Curriculum Design Committee

Course Design Committee

Course Preparation Committee

Dr. Dinesh Kumar Gupta $^{\alpha}$, Academic Consultant- Chemistry, School of Science, UPRTOU, Prayagraj, U.P. India	**Author** (Block-1)
Dr. Shashank Upadhyay $^{\beta}$**,** Dept. of Biotechnology, Invertis Univeristy, Bareilly, U.P. India	**Author** (Block-2, 3 & 4)
Prof. Sarad Kumar Mishra Dept. of Biotechnology, Deen Dayal Upadhayay Univeristy, Gorakhpur, U.P. India	**Editor**
Dr. Dinesh Kumar Gupta, Academic Consultant- Chemistry, School of Science, UPRTOU, Prayagraj, U.P. India	**SLM Coordinator**

Note: Symbols α = Block-1 (Unit-01,02 and 03) and β = Block-2, 3 and 4 (Unit-04, 05, 06, 07, 08, 09, 10, 11 and 12)

UNIT 1: INTRODUCTION TO MUNICIPAL SOLID WASTE MANAGEMENT

Structure

1.1 Introduction

Objective

1.2 Sources of Solid Waste

1.3 Types of Solid Waste

1.4 Effects of improper disposal of Solid Waste

1.5 Public Health effects

1.6 Terminal Questions

1.7 Answers

1.1 INTRODUCTION

In this unit you will come to know a very common environmental problem arises by the Municipal solid waste (MSW) which is one of the major environmental problems of the town and urban cities of the world. Rapid industrialization and population explosion in world has led to the migration of people from villages to cities, which generate thousands of tons of MSW daily. Improper management of municipal solid waste (MSW) causes hazards to inhabitants. Definitions of municipal solid waste (MSW) vary among countries. A working definition is 'wastes generated by households, and wastes of a similar nature generated by commercial and industrial premises, by institutions such as schools, hospitals, care homes, prisons and from public spaces such as streets, markets, slaughter houses, public toilets, bus stops, parks, and gardens. This working definition includes most commercial and business wastes as municipal solid waste, with the exception of industrial process and other hazardous wastes. Different countries define municipal solid waste rather differently. After the studying this unit learner comes to understand the effect of MSW.

Objective

- What is Solid Waste?
- Sources of Solid Waste
- Types of Solid Waste

- Effects of improper disposal of Solid Waste
- Public Health effects

1.2 SOURCES OF SOLID WASTE

Waste is any material that is not needed by the owner, producer or processor. Waste generators produce both municipal and non-municipal wastes: Manufacturing industries generate municipal solid waste from offices and canteens and industrial wastes from manufacturing processes.

- Some industrial wastes are hazardous and this part of the waste stream requires special management, separate from other wastes. Small workshops in urban areas generate both municipal and process wastes, some of which may be hazardous.
- Hospitals and healthcare establishments/ services generate municipal solid waste fractions that include food waste, newspapers and packaging, alongside specialized healthcare hazardous wastes that are often mixed with body fluids, chemicals and objects.
- Construction sites generate some municipal solid waste, including packaging and food and office wastes, wastes containing materials such as concrete, bricks, wood, windows and roofing materials.
- Construction and demolition wastes from household repairs and refurbishment, particularly 'do-it-yourself' wastes, are most likely to enter the municipal solid waste stream.
- In most cities, municipal solid waste includes 'household hazardous wastes' (HHWs; e.g. pesticides, paints and coatings, batteries, light bulbs and medicines). Similar hazardous wastes may come from small businesses. Cities in developed countries have systems that are designed to collect and handle these separately, or to prevent their generation and reduce their toxicity; but there are few cities in which this works completely and most MSW streams include some of these hazardous components when they reach disposal. Parallel collection systems sometimes exist for end-of-life vehicles and for waste electrical and electronic equipment (WEEE), some parts of which may again be classified as hazardous waste.
- There are also largely non-municipal waste streams, such as agricultural wastes and mining and quarrying wastes.

1.3 TYPES OF SOLID WASTE

"Municipal solid waste" (MSW) is a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region. The characteristics and quantity of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources. Urban wastes can be subdivided into two major components -- organic and inorganic. In general, the organic components of urban solid waste can be classified into three broad categories: putrescible, fermentable, and non-fermentable. Putrescible wastes tend to decompose rapidly and unless carefully controlled, decompose with the production of objectionable odours and visual unpleasantness. Fermentable wastes tend to decompose rapidly, but without the unpleasant accompaniments of putrefaction. Non-fermentable wastes tend to resist decomposition and, therefore, break down very slowly. A major source of putrescible waste is food preparation and consumption. As such, its nature varies with lifestyle, standard of living, and seasonality of foods. Fermentable wastes are typified by crop and market debris.

Wastes generated in countries located in humid, tropical, and semitropical areas usually are characterised by a high concentration of plant debris; whereas those generated in areas subject to seasonal changes in temperature or those in which coal or wood are used for cooking and heating may contain an abundance of ash.

Most disposable wastes are in form of solid, liquid or slurries. The main categories of such waste as follows:

- Domestic waste: Sewage, waste contaminated by detergents, dirts or grease, household garbage and bulk waste including packaging material, appliances, furniture, office waste, used cars, etc
- Waste from oil industry: Oil spills, oil leaks, water used for cleaning tankers, etc.
- Waste from the extraction industries: Mining, quarrying and dredging create solid waste.

- Construction waste: Building materials that are demolished or renovated and discarded materials after completion of buildings.
- Plastic waste: Different goods made of plastic thrown always after use, everywhere on land and sea.
- Agriculture waste: Mostly organic waste from plants and animals, irrigation water from farms containing fertilizers and pesticides.
- Factory waste: Solids and effluents form factories of all types. The worst pollutants are slaughterhouses, tanneries, textiles, paper and steel mills and most chemical industries; power plant discharge heated coolant water causing thermal pollution.
- Waste from food processing: Organic solid and liquid waste from discarded food materials.
- Biomedical waste: Discarded waste mainly by hospital and clinics which includes bloods, poisonous medicines, medical apparatus, etc.
- E-waste: Waste discarded by electronic equipments.
- Nuclear waste: Nuclear Thermal Power Plants use radioactive materials as fuels, Their discarded or dismantle plants produce radiations which cause health effects on livings for thousands of years.
- Waste from natural disorder: Earthquake, ash from volcanoes, floods, cyclones causes damage to the natural and manmade resources generating waste.
- Waste from wars and conflicts: During wars and conflicts, deadly materials such as nuclear weapons, bombs, bio-weapons, etc cause dead bodies & destroy buildings, etc. For example, In Hiroshima-Nagasaki War, Japan was highly destroyed by nuclear radiation and effects are seen till date, after **Little Boy** and **Fat Man** named two bombardments took place. In Vietnam War with US, **Agent Orange**, a herbicides was used as weapon.

Ideally, solid waste should not contain faecal matter or urine, and the mixing of these materials with household waste should be prohibited by law. However, enforcement difficulties, combined with variations in way of life, necessitate some tolerance in this matter. Solid waste collection in a manner satisfactory with respect to environmental health is made difficult when human excretory wastes are mixed with household wastes. Handling of pathological wastes, abattoir wastes, industrial wastes, and similar materials, in association with household wastes, also should not be permitted. Nevertheless, it is important to keep in mind that despite all precautions, some pathogens and chemical residues inevitably will be present in the waste.

- ✓ Construction and demolition debris
- ✓ Municipal wastewater treatment (sewage) sludge, septage, and slaughterhouse wastes
- ✓ Industrial hazardous waste, and some types of industrial solid waste (e.g., metal cuttings from metal processors or cannery waste)
- ✓ Pathological or infectious medical waste from hospitals, clinics, and laboratories
- ✓ "Hazardous" waste in the household waste stream (e.g., oil-based paints, paint thinners,
- ✓ Wood preservatives, pesticides, household cleaners, used motor oil, antifreeze, batteries)
- ✓ Discarded tires
- ✓ Used oils
- ✓ Electronic waste (e-waste)
- ✓ Wet batteries

Special type of Waste

In line with this definition, the following wastes are defined as Special Wastes:

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

Per capita waste generation is between 0.2 kg and 0.6 kg per day in the Indian cities amounting to about 1.15 lakh MT of waste per day and 42 million MT annually (NEERI-1995).

Comparison of solid waste characterisation worldwide (% wet wt)

Location	Putres-cibles	Paper	Metals	Glass	Plastics, Rubber, Leather	Tex-tiles	Ceramics, Dust, Stones	Wt (g)/ cap/ day
Bangaluru, India [1]	75.2	1.5	0.1	0.2	0.9	3.1	19.0	400
Manila, Philippines [2]	45.5	14.5	4.9	2.7	8.6	1.3	27.5	400
Asunción, Paraguay [2]	60.8	12.2	2.3	4.6	4.4	2.5	13.2	460
Seoul, Korea [3]	22.3	16.2	4.1	10.6	9.6	3.8	33.4[a]	2,000[a]
Vienna, Austria [4]	23.3	33.6	3.7	10.4	7.0	3.1	18.9[b]	1,180
Mexico City, Mexico [5]	59.8[c]	11.9	1.1	3.3	3.5	0.4	20.0	680
Paris, France [4]	16.3	40.9	3.2	9.4	8.4	4.4	17.4	1,430
Australia [7]	23.6	39.1	6.6	10.2	9.9		9.0	1,870
Sunnyvale, California, USA [6]	39.4[d]	40.8	3.5	4.4	9.6	1.0	1.3	2,000
Bexar County, Texas, USA [6]	43.8[d]	34.0	4.3	5.5	7.5	2.0	2.9	1,816

a Includes briquette ash (average).
b Includes "all others".
c Includes small amounts of wood, hay, and straw.
d Includes garden waste.

Source: UNEP IETC (Osaka, Japan) and Cal Recovery, Inc.(Concord, California, USA)

Municipal Waste Generation in the World: World Bank report 2012:

In 2012, the World Bank released a report on global municipal waste generation; the highlights of the report are given as follows:

- Solid waste is the most visible and pernicious by-product of a resource-intensive, consumer based economy lifestyle.
- The amount of municipal solid waste (MSW) is growing even faster than the rate of urbanization, in 2012, 3 billion urban residents were generating 1.2 Kg per person per day or about 1.3 billion tonnes per year. By 2025, this is likely to increase to 4.3 billion urban residents generating 1.42 Kg per person per day or about 2.2 billion tonnes per year.
- The rate of MSW growth is fastest in China, other part of East Asia and parts of Eastern Europe and Middle East. In 2004, China cross US as world's largest waste generator. By 2030, China will produce twice as much as the US.
- The collection rate is 41% in low income countries where as 98% in high income countries.

- As any country’s wealth increases, organic waste generally decreases, while paper and plastic increases.
- Low income countries spend most of their MSW budgets on waste collection, with only a fraction going towards disposal. This is the opposite in high income countries, where the main income is spent on disposal.

International awareness regarding waste:

- At the 1992 Rio Conference, waste was made one of the priorities of Agenda 21. Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally and was adopted by more than 178 Governments at the United Nations Conference in Rio de Janeiro
- At the Johannesburg World Summit on Sustainable Development in 2002, the focus was on: Initiatives to accelerate the shift to sustainable consumption and production, reduction of resource degradation, pollution and waste
- Implementation plan adopted by the Summit, stated the priority to:

"Prevent and minimize waste & maximize reuse, recycling & use of environment & friendly alternative materials, with the participation of government authorities, all stakeholders to minimize adverse effects on the environment and improve resource efficiency, with financial, technical and other assistance for developing countries.”

Developing countries like India: massive migration of their population from rural to urban centers, new consumption patterns, production techniques and expansion of human activity contributed to increase in all kinds of waste. No strategies/laws/rules which encourage reuse, recycle and reduction. Inaccurate estimates of waste produced in India. Health/Environment hazards caused by waste is not addressed.

1.4 EFFECTS OF IMPROPER DISPOSAL OF SOLID WASTE

The typical municipal solid waste stream contains general wastes as organics and recyclable, special wastes as household hazardous, medical, and industrial waste, and construction and demolition debris. Most adverse environmental impacts from solid waste management are rooted in inadequate or incomplete collection and recovery of recyclable or reusable wastes, as well as co-disposal of hazardous wastes. These impacts are also due to inappropriate sitting, design, operation or maintenance of dumps and landfills. Improper waste management activities can produce:

- **Increase disease transmission or otherwise threaten public health:** Rotting organic materials pose great public health risks, including, as mentioned above, serving as breeding grounds for disease vectors. Waste handlers and waste pickers are especially vulnerable and may also become vectors, contracting and transmitting diseases when human or animal excreta or medical wastes are in the waste stream. Risks of poisoning, cancer, birth defects, and other ailments are also high.

- **Contaminate ground and surface water:** Municipal solid waste streams can bleed toxic materials and pathogenic organisms into the leachate of dumps and landfills. (Leachate is the liquid discharge of dumps and landfills; it is composed of rotted organic waste, liquid wastes, infiltrated rainwater and extracts of soluble material.) If the landfill is unlined, this runoff can contaminate ground or surface water, depending on the drainage system and the composition of the underlying soils. Many toxic materials, once placed in the general solid waste stream, can be treated or removed only with expensive advanced technologies. Currently, these are generally not feasible in Africa. Even after organic and biological elements are treated, the final product remains harmful.

- **Create greenhouse gas emissions and other air pollutants:** When organic wastes are disposed off in deep dumps or landfills, they undergo anaerobic degradation and become significant sources of methane, a gas with 21 times the effect of carbon dioxide in trapping heat in the atmosphere. Garbage is often burned in residential areas and in landfills to reduce volume and uncover metals. Burning creates thick smoke that contains carbon monoxide, soot and nitrogen oxide, all of which are hazardous to human health and degrade urban air quality. Combustion of polyvinyl chlorides (PVCs) generates highly carcinogenic toxins.

- **Damage ecosystems:** When solid waste is dumped into rivers or streams it can alter aquatic habitats and harm native plants and animals. The high nutrient content in organic wastes can deplete dissolved oxygen in water bodies, denying oxygen to fish and other aquatic life form. Solids can cause sedimentation and change stream flow and bottom habitat. Sitting dumps or landfills in sensitive ecosystems may destroy or significantly damage these valuable natural resources and the services they provide.

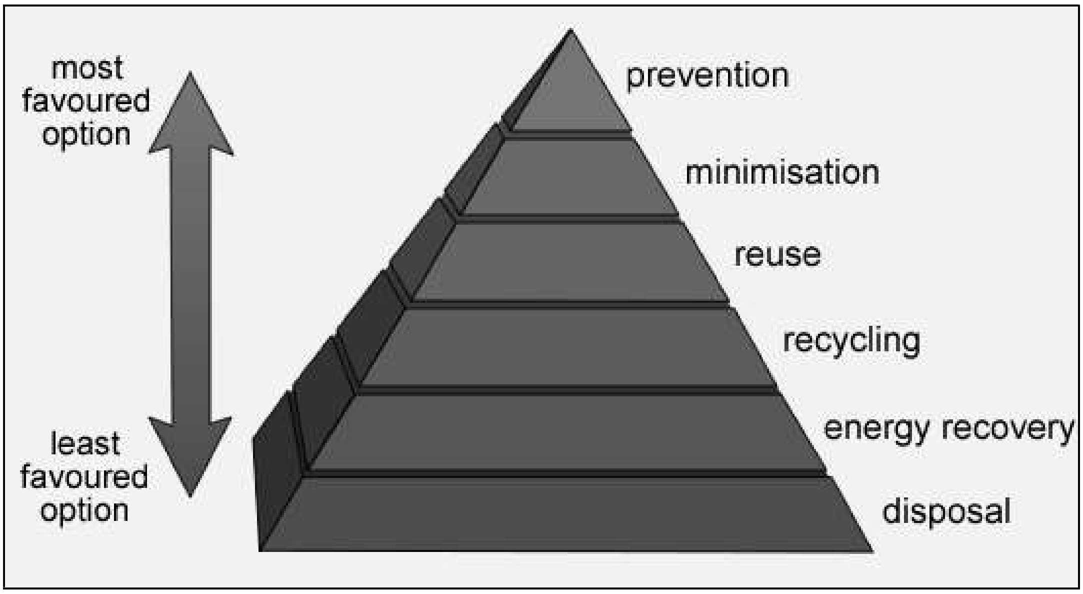
- **Injure people and property:** In locations where shanty towns or slums exist near open dumps or near badly designed or operated landfills, landslides or fires can destroy homes and injure or kill residents. The accumulation of waste along streets may present physical hazards, clog drains and cause localized flooding.

- **Discourages tourism and other business:** The unpleasant odor and unattractive appearance of piles of uncollected solid waste along streets and in fields, forests and other natural areas, can discourage tourism and the establishment and/or maintenance of businesses.

1.5 PUBLIC HEALTH EFFECTS

The organic fraction of MSW is an important component, not only because it constitutes a sizable fraction of the solid waste stream in a developing country, but also because of its potentially adverse impact upon public health and environmental quality. A major adverse impact is its attraction of rodents and vector insects for which it provides food and shelter. Impact on environmental quality takes the form of foul odours and unsightliness. These impacts are not confined merely to the disposal site. On the contrary, they pervade the area surrounding the site, wherever the wastes are generated, spread, or accumulated. Unless an organic waste is appropriately managed, its adverse impact will continue until it is fully decomposed or otherwise stabilised. Uncontrolled or poorly managed intermediate decomposition products can contaminate air, water and soil resources.

Solid waste management hierarchy



• Prevent the production of waste, or reduce the amount generated.

• Reduce the toxicity or negative impacts of the waste that is generated.

• Reuse in their current forms the materials recovered from the waste stream.

• Recycle, compost, or recover materials for use as direct or indirect inputs to new products.

• Recover energy by incineration, anaerobic digestion, or similar processes.

• Reduce the volume of waste prior to disposal.

• Dispose of residual solid waste in an environmentally sound manner, generally in landfills.

Globally, the waste management sector contributes just 3-5% of total emissions caused by human activities. However, the waste sector can indirectly become major investor of emissions. The prevention and recovery of wastes will reduce emissions in all other sector of the economy.

Collection of segregated municipal waste is an essential step in solid waste management. Inefficient waste collection service has an impact on public health and aesthetics of towns and cities. Collection of wet and dry waste separately enhances the potential of cost effective treatment of such wastes and ensure optimum advantage from the recyclable material fed into the system. Waste collection services are divided into primary and secondary collection. Primary collection refers to the process of collecting waste from households, markets, institutions and other commercial establishments and taking the waste to a storage depot/ transfer station or directly to the disposal site, depending on the size of the city and the waste management system prevalent in the city. Secondary collection includes picking up waste from community bins, waste storage depots or transfer stations and transporting it to waste processing sites or to the final disposal site. Primary collection must ensure separate collection of certain waste streams / fractions depending on the separation and reuse system applied by the respective town/ City. Segregated waste must be stored on-site in separate containers for further collection and should be kept separate during all steps of waste collection, transportation and processing.

Primary and secondary transportation system, with regular and well communicated intervals of operation is essential to avoid containers' overflow and waste littering on streets. It is essential to separate street sweeping and drainage waste completely from household waste streams through all stages of collection, transport and treatment since street sweeping and drainage infiltrates significant amounts of toxic substances.

Risks to the Communities

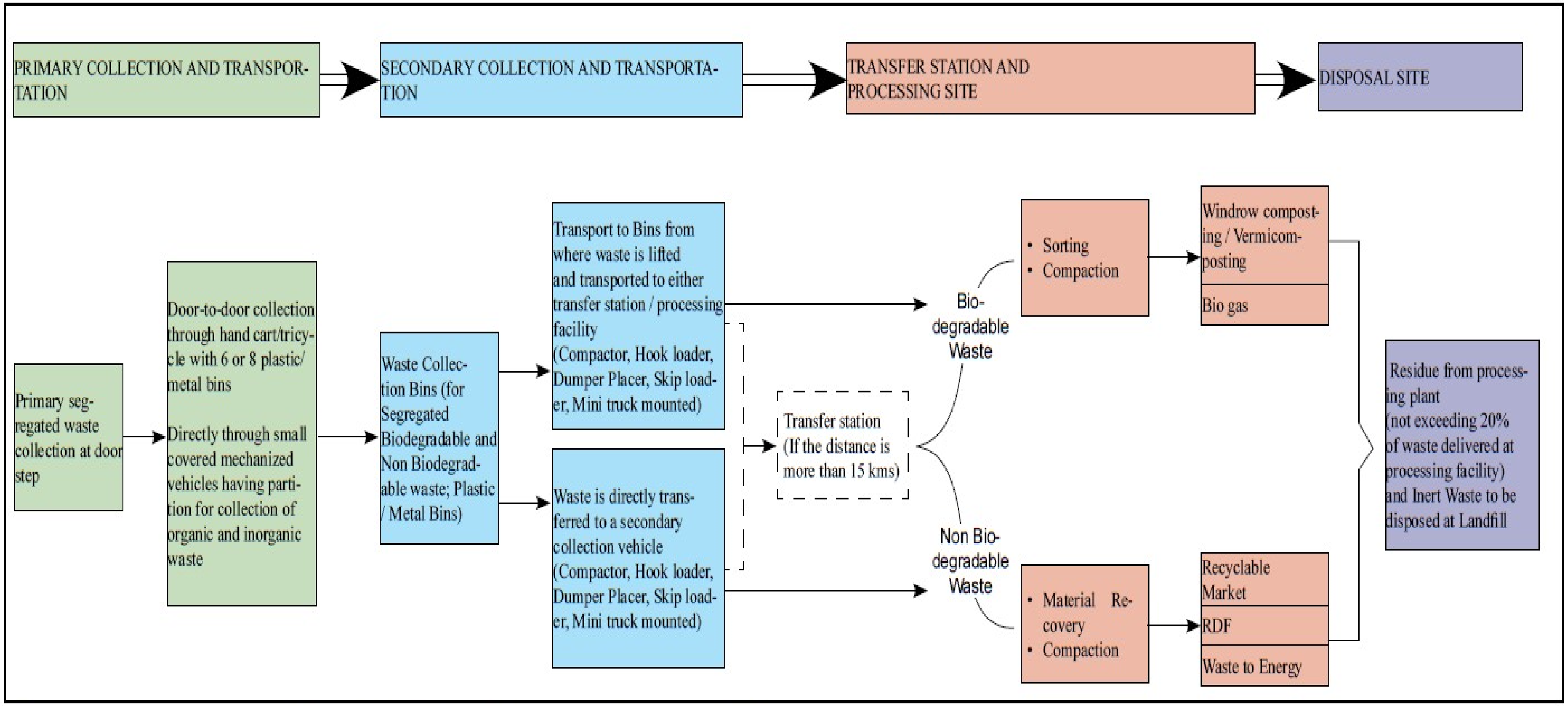
- There is a significant increase in the incidence of sickness among children who live in households where garbage is dumped or burned in the yard.
- Uncollected solid waste clogs drains and causes flooding and subsequent water-borne diseases.
- People living downwind of a burning dumpsite will likely suffer from respiratory diseases.
- Contaminated liquids or leachate, leaking from dumpsite could pollute city's drinking water supplies.
- Waste dumps potentially serve as breeding ground for Malaria, thus having implications in achieving Millennium Development Goals (MDGs).

Risks to Waste Pickers

Informal waste pickers, who most often operate without any protective measures, are exposed to a wide range of health risks such as:

- HIV (due to handling of hospital waste)
- Tetanus (due to handling of jagged metals)
- Respiratory problems (due to exposure to smoke)
- Neural damage (due to lead)
- Injuries
- Premature drinking
- Stress
- Skin and gastric problems

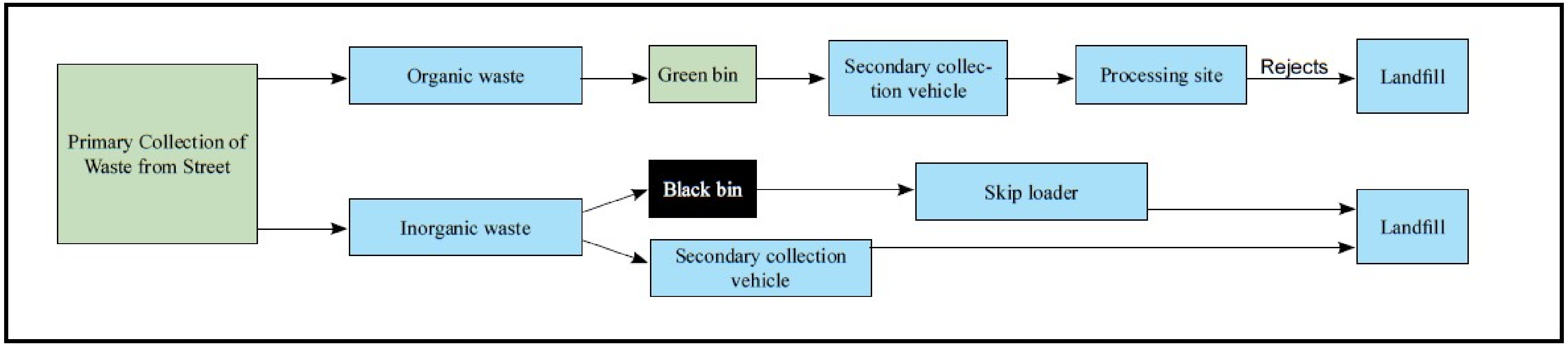
Source: Gunn, S. (2009), UN-HABITAT (2009), with modifications.



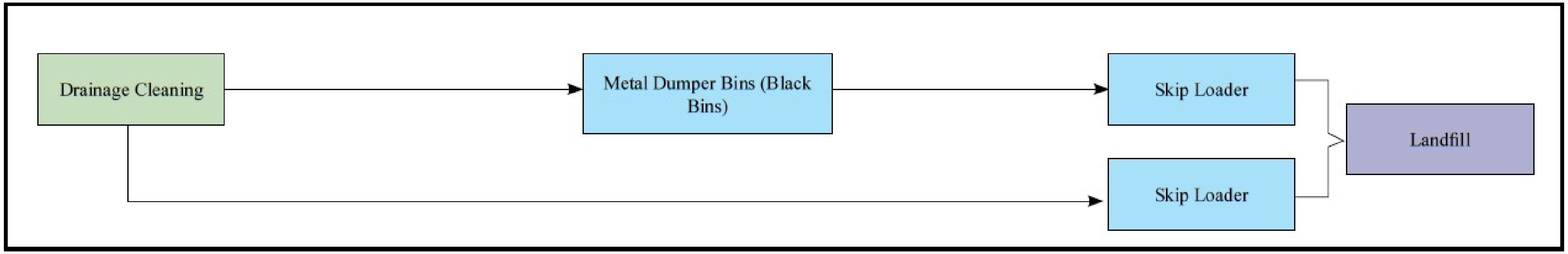
- *The compactor is an appropriate vehicle for collecting biodegradable and recyclable component of MSW*
- *Skip loaders/ Hook loaders are preferred for collecting inert waste or Construction and Demolition waste*
- *Waste may be transferred to the transfer station if the processing site is located at least 15 kms away from the city*

Flow chart for household waste collection, transportation & disposal

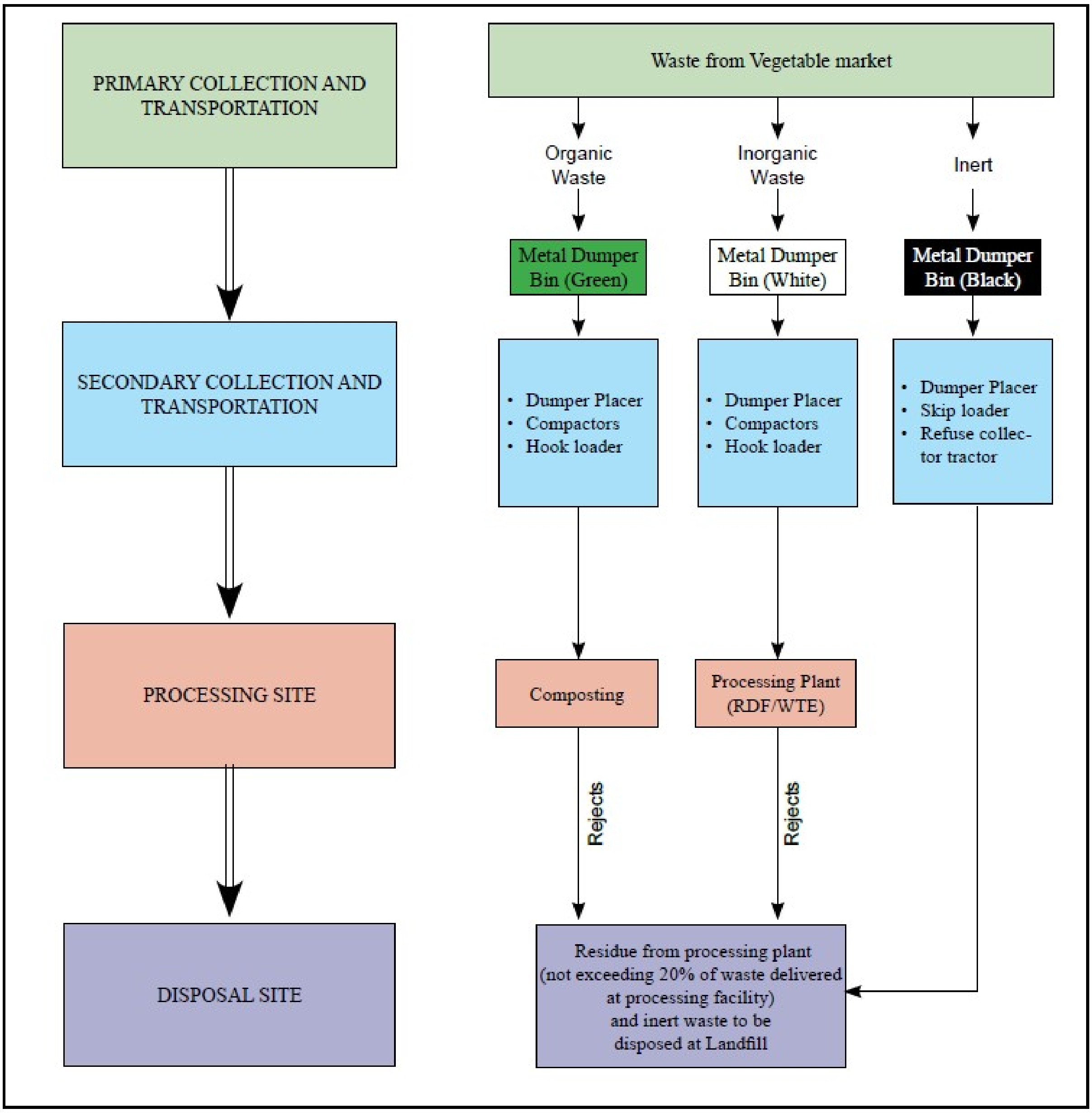
http://moud.gov.in



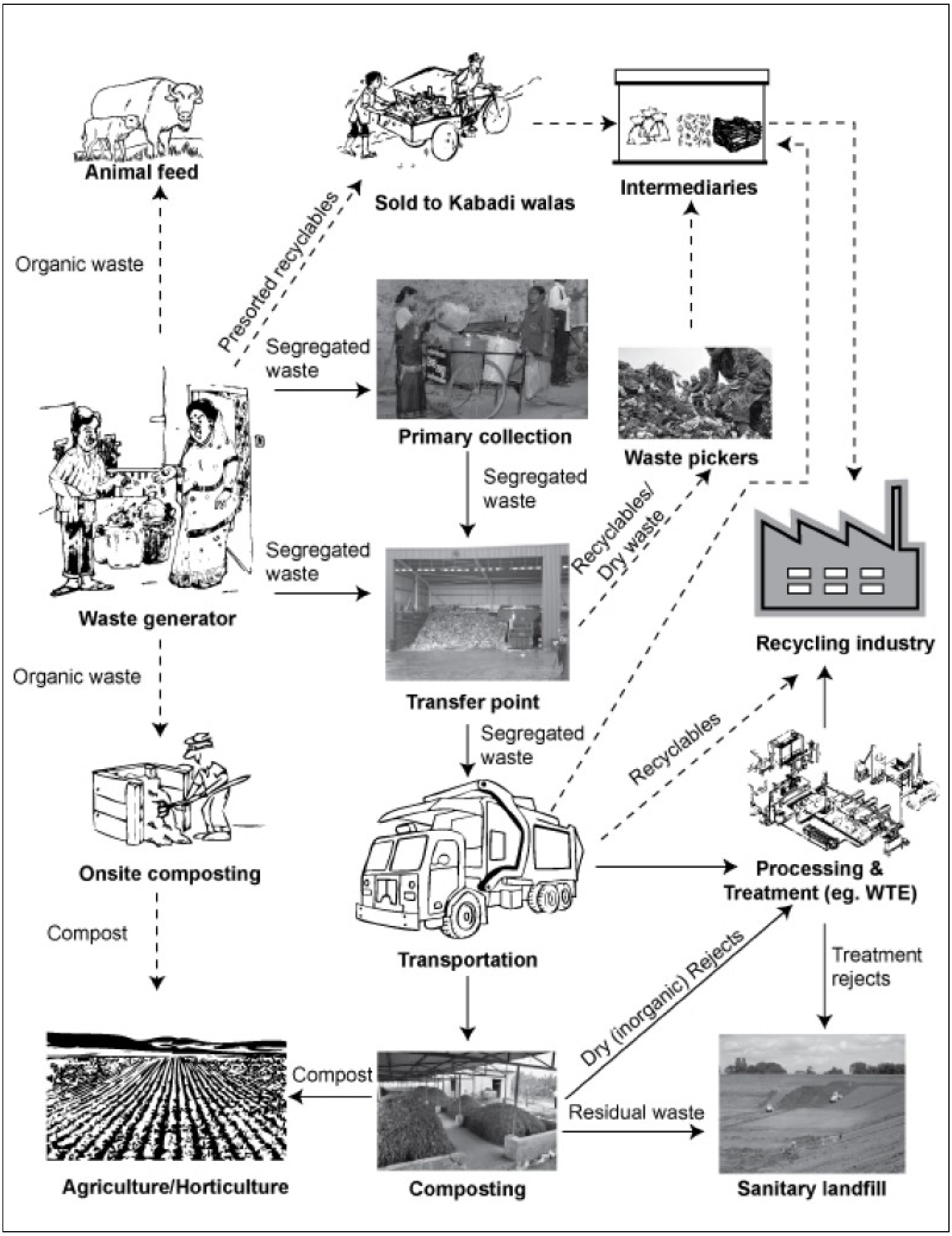
Street sweepings are predominantly inert wastes. A skip loader/ hook loader is preferred for transportation of street sweepings.



Flow charts for collection, transportation & disposal of street sweeping & drain silt



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



Stages of Material Recovery in Municipal

Adapted from: 'Improving Solid Waste Management in India,' D. Zhu, et al., (2008).
Source: http://w02/05/14ww.tn.gov.in/cma/swm_in_india.pdf

General Types of Water Pollutants

Class of pollutant	Significance
Trace Elements	Health, aquatic biota, toxicity
Heavy metals	Health, aquatic biota, toxicity
Organically bound metals	Metal transport
Radionuclides	Toxicity
Inorganic pollutants	Toxicity, aquatic biota
Asbestos	Human health
Algal nutrients	Eutrophication
Acidity, alkalinity, salinity (in excess)	Water quality, aquatic life
Trace organic pollutants	Toxicity
Polychlorinated biphenyls	Possible biological effects
Pesticides	Toxicity, aquatic biota, wildlife
Petroleum wastes	Effect on wildlife, esthetics
Sewage, human and animal wastes	Water quality, oxygen levels
Biochemical oxygen demand	Water quality, oxygen levels
Pathogens	Health effects
Detergents	Eutrophication, wildlife, esthetics
Chemical carcinogens	Incidence of cancer
Sediments	Water quality, aquatic biota, wildlife
Taste, odor, and color	Esthetics

Important Trace Elements in Natural Waters

Element	Sources	Effects and Significance
Arsenic (As)	Mining byproduct, chemical waste	Toxic, possibly carcinogenic
Beryllium (Be)	Coal, industrial wastes	Toxic
Boron (B)	Coal, detergents, wastes	Toxic
Chromium (Cr)	Metal plating	Essential as Cr(III), toxic as Cr(VI)
Copper (Cu)	Metal plating, mining, indus-trial waste	Essential trace element, toxic to plants and algae at higher levels
Fluorine (F^-)	Natural geological sources, wastes, water additive	Prevents tooth decay at around mg/L, toxic at higher levels
Iodine (I^-)	Industrial wastes, natural brines, seawater intrusion	Prevents goiter
Iron (Fe)	Industrial wastes, corrosion, acid mine water, microbial action	Essential nutrient, damages fixtures by staining
Lead (Pb)	Industrial waste, mining, fuels	Toxic, harmful to human and wildlife
Manganese (Mn)	Industrial wastes, acid mine water, microbial action	Toxic to plants, damages fixtures by staining

Mercury (Hg)	Industrial waste, mining, coal	Toxic, mobilized as methyl mercury compounds by anaerobic bacteria
Molybdenum (Mo)	Industrial wastes, natural sources	Essential to plants, toxic to animals
Selenium (Se)	Natural sources, coal	Essential at lower levels, toxic at higher levels
Zinc (Zn)	Industrial waste, metal plating, plumbing higher levels	Essential element, toxic to plants at

Case Study 1:

Alang: Toxic Ship-breaking Yard-

Alang is located in the Gulf of Kambhat on the coast of Gujrat, 56 Km from Bhavnagar.Due to high tide range and wide continental self; allow very high heavy ships to reach the coast easier makes Alang an ideal for big ship yard. The necklace shaped Alang is said to be the largest in the world. With 184 ship-breaking plots, it dismantles about 300 ships every year and has a turn over off ` 6000 crores. The yards employs about 40,000 people directly and 1,00,000 more indirectly.

Mostly workers migrants form Orissa, Uttar Pradesh, Bihar, etc. work under extremely hazardous conditions in toxic atmosphere. They work without training and absence of protective kit, accidents and related deaths are very common due lack of medical facilities, sanitation, housing, safe drinking water, etc. Alang among the workers popularly saying 'Alang se Palang' means from Alang to the death bad. From 1983 to 2013, there were 470 deaths in the yard, according to records. This is because ships come for dismantle carries toxic waste, which cause environment and health problems. Greenpeace and other organizations campaigning for adapting environmentally safe approach to ship-breaking and for improving conditions in ship-breaking yards. After the directives issued by supreme Court and Greenpeace some improvements have been made in working conditions.

1.6 TERMINAL QUESTIONS

Check your progress

1. Which of the following statements is true with regard to waste and its management?
(a) There is no real waste in nature

(b) Waste can always be carefully reused.
(c) Nature can handle our waste
(d) We can always handle waste by throwing it always

2. What is the most serious issue with ship-breaking?
(a) Lack of facilities for workers
(b) Toxic content of ships
(c) Marine pollution
(d) Air pollution

3. Which of the following is the most dangerous and long-lasting?

(a) Biomedical waste
(b) Ash from volcano
(c) Mining waste
(d) Nuclear waste

4. What is meant by upcycling?
(a) Recovering useful material material from waste
(b) Composting biodegradable waste
(c) Separation waste into categories
(d) Turning waste into products of higher qualities

Questions:

Q1. Define sources of Solid Waste?

Q2. Define types of Solid Waste?

Q3. Effects of improper disposal of Solid Waste?

Q4. Public Health effects of Solid Waste?

UNIT 2: COMPOSITION OF SOLID WASTE

Structure

2.1 Introduction

Objective

2.2 Composition of Solid Waste and its determination

2.3 Types of material recovered from MSW

2.4 Terminal Questions

2.5 Answers

2.1 INTRODUCTION

Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area. It may be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc). After studying this unit learner comes to describe the solid waste composition and its determination. Types of materials recovered from different Municipal Solid Wastes which was discarded. How MSW can reduced and reused for the society.

Objective

- Solid waste composition
- Determination of Solid waste
- Material recovered from the solid waste

2.2 COMPOSITION OF SOLID WASTE AND ITS DETERMINATION

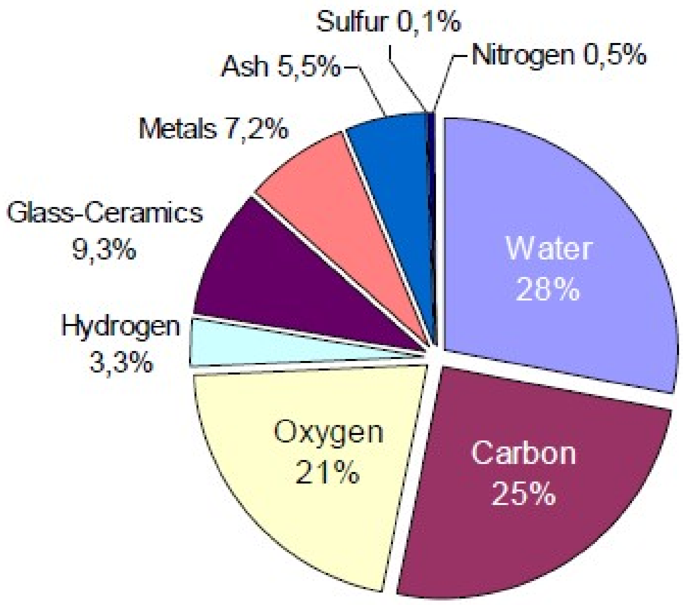
Solid waste is very heterogeneous in nature and its composition varies with place and time. Even samples obtained from the same place (sampling point) on the same day, but at different times may show totally different characteristics. But also Municipal solid waste composition and characteristics vary considerably, not only between cities but also within a Urban Local Bodies (ULB) – daily, seasonal and temporal fluctuations are usually observed. Quartering & coning method is a well established technique for waste characterization. The sample is reduced to a more manageable size as the actual classification is carried out by hand. Selection of sampling sites is a critical first step in this process.

Quartering & Coining Sampling Procedure

- Take 10 kg of municipal waste mixed from outside and inside of the waste pile, sourced from random entities in an identified sampling location.
- Samples from all heterogeneous sampling points shall be mixed thoroughly.
- The sample is placed as a uniform heap.
- The heap is divided into four portions using straight lines perpendicular to each other.
- Waste from opposing corners of the divided heap is removed to leave half of the original sample. The remaining portions are again thoroughly mixed and the quartering process is repeated until a desired size is obtained (10 kg of waste can be handled/ segregated efficiently).
- The last remaining opposing fractions of waste shall be mixed and analyzed for identifying physical and chemical properties of the waste.
- Chemical analysis of the waste sample follows the physical constituent analysis.
- Chemical analysis of the sample shall be performed.

Proportion of Waste Constituents

The size distribution of waste constituents in the waste stream is important because of its significance on the selection of appropriate collection/transportation/processing/treatment and disposal practices. The waste characterization method mentioned above shall be followed to assess proportions of waste constituents.



Chemical composition of typical MSW

Physical Characteristics of Municipal Waste

Critical parameters for selecting the appropriate processing technology are: waste quantity and characteristics, such as density, moisture, calorific value, toxicity etc.

Density of waste

The density of waste (mass per unit volume, kg/m^3) determines the storage and transportation volume requirements. Usually it refers to uncompacted waste. It varies with geographic location, season of the year, and length of time in storage. MSW density in India is typically around 450-500 kg/m^3. Low density wastes e.g. packaging wastes, plastic waste and high density wastes e.g. street sweeping waste, metal waste etc.

Typical Specific Weight Values

Component	Specific Weight (density), kg/m^3	
	Range	Typical
Food wastes	130-480	290
Paper	40-130	89
Plastics	40-130	64
Yard waste	65-225	100
Glass	160-480	194
Tin cans	50-160	89
Aluminum	65-240	160

Condition	Density (kg/m^3)
Loose MSW, no processing or compaction	90-150
In compaction truck	355-530
Baled MSW	710-825
MSW in a compacted landfill (without cover)	440-740

Moisture Content

Moisture content of solid wastes is usually expressed as the weight of moisture per unit weight of wet material. Solid waste with high moisture content results in increasing collection and transportation costs.

$$\textbf{Moisture Content}\ (\%) = \frac{\textbf{Wet weight} - \textbf{dry weight}}{\textbf{Wet weight}} x100$$

A typical range of moisture content is 20 – 45% representing the extremes of wastes in an arid climate and in the wet season of a region having large precipitation. Values greater than 45% are however not uncommon. Moisture increases the weight of solid waste and therefore the cost of collection and transport. Consequently, waste should be insulated from rainfall or other extraneous water.

Moisture content is a critical determinant in the economic feasibility of incineration processes since energy must be supplied for evaporation of water and in raising the temperature of the water vapour. Moisture content is generally found to be high in wastes containing a higher proportion of food wastes.

Analysis Procedure:

- Weigh the aluminum dish
- Fill the dish with SW sample and re-weigh
- Dry SW + dish in an oven for at least 24 hrs at 105°C.
- Remove the dish from the oven, allow to cool in a desiccator, and weigh.
- Record the dry weight of SW + dish.
- Calculate the moisture content (M) of the SW sample using the equation given above.

