can be recycled indefinitely because it does not deteriorate through reprocessing • Requires significantly less energy than producing aluminium ore	• Separate collection is important
Batteries	• Recovers valuable metals • Protects environment from heavy metals such as lead, cadmium and mercury	• Large variation in type and size of batteries • Only some types allow adequate material recovery.
Concrete and Demolition Waste (for specific information please refer to section 3.6 of Part II)	• Demolition waste can be sorted, crushed and reused for production of pavement material, flooring tiles, road construction, landscaping and other purposes. • Due to the amounts of demolition waste, its recycling allows significant reduction of otherwise required disposal capacities.	• Standards for recycled products are yet to be stipulated

[2] 'Improving Solid Waste Management in India,' D. Zhu, et al., (2008).Available at: http://www.tn.gov.in/cma/swm_in_india.pdf

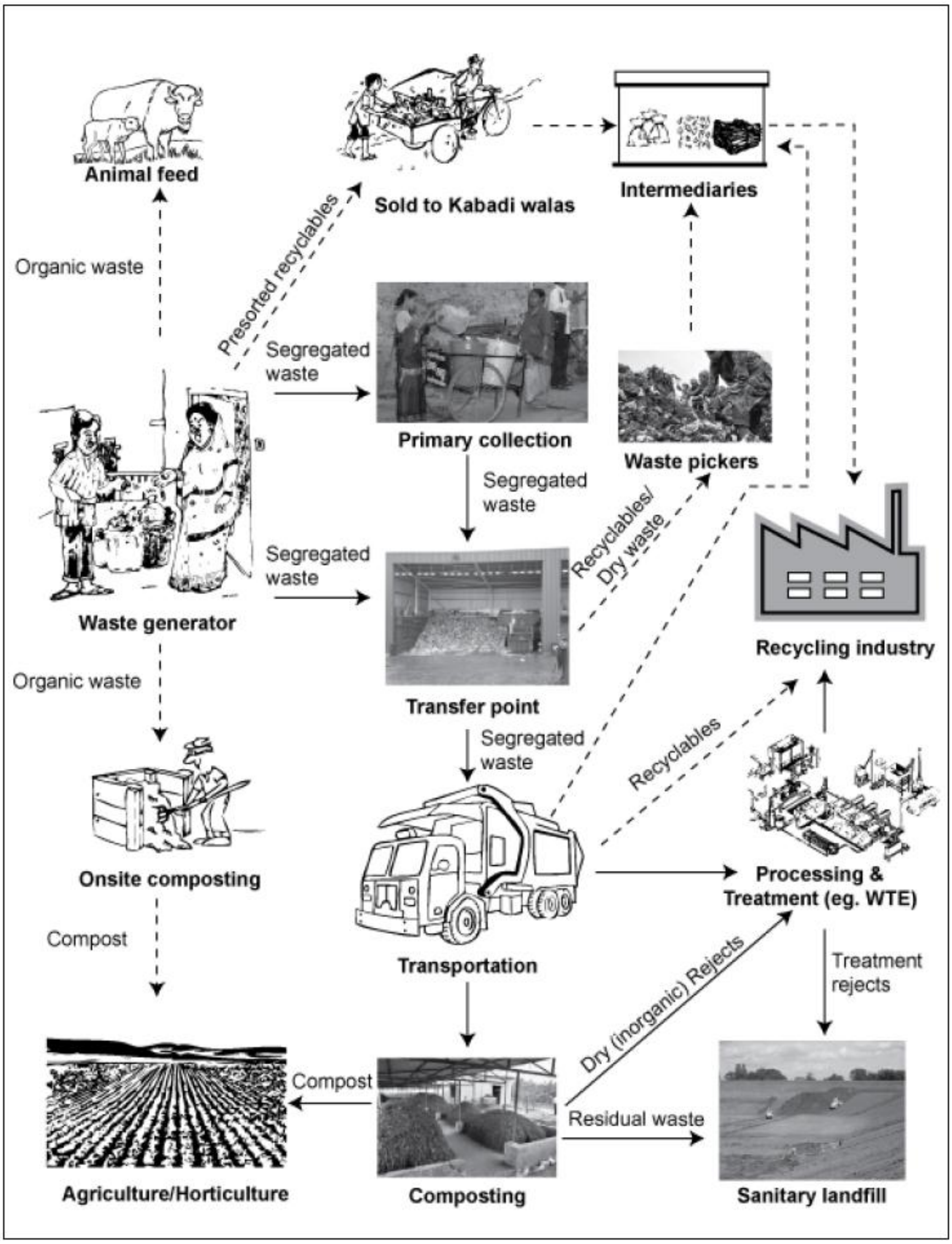
Material	Recycling Potential	Special Conditions
Glass	• Moderate market value • Sorted into colours and melted • Saves energy compared with processing raw material • Can be recycled indefinitely because it does not deteriorate by reprocessing	• Broken glass can contaminate and eliminate opportunities for recycling of other materials such as paper.
Paper and cardboard	• Easily recycled • Paper or cardboard from recycled paper requires less energy during production and helps protect forests	• Recycling potential is reduced with each recycling cycle through deterioration of fibres.
Polyethylene terephthalate (PET)	• PET can be recycled if segregated from other waste	• Quality of recycled product decreases with every processing cycle • Recycled products have specific designated uses and cannot be used for all purposes
Other Plastics (for specific information please refer to section 7.4 of Part II)	• Other plastics, such as polyethylene or polyvinyl chloride, can be recycled but have less value in the market than PET; the value depends on recycling and manufacturing options in the vicinity.	• Clean segregated plastics, are subjected to mechanical recycling into the same plastic type. • Where recycling is not possible due to mixed plastics, these are then co-processed for energy recovery or used as aggregates in road material
Electronic Waste	• Electronic wastes contain high- value metals • Electronic items can be dismantled and components reused or recycled	• Metals are often covered with polyvinyl chloride or resins, which are often smelted or burned, causing toxic emissions, if recycling is not carried out under controlled conditions. • Disaggregation of electronic waste for recycling can be costly.

Material	Recycling Potential	Special Conditions
Metals (steel, copper, nickel, zinc, silver etc.)	Scrap metal has a high market value (especially steel, copper and silver) Can be recycled indefinitely because it does not deteriorate through reprocessing	High value metals (such as copper and silver) are incorporated in electronic devices, but extraction can cause severe environmental impacts, if uncontrolled.

Of Material Recovery

Material recovery starts at the primary level, by households which segregate recyclables .

Figure 3.4 illustrates the different stages of material recovery along the solid waste



management chain.

Figure 3.4: Stages of Material Recovery in Municipal

Material Recovery Facility4

A Material Recovery Facility (MRF) accepts mixtures of waste fractions (e.g. selected materials

zz **Mixed stream:** Unsegregated waste if received at the processing facility, may be segregated manually or zz **Source separated:** Incoming recyclables are sorted at the point of collection. Some