Typical moisture contents of waste

Type of Waste		Moisture Content, %	
		Range	Typical
Resindential	Food wastes (mixed)	50 - 80	70
	Paper	4 - 10	6
	Plastics	1 - 4	2
	Yard Wastes	30 - 80	60
	Glass	1 - 4	2
Commercial	Food wastes	50 - 80	70
	Rubbish (mixed)	10 - 25	15
Construction & Demolition	Mixed demolition combustibles	4 - 15	8
	Mixed construction combustibles	4 - 15	8
Industrial	Chemical sludge (wet)	75 - 99	80
	Sawdust	10 - 40	20
	Wood (mixed)	30 - 60	35
Agricultural	Mixed Agricultural waste	40 - 80	50
	Manure (wet)	75 - 96	94

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. The calorific value is determined experimentally using a Bomb Calorimeter, in which the heat generated from the combustion of a dry sample is measured, at a constant temperature of 25°C. Since the test temperature is below the boiling point of water, the combustion water remains in the liquid state. However, during combustion the temperature of the combustion gases remains above 100°C so that the water resulting from combustion is in the vapour state.

Determining calorific value of waste is important to determine the potential for recovering Refuse Derived Fuel (RDF) and its utilization in cement/ power/ waste to energy plants.

Bio-Chemical Characteristics

Bio-chemical characteristics of waste determine the suitability of specific treatment processes. ULBs should use this information to select the most appropriate treatment process.

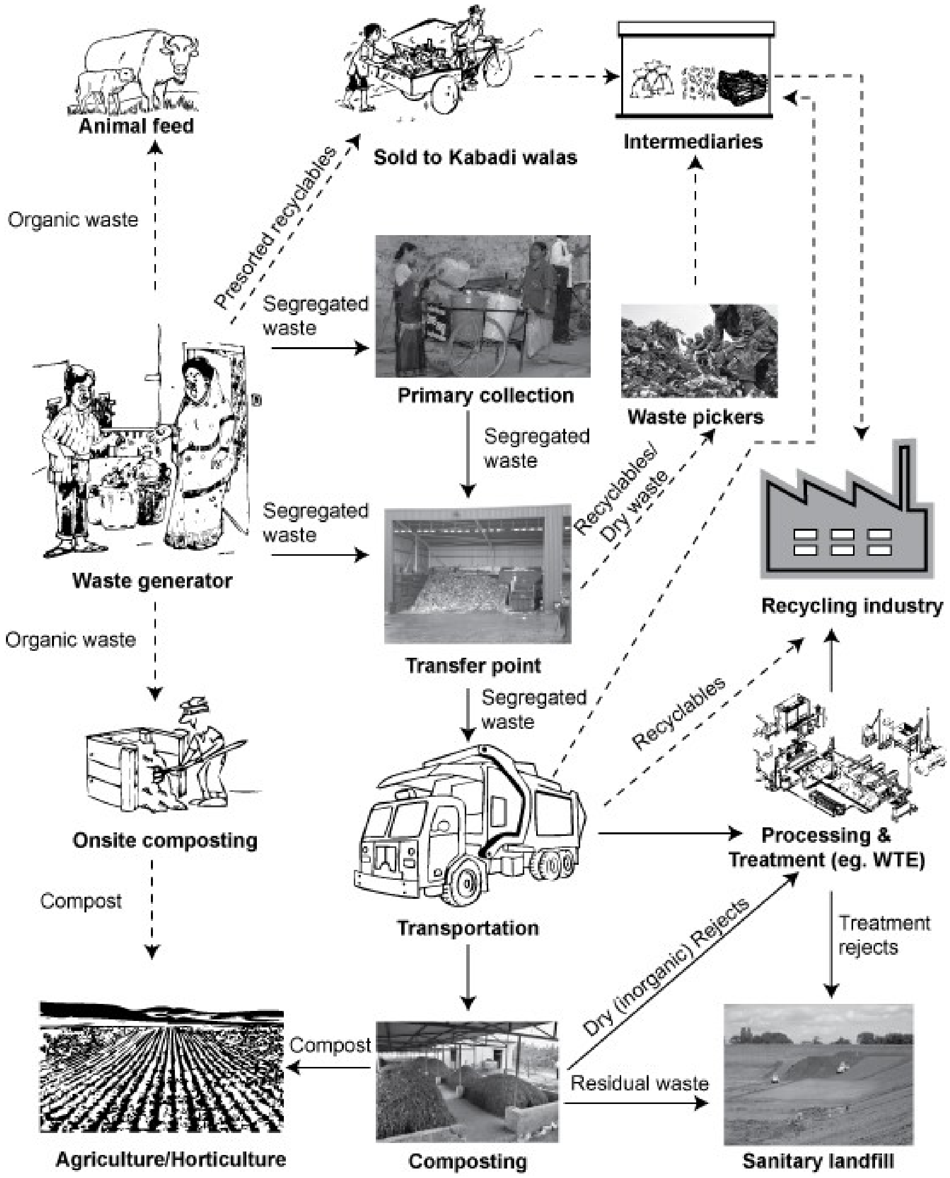
Chemical characteristics of waste are essential in determining the efficacy of any treatment process.

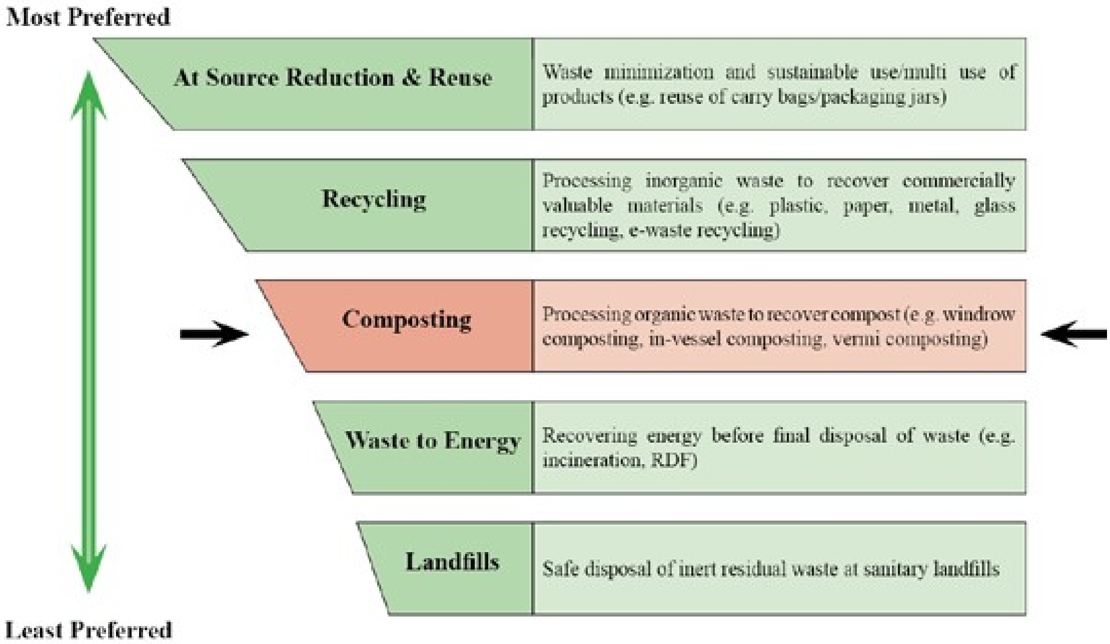
1. **Chemical characteristics:** pH, Nitrogen, Phosphorus and Potassium (N-P-K), total Carbon, C/N ratio, calorific value.
2. **Bio-Chemical characteristics:** carbohydrates, proteins, natural fiber, and biodegradable factor.
3. **Toxicity:** Toxicity profile of MSW includes heavy metals, Persistent Organic Pollutants (POPs), pesticides and insecticides. The Toxicity Characteristic Leaching Procedure (TCLP) is used for ascertaining the toxicity profile of MSW.

2.3 TYPES OF MATERIAL RECOVERED FROM MSW

Municipal authorities shall adopt suitable technology or combination of such technologies to make use of wastes so as to minimize burden on landfill. The biodegradable wastes shall be processed by composting, vermin-composting, anaerobic digestion or any other appropriate biological processing for stabilization of wastes. It is assumed that at least 65 to 80% of energy content of waste can be recovered as heat energy through waste to energy technologies.

Stages of Material Recovery in Municipal





Hierarchies to use MSW for recover the materials

Material Recovery Facility

A Material Recovery Facility (MRF) accepts mixtures of waste fractions (e.g. selected materials collected in the dry waste) for the purpose of separating and diverting recyclable materials and transferring the remaining waste for disposal. Configuration of a MRF depends upon factors such as types and quantities of material to be processed, quality and quantity of incoming waste, processing rates and desired quality of end products.

Recycling Of Plastics

It is estimated that approximately 4,000 to 5,000 metric tonnes per day of plastic waste is generated in India which is roughly 4 to 5 percent by weight of MSW. The major problems in plastic waste management are collection, segregation and disposal. At present, plastic waste collection is done through the informal sectors such as the kabadi system and rag pickers. One estimate says recycling of 1 plastic bottle would save enough energy to power a 60W bulb for 3 hours.

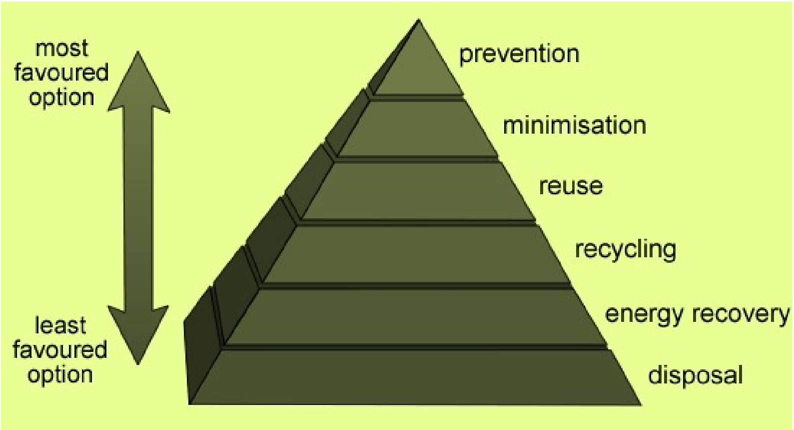
Recycling Paper and Board

In India the collection of waste paper is mainly performed by the informal sector, i.e., by door to door collectors/ kabadi system and rag pickers. As much as 95% of the collection of waste paper in the country is carried out by the informal sector. The value chain comprises direct collection from various source points and small shops, where primary sorting of the waste into different categories should take place; zonal segregation centres owned by wholesalers, where the waste material gets collected from small shops and baled and finally dispatch to end users, which are usually paper mills.

Waste Out of Wealth' in India

ITC Paperboards and Speciality Paper Division launched the waste paper collection programme called Waste Out of Wealth (WOW) in 2011 in select areas as Hyderabad, Bangalore and Coimbatore and are expanding it to more areas in South India including Chennai. In Chennai, it has tied up with 30-40 IT companies including Infosys, IBM, and Wipro which would sell their waste paper to ITC for recycling. It also plans to tie up with Residential Welfare Associations (RWAs), NGOs and local bodies to expand the waste paper collection programme.

Paper recyclers are developing new technologies for handling, identifying and separating paper grades for recycling. One such technology allows segregation of paper fibers during the recycling process according to fiber length, coarseness, and stiffness through a sequential centrifuging and screening process.



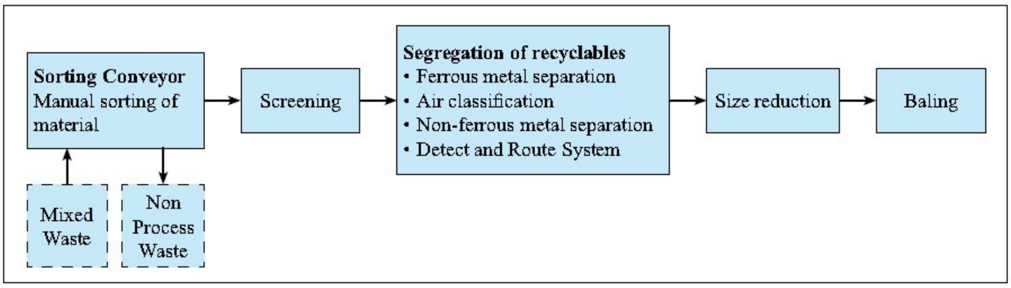
Waste management hierarchy

- **Making of Handmade Paper:** The Indian handmade paper industry produces a variety of paper and paper products mainly by using waste paper collected from various sources such as schools and colleges and also other materials such as cotton rags, tailor cuttings, hosiery cuttings.
- **Reuse of Sand & Inert:** Street sweeping normally comprises of street dust and tree leaves, besides domestic and commercial waste indiscriminately disposed in the streets. This waste contains a significant amount of sand, inert and debris, as well as

some amount of biodegradable wastes depending on the extent of door to door collection systems introduced in the city /town. Street sweepings should therefore be transported separately to waste disposal facility without mixing with domestic or other commercial establishment waste, to ensure efficient waste processing.

- **Construction & Demolition Waste:** Construction and Demolition Wastes (C & D waste) generally constitute upto 10-20 percent of all solid waste. The report of the Supreme Court's expert committee 1999 and the MSW (M&H) Rules 2000 recommend that ULBs shall facilitate the collection of construction and demolition waste generated in a city. Ward level debris banks should be created. Containers could be provided at such locations, and a small collection charge could be levied for receiving such waste and transporting it for disposal. Rates may be prescribed for such collection by the local body, and contracts could be given for managing such sites. Help-lines for lifting C&D waste should be created to ensure prompt clearance of such wastes.
- **E-Waste:** E-waste or Waste of Electrical and Electronic Equipment (WEEE) comprises of surplus, out of date, broken, electrical or electronic devices. Its quantum is increasing year by year and disposal of e-waste is becoming a global environmental and public health issue. According to a study about 380,000 tons of e-waste is generated annually in India which is expected to increase manifold. The study also reveals that only about 6 percent of the e-waste is recycled, of which 95 percent is operated through the informal sector. Recyclers, while mainly interested in precious metals (such as copper, silver, and platinum) are also interested in the glass, plastic, and batteries within these devices. Currently applied processes for recycling WEEE pose serious threats to the health of workers and the environment. It will be a challenge to reorganize the recycling of waste electrical and electronic equipment in order to establish recycling methods that protect both workers and the environment. One option would be the introduction of the extended producer responsibility (EPR) concept, where the producer of an electrical or electronic device guarantees product redemption after use through recycling and/or disposing it in an environmentally friendly manner.

Process in a Material Recovery Facility Receiving Mixed Wastes



1. **Pre-Sorting:** Bulky and contaminated wastes hamper further sorting/processing in the facility; mechanical or manual pre-sorting is essential to separate out these wastes. Manual sorting results in higher labour costs and lower processing rates. Bulky waste is removed by manual sorters as the waste passes along a conveyor belt, which carries the pre-sorted waste to the mechanized sorting unit of the facility.
2. **Sorting:** Mechanical processes based on principles of electro-magnetics, fluid mechanics, pneumatics etc. are used to segregate the different waste streams in the pre-sorted waste. Mechanical processes require specialized equipment for segregation of co-mingled municipal waste. Mechanical sorting typically employs the following processes:

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

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

c. **Air Classification:** The residual waste stream is passed through an air stream with sufficient velocity to separate light materials from heavy material, specifically for separating out light weight plastics and paper from the mixed stream. Three types of air classifiers may be employed i.e. 1) horizontal air classifier 2) vibrating incline air classifier 3) incline air classifier. Heavy or bulky plastics are sorted out either in the pre-processing line (manually) or in the "detect and route" systems, employed at later stages of material recovery.

d. **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.

e. **Detect and Route system:** This system separates out various grades of paper, plastics and glass, which are not sorted out in the air classifier. This system works in two stages. The first stage employs programmed optical sensors to determine the nature of different materials. In the second stage, based on information received from the sensor, sorted material is routed to appropriate bins by directional air jets.
f. **Size reduction:** Sorted materials after segregation are usually too large for further use or processing, they should be reduced to smaller sizes.
g. **Baling:** Sorted and sized material is baled for further processing/use.

STEP 1: POLICIES, PROGRAMMES & LEGAL FRAMEWORK

- Identify National and State Policies/Strategies and their Goals
- State Level/Regional/District SWM Strategies/Policies
- Identify Overall Goals for ULBs
- Role of Central/State and Local Government
- Institutions and Stakeholders Involved in MSWM Planning

↓

STEP 2: ASSESSMENT OF CURRENT SITUATION AND GAP ANALYSIS

Legal & Policy Framework	Institutional & Financial Set Up	Technical Aspects
Community Participation	MSW Generation, Collection & Transportation	Availability & Suitability of Land for Processing & Disposal
MSW Processing, Treatment & Disposal	Current Status of Dump Sites	Environmental Concerns

↓

STEP 3: STAKEHOLDER CONSULTATION FOR MSWM PLANNING

↓

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

↓

STEP 5: SCHEDULE FOR IMPLEMENTATION

- Timeline
- Manpower Requirement
- Financial Viability

↓

STEP 6: STAKEHOLDER CONSULTATION FOR MSWM PLAN VALIDATION

↓

STEP 7: CITY COUNCIL APPROVAL FOR MSWM PLAN

7-Step approach for developing a MSWM Plan
Recommended methods for managing medical waste

Source separation within the health care facility	• Isolates infectious and hazardous wastes from non-infectious and non-hazardous ones, through colour coding of bags or containers • Source separates and recycles the relatively large quantities of non-infectious cardboard, paper, plastic, and metal • Source separates compostable food and grounds the major fraction of organic wastes and directs them to a composting facility if available • Includes and is characterised by thorough management monitoring program
Take-back systems	• Where vendors or manufacturers take back unused or out-of-date medications for controlled disposal
Tight inventory control over medications	• To avoid wastage due to expiration dates (a form of waste reduction)
Piggy-back systems for nursing homes, clinics, and doctors' offices	• Can send respective wastes for treatment to proper health care waste treatment facilities using health care waste collection and transport systems located in the vicinity
Treatment of infectious waste through incineration, or by disinfection	• Includes autoclaving, chemical reaction, microwaves, and irradiation • In the case of incineration, the processing may be performed within the premises of the health care facility (onsite) or in a centralised facility (offsite). An incinerator is difficult and expensive to maintain, so it should be installed in a health care facility only when the facility has sufficient resources to properly manage the unit. Otherwise, a centralised incinerator that provides services to health care facilities in one region or city may be more appropriate. Regardless of location, the incinerator must be equipped with the proper air pollution control devices and operated and maintained properly, and the ash must be disposed in a secure disposal site. In the case of disinfection, residues from these processes should still be treated as special wastes, unless a detailed bacteriological analysis is carried out.
Proper disposal of hospital wastes	• In many developing countries, none of the treatment systems discussed in this table are widely available, so final disposal of infectious and hazardous components of the wastes is necessary. Since in many developing countries there are no landfills specifically designed to receive special wastes, infectious and hazardous health care wastes normally are disposed at the local MSW landfill or dump. In this case, close supervision of the disposal process is critical in order to avoid exposure of scavengers to the waste. Final disposal should preferably be conducted in a cell or an area specially designated for that purpose. The health care waste should be covered with a layer of lime and at least 50 cm of soil. When no other alternative is available for final disposal, health care wastes may be disposed jointly with regular MSW waste. In this case, however, the health care wastes should be covered immediately by a 1 m thickness of ordinary MSW and always be placed more than 2 m from the edge of the deposited waste.

Source: United Nations Environment Programme, (2005)

UNIT 3: PRINCIPLE OF SOLID WASTE MANAGEMENT

3.0 INTRODUCTION

The status of development of a country may be categorised in several ways. With respect to its impact on solid waste management, status of development is categorised on the basis of availability of economic resources and on degree of industrialisation. Status of economic development is more a measure of the permanent economic framework than of the existing condition of the economy. Such management is adapted to the nature and quantities of waste generated and to the availability of technology for handling and processing characteristic of non-industrial settings. Degree of industrialisation is measured in terms of extent of mechanisation and availability of technological resources.

Objective

After studying this unit learner is able to know following:

- Principles of Solid waste management
- Importance of Social and Economic aspect
- Need of Public Awareness
- Role of NGOs

- Rules/ Legislation
- Physical, Chemical and Biological properties of solid waste
- Transformation of Municipal Solid Waste

3.1 PRINCIPLE OF SOLID WASTE MANAGEMENT

In an attempt to accelerate the pace of its industrial development, an economically developing nation may fail to pay adequate attention to solid waste management. Such a failure incurs a severe penalty at a later time in the form of resources needlessly lost and a staggering adverse impact on the environment and on public health and safety. The penalty is neither avoided nor lessened by a resolve to do something about the waste at a later time, when the country may be in a better position to take appropriate procedures.

Solid waste management hierarchy

- ✓ Prevent the production of waste, or reduce the amount generated.
- ✓ Reduce the toxicity or negative impacts of the waste that is generated.
- ✓ Reuse in their current forms the materials recovered from the waste stream.
- ✓ Recycle, compost, or recover materials for use as direct or indirect inputs to new products.
- ✓ Recover energy by incineration, anaerobic digestion, or similar processes.
- ✓ Reduce the volume of waste prior to disposal.
- ✓ Dispose of residual solid waste in an environmentally sound manner, generally in landfills.

The hierarchy is a useful policy tool for conserving resources, for dealing with landfill shortages, for minimising air and water pollution, and for protecting public health and safety. In many developing countries, some aspects of this hierarchy are already in place, since traditional practices revolving around waste prevention, reuse, and recycling are prevalent.

Consequences of Conventional Waste Management

Conventional waste management focuses largely on waste collection, treatment (composting and incineration) and disposal (landfills). Only limited attempts are made to adopt integrated waste management practices that involve waste reduction at the source, resource recovery and recycling. The resource value of waste cannot be realized unless separation of wastes is practised effectively at the source. Meanwhile, in many cities in developing countries, collection rates remain low and the quality of collection services are poor. Waste collection services are generally non-existent in poorer neighbourhoods such as slums. While there are some successful examples where the private sector and communities are involved in waste management services, in many cities of developing countries, involvement of these segments of society is still very limited. The wastes collected typically end up in open dumps, where they may be burnt, and in some cases are deposited in illegal dumping sites.

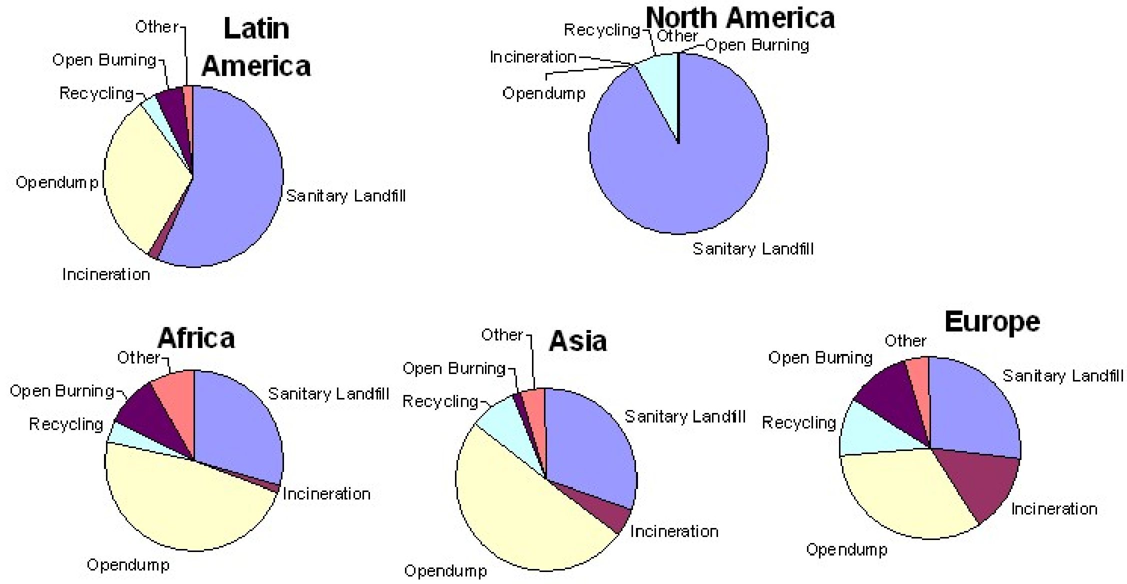


Figure showing Waste Management Practices in Different Parts of the World
Source: Chandak (2010), Trends in Solid Waste Management – Issues, Challenges, and Opportunities presented at the International Consultative Meeting on Expanding Waste Management Services in Developing Countries, 18-19 March 2010, Tokyo, Japan.

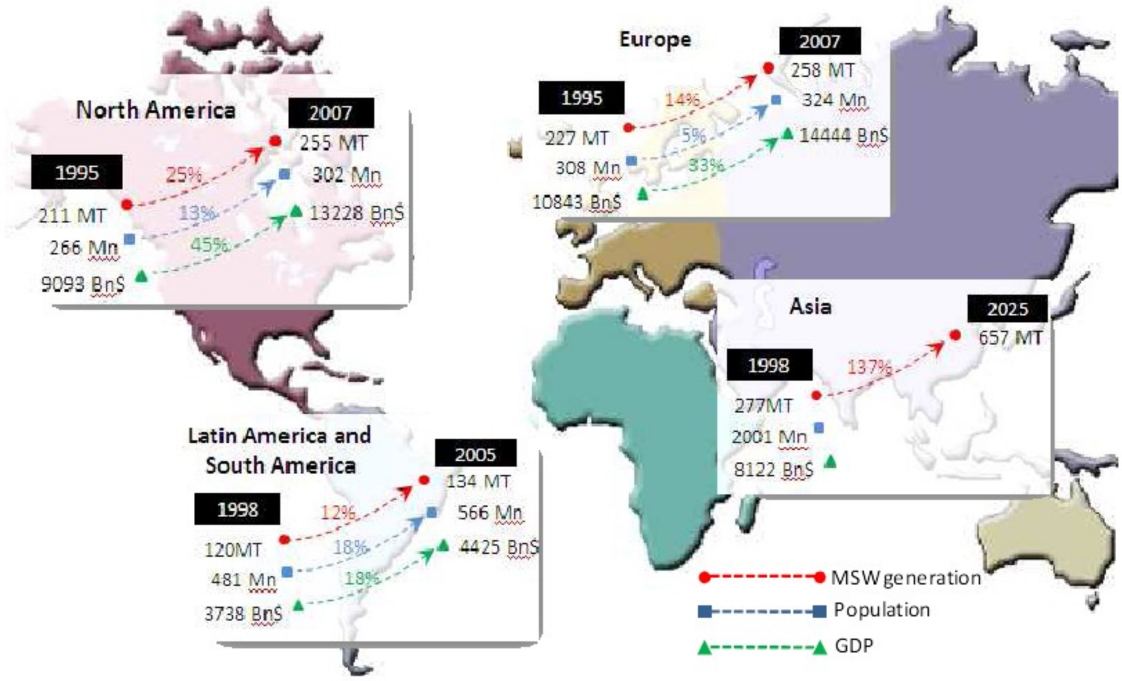


Figure Showing Correlation between MSW Generation, Population and GDP
(Source: Modak (2011), End-of-life vehicles (ELVs), Reuse and Recovery rate.

A pattern shift from conventional waste management practices to Integrated Solid Waste Management (ISWM) is essential for cities in order to effectively manage the waste stream. ISWM is a comprehensive waste prevention, recycling, composting, and disposal programme. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. As a consequence of conventional waste management practices, many cities in developing countries are facing environmental and health risks as well as losing economic opportunities in terms of the resource value of the waste.

Comparison between Conventional Waste Management & Integrated Solid Waste Management

Risks due to Conventional Waste Management	Opportunities from Integrated Solid Waste Management
• Poor efficiencies, undesirable health impacts (such as vector-borne diseases), environmental problems (such as deterioration of ground water quality due leachate contamination) and social issues (such as informal communities working in unsafe conditions) due to centralized approach to waste management • Developmental activities and consumption driven lifestyles leading to increased generation of waste • Valuable resources go unutilized • No extensions towards innovation and creation of safe jobs • Fails to involve all stakeholders , particularly neglecting the contribution of communities and private sector participation • Health hazards to waste workers and prevalence of social evils like child labour • No attention given to other newer waste streams for special handling as well as recovering resources	• Combination of centralized and decentralized options with effective pollution control systems (such as leachate treatment and gas capture systems) leading to economic gains due to improved efficiency, overall cost reduction, minimal environmental impacts and social acceptance. • Strategically planned waste minimization and green procurement programmes leading to more sustainable consumption patterns along with economic development • Facilitates recycling of valuable resources such as plastic, glass, paper and metals, recovery of alternate energy sources such as Refuse Derived Fuel (RDF) from high-calorific value fraction of waste, recovery of biogas or compost from biodegradable waste • Encourages innovative technology development in newer areas such as waste to energy and recycling and promotes green jobs that ensure safe working conditions • Ensures multi-stakeholder participation in decision-making process by involving Non-Governmental Organization (NGOs), Community Based Organization (CBOs), rag pickers, private sector, residential and

	commercial communities with the government • Brings waste workers into the formal economy and providing them with safe working conditions • Addresses management of both MSW and other newer waste streams such as e-waste, construction waste and scrapped vehicles.

International awareness regarding waste

At 1992, Rio Conference, waste was made one of the priorities of Agenda 21

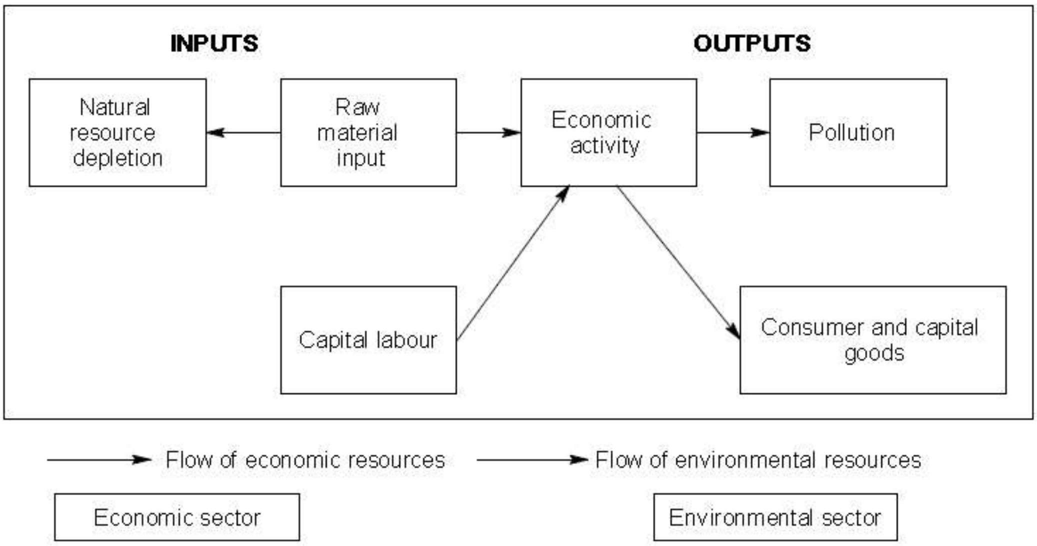
- Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally and was adopted by more than 178 Governments at the United Nations Conference in Rio de Janeiro
- At Johannesburg World Summit on Sustainable Development in 2002, the focus was on Initiatives to accelerate the shift to sustainable consumption and production reduction of resource degradation, pollution and waste
- Implementation plan adopted by the Summit, stated the priority to:
  - ✓ "Prevent and minimize waste & maximize reuse, recycling & use of environmental friendly alternative materials, with the participation of government authorities.
  - ✓ All stakeholders to minimize adverse effects on the environment and improve resource efficiency, with financial, technical and other assistance for developing countries."
  - ✓ This would include actions at all levels to:

    Develop waste management systems, with the highest priority placed on waste prevention and minimization, reuse and recycling, and environmentally sound disposal facilities, including technology to recapture the energy contained in waste

    Promote waste prevention and minimization by encouraging production of reusable consumer goods and biodegradable products

3.2 SOCIAL AND ECONOMIC ASPECT

In recent years, the world economy has achieved considerable economic and social development. The adoption of market oriented policies and the active participation of the private sector has contributed immensely to this development process. Although significant economic and social progress has been made, this has resulted in the widespread degradation and depletion of our natural environment. The essence of the environmental problem is the economy-producer behaviour and consumer desires. Without the economy, most environmental issues are concern with no policy significance. Palmer (1998) adds political, economic, technological, moral, aesthetic, and spiritual aspects to the environment. Human beings are dependent for their living, health and enjoyment of life on the basic biological systems. Ecosystems provide many services to mankind such as recreation, tourism, etc. This multiplicity in nature indicates the complexity of the issues concerning natural resource management. Benefits derived from the sustainable use of natural and environmental resources are generally categorized into three groups: ecosystem services, biological benefits and socio-economic benefits. Ecosystem services include the protection of water resources, soil formation and protection, nutrient storage and cycling, pollution breakdown and absorption, contribution to climate stability, maintenance of ecosystems and recovery from unpredictable events. Ecological diversity is essential in the maintenance of ecosystems. Any degradation in ecosystems will not only affect production of plants and animals but also represent real threats to human life on the planet. Biological benefits represent the bulk of human consumption, whether direct consumptive use (i.e., food consumption, medicinal resources, wood products, breeding stocks, etc.) or indirect consumptive use (i.e., recreation, bird watching, ecotourism, etc.).Socio-economic benefits that can be generated from sustainable and efficient use of environmental resources include recreation and ecotourism. The issue of solid waste emerged in the literature mainly due the environmental awareness created by the publication of “Silent Spring” by Rachel Carson in the early seventies. One of the earlier definitions for solid waste was given by World Health Organization (W.H.O) in 1971 defining solid waste as waste arising out of man‘s activity which is not free flowing. Solid waste is broadly defined as including non-hazardous industrial, commercial and domestic refuse including household organic trash, street sweepings, hospital and institutional garbage and construction wastes; generally sludge and human wastes are regarded as a liquid waste problem outside the scope of MSW by Olar Zorbeck et al 2003. Cointreau in 1982 defined solid waste as organic and inorganic waste materials produced by households, commercial, institutional and industrial activities, which have lost their value in the eyes of the first owner. There exists a close relation between economy and environment.



Source: Prabha Panth (2005).

Improper solid waste management causes all types of pollution. The main impacts created by solid waste pollution are health impacts, environmental impacts like contamination of surface and ground water due to indiscriminate dumping of wastes and the formation of leachate, economic impacts like land price decrease and social impacts like disamenity effects. The major problems due to solid waste in developing countries are i) health hazards from uncollected waste ii) health hazards from collected but poorly disposed of waste iii) the economic burden of waste disposal on towns and cities (David Pearce et al 1994).

3.3 PUBLIC AWARENESS

Municipal Solid Wastes (MSW) are produced by people and have to be managed following legislative, technical and social rules. In general, people are ‘‘rule” followers in the sense that they observe others and upon having learned, they have an interest in abiding the rules (Borgstede and Biel, 2002). A separate collection programme is based on several rules that the citizen has to follow. If he /she does not have the correct instructional information, it is impossible to correctly participate in the programme (Alexander et al., 2009). Obviously, the knowledge of rules does not necessarily mean that citizens translate these into action. Although many individuals say that they are in favour of recycling, they do not necessarily translate this into action due to the action of several situational (Corraliza and Berenguer, 2000; Borgstede and Biel, 2002), attitudinal (Costarelli and Colloca, 2004) and institutional barriers. Insufficient availability of space to store recyclables both inside and outside the home as well as inadequate local facilities, typeof accommodation lack of time, delay in bag delivery or poor collection service, the amount of effort it entails, lack of incentive to recycle, householders’ attitudes to recycling and their perceptions of the barriers to recycling, thinking ‘‘do not produce enough waste”, apathy towards recycling, lack of awareness of recycling provision, lack of motivation and stimulus, negative nearest neighbour effects, parental influences for young people, institutional context, limited public participation, as well as lethargy and disinterest from the public.

The youngest and oldest people showed the lowest level of awareness. A high level of education did not necessarily imply a high level of environmental awareness as well as a greater acceptance of MSW facilities. The satisfaction level of the recycling program was higher amongst the oldest age group. All the citizens in the several areas were unanimous in pointing out the presence of dirt in the street as the main shortcoming of the bring separate collection program. Only the youngest age group self-criticised, considering that they revealed a low level of participation to the separate collection program. While, the oldest people retaining them less influential, claimed that the citizens were not responsible for the failure of the separate collection program. Thus we can say awareness and management of MSW can reduce their impact on health and economy to get Sustainable Development.

Swachh Bharat Abhiyan (English: Clean India Mission) (SBA or SBM): It is a national campaign by the Government of India, It covering 4,041 statutory cities and towns, to clean the streets, roads and infrastructure of the country. The campaign was officially launched on 2 October 2014 at Rajghat, New Delhi, by Prime Minister Narendra Modi. It is India's biggest ever cleanliness drive with 3 million government employees and school and college students of India participating in this event. The objective is to reach the goal in five year by the 150th birth anniversary of Mahatma Gandhi.

1 April 1999, the Government of India restructured the Comprehensive Rural Sanitation Programme and launched the Total Sanitation Campaign (TSC) which was later (on 1 April 2012) renamed Nirmal Bharat Abhiyan(NBA). On 2 October 2014, Prime Minister of India Narendra Modi launched the Swachh Bharat Mission, which aims to eradicate open defecation by 2019, thus restructuring the Nirmal Bharat Abhiyan to Swachh Bharat Abhiyan a national campaign. Logo of the mission given below.

Finance

The programme has also received funding and technical support from the World Bank, corporations as part of corporate social responsibility initiatives, and by state governments under the Sarva Shiksha Abhiyan and Rashtriya Madhyamik Shiksha Abhiyanschemes. Swachh Bharat Abhiyan is expected to cost over 620 billion (US$9.2 billion). The government provides an incentive of 12,000 (US$180) for each toilet constructed by a BPL family. Total fund mobilised under Swachh Bharat Kosh (SBK) as on 31 January 2016 stood at 3.69 billion (US$55 million). An amount of 90 billion (US$1.3 billion) was allocated for the mission in 2016 Union budget of India.

Modi selected 11 public figures to propagate this campaign. They are:

- Sachin Tendulkar
- Priyanka Chopra

- Anil Ambani
- Baba Ramdev
- Salman Khan
- Shashi Tharoor
- Team of Tarak mehta ka ooltah chashmah
- Mridula Sinha
- Kamal Hasan
- Virat Kohli
- Mahendra Singh Dhoni

A Swachh Bharat Run was organized at the Rashtrapati Bhavan on 2 October 2014. According to a statement from the Rashtrapati Bhavan around 1500 people participated and the event was flagged off by President Pranab Mukherjee. Participants in the run included officers and their families.

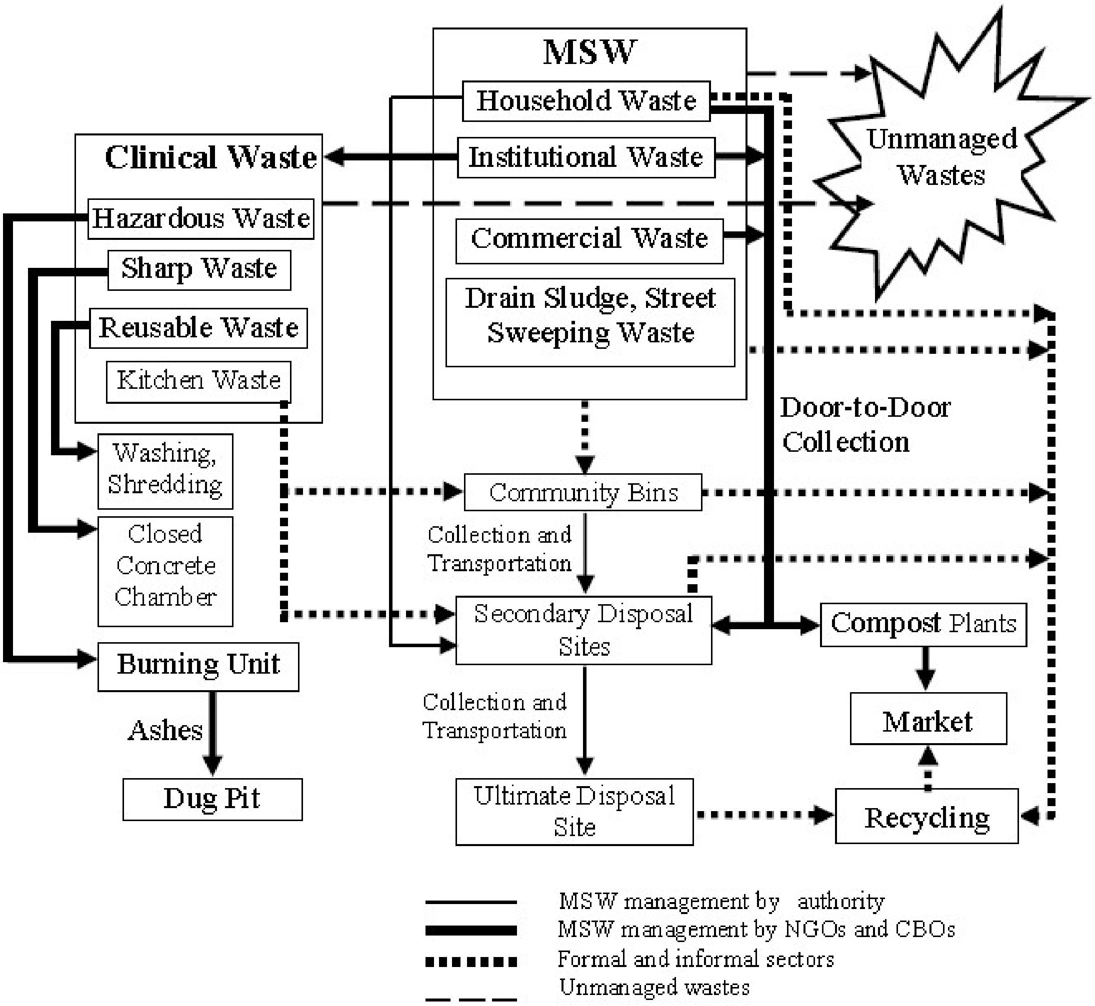
Government of India released a "Cleanliness Ranking" for 73 cities on 15 February 2016. Some of top 10 cities.

1. Mysore
2. Chandigarh
3. Tiruchirapalli
4. New Delhi Municipal Council
5. Visakhapatnam
6. Surat
7. Rajkot
8. Gangtok
9. Pimprichinchwad
10. Greater Mumbai

"Swachh Bharat Swachh Vidyalaya" campaign was launched by Smriti Irani, Ministry of Human Resource Development (India) the then Minister of Human Resource Development, Government of India by participating in the cleanliness drive along with the school's teachers and students.

3.4 ROLE OF N.G.O.'s

After the public support for MSWs in cities, non-governmental organizations (NGOs) and community based organizations (CBOs) in municipal solid waste (MSW) management plays important role. NGOs are providing a prominent support to informal sector waste workers and enterprises to organize themselves to improve working conditions and facilities, increase earnings, and extend access to essential social services such as health care and schooling for children. Whilst privatization involves the transfer of management responsibility and ownership from the public to the private sector and has proved to be a powerful means of improving the efficiency of some waste management services such as collection, haulage and disposal. Operating in various forms of partnership with the public sector, they may provide capital, management and organizational capacity, labor and technical skills. When any NGOs are interested to involve MSW management, first they should consult with the Authority as Commissioner/Magistrate of the respective area. Then, they may obtain the permission from the conservancy department of the city corporation office. A number of NGOs are involved in MSW management in different areas in cooperation with the city authority and respective area Authority. Role NGOs and CBOs are mainly involved in the collection of wastes from different generation sources, e.g. houses, markets, restaurants and hotels. Then, they dispose the collected wastes to the nearest SDSs. However, only a few NGOs handle the composting of organic wastes and medical waste management in City. Some NGOs transfer the collected wastes to compost plants. Most of the NGOs collects waste from household and receive tiny payment from the dwellers as collection charge.



Involvement of different agencies in MSW management

Door-to-door wastes collection by NGOs and CBOs

Discarding collected wastes to roadsides

(a) Black Kitchen waste	(b) Gray General waste	(c) Yellow Reusable waste	(d) Red Sharp waste

NGOs Involvement in Medical Waste: Containers for the storage of clinical wastes

NGOs (nongovernmental organizations) has improved the municipal solid waste (MSW) management system in some aspects, e.g. collection process from sources and able to create much awareness among the people about the responsibility to cooperate in these striking social and environmental issues. NGOs are mainly involved in collection of wastes from generation sources and discard to secondary disposal sites, composting of organic wastes and hospital/ medical waste management. There are six composting plants are in operation now, however, the technical and environmental conditions are not at the required level. A potential sector to reduce the amount of waste generation is recycling. Thus have an integrated management and safe disposal system to handle MSW, continuous and effective support from city authority, city dwellers, and the concerned stakeholders should be extended to the NGOs.

3.5 LEGISLATION

MSW Rules:

Implementation Status Of Municipal Solid Waste (Management & Handling) Rules, 2000.

Municipal Solid Waste (Management & Handling)Rules, 2000 (MSW Rules) are applicable to every municipal authority responsible for collection, segregation, storage, transportation, processing and disposal of municipal solids. The Rules contains four Schedules namely;

S. N.	Schedule	Role
1.	Schedule I	Relates to implementation Schedule
2.	Schedule II	Specifications relating to collection, segregation, storage, transportation, processing and disposal of municipal solid waste (MSW).
3.	Schedule III	Specifications for landfilling indicating; site selection, facilities at the site, specifications for landfilling, Pollution prevention, water quality monitoring, ambient air quality monitoring, Plantation at landfill site, closure of landfill site and post care.
4.	Schedule IV	Indicate waste processing options including; standards for composting, treated leachates and incinerations.

Authorities and Responsibilities

S.No	Agencies/ Authorities	Responsibility
1.	Municipal Authorities	i. Ensuring that municipal solid wastes to be handled as per rules. ii. Seeking authorization from State Pollution Control Board (SPCB) for setting up waste processing and disposal facility including landfills. iii. Furnishing annual report. iv. Complying with Schedule I, II, III and IV of the rules
2.	**State Government** i. Secretary In-Charge of Department of Urban Development ii. District Magis-trates/ Deputy Commissioner	Overall responsibility for the enforcement of the provisions of the rules in the metropolitan cities. Overall responsibility for the enforcement of the provisions of the rules within the territorial limits of their jurisdiction.
3.		i. Co-ordinate with State Boards and Committees with reference to implementation and review of

	Central Pollution Control Board (CPCB)	standards and guidelines and compilation of monitoring data. ii. Prepare consolidated annual review report on management of municipal solid wastes for forwarding it to Central Government along with its recommendations before the 15th of December every year. iii. Laying down standards on waste processing/ disposal technologies including approval of technology.
4.	State Pollution Control Board (SPCB)	i. Monitor the compliance of the standards regarding ground water, ambient air leachate quality and the compost quality including incineration standards as specified under Schedule II, III & IV. ii. Issuance of authorization to the municipal authority or an operator of a facility stipulating compliance criteria and standards. s iii. Prepare and submit to the CPCB an annual report with regard to the implementation of the rules.

3.6 PHYSICAL PROPERTIES OF SOLID WASTE

Physical properties of Municipal Solid Waste (MSW) depend upon the following characteristics:

1. Specific Weight (Density)
2. Moisture Content
3. Particle Size and Distribution
4. Field Capacity
5. Permeability of Compacted Waste

1. **Specific Weight (Density)**

- Specific weight is defined as the weight of a material per unit volume (e.g. kg/m^3, lb/ft^3)
- Usually it refers to uncompacted waste.
- It varies with geographic location, season of the year, and length of time in storage.

Typical Specific Weight Values of MSW

Component	Specific Weight (density), kg/m^3	
	Range	Typical
Food wastes	130-480	290
Paper	40-130	89
Plastics	40-130	64
Yard waste	65-225	100
Glass	160-480	194
Tin cans	50-160	89
Aluminum	65-240	160

Typical Specific Weight Values of MSW

Condition	Density (kg/m^3)
Loose MSW, no processing or compaction	90-150
In compaction truck	355-530
Baled MSW	710-825
MSW in a compacted landfill (without cover)	440-740

2. Moisture Content

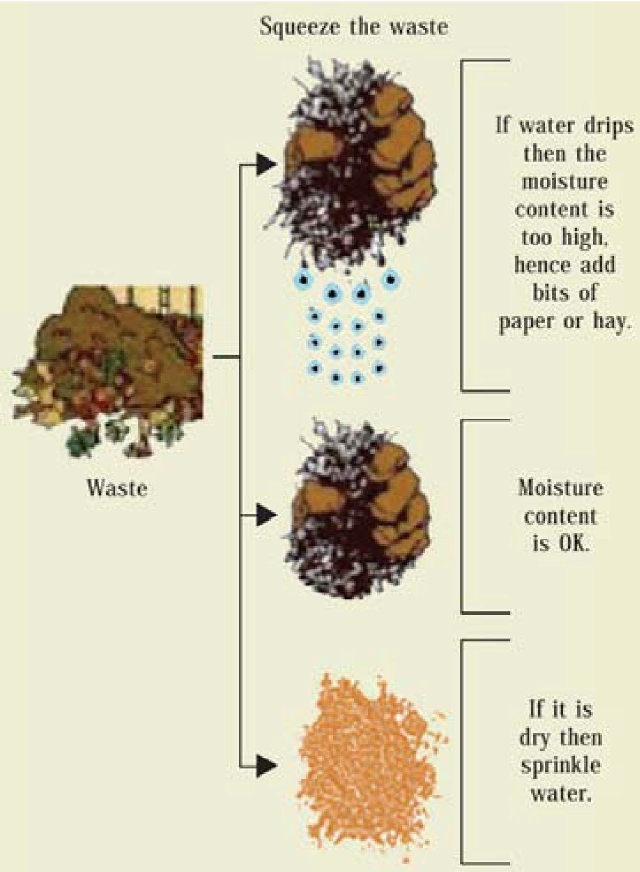
The moisture in a sample is expressed as percentage of the wet weight of the MSW material.

Analysis Procedure of MSWs

:

- Weigh the aluminum dish
- Fill the dish with SW sample and re-weigh
- Dry SW + dish in an oven for at least 24 hrs at 105°C.
- Remove the dish from the oven, allow to cool in a desiccator, and weigh.
- Record the weight of the dry SW + dish.
- Calculate the moisture content (*M*) of the SW sample using the equation given below

$$\text{M} = \frac{w - d}{w} x100$$



Demonstration Squeeze the Waste

Typical Moisture Contents of Wastes

	Type of Waste	Moisture Content, %	
		Range	Typical
Resindential	Food wastes (mixed)	50 - 80	70
	Paper	4 - 10	6
	Plastics	1 - 4	2
	Yard Wastes	30 - 80	60
	Glass	1 - 4	2
Commercial	Food wastes	50 - 80	70
	Rubbish (mixed)	10 - 25	15
Construction & Demolition	Mixed demolition combustibles	4 - 15	8
	Mixed construction combustibles	4 - 15	8
Industrial	Chemical sludge (wet)	75 - 99	80
	Sawdust	10 - 40	20
	Wood (mixed)	30 - 60	35
Agricultural	Mixed Agricultural waste	40 - 80	50
	Manure (wet)	75 - 96	94

3. Particle Size and Distribution

- The size and distribution of the components of wastes are important for the recovery of materials, especially when mechanical means are used, such as trommel screens and magnetic separators.

- For example, ferrous items which are of a large size may be too heavy to be separated by a magnetic belt or drum system.

The size of waste components can be determined using the following equations:

$$Sc = L$$

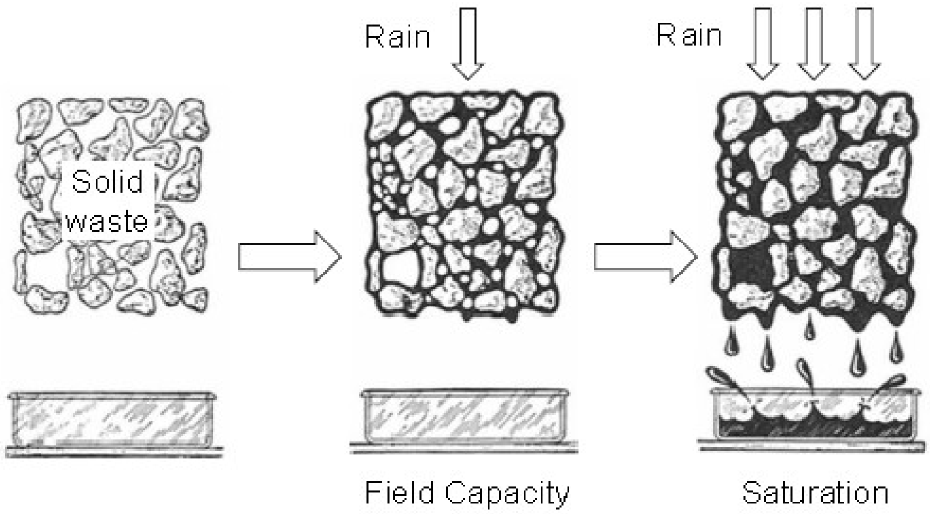
$$Sc = (L+W)/2$$

$$Sc = (L+W+h)/3$$

Were as, *Sc : size of component, mm*
L : length, mm
W : width, mm
h : height, mm

4. Field Capacity

The total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity. Field capacity is critically important in determining the formation of leachate in landfills. It varies with the degree of applied pressure and the state of decomposition of wastes, but typical values for uncompacted commingled wastes from residential and commercial sources are in the range of 50 - 60%.



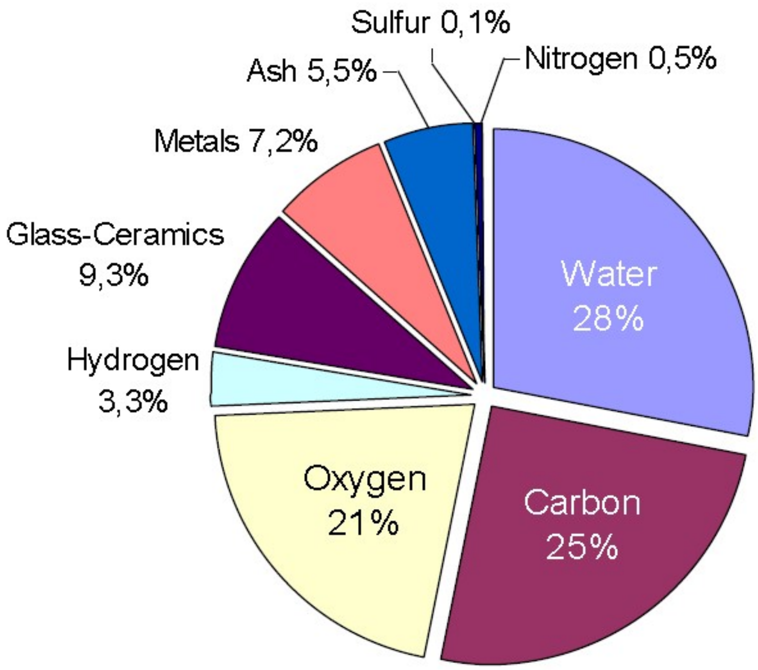
5. Permeability of Compacted Waste

The permeability (hydraulic conductivity) of compacted solid waste is an important physical property because it governs the movement of liquids & gases in a landfill.
Permeability depends on;

- Pore size distribution
- Surface area
- Porosity

3.7 CHEMICAL PROPERTIES OF SOLID WASTE

Chemical composition of typical MSW



Chemical properties of MSW are very important in evaluating the alternative processing and recovery options:

- Proximate analysis
- Fusing point of ash
- Ultimate analysis (major elements)
- Energy content

Proximate Analysis

Proximate analysis for the combustible components of MSW includes the following tests:

Moisture (drying at 105 ^{o}C for 1 h)

Volatile combustible matter (ignition at 950 oC in the absence of oxygen)

Fixed carbon (combustible residue left after Step 2)

Ash (weight of residue after combustion in an open crucible)

Typical Proximate Analysis Values (% by weight)

Type of Waste	Moisture	Volatiles	Carbon	Ash
Mixed food	70.0	21.4	3.6	5.0
Mixed paper	10.2	75.9	8.4	5.4
Mixed plastics	0.2	95.8	2.0	2.0
Yard wastes	60.0	42.3	7.3	0.4
Glass	2.0	-	-	96-99
Residential MSW	21.0	52.0	7.0	20.0

Fusing Point of Ash

Fusing point of ash is the temperature at which the ash resulting from the burning of waste will form a solid (clinker) by fusion and agglomeration.

- ✓ Typical fusing temperatures: 1100 - 1200 ^oC

Ultimate Analysis

- ✓ Involves the determination of the percent C (carbon), H (hydrogen), O (oxygen), N (nitrogen), S (sulfur) and ash.
- ✓ The determination of halogens are often included in an ultimate analysis.
- ✓ The results are used to characterize the chemical composition of the organic matter in MSW. They are also used to define the proper mix of waste materials to achieve suitable C/N ratios for biological conversion processes.

Typical data on ultimate analysis of combustible materials found in SW

Type of waste	Percent by weight (dry basis)					
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
Food and food products						
Fats	73.0	11.5	14.8	0.4	0.1	0.2
Food wastes (mixed)	48.0	6.4	37.6	2.6	0.4	5.0
Fruit wastes	48.5	6.2	39.5	1.4	0.2	4.2
Meat wastes	59.6	9.4	24.7	1.2	0.2	4.9
Paper products						
Cardboard	43.0	5.9	44.8	0.3	0.2	5.0
Magazines	32.9	5.0	38.6	0.1	0.1	23.3
Newsprint	49.1	6.1	43.0	<0.1	0.2	1.5
Paper (mixed)	43.4	5.8	44.3	0.3	0.2	6.0
Waxed cartons	59.2	9.3	30.1	0.1	0.1	1.2
Plastics						
Plastics (mixed)	60.0	7.2	22.8	—	—	10.0
Polyethylene	85.2	14.2	—	<0.1	<0.1	0.4
Polystyrene	87.1	8.4	4.0	0.2	—	0.3
Polyurethane[b]	63.3	6.3	17.6	6.0	<0.1	4.3
Polyvinyl chloride[b]	45.2	5.6	1.6	0.1	0.1	2.0
Textiles, rubber, leather						
Textiles	48.0	6.4	40.0	2.2	0.2	3.2
Rubber	69.7	8.7	—	—	1.6	20.0
Leather	60.0	8.0	11.6	10.0	0.4	10.0
Wood, trees, etc.						
Yard wastes	46.0	6.0	38.0	3.4	0.3	6.3
Wood (green timber)	50.1	6.4	42.3	0.1	0.1	1.0
Hardwood	49.6	6.1	43.2	0.1	<0.1	0.9
Wood (mixed)	49.5	6.0	42.7	0.2	<0.1	1.5
Wood chips (mixed)	48.1	5.8	45.5	0.1	<0.1	0.4
Glass, metals, etc.						
Glass and mineral[c]	0.5	0.1	0.4	<0.1	—	98.9
Metals (mixed)[c]	4.5	0.6	4.3	<0.1	—	90.5
Miscellaneous						
Office sweepings	24.3	3.0	4.0	0.5	0.2	68.0
Oils, paints	66.9	9.6	5.2	2.0	—	16.3
Refuse-derived fuel (RDF)	44.7	6.2	38.4	0.7	<0.1	9.9

Typical data in elemental analysis (% by weight)

Type	C	H	O	N	S	Ash
Mixed food	73.0	11.5	14.8	0.4	0.1	0.2
Mixed paper	43.3	5.8	44.3	0.3	0.2	6.0
Mixed plastic	60.0	7.2	22.8	-	-	10.0
Yard waste	46.0	6.0	38.0	3.4	0.3	6.3
Refuse Derived Fuel (RDF)	44.7	6.2	38.4	0.7	<0.1	9.9

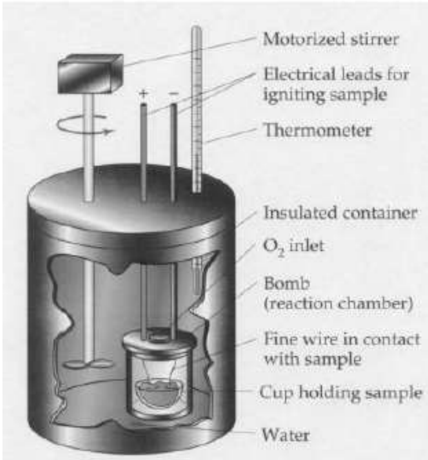
Energy Content of Solid Waste

Energy content can be determined by;

1. By using a full scale boiler as a calorimeter
2. By using a laboratory bomb calorimeter
3. By calculation

Most of the data on the energy content of the organic components of MSW are based on the results of bomb calorimeter tests.

Bomb Calorimeter



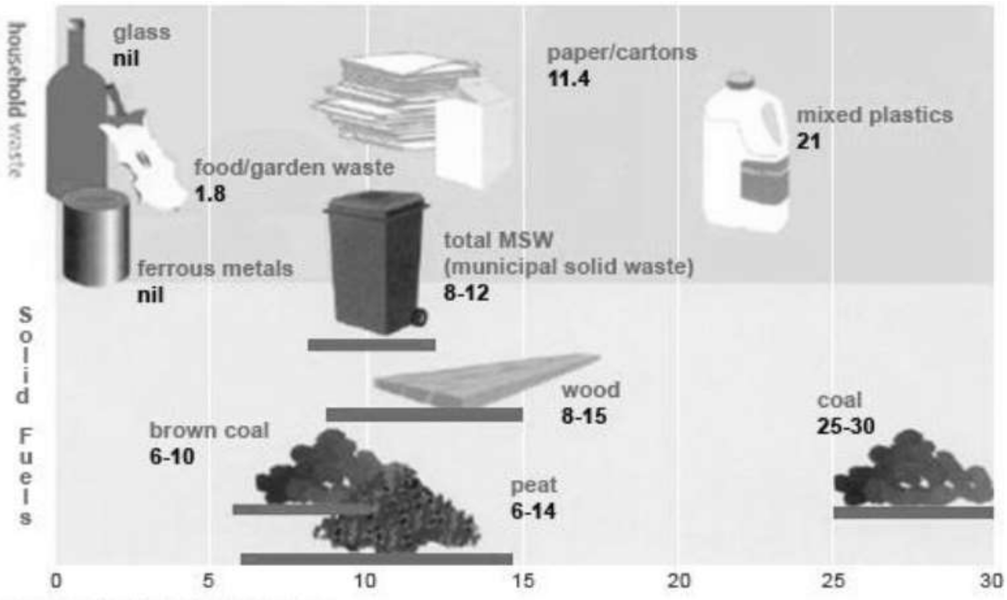
Average composition and heating values for MSW

The average energy content of typical MSW is ~10,000 kJ/kg

Waste Component	Weight %	Heating Value (MJ/kg)
Paper and paper products	37.8	17.7
Plastic	4.60	33.5
Rubber and leather	2.20	23.5
Textiles	3.30	32.5
Wood	3.00	20.0
Food wastes	14.2	15.1
Yard wastes	14.6	17.0
Glass and ceramics	9.00	0
Metals	8.20	0
Miscellaneous inorganic	3.10	0

Inert residue and energy content of residential MSW

Components	Inert Residue Percentage		Energy, kJ/kg	
	Range	Typical	Range	Typical
Organic				
Food wastes	2-8	5	3489-6978	4652
Paper	4-8	6	11630-18608	16747
Cardboard	3-6	5	13956-17445	16282
Plastics	6-20	10	27912-37216	32564
Textiles	2-4	2.5	15119-18608	17445
Rubber	8-20	10	20934-27912	23260
Leather	8-20	10	15119-19771	17445
Yard wastes	2-6	4.5	2326-18608	6513
Wood	0.6-2	1.5	17445-19771	18608
Misc. organics	-	-	-	-
Inorganic				
Glass	96-99 +	98	116-233	140
Tin cans	96-99 +	98	233-1163	698
Aluminum	90-99 +	96	-	-
Other metal	94-99 +	98	233-1163	698
Dirt,ashes,etc	60-80	70	2326-11630	6978
Municipal solid waste	-	-	9304-13956	11630



3.8 BIOLOGICAL PROPERTIES OF MSW

The organic fraction of MSW (excluding plastics, rubber and leather) can be classified as:

- Water-soluble constituents - sugars, starches, amino acids and various organic acids
- Hemicellulose - a product of 5 and 6-carbon sugars
- Cellulose - a product of 6-carbon sugar glucose
- Fats, oils and waxes - esters of alcohols and long-chain fatty acids
- Lignin - present in some paper products
- Lignocellulose - combination of lignin and cellulose
- Proteins - amino acid chains

Biodegradability of MSW

- The most important biological characteristic of the organic fraction of MSW is that almost all the organic components can be converted biologically to gases and relatively inert organic and inorganic solids.

- The production of odours and the generation of flies are also related to the putrescible nature of the organic materials. These will be discussed when talking about landfill processes.

- Volatile solids (VS), determined by ignition at 550 oC, is often used as a measure of the biodegradability of the organic fraction of MSW.
- Some of the organic constituents of MSW are highly volatile but low in biodegradability (e.g. Newsprint) due to lignin content.
- The rate at which the various components can be degraded varies markedly. For practical purposes, the principal organic waste components in MSW are often classified as rapidly and slowly decomposable.

Biodegradable fraction of selected organic waste components

$$\mathbf{BF = 0.83 - 0.028\ LC}$$

Were as
BF= Biodegradable Fraction expressed on a Volatile Solid (VS) basis
LC= Lignin Constant of the VS expressed as a percent of dry weight
0.83 and 0.028 = empirical constant

BF of selected organic waste component based on lignin content

Component	Volatile solids (VS), percent of total solids (TS)	Lignin content (LC), percent of VS	Biodegradable fraction (BF)[a]
Food wastes	7–15	0.4	0.82
Paper			
Newsprint	94.0	21.9	0.22
Office paper	96.4	0.4	0.82
Cardboard	94.0	12.9	0.47
Yard wastes	50–90	4.1	0.72

Calculation of biodegredable fraction of MSW

Component	Percent of MSW	Percent of each component that is biodegredable
Paper and paperboard	37.6	0.50
Glass	5.5	0
Ferrous metals	5.7	0
Aluminum	1.3	0
Other nonferrous metals	0.6	0
Plastics	9.9	0
Rubber and leather	3.0	0
Textiles	3.8	0.5
Wood	5.3	0.7
Other materials	1.8	0.5
Food waste	10.1	0.82
Yard trimmings	12.8	0.72
Miscellaneous inorganic	1.5	0.8
Total	100	

Production of odors

- Odors are developed when solid wastes are stored for long periods of time on-site between collections, in transfer stations, and in landfills.
- It is more significant in warm climates.

- The formation of odors results from the anaerobic decomposition of the readily decomposable organic components found in MSW.

3.9 TRANSFORMATION OF MUNICIPAL SOLID WASTE

Physical Transformations

The principal physical transformations that may occur in the operation of solid waste management systems include:

- component separation
- mechanical volume reduction
- mechanical size reduction
- Physical transformations do not involve change in phase (e.g., solid to gas), unlike chemical and biological transformation.

Chemical Transformations

- Chemical transformations of solid waste typically involve a change of phase (e.g., solid to liquid, solid to gas, etc.)
- To reduce the volume and/or to recover conversion products, the principal chemical processes used to transform MSW include:

Combustion (chemical oxidation) Pyrolysis Gasification	} Thermal Processes

Biological Transformations

The biological transformations of the organic fraction of MSW may be used;

1) To reduce the volume and weight of the material

2) To produce compost

3) To produce methane

and include:

1) Aerobic composting

2) Low-solids anaerobic digestion

3) High-solids anaerobic digestion (anaerobic composting)

Importance of Transformation:

Typically waste transformations are used:

- To improve the efficiency of solid waste management systems
- To recover reusable and recyclable materials
- To recover conversion products and energy

The organic fraction of MSW can be converted to usable products and ultimately to energy in a number of ways including:

- Combustion to produce steam and electricity
- Pyrolysis to produce a synthetic gas, liquid or solid fuel, and solids
- Gasification to produce a synthetic fuel
- Biological conversion to produce compost
- Biodigestion to generate methane and to produce a stabilized organic humus

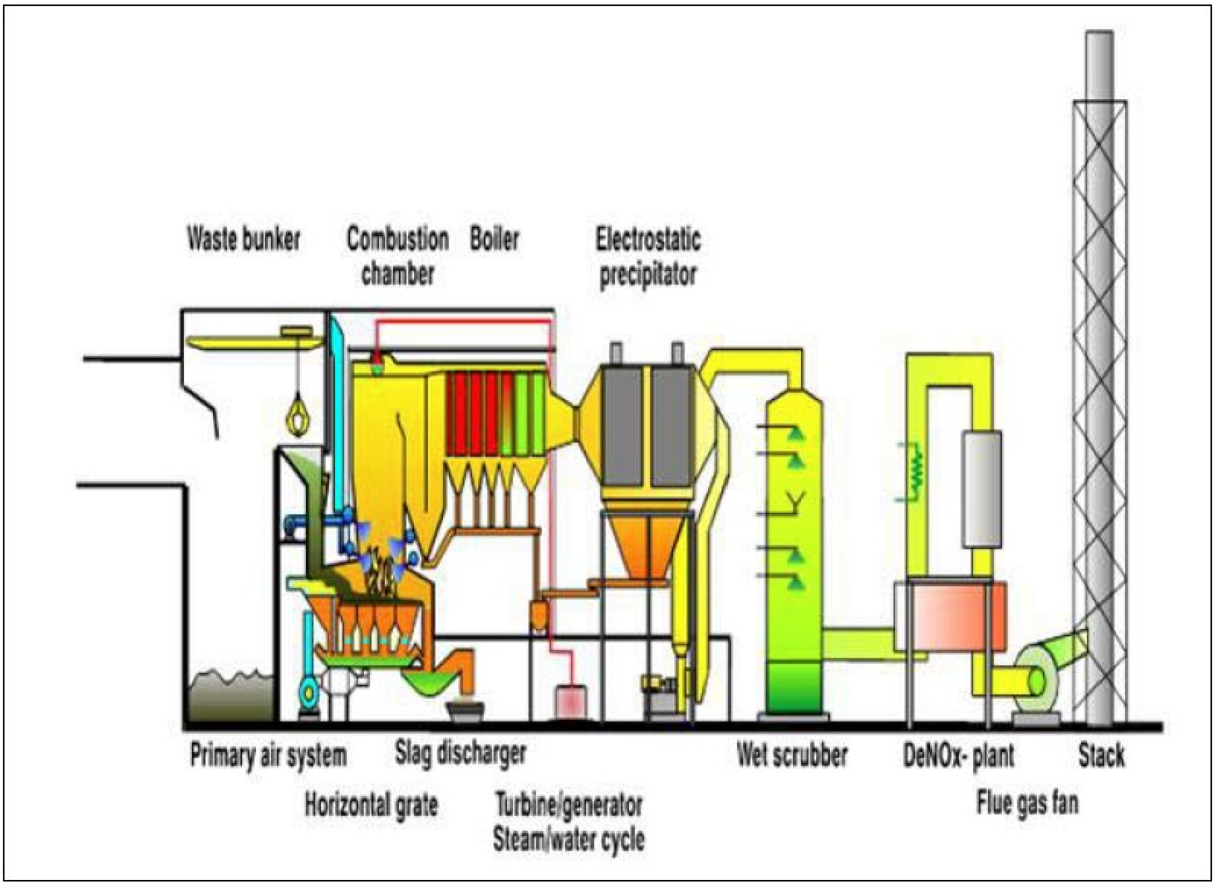
Transformation Processes in MSW Management

	Process	Method	Principal Conversion Products
Physical Transformation	separation	manual and/or mechanical	individual components found in comingled MSW
	volume reduction	Force or pressure	original waste reduced in volume
	size reduction	Shredding, grinding, or milling	altered in form and reduced in size
Chemical Transformation	combustion	thermal oxidation	CO_2, SO_2, oxidation products, ash
	pyrolysis	destructive distillation	a variety of gases, tar and/or oil
	gasification	starved air combustion	gases and inerts
Biological Transformation	aerobic compost	aerobic biological conversion	compost
	anaerobic digestion	anaerobic biological conversion	methane, CO_2, trace gases, humus
	anaerobic composting (in landfills)	anaerobic biological conversion	methane, CO_2, digested waste

Siting of Incineration Plant:

The location of a municipal solid waste incineration plant should always be determined with respect to both economic and environmental issues. Some of the key criteria for siting an incineration facility include:

- A controlled and well-operated landfill must be available for disposing residues (bed and fly ash).
- MSW incineration plants should be located in land-zones dedicated to medium or heavy industry
- MSW incineration plants should be at least 300 to 500 meters from residential zones
- In case of steam production, the plants should be located near suitable energy consumers



Setup of Mass Burn Incinerator

Consumption of Raw Materials and Energy by Incineration Plants

Waste incineration plants may consume:

- electricity, for process plant operation
- Fly ash should be transported
- heat, for specific process needs
- fuels, support fuels (e.g. gas, light oils, coal, char)
- water, for flue-gas treatment, cooling and boiler operation
- flue-gas treatment reagents, e.g. caustic soda, lime, sodium bicarbonate, sodium sulphite, hydrogen peroxide, activated carbon, ammonia, and urea
- water treatment reagents, e.g. acids, alkalis, tri-mercapto tri-azine, sodium sulphite, etc.
- high pressure air, for compressors.

4.0 TERMINAL QUESTIONS

1. What is Recycling?
2. What are some items at your home that can be recycled?
3. Why is it that some people do not recycle?
4. What is made from recyclable materials?
5. What can be done with some difficult to recycle items that are found in the home?
6. Why is it so important to recycle?
7. Isn't there plenty of money to be made by recycling?
8. What does the recycling symbol with the three arrows represent?
9. What is composting?
10. Why is composting important?
11. How does composting work?
12. What can be done to stop the foul smell sometimes emitted by a compost pile?
13. Where can you put a compost pile?
14. What can the average person do to increase composting activities in their community?
15. What can you do with the final compost material?
16. Can earthworms help in the composting process?

4.1 ANSWERS

Ans. 1- Recycling is the process of collecting, separating, processing, and selling recyclable materials so
they can be turned into new products. Simply put, recycling is taking something old and worn-out and turning it into something new.

Ans.2- There are many items in your home that can often be recycled in your community. These items
include aluminum and steel cans, newspapers, corrugated boxes, telephone books, plastic and

glass bottles, used motor oil, large appliances, rechargeable batteries, automotive batteries and tires, clothing, and yard and food waste.

Ans.3- Comments most often used by people who don't recycle include 1) takes too much time out of
their day, 2) inconvenient, 3) too many other things to do, 4) don't have enough recyclable materials at home, 5) forget the recycling pickup day and 6) don't know what to recycle. Those that do recycle can tell you that once you get into the habit, it becomes second nature, takes very little time, and becomes part of your daily activities. Finally, many people do not see recyclables as resources for new products but as trash to be placed in their garbage can. Education is the key if we are to make recycling a success in our communities and state.

Ans.4- Aluminum cans are melted down and recycled into new aluminum cans and other products made of aluminum. Steel cans are melted down and recycled into new steel cans and other productsmade of steel. Newspapers and telephone books are ground up and made into newsprint, cerealboxes, cellulose insulation for keeping homes warm, paper egg cartons, and ceiling tiles.Corrugated boxes are ground up and made into more corrugated boxes. Glass bottles are crushed,melted and recycled into more glass bottles, or used along with sand and gravel in asphalt roads.Plastic bottles such as soft drink and water bottles are ground up, washed and melted to producefiber for carpet and clothing. Plastic bottles such as milk, shampoo and detergent bottles areground up, washed and melted to produce plastic parts for automobiles, plastic lumber and otherplastic products. Used motor oil is generally burned for fuel as an alternative energy resource inindustrial facilities. Automobile scrap tires are generally chipped and burned as a fuel in place ofor in addition to coal. Scrap tires are also manufactured into numerous rubber products includingrubber mats and rubber bumpers. Yard and food waste can be composted in your backyard. Sincethe compost contains plenty of nitrogen and other organic nutrients, it is great in gardens andflower beds.

Ans.5- Items such as used motor oil, automotive batteries and tires, paint, home cleaning products,pesticides, rechargeable batteries and large appliances are sometimes considered special wastesand must be recycled/disposed of with greater care. Used motor oil can be recycled at severallocations in most communities including AutoZone, Advanced Auto Parts, and Wal-Mart Supercenter's Tire and Lube Center. In addition, some quick lube centers will also accept used motor oil from the public for disposal. Automotive batteries and tires are recycled when you leave them at the retailer where you purchased them. Automotive battery retailers are required by state law to accept an old battery when selling a new battery. In addition, some automotive battery 3 retailers will accept an old battery without the purchase of a new one. Scrap tire collection sites are available to the public in one or more locations in each county as required by state law. Check with your County Board of Supervisors to learn where the site is in your area for scrap tire disposal. Paint, cleaning products, and pesticides should be used for their intended purpose. If they cannot be used up, either give them to a neighbor or organization that can use them, or take them to a household hazardous waste collection event in your area. Rechargeable batteries including nickel-cadmium and nickel metal hydride batteries can be recycled by calling 1/800-8BATTERY to find out your nearest collection site. Large appliances including refrigerators, freezers, washers and dryers are often collected for recycling at special sites by the community or county. You'll need to contact your county or city solid waste official to see what you're required to do with these large appliances.

Ans.6- Recycling is important for several reasons. 1) Recycling conserves natural resources. Some of these natural resources such as oil, natural gas and minerals are non-renewable resources. Simply put, they don't get replaced as we pull them out of the ground. Once they're gone, they're gone forever. 2) Recycling conserves landfill space. Landfill space will last longer if we only put items that are not recyclable into them. It costs a great deal of money to build a landfill and we need to be careful how much and how fast we fill them up. 3) Recycling employs people. Recycling employs people who a) collect the recyclable material, b) process the material or get it ready to sell to a manufacturer, c) transport the materials to factories where it will be turned into new products, d) take the material and manufacture it into new products, e) manufacture equipment and products used by the recycling industry, and f) manage local, state and federal government recycling programs and private and non-profit recycling programs. 4) Recycling conserves energy. Without question, recycling conserves the energy that would be necessary to create the same product from its raw resource. 5) Recycling reduces our dependence on overseas natural resources. This is important in two very important ways, a) it reduces our dependence on overseas oil and gas which has national security implications and b) it reduces our foreign trade deficit which is important to the strength of our economy.

Ans. 7- Recycling can make money, but it also has many expenses related to it. Expenses are incurred in collecting and transporting the recyclable materials to the recycling facility; in sorting, processing and loading the recyclable materials at the recycling facility; and in transporting the recyclable materials to market. Sometimes all these costs can be equal to or more than what the recycling facility receives for the recyclable material they sell to the manufacturing facility. Much depends on the state of the economy of the country as to the value of the recyclables. If people are not buying products, the manufacturers won't pay a high price for the materials they are purchasing from the recycling facilities. The better the U.S. economy, the more value there will be in recyclable materials.

Ans. 8- The recycling symbol with the three arrows represents the three steps in the recycling process. 1) Collection and processing of recyclable materials, 2) Manufacturing of those materials into new products, and 3) Products sold to consumers which then starts the process over again.

Ans.9- Composting is the process of converting organic materials such as grass, leaves, food waste,
woody material, and manure into humus, a soil-like material.

Ans.10- Composting is important because it puts organic materials back into the ground which is necessary for a naturally healthy lawn and garden. In addition, composting is important because it's a better alternative then sending these natural organic materials to the landfill.

Ans.11- When grass, leaves, food waste, manure and woody material are placed of the ground, microorganisms from the ground begin to eat the material. The breakdown of this material is sped up with assistance from air (oxygen), water, and sunlight. Generally it will take several months for the material to become compost and that will also depend on how often you turn the pile of material.

Ans.12- Smelly compost piles can be avoided by not placing meats, oils, dairy products, and pet waste in the compost pile. Also, too many grass clippings (source of nitrogen) can cause the compost pile
to smell.

Ans.13- Compost piles need to be placed in an area that is well drained and receives good sunlight for heat. Other than those two items, just go out and compost.

Ans.14- For starters, the average person can get a compost pile started in their backyard. When you have friends and family over, show them how simple it is to make it work and the great compost and humus that is generated for the lawn and garden. You can also work with your local school to get a compost program started or put them in touch with MDEQ so that information and other materials on starting a compost program can be provided to them.

Ans.15- The final compost and humus material from a compost pile can be added to your garden, lawn and potted plants. It is often high in nitrogen which your plants need.

Ans. 16- Earthworms are actually a good sign of healthy soil. Vermi-composting, which is the use of earthworms in composting, is very important in the composting process. In fact, earthworms can greatly speed up the composting process and the castings, earthworm poop, is high.

SUGGESTED READINGS

1. Manual on Municipal Solid Waste Management, Ministry of Urban Development , Govt. of India

BLOCK -II

Measurement of Solid Waste and public health

UNIT-IV

Quantities and methods to measure solid waste quantities

UNIT-V

Solid waste and public health

UNIT-VI

Factors affecting solid waste

Block-II Measurement of Solid Waste and public health

This is the second block on Measurement of Solid Waste and public health and having detail description of the Improper MSW disposal and management causes all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates surface and ground water supplies. In urban areas, MSW clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Uncontrolled burning of MSW and improper incineration contributes significantly to urban air pollution. Greenhouse gases are generated from the decomposition of organic wastes in landfills, and untreated leachate pollutes surrounding soil and water bodies. Health and safety issues also arise from improper MSWM. Insect and rodent vectors are attracted to the waste and can spread diseases such as cholera and dengue fever. Using water polluted by MSW for bathing, food irrigation and drinking water can also expose individuals to disease organisms and other contaminants. The U.S. Public Health Service identified 22 human diseases that are linked to improper MSWM. Waste worker and pickers in developing countries are seldom protected from direct contact and injury, and the co-disposal of hazardous and medical wastes with MSW poses serious health threat. Exhaust fumes from waste collection vehicles, dust stemming from disposal practices and the open burning of waste also contribute to overall health problems. People know that poor sanitation affects their health, especially in developing and low-income countries like india , where the people are the most willing to pay for environmental improvements. The environment and health is very important and wide topic in SWMP students. So this block has four following units.

So we will begin the first unit on introduction of quantities and methods to measure solid waste quantities ,Waste stream assessment (WSA) is a means to determine the basic aspects of quantity (i.e., the amount of waste generated in the community, both in terms of weight and volume), composition (i.e., the different components of waste stream) and sources of wastes. The information relating to these basic aspects of wastes is vital for making decisions about the SWM system, finance and regulations.

Second unit begins with Solid waste and public health indiscriminate disposal of solid waste in dumpsites located within urban areas has proved to be a problem to nearby residents in most developing cities of the world, Free town is no exception. Open dumps have environmental safe guards; they can pose major public health threats and environmental effects in urban cities

In the third unit, we provide another important topic   Factors affecting solid waste generation rate. 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 considerations.

In the last, Municipal solid wastes heap up on the roads due to improper disposal system. People clean their own houses and litter their immediate surroundings which affect the community including themselves

As you study the material, you will find that figures, tables are properly used and these will help to understand the concept. There are many sections in the units to easily understand the topic. Every unit has summary and review questions in the end of the unit which will help you to review yourself.

In your study, you will find that the every unit has different equal length and your study time will vary for each unit.

We hope you enjoy studying the material and once again wish you all the best for your success.

UNIT-4 Quantities and methods to measure solid waste quantities

Structure

4.0 Introduction

This is the first unit of this block. In this unit we have described the concept of solid waste assessments basics. In this unit there are five sections. In the first section, there is an introduction of WASTE STREAM ASSESSMENTS (WSA). In Section 1.1 you will learn about the importance of collecting data on waste generation and composition, and the mechanism that may be used for the purpose. In this unit we introduce the WASTE STREAM ASSESSMENTS (WSA) and its generation. In Sec.1.3, we learn about its composition In the next section i.e. Sec. 1.3, we define the concept of Quantities of Solid Waste techniques. In the next section you will also learn about solid waste treatment. In Sec. 1.6 and 1.7 you will find summary and review questions respectively.

The focus of the study was on impact of solid waste due to non engineering and non scientific disposal It is found that with increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Waste that is not properly managed, especially excreta and other liquid and solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases

Objectives

After studying this unit you should be able to know about:

- Waste Stream Assessments (WSA)
- Waste Generation and Composition
- Quantities of Solid Waste

- Solid Waste Treatment
- Material Flow and Waste
- Causes of increasing solid waste material

4.1 WASTE STREAM ASSESSMENT (WSA)

Before we discuss waste generation *per se*, let us first explain the importance of collecting data on waste generation and composition, and the mechanisms that may be used for the purpose.

Waste stream assessment (WSA) is a means to determine the basic aspects of quantity (i.e., the amount of waste generated in the community, both in terms of weight and volume), composition (i.e., the different components of waste stream) and sources of wastes. The information relating to these basic aspects of wastes is vital for making decisions about the SWM system, finance and regulations. Put differently, an assessment of waste stream is essential in the analyses of short- and long-term problems within the local waste management system. It also helps in targeting waste management activities and setting goals for different elements of a waste management plan.

Waste stream assessment, however, is not a one-time activity. It is a continuous and dynamic process, because the characteristics of wastes differ depending on the regions, communities, seasons, etc. We will explain this further in Subsections 2.1.1 and 2.1.2.

4.1.1 Rationale for analysis

The reasons for the analysis of waste composition, characteristics and quantity include the following (Phelps, et al., 1995):

(i) It provides the basic data for the planning, designing and operation of the management systems.
(ii) An ongoing analysis of the data helps detect changes in composition, characteristics and quantities of wastes, and the rates at which these changes take place, which facilitates effective implementation of management systems.
(iii) It quantifies the amount and type of materials suitable for processing, recovery and recycling.
(iv) It provides information that helps in deciding appropriate technologies and equipment.
(v) The forecast trends assist designers and manufacturers in the production of collection vehicles and equipment suitable for future needs. In the absence of a reliable basic data, carrying out field investigations becomes necessary (Phelps et al., 1995).

4.1.2 Field investigation

Field investigations may take any one or a combination of the following forms:

(i) **Waste sorting**: Sorting of wastes into predetermined components takes place at disposal sites for weighing and sampling in order to determine the percentage of each component and the physical and chemical characteristics of wastes. It is carried out manually, and the sample size for analysis is between 100 and 150 kg. The implements required for the purpose include sorting table, measuring box, bins or boxes to contain sorted materials and platform weighing machine.

(ii) (ii) **Vehicle weighing**: Vehicles are weighed when they enter the disposal sites loaded, and exit the sites empty. The vehicle's front wheels are weighed first, followed by the rear wheels and the sum of the two gives the total weight. Weighing is carried out each day of the weighing period in order to determine the average weight. The weighing of loaded and unloaded vehicles is accomplished with a weighing scale or weighbridge. Ideally, the weighing scale should be operated during the entire period of operation of the disposal site, round the clock, if necessary. An electronic or a mechanical portable axle scale, with a capacity of 20 tones is suitable for the purpose. An electronic scale comprises two load-cell platforms and an electronic control and a display unit. The quantity of waste measured at disposal sites reflects a disposal factor rather than a generation factor, since the measurements do not include following wastes that are:

i. salvaged at the generation and disposal sites;
ii. disposed of in unauthorized places such as vacant plots, alleys, ditches, etc.;
iii. salvaged by collectors;
iv. Lost during transport.

(iii) **Field visits:** This means visiting institutional and industrial sites to identify wastes being generated and disposal methods. Field visits involve visiting the facility, i.e., industry, institutions, etc., viewing the waste handling system and completing a questionnaire with the assistance of the plant manager or senior technical personnel, who usually investigate wastes from industries and institutions. Collection of samples in sealed polythene bags follows for laboratory analysis to identify physical and chemical characteristics. Each sample may be in the range of 1.5 to 5 kg.

An assessment of waste stream, in essence, helps us identify components that require improvement for effective implementation of waste management programmes (EPA, 1989 and 1995).

Check your progress

Q1. State the importance of waste stream assessment (WSA)?

Q2. How WSA is carried out in your locality?

1.2 WASTE GENERATION AND COMPOSITION

Information on waste quantity and composition is important in evaluating alternatives in terms of equipment, systems, plans and management programmes. For example, if wastes generated at a commercial facility consist of only paper products, the appropriate equipment are shredders and balers. Similarly, on the basis of quantity generated, we can plan appropriate means for separation, collection and recycling programmes. That is to say, the success of SWM depends on the appropriate assessment of quantity of wastes generated. We will elaborate on the aspects of waste generation and composition, respectively, in Subsections 1.1.1 and other section.

4.2.1 Waste generation

Waste generation encompasses those activities in which waste, be it solid or semi-solid material, no longer has sufficient economic value for its possessor to retain it.