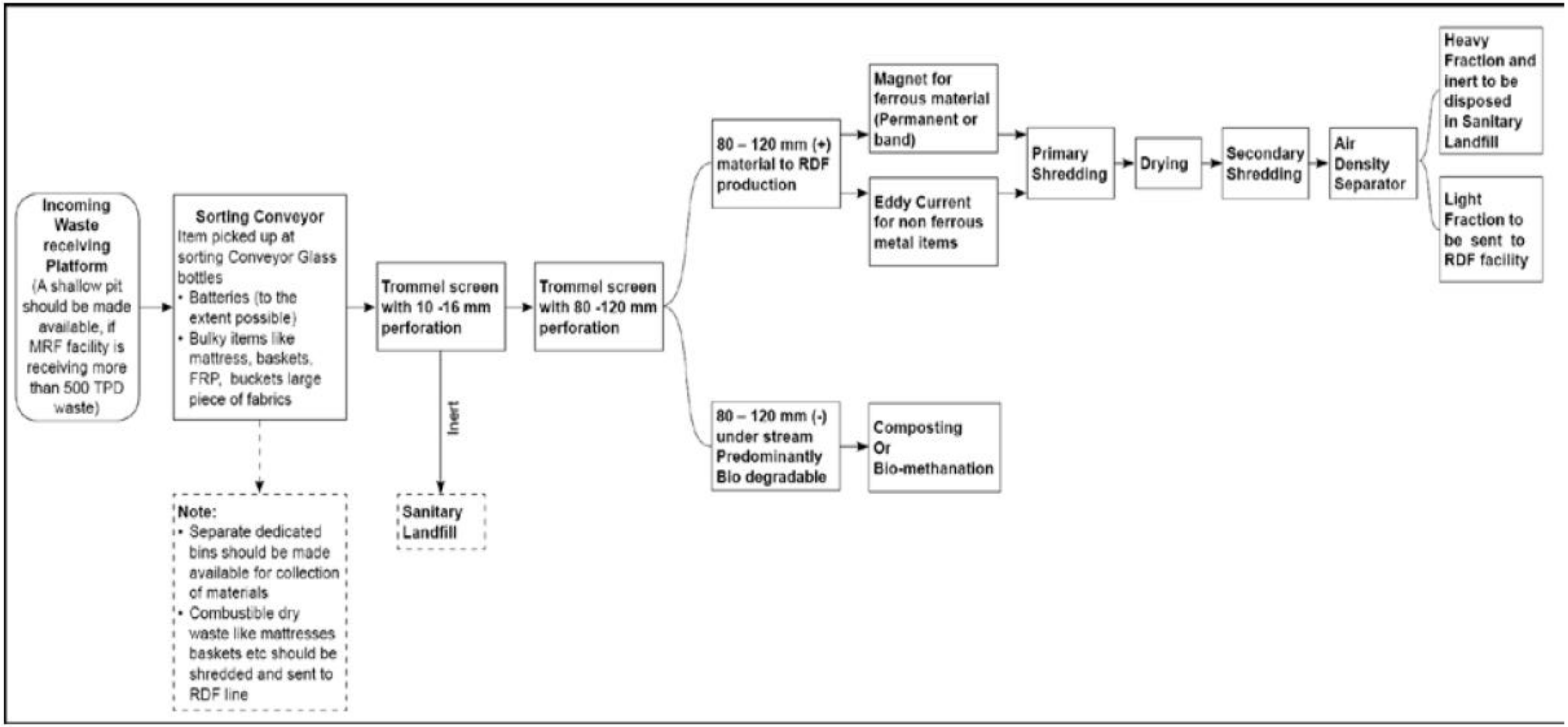


Figure 3.5: Indicative MRF & Pre-Sorting Facility for Mixed Waste

Dry waste stream: Dry segregated material is received in a mixed form consisting of a combination.

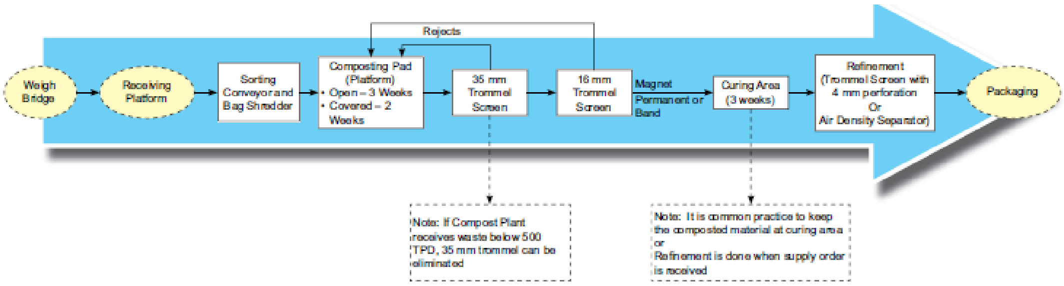


Figure 3.7: Indicative MRF & Pre-sorting Facility Dedicated to Wet Waste

MRF Unit Processes

MRF units employ varying combinations of manual and mechanical processes, based on the

.

A MRF unit, depending on the level of complexity, will consist of a combination of unit processes as shown in figure 3.8, in varying degrees of mechanization:

zz **Pre-Sorting:** Bulky and contaminated wastes hamper further sorting/processing in the facility;

zz **Mechanical Sorting:** Mechanical processes based on principles of electro-magnetics, fluid

— **Screening:** Screening segregates waste into two or more size distributions. Two types of screens are used in MRF centres; 1) Disc screens 2) Trommels.

— **Ferrous Metal separation:** In the second stage, electromagnets are used for separating heavy ferrous metals from mixed waste.

— **Air Classification:** The residual waste stream is passed through an air stream with sufficient

— **Non-ferrous metal separation:** The non-ferrous metal separator segregates zinc, aluminium, copper, lead, nickel and other precious metal from commingled waste. An eddy current separator removes non-ferrous items from the comingled waste based on their electrical conductivity.

— **Detect and Route system:** This system separates out various grades of paper, plastics and

Size reduction: Sorted materials after segregation are usually too large for further use or processing, they should be reduced to smaller sizes.

— **Baling:** Sorted and sized material is baled for further processing/use.

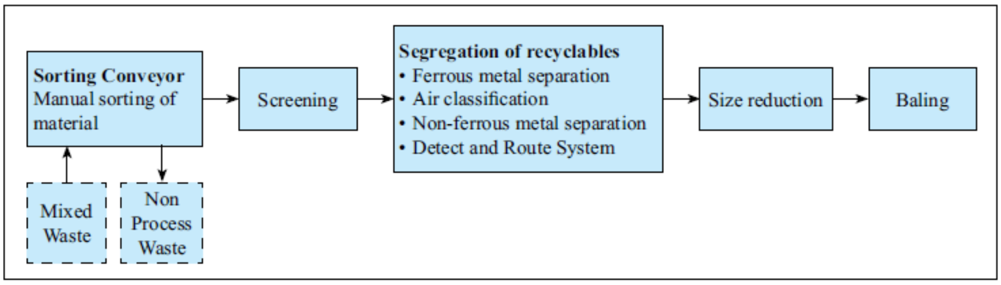


Figure 3.8: Indicative Unit Process in a Material Recovery Facility Receiving Mixed Wastes

Table 3.2 lists specific types of equipment employed at a MRF in a waste processing centre.

Table 3.2: Different Processes/Stages and Equipment Employed in a MRF

Process/Stages	Equipment
Pre- sorting material handling equipment	• Belt conveyor • Screw conveyor • Apron conveyor • Bucket elevator • Drag conveyor • Pneumatic conveyor • Vibrating conveyor • Debagger
Ferrous metal separation	• Magnetic Separator and Screening
Screening	• Disc Screening • Trommels
Air classification	• Horizontal air classifier • Vibrating inclined air classifier • Inclined air classifier
Non-ferrous metal separation	• Rotating disk separator • Eddy current separator

Process/Stages	Equipment
Size reduction	• Can densifier • Can flattener • Glass crusher • Plastic granulator • Plastic perforator • Baler
Pollution control	• Dust Collection System • Noise Suppression Devices • Odour Control System • Heating, Ventilating, & Air Conditioning (HVAC)
Other fixed equipment	• Fixed storage bin • Live-bottom storage bin • Floor scale for pallet or bin loads • Truck scale • Belt scale

Recycling Of Plastics

It is estimated that are collection, segregation and disposal. At present, plastic waste collection is done through the informal sectors such as the kabadi system and rag pickers6.

Making of Handmade Paper

The Indian handmade paper industry produces a variety of paper and paper products mainly by using

making process are discussed below:

A. Chopping & Dusting

The paper raw material and waste cotton rags are sorted manually to remove.

B. Beating

The chopped rags are converted into a fine pulp in a Hollander Beater. Pulping of the

.

C. Sheet Formation

There are two methods of sheet formation which are being used in India:

i. Lifting: Lifting is a modern method done with the help of Univat. Lifting employs the use of a steel water

ii. Dipping: Dipping is a traditional method where the pulp is transferred from the beater into a masonry

D. Pressing & Drying

A manual/ hydraulic press is used for squeezing out the excess water from the sheets. This compresses the pulp adding strength to the fiber.

E. Calendaring

The calendaring machine is fitted with two chilled cylinders rotating in opposite direction to give a smooth finish to the sheets of paper passed through them. Calendaring also tends to enhance the gloss of the paper.

F. Sheet Cutting

At this phase, the calendered sheet still has a deckle edge. The sheets are cut to standard size of 22’’x 30” or to desired sizes as required by the customers.

G. Paper Products

While

Reuse Of Sand & Inert

Street sweeping normally comprises of street dust and tree leaves, besides domestic and commercial

Construction & Demolition Waste

Construction and Demolition Wastes (C & D waste) generally constitute up to 10-20 percent of

E-Waste

E-waste or Waste of Electrical and Electronic Equipment (WEEE) comprises of surplus, obsolete,

Composting

3.2.1 MSW (M&H) Rules 2000: Guidance On Composting

Rules The MSW Rules, 2000 specify that “Municipal authorities shall adopt suitable technology or combination of

What Is Composting?