The processing of raw materials is the first stage when wastes are generated, and waste generation continues thereafter at every step in the process as raw materials are converted into final products for consumption. Figure 2.1 below shows a simplified material-flow diagram indicating the path of generation of solid wastes (Tchobanoglous, et al., 1977):

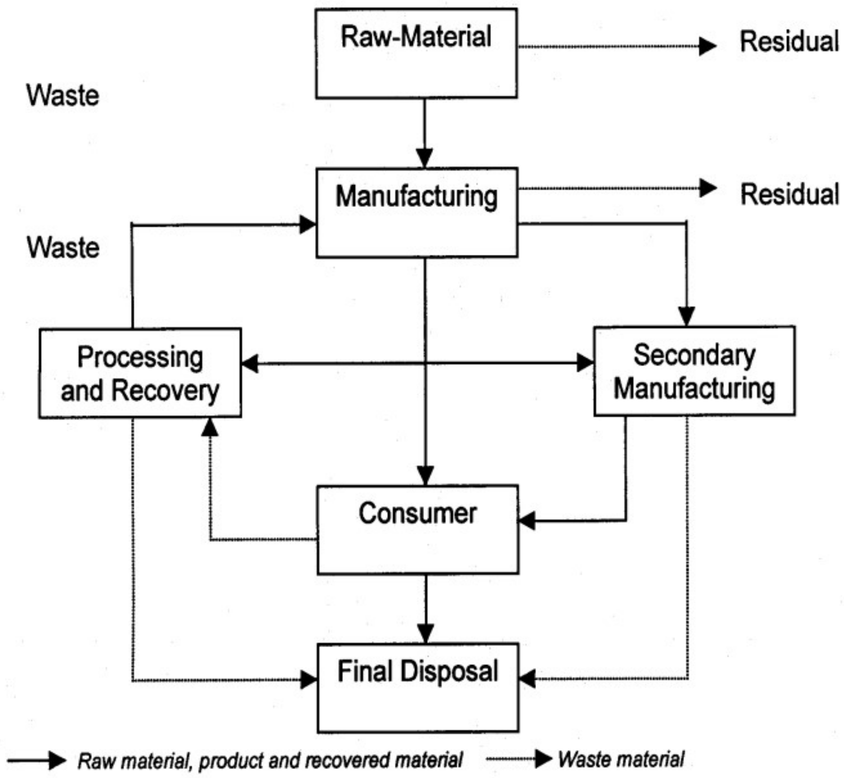
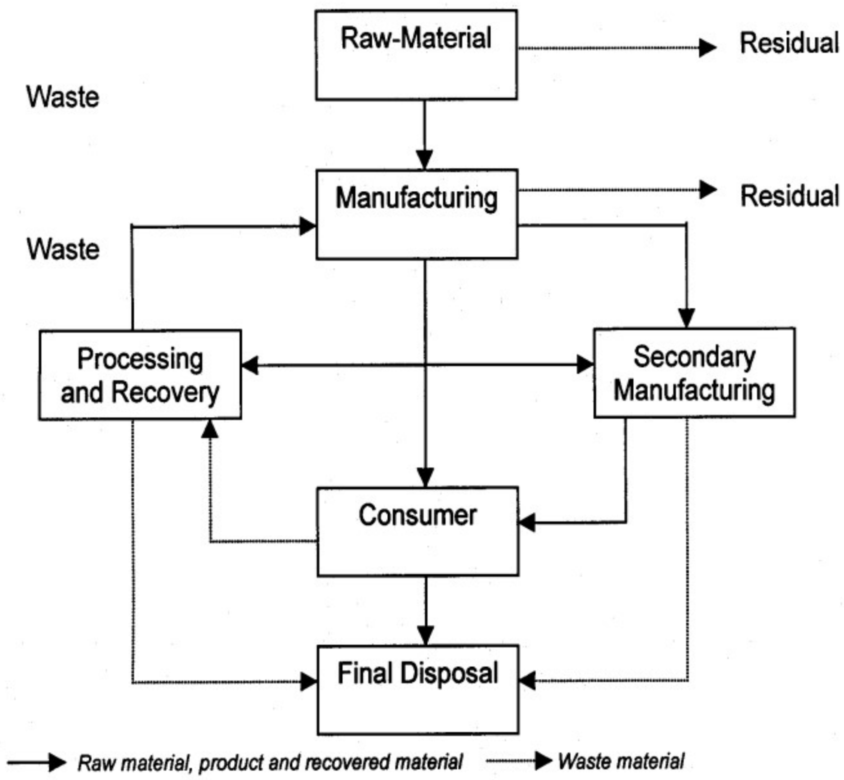


Figure 1.1 Material Flow and Waste



Generation

Figure 2.1 suggests that we can reduce the amount of solid waste by limiting the consumption of raw materials and increasing the rate of recovery and reuse.

Therefore, there is need of a societal change in the perception of wastes. This sounds simple. But, implementing changes in the society is difficult, unless appropriate management solutions are provided. That said, we also must note that the changes in waste generation contribute to changes in waste composition, which will be discussed next.

4.2.2 Waste composition

Some of the general observations associated with the composition of wastes include the following:

- The major constituents are paper and decomposable organic materials.
- More often than not, metal, glass, ceramics, textile, dirt and wood form part of the composition, and their relative proportion depends on local factors.
- Average proportions of the constituents reaching the disposal sites are consistent and urban wastes are fairly constant although subject to long-term changes such as seasonal variations.

Waste composition varies with the socio-economic status within a particular community, since income, for example, determines life style, composition pattern and cultural behaviour (http://ces.iisc.ernet.in/energy/SWMTR/TR85.html). Table 2.1 illustrates this phenomenon in India:

Table 1.1 Typical Waste Composition: Low/High Income Population

Characteristics	Low income	High income	Comments
Paper	1-4%	20-50%	Low paper content indicates low calorific value.
Plastics	1-6%	5-10%	Plastic is low as compared to high-income areas though the use of plastic has increased in recent years.
Ash and Fines	17-62%	3-10%	Ash and fines do not contribute to combustion process.
Moisture Content	30-40%	15-30%	Moisture content depends largely on the nature of the waste, climate and collection frequency. Waste can dry out while awaiting collection.

Bulk Density	300 – 400 kg/ m^3	150 kg/m^3	Heavier waste may cost more to handle and difficult to burn.

Waste composition also depends on the moisture content, density and relative distribution of municipal wastes, as shown in Table 2.2 below, and is important for the characterization of solid waste for most applications (Ali, et al., 1999):

Table 1.2 Solid Wastes: Typical Composition, Moisture and Density

Components	**Mass %**		**Moisture content %**		**Density in kg/m**	
	Range	**Typical**	**Range**	**Typical**	**Range**	**Typical**
Food wastes	6-26	14	50-80	70	120-480	290
Paper	15-45	34	4-10	6	30-130	85
Cardboard	3-15	7	4-8	5	30-80	50
Plastics	2-8	5	1-4	2	30-130	65
Textiles	0-4	2	6-15	10	30-100	65
Rubber	0-1	0.5	1-4	2	90-200	130
Leather	0-2	0.5	8-12	10	90-260	160
Garden Trimming	0-20	12	30-80	60	60-225	105
Wood	1-4	2	15-40	20	120-320	240
Misc. Organic substances	0-5	2	10-60	25	90-360	240
Glass	4-16	8	1-4	2	160-480	195
Tin cans	2-8	6	2-4	3	45-160	90
Non-ferrous metals	0-1	1	2-4	2	60-240	160
Ferrous metals	1-4	2	2-6	3	120-1200	320
Dirt, ash, bricks, etc.	0-10	4	6-12	8	320-960	480

Note that the density of waste changes as it moves from the source of generation to the point of ultimate disposal, and such factors as storage methods, salvaging activities, exposure to weather, handling methods and decomposition influence the density. In short, predicting changes of waste composition is as difficult as forecasting waste quantities.

4.2.3 Factors causing variation

As we know, wastes cause pollution. While the nature of wastes determines the type and intensity of pollution, it also helps us decide on the appropriate application, engineering design and technology for management. For example, the nature of wastes has implications for collection, transport and recycling. For effective SWM, therefore, we not only need information about the present but also the expected future quantity and composition of wastes.

There are several factors, which affect the present as well as the future waste quantity and composition (Tchobanoglous, et al., 1977), and some of which are listed below:

- Geographic location: The influence of geographic location is related primarily to different climates that can influence both the amount of certain types of solid wastes generated and the collection operation. For instance, substantial variations in the amount of yard and garden wastes generated in various parts of India are related to the climate. To illustrate, in the warmer southern areas, where the growing season is considerably longer compared to the northern areas, yard wastes are collected in considerably larger quantities and over a longer period of time.
- Seasons: Seasons of the year have implications for the quantities and composition of certain types of solid wastes. For example, the growing season of vegetables and fruits affect the quantities of food wastes.
- Collection frequency: A general observation is that in localities, where there are ultimate collection services, more wastes are collected. Note that this does not mean that more wastes are generated. For example, if a homeowner has access to only one or two containers per week, due to limited container capacity, he or she will store newspapers or other materials in some specified storage area. However, the same homeowner will tend to throw them away, if there is access to unlimited container services. In this latter situation, the quantity of waste generated may actually be the same but the quantity collected, as it relates to the frequency of collection, is considerably different.
- Population diversity: The characteristics of the population influence the quantity and composition of waste generated. The amount of waste generated is more in low-income areas compared to that in high-income areas. Similarly, the composition differs in terms of paper and other recyclables, which are typically more in high-income areas as against low-income areas (see Table 2.1).
- Extent of salvaging and recycling: The existence of salvaging and recycling operation within a community definitely affects the quantity of wastes collected.
- Public attitude: Significant reduction in the quantity of solid waste is possible, if and when people are willing to change – on their own volition – their habits and lifestyles to conserve the natural resources and to reduce the economic burden associated with the management of solid wastes.
- Legislation: This refers to the existence of local and state regulations concerning the use and disposal of specific materials and is an important factor that influences the composition and

generation of certain types of wastes. The Indian legislation dealing with packing and beverage container materials is an example.

In short, elements that relate to waste generation include land use characteristics, population in age distribution, legislation, socio economic conditions, household and approximate number.

Check your progress

Q1. Discuss the factors that contribute to the variations in composition of solid wastes?

4.2.4 Quantities of Solid Waste

Information on waste quantity and composition is important in evaluating alternatives in terms of equipment, systems, plans and management programmes. Based on the quantity of wastes generated, one can plan appropriate means for separation, collection and recycling programmes. That is to say, the success of solid waste management depends on the appropriate assessment of quantity of wastes generated. This lesson deals with the estimation of quantity of solid waste

The quantity of solid waste generated depends on a number of factors such as

- food habits,
- standard of living
- degree of commercial activities
- seasons

The quantity of solid waste can be expressed in units of volume or in units of weight. The advantage of measuring quantity in terms of weight rather than volume is that weight is fairly constant for a given set of discarded objects, whereas volume is highly variable. Waste generated on a given day in a given location occupies different volumes in the collection truck, on the transfer station, in the storage pit or in a landfill. In addition, the same waste can occupy different volumes in different trucks or landfills. Hence, it is always preferable to express the quantity of solid waste on weight basis.

The best method for estimating waste quantity is to install permanent scales at disposal facilities and weigh every truck on the way in and again in the way out. At disposal facilities without permanent scales, portable scales can be used to develop a better estimate of the weight of waste being deliverd. Selected trucks are weighed and environmental engineers use the results to estimate the overall weight of the waste stream. Weighing all trucks entering the disposal facility is a tedious job and hence a method of truck selection must be done. A simple approach will be to weigh every nth truck (for instance, every 4th truck) that delivers waste to the facility. This approach assumes that the trucks weighed represent all trucks arriving at the facility. The total waste taonnage can be estimated with the following equation

$W = T (w/t)$

Where,

W is the total weight of the waste delivered to the facility

T is the total number of trucks that delivered waste in the facility

w is the total weight of the truck that were weighed

t is the number of trucks that were weighed

Similarly the total weight of waste delivered for the whole year is summed up and total tones of waste generated in a year can be calculated.

The quantity of solid waste is often expressed in kg per capita per day so that the waste streams in different areas can be compared. The quantity is typically calculated with the following equation

$Q = 1000\ T / 365 * P$

Where, Q – Quantity of waste in kg per capita per day

T – Tonnes of waste generated in a year

P – Population of the area in which the waste is being generated

Data on quantity variation and generation are useful in planning for collection and disposal systems. Indian cities now generate eight times more municipal solid wastes than they did in 1947 because of increasing urbanization and changing life styles. Municipal solid wastes generation rates in small towns are lower than those of metro cities, and the per capita generation rate of municipal solid wastes in India varies in towns and cities. It was also estimated that the total municipal solid wastes generated by 217 million people living in urban areas was 23.86 million t/yr in 1991, and more than 39 million ton in 2001. Waste generation rate in Indian cities ranges between 200 - 500 grams/day, depending upon the region's lifestyle and the size of the city. The per capita waste generation is increasing by about 1.3% per year in India.

Waste generation and GDP

The per capita waste generation rate is strongly correlated to the gross domestic product (GDP) of a country (Table 2). Per capita waste generation is the amount of waste generated by one person in one day in a country or region. The waste generation rate generally increases with increase in GDP. High income countries generate more waste per person compared to low income countries due to reasons discussed in further sections. The average per capita waste generation in India is 370 grams/day as compared to 2,200 grams in Denmark, 2,000 grams in US and 700 grams in China.

Table 1.3 Gross domestic product (GDP)

Country	Per Capita Urban MSW Generation (kg/day)	
	1999	2025
Low Income Countries	0.45 - 0.9	0.6 - 1.0
Middle Income Countries	0.52 - 1.1	0.8 - 1.5
High Income Countries	1.1 - 5.07	1.1 - 4.5

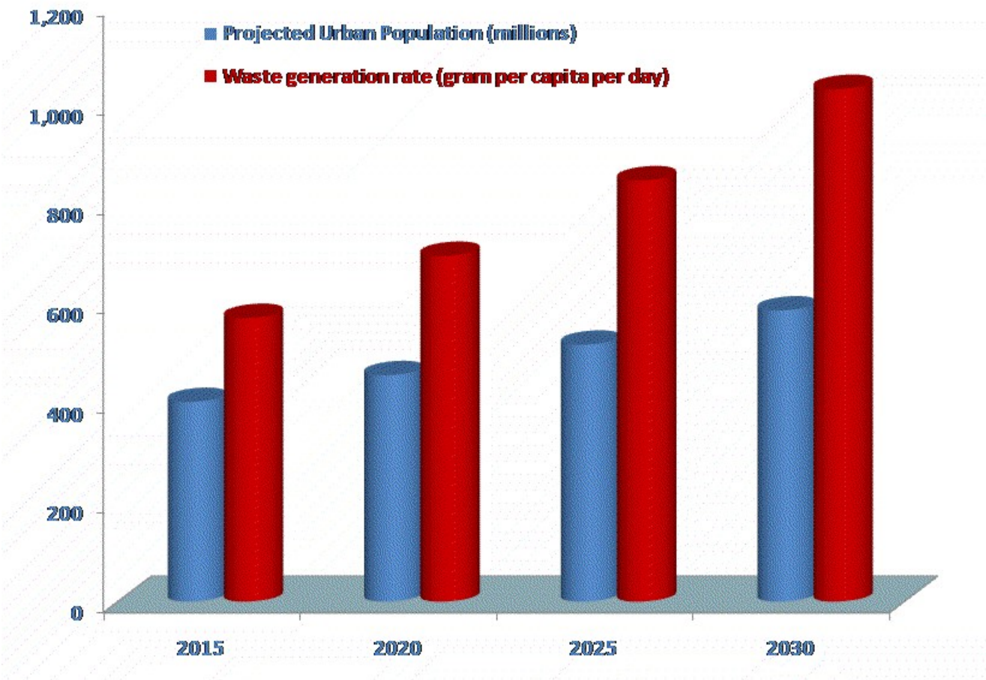


Figure 1.3:The projected MSW quantities

The urban population of India is approx. 341 million in 2010. Figure 1.3 suggest the projected MSW quantities are expected to increase from 2015 to 2030 and that per capita per day production will increase to 1.032 kg, and urban population as 586 million in 2030.

4.3 CHARACTERIZATION OF WASTES

Solid waste are characterized on the basis of following parameters
Their sources, By the types of wastes produced, By generation rates and composition. Accurate information in these areas is necessary in order to monitor and control existing waste management systems and to make regulatory, financial and institutional decisions.

TYPE OF SOLID WASTE

Depending on their source the solid waste may be of different types such as

- Institutional
- Residential waste
- Construction and demolition
- Industrial
- Municipal services
- Corrosive: these are wastes that include acids or bases that are capable of corroding metal containers, e.g. tanks. Ignitability the is waste that can create fires under certain condition, e.g. waste oils and solvents. Reactive: these are unstable in nature, they cause explosions, toxic fumes when heated.
- Toxic: waste which are harmful or fatal when ingested or absorbed.

4.4 S**OLID WASTE TREATMENT**

Current treatment strategies are directed towards reducing the amount of solid waste that needs to be land filled, as well as recovering and utilizing the materials present in the discarded wastes as a resource to the largest possible extent. Different methods are used for treatment of solid waste and the choice of proper method depends upon refuse characteristics, land area available and disposal cost which are as follows

- Incineration
- Compaction
- Pyrolysis
- Gasification
- Composting

A. Incineration

It is a controlled combustion process for burning solid wastes in presence of excess air (oxygen) at high temperature of about 1000^{o} C and above to produce gases and residue containing noncombustible material.One of the most attractive features of the incineration process is that it can be used to reduce the original volume of combustible MSW by 80-90%.

B. Compaction

The waste is compacted or compressed. It also breaks up large or fragile items of waste. This process is conspicuous in the feed at the back end of many garbage collection vehicles. deposit refuse at bottom of slope for best compaction and control of blowing litter

C .Pyrolysis

Pyrolysis is defined as thermal degradation of waste in the absence of air to produce char, pyrolysis oil and syngas, e.g. the conversion of wood to charcoal also, It is defined as destructive distillation of waste in the absence of oxygen. External source of heat is employed in this process. Because most organic substances are thermally unstable, they can upon heating in an oxygen free atmosphere be split through a combination of thermal cracking and condensation reactions into gaseous, liquid and solid fraction.

D. Gasification

Gasification is a process in which partial combustion of MSW is carried out in the presence of oxygen, but in lesser amount than that is required for complete combustion, to generate a combustible gas (fuel gas) rich in carbon monoxide and hydrogen e.g. the conversion of coal into town gas. When a gasifier is operated at atmospheric pressure with air as the oxidant, the end products of the gasification process are a low energy gas typically containing (by volume) 20% CO, 15% H_2, 10% $CO_2$and 2% CH_4.

E. Composting

Composting is the most responsible technical solution for many developing countries especially, where the climate is arid and the soil is in serious need of organic supplements. The composting process usually follows 2 basic steps as shown in Fig. 2.13, which may be preceded or followed by proper post treatments (crushing, sorting, humidification, mixing with other waste, etc

4.5. SOLID WASTE DISPOSAL

•**Landfills:-**Land filling is the most simple and economical measure as far as natural decomposition occurs at the disposal site. Unscientific and ordinary Land filling is the common practice for solid waste disposal in many developing countries like India.

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•Sanitary Landfills Sanitary Land filling is a process of dumping of MSW in a scientifically designed area spreading waste in thin layers, compacting to the smallest practicable volume and covering with soil on daily basis. The methane (rich biogas) is produced due to anaerobic decomposition of organic matters in solid waste.

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•Underground injection wells:-waste are injected under pressure into a steel and concrete encased shafts placed deep in the earth.

•Waste piles: It is accumulations of insoluble solid, non flowing hazard waste. Piles serve as temporary or final disposal

•Land treatment it is a process by which solid waste, such as sludge from wastes is applied onto or incorporated into the soil surface.

4.6 CAUSES OF INCREASE IN SOLID WASTE

•Population growth
•Increase in industrials manufacturing
•Urbanization
•Modernization
Modernization, technological advancement and increase in global population created rising in demand for food and other essentials. This has resulted to rise in the amount of waste being generated daily by each household.

ADVERSE EFFECTS ON LIVING ORGANISMS DUE TO SOLID WASTE
•Populations in areas where there is no proper waste treatment method.
•Children
•Waste workers
•Populations living close to waste dump
•Animals

SOURCES OF HUMAN EXPOSURES.

The group at risk from the unscientific disposal of solid waste includes the population in areas where there is no proper waste disposal method, especially
•Pre-school children
•Waste workers
•Workers in facilities producing toxic and infectious material Other high risk group includes population living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection.

POINTS OF CONTACT TOLIVING ORGANISM
There are number of points by which solid waste may be come in contact with living organisms such as
•Soil adsorption, storage and biodegrading
•Plant uptake
•Ventilation
•Leaching

•Insects, birds, rats, flies and animals
•Direct dumping of untreated waste in seas, rivers and lakes results in contact of plants and animals that feed on it

4.7 IMPACTS OF SOLID WASTE ON HUMAN HEALTH, ANIMALS AND AQUATIC LIFE

There are potential risks to environment and health from improper handling of solid wastes. Direct health risks concern mainly the workers in this field, who need to be protected, as far as possible, from contact with wastes. There are also specific risks in handling wastes from hospitals and clinics. For the general public, the main risks to health are indirect and arise from the breeding of disease vectors, primarily flies and rats. Uncontrolled hazardous wastes from industries mixing up with municipal wastes create potential risks to human health. Traffic accidents can result from toxic spilled wastes. There is specific danger of concentration of heavy metals in the food chain, a problem that illustrates the relationship between municipal solid wastes and liquid industrial effluents containing heavy metals discharged to a drainage/sewage system and /or open dumping sites of municipal solid wastes and the wastes discharged thereby maintains a vicious cycl including these some other types of problem are as follows
•Chemical poisoning through chemical inhalation
•Uncollected waste can obstruct the storm water runoff resulting in flood
•Low birth weight
•Cancer
•Congenital malformations
•Neurological disease
•Nausea and vomiting
•Mercury toxicity from eating fish with high levels of mercury
•Plastic found in oceans ingested by birds
•Resulted in high algal population in rivers and sea.
•Degrades water and soil quality

4.8. IMPACTS OF SOLID WASTE ON ENVIRONMENT

The decomposition of waste into constituent chemicals is a common source of local environmental pollution. This problem is especially acute in developing nations. Very few existing landfills in the world poorest countries would meet environmental standards accepted in industrialized nations, and with limited budgets there are likely to be few sites rigorously evaluated prior to use in the future. The problem is again compounded by the issues associated with rapid urbanization..A major environmental concern is gas released by decomposing garbage. Methane is a byproduct of the anaerobic respiration of bacteria, and these bacteria thrive in landfills with high amounts of moisture. Methane concentrations can reach up to 50% of the composition of landfill gas at maximum anaerobic decomposition (Cointreau-Levine, 1997). A second problem with these gasses is their contribution to the enhanced greenhouse gas effect and climate change. Liquid leachate management varies throughout the landfills of the developing world. Leachate possesses a threat to local surface and ground water systems. The use of dense clay deposits at the bottom of waste pits, coupled with plastic sheeting type liners to prevent infiltration into the surrounding soil, is generally regarded as the optimum strategy to contain excess liquid. In this way, waste is encouraged to evaporate rather than infiltrate.

4.9 Summary

PREVENTIVE MEASURES FOR REDUCTION OF ADVERSE IMPACT ON ENVIRONMENT AND HUMAN
Proper solid waste management has to be undertaken to ensure that it does not affect the environment and not cause health hazards to the people living there. At the household level, proper segregation of waste has to be done and it should be ensured that all organic matter is kept aside for composting, which is undoubtedly the best method for the correct disposal of this segment of the waste. In fact, the organic part of the waste that is generated decomposes more easily, attracts insects and causes disease. Organic waste can be composted and then used as a fertilizer. These steps may be taken for prevention of impact

- Generation of waste should be decreased
- Promoting the production of goods which minimize waste generation after use
- Material recycling and recovery should be increased
- Promoting the use of plastic recycling identification codes and labels in order to make sorting and recycling of plastic packaging easier
- Municipalities increasing their level of service to the public regarding sorting of waste.
- Education of producers, the public and people who work in the waste sector should be increased
- Promoting the use of less hazardous alternatives to hazardous chemicals during production of goods.
- Legislation in the waste sector should be improved
- Collection of hazardous waste at collection points shall be safe, secure and performed in an environmentally sound manner

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4.10 Review Questions

Q1. Describe solid waste treatment?

Q2. Significance of SWA?

Q3. Define composition of waste substance?

Q4.Illustrate the impact of SW on human health, animals and causing diseases?

UNIT-V SOLID WASTE AND PUBLIC HEALTH

Structure

5.0 INTRODUCTION

Modernization and progress has had its share of disadvantages and one of the main aspects of concern is the pollution it is causing to the earth – be it land, air, and water. With increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. This waste is ultimately thrown into municipal waste collection centers from where it is collected by the area municipalities to be further thrown into the landfills and dumps. However, either due to resource crunch or inefficient infrastructure, not all of this waste gets collected and transported to the final dumpsites. If at this stage the management and disposal is improperly done, it can cause serious impacts on health and problems to the surrounding environment

This is the fifth unit of this block. In this unit we described the concept of solid waste assessments & public helth basics. In this unit there are five sections. In the first section there is an introduction of 2.1 Public health& economic aspects of storage you will learn about the importance of key questions concerning the effects of the various practices on public health and environmental safety remain unanswered. and the mechanisms that may be used for the purpose. In this unit 2.2 Options under Indian conditions.

The importance of proper solid waste management is one of the prime functions of the civic body, as insanitary management of solid wastes is a cause of much discomfort In the next section you will also learn COLLECTION METHODS Most of the collection systems followed in India. In Sec. 1.6 and 1.7 you will find summary and review questions respectively.

Objectives

After studying this unit you should be able to:

Solid waste & Public health

Economic aspects of storage

Options under Indian conditions

Critical Evaluation of Options

5.1 Public health & economic aspects of storage

Solid waste treatment and disposal: **effects on public health** and environmental safety. ... Such concern stems from both distrust of policies and solutions proposed by all tiers of government for the management of **solid waste** and a perception that many **solid waste** management facilities use poor operating procedures.

The safety and acceptability of many widely used solid waste management practices are of serious concern from the public health point of view. Such concern stems from both distrust of policies and solutions proposed by all tiers of government for the management of solid waste and a perception that many solid waste management facilities use poor operating procedures. Waste management practice that currently encompasses disposal, treatment, reduction, recycling, segregation and modification has developed over the past 150 years. Before that and in numerous more recent situations, all wastes produced were handled by their producers using simple disposal methods, including terrestrial dumping, dumping into both fresh and marine waters and uncontrolled burning. In spite of ever-increasing industrialization and urbanization, the dumping of solid waste, particularly in landfills, remains a prominent means of disposal and implied treatment. Major developments have occurred with respect to landfill technology and in the legislative control of the categories of wastes that can be subject to disposal by landfilling. Even so, many landfills remain primitive in their operation. Alternative treatment technologies for solid waste management include incineration with heat recovery and waste gas cleaning and accelerated composting, but both of these technologies are subject to criticism either by environmentalists on the grounds of possible hazardous emissions, failure to eliminate pathogenic agents or failure to immobilize heavy metals, or by landfill operators and contractors on the basis of waste management economics, while key questions concerning the effects of the various practices on public health and environmental safety remain unanswered. The probable and relative effects on both public health and environmental safety of tradition and modern landfill technologies will be evaluated with respect to proposed alternative treatment technologies.

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Waste that is not properly managed, especially excreta and other liquid and solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases. Unattended waste lying around attracts flies, rats, and other creatures that in turn spread disease. Normally it is the wet waste that decomposes and releases a bad odor. This leads to unhygienic conditions and thereby to a rise in the health problems. The plague outbreak in Surat is a good example of a city suffering due to the callous attitude of the local body in maintaining cleanliness in the city. Plastic waste is another cause for ill health. Thus excessive solid waste that is generated should be controlled by taking certain preventive measures

Impacts of solid waste on health

The group at risk from the unscientific disposal of solid waste include – the population in areas where there is no proper waste disposal method, especially the pre-school children; waste workers; and workers in facilities producing toxic and infectious material. Other high-risk group include population living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection.

In particular, *organic domestic waste* poses a serious threat, since they ferment, creating conditions favorable to the survival and growth of microbial pathogens. Direct handling of solid waste can result in various types of infectious and chronic diseases with the waste workers and the rag pickers being the most vulnerable.

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Waste from agriculture and industries can also cause serious health risks. Other than this, co-disposal of industrial hazardous waste with municipal waste can expose people to chemical and radioactive hazards. Uncollected solid waste can also obstruct storm water runoff, resulting in the forming of stagnant water bodies that become the breeding ground of disease. Waste dumped near a water source also causes contamination of the water body or the ground water source. Direct dumping of untreated waste in rivers, seas, and lakes results in the accumulation of toxic substances in the food chain through the plants and animals that feed on it.

Disposal of hospital and other medical waste requires special attention since this can create major health hazards. This waste generated from the hospitals, health care centers, medical laboratories, and research centers such as discarded syringe needles, bandages, swabs, plasters, and other types of infectious waste are often disposed with the regular non-infectious waste.

Waste treatment and disposal sites can also create health hazards for the neighborhood. Improperly operated incineration plants cause air pollution and improperly managed and designed landfills attract all types of insects and rodents that spread disease. Ideally these sites should be located at a safe distance from all human settlement. Landfill sites should be well lined and walled to ensure that there is no leakage into the nearby ground water sources.

Recycling too carries health risks if proper precautions are not taken. Workers working with waste containing chemical and metals may experience toxic exposure. Disposal of health-care wastes require special attention since it can create major health hazards, such as Hepatitis B and C, through wounds caused by discarded syringes. Rag pickers and others who are involved in scavenging in the waste dumps for items that can be recycled, may sustain injuries and come into direct contact with these infectious items.

Diseases

Certain chemicals if released untreated, e.g. cyanides, mercury, and polychlorinated biphenyls are highly toxic and exposure can lead to disease or death. Some studies have detected excesses of cancer in residents exposed to hazardous waste. Many studies have been carried out in various parts of the world to establish a connection between health and hazardous waste.

The role of plastics

The unhygienic use and disposal of plastics and its effects on human health has become a matter of concern. Colored plastics are harmful as their pigment contains heavy metals that are highly toxic. Some of the harmful metals found in plastics are copper, lead, chromium, cobalt, selenium, and cadmium. In most industrialized countries, color plastics have been legally banned. In India, the Government of Himachal Pradesh has banned the use of plastics and so has Ladakh district. Other states should emulate their example.

Preventive measures

Proper methods of waste disposal have to be undertaken to ensure that it does not affect the environment around the area or cause health hazards to the people living there.

At the household-level proper segregation of waste has to be done and it should be ensured that all organic matter is kept aside for composting, which is undoubtedly the best method for the correct disposal of this segment of the waste. In fact, the organic part of the waste that is generated decomposes more easily, attracts insects and causes disease. Organic waste can be composted and then used as a fertilizer.

5.2 Options under Indian conditions

The importance of proper solid waste management is one of the prime functions of the civic body, as insanitary management of solid wastes is a cause of much discomfort. Since waste management is the fundamental requirement for public health, Article 48-A of the Indian Constitution establishes the responsibility of the state to manage these wastes properly. On the basis of available data, it is estimated that the nine major metropolitan centres in India are presently producing 23,000 tones of solid waste per day. As per recent estimates, Benguluru generates about 3,600 tonnes per day and the following table provides comparative details about garbage generated and cleared in nine major Indian cities (IIED, 1999).

Urban waste situation in some major Indian cities

Major cities	**Garbage generated (tonnes per day)**	**Garbage cleared (tonnes per day)**
Mumbai	5800	5000
Kolkata	3500	3150
Chennai	2675	2140
Delhi	3880	2420
Bangaluru	**2130**	**1800**
Lucknow	1500	1000
Patna	1000	300
Surat	1250	1000
Ahmedabad	1500	1200

LACK OF STRATEGIC APPROACH OF FORMAL SECTOR

In most cities, the municipal service for the collection and transportation of urban solid wastes comprises three separate functions as follows,

a)	sweeping, curbside and domestic waste collection from garbage bins
b)	Transportation by handcarts to large or road collection points, which may be open dumps.
c)	Transportation by vehicles to the disposal sites

Indian waste management system is starved of resources to tackle the increasing demands associated with growing urbanization. Due to budgetary constraints, inadequate equipment and poor planning, house-to-house collection is very rare in India, particularly in certain low-income areas where waste is not collected at all. It is estimated that upto 30-40 percent (UNCHS, 1994) of disposed solid wastes are left uncollected. The areas, which are not serviced, are left with clogged sewers and litter, which create serious health problems for the resident population.

STORAGE

Storage of wastes before final disposal is done at three levels:

- At source:Solid wastes are often stored at the source until they are picked up by waste collectors (collection crew) or taken out to be thrown into an open space or a community bin.
- At community level: Community bins are used in crowded and narrow market areas, which is a common feature of most developing countries. Because of the high cost of door to door collection many waste management authorities have introduced community bins.
- At transfer stations: Transfer stations are established, for economic reasons in cities, which have long haulage distances to final disposal sites. Smaller collection vehicles bring in the wastes collected at their source of generation or from the community bins and larger vehicles transport them away to final disposal sites. Transfer stations are also used as collection and sorting points for recycling materials.

COLLECTION METHODS

Most of the collection systems followed in India are:

Door to door collection

This system is used in narrow streets where a collection truck cannot reach individual houses. The house places the filled containers outside their doors when the waste collectors arrive. Some cities such as Chennai (Madras) and Chandigarh have implemented this in posh localities where influential people reside. On similar lines, Benguluru City Corporation (BCC) recently introduced door to door collection in some wards and management seems to be satisfactory.

Curbside collection

This method is used in wider streets, where the collection trucks can pass through conveniently. The house owners leave the waste containers at the edge of the pavement. The waste collectors collect the waste from the curbside or empty the containers into the vehicle as it passes through the street at a set time and day and return the containers as practiced in Kanpur (UNCHS, 1994).

Block collection

The collection vehicles arrive at a particular place or a set day and time to collect waste from the households. Households bring their waste containers and empty directly into the vehicle (UNCHS, 1994).

Community bins

Community storage bins are placed at convenient locations, where the community members carry their waste and throw it. (These bins are also called Delhi bins, since it was introduced first time in Delhi)

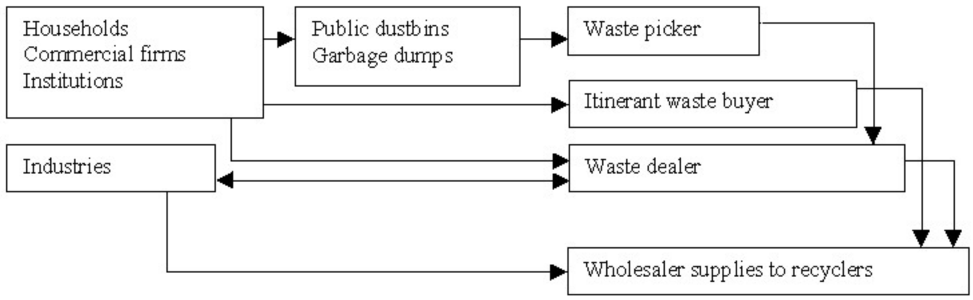
Comparison of Collection Systems

	Collection Methods			
Sustainability Indicators	**Door to Door Collection**	**Curbside Collection**	**Block Collection**	**Community Bins**
Area improvement	√	√	√	X
Convenience of the people	√	X	X	X
Convenience of the staff	X	√	√	√
Handling the extra waste during festival	X	√	√	√
Frequency and Reliability	X	√	X	√

5.3 Critical Evaluation of Options

INFORMAL RECYCLING ACTIVITIES

The phenomenon of recycling by means of repair, reprocessing, and reuse of waste materials is a common practice in India. At the household level recycling is very common. Waste is accessible to waste pickers; they segregate it into saleable materials such as paper, plastics, glasses, metal pieces, textile, etc. Rag pickers segregate the wastes directly from the dumps and bins with no precautions and they are exposed directly to harmful wastes. The separated waste is sold to a small waste dealer, from where the waste is transferred to a medium sized dealer or wholesaler. All these activities are not regulated or monitored by any governmental organization. Due to this informal segregation, volume reduction is achieved, while it ignores social, economic, environmental, and health aspects.



TREATMENT AND TREATMENT OPTIONS

Waste collected by the formal and informal sectors is delivered mainly to three destinations. The remaining waste goes for disposal. First, high quality materials and used products are cleaned or transformed for reuse. A well-known example is the reuse of old newspapers for packaging material. Second, recyclable materials are traded for recycling purposes. As a result, a wide range of products is generated. Third, organic waste can be converted into compost, which, when used as manure instead of chemical fertilizer contributes to improved fertility of the soil.

Recycling & Reuse

The processes, by which materials otherwise destined for disposal are collected, reprocessed or remanufactured and are reused. Annexure 3 gives the list of commonly separated recyclable components in the municipal waste stream in India. The separation for recycling takes place at households, community bins, and open dumps and even in final disposal yards. The recycling business is a complicated chain of operations and varies from place to place. The recycling and reuse (the use of a product more than once in its same form for the same or another purpose) sector of waste management in cities of Asian developing countries is potentially high. Its economic assessment is a difficult task since it is practiced in an informal manner.

Biogas

Biogas contains approximately 60:40 mixture of methane (CH_4), and carbon dioxide (CO_2) produced by the anaerobic fermentation of cellulose biomass materials - simultaneously generating an enriched sludge fertilizer - with enenergy content of 22.5 MJ/m^3, clean gaseous fuel for cooking, for running engines for shaft and electrical power generation with little or no pollution. Many cellulose biomass materials are available in urban and rural solid wastes and may be utilized to produce eco-friendly renewable energy, contributing to the clean waste management. In India, biogas production is currently practiced in many places in rural areas (with cattle dung) and few places in urban areas (with sewage).

DISPOSAL AND DISPOSAL OPTIONS

WASTE DISPOSAL OPTIONS

Final destination of solid waste in India is disposal. Most urban solid waste in Indian cities and towns is landfilled and dumped. A wide range of disposal options in many developing countries is available and some of them are listed below:

- **Non-engineered disposal**

  This is the most common method of disposal in low-income countries, which has no control, or with only slight or moderate controls. They tend to remain for longer time and environmental degradation could be high, include mosquito, rodent and fly breeding, air, and water pollution, and degrading of the land.

- **Sanitary landfilling**

  Sanitary landfill is a fully engineered disposal option, which avoids harmful effects of uncontrolled dumping by spreading, compacting and covering the wasteland that has been carefully engineered before use. Through proper site selection, preparation and management, operators can minimize the effects of leachates (polluted water which flows from a landfill) and gas production both in the present and in the future. This option is suitable when the land is available at an affordable price. Human and technical resources available are to operate and manage the site.

- **Composting**

  Composting is a biological process of decomposition carried out under controlled conditions of ventilation, temperature, moisture and organisms in the waste themselves that convert waste into humus-like material by acting on the organic portion of the solid waste. If carried out effectively, the final product is stable, odor-free, does not attract flies and is a good soil conditioner. Composting is considered when biodegradable waste is available in considerable fraction in the waste stream and there is use or market for compost. Centralized composting plant for sector may only be undertaken if adequate skilled manpower and equipment are available, hence at household level and small level composting practices could be effective which needs the people's awareness.

- **Incineration**

Incineration is the controlled burning of waste in a purpose built facility. The process sterilizes and stabilizes the waste. For most wastes, it will reduce its volume to less than a quarter of the original. Most of the combustible material is converted into carbon dioxide and ash. An extensive sample programe conducted in India (Bhide and Sundaresan, 1984) reveals that most of the waste had a calorific value of just 3350 joules/g compared with 9200 joules/g in high income countries. Incineration may be used as a disposal option, only when landfilling is not possible and the waste composition is of high combustible (i.e. self-sustaining combustible matter which saves the energy needed to maintain the combustion) paper or plastics. It requires an appropriate technology, infrastructure, and skilled manpower to operate and maintain the plant. In Indian cities, Incineration is generally limited to hospital and other biological wastes and mostly others are either landfilled or dumped. Composition of urban solid waste in Indian cities (% by weight)

City	Paper	Metal	Glass	Textiles	Plastics*	Ash & dust	Organic	Others**
Chennai	5.90	0.70	-	7.07	-	16.35	56.24	13.74
Delhi	5.88	0.59	0.31	3.56	1.46	22.95	57.71	7.52
Kolkata	0.14	0.66	0.24	0.28	1.54	33.58	46.58	16.98
Bangalore	1.50	0.10	0.20	3.10	0.90	12.00	75.00	7.20
Ahmedabad	5.15	0.80	0.93	4.08	0.69	29.01	48.95	10.39
Mumbai	3.20	0.13	0.52	3.26	-	15.45	59.37	18.07

COMPARISON OF DISPOSAL OPTIONS

	Disposal Options			
Sustainability indicators	**Non Engineered Disposal**	**Sanitary Landfill**	**Composting**	**Incineration***
Volume reduction	X	X	X	√
Expensive	X	√	√	√
Long term maintenance	√	√	X	X

By product recovery	X	√	√	√
Adaptability To all wastes	√	√	X	X
Environmental adverse effect	√	√	X	√

Check your progress

Q1. Define collection systems in india.

Q2. Explain Options under Indian conditions.

5.4 Summary

PREVENTIVE MEASURES FOR REDUCTION OF ADVERSE IMPACT ON ENVIRONMENT AND HUMAN

Proper solid waste management have to be undertaken to ensure that it does not affect the environment and not cause health hazards to the people living there. At the household level proper segregation of waste has to be done and it should be ensured that all organic matter is kept aside for composting, which is undoubtedly the best method for the correct disposal of this segment of the waste. In fact, the organic part of the waste that is generated decomposes more easily, attracts insects and causes disease. Organic waste can be composted and then used as a fertilizer. These steps may be taken for prevention of impact. *Exposure to hazardous waste* can affect human health, children being more vulnerable to these pollutants. In fact, direct exposure can lead to diseases through chemical exposure as the release of chemical waste into the environment leads to chemical poisoning. Many studies have been carried out in various parts of the world to establish a connection between health and hazardous waste. Modernization and progress has had its share of disadvantages and one of the main aspects of concern is the pollution it is causing to the earth – be it land, air, and water. With increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. This waste is ultimately thrown into municipal waste collection centres from where it is collected by the area municipalities to be further thrown into the landfills and dumps. However, either due to resource crunch or inefficient infrastructure, not all of this waste gets collected and transported to the final dumpsites. If at this stage the management and disposal is improperly done, it can cause serious impact health and problems to the surrounding environment.

Waste that is not properly managed, especially excreta and other liquid and solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases. Unattended waste lying around attracts flies, rats, and other creatures that in turn spread disease. Normally it is the wet waste that decomposes and releases a bad odour. This leads to unhygienic conditions and thereby to a rise in the health problems. The plague outbreak in Surat is a good example of a city suffering due to the callous attitude of the local body in maintaining cleanliness in the city. Plastic waste is another cause for ill health. Thus excessive solid waste that is generated should be controlled by taking certain preventive measures

5.5Review Questions

Q.1.What are remedies provided by Indian constitution for solid wastes.

Q.2.Explain the impact on health issues regarding solid waste management.

UNIT-VI Factors affecting solid waste

Structure

6.0 Introduction

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 publichealth, economics, engineering, conservation, aesthetics, public attitude and other environmental considerations. The quantity of MSW generated is increasing rapidly due to increasing population and change in lifestyle. The current MSW crisis should be approached holistically; while planning for long term solutions, focus on the solving the present problems should be maintained. The Government and local authorities should work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. While this is being achieved and recycling is increased, provisions should be made to handle the non-recyclable wastes that are being generated and will continue to be generated in the future. Policy to include waste-pickers in the private sector must be introduced to utilize their low cost public and environmental service and to provide better working conditions to these marginalized populations.

SWM has socio-economic and environmental dimensions. In the socio-economic dimension, for example, it includes various phases such as waste storage, collection, transport and disposal, and the management of these phases has to be integrated. In other words, wastes have to be properly stored, collected and disposed of by co-operative management. In addition, poor management of wastes on the user side such as disposing of wastes in the streets, storm water drains, rivers and lakes has to be avoided to preserve the environment, control vector-born diseases and ensure water quality/resource.

Objectives

- After studying this unit you should be able to:
- Factors affecting solid waste generation rate
- Quantities of materials recovered from MSW
- Solid waste as pollutant

- Effect of solid waste to environment.

6.1 Factors affecting solid waste generation rate

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 considerations. Put differently, the SWM processes differ depending on factors such as economic status (e.g., the ratio of wealth created by the production of primary products to that derived from manufactured goods, per capita income, etc.), degree of industrialization, social development (e.g., education, literacy, healthcare, etc.) and quality of life of a location. In addition, regional, seasonal and economic differences influence the SWM processes. This, therefore, Solide Waste Management strategies that are economically viable, technically feasible and socially acceptable to carry out such of the functions as are listed below:

- Protection of environmental health.
- Promotion of environmental quality.
- Supporting the efficiency and productivity of the economy.
- Generation of employment and income.

SWM has socio-economic and environmental dimensions. In the socio-economic dimension, for example, it includes various phases such as waste storage, collection, transport and disposal, and the management of these phases has to be integrated. In other words, wastes have to be properly stored, collected and disposed of by co-operative management. In addition, poor management of wastes on the user side such as disposing of wastes in the streets, storm water drains, rivers and lakes has to be avoided to preserve the environment, control vector-born diseases and ensure water quality/resource.

6.1.1 SWM system

A SWM system refers to a combination of various functional elements associated with the management of solid wastes. The system, when put in place, facilitates the collection and disposal of solid wastes in the community at minimal costs,while preserving public health and ensuring little or minimal adverse impact on the environment. The functional elements that constitute the system are:

(i) Waste generation: Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted into goods for consumption. The source of waste generation, determines quantity, composition and waste characteristics. For example, wastes are generated from households, commercial areas, industries, institutions, street cleaning and other municipal services. The most important aspect of this part of the SWM system is the identification of waste.

(ii) Waste storage: Storage is a key functional element because collection of wastes never takes place at the source or at the time of their generation. The heterogeneous wastes generated in residential areas must be removed within 8 days due to shortage of storage space and presence of biodegradable material. Onsite storage is of primary importance due to aesthetic consideration, public health and economics involved. Some of the options for storage are plastic containers, conventional dustbins (of households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc. Obviously, these vary greatly in size, form and material.

(iii) Waste collection: This includes gathering of wastes and hauling them to the location, where the collection vehicle is emptied, which may be a transfer station (i.e., intermediate station where wastes from smaller vehicles are transferred to larger ones and also segregated), a processing plant or a disposal site. Collection depends on the number of containers, frequency of collection, types of collection services and routes. Typically, collection is provided under various management arrangements, ranging from municipal services to franchised services, and under various forms of contracts.

Note that the solution to the problem of hauling is complicated. For instance, vehicles used for long distance hauling may not be suitable or particularly economic for house-to-house collection. Every SWM system, therefore, requires an individual solution to its waste collection problem.

(iv) Transfer and transport: This functional element involves:

a. the transfer of wastes from smaller collection vehicles, where necessary to overcome the problem of narrow access lanes, to larger ones at transfer stations;
b. the subsequent transport of the wastes, usually over long distances, to disposal sites.