Municipal Solid Waste primarily consists of organic, inorganic and inert fractions. Under natural

Benefits Of Composting

3.2.6 The Composting Process – Phases And Critical Parameters

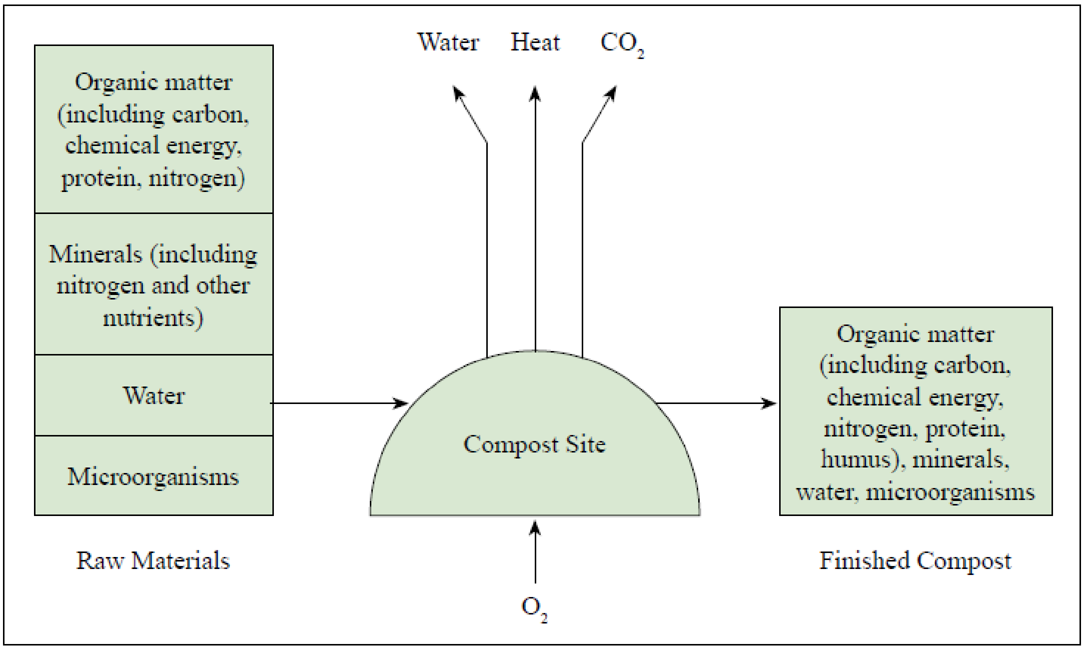


Figure 3.10: Process of Aerobic Composting[13]

3.2.6.1 Biological Processes

The process of aerobic composting passes through two distinct stages of high significance

zz Thermophilic stage (Sanitization)

zz Mesophilic stage (Decomposition)

(i) Thermophilic Stage (Sanitization)

zz This is the first phase of composting wherein microorganisms decompose the easily degradable organic substances producing heat as a result of intense metabolic activity.

In the majority of cases with moisture content between 55-60% and air voids between 20-30% in the windrow, a temperature rise from 35°C to 55-60°C is achieved within 2-3 days.

zz Typically thermo tolerant fungi, thermophilic bacteria and actinomycetes are the predominantly active micro-organisms at this stage.

(ii) Mesophilic Stage

zz In the second stage, due to reduction in available nutrients and readily available carbon, the microbial activity reduces causing a decline in the temperature of the heap. There is a shift in the type of active microbial species in the compost heaps.

zz The composted material becomes dark brown during this stage due to humus synthesis and starts to stabilize.

Curing Stage

zz Curing of compost is done after the material from the windrow is screened. The screened material is then allowed to mature in the curing stage. This is a very important phase in the composting process. Microbial species degrading complex polymers such as cellulose, lignin and hemicelluloses increase drastically during this phase.

zz Bacteria represent 80% of this population. Free living N-fixing, de-nitrifiers, sulphate reducers and sulphur oxidizers are important constituents of the total microbial population.

Chemical Parameters

(i) Moisture: Moisture is a

(ii) Aeration: The composting process requires adequate supply of oxygen for biodegradation

(iii) Carbon/Nitrogen (C/N) Ratio

zz MSW

zz Whenever the C/N ratio is less than the optimum, carbon source such as straw, sawdust, paper are added.

zz Higher C/N ratios

3.2.6.3 Physical Processes

(i) Temperature: Under properly controlled conditions temperatures are known to rise beyond 70°C in

(ii) Particle Size: The optimum

3.2.7 MSW Feedstock For Composting

The segregated wet fraction of municipal solid waste (comprising mainly biodegradable waste)

Tipping cum storage area: Unregulated storage of waste should be avoided. MSW feedstock should be delivered at a

Composting Technologies

Technologies for composting can be classified into the following general categories:

zz Windrow Composting

zz Aerated Static Pile Composting

zz In-Vessel Composting

zz Decentralized Composting

zz Vermicomposting

3.2.9.1 Windrow Composting

Windrow composting process consists of placing the pre-sorted feed stock in long narrow piles called windrows that are turned on a regular basis for boosting passive aeration. The turning operation mixes the composting materials and enhances passive aeration. Figure 3.12 gives a brief overview of the windrow composting process.

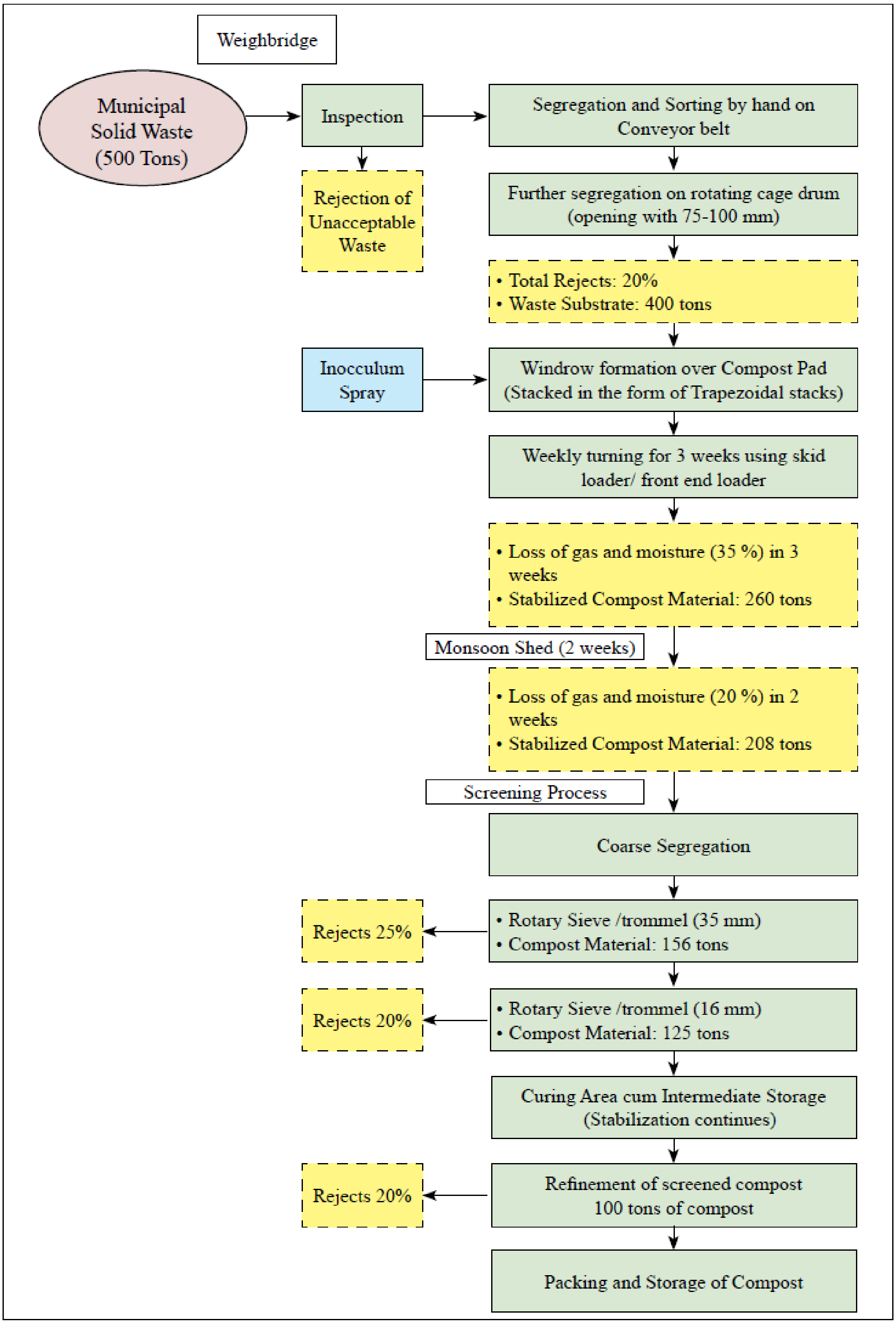
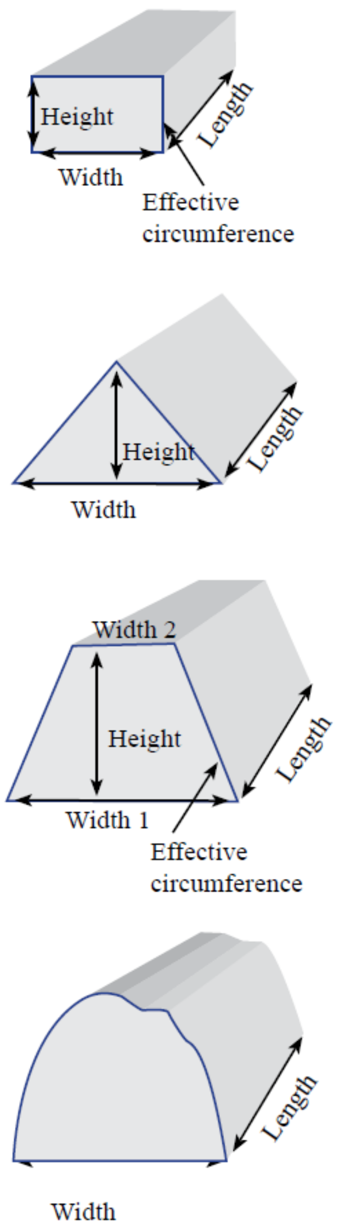


Figure 3.12: Process Flowchart and Mass-Balance for Aerobic Windrow Composting of 500 TPD[15]

Unit Operations In Windrow Composting

Following factors have to be considered in the location and design of the composting pad:

1. The base has to provide a barrier to prevent the percolation of leachate and/or nutrients to the sub-soil and groundwater.
2. The surface has to facilitate equipment movement even during wet weather conditions.
3. The surface area has to accommodate waste for 5 weeks, with sufficient room for



Rectangle

Volume = Height x Width x Length

Effective circumference= 2x height + width

Mass = Volume x Bulk Density

Triangle

Volume = Height x Width x Length x 0.5

Effective circumference= $2x\sqrt{height^2 + (width/2)^2}$

Mass = Volume x Bulk Density

Trapezoid

Volume= Height x (Width1+Width2) x Length x 0.5 *1

Effective circumference =

$2 \times (\sqrt{((width2-width1)/2))^2 + height^2}) + width2$

Mass = Volume x Bulk Density

Oval

Approximations:

Volume = Height x Width x Length x 0.75 *1

Effective circumference= $2.3 \times \sqrt{height^2 + (width/2)^2}$

Mass = Volume x Bulk Density

Figure 3.13: Windrow Sizing Calculation[16]

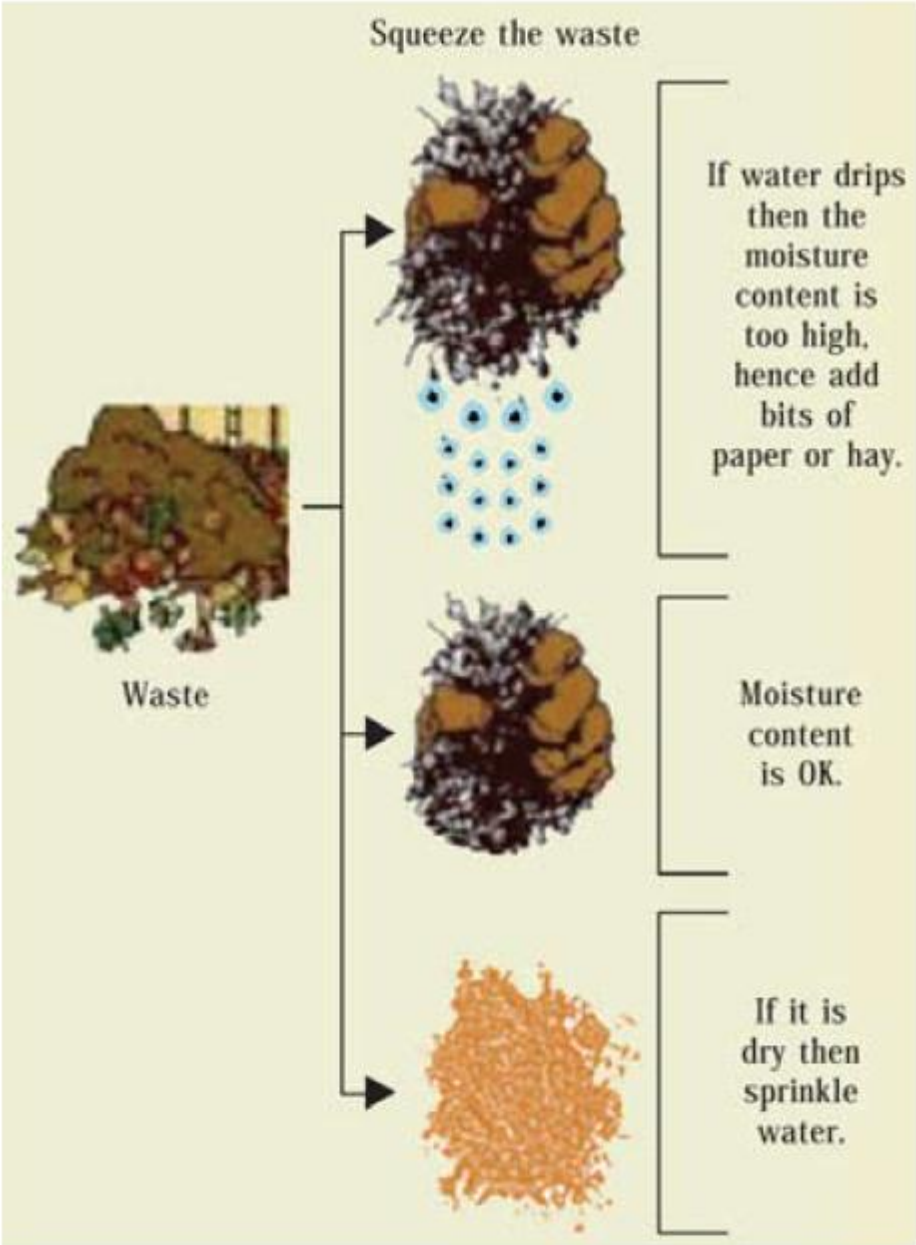


Figure 3.15: Squeeze test to estimate moisture content[17]

Curing: Screened material

Compost Refinement: At the end of composting phase, the material usually contains 30 to 35% moisture. The composting is normally taken to be complete when the active decomposition stage is over and the C/N ratio is around 20:1.

Figure 3.16: Unit operations in windrow composting

Leachate Management: Leachate

Aerated Static Pile Composting

Aerated static pile composting is a technology that requires the composting mixture

MSW Feedstock: Municipal solid waste

Pre-processing: Aerated

static pile.