The factors that contribute to the designing of a transfer station include the type of transfer operation, capacity, equipment, accessories and environmental requirements.

(v) Processing: Processing is required to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling. The important processing techniques include compaction, thermal volume reduction, manual separation of waste components, incineration and composting.

(vi) Recovery and recycling: This includes various techniques, equipment and facilities used to improve both the efficiency of disposal system and recovery of usable material and energy. Recovery involves the separation of valuable resources from the mixed solid wastes, delivered at transfer stations or processing plants. It also involves size reduction and density separation by air classifier, magnetic device for iron and screens for glass. The selection of any recovery process is a function of economics, i.e., costs of separation versus the recovered-material products. Certain recovered materials like glass, plastics, paper, etc., can be recycled as they have economic value.

(vi) Waste disposal: Disposal is the ultimate fate of all solid wastes, be they residential wastes, semi-solid wastes from municipal and industrial treatment plants, incinerator residues, composts or other substances that have no further use to the society. Thus, land use planning becomes a primary determinant in the selection, design and operation of landfill operations. A modern sanitary landfill is a method of disposing solid waste without creating a nuisance and hazard to public health. Generally, engineering principles are followed to confine the wastes to the smallest possible area, reduce them to the lowest particle volume by compaction at the site and cover them after each day’s operation to reduce exposure to vermin. One of the most important functional elements of SWM, therefore, relates to the final use of the reclaimed land.

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

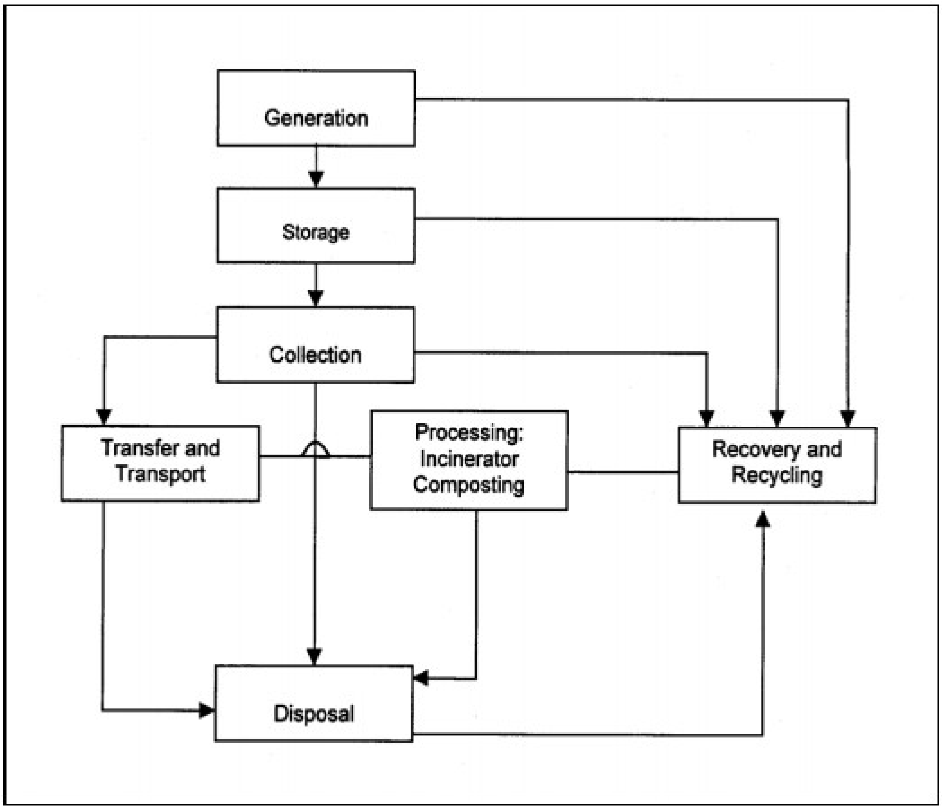


Figure 1.1 Typical SWM System: Functional Elements

You must, however, note that all the elements and linkages shown in Figure 1.1 need not necessarily be always present in a SWM system. Being generic in its form, this system is applicable to all regions, irrespective of their relative state of development.

6.2 Quantities of materials recovered from MSW

Domestic, commercial and industrial wastes are collectively referred to as municipal solid waste (MSW) in Hong Kong. About 3.33 million tonnes and 3.60 million tonnes of MSW were disposed of and recovered in Hong Kong in 2010 respectively. In 2010, the overall recovery rate in Hong Kong is 52%. The recovered wastes were mostly exported to the Mainland and other countries for recycling (3.57 million tonnes). The major types of recyclable wastes recovered included paper, plastics, ferrous metal and non-ferrous metal, which accounted for about 97% of the waste recovered. The remaining 3% include electrical & electronic equipment, wood, textile, rubber tyres and glass. Figure 1 (a) & (b) illustrates the overall quantities of wastes recovered in 2010.

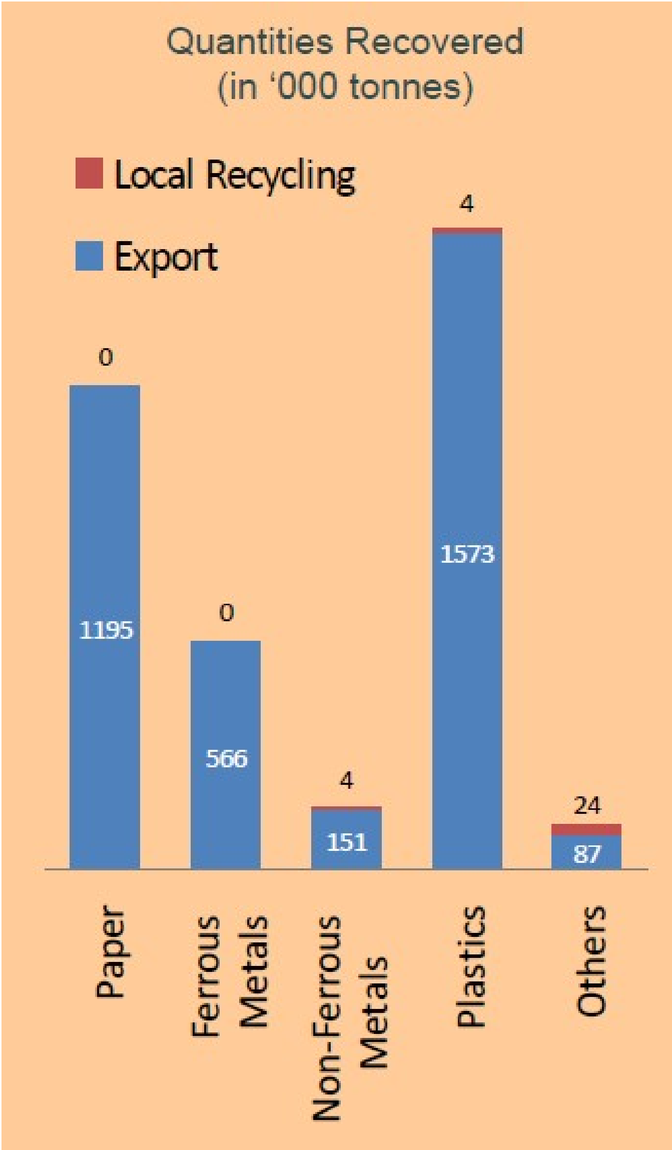


Figure 1 (a) Quantities of Major Types of Recyclable Waste Recovered in Hong Kong

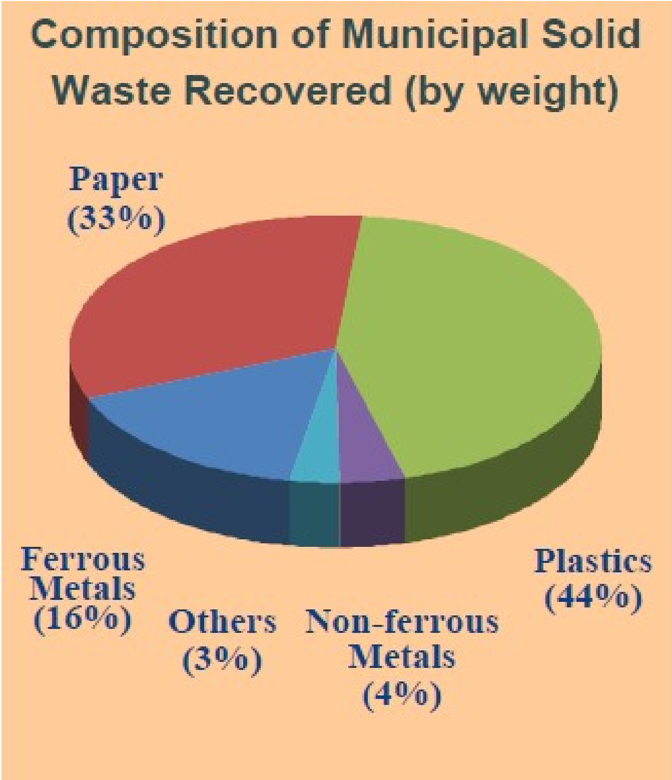


Figure 1 (b) Quantities of Major Types of Recyclable Waste Recovered in Hong Kong

6.2.1 Government Policy in Waste Management

Although we are recovering 52% of our waste for recycling, our landfills will be exhausted one by one during the period from mid to late 2010s. There is a pressing need to further reduce the generation of waste and the amount of waste we send to the landfills. It is the Government's policy to promote waste avoidance, minimisation, recovery for reuse and recycling. To tackle our waste problem, the Government published "A Policy Framework for the Management of Municipal Solid Waste (2005-2014)" in December 2005.

This Policy Framework sets out a comprehensive strategy consisting of a series of policy tools and measures to tackle our waste problem head on with a view to achieving the following targets

- To reduce the amount of municipal solid waste (MSW) generated in Hong Kong by 1% per annum up to the year 2014.
- To increase the overall recovery rate of MSW to 45% by 2009 and 50% by 2014.
- To reduce the total MSW disposed of in landfills to less than 25% by 2014.

6.2.2 Waste Collection and Disposal

The waste collection arrangement in Hong Kong is complex. Figure 2 illustrates the main collection and disposal routes of MSW. In general, the domestic waste produced at households is collected by cleansing workers and taken to public/private refuse collection points. The Food and Environmental

Hygiene Department then transfers the waste collected from domestic sector and street level to refuse transfer stations for final disposal at landfills. The waste produced by commercial and industrial sectors is handled primarily by private waste collectors. The exact collection routes depend on the waste arising locations and the provision of local waste collectors. Alternative routes are not uncommon. For instance, people living in rural areas may bring their domestic waste to nearby public refuse collection points directly without the involvement of private waste collectors.

Figure 2 Main Collection and Disposal Routes of Municipal Solid Waste in Hong Kong

6.2.3 Waste Recovery

Waste materials are recovered at different points along the waste collection and disposal routes. The materials recovered usually bear good market values. They include paper, cardboard, plasticsandaluminium metal cans. According to the data collected by the Environmental Protection Department (EPD) in early 2011, there are around 340 active waste collectors in Hong Kong, while about

45 of them are also involved in waste recycling and reprocessing operations. The majority of these waste collectors collect more than one kind of recyclables, whereas the recyclers and re processors usually handle only one kind of recyclables in their workshops. The key recovery activities are:

a) waste generators (mainly industrial waste generators) separate recyclables from their waste as it is economic to do so by selling the recovered materials directly to waste dealers;

b) "scavengers", including the workers of waste collection services, separate valuable materials from the mixed wasteland sell the recovered materials to waste collectors for further processing;

c) organizations such as schools, housing estates, government departments and community bodies implement their own waste recovery schemes or participate in the Source Separation of Waste Program me organized by EPD and sellor give the recovered materials to waste collectors or other waste dealers

The key players in waste recovery and the related recovery routes are illustrated in Figure 3.

Figure 3:The Key Players of Local Waste Recovery

6.2.4 Major Constraints on Waste Recovery/Recycling

There are a number of constraints which limit the extent of waste recovery and recycling activities in Hong Kong. These include:

a) Although the environmental awareness of the general public has increased significantly in recent years, their willingness to actively participate in waste reduction still needs to be enhanced.

b) The promotion of waste avoidance purely on environmental grounds might not be sufficient. Waste charging is a key policy tool in waste avoidance and minimization. By putting price on generating waste, we can induce change in people's waste habits and behavior.

c) To facilitate the collection and recovery of recyclable materials that have marginal recycling values, the adoption of producer responsibility schemes will enhance their recovery and help sustain the local recycling industry.

d) The built environment inhibits recycling activities from the domestic waste stream. Small flat sizes and communal utility areas restrict source separation and storage practices.

e) Low values, high transportation cost or lack of market demand for recovered materials particularly for glass, wood, tires and organic materials.

f) The predominance of small and medium recovery and recycling enterprises discourages investments in waste recovery technologies.

g) High land premium and labor cost affect the economic viability of setting up local recycling facilities.

6.2.5 Government Initiatives in Waste Reduction and Recycling

The EPD is working closely with various sectors including housing and property management, education, non-governmental organizations, as well as the construction industry, the waste recycling industry and the Government to implement sector-specific waste reduction and recycling measures.

Waste Separation Bins

To facilitate public participation in waste separation and recovery, the Government has placed waste separation bins to collect waste paper, aluminum cans and plastic bottles throughout the territory since 1998. Starting from May 2006 onwards, the waste separation bins in public places can also be used for putting all kinds of waste plastics and metals. By the end of 2011, over44 000 waste separation bins are placed by the roadside, in parks, leisure and cultural facilities, government buildings, hospitals, clinics, public and private housing estates, schools and refuse collection points.

Land Allocation Policy

The Government encourages materials re-use, recovery and recycling to help achieve waste reduction. Allocating suitable land solely for recycling purpose at affordable rent is a major measure for supporting the waste recycling industry. As the profit of waste recovery and recycling is often marginal, leasing land through open tendering exclusively to waste recyclers could lower their operation cost and help to promote the local recycling activities in Hong Kong.

At the end of 2010, a total of 33 sites (about 6 hectares) have been allocated to waste recyclers under short term tenancy. These sites are located in different parts of the territory and are being used for recycling and processing a wide range of waste materials including paper, glass, plastics, metals, wood and tires. More sites are being identified and will be put out for open tender from time to time.

In addition, a 20 hectare Eco Park is being developed in TuenMun Area 38 to provide long term and affordable land to the waste recycling industry. All the six Phase I lots have been awarded for recycling of waste cooking oil, waste metals, waste wood, waste computer equipment, waste plastics and waste batteries. The first batch of five lots in Phase 2 was also awarded in August 2011 for the recycling of waste metals, waste batteries, waste construction materials / waste glass, waste electrical and electronic equipment, and waste rubber tires. Besides, tender invitation for lease of another Phase 2 lot will be commenced in 2012. The whole Eco Park could provide a total of14 hectares of rentable land for recycling and environmental industries.

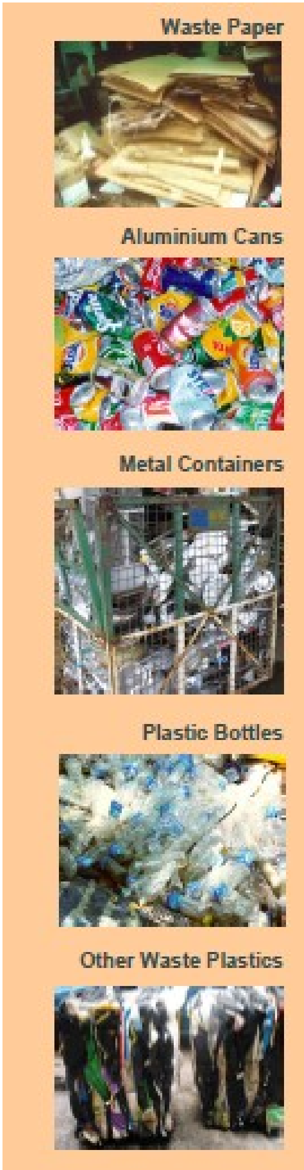


Fig: Common Recyclable Materials

Amendment of Building Regulations

Amendment of the Building (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Regulations (Chapter123H) was made in the 2007-08 legislative session. Commencing from 1 December 2008, all new domestic buildings and the domestic part of new composite buildings are required to provide a refuse storage and material recovery room on every building floor to facilitate residents to participate in waste recovery.

Programme on Source Separation of Domestic Waste

EPD has launched a territory-wide Programme on Source Separation of Domestic Waste since January 2005 and we are calling on the public to actively participate in the programme.The main objectives of the programme are (a) to make it more convenient for residents to separate waste at source by encouraging and assisting property management companies to provide waste separation facilities on each building floor; and (b) to broaden the types of recyclables to be recovered to waste paper, plastics, metals, electrical and electronic equipment, and used clothing etc.

As at end of 2011, more than 1 790 housing estates/residential buildings participating in the Programme. The total population in Hong Kong now covered by the Programme has exceeded 80%.

Programme on Source Separation of Commercial and Industrial Waste

In 2007, EPD launched the Programme on Source Separation ofCommercial and Industrial Waste which aims to encourage the property management sector of the commercial & industrial (C&I) buildings to undertake initiatives to set up and implement effective mechanism to separate and recover waste within the C&I premises and commend the C&I buildings which have implemented source separation of waste within their premises.This will facilitate the tenants/occupants to practice waste separation and recycling in workplaces and increase the quantitiesof C&I waste being recycled. Up to end 2011, 732 buildingshave signed up the programme.

Promotion Programme on Source Separation of Waste

To encourage public participation in waste separation andrecycling, the Environmental Campaign Committee (ECC) and the EPD have jointly organized a territory-wide campaign, titled Promotion Programme on Source Separation of Waste (the Programme), by distributing newly designed waste separation bins to residential, commercial and industrial buildings on a free-of-charge basis. Through the provision of new waste separation bins, not only can the waste separation facilities be improved but also the variety of recyclables can be expanded. Besides, property management companies are encouraged to implement waste separation in the premises, so as to increase the recycling rate in long-run.

The response of the Programme has been promising. Since its launching in the end of 2008, nearly 5 000 sets of the newly designed waste separation bins had been distributed to the participants.

Community Recycling Network

With the goal to achieve the waste recovery target of 55% by 2015, EPD has established the Community Recycling Network (CRN) to promote waste reduction and recovery and collect recyclables of low commercial value, including plastics, glass bottles and small Waste Electrical and Electronic Equipment (WEEE). Through face-to-face promotion and the provision of territory-wide district-based recyclables collection network, the CRN encourages public participation in recycling.

The CRN comprises (1) community recycling centers funded by the Environmental Conservation Fund (ECF) in various districts. There are practical difficulties in installing waste separation facilities in some buildings. The community recycling centersfacilitate the residents of these buildings to practice waste separation and recovery; (2) collection points at public service centers of non-governmental organizations; (3) promotion booths set up regularly at busy locations, including parks, walkways, shopping malls and markets, to promote waste reduction and collect recyclables; (4) promotion vehicles that travel around Hong Kong to enhance promotion in housing estates and to provide an alternative outlet for the low-valued recyclables; (5) the school waste reduction and recycling education and awareness campaign that is targeted to enhance students' knowledge of plastics recycling with a view to developing a recycling habit among them; and (6) a material transfer center in Kowloon Bay that provides free bulk transfer of recyclables collected through the above-mentioned collection outlets to the EcoPark in TuenMun and other recyclers forfurther processing.

Cooperation with District Councils

EPD continues to work closely with District Councils (DC) to enhance public awareness and participation in waste reduction at the district level. In 2011, EPD visited each of the 18 DCs to brief about the strengthened waste management strategy, and in particular the new action plan on promotion of source separation of waste and recycling. As in previous years, EPD has worked jointly with Areas Sub-committees of YauTsimMong, Sham Shui Po and Wong Tai Sin District Councils in organizing localwaste recovery promotional and other environmental protection activities. Besides, EPD has continued to provide technicalupport to local non-government organizations to organize waste reduction and environmental protection activities.

Environment and Conservation Fund

In order to enhance awareness and ensure sustained participation of the public in waste prevention and recovery, the ECF has supported non-profit making organizations such as green groupsand community groups, etc. to organize community waste recovery projects. Since 2001, 69 organizations have been granted with the ECF to organize 116 community waste recoveryprojects. To encourage more housing estates/residentialbuildings to participate in the Programme on Source Separationof Domestic Waste, the ECF is now open for resident organizations and property management companies to apply for funding support to implement the Programme. A total sum of $10 million has been earmarked by the ECF Committee to support the Programme. Up to end 2011, 112 housing estateshave been successfully granted funding support to implement theProgramme on Source Separation of Domestic Waste. The

ECF Committee also endorsed in 2008 the extension of the Programme to cover commercial and industrial buildings.

In addition, a new funding scheme to provide support to housing estates for collecting and treating food waste at source, and organizing educational activities on food waste reduction was launched in July 2011.

Producer Responsibility Scheme

Producer responsibility scheme (PRS) is one of the major policy tools in municipal solid waste management. Under PRS, different stakeholders involved in the generation of waste, who can be manufacturers, importers, brand agents, distributors, retailers and consumers, shall share the financial and/or physical responsibility for the collection, recycling, treatment and disposal of end-of-life products, with a view to avoiding and reducing the environmental impact caused by such wastes.

In April 2002, a mobile phone battery recovery and recyclingprogramme under a voluntary producer responsibility scheme was launched. Learning from the experience, the programme was extended in April 2005 to include the recovery of all types ofportable rechargeable batteries. The Rechargeable Battery Recycling Programme is organized and funded by 40 producers and importers of rechargeable battery and electronic equipment. Under this programme, 590 conveniently located collection points are set up in the shops and stations of participating companies. To provide additional convenience to the public, secondary collection points are also set up at housing estates, commercial/industrial buildings and schools. Up to end 2011, about 278 tons of rechargeable batteries (equivalent to2 300 000 pieces) have been collected and shipped to overseas treatment facilities for recycling.

In January 2008, the second voluntary PRS programme “Computer Recycling Programme” was launched. It was funded and organized by 19 local and international computer equipment suppliers. Under this programme, 16 public collection points have been set up. In addition, 894 housing estates and commercial/industrial buildings have signed up to join the programme. Up to end 2011, about 71 000 pieces of major computer equipment have been collected. Better quality computers collected under the programme are donated to the needy through a charitable organization. Others have been dismantled and recycled.

In March 2008, the third voluntary PRS programme “Fluorescent Lamp Recycling Programme” was launched. It was funded and organized by 15 suppliers of fluorescent lamps. Under this programme, 157 public collection points have been provided at the retail outlets of participating companies, designated shopping malls and houseware stores. In addition, 991 housing estates have signed up to join the programme. Up to end 2011, about 1 260 000 lamps have been collected and delivered to a mercury lamp treatment facility set up at the Chemical Waste Treatment Centre.

The Legislative Council enacted the Product Eco-responsibility Ordinance in July 2008 to provide a legal framework for implementation of producer responsibility schemes in HongKong. The environmental levy on plastic shopping bags is the first scheme introduced under the Ordinance.

Waste electrical and electronic equipment is the next target for implementation of the mandatory scheme. The public were consulted in the period from January to April of 2010. It revealed that stakeholders and the public generally supported the introduction a mandatory PRS by legislation for the proper management of WEEE. We will continue to engage the relevant trades to discuss the operational details of the scheme with a view to commencing legislative drafting work as soon as possible. At the same time, we also plan to take the lead to invest in the development of a local treatment facility required under the scheme to treat locally generated WEEE

Recovery Programme for Waste Electrical and Electronic Equipment (WEEE)

Apart from the collection service provided under the voluntary producer schemes, EPD has also engaged St. James' Settlement and Caritas Hong Kong to organize this territory-wide trial recovery programme since January 2003 to recover waste electrical appliances and computers respectively. In October 2010, St James' was granted funding support from the Environment and Conservation Fund (ECF) to implement the WEEE Go Green programme and operated the EcoPark WEEERecycling Centre. The repaired appliances and computers are donated to the needy. If there is no suitable receiver, the repaired goods will be put on charitable sale and the proceeds will be put back to this programme. The appliances and computers that are beyond repair will be dismantled with the useable components and materials recovered for reuse and recycling.The programme is well received by the public. Over 46 900 units of waste appliances and 66 000 units of computers werecollected in 2011.

Mobile WEEE Collection Centre Service

In March 2008, the EPD launched a mobile service for collection of Waste Electrical and Electronic Equipment (WEEE) in 18 districts, in rotation one district per week. Under the programme, a collection vehicle is parked at designated sites from9am to 6pm on Saturdays and Sundays to facilitate local residents to recycle their used computer items, electrical appliances, fluorescent lamps and rechargeable batteries. The items collected are sorted and handled under different recycling programmes. Up to end 2011, about 16 000 electricalappliances, 8 500 items of computer equipment, 18 000fluorescent lamps, 3 500 rechargeable batteries and 17 700 accessory items were collected through the service.

Check your progress

Q1. Factors affecting solid waste generation rate?

Q.2 Quantities of materials recovered from MSW?

Q.3 Solid waste as pollutant?

Q.4 Effect of solid waste to environment?

6.3 Solid waste as pollutant

Municipal solid wastes heap up on the roads due to improper disposal system. People clean their own houses and litter their immediate surroundings which affects the community including themselves.

This type of dumping allows biodegradable materials to decompose under uncontrolled and unhygienic conditions. This produces foul smell and breeds various types of insects and infectious organisms besides spoiling the aesthetics of the site. Industrial solid wastes are sources of toxic metals and hazardous wastes, which may spread on land and can cause changes in physicochemical and biological characteristics thereby affecting productivity of soils.

Toxic substances may leach or percolate to contaminate the ground water. In refuse mixing, the hazardous wastes are mixed with garbage and other combustible wastes. This makes segregation and disposal all the more difficult and risky.Various types of wastes like cans, pesticides, cleaning solvents, batteries (zinc, lead or mercury), radioactive materials, plastics and e-waste are mixed up with paper, scraps and other non-toxic materials which could be recycled. Burning of some of these materials produces dioxins, furans and polychlorinated biphenyls, which have the potential to cause various types of ailments including cancer.

Methods of Solid Wastes Disposal:

(i) Sanitary Landfill
(ii) Incineration
(iii) Composting
(iv) Pyrolysis

(i) Sanitary Land Filling:

In a sanitary landfill, garbage is spread out in thin layers, compacted and covered with clay or plastic foam. In the modern landfills the bottom is covered with an impermeable liner, usually several layers of clay, thick plastic and sand. The liner protects the ground water from being contaminated due to percolation of leachate.

Leachate from bottom is pumped and sent for treatment. When landfill is full it is covered with clay, sand, gravel and top soil to prevent seepage of water. Several wells are drilled near the landfill site to monitor if any leakage is contaminating ground water. Methane produced by anaerobic decomposition is collected and burnt to produce electricity or heat. Sanitary Landfills Site Selection:

a. Should be above the water table, to minimize interaction with groundwater.
b. Preferably located in clay or silt.
c. Do not want to place in a rock quarry, as water can leech through the cracks inherent in rocks into a water fracture system.
d. Do not want to locate in sand or gravel pits, as these have high leeching. Unfortunately, most of Long Island is sand or gravel, and many landfills are located in gravel pits, after they were no longer being used.
e. Do not want to locate in a flood plain. Most garbage tends to be less dense than water, so if the area of the landfill floods, the garbage will float to the top and wash away downstream.

A large number of adverse impacts may occur from landfill operations. These impacts can vary:

a. Fatal accidents (e.g., scavengers buried under waste piles).
b. Infrastructure damage (e.g., damage to access roads by heavy vehicles).
c. Pollution of the local environment (such as contamination of groundwater and/or aquifers by leakage and residual soil contamination during landfill usage, as well as after landfill closure).
d. Off gassing of methane generated by decaying organic wastes (methane is a greenhouse gas many times more potent than carbon dioxide, and can itself be a danger to inhabitants of an area).
e. Harbouring of disease vectors such as rats and flies, particularly from improperly operated landfills.

ii. Incineration:

The term incinerates means to burn something until nothing is left but ashes. An incinerator is a unit or facility used to burn trash and other types of waste until it is reduced to ash. An incinerator is constructed of heavy, well-insulated materials, so that it does not give off extreme amounts of external heat.

The high levels of heat are kept inside the furnace or unit so that the waste is burned quickly and efficiently. If the heat were allowed to escape, the waste would not burn as completely or as rapidly. Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of residue of both solid waste management and solid residue from waste water management. This process reduces the volumes of solid waste to 20 to 30 per cent of the original volume.

Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam and ash. Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials. Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants.

iii. Composting:

Due to shortage of space for landfill in bigger cities, the biodegradable yard waste (kept separate from the municipal waste) is allowed to degrade or decompose in a medium. A good quality nutrient rich and environmental friendly manure is formed which improves the soil conditions and fertility.

Organic matter constitutes 35%-40% of the municipal solid waste generated in India. This waste can be recycled by the method of composting, one of the oldest forms of disposal. It is the natural process of decomposition of organic waste that yields manure or compost, which is very rich in nutrients.

Composting is a biological process in which micro-organisms, mainly fungi and bacteria, convert degradable organic waste into humus like substance. This finished product, which looks like soil, is high in carbon and nitrogen and is an excellent medium for growing plants.

The process of composting ensures the waste that is produced in the kitchens is not carelessly thrown and left to rot. It recycles the nutrients and returns them to the soil as nutrients. Apart from being clean, cheap, and safe, composting can significantly reduce the amount of disposable garbage.

The organic fertilizer can be used instead of chemical fertilizers and is better specially when used for vegetables. It increases the soil's ability to hold water and makes the soil easier to cultivate. It helped the soil retain more of the plant nutrients.

Vermi-composting has become very popular in the last few years. In this method, worms are added to the compost. These help to break the waste and the added excreta of the worms makes the compost very rich in nutrients. In the activity section of this web site you can learn how to make a compost pit or a vermi-compost pit in your school or in the garden at home.

To make a compost pit, you have to select a cool, shaded corner of the garden or the school compound and dig a pit, which ideally should be 3 feet deep. This depth is convenient for aerobic composting as the compost has to be turned at regular intervals in this process.

Preferably the pit should be lined with granite or brick to prevent nitrite pollution of the subsoil water, which is known to be highly toxic. Each time organic matter is added to the pit it should be covered with a layer of dried leaves or a thin layer of soil which allows air to enter the pit thereby preventing bad odour. At the end of 45 days, the rich pure organic matter is ready to be used. Composting: some benefits

Compost allows the soil to retain more plant nutrients over a longer period.

a. It supplies part of the 16 essential elements needed by the plants.
b. It helps reduce the adverse effects of excessive alkalinity, acidity, or the excessive use of chemical fertilizer.
c. It makes soil easier to cultivate.
d. It helps keep the soil cool in summer and warm in winter.
e. It aids in preventing soil erosion by keeping the soil covered.
f. It helps in controlling the growth of weeds in the garden.

iv. Pyrolysis:

Pyrolysis is a form of incineration that chemically decomposes organic materials by heat in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430 °C (800 °F).

In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs. If volatile or semi-volatile materials are present in the waste, thermal desorption will also occur.

Organic materials are transformed into gases, small quantities of liquid, and a solid residue containing carbon and ash. The off-gases may also be treated in a secondary thermal oxidation unit. Particulate removal equipment is also required. Several types of pyrolysis units are available, including the rotary kiln, rotary hearth furnace, and fluidized bed furnace. These units are similar to incinerators except that they operate at lower temperatures and with less air supply.

Limitations and Concerns:

a. The technology requires drying of soil prior to treatment.
b. Limited performance data are available for systems treating hazardous wastes containing polychlorinated biphenyls (PCBs), dioxins, and other organics. There is concern that systems that destroy chlorinated organic molecules by heat have the potential to create products of incomplete combustion, including dioxins and furans. These compounds are extremely toxic in the parts per trillion ranges. The MSO process reportedly does not produce dioxins and furans.
c. The molten salt is usually recycled in the reactor chamber. However, depending on the waste treated (especially inorganics) and the amount of ash, spent molten salt may be hazardous and require special care in disposal.
d. Pyrolysis is not effective in either destroying or physically separating in organics from the contaminated medium. Volatile metals may be removed as a result of the higher temperatures associated with the process, but they are not destroyed. By-products containing heavy metals may require stabilization before final disposal.
e. When the off-gases are cooled, liquids condense, producing an oil/tar residue and contaminated water. These oils and tars may be hazardous wastes, requiring proper treatment, storage, and disposal.

6.4 Effect of solid waste to environment

An effective solid waste management system is necessary to avoid public health disasters, spread of disease by insects and vectors and adverse effect on water and air (Phelps, et al., 1995). Solid waste workers are the most exposed to the risks of parasitic infections and accidents, and therefore, a SWM system must include proper mechanisms to avoid these incidences. To the direct and indirect risks through accidents, exposure and spread of disease, we must add the effect of visual pollution caused by litter and nuisance created by smoke and dust at disposal sites.

6.4.1 Public health effect

The volume of waste is increasing rapidly as a result of increasing population and improving economic conditions in various localities. This increased volume of wastes is posing serious problems due to insufficient workforce and other constraints in disposing of it properly. What are the consequences of improper management and handling of wastes? Consider the following:

(i) **Disease vectors and pathways:** Wastes dumped indiscriminately provide the food and environment for thriving populations of vermin, which are the agents of various diseases. The pathways of pathogen transmission fromwastes to humans are mostly indirect through insects – flies, mosquitoes and roaches and animals – rodents and pigs. Diseases become a public health problem when they are present in the human and animal population of surrounding communities, or if a carrier transmits the etiological agent from host to receptor.

(ii) **Flies:** Most common in this category is the housefly, which transmits typhoid, salmonellosis, gastro-enteritis and dysentery. Flies have a flight range of about 10 km, and therefore, they are able to spread their influence over a relatively wide area. The four stages in their life-cycle are egg, larva, pupa and adult. Eggs are deposited in the warm, moist environment of decomposing food wastes. When they hatch, the larvae feed on the organic material, until certain maturity is reached, at which time they migrate from the waste to the soil of other dry loose material before being transformed into pupae. The pupae are inactive until the adult-fly emerges. The migration of larvae within 4 to 10 days provides the clue to an effective control measure, necessitating the removal of waste before migration of larvae. Consequently, in warm weather, municipal waste should be collected twice weekly for effective control. In addition, the quality of household and commercial storage containers is very significant. The guiding principle here is to restrict access to flies. Clearly, the use of suitable storage containers and general cleanliness at their location, as well as frequent collection of wastes, greatly reduces the population of flies. Control is also necessary at transfer stations, composting facilities and disposal sites to prevent them from becoming breeding grounds for flies. Covering solid wastes with a layer of earth at landfill sites at the end of every day arrests the problem of fly breeding at the final stage.

(iii) **Mosquitoes:** They transmit diseases such as malaria, filarial and dengue fever. Since they breed in stagnant water, control measures should center on the elimination of breeding places such as tins, cans, tires, etc. Proper sanitary practices and general cleanliness in the community help eliminate the mosquito problems caused by the mismanagement of solid waste.

(iv) **Roaches:** These cause infection by physical contact and can transmit typhoid, cholera and amoebiasis. The problems of roaches are associated with the poor storage of solid waste.

(v) **Rodents:** Rodents (rats) proliferate in uncontrolled deposits of solid wastes, which provide a source of food as well as shelter. They are responsible for the spread of diseases such as plague, murine typhus, leptospirosis, histoplasmosis, rat bite fever, dalmonelosis, trichinosis, etc. The fleas, which rats carry, also cause many diseases. This problem is associated not only with open dumping but also poor sanitation.

(vi) **Occupational hazards:** Workers handling wastes are at risk of accidents related to the nature of material and lack of safety precautions. The sharp edges of glass and metal and poorly constructed storage containers may inflict injuries to workers. It is, therefore, necessary for waste handlers to wear gloves, masks and be vaccinated. The infections associated with waste handling, include:

- skin and blood infections resulting from direct contact with waste and from infected wounds;

- eye and respiratory infections resulting from exposure to infected dust, especially during landfill operations;
- diseases that result from the bites of animals feeding on the waste;
- intestinal infections that are transmitted by flies feeding on the waste;
- Chronic respiratory diseases, including cancers resulting from exposure to dust and hazardous compounds.

In addition, the accidents associated with waste handling include:

- Bone and muscle disorders resulting from the handling of heavy containers and the loading heights of vehicles;
- infecting wounds resulting from contact with sharp objects;
- reduced visibility, due to dust along the access routes, creates greater risk of accidents;
- poisoning and chemical burns resulting from contact with small amounts of hazardous chemical wastes mixed with general wastes such as pesticides, cleaning solutions and solvents in households and commercial establishments;
- burns and other injuries resulting from occupational accidents at waste disposal sites or from methane gas explosion at landfill sites;
- Serious health hazards, particularly for children, due to careless dumping of lead-acid, nickel-cadmium and mercuric oxide batteries.

(vii) Animals: Apart from rodents, some animals (e.g., dogs, cats, pigs, etc.) also act as carriers of disease. For example, pigs are involved in the spread of diseases like trichinosis, cysticerosis and toxoplasmosis, which are transmitted through infected pork, eaten either in raw state or improperly cooked. Solid wastes, when fed to pigs, should be properly treated (cooked at 100C for at least 50 minutes with suitable equipment).

6.4.2 Environmental effect

(i) **Air pollution:** Burning of solid wastes in open dumps or in improperly designed incinerators emit pollutants (gaseous and particulate matters) to the atmosphere. Studies show that the environmental consequences of open burning are greater than incinerators, especially with respect to aldehydes and particulates. Emissions from an uncontrolled incinerator system include particulate matter, Sulphur oxides, nitrogen oxides, hydrogen chloride, carbon monoxide, lead and mercury. Discharge of arsenic, cadmium and selenium is to be controlled, since they are toxic at relatively low exposure levels. Polychlorinated dibenzofurans (PCDFs), commonly called dioxins and furans, are of concern because of their toxicity, carcinogenicity and possible mutagenicity.

(ii) **Water and land pollution:** Water pollution results from dumping in open areas and storm water drains, and improper design, construction and/or operation of a sanitary landfill. Control of infiltration from rainfall and surface runoff is essential in order to minimize the production of leachate. Pollution of groundwater can occur as a result of:

a. The flow of groundwater through deposits of solid waste at landfill sites;
b. Percolation of rainfall or irrigation waters from solid wastes to the water table;
c. Diffusion and collection of gases generated by the decomposition of solid wastes.

The interaction between leachate contaminants and the soil depends on the characteristics of the soil. Soil bacteria stabilize biochemical oxygen demand (BOD), i.e., the amount of oxygen required by micro-organisms to degrade organic matter, by anaerobic action, if toxic substances are in low concentration. The carbon dioxide produced keeps the pH level low, causing the water to dissolve minerals in the aquifers. Consequently, the change in groundwater quality may take place depending on the characteristics of the aquifer. Contamination can spread over considerable distances from the landfill, if the aquifers are of sand or gravel. In clayey soils, the rate of movement is greatly reduced. The capacity of clay to exchange ions restricts the movement of metal ions by capturing them in the soil matrix. Changes in its chemical characteristics are due to hardness, iron and manganese compounds.

(iii) **Visual pollution:** The aesthetic sensibility is offended by the unsightliness of piles of wastes on the roadside. The situation is made worse by the presence of scavengers rummaging in the waste. Waste carelessly and irresponsibly discarded in public thoroughfares, along roads and highways and around communal bins (i.e., makeshift containers, without lids, used for the storage of residential, commercial and institutional wastes) gives easy access to animals scavenging for food. The solution to this social problem undoubtedly lies in the implementation of public education at all levels – primary, secondary, tertiary and adult, both short- and long-term, and in raising the status of public health workers and managers in solid waste management.

(iv) **Noise pollution:** Undesirable noise is a nuisance associated with operations at landfills, incinerators, transfer stations and sites used for recycling. This is due to the movement of vehicles, the operation of large machines and the diverse operations at an incinerator site. The impacts of noise pollution may be reduced by careful siting of SWM operations and by the use of noise barriers.

(v) **Odor pollution:** Obnoxious odors due to the presence of decaying organic matter are characteristic of open dumps. They arise from anaerobic decomposition processes and their major constituents are particularly offensive. Proper landfill covering eliminates this nuisance.

(vi) **Explosion hazards:** Landfill gas, which is released during anaerobic decomposition processes, contains a high proportion of methane (35 – 73%). It can migrate through the soil over a considerable distance, leaving the buildings in the vicinity of sanitary landfill sites at risk, even after the closure of landfills. Several methods are available for control of landfill gas, such as venting, flaring and the use of impermeable barriers.

Evolution methodology for generated solid waste involves analysis of landfill performance, the unit weight and compressibility, economic viability, MSW constituents, equations for evaluating MSW, data acquisition, source of evaluating that is study plan, demographic study, Questionnaire design to know who, what, where and why and statistics generation to analyze planning data.

Check your progress

Q1. List the adverse health and environment impacts due to improper handling of solid waste.

Q2. Identify at least four such effects in your locality.

6.5 Summary

increasing amounts of waste, both solid and liquid, are being generated as a result of the rapid rate of urbanisation. This in turn presents greater difficulties for disposal. The problem is more acute in developing countries, such as India, where the pace of economic growth as well as urbanisation isfaster.Variousconceptshavebeendeveloped over theyears to provide the basis for improving the solid wasteconditions in developing cities. Among them, integrated Solid Waste Management (SWM) provides aframework which has been very successful in various industrialised countries. However, urbangovernments in developing countries are constrained by limited finances and inadequate services whichprevent them from tackling the problem effectively. In addition, their SWM planning is hampered by a lack of data while information at all levels, if available, is generally unreliable, scattered andunor ganised. As a result, planning of SWM is a difficult task. This topic attempts to understand the SWM process on the basis of an evaluation of the waste flow inthe study area of Bangalore. The objective here is to review the available literature in order to derivelessons and apply the insights to an analysis of the situation in the field. In addition to the literaturedata are collected from the field. Despite several analytical shortcomings of this study, the flowevaluation highlights various priority issues that need to be addressed in future SWM planning inBangalore as well as other Indian cities. These include:

- inadequate municipal services due to limited resources;
- an absence of hygienic and scientific disposal systems;
- a lack of public awareness for waste management resulting in high levels of unsegregated wastegeneration and littering;- the existence of an extensive informal network which is mainly driven by market forces and functionspartly on subsistence levels;- the absence of sufficient capacity for waste processing, in particular fororganic waste which is inmost abundance; the existence of a relatively small market for recycled waste products.Although SWM includes a range of stakeholders, the contribution of government is imperative. Thisdoes not necessarily have to be financial. For example, the government should make a formalcommitment to an integrated SWM approach, and recognise the contribution of existing informal

recycling networks. Moreover, waste recycling can be promoted through consumer campaigns encouraging citizens to co-operate in waste separation. A more realistic fee for waste services could be extracted in return for a guarantee that these services will be provided. Finally, to be effective. SWMrequires regular and proper monitoring of disposal activities

As the world becomes more urbanized and developed consumption rates are on The rise. An inevitable consequence of more consumption is the rapid increase in the amount of solid waste that is produced. Today, solid-waste management (SWM) conditions in the developing world are often quite direand reminiscent of those found in the developed world several generations ago. The impact of inadequate SWM practices on natural and human environmentsis now being acknowledged. Solid-waste management is a multidimensional issue that incorporates political,institutional, social, environmental, and economic aspects. Improving SWM in developing countries requires efforts to raise public awareness, increase funding, build expertise, and invest in infrastructure. To make progress communities will need to embrace new systems for SWM that are participatory, contextually integrated, complex, and adaptive.The modern waste-management industry in the developed world has come far, and with recycling and other advances it will continue to grow and change with the needs of the community.However, countries in the developing world have yet to see many of these changes to their own solid-waste management systems(SWMS). Today, solid-waste management conditions in the developing world are quite dire; present SWMS in these countries are more reminiscent of conditions found in past SWMS in the developed world.

6.6 Review Questions

Q1. Explain Methods of Solid Wastes Disposal.

Q2. Illustrate the case study in your area of locality.

BLOCK -III

Collection, Handling, Segregation, Storage and processing of Solid Waste

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UNIT-VII

Collection of solid waste

UNIT-VIII

Waste handling and segregation

UNIT-IX

Processing of Solid Waste

Block-VII Collection, Handling, Segregation, Storage and processing of Solid Waste

Solid wastes may be defined as useless, unused, unwanted, or discarded material available in solid form. Semisolid food wastes and municipal sludge may also be included in municipal solid waste. The subject of solid wastes came to the national limelight after the passage of the solid waste disposal act of 1965. Today, solid waste is accepted as a major problem of our society. In the United States, over 180 million tons of municipal solid waste (MSW) was generated in 1988. At this generation quantity, the average resident of an urban community is responsible for more than 1.8 kg (4.0 lbs.) of solid waste per day. This quantity does not include industrial, mining, agricultural, and animal wastes generated in the country each year. If these quantities are added, the solid waste production rate reaches 45 kg per capita per day (100 lb. /c.d.). To introduce the reader to the solid waste management field, an overview of municipal solid waste problems, sources, collection, resource recovery, and disposal methods are presented in this paper. Greater emphasis has been given to the design and operation of municipal sanitary landfills, regulations governing land disposal, and leachate generation, containment and treatment methods.Municipal solid waste (MSW) includes wastes such as durable goods, nondurable goods, containers and packaging, food wastes yard wastes, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. Example of waste from these categories include appliances, newspapers, clothing, food scarps, boxes, disposable tableware, office and classroom paper, wood pallets, and cafeteria wastes. MSW does not include wastes from sources such as municipal sludge, combustion ash, and industrial non-hazardous process wastes that might also be disposed of in municipal waste landfills or incinerators. Determining actual MSW generation rates is difficult. Different studies report a wide variation as they use different components. Many times industrial and demolition wastes are included in municipal solid wastes.In your study, you will find that the every unit has different equal length and your study time will vary for each unit.

We hope you enjoy studying the material and once again wish you all the best for your success.

UNIT-VII Collection of solid waste

Structure

7.0 Introduction

To introduce the reader to the solid waste management field, an overview of municipal solid waste problems, sources, collection, resource recovery, and disposal methods are presented in this paper. Greater emphasis has been given to the design and operation of municipal sanitary landfills, regulations governing land disposal, and leachate generation, containment and treatment methods. Municipal solid waste (MSW) includes wastes such as durable goods, nondurable goods, containers and packaging, food wastes yard wastes, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. In this chapter we learn about Methods of Collection, types of vehicles, materials used for containers, Manpower requirement, collection routes, transfer stations, selection of location, operation & maintenance, options under Indian conditions

A successful solid waste management system utilizes many functional elements associated with generation, on-site storage, collection, transfer, transport, characterization and processing, resource recovery and final disposal [4]. All these elements are interrelated, and must be studied and evaluated carefully before any solid waste management system can be adapted. It is a multidisciplinary activity involving engineering principles, economics, and urban and regional planning.

Objectives

After studying this unit you should be able to understand SOURCES AND CHARACTERISTICS of Municipal solid waste (MSW) or urban solid waste which is normally comprised of food wastes, rubbish, demolition and construction wastes, street sweepings, garden wastes, abandoned vehicles and appliances, and treatment plant residues. Quantity and composition of MSW vary greatly for different municipalities and time of the year. Factors influencing the characteristics of MSW are climate, social ,customs, per capita income, and degree of urbanization and industrialization. The composition of MSW as collected may vary greatly depending upon geographical region and season. The typical moisture content of MSW may vary from 15 to 40 percent depending upon the composition of the waste and the climatic conditions. The density of MSW depends upon the composition and degree of compaction. The uncompacted density of MSW is around “150 kg/m^3(250 lb. /yd^3).”The density of collected solid waste is “235-350 kg/m^3.”The energy content of MSW as collected is “9,890 kJ/kg (4,260 BTU/lb.)”. Information of chemical composition of the organic portion of MSW is important for many processes such as incineration, composting, biodegradability, leachate generation, and others. The ultimate analysis of the organic fraction of MSW is in terms of the constituents carbon, hydrogen, oxygen, nitrogen, sulfur and ash **.The major objectives are to learn about:**

- Methods of Collection
- Types of vehicles
- Materials used for containers
- Manpower requirement
- Collection routes
- Transfer stations
- Selection of location
- Operation & maintenance
- Options under Indian conditions.

7.1 Methods of Collection

a) Hauling of Solid Waste.

It shall be unlawful for any collector or person to transport solid waste except in a covered, watertight and drip-proof vehicle equipped with a metal box with welded seams; provided, however, that dry solid waste or tightly bagged garbage may be conveyed in suitable containers and vehicles with appropriate coverings which keep the contents from escaping.

(b) Solid Waste Collection.

- Solid waste collection shall be required by all residential dwelling units. It shall be the responsibility of the owner or occupant of any residential dwelling unit to apply for solid waste collection services. The city public works department, sanitation collection division, shall be the sole, exclusive solid waste collection service for all residential dwelling units, including but not limited to single-family dwellings, multiple-family dwellings, townhouses, apartment complexes and trailer parks. Collection of household solid waste generated at a residential dwelling unit by a solid waste collector other than the city public works department, sanitation collection division must be approved through a formal agreement between the city and the solid waste collector. Collection and hauling of household hazardous waste, white goods, recyclables and other solid wastes which are not household solid waste shall be the responsibility of the residential dwelling unit owner or occupant.
- Owners or occupants of residential dwelling units may haul and deliver to the municipal landfill household solid waste generated from their residential dwelling unit; however, such hauling and delivery shall not reduce the solid waste collection fees owed to the city.
- Commercial accounts may use their own equipment and their own employees to collect and haul solid waste generated by the business to the municipal landfill or contract solid waste collection services to the city of Ketchikan public works department, sanitation collection division. Collection of commercial solid waste by a solid waste collector other than the city public works department, sanitation collection division must be approved through a formal agreement between the city and the solid waste collector.
- Collection Schedule.
    - All solid waste shall be collected and disposed of at intervals determined by the director of public works or his designee.
    - Residential dwelling units shall have a minimum of weekly service unless otherwise determined by the director of public works or his designee.
    - Cafes, restaurants and other establishments serving food; commercial business; industrial businesses, and all other establishments shall have a level of service that does not create a public nuisance or health hazard as determined by the director of public works or his designee.
    -

(c) Solid Waste Collection Fees.

- Solid Waste Collection Fee for Residential Accounts. All residential accounts can be assessed and charged a solid waste collection fee per month for the collection of household solid waste. The owner of the residential dwelling unit shall be responsible for solid waste collection fees which are not paid by the occupant.

- Solid Waste Collection Fee for Commercial Accounts. Unless otherwise negotiated and agreed to by the city, commercial accounts for which the city provides solid waste collection services shall be charged the fees per month, whichever is greater.

  $3.41 per can per pickup

  $22.74 per cubic yard container

  $34.10 per one-and-one-half-cubic-yard container

  $45.47 per two-cubic-yard container

Solid waste collection fees for commercial accounts shall include the cost for disposal. Multiple residential dwelling unit complexes which have established commercial accounts for collection and disposal of household solid waste shall be eligible for a solid waste residential credit times the number of cans of residential solid waste collected from the residential dwelling units. The credit shall represent disposal costs for household solid waste paid for through the community solid waste disposal fee identified in KMC 7.16.070(d). The solid waste residential credit application, terms and conditions shall be subject to approval by the city public works and city finance departments. The solid waste residential credit shall be posted on a monthly basis, in arrears, and shall be based on the number of multiple residential units listed in the application for the solid waste residential credit on file with the city finance department.

- **Solid Waste Collection Billings.**
  - Billings for residential accounts will be mailed or delivered to the same name and address as appears on the residential electrical account serving the residence, except for instances when two or more dwelling units are served by one electrical account or if the residential dwelling unit does not receive electrical service, in which case each residential dwelling unit will be billed separately. Billing for household solid waste collection services shall be on a monthly basis, commencing with the date of residential dwelling occupancy or beginning date of the residential unit’s electrical account, whichever is earlier. Failure to receive a bill does not relieve the owner/occupant of responsibility for the charges.
  - The city manager is authorized to negotiate special billing rates, terms and conditions for the collection of commercial accounts.
  - All monthly bills for services rendered are due and payable within 25 days after the billing date, and if not paid, become delinquent and the account shall be deemed in default. Accounts in default shall be assessed a penalty of five percent. Billings delinquent in excess of 120 days may be turned over to a collection agency.
  - In the event of overcharges or undercharges for solid waste collection services, adjustments will be limited to the most recent six-month period prior to discovery and notification of the error.

- Vacant residential dwelling units shall not be charged solid waste collection fees. Vacant residential dwelling units shall not mean a residential dwelling unit unoccupied due to vacations or extended absences.

7.2 Types of vehicles

A waste collection vehicle is more generally known as garbage truck and dustbin lorry. These trucks are used for picking up waste and then moving it to landfills or other places where waste materials are managed and treated. You can have their view mostly in urban areas. Most of the time Garbage cart is mistaken as dump truck.

Almost all collections are based on collector and collection crew, which move through the collection service area with a vehicle for collecting the waste material. The collection vehicle selected must be appropriate to the terrain, type and density of waste generation points, the way it travels and type and kind of material (UNEP, 1996). It also depends upon strength, stature and capability of the crew that will work with it. The collection vehicle may be small and simple (e.g., two-wheeled cart pulled by an individual) or large, complex and energy intensive (e.g., rear loading compactor truck). The most commonly used collection vehicle is the dump truck fitted with a hydraulic lifting mechanism. A description of some vehicle types follows:

(i) Small-scale collection and muscle-powered vehicles: These are common vehicles used for waste collection in many countries and are generally used in rural hilly areas. As Figure 1.1 illustrates, these can be small rickshaws, carts or wagons pulled by people or animals, and are less expensive, easier to build and maintain compared to other vehicles:

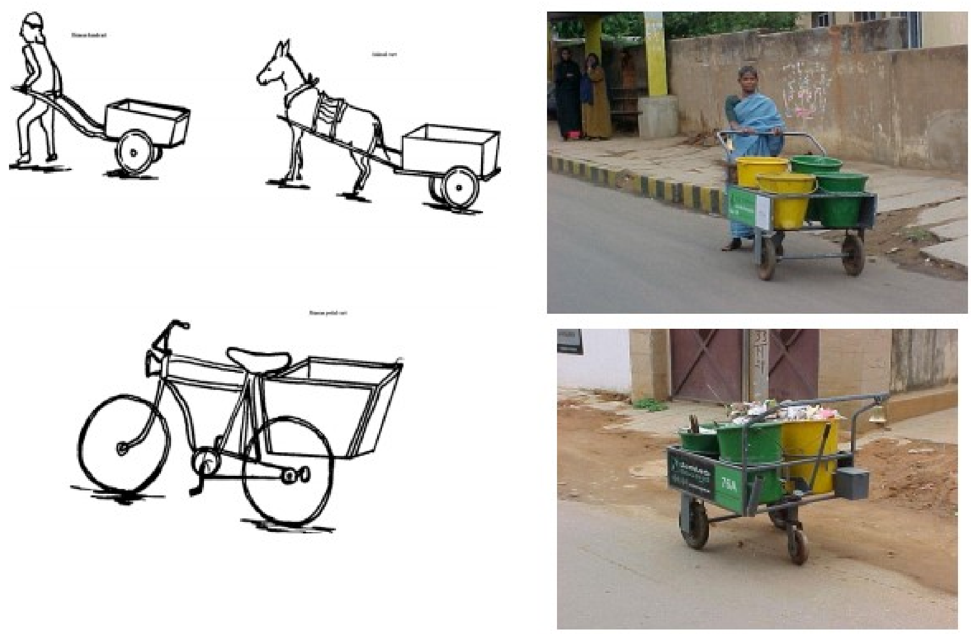


Figure 1.1 Small-scale Collection Vehicles: An Illustration

They are suitable for densely populated areas with narrow lanes, and squatter settlements, where there is relatively low volume of waste generated. Some drawbacks of these collection vehicles include limited travel range of the vehicles and weather exposure that affect humans and animals.

(ii) Non-compactor trucks: Non-compactor trucks are efficient and cost effective in small cities and in areas where wastes tend to be very dense and have little potential for compaction. Figure 1.2 illustrates a non-compactor truck:

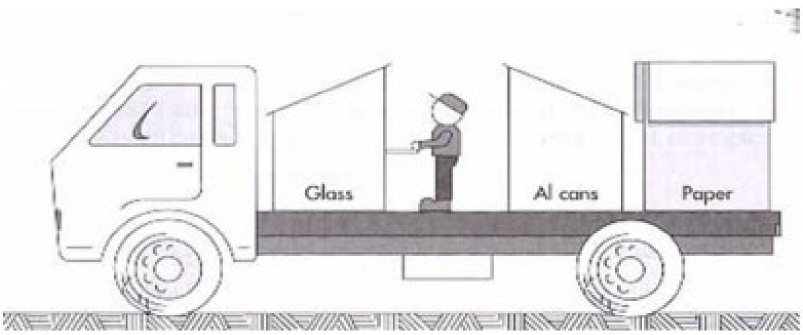
Figure 1.2 Non-compactor Trucks

When these trucks are used for waste collection, they need a dumping system to easily discharge the waste. It is generally required to cover the trucks in order to prevent residue flying off or rain soaking the wastes. Trucks with capacities of 10 – 12 m^3 are effective, if the distance between the disposal site and the collection area is less than 15 km. If the distance is longer, a potential transfer station closer than 10 km from the collection area is required. Non-compactor trucks are generally used, when labor cost is high. Controlling and operating cost is a deciding factor, when collection routes are long and relatively sparsely populated.

(iii) Compactor truck: Compaction vehicles are more common these days, generally having capacities of 12 – 15 m^3 due to limitations imposed by narrow roads. Although the capacity of a compaction vehicle, illustrated in Figure 1.3, is similar to that of a dump truck, the weight of solid wastes collected per trip is 2 to 2.5 times larger since the wastes are hydraulically compacted:

Figure 1.3 Compactor Truck

The success of waste management depends on the level of segregation at source. One of the examples for best collection method is illustrated in the figure below



A compactor truck allows waste containers to be emptied into the vehicle from the rear, front or sides and inhibits vectors (of disease) from reaching the waste during collection and transport. It works poorly when wastestream is very dense, wet, collected materials are gritty or abrasive, or when the roads are dusty. The advantages of the compactor collection vehicle include the following:

- containers are uniform, large, covered and relatively visually inoffensive;
- waste is set out in containers so that the crew can pick them up quickly;
- health risk to the collectors and odor on the streets are minimized;
- Waste is relatively inaccessible to the waste pickers.

Check your progress

Q1. Define methods of collection processes of Municipal Corporation.

Q2. Illustrate the types of vehicle used in local municipality.

7.3 Materials used for containers

The design of an efficient waste collection system requires careful consideration of the type, size and location of containers at the point of generation for storage of wastes until they are collected. While single-family households generally use small containers, residential units, commercial units, institutions and industries require large containers. Smaller containers are usually handled manually whereas the larger, heavier ones require mechanical handling. The containers may fall under either of the following two categories:

(i) Stationary containers: These are used for contents to be transferred to collection vehicles at the site of storage.
(ii) Hauled containers: These are used for contents to be directly transferred to a processing plant, transfer station or disposal site for emptying before being returned to the storage site.

The desirable characteristics of a well-designed container are low cost, size, weight, shape, resistance to corrosion, water tightness, strength and durability (Phelps, et al., 1995). For example, a container for manual handling by one person should not weigh more than 20 kg, lest it may lead to occupational health hazards such as muscular strain, etc. Containers that weigh more than 20 kg, when full, require two or more crew members to manually load and unload the wastes, and which result in low collection efficiency. Containers should not have rough or sharp edges, and preferably have a handle and a wheel to facilitate mobility. They should be covered to prevent rainwater from entering (which increases the weight and rate of decomposition of organic materials) into the solid wastes. The container body must be strong enough to resist and discourage stray animals and scavengers from ripping it as well as withstand rough handling by the collection crew and mechanical loading equipment. Containers should be provided with a lifting bar, compatible with the hoisting mechanism of the vehicle. The material used should be light, recyclable, easily moulded and the surface must be smooth and resistant to corrosion. On the one hand, steel and ferrous containers are heavy and subject to corrosion; the rust peels off exposing sharp edges, which could be hazardous to the collection crew. On the other, wooden containers (e.g., bamboo, rattan and wooden baskets) readily absorb and retain moisture and their surfaces are generally rough, irregular and difficult to clean.

Communal containers

Generally, the containers used for waste storage are communal/public containers. Figure 1.4 below shows a typical communal container, which a compactor collection vehicle can lift and empty mechanically:

Figure 1.4 Typical Communal Container

The use of communal containers is largely dependent on local culture, tradition and attitudes towards waste. Communal containers may be fixed on the ground (stationary) or movable (hauled). Movable containers are provided with hoists and tails compatible with lifting mechanism of collection vehicles and such containers have capacities of 1 – 4 m^3. The waste management authority must monitor, maintain and upgrade the communal containers. Note that in residential and commercial areas in India, the communal containers are often made of concrete.

In areas with very high waste generation rates, i.e., rates exceeding two truckloads daily, such as wet markets, large commercial centers and large business establishments, roll-on-roll or hoisted communal containers with capacities of 12 – 20 m^3 and a strong superstructure with wheels are used. Normally, the collection vehicle keeps an empty container as a replacement before it hauls the filled container. When a truck is used as a collection vehicle, the use of communal containers may be appropriate. It is advisable to place the containers 100 – 200 m apart for economic reasons. The communal containers are usually staggered such that the effective distance of 100 m is maintained as shown in Figure 1.5:

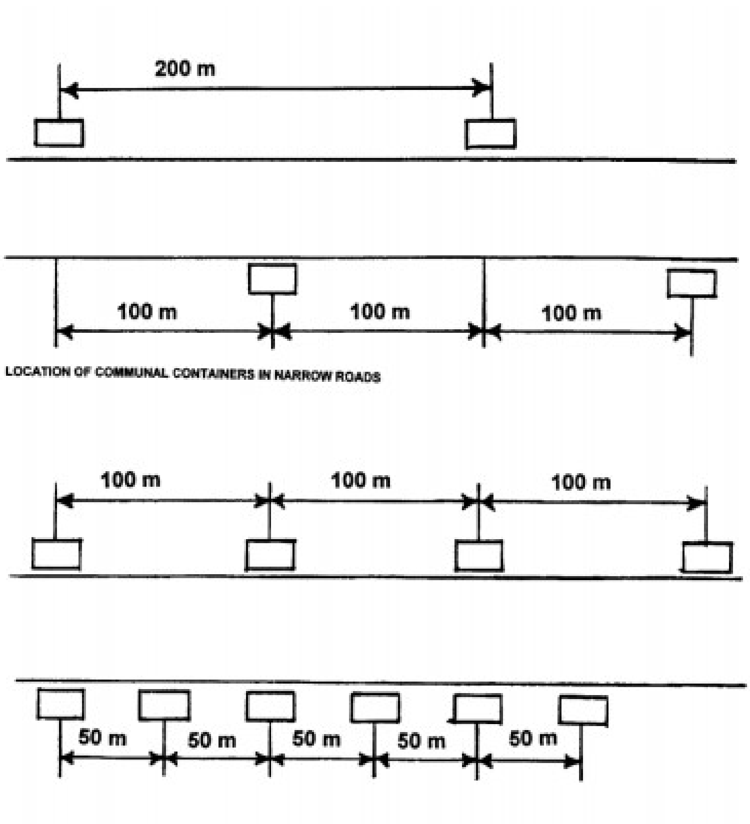


Figure 1.5: Location of Communal Container

This means that the farthest distance the householder will have to walk is 50 meters. However, in narrow streets with low traffic, where the house owner can readily cross the street, a longer distance is advisable. If the collection vehicle has to stop frequently, say, at every 50 m or so, fuel consumption increases, and this must be avoided.

Disadvantages

The major disadvantage of communal containers is the potential lack of maintenance and upgrading. The residuals and scattered solid wastes emit foul odors, which discourage residents from using the containers properly. In addition, if fixed containers are built below the vehicle level, the collection crew may be held responsible for sweeping and loading the solid wastes into transfer containers before being loaded into the collection vehicle. Sweeping and cleaning the communal containers of residuals obviously impinge on the time of the crew members and take a longer time than if the wastes are placed in smaller containers. As fixed communal containers have higher rates of failure, their use is not advisable.

To overcome the problem of maintaining communal containers, individual residents should maintain their own containers and locate them in designated areas. The communal area must have water and drains to facilitate the cleaning of the containers. This practice has the advantage of reducing the number of collection stops and at the same time maintaining the householder's responsibility for cleaning them. The residents must also be properly educated on the importance of good housekeeping as the containers in the communal area are subject to vandalism. In the main, if communal containers are to be successful, the design of the containers, loading and unloading areas, and collection vehicle accessories should be coordinated.

7.4 Manpower requirement

The organizational and administrative structure for municipal solid waste management in a city depends upon the size of the municipal agency. Landfilling activity should be the responsibility of an independent sectional authority which should report directly to the Director/Chief Engineer/Head of Solid Waste Management. A senior engineer should be incharge of landfilling activity. He should be supported by assistant engineer(s), junior engineer(s), foremen, technicians and workers. The level of the engineer incharge will be dependent on the scale of work (i.e. waste received at the landfill and the following is recommended.

Waste Received at Landfill (tons/day)	Engineer Incharge of Landfilling
Upto 200	Junior Engineer
200 to 500	Assistant Engineer
500 to 1000	Executive Engineer
Above 1000	Superintending Engineer

Check your progress

Q1. Define the types of containers for collection of waste substance around local municipality.

Q2. Explain the disadvantage of communal container.

7.5 Collection routes

In previous Section, we introduced you to different types of containers and collection vehicles. We now discuss the movement of collection crew in terms of workforce efficiency and collection routes.

7.5.1 Movement of collection crew

In cultures such as India, Bangladesh, etc., solid waste collection is assigned to the lowest social group. More often, the collection crew member accepts the job as a temporary position or stopgap arrangement, while looking for other jobs that are considered more respectable. Apart from this cultural problem, the attitude of some SWM authorities affects collection operation. For example, some authorities still think that the collection of solid waste is mechanical, and therefore, the collection crew does not need any training to acquire special skills. As a result, when a new waste collector starts working, he or she is sent to the field without firm instruction concerning his or her duties, responsibilities and required skills. For an effective collection operation, the collection team must properly be trained. The collection crew and the driver of the collection vehicle must, for example, work as a team, and this is important to maintain the team morale and a sense of social responsibility among these workers. You must also note that the movement of collection crew, container location and vehicle stopping point affect collection system costs. Figure 1.6 highlights the distance the collection crew will have to walk, if it were to serve the farthest point first or serve the point closest to the vehicle:

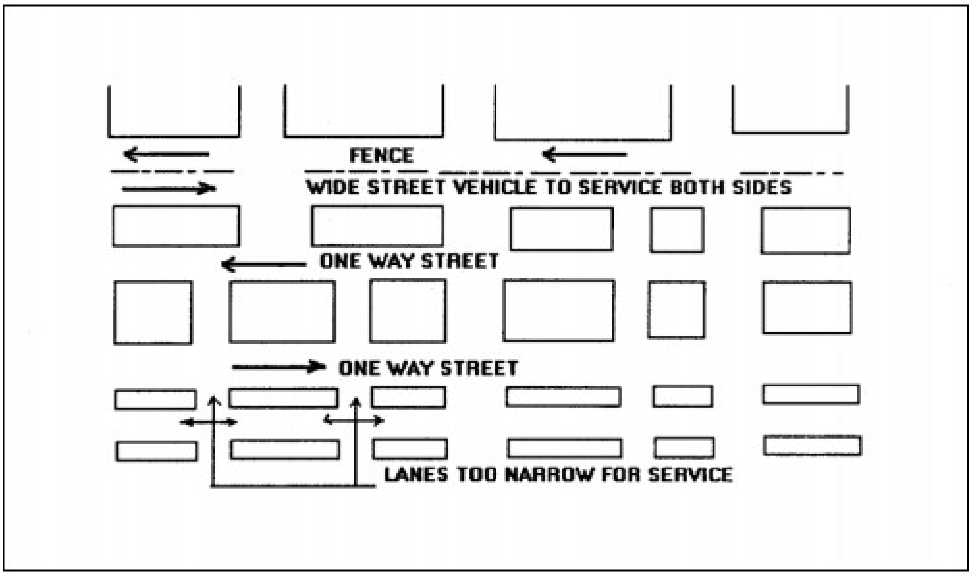


Figure 1.6 Effect of Container Location and Vehicle Stopping

The difference may be one or two minutes per collection stop, but it matters with the number of stops the crew will take in a working shift. Multiplying the minutes by the total number of crew working and labor cost depicts the amount of labor hours lost in terms of monetary value. Generally, familiarity of the crew with the collection area improves efficiency. For example, the driver becomes familiar with the traffic jams, potholes and other obstructions that he or she must avoid. The crew is aware of the location of the containers and the vehicle stops. It is, therefore, important to assign each crew specific areas of responsibility. Working together also establishes an understanding of the strong and weak points of the team members and efficient work sequences. The collection operation must also observe a strict time schedule. Testing of new routes, new gadgets and vehicles is best carried out first in the laboratory and later in a pilot area. Testing of a new sequence using the whole service area could result in disorder and breakdown of the solid waste collection system. Studies show that it takes two hours to recover for every hour of a failed system.

Motion time measurement (MTM) technique

Motion time measurement (MTM) studies are now an integral part of the standard procedure in the development of solid waste collection systems. MTM is a technique to observe and estimate the movement of the collection crew with the help of stopwatches. The results thus gathered are tabulated as shown in Table 1.1 to determine the best sequence of activities that workers must follow in order to complete a repetitive task in the shortest possible time:

	Time		Odometer (Km)	Number of Containers	Collection time (Minute Second)	Trip time to next Station
	Arrival	Departure				
Garage						
1 Station	::	::				
2 Station	::	::				
.	::	::				
.	::	::				
.	::	::				
20 Station	::	::				
Last Station	::	::				
Disposal Site	::	::				
Total	::	::				
Weight	With Load tonne		With Load tonne		With Load tonne	

Source: Phelps, et al., 1995

Table 1.1 MTM Study: Determination of Time, Distance and Number on Containers in Collection Route

MTM also helps in deciding the best combination of equipment to maintain a desired level of output, reduce health problems related to the repetitive work sequence and predict the effects of changes in materials handled. Sophisticated MTM studies involve hidden or open video cameras at different collection stops to record, replay and study the operation sequence of the collection crew. If the crew is conscious of being observed, they tend to work faster and reduce time wastage in unauthorized salvaging and other nonscheduled activities. Once the crew is familiar with the person(s) observing them,it begins to perform more credibly. In studies involving video cameras, therefore, the first two or three hours of observation are often neglected.

7.5.2 Collection vehicle routing

Efficient routing and re-routing of solid waste collection vehicles can help decrease costs by reducing the labour expended for collection. Routing procedures usually consist of the following two separate components:

(i) Macro-routing: Macro-routing, also referred to as route-balancing, consists of dividing the total collection area into routes, sized in such a way as to represent a day's collection for each crew. The size of each route depends on the amount of waste collected per stop, distance between stops, loading time and traffic conditions. Barriers, such as railroad embankments, rivers and roads with heavy competing traffic, can be used to divide route territories. As much as possible, the size and shape of route areas should be balanced within the limits imposed by such barriers.

(ii) Micro-routing: Using the results of the macro-routing analysis, micro routing can define the specific path that each crew and collection vehicle will take each collection day. Results of micro-routing analyses can then be used to readjust macro-routing decisions. Micro-routing analyses should also include input and review from experienced collection drivers.

Districting is the other method for collection route design. For larger areas it is not possible for one institution to handle it then the best way is to sub divide the area and MSW collection districting plan can be made. This routing will be successful only when road network integrity is good and the regional proximity has been generated. The heuristic (i.e., trial and error) route development process is a relatively simple manual approach that applies specific routing patterns to block configurations. The map should show collection, service garage locations, disposal or transfer sites, one-way streets, natural barriers and areas of heavytraffic flow. Routes should then be traced onto the tracing paper using the following rules:

- Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.
- Total collection plus hauling time should be reasonably constant for each route in the community.
- The collection route should be started as close to the garage or motor pool as possible, taking into account heavily travelled and one-way streets.
- Heavily travelled streets should not be visited during rush hours.
- In the case of one-way streets, it is best to start the route near the upper end of the street, working down it through the looping process.
- Services on dead-end streets can be considered as services on the street segment that they intersect, since they can only be collected by passing down that street segment. To keep right turns at a minimum, (in countries where driving is left-oriented) collection from the dead-end streets is done when they are to the left of the truck. They must be collected by walking down, reversing the vehicle or taking a U-turn.
- Waste on a steep hill should be collected, when practical, on both sides of the street while vehicle is moving downhill. This facilitates safe, easy and fast collection. It also lessens wear of vehicle and conserves gas and oil.
- Higher elevations should be at the start of the route.
- For collection from one side of the street at a time, it is generally best to route with many anti-clockwise turns around blocks.
- For collection from both sides of the street at the same time, it is generally best to route with long, straight paths across the grid before looping anticlockwise.
- For certain block configurations within the route, specific routing patterns should be applied.

Based on the above rules, Figure 1.7 below illustrates a typical collection vehicle routing:

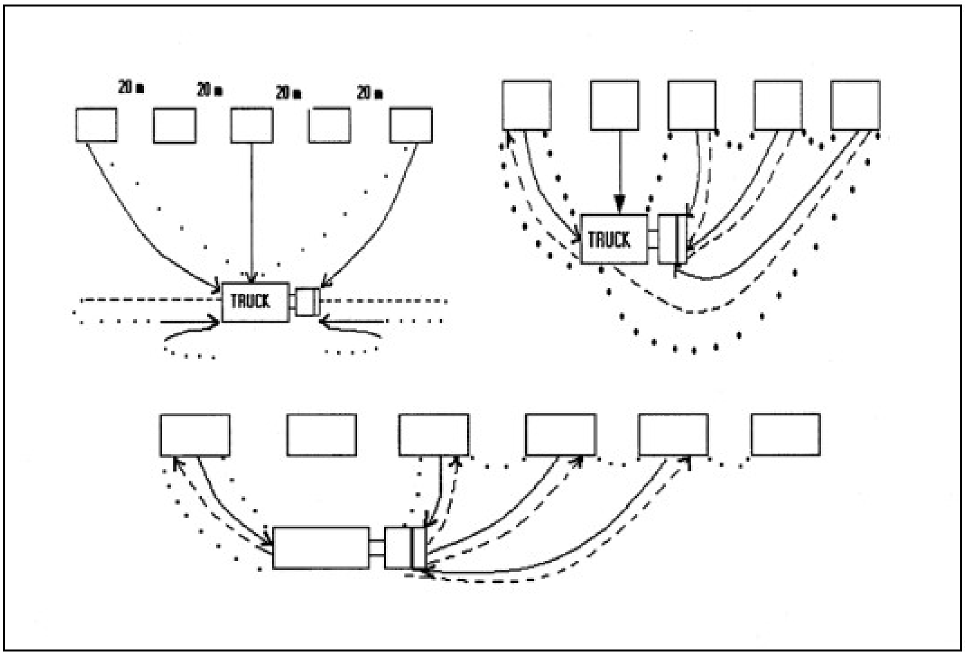


Figure 1.7 Collection Vehicle Route

7.6Transfer Stations

As mentioned earlier in Section, transfer station is a centralized facility, where waste is unloaded from smaller collection vehicles and re-loaded into large vehicles for transport to a disposal or processing site. This transfer of waste is frequently accompanied by removal, separation or handling of waste. In areas, where wastes are not already dense, they may be compacted at a transfer station. The technical limitations of smaller collection vehicles and the low hauling cost of solid waste, using larger vehicles, make a transfer station viable. Also, the use of transfer station proves reasonable, when there is a need for vehicles servicing a collection route to travel shorter distances, unload and return quickly to their primary task of collecting the waste.

Limitations in hauling solid wastes are the main factors to be considered, while evaluating the use of transfer stations. These include the additional capital costs of purchasing trailers, building transfer stations and the extra time, labour and energy required for transferring wastes from collection truck to transfer trailer.

Consider also the following factors that affect the selection of a transfer station:

- Types of waste received.
- Processes required in recovering material from wastes.
- Required capacity and amount of waste storage desired.
- Types of collection vehicles using the facility.
- Types of transfer vehicles that can be accommodated at the disposal facilities.
- Site topography and access.

The main problem in the establishment of a transfer station, however, is securing a suitable site. Stored solid wastes and recyclable materials, if not properly handled, will attract flies and other insect vectors. Odours from the transferred solid wastes will also be a nuisance, if not properly controlled. In addition, the traffic and noise due to small and large collection vehicles, collectors, drivers, etc., invite the resentment of the communities living in the vicinity of transfer stations.

7.6.1 Types

Depending on the size, transfer stations can be either of the following two types:

(i) **Small to medium transfer stations:** These are direct-discharge stations that provide no intermediate waste storage area. The capacities are generally small (less than 100 tones/day) and medium (100 to 500 tones/day). Depending on weather, site aesthetics and environmental concerns, transfer operations of this size may be located either indoor or outdoor. More complex small transfer stations are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, it includes a recyclable material separation and processing center. The required overall station capacity (i.e., the number and size of containers) depends on the size and population density of the area served and the frequency of collection.

(ii) **Large transfer stations:** These are designed for heavy commercial use by private and municipal collection vehicles. The typical operational procedure for a larger station is as follows:

a. when collection vehicles arrive at the site, they are checked in for billing, weighed and directed to the appropriate dumping area;
b. collection vehicles travel to the dumping area and empty the wastes into a waiting trailer, a pit or a platform;
c. after unloading, the collection vehicle leaves the site, and there is no need to weigh the departing vehicle, if its weight (empty) is known;
d. Transfer vehicles are weighed either during or after loading. If weighed during loading, trailers can be more consistently loaded to just under maximum legal weights and this maximizes payloads and minimizes weight violations.

Designs for larger transfer operations

Several different designs for larger transfer operations are common, depending on the transfer distance and vehicle type. Most designs, however, fall into one of the following three categories:

(i) Direct-discharge non-compaction station: In these stations, waste is dumped directly from collection vehicle into waiting transfer trailers and is generally designed with two main operating floors. In the transfer operation, wastes are dumped directly from collection vehicles (on the top floor) through a hopper and into open top trailers on the lower floor. The trailers are often positioned on scales so that dumping can be stopped when the maximum payload is reached. A stationary crane with a bucket is often used to distribute the waste in the trailer. After loading, a cover or tarpaulin is placed over the trailer top. However, some provision for waste storage during peak time or system interruptions should be developed. Because of the use of little hydraulic equipment, a shutdown is unlikely and this station minimizes handling of waste.

(ii) Platform/pit non-compaction station: In this arrangement, the collection vehicles dump their wastes onto a platform or into a pit using waste handling equipment, where wastes can be temporarily stored, and if desired, picked through for recyclables or unacceptable materials.

The waste is then pushed into open-top trailers, usually by front-end loaders. Like direct discharge stations, platform stations have two levels. If a pit is used, however, the station has three levels. A major advantage of these stations is that they provide temporary storage, which allows peak inflow of wastes to be levelled out over a longer period. Construction costs for this type of facility are usually higher because of the increased floor space. This station provides convenient and efficient storage area and due to simplicity of operation and equipment, the potential for station shutdown is less.

(iii) Compaction station: In this type of station, the mechanical equipment is used to increase the density of wastes before they are transferred. The most common type of compaction station uses a hydraulically powered compactor to compress wastes. Wastes are fed into the compactor through a chute, either directly from collection trucks or after intermediate use of a pit. The hydraulic ram of the compactor pushes waste into the transfer trailer, which is usually mechanically linked to the compactor (EPA, 1995). Compaction stations are used when:

- wastes must be baled for shipment;
- open-top trailers cannot be used because of size restrictions;
- Site topography or layout does not accommodate a multi-level building.

The main disadvantage of a compaction facility is that the facility's ability to process wastes is directly dependent on the operative-ness of the compactor. Selection of a quality compactor, regular maintenance of the equipment, easy availability of spare parts and prompt availability of the service personnel are essential for the station's reliable operation.

7.6.2 Capacity

A transfer station should have enough capacity to manage and handle the wastes at the facility throughout its operating life. While selecting the design capacity of a transfer station, we must, therefore, consider trade-offs between the capital costs associated with the station and equipment and the operational costs. Designers should also plan adequate space for waste storage and, if necessary, waste processing. Transfer stations are usually designed to have 1.5 – 2 days of storage capacity. The collection vehicle unloading area is usually the waste storage area and sometimes a waste sorting area. When planning the unloading area, designers should allow adequate space for vehicle and equipment maneuvering. To minimize the space required, the facility should be designed such that the collection vehicle backs into the unloading position. Adequate space should also be available for offices, employee facilities, and other facility-related activities (EPA, 1995). Factors that should be considered in determining the appropriate capacity of a transfer facility include:

- Capacity of collection vehicles using the facility;
- Desired number of days of storage space on tipping floor;
- Time required to unload collection vehicles;
- Number of vehicles that will use the station and their expected days and hours of arrival;
- Waste sorting or processing to be accomplished at the facility;
- Transfer trailer capacity;
- Hours of station operation;
- Availability of transfer trailers waiting for loading;
- Time required, if necessary, to attach and disconnect trailers from tractors or compactors.

Transfer station capacity can be determined using the following formulae:

- **Pit stations:** Based on the rate at which wastes can be unloaded from collection vehicles:

  C = Pc x (L/W) x (60 x H w/Tc) x F

  Based on rate at which transfer trailers are loaded:

  C = (Pt x N x 60 x H t)/(Tt + B)

- **Direct dump stations:** *C = (Nn x Pt x F x 60 x Hw)/ [((Pt/Pc) x (W/Ln)) x Tc + B]*
- **Hopper compaction stations:** *C = (Nn x Pt x F x 60 x Hw)/[(Pt/Pc x Tc) + B]*
- **Push pit compaction station:** *C = (Np x Pt x F x 60 x Hw)/[(Pt/Pc x W/Lp x Tc) + Bc + B]*

  Where:
  = Station capacity (tonnes/day); Pc = Collection vehicle payload (tonnes); L = Total length of dumping space (feet); Hw = Hours per day that waste is delivered; Tc = Time (in minutes) to unload each collection vehicle; F = Peaking factor (ratio of the number of collection vehicles received during an average 30-minute period to the number received during a peak 30-minute period); Lp = Length of push pit (feet); Np = Number of push pits; Bc = Total cycle time for clearing each push pit and compacting waste into trailer; Pt = Transfer trailer payload (tonnes); N = Number of transfer trailers loading simultaneously; Ht = Hours per day used to load trailers (minutes); B = Time to remove and replace each loaded trailer (minutes); Tt = Time to load each transfer trailer (minutes); Nn = Number of hoppers; Ln = Length of each hopper (feet).

These formulae are useful in estimating the capacity of various types of transfer stations (EPA, 1995) and should be adapted, as necessary, for specific applications.

7.6.3 Viability

Transfer stations offer benefits such as lower collection costs (because crews waste less time travelling to the site), reduced fuel and maintenance costs for collection vehicles, increased flexibility in selection of disposal facilities, opportunity to recover recyclables or compostable at the transfer site and the opportunity to shred or scoop wastes prior to disposal. These benefits must be weighed against the costs to develop and operate the facility.

The classical approach to arrive at the economic viability of operating a transfer station, is to add the unit cost of the transfer station to the cost of hauling using large vehicles, and to compare this cost with the cost of hauling directly to the disposal site using the smaller vehicles that service the collection area. The cost of hauling using small vehicles is the sum of the depreciation cost of the vehicle, driver’s salary, salary of the collection crew (if they are on standby waiting for the vehicle to return to the collection area) and fuel cost. The transfer station cost is the sum of the transfer station's depreciation cost and the operating and maintenance costs divided by the capacity of the station. The cost of using the large vehicle is the sum of the vehicle depreciation, fuel cost and driver’s salary.

The cost-effectiveness of a transfer station depends on the distance of disposal site from the generation area, and a distance of 10 – 15 km is usually the minimum cost-effective distance (Phelps, et al., 1995). The distance between the disposal site and collection area is one of the principal variables in deciding whether to use a transfer station or haul the solid wastes directly from the collection area to the disposal site. Figure 1.8 illustrates the economic analysis involving the effect of the hauling distance on the collection cost:

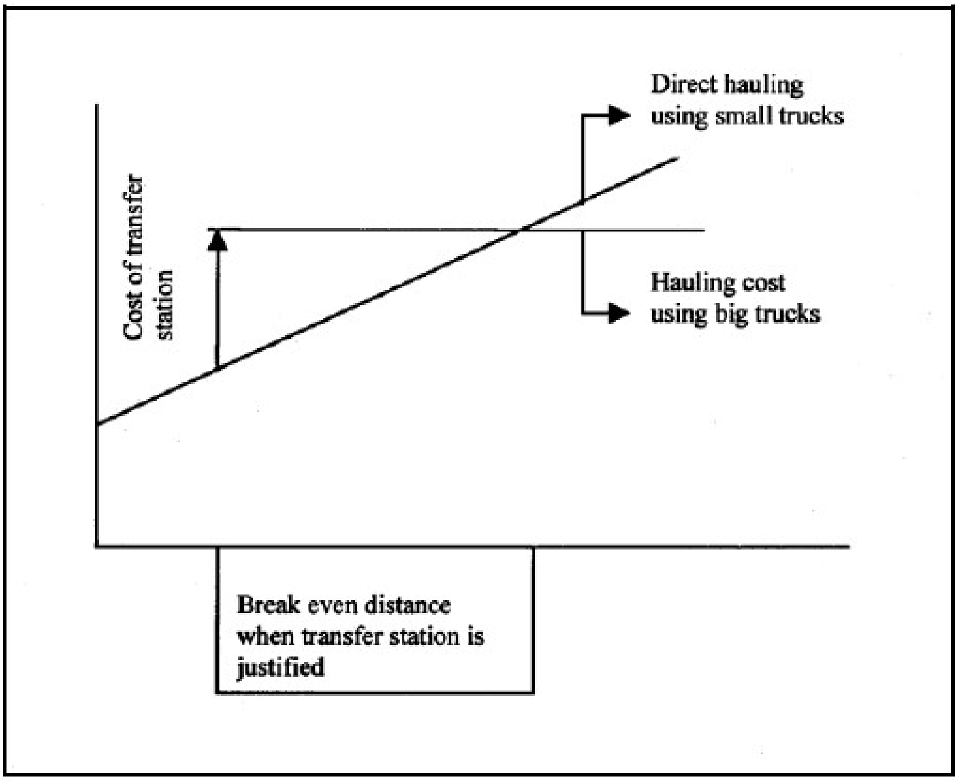


Figure 1.8 Cost Analysis to Determine Viability of Transfer Station

Now, let us consider first the case in which the transfer station is located directly along the hauling route between the disposal site and the collection area. Let the unit cost of hauling using a small vehicle be *Rs. A/m3 km*. The cost of operation, maintenance, and depreciation, loading and unloading at the transfer station be *Rs. B/m3* and the cost of hauling using large vehicles be *Rs. C/m3 km*. If the distance between the collection area and the transfer station is *X km* and the distance between the transfer station and the disposal site is *Y km*, then the distance between the collection area and the disposal site is *X + Y km*. Then, the total cost of hauling the solid wastes from the collection area to the disposal site using a transfer station is:

$$T = 2AX + B + 2CY$$

The factor 2 is added to account for the round trip, which effectively doubles the distance travelled. The total cost of hauling without the transfer station is:

$$T1 = 2A(X + Y)$$

The transfer station is justified, when:

$$T < T1$$

That is, the hauling cost using a transfer station is lower than the direct hauling costs between the collection area and the disposal site. Substituting the values of T and T1 yields:

$$2AX + B + 2CY < 2AX + 2AY$$

or

$$Y > B/(2A - 2C)$$

Note that X cancels out. The distance between the potential transfer station site and the disposal site is the variable to consider. The distance between the collection area and the disposal site is important in deciding the utilisation of a transfer station, if X is equal to zero, in which case the transfer station is located right at the centroid of the collection area. Under normal conditions, the centroid of the collection area has a high land value, and it would be impractical to locate a solid waste transfer station in this area. Figure 3.8 shows the effect of the distance between the potential transfer station site and the disposal site on the hauling cost.

Consider a general case in which the transfer station is located away from the hauling route between the collection area and the disposal site. Let Z be the additional distance travelled by the vehicles. The cost T, when using a transfer station, is then equal to:

$$T = B + 2AX + 2AZ + 2CY + 2CZ$$

The cost of direct hauling from the collection area to the disposal site remains the same as previously defined. The use of a transfer station is justified, if:

$$B + 2AX + 2AZ + 2CY + 2AZ < 2AX + 2AY$$

or

$$Y > (B + 2CZ + 2AZ)/(2A - 2C)$$

Again, the decision whether or not to use a transfer station is independent of the distance between the collection area and the proposed transfer station.

7.7 Selection of location

Geographic information system (GIS) is a computerize database management system that designed to manage large volumes of spatially distributed data from a variety of sources (Charnpratheep et al., 1997). They are ideal for advanced site-selection studies because they efficiently store, retrieve, analyze, and display information according to user-defined specifications (Kao et al., 1997). GIS has been extensively used to facilitate and lower the cost of the landfill site-selection process (Sener et al., 2006).

GIS often been employed for the siting and placement of facilities (Church, 2002). GIS has emerged as a very important tool for land use suitability analysis (Malczewski, 2004). GIS also can recognize, correlate and analyze the spatial relationship between mapped phenomena, thereby enabling policy-makers to link disparate sources of information, perform sophisticated analysis, visualize trends, project outcomes and strategize long-term planning goals (Malczewski, 2004).

GIS as a box of tools for handling geographical data is very useful, however, the list of tools provided by GIS although impressive is not complete. For example in most GIS packages spatial analytical functionality, lies mainly in the ability to perform deterministic overlay and buffer functions (Carver, 1991). Such abilities whilst ideal for performing spatial searches based on nominally mapped criteria, are of limited use when multiple criteria and targets, such as in the case of landfills selection, are applied (Jeff and Baxter, 1996). The integration of GIS with analytical techniques will be a valuable addition in GIS toolbox. Progress in this area is inevitable and future developments will continue to place increasing emphasis upon the analytical capabilities of GIS (Fotheringham and Rogerson, 1994).

GIS have the capability to handle and simulate the necessary economic, environmental, social, technical, and political constraints. Many of the attributes involved in the process of selection of sanitary landfill sites have a spatial representation, which in the last few years has motivated the predominance of geographical approaches that allow for the integration of multiple attributes using geographic information systems (Kontos et al. 2003; Sarptas et al. 2005; Sener et al. 2006; Gomez-Delgado and Tarantola 2006; Delgado et al. 2008; Chang et al. 2008). Site selection procedures can benefit from the appropriate use of GIS.