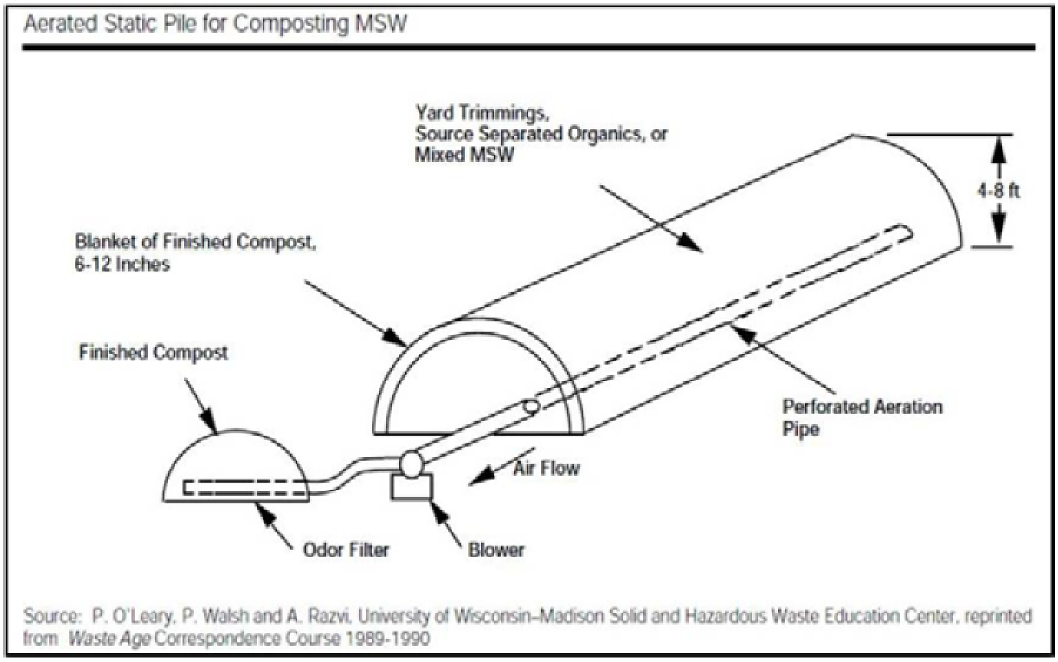
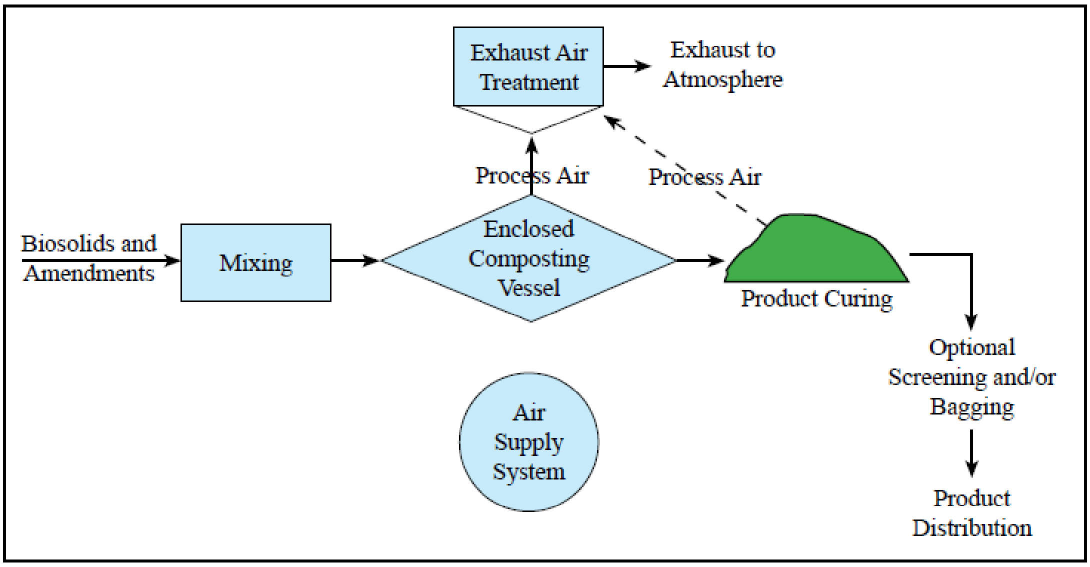


Figure 3.17: Aerated Static Pile[19]

Post processing: The compost

In Vessel Composting

In-vessel composting systems enclose the feedstock in a chamber or vessel that provides adequate mixing,



Source: Modified from U.S. EPA, 1989

Figure 3.18: Composting process in In Vessel Composting[21]

MSW Feedstock: The ideal

Pre-processing: In-vessel

Process: In-vessel composting

Curing: After the

Decentralized Composting

Transportation of municipal solid waste

MSW Feedstock: The feedstock

Pre-processing: The waste

.

Processing: Decentralized.

3.2.9.6.1 Bin Composting

Depending on the

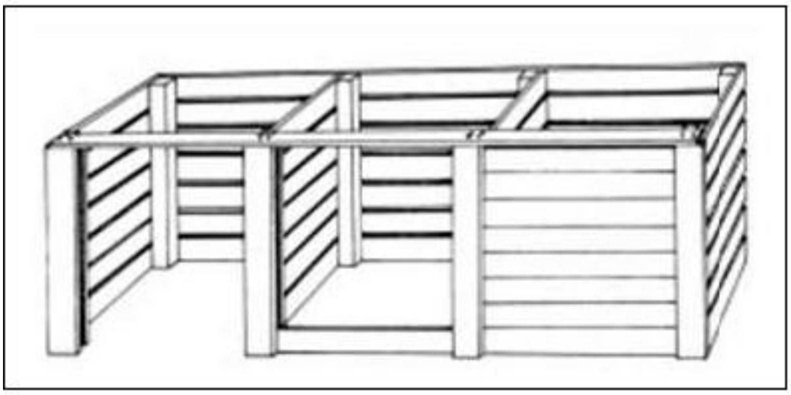


Figure 3.19: Bin Composting[23]

3.2.9.6.2 Box Composting

Box composting is practiced

Curing: After about 40 days, the material in the piles has a soil like colour and the pile temperature

Screening: The mature

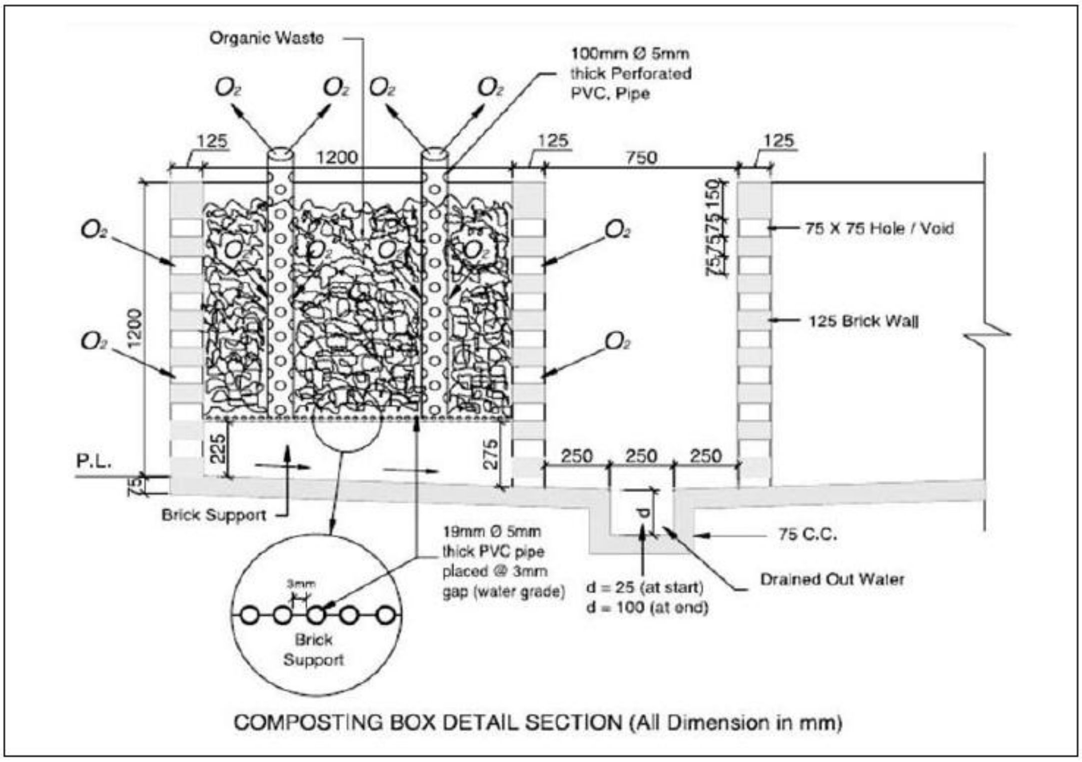


Figure 3.21: Typical Cross Section of Composting Box[25]

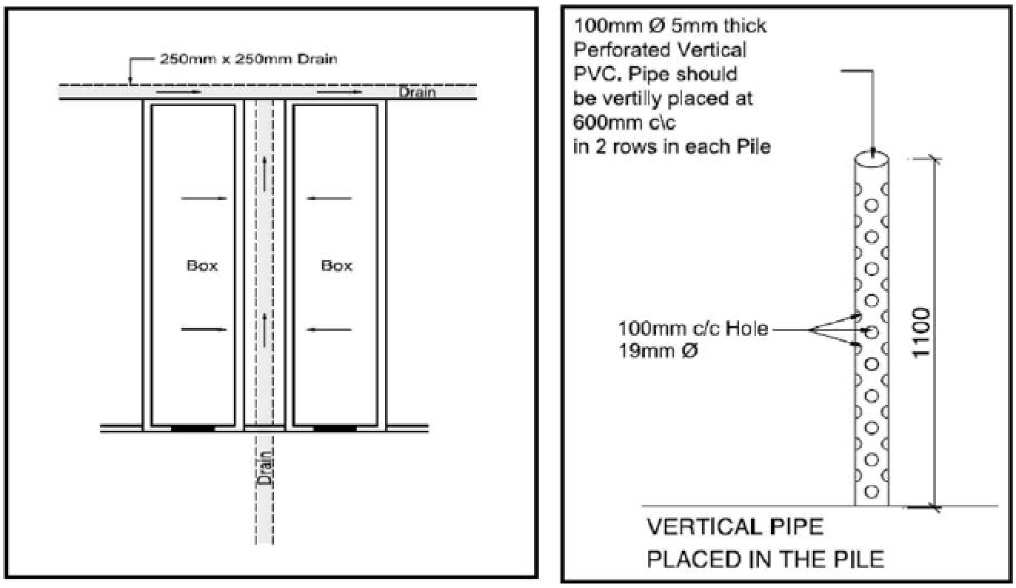


Figure 3.22: Cross section of drainage channels and vertical pipes[26]