Common benefits of GIS include its ability to: (a) capture, store, and manage spatially referenced data; (b) provide massive amounts of spatially referenced input data and perform analysis of the data; (c) perform sensitivity and optimization analysis easily; and (d) communicate model results (Vatalis and Manoliadis 2002).

GIS also provides a spatial framework to land use analysis and it has been recognized as a useful decision support technology. The role of GIS is to generate a set of feasible solutions representing the relative land suitability with respect to any given map layers and to display it. Nevertheless, it does not provide means to deal with multiple decision factors. There has been a recent trend to integrate GIS with other software for better decision making in planning.

7.8 Operation & maintenance

A facility Operations and Maintenance Manual is required for all waste management facilities and systems. The following shall be addressed in detail and as applicable:

- Site security, manpower, supervision, access and signage
- Unacceptable/prohibited activities e.g. no open burning or smoking on-site
- Control systems for nuisance factors including vectors, rodents, scavenging, illegal dumping, malodor, dust and litter
- Procedures for inspection of materials prior to acceptance at the facility.
- Acceptable and unacceptable waste material/waste streams and contingency options
- Contingency and Environmental Emergency plans
- Environmental monitoring program(s)
- Facility/System day-to-day operations protocol /procedures

- Site and equipment maintenance schedule / regime
- Staff/operator training in facility operations, & environmental health and safety Record keeping and Reporting
- Contact information for owner/operator and site managers / supervisors
- On-going Quality Control / Quality Assurance protocol (Plan, do, check, repair/revise/repeat where appropriate).
- A copy of the facility Certificate of Approval

The Operations Management/Maintenance Manual shall be prepared by the owner/operator and approved by the Department. The operation of the facility shall be in compliance with the provisions of the Certificate of Approval and a copy of the Operations Manual is to be kept on site and readily available to staff and regulators.

7.8.1 Environmental Emergency Health and Safety Contingency Plans

The owner/ operator shall have up-to-date contingency plans in place to effectively handle all reasonably forces eable emergencies such as, fire, malodor, flood, power outage, delivery or spillage of hazardous waste/ materials, explosion, leachate leakage, or any other emergency or issue which could result in disruption of facility operations and/or environmental damage. Bound copies of the contingency plan(s) shall be kept at the facility (ies) with the Operations Manual. The plans shall describe appropriate mitigation measures required to prevent damage to the waste management facility and the environment. Employees shall be familiar with the contingency plan(s) and participate in regular practice response exercises. The attendant on site shall be equipped with an effective and quick means of communication for personal safety and to contact first responders (facility owner/operator, fire, police, and medical) in the event of an emergency. An appropriate fire control program shall be in place on a continual basis. The program shall be developed in consultation with the local Fire Department. Fire safety plans, including the comments of the first responder fire department as to the adequacy of the plan, are to be provided to the Department. The Department of Natural Resources shall also be advised in areas where there is a forest fire risk. The contingency plan shall be reviewed annually and revised as needed.

Check your progress

Q1. Explain facility operations and maintenance manual is required for all waste management facilities and systems.

Q2. Illustrate factors that affect the selection of a transfer station.

7.9 Options under Indian conditions.

In India, recently solid waste management systems are assuming larger dimensions in keeping with the Municipal Solid Wastes (Management & Handling) Rules, 2000.

Figure 1.9: Solid Waste in India

Many of the municipalities are taking appropriate actions to improve various component systems like collection of solid waste from generation areas, its transportation to processing and disposal site(s), utilizing the recycling potential of Municipal Solid Waste (MSW) and ultimately disposing of by landfilling.

In view of this, under the sponsorship of Central Pollution Control Board (CPCB), NEERI has carried out the extensive studies to assess the pathways of pollution for various environmental media. Further, a site selection criteria has been developed in the form of guidelines to suit Indian condition in keeping with the findings of the other studies.

The urban solid waste management is an essential municipal service for protection of environment and health of citizens. All the citizens, industries, hospitals and NGOs should co-operate with the municipal authorities to ensure safe management of urban solid waste.

Segregation of inorganic recyclable materials like plastic, glass, metal, papers at the source should be promoted and every effort made to provide collection of these in separate containers or bags in each house.

Solid waste should be collected from each house on a daily basis and transported to the disposal site. Direct transfer of garbage from primary collection carts to covered transportation vehicles should be encouraged.

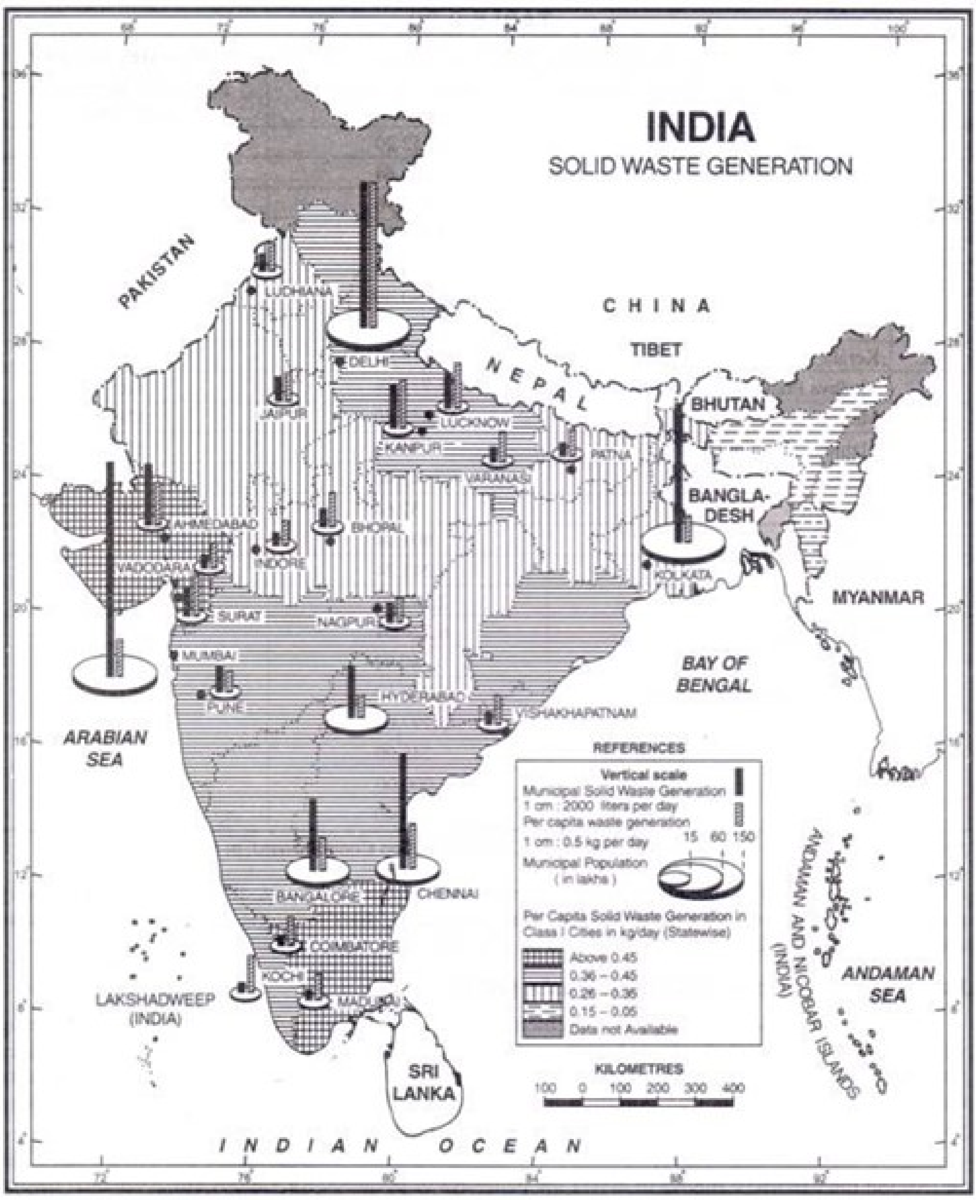


Figure 1.10: Solid Waste Generation in India

Refuse from vegetable and fruit markets should be collected and transported to the composting facilities. Large restaurants/hotels should be encouraged to develop their own onsite treatment facilities.

Sanitary landfills would be the main option for disposal of urban solid waste. The concerned authorities must make adequate provision of land allocated for scientific landfill sites.

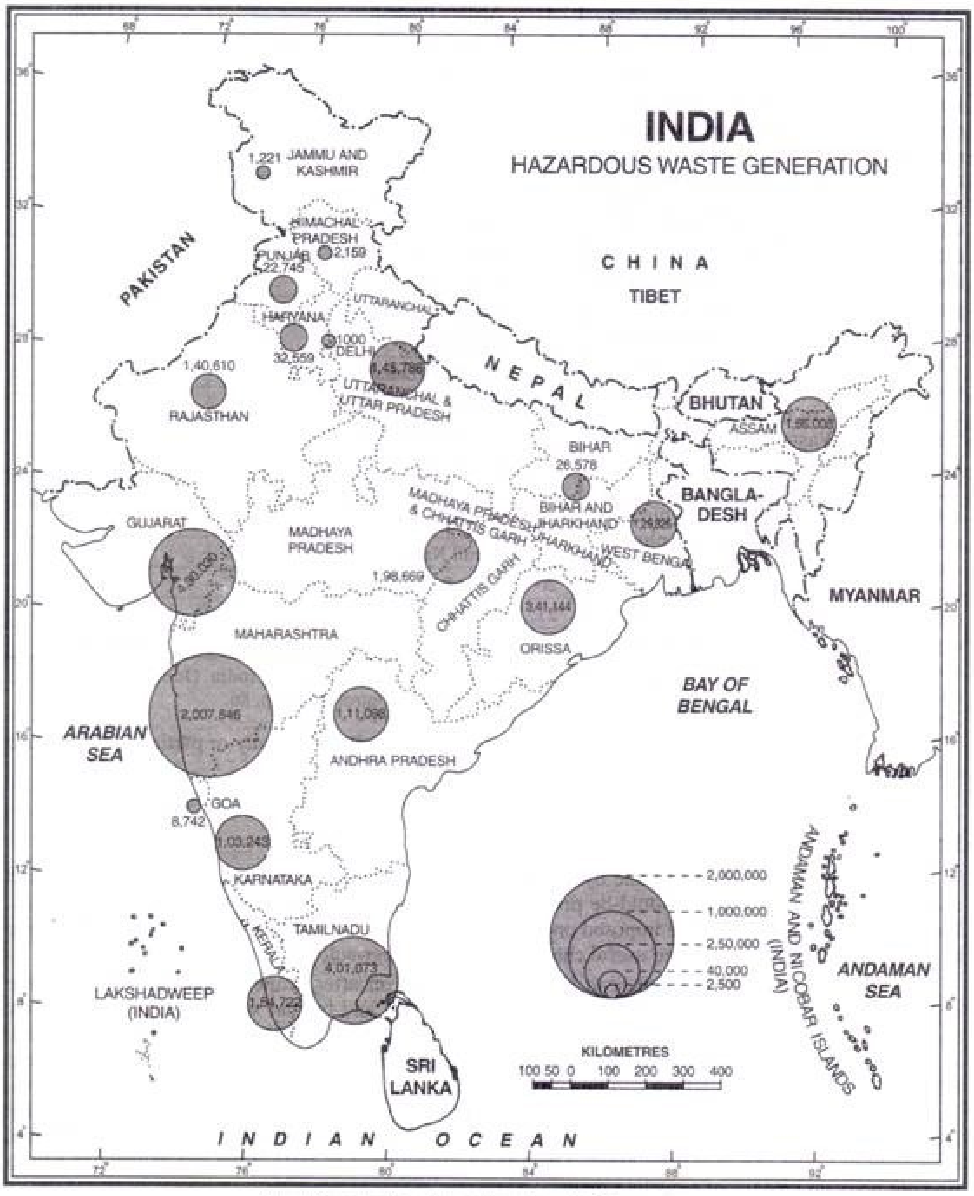


Fig 1.11: Hazardous Waste Generation

Composting along with land disposal on non-compostable are the most preferred options for MSW and could take care of up to 20-30 per cent of municipal solid waste/organic fraction. The urban solid wastes of Indian cities have low calorific value and high moisture content with high percentage of noncombustible materials and hence it is unsuitable for thermal technologies. However, application of technologies such as incineration, palletization and pyrolysis-gasification should be evaluated through research and development and pilot scale studies.

According to latest figures (2004) Delhi is generating about 7,000 metric tonnes of garbage every day and is fast running out of landfill sites. It appears that garbage will soon become the single most important issue for Delhi which requires immediate solution. It is felt that unless a new technology is adopted, there will be no space left for garbage in the next few years.

7.10 Review Questions

Q1. Define the remedies under Indian constitution.

Q2. Illustrate factors that affect the selection of hazardous waste generation at nearer municipal station.

UNIT-VIII Waste Handling And Segregation

Structure

8.0 Introduction

Many components of municipal solid wastes can be reused as secondary material. Among these are papers, cardboard, plastic, glass, ferrous metal, aluminum, and other nonferrous metals. These materials must be separated from MSW before they can be recycled. In this section, material recycling, and separation methods are first briefly presented, followed by bioconversion and refuse derived fuel (RDF) methods.

The waste handling and segregation of solid waste at site, material separation by pick in, screens, float and separator magnets are the major issues .Moreover electromechanical separator and other latest devices for material separation, Waste handling and separation at Commercial and industrial facilities, Storage of solid waste at the sources are handling by modern technology.

The ISWM (Integrated Solid Waste Management) hierarchy of waste management as explained above prioritizes waste minimization (reduction at source and reuse) as the preferred waste management strategy because it is the most effective way to reduce the quantity of waste, the cost associated with its handling, and its environmental impacts.

Waste minimization strategies require policy interventions at the National, State and/or Local level, depending on the type of the intervention (e.g. minimizing use of packaging material, promoting use of refill containers, buy back of reusable or recyclable packing material, introducing a national deposit system on beverage packages) and the scale at which the intervention needs to be initiated for effective implementation. Initiatives which require a behavior change in the community need to be supported by consistent awareness programmes.

Objectives

After studying this unit you should be able to:

- Handling and segregation of solid waste at site
- Material separation by pick in
- Screens, float and separator magnets, electromechanical separator and other latest devices for material separation
- Waste handling and separation at Commercial and industrial facilities Storage of solid waste at the sources.

8.1 Handling and segregation of solid waste at site

The ISWM (Integrated Solid Waste Management) hierarchy of waste management as explained above prioritizes waste minimization (reduction at source and reuse) as the preferred waste management strategy because it is the most effective way to reduce the quantity of waste, the cost associated with its handling, and its environmental impacts.

Waste minimization strategies require policy interventions at the National, State and/or Local level, depending on the type of the intervention (e.g. minimizing use of packaging material, promoting use of refill containers, buy back of reusable or recyclable packing material, introducing a national deposit system on beverage packages) and the scale at which the intervention needs to be initiated for effective implementation. Initiatives which require a behavior change in the community need to be supported by consistent awareness programmes.

Waste Minimization Strategies requiring National or State level interventions or support

- Extended Producer Responsibility (EPR): EPR can be established for wastes like electronics, batteries, packaging and consumer durables by State and National governments. States can take initiatives in this matter; regulations are usually legislated at State and National levels.
- Promotion of voluntary action: Encouraging business groups to reduce volumes of packaging, while maintaining the requisite strength. Example: Godrej has a 'No Packaging Policy' for refrigerators. The company ensures that the packaging, in which the appliance is delivered, is taken back by the supplier and reused.
- Frame rules and bye laws banning use and/or sale of certain types of products and packaging that cannot be reused, repaired, recycled, or composted. With State support, local authorities are enabled to issue and enforce such ordinances
- Developing eco-labelling standards for certain products based on their potential for waste reduction and recycling in respect to the product or connected packaging.

Waste Minimization Initiatives usually requiring ULB Support/Action

- Promoting and implementing awareness and education programs that address different stakeholders: residential, commercial and industrial educational programs, school programs that increase public awareness and participation in at-source waste reduction programs. Campaigns might include promotion of material substitution where possible (e.g. promoting the use of rechargeable batteries instead of single use batteries, buying refills etc.).
- Developing and promoting at-source reduction programs in the community, e.g. domestic composting programs can reduce the volume of food waste, leaves and garden trimmings entering the city level collection system.
- Bans within local authorities' jurisdiction (usually National / State Level authorization required; see above): Replacing non-recyclable / disposable materials and products with recyclables and reusable materials and products (e.g. banning the use of plastic bags).
- Product stewardship and Green Procurement implementing programs whereby the suppliers of a product are responsible for providing a take-back program to promote recycling. Take- back examples are computer monitors, auto oil, batteries, paper, milk pouches, etc. Procurement programs in local governments and businesses should be designed to give preference to recyclable products.
- Local businesses should be encouraged to reward consumers for returning recyclable products/ products which are toxic (e.g. batteries). These initiatives require existing manufacturers' EPR programs (see above).
- Business assistance programs advise businesses how to use materials more efficiently and reduce waste generation.
- Supermarkets & retail stores are often some of the most effective partners for a municipal waste minimization program. These provide a central and consistent point for consumer education, packaging reduction projects and collection of recyclable wastes.
- Promoting materials exchange and reuse programs that divert materials from the waste stream going to landfill (e.g. programs which link sellers of used furniture with potential second hand furniture buyers).
- Establishing incentives for at-source reduction through the principle of "pay as you throw", supported by bye-laws. ULBs can stipulate variable solid waste management charges, based on the quantities being disposed per household/establishment. 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.

MSW should be stored at the source of waste generation till it is collected for disposal by ULB staff or appointed contractors. It is essential to segregate wastes into different fractions, commonly referred to as primary segregation. Segregation of municipal solid waste needs to be linked to primary collection of waste from the door step and given high priority by the ULBs. Unless primary collection of segregated waste is not planned by the ULBs the source segregation by waste generators will be meaningless. The fractions into which the waste has to be segregated should be decided upon by the respective ULB based on the waste characterization, the ULB's capacities and facilities, and other framework conditions (existing kabadi systems, traditions in the community, available space in residential areas and in streets etc.). At a minimum level, indicated as the basic segregation, waste should be segregated by waste generators into two fractions: wet (green container) and dry (bluecontainer) (see figure 1.6). This system is referred to as the 2-bin system. The wet fraction should preferably be used for composting and as many fractions as possible from the dry waste should be sent for recycling.

Figure 2.1: 2-bin system for dry and wet waste

8.1.1 Segregated Collection

Collection of segregated municipal waste from the source of its generation is an essential step in solid waste management. Inefficient waste collection service has an impact on public health and aesthetics of towns and cities. Collection of wet and dry waste separately enhances the potential of cost effective treatment of such wastes and of deriving optimum advantage from the recyclable material fed into the system.

Waste collection service is divided into primary and secondary collection.

Primary collection refers to the process of collecting waste from households, markets, institutions and other commercial establishments and taking the waste to a storage depot/ transfer station or directly to the disposal site, depending on the size of the city and the prevalent waste management system. Secondary collection includes picking up waste from community bins, waste storage depots or transfer stations and transporting it to waste processing sites or to the final disposal site. Primary collection must be introduced both in small and large towns/cities.

Secondary collection systems are necessary in all cities and towns for collection of waste deposited by the waste generators in the community bins or by sanitation workers at the secondary waste storage depots or for onward transportation of waste to processing / disposal facilities.

A well synchronized primary and secondary collection and transportation system is essential to avoid containers' overflow and waste littering on streets. Further, the transport vehicles should be compatible with the equipment design at the waste storage depot in order to avoid multiple handling of wastes and should be able to transport segregated waste. They should also be easy to maintain.

8.1.2 Street Cleaning and Drain Cleaning Material

Street cleaning is an age old fundamental service rendered by municipal authorities in India to ensure clean and hygienic urban conditions. Until recently all domestic and trade waste was being discharged on the streets or street bins and street sweeping was the principal method of waste collection. With the introduction of door to door collection systems in many urban areas, there is a sizeable reduction in the quantity of waste and change in its composition. The street waste should ideally comprise of dust and tree leaves and some litter disposed by citizens on the streets but till such time door to door collection becomes effective, the street sweeping will also include sizeable portions of food waste as well as recyclable waste. Manual sweeping is commonly practiced in India as many streets are congested and narrow road conditions are not conducive for mechanical sweeping. Inefficient waste collection systems coupled with public littering significantly contribute to waste piles in streets.

A wide variety of tools and equipment are available for manual and mechanical sweeping. Municipal authorities must avoid multiple handling of waste by converting traditional handcarts into containerized handcarts to facilitate direct transfer of waste from handcart to a container of collection vehicle. Through the introduction of efficient methods, municipal authorities can achieve significant improvement in quality of service and financial savings. ULBs should determine the frequency of street cleaning based on local conditions for efficiency of staff. Also, the time of street cleaning should be carefully defined to avoid conflicts with traffic, parked vehicles and pedestrians.

In many cities there are open surface drains along the road side, which need to be cleaned on a regular basis to permit free flow of storm/grey water. Solid waste management authorities should ensure that citizens and sweepers do not dispose waste into drains, through training, campaigning, statutory regulations and monetary fines. A further approach to prevent this is to make the same staff responsible for cleaning streets as well as adjacent surface drains up to a depth of 90 cm.

It is very important to ensure that street sweepings and drain cleaning material are not allowed to be mixed with the waste collected from households and commercial establishments as it can seriously hamper treatment and recycling options for the household and commercial wastes and add to the cost of processing of waste.

8.2 Material separation by pick in

Effective recycling relies on effective sorting. With a wide range of sorting technologies on the market today, WMW reviews the options and looks at the issues that are driving the development of new technology.

European citizens will not have failed to notice that the sorting of waste, particularly at a household level, is becoming increasingly important. While the various EU countries currently take different stances on how and which waste to separate, the trend will be to separate as much useful waste as possible and deal with it in the most appropriate manner.

Separating the different elements found in waste streams is essential for enabling the recovery of useful materials, minimizing the amount of material sent to landfill and allowing recyclable materials to find a new incarnation. Companies sort and recycle materials in order to extract value, but those operating in EU Member States are also bound by EU rules and regulations relating to the environment.

In June 2008 MEPs voted to reshape the waste framework directive and the new rules are that each country will have to set and adhere to its own targets on waste. In terms of recycling, the new legislation states that 50% of all household waste and 70% of all construction waste must be re-used or recycled by the year 2020, so the need to make sure sorting processes are as effective and economical as possible is of paramount importance.

8.2.1 Separation technologies

Waste disposal companies dealing with the sorting of materials will commonly use one or more of these five methods:

- Trommel separators/drum screens: These separate materials according to their particle size. Waste is fed into a large rotating drum which is perforated with holes of a certain size. Materials smaller than the diameter of the holes will be able to drop through, but larger particles will remain in the drum.
- Eddy current separator: This method is specifically for the separation of metals. An 'eddy current' occurs when a conductor is exposed to a changing magnetic field. Put simply, it is an electromagnetic way of dividing ferrous and non-ferrous metals.
- Induction sorting Material is sent along a conveyor belt with a series of sensors underneath. These sensors locate different types of metal which are then separated by a system of fast air jets which are linked to the sensors.
- Near infrared sensors (NIR) When materials are illuminated they mostly reflect light in the near infrared wavelength spectrum. The NIR sensor can distinguish between different materials based on the way they reflect light.
- X-ray technology X-rays can be used to distinguish between different types of waste based on their density.

Manual sorting

It should also be mentioned that manual sorting of waste is still very much a technique that is used in the world today. Danish company M&J says many of its shredders are bought by companies that want to use them prior to material being sorted by hand on so-called manual picking lines. M&J has shredders that can produce large-sized particles, making it easier for those hand-sorting the waste to do their jobs effectively.

Those companies paving the way in the sorting of waste use the afore mentioned technologies, but are also constantly developing new and more effective methods. In sorting there is a multitude of ways to get the job done. This article aims to provide a flavor of the most common, as well as the most innovative, methods of sorting being used by European waste disposal companies today. We do not have the space to go into detail on every method currently available and in use, but hope this article serves to give an overall impression of the technologies employed in today's market and their value to society.

Mobile sorting

With today's recycling culture, sorting is surely set to increase. Not all companies can transport the waste to their own plants in order to separate it. Sometimes this work needs to be done on site. Mobile sorting machines are therefore a must, and one company that is leading the way in this field of waste screening is Doppstadt with its SM series of mobile sorters.

The SM series uses drum screens and is adaptable to a variety of uses. There are four different machines to choose from depending on the type and size of waste to be sorted, and each of them includes features designed to make them easy to maintain, keep clean and transport. The rotating drums have rotating brushes to keep them from getting clogged up and are capable of dealing with heavy materials. They employ a patented load-sensing technology which optimizes the flow of material through the drum and the machines benefit from short set-up times as they have hydraulically-folding discharge conveyors. The SM series can sort anything from compost to construction waste and soil to materials excavated from landfill.

Just one example of a use for mobile sorting technology is a plant set up by Cesaro Mac Import in Italy using Doppstadt machinery. As well as a shredding machine this plant makes use of a screening station, SST 1025, with a 40 mm trommel screen. The plant processes waste that is the by-product of paper recycling. This waste comprises paper rejects and sledges. These rejects or foreign fibers can be processed once they are separated and their calorific value is useful. So it is important to use effective technology that can remove this matter from the sludge. The Doppstadt screens in Italy process 550 tonnes of rejects each day.

Enhanced resolution

One of the key features of companies leading the way in today's market is the ability to sort the increasingly diverse range of materials coming through, and deal with them appropriately. Titech, a global company with its headquarters in Norway, has long been aware of this issue and has been spearheading technologies which have now been adopted across the industry. The 15-year-old company sorts a huge range of materials; everything from plastic bottles and WEEE to construction and industrial waste. It places a great deal of importance on research and development. It knows that new materials will be created, but the need to dispose of them correctly will also be paramount. In light of this it uses a diverse range of sensor technology in order to get the purest fractions from every waste stream.

The sensor technologies applied at Titech include: NIR (near infrared), which recognizes different materials based on their spectral properties of reflected light; CMYK (cyan, magenta, yellow, key) sorts paper or carton that has been printed using CMYK; VIS (visual spectrometry) recognizes all colours that are visible and works for both transparent and opaque objects; EM (electromagnetic) sorts metals with electromagnetic properties, as well as sorting metals from non-metals and recovers stainless steel or metallic compounds; RGB sorts specifically in the colour spectrums of red, green and blue for specialized applications and X-ray sorts by recognizing the atomic density of materials. This enables Titech to achieve a high purity level regardless of size, moisture or pollution level.

Another emerging technology is MIR (mid infrared) which works on a similar principle to NIR, but projects light in the mid infrared range onto materials to be analyzed. French company Pellenc ST has been piloting this technology since 2008 as a more efficient way to separate paper and cardboard.

Traditionally, machines have employed the same technology used to sort plastics, i.e. colour sorting methods, to sort paper and cardboard but this results in a much lower level of efficiency. Pellenc ST says that new MIR method brings efficiency levels up to 90% which is an improvement of around 30%.

The range of sensors used at Titech gives us a good indication of the direction the European, and indeed global, sorting market is taking. The company's flagship machines at the moment are the Titech Finder, which can take a high throughput of material and achieve excellent purity, and the TitechPolysort Flake, which can sort smaller particles at extremely high resolution. As many readers will know, Titech has recently expanded its operations by forming a partnership with leading German company CommoDas, which has further increased the range of materials that it is capable of sorting.

German company RTT has been operating since 1990 and is famous for its trademarked. Unisort machines, which have been tailored to specific waste streams. The Unisort CB, for example, salvages circuit boards from WEEE, while the Unisort P can sort a wide range of polymers, papers and more using NIR technology.

The company has always been ahead of the game and its response to the demand for high resolution has been another of its successes. The Unisort Flake deals with waste at a fraction size of 350 mm and can be programmed with specific criteria for every waste stream. As with most sensor sorting machines, the waste is fed in on a conveyor belt under the sensors which then instruct the high-pressure air jets to separate the waste into the appropriate containers.

Compact sorting

So, with the high level of variation in waste streams it usually takes a combination of technologies to separate it all successfully and the stream may also need more than one run through the filtering machine. But these days, customers are increasingly demanding. They want a machine that can separate as much waste as quickly as possible and, with the size of machines also a factor, they are looking for something that takes up the least amount of space.

Enter S+S Separation and Sorting technology GmbH and its Varisort Compact system, which had its grand unveiling at the 2008 IFAT show. This Bavarian company focuses on the detection and separation of contaminants from material streams, and has worked hard to produce a machine that industry professionals would see as a good investment. S+S obviously knows its market. The Varisort machine combines inductive, optical and NIR sensors which can run simultaneously, and its accuracy of detection is impressive sorting up to 500,000 parts per second. It also includes high-speed valves which can process up to 500 switching cycles per second.

Its modest size means it appeals to those companies for whom space is a factor. And it is also impressive to note that its lack of stature has in no way compromised its ability to separate waste. S+S has simply made its shorter conveyor belt faster and the compressed air blasts even more precise in order to make sure the job is done properly. Peter Mayer, Sorting Sales Manager at S+S says 'Because of its outstanding flexibility the Varisort Compact system is ideal for sorting electronic waste. Irrespective of the type of electronic waste that needs to be sorted, the Varisort Compact can always optimally perform the sorting task by employing different sensors.'

For companies that deal with large-scale waste such as WEEE, a compact sorting machine like this can be a godsend. With any recycling technology one must consider that it is only one part of a larger processing system, which usually comprises several machines and takes up a large amount of space.

One cog in a larger wheel

Sorting is, of course, just a single element of the waste disposal/recovery process. But it is a vital part and can come at almost any stage in the life of the waste stream once the material has been discarded. With this in mind the big players in the sorting market have to remain flexible and provide technology that can cope with literally any type of waste. Obviously, technology which is designed to deal with small scale flakes cannot also cope with large scale WEEE or wet agricultural waste, but companies are trying to get as close as they can to developing machines that are multi-purpose and combine technologies to do several different jobs at once.

Check your progress

Q1. What is ISWM (Integrated Solid Waste Management).

Q2. Define Handling and segregation of solid waste at site.

8.3 Screens, float and separator magnets, electromechanical separator and other latest devices for material separation

Component separation is a necessary operation in which the waste components are identified and sorted either manually or mechanically to aid further processing. This is required for the:

- Recovery of valuable materials for recycling;
- Preparation of solid wastes by removing certain components prior to incineration, energy recovery, composting and biogas production.

The most effective way of separation is manual sorting in households prior to collection. In many cities (e.g., Bangalore, Chennai, etc., in India), such systems are now routinely used. The municipality generally provides separate, easily identifiable containers into which the householder deposits segregated recyclable materials such as paper, glass, metals, etc. Usually, separate collections are carried out for the recyclable material. At curbside, separate areas are set aside for each of the recyclable materials for householders to deliver material – when there is no municipal collection system. In case the separation is not done prior to collection, it could be sorted out through mechanical techniques such as air separation, magnetic separation, etc., to recover the wastes.

8.3.1 Air separation

This technique has been in use for a number of years in industrial operations for segregating various components from dry mixture. Air separation is primarily used to separate lighter materials (usually organic) from heavier (usually inorganic) ones. The lighter material may include plastics, paper and paper products and other organic materials. Generally, there is also a need to separate the light fraction of organic material from the conveying air streams, which is usually done in a cyclone separator. In this technique, the heavy fraction is removed from the air classifier (i.e., equipment used for air separation) to the recycling stage or to land disposal, as appropriate. The light fraction may be used, with or without further size reduction, as fuel for incinerators or as compost material. There are various types of air classifiers commonly used, some of which are listed below:

- Conventional chute type: This, as shown in Figure 2.2, is one of the simplest types of air classifiers:

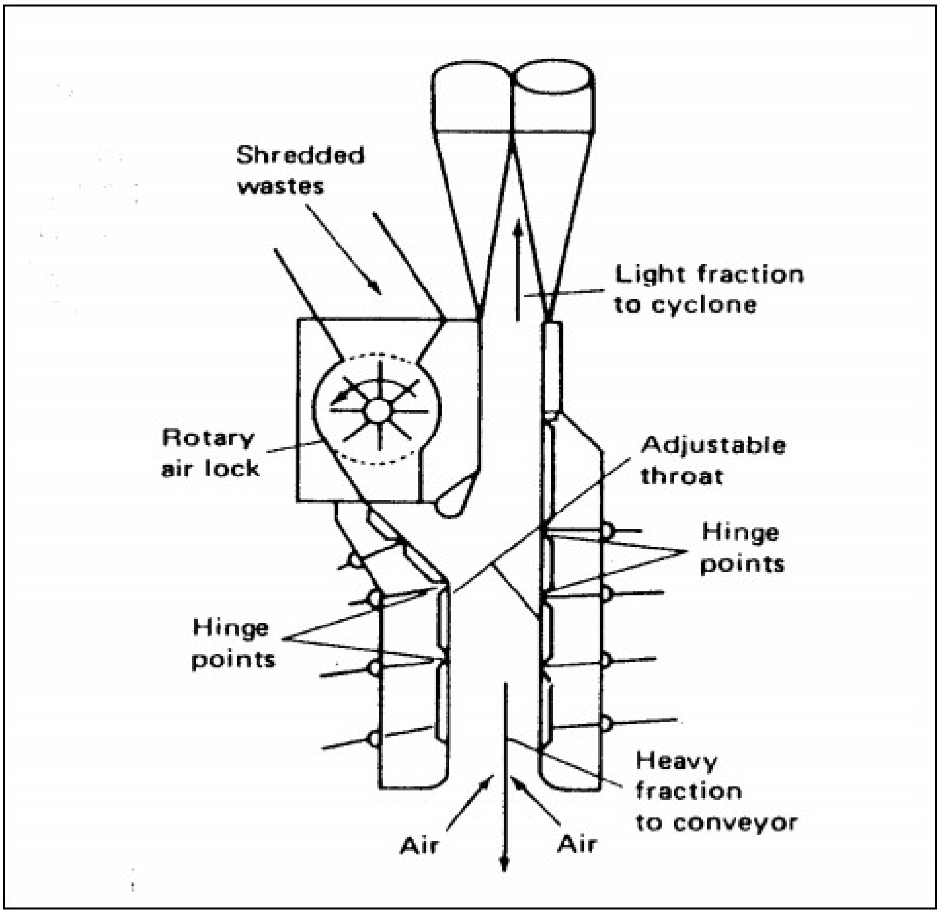


Figure 2.2 Conventional Chute Type

In this type, when the processed solid wastes are dropped into the vertical chute, the lighter material is carried by the airflow to the top while the heavier materials fall to the bottom of the chute. The control of the percentage split between the light and heavy fraction is accomplished by varying the waste loading rate, airflow rate and the cross section of chute. A rotary air lock feed mechanism is required to introduce the shredded wastes into the classifier.

- Zigzag air classifier: An experimental zigzag air classifier, shown in Figure 2.3 below, consists of a continuous vertical column with internal zigzag deflectors through which air is drawn at a high rate:

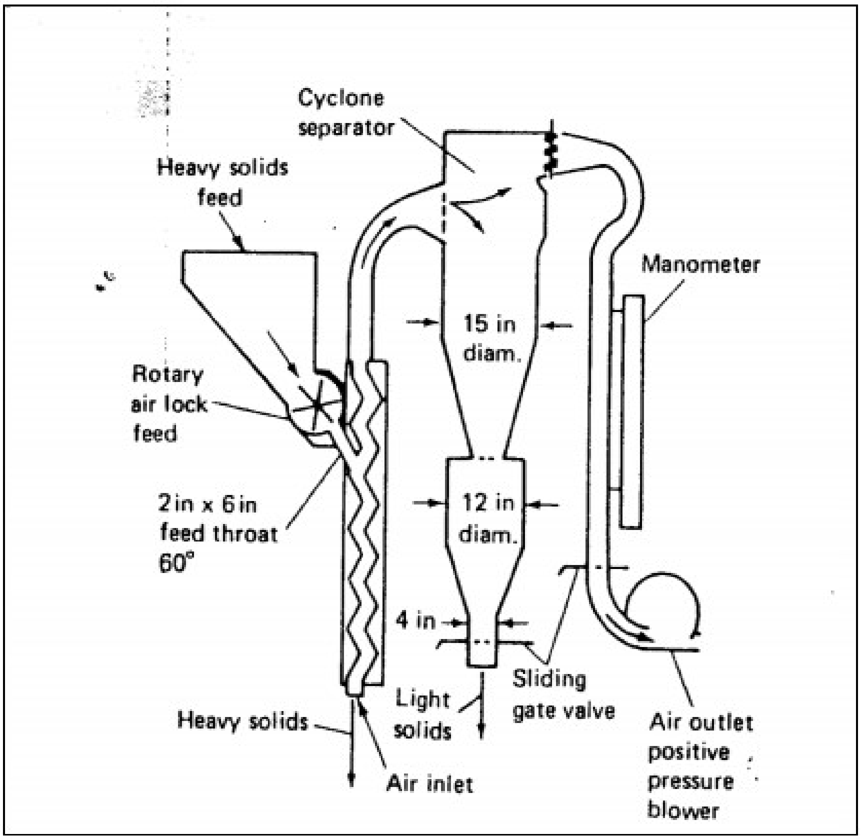


Figure 2.3: Zigzag Air Classifier

Shredded wastes are introduced at the top of the column at a controlled rate, and air is introduced at the bottom of the column. As the wastes drop into the air stream, the lighter fraction is fluidized and moves upward and out of column, while the heavy fraction falls to the bottom. Best separation can be achieved through proper design of the separation chamber, airflow rate and influent feed rate.

- Open inlet vibrator type: Figure 2.4` below illustrates this type of air classifier:

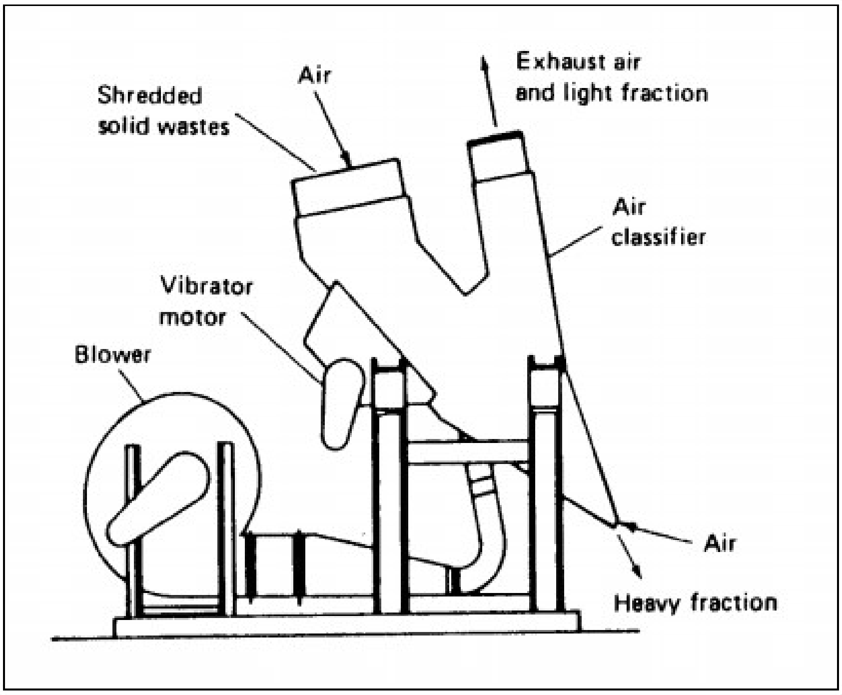


Figure 2.4 Open Inlet Vibrator

In this type of air classifier, the separation is accomplished by a combination of the following actions:

- Vibration: This helps to stratify the material fed to the separator into heavy and light components. Due to this agitation, the heavier particles tend to settle at the bottom as the shredded waste is conveyed down the length of the separator.
- Inertial force: In this action, the air pulled in through the feed inlet imparts an initial acceleration to the lighter particle, while the wastes travel down the separator as they are being agitated.
- Air pressure: This action refers to the injection of fluidizing air in two or more high velocity and low mass flow curtains across the bed. A final stripping of light particles is accomplished at the point where the heavy fraction discharges from the elutriators. It has been reported that the resulting separation is less sensitive to particle size than a conventional vertical air classifier, be it of straight or zigzag design. An advantage ofthis classifier is that an air lock feed mechanism is not required and wastes are fed by gravity directly into the separator inlet.

Selection of air separation equipment

The factors that are to be considered for selecting air separation equipment include the following:

- Characteristics of the material produced by shredding equipment including particle size, shape, moisture content and fiber content.
- Material specification for light fraction.
- Methods of transferring wastes from the shredders to the air separation units and feeding wastes into the air separator.
- Characteristics of separator design including solids-to-air ratio, fluidizing velocities, unit capacity, total airflow and pressure drop.

- Operational characteristics including energy requirement, maintenance requirement, simplicity of operation, proved performance and reliability, noise output, and air and water pollution control requirements.
- Site considerations including space and height access, noise and environmental limitations.

So far, we have studied the separation of solid waste components by air separation. We will next learn about the separation of wastes based on their magnetic properties.

8.3.2 Magnetic separation

The most common method of recovering ferrous scrap from shredded solid wastes involves the use of magnetic recovery systems. Ferrous materials are usually recovered either after shredding or before air classification. When wastes are mass-fired in incinerators, the magnetic separator is used to remove the ferrous material from the incinerator residue. Magnetic recovery systems have also been used at landfill disposal sites. The specific locations, where ferrousmaterials are recovered will depend on the objectives to be achieved, such as reduction of wear and tear on processing and separation equipment, degree of product purity achieved and the required recovery efficiency.

Equipment used for magnetic separation

Various types of equipment are in use for the magnetic separation of ferrous materials. The most common types are the following:

- Suspended magnet: In this type of separator, a permanent magnet is used to attract the ferrous metal from the waste stream. When the attracted metal reaches the area, where there is no magnetism, it falls away freely. This ferrous metal is then collected in a container. Figure 2.5 shows a typical suspended magnet:

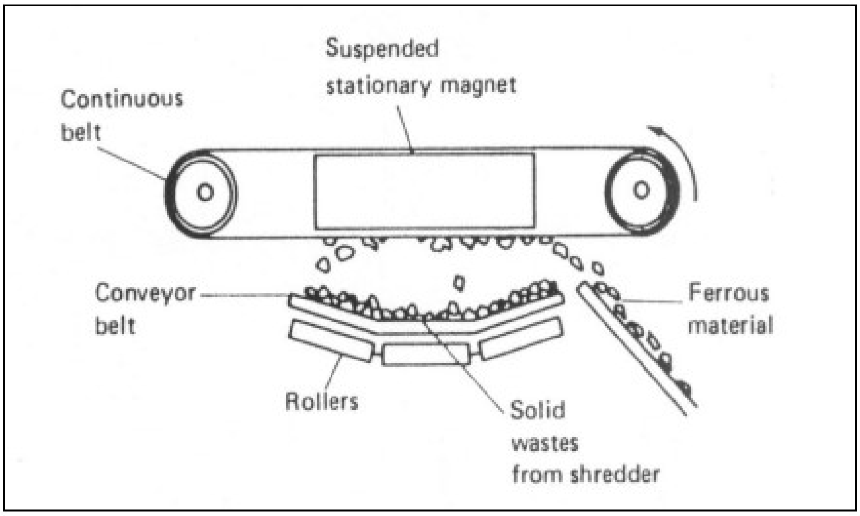


Figure 2.5 Suspended Type Permanent Magnetic Separator

This type of separation device is suitable for processing raw refuse, where separators can remove large pieces of ferrous metal easily from the waste stream.

- Magnetic pulley: This consists of a drum type device containing permanent magnets or electromagnets over which a conveyor or a similar transfer mechanism carries the waste stream. The conveyor belt conforms to the rounded shape of the magnetic drum and the magnetic force pulls the ferrous material away from the falling stream of solid waste. Figure 2.6 illustrates this type of magnetic separator:

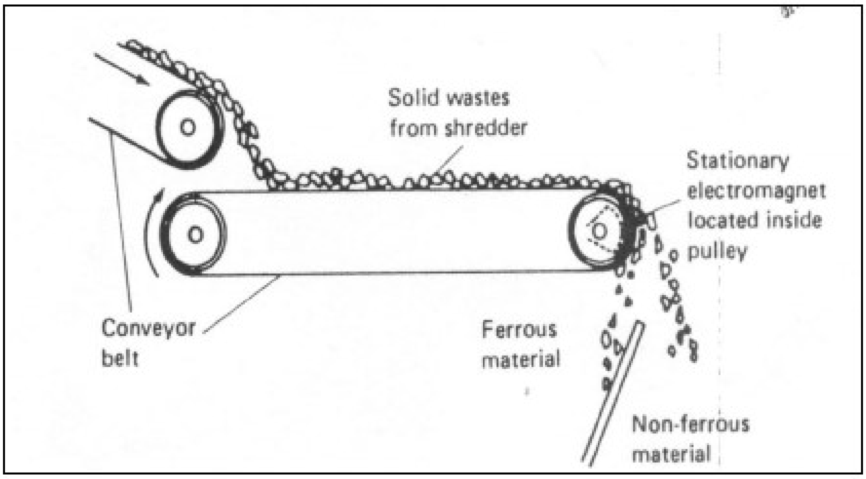


Figure 2.6 Pulley Type Permanent Magnetic Separator

Selection of magnetic separation equipment

We must consider the following factors in the selection of magnetic separation equipment:

- Characteristics of waste from which ferrous materials are to be separated (i.e., the amount of ferrous material, the tendency of the wastes to stick to each other, size, moisture content, etc.)
- Equipment used for feeding wastes to separator and removing the separated waste streams.
- Characteristics of the separator system engineering design, including loading rate, magnet strength, and conveyor speed, material of construction, etc.
- Operational characteristics, including energy requirements, routine and specialized maintenance requirements, and simplicity of operation, reliability, noise output, and air and water pollution control requirements.
- Locations where ferrous materials are to be recovered from solid wastes.
- Site consideration, including space and height, access, noise and environmental limitations.