Vermi Composting

Vermi-compost is the castings of earthworms. Vermicomposting is the process of composting the biodegradable fraction of municipal solid waste with the help of earth worms,

MSW Feedstock: Kitchen waste is the preferred feed stock for vermicomposting, however wastes like meat

Process: A vermicompost pit of any convenient dimension can be constructed in the backyard or garden or in a field. It may be a single pit, two pits or brick tank of any

Table 3.5: Summary of Different Composting Technologies[27]

Parameters	Windrow	Aerated Static Pile	In-Vessel	Vermicomposting
General	Simple Technology	Effective for farm and municipal use	Large- scale systems for commercial applications	Suitable for quantities less than 50 TPD generation of mixed MSW
Amount of waste treated	1 ton-500 tons per module	1 ton-500 tons per module	1 ton-300 tons per module	1 ton- 50 tons
Land Requirement	8 ha - 500 TPD	5 ha - 500 TPD (Less land required given faster rates and effective pile volumes)	4 ha - 500 TPD (Very limited land due to rapid rates and continuous operations)	2 ha: 50 TPD

Parameters	Windrow	Aerated Static Pile	In-Vessel	Vermicomposting
Time	8 weeks	5 weeks	3 weeks (3-5 days in vessel; 3 weeks to mature)	8 weeks
Ambient Temperature	Not temperature sensitive	Not temperature sensitive	Not temperature sensitive	Temperature sensitive (30-40°C ideal range; 35-37°C specific to particular earthworm sp.)
Energy Input	Moderate	Moderate (2-3 hours aeration)	High	Low
Financial Implications	Moderate	Costly	Very Costly	Moderate. Purchase of exotic earthworms suitable for MSW composting are expensive
Odour/ Aesthetic Issues	Odour is an issue if turning is inadequate.	Moderate. Odour can occur but controls can be used such as pile insulation and filters on air system	Minimum. Odour can occur due to equipment failure or system design failure	None

Monitoring Of Compost Plants

Routine testing and monitoring is an essential part of any composting operation. Monitoring the composting process provides information necessary to maintain a high quality operation. At least the following parameters should be monitored:

zz Compost windrow temperature

zz Oxygen concentrations in the compost mass

zz Moisture content

zz Maturity of the compost

zz pH

zz Soluble salts

zz Ammonia

Organic and volatile materials content

zz Heavy metals

Table 3.6: Compost Quality Standards as per MSW Rules, FCO 2009 and FCO 2013 (PROM)

Parameters	Organic Compost		Phosphate Rich Organic Manure
	MSW Rules 2000	FCO 2009	FCO (PROM) 2013
Arsenic (mg/Kg)	10.00	10.00	10.00

Waste To Energy

Waste to Energy (W to E) refers to the process of generating energy in the form of heat or electricity from municipal solid waste.

3.3.1 W To E In The Iswm Hierarchy

The ISWM

Incineration

Incineration is a waste treatment process that involves combustion of waste at very high temperatures,

Key Criteria For Msw Incineration

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

3.3.2.2 Key Considerations For Incineration Of MSW

Incineration of municipal solid waste should meet with the following criteria:

zz Minimum gas

zz Optimum

zz Fly ash acts

zz The flue

OVER VIEW OF THE INC INER ATION PROCE SS

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

zz Siting of an Incineration Plant

zz Waste reception and handling (storage, on site pre-treatment facilities)

zz Combustion and steam generation system

zz Flue gas cleaning system

zz Energy generation system (steam turbine and generator in case the unit is equipped for waste to energy recovery)

zz Residual hauling and disposal system

zz Monitoring and controlling incineration conditions In designing each of these process steps, the type(s) of waste that are treated in a concrete installation has to be reflected.

Siting Of Incineration Plant

zz A controlled and well-operated landfill must be available for disposing residues (bed and fly ash).

zz MSW incineration plants should be located in land-zones dedicated to medium or heavy industry

zz MSW incineration plants should be at least 300 to 500 meters from residential zones

zz In case of steam production, the plants should be located near suitable energy consumers

Waste Reception And Handling:

Figure 3.24

Waste Feeder:

3.3.2.6 Combustion And Steam Generation System

zz Vortexing and homogeneity of flue-gas flow

zz Residence time for the flue-gases in the hot furnace

zz Partial cooling of flue-gases

The detailed design of a combustion chamber is usually linked to the grate type. Its precise design demands certain compromises as the process requirements change with the fuel characteristics.

Grate Incinerators

The incineration grate accomplishes the following functions:

zz transport of materials to be incinerated through the furnace zz stoking and loosening of the materials to be incinerated

zz positioning of the main incineration zone in the incineration chamber, possibly in combination with furnace performance control measures.

Incinerator Chamber & Boiler

Combustion takes place above the grate in the incineration chamber. The incineration chamber

zz form and size

zz vortexing

zz sufficient residence time

zz partial cooling

3.3.2.8 Incinerator Air Feeding

Injection of air into the incinerator is required for:

zz provision of oxidant cooling

zz avoidance

zz mixing

3.3.2.9 Flue Gas Recirculation

Flue gas recirculation

Among its primary advantages, flue gas recirculation:

zz leads to a higher thermal efficiency, as the excess air and the oxygen content can be significantly reduced (efficiency can increase about 1to 3 percent)

zz reduces NOx content by 20 to 40 percent

zz reduces dioxin and furan generation

zz stabilizes and improves the flow and turbulence conditions- particularly at partial load

3.3.2.10 Residual Haulage And Disposal System

During the incineration process

3.3.2.11 Consumption Of Raw Materials And Energy By Incineration Plants

Waste incineration plants (process dependent) may consume:

zz electricity

zz fuels,

zz water,

zz flue-gas

zz water

zz high **3.3.2.12 Environmental Considerations**

Municipal solid waste

3.3.2.13 Emission Reduction In Incinerators

Incineration of MSW generates

Primary control measures include initiatives that actually retard the formation of pollutants, especially NOx and dioxins. It includes:

zz Efficient combustion process

zz Precipitation of ashes in the boiler

zz Short flue gas retention time at intermediate temperature

Table 3.8: Air Emission Control Technologies[33]

Flue Gas Constituents	Technology Description
Total dust	Effective maintenance of dust control systems is very important. Controlling dust levels generally reduces metal emissions too. Flue Gas Treatment (FGT): Pre-dust control before the Flue Gas Treatment : Bag filters, Electrostatic Precipitators, Cyclones and multi-cyclones Additional flue gas polishing system: Bag filters, wet-ESP, electro dynamic venture scrubbers, agglo-filtering modules, ionizing wet scrubber.
Hydrogen Chloride (HCl)/ Hydrogen Fluoride (HF)/ Sulphur dioxide (SO_2)	Waste control: Blending and mixing can reduce fluctuations in raw gas concentrations that can lead to elevated short-term emissions. FGT: Wet flue gas treatment systems generally have the highest absorption capacity and deliver the lowest emission levels for these substances, but are generally more expensive and difficult to maintain

Flue Gas Constituents	Technology Description
Nitrogen monoxide (NO) and Nitrogen dioxide (NO_2), expressed as Nitrogen dioxide for installations using SCR	Waste and combustion control techniques coupled with Selective Catalytic Reduction (SCR) generally result in operation within acceptable emission ranges. The use of SCR imposes an additional energy demand and costs. In general at larger installations the use of SCR results in less significant additional cost per tonne of waste treated. Waste with high nitrogen content may result in increased raw gas NOx concentrations
Nitrogen monoxide (NO) and Nitrogen dioxide (NO_2), expressed as Nitrogen dioxide for installations not using SCR	Waste and combustion control techniques with Selective Non-catalytic Reduction (SNCR) generally result in operation within acceptable emission ranges.
Gaseous and vaporous organic substances, expressed as TOC/Carbon monoxide (CO)	Techniques that improve combustion conditions reduce emissions of these substances. CO levels may be higher during start-up and shut-down, and with new boilers that have not yet established their normal operational fouling level.
Mercury and its compounds (as Hg)	Adsorption using carbon based reagents is generally required to achieve these emission levels with many wastes- as metallic Hg is more difficult to control than ionic Hg. The precise abatement performance and technique required will depend on the levels and distribution of Hg in the waste. Some waste streams have very highly variable Hg concentrations; waste pre-treatment may be required in such cases to prevent peak overloading of flue gas circulation system capacity.
Total Cadmium and Thallium	Dust and other metal control methods are more effective at controlling these substances
Other Metals	Techniques that control dust levels generally also control these metals
PCDD (Polychlorinated dibenzodioxins)/Dioxins and PCDF (Polychlorinated dibenzofurans)/Furans (ng TEQ/NM3)	Combustion techniques destroy PCDD/F in the waste. Specific design and temperature controls reduce de-novo synthesis. FGT: Static activated Carbon filters or Activated carbon is injected into the gas flow. The carbon is filtered from the gas flow using bag filters. The activated carbon shows a highabsorption efficiency for mercury as well as for PCDD/F. Catalytic bag filters are also used to reduce concentrations of PCDD/PCDF
Ammonia	Effective control of NOx abatement systems, including reagent dosing contributes to reducing NH3 emissions.

Flue Gas Constituents	Technology Description
Benz(a)pyrene/ PCBs/PAHSs	Techniques that control PCDD/F also control Benz(a) pyrene, PCBs and PAHs
Nitrous oxide (N_2O)	Effective oxidative combustion and control of NOx abatement systems contribute to reducing N_2O emissions.

Monitoring Requirements

The MSW (M&H) Rules, 2000 provides operating and emission standards for incineration.

A. Operating Standards

(1) The combustion efficiency (CE) shall be at least 99.00%

B. Emission Standards

Table 3.9: Emission standards for incineration

Parameters	Concentration mg/Nm^3 at (12% CO, correction)
Particulate Matter	150
Nitrogen Oxides	450
HCl	50
Minimum stack height shall be 30 meters above ground.	
Volatile organic compounds in ash shall not be more than	0.01 %

Table 3.10: German standards for air emissions from incineration plants - I

Parameter	Unit	Average per day	Half hour limit	Mean value per year
Dust	mg/m^3	5 (10)*	20	-
TOC	mg/m^3	10	20	-
HCl	mg/m^3	10	60	-
HF	mg/m^3	1	4	-
SO_2	mg/m^3	50	200	-
NOx	mg/m^3	150 (200)*	400	100
Hg	mg/m^3	0.03	0.05	0.01
CO	mg/m^3	50	100	-
Ammonia	mg/m^3	10	15	-
Minimum temperature of 850 C for at least 2 sec, O_2 content 11% ( )* Values for plants with firing thermal capacity <50 MW				

Table 3.11: German standards for air emissions from incineration plants - II

Mean values over sampling period per group	Unit	value
Cd, Tl	mg/m^3	0.05
Sb, As, Pb, Cr, Co, Cu, Mn, Ni,V, Sn	mg/m^3	0.5
As, Benzo(a)pyrene, Cd, Co, Cr	mg/m^3	0.05
Dioxine/Furanes	ng/m^3	0.1
Mean value per year of NOx	mg/m^3	100

Table 3.12: Emission Norms for Incineration of MSW as per EU Directive

(a) Daily average values	
Total dust	10 mg/m^3
Gaseous and vaporous organic substances, expressed as total organic carbon	10 mg/m^3
Hydrogen chloride (HCl)	10 mg/m^3

Hydrogen fluoride (HF)		1 mg/m^3
Sulphur dioxide (SO_2)		50 mg/m^3
Nitrogen monoxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide for existing incineration plants with a nominal capacity of 6 tonnes per hour or new incineration plants		200 mg/m^3
Nitrogen monoxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide for existing incineration plants with a nominal capacity of 6 tonnes per hour or less		400 mg/m3
(*) Until 1 January 2007 and without prejudice to relevant (Community) legislation the emission limit value for NOx does not apply to plants only incinerating hazardous waste.		
Exemptions for NOx may be authorised by the component authority for existing incineration plants		
* with a nominal capacity of 6 tonnes per hour, provided that the permit foresees the daily average values do not exceed 500 mg/m^3 and this until 1 January 2008,		
* with a nominal capacity of >6 tonnes per hour but equal or less than 16 tonnes per hour, provided the permit foresees the daily average values do not exceed 400 mg/m^3 and this until 1 January 2010.		
* with a nominal capacity of >16 tonnes per hour but <25 tonnes per hour and which do not produce water discharges, provided that the permit foresees the daily average values do not exceed 400 mg/m^3 and this until 1 January 2008.		
Until 1 January 2008, exemptions for dust may be authorised by the competent authority for existing incinerating plants, provided that the permit foresees the daily average values do not exceed 20 mg/m^3.		
(b) Half-hourly average values		
	(100%) A	(97 %) B
Total dust	30 mg/m^3	10 mg/m^3
Gaseous and vaporous organic substances, expressed as total organic carbon	20 mg/m^3	10 mg/m^3
Hydrogen chloride (HCl)	60 mg/m^3	10 mg/m^3
Hydrogen fluoride (HF)	4 mg/m^3	2 mg/m^3
Sulphur dioxide (SO_2)	200 mg/m^3	50 mg/m^3
Nitrogen monoxide (NO) and nitrogen dioxide(NO_2), expressed as nitrogen dioxide for existing incineration plants with a nominal capacity exceeding 6 tonnes per hour or new incineration plants	400 mg/m^3 (*)	200 mg/m^3 (*)
(*) Until 1 January 2007 and without prejudice to relevant Community legislation the emission limit value for NOx, does not apply to plants only incinerating hazardous waste.		
Until 1st January 2010, exemptions for NOx may be authorised by the competent authority for existing incineration plants with a nominal capacity between 6 and 16 tonnes per hour, provided the half-hourly average value does not exceed 600 mg/m^3 for column A or 400 mg/m^3 for column B.		
(c) All average values over the sample period of a minimum of 30 minutes and a maximum of 8 hours		

Cadmium and its compounds, expressed as cadmium (Cd)	total 0.05 mg/m³	total 0,1 mg/m³ (*)
Thallium and its compounds, expressed as thallium (TI)		
Mercury and its compounds, expressed as mercury (Hg)	0.05 mg/m³	0,1 mg/m³
Antimony and its compounds, expressed as antimony (Sb)	0.05 mg/m³	total 1 mg/m³ (*)
Arsenic and its compounds, expressed as arsenic (As)		
Lead and its compounds, expressed as lead (Pb)		
Chromium and its compounds, expressed as chromium (Cr)		
Cobalt and its compounds, expressed as cobalt (Co)		
Copper and its compounds, expressed as copper (Cu)		
Manganese and its compounds, expressed as manganese (Mn)		
Nickel and its compounds, expressed as nickel (Ni)		
Vanadium and its compounds, expressed as vanadium (V)		
(*) Until 1 January 2007 average values for existing plants for which the permit to operate has been granted before 31 December 1996, and which incinerate hazardous waste only.		
These average values cover also gaseous and the vapour forms of the relevant heavy metal emissions as well as their compounds.		
(d) Average values shall be measured over a sample period of a minimum of 6 hours and a maximum of 8 hours. The emission limit value refers to the total concentration of dioxins and furans calculated using the concept of toxic equivalence.		
Dioxins and furans		
(e) The following emission limit value of carbon monoxide (CO) concentrations shall not be exceeded in the combustion gases (excluding the start-up and shut-down phase):		
50 milligrams/m³ of combustion gas determined as daily average value;		
150 milligrams/m³ of combustion gas of at least 95 % of all measurement determined as 10-minutes average values or 100 mg/m³ of combustion gas of all measurements determined as half-hourly average values taken in any 24-hours period.		
Exemptions may be authorized by the competent authority for incineration plants using fluidized bed technology, provided that the permit foresees an emission limit value for carbon monoxide (CO) of not more than 100 mg/m³ as an hourly average value.		

Biomethanation

Biomethanation is the anaerobic

3.3.3.1 Merits Of Biomethanation Process

zz Energy generation

zz Reduction in land requirement for MSW disposal

zz Reduction of environmental impacts from landfilling by avoiding contamination of land and water sources from leachate zz Biomethanation of biodegradable organic material would ultimately result in stabilized sludge which can be used as a soil conditioner.

3.3.3.2 Applicability Of Biomethanation

Following are the necessary key criteria for successful biomethanation of MSW:

zz Biomethanation

zz There has to

zz Decentralized

zz The biomethanation

zz The

General Process Involved In Biomethanation

Generally the overall process can be divided into four stages:

zz Pre-treatment

zz Waste digestion

zz Gas recovery and usage

zz Residue treatment

Pre-treatment: Most digestion systems

Waste Digestion: Inside the digester,

Gas Recovery: The biogas

Residue Treatment: In case of residue treatment

3.3.3.4 Important Operating Parameters For Biomethanation

Some of the important

These parameters include:

zz **Temperature**: Temperature affects

At higher temperatures:

zz **pH**: The anaerobic

zz **Moisture:** The moisture content

zz **Toxicity**: A number of compounds are toxic to

zz **C/N Ratio**: Optimum C/N ratio in anaerobic digesters

zz **Organic Loading Rate:** Organic loading rate is the frequency

zz **Retention time**: The required retention time

- Temperature
- Ph
- Moisture
- Toxicity

• C/N Ratio

• Organic

Loading Rate

• Retention

Period

Organic loading rate for a plant of particular size determines the amount substrate to be added for optimum biogas production Anaerobic digestion process can be:

• Single Stage: all three stages of anaerobic process occur in one reactor

• Multi Stage: Acetogenesis and Methanogenesis are separated

Types Of Anaerobic Digestion (AD) System

Pyrolysis

Pyrolysis involves an irreversible chemical change

i) Gas:.

ii) Liquid:

Caution on Adopting Alternative Technologies for MSW Processing

zz Established technologies for defined and clean substances don‘t work automatically for heterogeneous wastes.

zz Alternative technologies have to demonstrate:

zz Decisions to rely on alternative technologies need backup by other possibilities to dispose off the wastes – in case of the new technology system will fail.

zz If an immediate solution for managing MSW is needed urgently – proven technologies are recommended.

Char: Consisting of elemental carbon along with the inert materials in the waste feed. The char,

3.5.1.1 Feed Stock For Pyrolysis

Many plastics, particularly the poly-olefins,

3.5.1.2 MSW Pyrolysis Process

Sorted and pre-treated feed stock is supplied to pyrolysis reactor, (Rotary kilns, rotary hearth furnaces, and fluidized bed furnaces are commonly used as MSW pyrolysis reactors

In order to recover the energy content of syn gas, it should be further processed in the following ways:

1) Syngas can be burned in a boiler to generate steam which may be used for power generation or industrial heating.

2) Syngas can be used as a fuel in a dedicated gas engine.

3) Syngas, after reforming, may be suitable for use in a gas turbine

4) Syngas can also be used as a chemical feedstock.

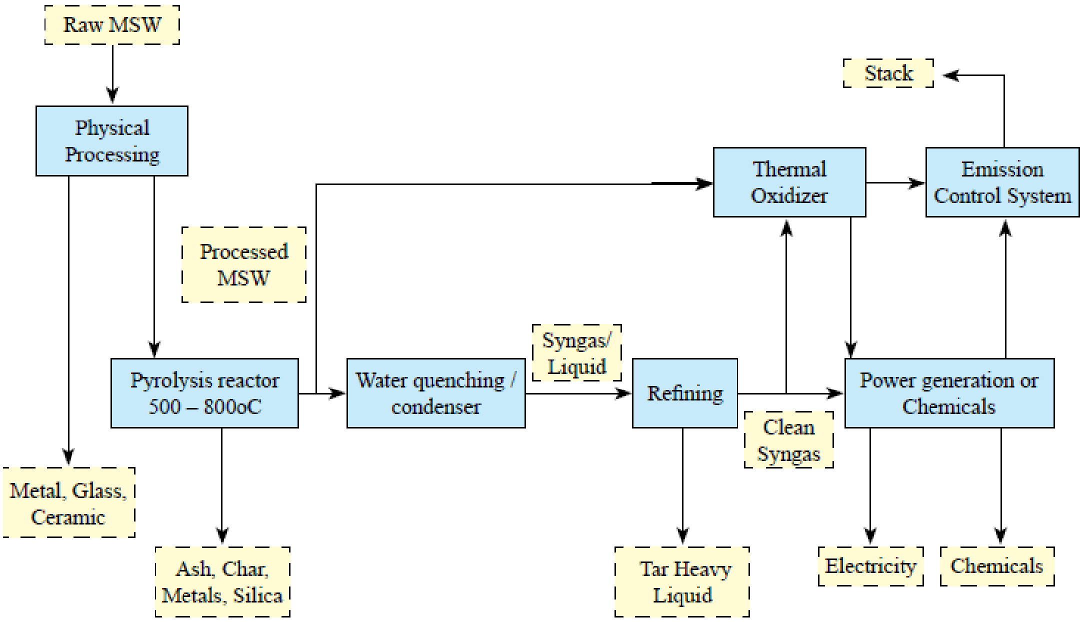


Figure 3.28: MSW Pyrolysis Process

Plasma Pyrolysis Vitrification

This is a modified pyrolysis technology aiming at energy/resources recovery from organic wastes.

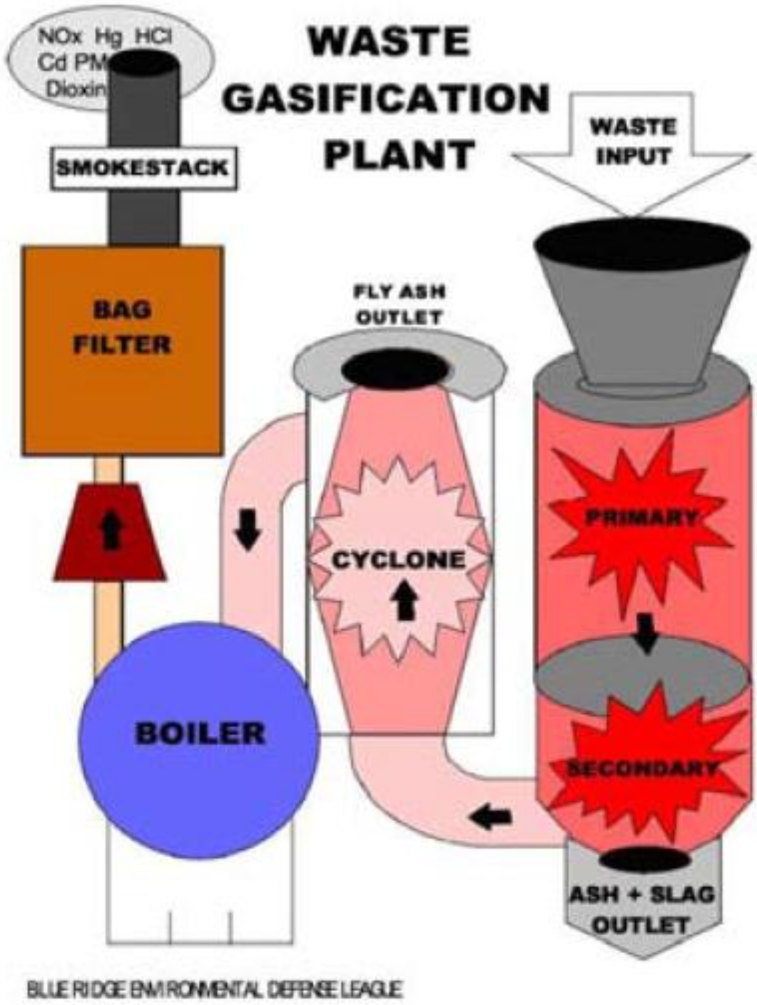
3.5.2 Gasification

Gasification is a partial combustion

3.5.2.1 Gasification Of Municipal Solid Waste

Feedstock Preparation: MSW should be pre-processed before it can be used as feedstock for the gasification process.

Figure 3.29: Waste gasification plant[42]



Types Of Gasifiers For Msw Treatment

Gasification technology is selected on the basis of available fuel quality, capacity **1) Fixed Beds**

Fixed bed gasifiers typically have a grate to support the feed material and maintain a stationary reaction zone.

2) Fluidized Beds

Fluidized beds are an attractive proposition for the gasification of MSW.

Bioreactor Landfill

A Bio Reactor Landfill (BRL) is a municipal solid waste

However, in the Indian context the following issues have to be considered:

zz As per the MSW (M&H)

zz While a BRL may be

Aerobic bioreactor: An aerobic bioreactor as shown in figure 3.30 collects leachate.

Figure 3.30: Aerobic Bioreactor[43]

Anaerobic Bioreactor: An anaerobic bioreactor, as shown in figure 3.31 collects leachate