8.3.3 Screening

Screening is the most common form of separating solid wastes, depending on their size by the use of one or more screening surfaces. Screening has a number of applications in solid waste resource and energy recovery systems. Screens can be used before or after shredding and after air separation of wastes in various applications dealing with both light and heavy fraction materials. The most commonly used screens are rotary drum screens and various forms of vibrating screens. Figures 2.7 shows a typical rotary drum screen:

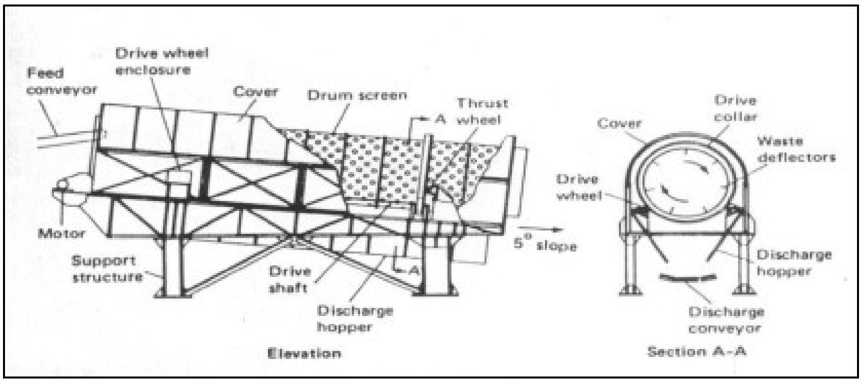


Figure 2.7 Rotary Drum Screen

Note that rotating wire screens with relatively large openings are used for separation of cardboard and paper products, while vibrating screens and rotating drum screens are typically used for the removal of glass and related materials from the shredded solid wastes.

Selection of screening equipment

The various factors that affect the selection of screens include the following:

- Material specification for screened component.
- Location where screening is to be applied and characteristics of waste material to be screened, including particle size, shape, bulk, density and moisture content.
- Separation and overall efficiency.
- Characteristics screen design, including materials of construction, size of screen openings, total surface screening area, oscillating rate for vibrating screens, speed for rotary drum screens, loading rates and length.
- Operational characteristics, including energy requirements, maintenance requirements, and simplicity of operation, reliability, and noise output and air and water pollution control requirements.
- Site considerations such as space and height access, noise and related environmental limitations.

Check your progress

Q1. Define The various factors that affect the selection of screening.

Q2. Illustrate Various types of equipment are in use for the magnetic separation of ferrous materials.

8.4 Waste handling and separation at Commercial and industrial facilities

All waste and recycling generated by a commercial building needs to be stored in appropriate bins or containers with permanent, well-fitting lids. Waste bins and containers should conform to AS 4123 Mobile Waste Containers if the standard is applicable for the selected bin or container type. Waste bins and containers greater than the capacity covered in the Standard (>1,700 L) should be designed to address safety risk. Coloured and labelled bin lids are an important means of correctly identifying what material should go into each bin, therefore replacing or repairing damaged and missing lids should be a priority for those managing the area. Whether they are situated indoors or outdoors, bins should always be in a clean and presentable condition and free of any dirt, accumulated waste or dried liquids. Maintaining bins in a clean and presentable condition will help to encourage appropriate waste and recycling behavior, with users more likely to take care when disposing of waste and avoid or clean up any accidental spills. Waste handling equipment, including balers and compactors, should conform to the relevant design and safety standards. Volume reductions achieved by such compacting and/or baling recyclables and waste offers potentially cost savings through reduced collection requirements

8.4.1 Bin Storage Area– General Considerations

Bin storage areas are where the bins receiving waste and recyclables from across the development are stored. Well-designed bin storage areas eliminate potential issues with conflicting uses of areas as well as minimize the impacts of inappropriately stored bins on local amenity and employee health and safety (Figure 2.8 and Figure 2.9). This is particularly important for commercial operations situated within mixed-use developments. Building and development designs need to incorporate sufficient space to store, in separate bins or containers, the volume of waste and recycling (and potentially organics) likely to be generated during the period between waste collections. Space should also be included for appropriate signage to clearly identify how to use the bins/equipment.

When calculating the likely storage space requirements, consider:

- Waste and recycling generation rates
- Frequency of likely collection
- Suitable waste and recycling storage equipment
- Ability of those depositing waste to access the area
- The likely collection service type, including the access requirements for collection vehicles (such as width and height of gates).

In relation to the design of the storage area, it should have smooth, cleanable and durable floor and wall surfaces that extend up the wall to a height equivalent to any containers held within the area. A further feature could be a bin wash option. It is also suggested that bin storage areas are fitted with doors, gates or roller doors that are durable, self-closing, and lockable and are able to be opened from both inside and outside the storage area. How the bin storage will be serviced is an essential consideration. Bins may be taken and emptied directly from the bin store area, or transported to a separate presentation point where they will be emptied by the service provider. If the storage is located away from the collection point, a responsible individual will be needed to transport separated waste from individual tenancies or areas.

Figure 2.8: Haphazard storage of commercial bins within a rear laneway.

Figure 2.9: Inappropriate and unsafe storage MGBs

8.4.2 Bin Storage Area – Size

The most difficult part of calculating the size of a bin storage area is predicting the collection service that will be needed as businesses expand or as tenancies change. Service requirements should be discussed with waste contractors or consultants and some flexibility needs to be built into the design to provide for future needs. The design of the building can incorporate flexibility by:

- Identifying suitable waste storage and collection point locations that would enable onsite collection in the future
- Keeping waste storage areas clear of potential obstacles that would limit bin size. For example, fixed structures to separate individual bins or bays should be avoided as bin sizes and/or configurations may change

- Designing access paths and doorways greater than the minimum width requirements to allow for potential changes in bin size. For example, installing double doors on a waste storage area would allow easy movement of either MGBs or bulk bins should either system be installed
- Sizing bin storage areas to allow for a potential increase in waste generation from the development, for example, if the building is expanded or its use is changed.

8.4.3 Bin Storage Area – Design

When designing the bin storage area, there are some general consideration, the areas need to:

- Be constructed in accordance with the requirements of the Building Code of Australia
- If enclosed, have a separate ventilation system to comply with AS 1668 – The use of mechanical ventilation and air-conditioning in buildings.

Bin storage areas should not affect the aesthetics of a development and should blend in with the surrounding buildings and landscape (Figure 2.9). Aside from aesthetics, locating storage areas out of sight of the public can reduce the chance of vandalism (as bins are less accessible) and reduce the impact of noise and odour.

Figure 2.9: These bins are easily accessible, but highly visible from the roadway. A bin store would help to minimize their impact on local amenity.

It is essential to provide an adequate area to enable waste and recycling (and organics collected) bins to be kept separate within the storage area (Figure 2.10). However, bin storage areas that are too large may encourage bulky items to be dumped. The storage area should be designed for easy access and maneuvering of bins to allow trouble-free cleaning. It is also important to consider the access requirements for maintenance and servicing. Other services and appliances, such as electrical meter boards, gas meters or conduits, should not be located in bin storage areas as they may be damaged during collection or cleaning.

Figure 2.10: Appropriate storage of bins.

Check your progress

Q1. Define Bin storage areas.

Q2. Illustrate Bin storage area designing in your local municipality.

8.5 Storage of solid waste at the sources.

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. While wastes have little or no value in one setting or to the one who wants to dispose them, the discharged wastes may gain significant value in another setting. Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated/ disposed is, therefore, essential for the design and operation of the functional elements associated with the management of solid wastes.

8.5.1 Source-based classification

Historically, the sources of solid wastes have been consistent, dependent on sectors and activities (Tchobanoglous, et al., 1977), and these include the following:

(i) Residential: This refers to wastes from dwellings, apartments, etc., and consists of leftover food, vegetable peels, plastic, clothes, ashes, etc.
(ii) Commercial: This refers to wastes consisting of leftover food, glasses, metals, ashes, etc., generated from stores, restaurants, markets, hotels, motels, auto-repair shops, medical facilities, etc.
(iii) Institutional: This mainly consists of paper, plastic, glasses, etc., generated from educational, administrative and public buildings such as schools, colleges, offices, prisons, etc.
(iv) Municipal: This includes dust, leafy matter, building debris, treatment plant residual sludge, etc., generated from various municipal activities like construction and demolition, street cleaning, landscaping, etc. (Note, however, in India municipal can typically subsume items at (i) to (iii) above).
(v) Industrial: This mainly consists of process wastes, ashes, demolition and construction wastes, hazardous wastes, etc., due to industrial activities.
(vi) Agricultural: This mainly consists of spoiled food grains and vegetables, agricultural remains, litter, etc., generated from fields, orchards, vineyards, farms, etc.
(vii) Open areas: this includes wastes from areas such as Streets, alleys, parks, vacant lots, playgrounds, beaches, highways, recreational areas, etc.

8.5.2 Type-based classification

Classification of wastes based on types, i.e., physical, chemical, and biological characteristics of wastes, is as follows (Phelps, et al., 1995):

(i) Garbage: This refers to animal and vegetable wastes resulting from the handling, sale, and storage, preparation, cooking and serving of food. Garbage comprising these wastes contains putrescible (rotting) organic matter, which produces an obnoxious odour and attracts rats and other vermin. It, therefore, requires special attention in storage, handling and disposal.
(ii) Ashes and residues: These are substances remaining from the burning of wood, coal, charcoal, coke and other combustible materials for cooking and heating in houses, institutions and small industrial establishments. Whenproduced in large quantities, as in power-generation plants and factories, these are classified as industrial wastes. Ashes consist of fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass. Since ashes and residues are almost entirely inorganic, they are valuable in landfills.
(iii) Combustible and non-combustible wastes: These consist of wastes generated from households, institutions, commercial activities, etc., excluding food wastes and other highly putrescible material. Typically, while combustible material consists of paper, cardboard, textile, rubber, garden trimmings, etc., non-combustible material consists of such items as glass, crockery, tin and aluminum cans, ferrous and non-ferrous material and dirt.
(iv) Bulky wastes: These include large household appliances such as refrigerators, washing machines, furniture, crates, vehicle parts, tires, wood, trees and branches. Since these household wastes cannot be accommodated in normal storage containers, they require a special collection mechanism.
(v) Street wastes: These refer to wastes that are collected from streets, walkways, alleys, parks and vacant plots, and include paper, cardboard, plastics, dirt, leaves and other vegetable matter. Littering in public places is indeed a widespread and acute problem in many countries including India, and a solid waste management system must address this menace appropriately.
(vi) Biodegradable and non-biodegradable wastes: Biodegradable wastes mainly refer to substances consisting of organic matter such as leftover food, vegetable and fruit peels, paper, textile,

wood, etc., generated from various household and industrial activities. Because of the action of micro-organisms, these wastes are degraded from complex to simpler compounds. No biodegradable wastes consist of inorganic and recyclable materials such as plastic, glass, cans, metals, etc. Table 2.1 below shows a comparison of biodegradable and non-biodegradable wastes with their degeneration time, i.e., the time required to break from a complex to a simple biological form:

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

Table 2.1 Biodegradable and Non-Biodegradable Wastes: Degeneration Time

From Table 2.1, we can easily deduce the environmental consequences associated with non-biodegradable wastes such as plastics, glass, etc.

(vii) Dead animals: With regard to municipal wastes, dead animals are those that die naturally or accidentally killed on the road. Note that this category does not include carcasses and animal parts from slaughter-houses, which are regarded as industrial wastes. Dead animals are divided into two groups – large and small. Among the large animals are horses, cows, goats, sheep, pigs, etc., and among the small ones are dogs, cats, rabbits, rats, etc. The reason for this differentiation is that large animals require special equipment for lifting and handling when they are removed. If not collected promptly, dead animals pose a threat to public health since they attract flies and other vermin as they decay. Their presence in public places is particularly offensive from the aesthetic point of view as well.

(viii) Abandoned vehicles: This category includes automobiles, trucks and trailers that are abandoned on streets and other public places. However, abandoned vehicles have significant scrap value for their metal, and their value to collectors is highly variable.

(ix) Construction and demolition wastes: These are wastes generated as a result of construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. They consist mainly of earth, stones, and concrete, bricks, lumber, roofing and plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream.

(x) Farm wastes:These wastes result from diverse agricultural activities such as planting, harvesting, production of milk, rearing of animals for slaughter and the operation of feedlots. In many areas, the disposal of animal waste has become a critical problem, especially from feedlots, poultry farms and dairies.

(xi) Hazardous wastes: Hazardous wastes are those defined as wastes of industrial, institutional or consumer origin that are potentially dangerous either immediately or over a period of time to human beings and the environment. This is due to their physical, chemical and biological or radioactive characteristics like ignitability, corrosively, reactivity and toxicity. Note that in some cases, the active agents may be liquid or gaseous hazardous wastes. These are, nevertheless, classified as solid wastes as they are confined in solid containers. Typical examples of hazardous wastes are empty containers of solvents, paints and pesticides, which are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous wastes may cause explosions in incinerators and fires at landfill sites. Others such as pathological wastes from hospitals and radioactive wastes also require special handling. Effective management practices should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them harmless.

(xii) Sewage wastes: The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derived from the treatment of organic sludge separated from both raw and treated sewages. The inorganic fraction of raw sewage such as grit and eggshells is separated at the preliminary stage of treatment, as it may entrain putrescible organic matter with pathogens and must be buried without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but is invariably uneconomical. Solid sludge, therefore, enters the stream of municipal wastes, unless special arrangements are made for its disposal.

Table 2.2 below summarizes our discussion of waste classification based on sources of generation and their types:

	Type	Description	Sources
Solid Wastes	Garbage	Food waste: wastes from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meat.	Households, institutions and commercial concerns such as hotels, stores, restaurants, markets, etc.
	Combustible and non–combustible	Combustible (primary organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings, etc.	
		Non-combustible (primary inorganic) metals, tin, cans, glass bottles, crockery, stones, etc.	
	Ashes	Residue from fires used for cooking and for heating building cinders	
	Bulky wastes	Large auto parts, tyres, stoves, refrigerators other large appliances, furniture, large crates, trees, branches, stumps, etc.	Streets, sidewalks, alleys, vacant lots, etc.
	Street wastes	Street sweepings, dirt, leaves, etc.	
	Dead animals	Dogs, cats, rats, donkeys, etc.	
	Abandoned vehicles	Automobiles and spare parts	
	Construction and demolition wastes	Roofing, and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc.	Construction and demolition sites.
	Industrial wastes	Solid wastes resulting from industry processes and manufacturing operations, such as, food processing wastes, boiler house cinders, wood, plastic and metal scraps, shavings, etc	Factories, power plants, etc.
	Hazardous wastes	Pathological wastes, explosives, radioactive materials, etc.	Households, hospitals, institutions, stores, industry, etc.
	Animal and agricultural wastes	Manure, crop residues, etc.	Livestock, farms, feedlots and agriculture
	Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

Table 2.2 Classification of Solid Wastes

8.6 Review Questions

Q1. Define biodegradable & non biodegradable waste.

Q2. What are Hazardous wastes.

Q3. Illustrate sewage waste in local Municipal Corporation.

UNIT-IX Processing of Solid Waste

Structure

9.0 Introduction

Management of solid waste may be defined as the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes based on scientific principles. This includes all technological, financial, institutional and legal aspects involved to solve the whole spectrum of issues related solid wastes. The SWM processes differ depending on factors such as socio-economic status, degree of industrialization, social development (e.g., education, literacy, healthcare etc.), life style and quality of life of a location. In addition regional, seasonal and economic differences influence the SWM processes.

The Processing of solid waste is biggest challenge in India .quantity of MSW generated is increasing rapidly due to increasing population and change in lifestyle. The current MSW crisis should be approached holistically; while planning for long term solutions, focus on the solving the present problems should be maintained. The Government and local authorities should work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. While this is being achieved and recycling is increased, provisions should be made to handle the non-recyclable wastes that are being generated and will continue to be generated in the future. Policy to include waste-pickers in the private sector must be introduced to utilize their low cost public and environmental service and to provide better working conditions to these marginalized populations

Objectives

After studying this unit you should be able to:

- Processing of solid waste at residence
- Processing of solid waste at Commercial and industrial site.

9.1 Processing of solid waste at residence

Management of solid waste may be defined as the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes based on scientific principles. This includes all technological, financial, institutional and legal aspects involved to solve the whole spectrum of issues related solid wastes. The SWM processes differ depending on factors such as socio-economic status, degree of industrialization, social development (e.g., education, literacy, healthcare etc.), life style and quality of life of a location. In addition regional, seasonal and economic differences influence the SWM processes. There are various functional elements associated with the management of solid wastes such as segregation, collection, processing and disposal.

(i) Major Functional Elements

Waste generation: Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted into goods for consumption. The source of waste generation determines quantity, composition and waste characteristics.

Waste storage: Storage of waste after collection and before transportation to the processing/disposal site is an important functional component. The time of storage depends on the type of waste. For example, the biodegradable waste cannot be stored for long in a storage container because of its putrescible nature. There are many options for storage like plastic containers, conventional dustbins (of households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc.

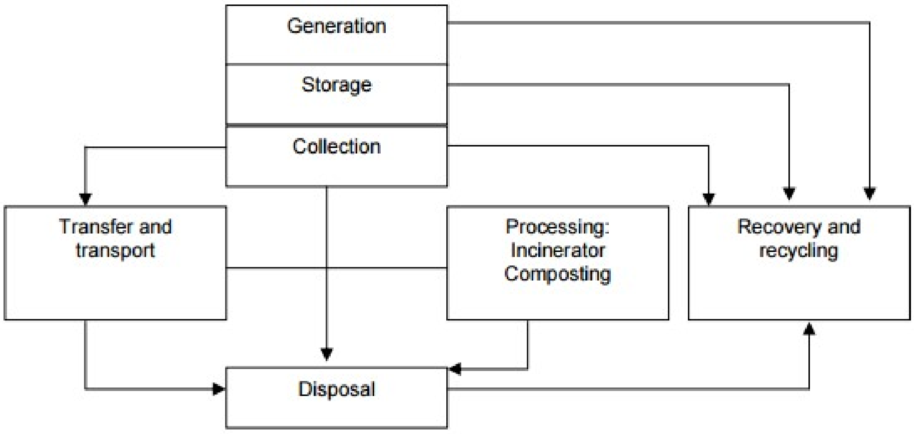
Waste collection: Collection refers to mainly two aspects; collection from the source of generation to the next collection point and collection from that point to the large vehicles for transportation or to the transfer stations and finally to the processing plant/disposal area. Collection depends on the number of containers, frequency of collection, types of collection services and routes. Collection is done either directly through the municipal services to franchised services or contracts. Recently, collection of waste from the source to the next step is carried out by Self Help Groups (SHGs) in many cities in India, which is very common in the state of Kerala.

Transfer and transport: This functional element involves:

- The transfer of wastes from smaller collection vehicles to larger ones at transfer stations.
- The subsequent transport of the waste to disposal sites

Processing: Processing of waste is the most important functional component of SWM system, which leads to various types of resource recovery, recycling, energy generation, production of organic manure, etc.

Disposal of final rejects: Disposal of final rejects after resource recovery is one of the important functional components of SWM system. This is mainly achieved through construction of engineered sanitary landfill. Engineering principles are followed to confine the wastes to the smallest possible area, reduce them to the lowest particle volume by compaction at the site and cover them after each day’s operation to reduce exposure to vermin



Flow chart of a typical SWM system with its functional elements and linkages

(ii) Factors to be considered in SWM planning

There are many factors influencing the SWM planning (Phelps et al., 1995), such as:

Quantity and characteristics of wastes: The quantity of wastes generated generally depends on the income level of a family, as higher income category tends to generate larger quantity of wastes, compared to low-income category. The quantity ranges from about 0.25 to about 0.65 kg per person per day, indicating a strong correlation between waste production and per capita income. One of the measures of waste composition (and characteristics) is density, which ranges from 150 kg/m3 to 600 kg/m3 . Proportion of paper and packaging materials in the waste largely account for the differences. When this proportion is high, the density is low and vice versa. The wastes of high density reflect a relatively high proportion of organic matter and moisture and lower levels of recycling.

Climate and seasonal variations: Climate has a major influence in SWM planning. In cold climates, drifting snow and frozen ground interfere with landfill operations, and therefore, trenches must be dug in summer and cover material stockpiles for winter use. Tropical climates, on the other hand, are subject to sharp seasonal variations from wet to dry season, which cause significant changes in the moisture content of solidwaste, varying from less than 50% in dry season to greater than 65% in wet months. Collection and disposal of wastes in the wet months are often problematic. High temperatures and humidity cause solid wastes decompose far more rapidly than in colder climates.

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 possible, door-to-door collection of solid wastes is comparatively easy using large compactor vehicle or smaller vehicle. Added to this is the problem of urban sprawl in the outskirts (of the cities) where population is growing at an alarming rate. Problems of solid waste storage and collection are most acute in such areas.

Management and technical resources: Solid waste management, to be successful, requires wide spectrum of work force in keeping with demands of the system. The best system for a region is one which makes full use of indigenous crafts and professional skills and/or ensures that training programs are in place to provide a self-sustaining supply of trained work force.

9.2 Processing of solid waste at Commercial and industrial site.

Commercial wastes are those produced from businesses such as food and drink establishments, shops, banks and by public administration offices. These wastes contain similar materials to residential waste, although the proportions may vary. For example, a restaurant will produce more food waste than a normal household and an insurance office will produce more paper and less food waste.

There are also many industrial facilities in Ethiopia that process agricultural products such as cotton, flour, hides and skins. Other important industries include plastic and resin manufacturing, textiles, cement, metallurgical, foods, general chemicals and pharmaceuticals. All these industries manufacture useful products and contribute to the country's economy but, at the same time, they can also be a major contributor to the country's solid waste and pollution problems.

The composition of the waste produced by industry depends very much on the nature of the industry concerned. For example, animal hide processing produces large amounts of biodegradable waste (animal parts), while the construction industry produces a lot of excavated soil, rock and demolition waste (bricks, stones, wood, glass, etc.). For this reason, industrial waste is usually processed and disposed of by the industry itself, often using specialized technologies. As explained in previous section, these wastes can be classed as either hazardous or non-hazardous depending on the inherent dangers associated with their physical and chemical properties.

Industrial and commercial organizations only produce a small proportion of a city's waste. Because of this, less attention is given to these wastes and the amounts produced are not known accurately. However, for urban WASH workers, it is useful to understand the characteristics of the solid waste generated from these sources in order to:

- advise workers on the potential health and environmental hazards of handling the solid waste
- give advice on the transportation, treatment, and disposal systems needed
- develop precautions and procedures to protect people during collection and disposal
- Understand and determine which of the solid wastes generated in any particular industry can be managed along with the household and commercial wastes.

9.4 REVIEW QUESTIONS

Q1.Define the processing of Commercial wastes are those produced from businesses such as food and drink establishments, shops, banks and by public administration offices.

Q2. Examine the industrial waste processing in your city.

BLOCK -III

Collection, Handling, Segregation, Storage and processing of Solid Waste

UNIT-VII

Collection of solid waste

UNIT-VIII

Waste handling and segregation

UNIT-IX

Processing of Solid Waste

Block-VII Collection, Handling, Segregation, Storage and processing of Solid Waste

Solid wastes may be defined as useless, unused, unwanted, or discarded material available in solid form. Semisolid food wastes and municipal sludge may also be included in municipal solid waste. The subject of solid wastes came to the national limelight after the passage of the solid waste disposal act of 1965. Today, solid waste is accepted as a major problem of our society. In the United States, over 180 million tons of municipal solid waste (MSW) was generated in 1988. At this generation quantity, the average resident of an urban community is responsible for more than 1.8 kg (4.0 lbs.) of solid waste per day. This quantity does not include industrial, mining, agricultural, and animal wastes generated in the country each year. If these quantities are added, the solid waste production rate reaches 45 kg per capita per day (100 lb. /c.d.). To introduce the reader to the solid waste management field, an overview of municipal solid waste problems, sources, collection, resource recovery, and disposal methods are presented in this paper. Greater emphasis has been given to the design and operation of municipal sanitary landfills, regulations governing land disposal, and leachate generation, containment and treatment methods.Municipal solid waste (MSW) includes wastes such as durable goods, nondurable goods, containers and packaging, food wastes yard wastes, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. Example of waste from these categories include appliances, newspapers, clothing, food scarps, boxes, disposable tableware, office and classroom paper, wood pallets, and cafeteria wastes. MSW does not include wastes from sources such as municipal sludge, combustion ash, and industrial non-hazardous process wastes that might also be disposed of in municipal waste landfills or incinerators. Determining actual MSW generation rates is difficult. Different studies report a wide variation as they use different components. Many times industrial and demolition wastes are included in municipal solid wastes.In your study, you will find that the every unit has different equal length and your study time will vary for each unit.

We hope you enjoy studying the material and once again wish you all the best for your success.

UNIT-VII Collection of solid waste

Structure

7.0 Introduction

To introduce the reader to the solid waste management field, an overview of municipal solid waste problems, sources, collection, resource recovery, and disposal methods are presented in this paper. Greater emphasis has been given to the design and operation of municipal sanitary landfills, regulations governing land disposal, and leachate generation, containment and treatment methods. Municipal solid waste (MSW) includes wastes such as durable goods, nondurable goods, containers and packaging, food wastes yard wastes, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. In this chapter we learn about Methods of Collection, types of vehicles, materials used for containers, Manpower requirement, collection routes, transfer stations, selection of location, operation & maintenance, options under Indian conditions

A successful solid waste management system utilizes many functional elements associated with generation, on-site storage, collection, transfer, transport, characterization and processing, resource recovery and final disposal [4]. All these elements are interrelated, and must be studied and evaluated carefully before any solid waste management system can be adapted. It is a multidisciplinary activity involving engineering principles, economics, and urban and regional planning.

Objectives

After studying this unit you should be able to understand SOURCES AND CHARACTERISTICS of Municipal solid waste (MSW) or urban solid waste which is normally comprised of food wastes, rubbish, demolition and construction wastes, street sweepings, garden wastes, abandoned vehicles and appliances, and treatment plant residues. Quantity and composition of MSW vary greatly for different municipalities and time of the year. Factors influencing the characteristics of MSW are climate, social ,customs, per capita income, and degree of urbanization and industrialization. The composition of MSW as collected may vary greatly depending upon geographical region and season. The typical moisture content of MSW may vary from 15 to 40 percent depending upon the composition of the waste and the climatic conditions. The density of MSW depends upon the composition and degree of compaction. The uncompacted density of MSW is around "150 kg/m^3(250 lb. /yd^3)."The density of collected solid waste is "235-350 kg/m^3."The energy content of MSW as collected is "9,890 kJ/kg (4,260 BTU/lb.)". Information of chemical composition of the organic portion of MSW is important for many processes such as incineration, composting, biodegradability, leachate generation, and others. The ultimate analysis of the organic fraction of MSW is in terms of the constituents carbon, hydrogen, oxygen, nitrogen, sulfur and ash .**The major objectives are to learn about:**

- Methods of Collection
- Types of vehicles
- Materials used for containers
- Manpower requirement
- Collection routes
- Transfer stations
- Selection of location
- Operation & maintenance
- Options under Indian conditions.

7.1 Methods of Collection

a) Hauling of Solid Waste.

It shall be unlawful for any collector or person to transport solid waste except in a covered, watertight and drip-proof vehicle equipped with a metal box with welded seams; provided, however, that dry solid waste or tightly bagged garbage may be conveyed in suitable containers and vehicles with appropriate coverings which keep the contents from escaping.

(b) Solid Waste Collection.

- Solid waste collection shall be required by all residential dwelling units. It shall be the responsibility of the owner or occupant of any residential dwelling unit to apply for solid waste collection services. The city public works department, sanitation collection division, shall be the sole, exclusive solid waste collection service for all residential dwelling units, including but not limited to single-family dwellings, multiple-family dwellings, townhouses, apartment complexes and trailer parks. Collection of household solid waste generated at a residential dwelling unit by a solid waste collector other than the city public works department, sanitation collection division must be approved through a formal agreement between the city and the solid waste collector. Collection and hauling of household hazardous waste, white goods, recyclables and other solid wastes which are not household solid waste shall be the responsibility of the residential dwelling unit owner or occupant.
- Owners or occupants of residential dwelling units may haul and deliver to the municipal landfill household solid waste generated from their residential dwelling unit; however, such hauling and delivery shall not reduce the solid waste collection fees owed to the city.
- Commercial accounts may use their own equipment and their own employees to collect and haul solid waste generated by the business to the municipal landfill or contract solid waste collection services to the city of Ketchikan public works department, sanitation collection division. Collection of commercial solid waste by a solid waste collector other than the city public works department, sanitation collection division must be approved through a formal agreement between the city and the solid waste collector.
- Collection Schedule.
    - All solid waste shall be collected and disposed of at intervals determined by the director of public works or his designee.
    - Residential dwelling units shall have a minimum of weekly service unless otherwise determined by the director of public works or his designee.
    - Cafes, restaurants and other establishments serving food; commercial business; industrial businesses, and all other establishments shall have a level of service that does not create a public nuisance or health hazard as determined by the director of public works or his designee.
    -

(c) Solid Waste Collection Fees.

- Solid Waste Collection Fee for Residential Accounts. All residential accounts can be assessed and charged a solid waste collection fee per month for the collection of household solid waste. The owner of the residential dwelling unit shall be responsible for solid waste collection fees which are not paid by the occupant.

- Solid Waste Collection Fee for Commercial Accounts. Unless otherwise negotiated and agreed to by the city, commercial accounts for which the city provides solid waste collection services shall be charged the fees per month, whichever is greater.

  $3.41 per can per pickup

  $22.74 per cubic yard container

  $34.10 per one-and-one-half-cubic-yard container

  $45.47 per two-cubic-yard container

Solid waste collection fees for commercial accounts shall include the cost for disposal. Multiple residential dwelling unit complexes which have established commercial accounts for collection and disposal of household solid waste shall be eligible for a solid waste residential credit times the number of cans of residential solid waste collected from the residential dwelling units. The credit shall represent disposal costs for household solid waste paid for through the community solid waste disposal fee identified in KMC 7.16.070(d). The solid waste residential credit application, terms and conditions shall be subject to approval by the city public works and city finance departments. The solid waste residential credit shall be posted on a monthly basis, in arrears, and shall be based on the number of multiple residential units listed in the application for the solid waste residential credit on file with the city finance department.

- **Solid Waste Collection Billings.**
  - Billings for residential accounts will be mailed or delivered to the same name and address as appears on the residential electrical account serving the residence, except for instances when two or more dwelling units are served by one electrical account or if the residential dwelling unit does not receive electrical service, in which case each residential dwelling unit will be billed separately. Billing for household solid waste collection services shall be on a monthly basis, commencing with the date of residential dwelling occupancy or beginning date of the residential unit's electrical account, whichever is earlier. Failure to receive a bill does not relieve the owner/occupant of responsibility for the charges.
  - The city manager is authorized to negotiate special billing rates, terms and conditions for the collection of commercial accounts.
  - All monthly bills for services rendered are due and payable within 25 days after the billing date, and if not paid, become delinquent and the account shall be deemed in default. Accounts in default shall be assessed a penalty of five percent. Billings delinquent in excess of 120 days may be turned over to a collection agency.
  - In the event of overcharges or undercharges for solid waste collection services, adjustments will be limited to the most recent six-month period prior to discovery and notification of the error.

- Vacant residential dwelling units shall not be charged solid waste collection fees. Vacant residential dwelling units shall not mean a residential dwelling unit unoccupied due to vacations or extended absences.

7.2 Types of vehicles

A waste collection vehicle is more generally known as garbage truck and dustbin lorry. These trucks are used for picking up waste and then moving it to landfills or other places where waste materials are managed and treated. You can have their view mostly in urban areas. Most of the time Garbage cart is mistaken as dump truck.

Almost all collections are based on collector and collection crew, which move through the collection service area with a vehicle for collecting the waste material. The collection vehicle selected must be appropriate to the terrain, type and density of waste generation points, the way it travels and type and kind of material (UNEP, 1996). It also depends upon strength, stature and capability of the crew that will work with it. The collection vehicle may be small and simple (e.g., two-wheeled cart pulled by an individual) or large, complex and energy intensive (e.g., rear loading compactor truck). The most commonly used collection vehicle is the dump truck fitted with a hydraulic lifting mechanism. A description of some vehicle types follows:

(iv) Small-scale collection and muscle-powered vehicles: These are common vehicles used for waste collection in many countries and are generally used in rural hilly areas. As Figure 1.1 illustrates, these can be small rickshaws, carts or wagons pulled by people or animals, and are less expensive, easier to build and maintain compared to other vehicles:

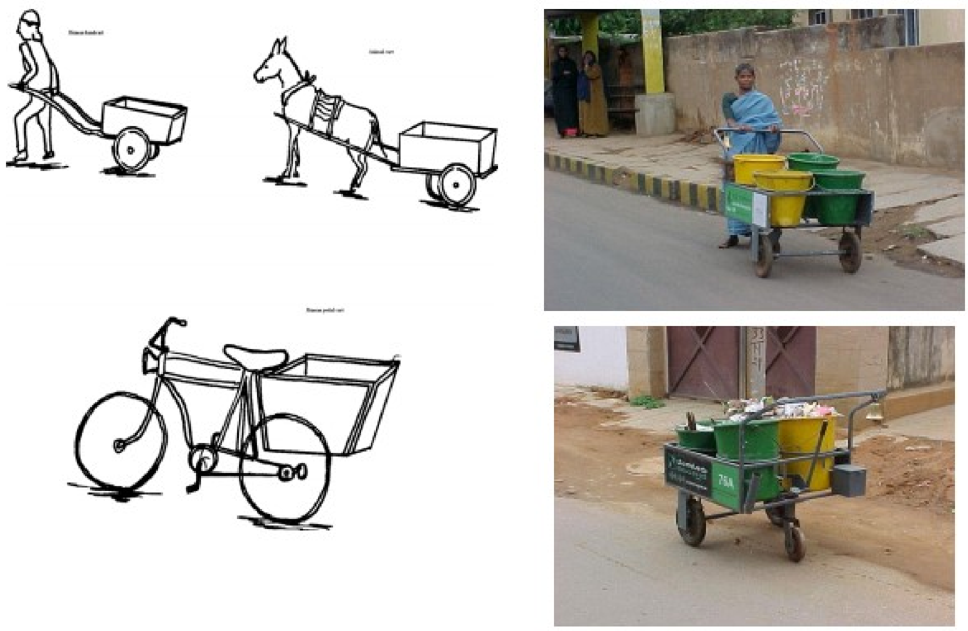


Figure 1.1 Small-scale Collection Vehicles: An Illustration

They are suitable for densely populated areas with narrow lanes, and squatter settlements, where there is relatively low volume of waste generated. Some drawbacks of these collection vehicles include limited travel range of the vehicles and weather exposure that affect humans and animals.

(v) Non-compactor trucks: Non-compactor trucks are efficient and cost effective in small cities and in areas where wastes tend to be very dense and have little potential for compaction. Figure 1.2 illustrates a non-compactor truck:

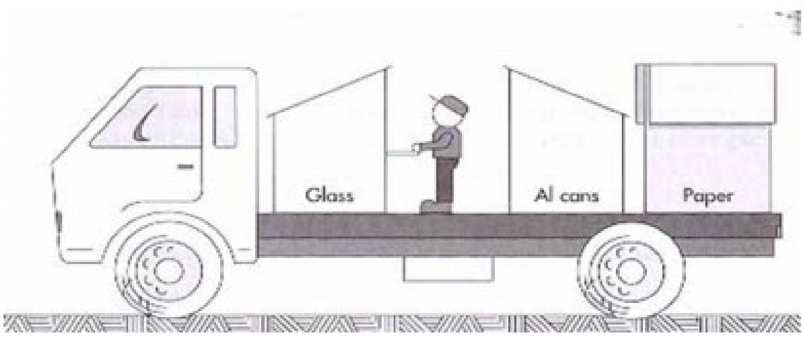
Figure 1.2 Non-compactor Trucks

When these trucks are used for waste collection, they need a dumping system to easily discharge the waste. It is generally required to cover the trucks in order to prevent residue flying off or rain soaking the wastes. Trucks with capacities of 10 – 12 m^3 are effective, if the distance between the disposal site and the collection area is less than 15 km. If the distance is longer, a potential transfer station closer than 10 km from the collection area is required. Non-compactor trucks are generally used, when labor cost is high. Controlling and operating cost is a deciding factor, when collection routes are long and relatively sparsely populated.

(vi) Compactor truck: Compaction vehicles are more common these days, generally having capacities of 12 – 15 m^3 due to limitations imposed by narrow roads. Although the capacity of a compaction vehicle, illustrated in Figure 1.3, is similar to that of a dump truck, the weight of solid wastes collected per trip is 2 to 2.5 times larger since the wastes are hydraulically compacted:

Figure 1.3 Compactor Truck

The success of waste management depends on the level of segregation at source. One of the examples for best collection method is illustrated in the figure below



A compactor truck allows waste containers to be emptied into the vehicle from the rear, front or sides and inhibits vectors (of disease) from reaching the waste during collection and transport. It works poorly when wastestream is very dense, wet, collected materials are gritty or abrasive, or when the roads are dusty. The advantages of the compactor collection vehicle include the following:

- containers are uniform, large, covered and relatively visually inoffensive;
- waste is set out in containers so that the crew can pick them up quickly;
- health risk to the collectors and odor on the streets are minimized;
- Waste is relatively inaccessible to the waste pickers.

Check your progress

Q1. Define methods of collection processes of Municipal Corporation.

Q2. Illustrate the types of vehicle used in local municipality.

7.3 Materials used for containers

The design of an efficient waste collection system requires careful consideration of the type, size and location of containers at the point of generation for storage of wastes until they are collected. While single-family households generally use small containers, residential units, commercial units, institutions and industries require large containers. Smaller containers are usually handled manually whereas the larger, heavier ones require mechanical handling. The containers may fall under either of the following two categories:

(iii) Stationary containers: These are used for contents to be transferred to collection vehicles at the site of storage.

(iv) Hauled containers: These are used for contents to be directly transferred to a processing plant, transfer station or disposal site for emptying before being returned to the storage site.

The desirable characteristics of a well-designed container are low cost, size, weight, shape, resistance to corrosion, water tightness, strength and durability (Phelps, et al., 1995). For example, a container for manual handling by one person should not weigh more than 20 kg, lest it may lead to occupational health hazards such as muscular strain, etc. Containers that weigh more than 20 kg, when full, require two or more crew members to manually load and unload the wastes, and which result in low collection efficiency. Containers should not have rough or sharp edges, and preferably have a handle and a wheel to facilitate mobility. They should be covered to prevent rainwater from entering (which increases the weight and rate of decomposition of organic materials) into the solid wastes. The container body must be strong enough to resist and discourage stray animals and scavengers from ripping it as well as withstand rough handling by the collection crew and mechanical loading equipment. Containers should be provided with a lifting bar, compatible with the hoisting mechanism of the vehicle. The material used should be light, recyclable, easily moulded and the surface must be smooth and resistant to corrosion. On the one hand, steel and ferrous containers are heavy and subject to corrosion; the rust peels off exposing sharp edges, which could be hazardous to the collection crew. On the other, wooden containers (e.g., bamboo, rattan and wooden baskets) readily absorb and retain moisture and their surfaces are generally rough, irregular and difficult to clean.

Communal containers

Generally, the containers used for waste storage are communal/public containers. Figure 1.4 below shows a typical communal container, which a compactor collection vehicle can lift and empty mechanically:

Figure 1.4 Typical Communal Container

The use of communal containers is largely dependent on local culture, tradition and attitudes towards waste. Communal containers may be fixed on the ground (stationary) or movable (hauled). Movable containers are provided with hoists and tails compatible with lifting mechanism of collection vehicles and such containers have capacities of 1 – 4 m^3. The waste management authority must monitor, maintain and upgrade the communal containers. Note that in residential and commercial areas in India, the communal containers are often made of concrete.

In areas with very high waste generation rates, i.e., rates exceeding two truckloads daily, such as wet markets, large commercial centers and large business establishments, roll-on-roll or hoisted communal containers with capacities of 12 – 20 m^3 and a strong superstructure with wheels are used. Normally, the collection vehicle keeps an empty container as a replacement before it hauls the filled container. When a truck is used as a collection vehicle, the use of communal containers may be appropriate. It is advisable to place the containers 100 – 200 m apart for economic reasons. The communal containers are usually staggered such that the effective distance of 100 m is maintained as shown in Figure 1.5:

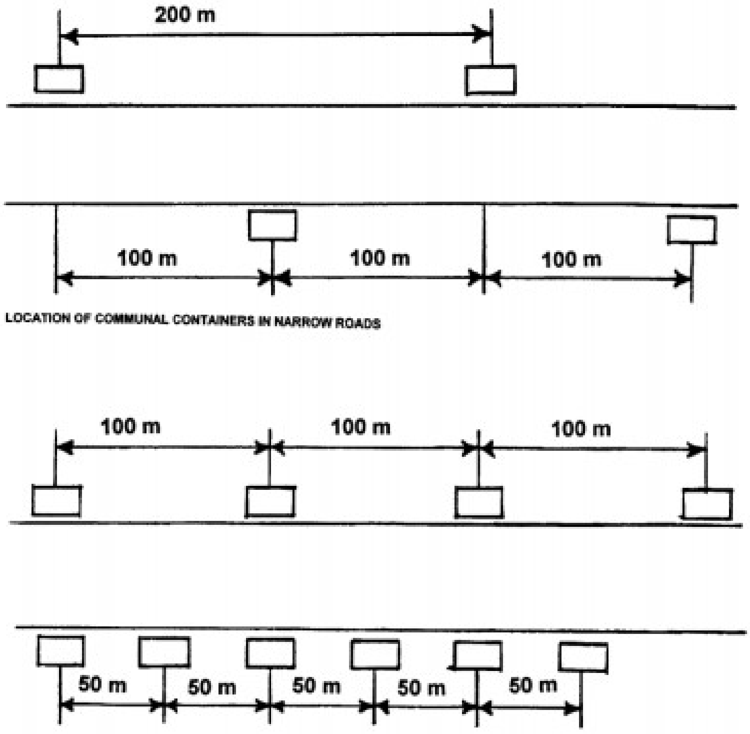


Figure 1.5: Location of Communal Container

This means that the farthest distance the householder will have to walk is 50 meters. However, in narrow streets with low traffic, where the house owner can readily cross the street, a longer distance is advisable. If the collection vehicle has to stop frequently, say, at every 50 m or so, fuel consumption increases, and this must be avoided.

Disadvantages

The major disadvantage of communal containers is the potential lack of maintenance and upgrading. The residuals and scattered solid wastes emit foul odors, which discourage residents from using the containers properly. In addition, if fixed containers are built below the vehicle level, the collection crew may be held responsible for sweeping and loading the solid wastes into transfer containers before being loaded into the collection vehicle. Sweeping and cleaning the communal containers of residuals obviously impinge on the time of the crew members and take a longer time than if the wastes are placed in smaller containers. As fixed communal containers have higher rates of failure, their use is not advisable.

To overcome the problem of maintaining communal containers, individual residents should maintain their own containers and locate them in designated areas. The communal area must have water and drains to facilitate the cleaning of the containers. This practice has the advantage of reducing the number of collection stops and at the same time maintaining the householder's responsibility for cleaning them. The residents must also be properly educated on the importance of good housekeeping as the containers in the communal area are subject to vandalism. In the main, if communal containers are to be successful, the design of the containers, loading and unloading areas, and collection vehicle accessories should be coordinated.

7.4 Manpower requirement

The organizational and administrative structure for municipal solid waste management in a city depends upon the size of the municipal agency. Landfilling activity should be the responsibility of an independent sectional authority which should report directly to the Director/Chief Engineer/Head of Solid Waste Management. A senior engineer should be incharge of landfilling activity. He should be supported by assistant engineer(s), junior engineer(s), foremen, technicians and workers. The level of the engineer incharge will be dependent on the scale of work (i.e. waste received at the landfill and the following is recommended.

Waste Received at Landfill (tons/day)	Engineer Incharge of Landfilling
Upto 200	Junior Engineer
200 to 500	Assistant Engineer
500 to 1000	Executive Engineer
Above 1000	Superintending Engineer

Check your progress

Q1. Define the types of containers for collection of waste substance around local municipality.

Q2. Explain the disadvantage of communal container.

7.5 Collection routes

In previous Section, we introduced you to different types of containers and collection vehicles. We now discuss the movement of collection crew in terms of workforce efficiency and collection routes.

7.5.1 Movement of collection crew

In cultures such as India, Bangladesh, etc., solid waste collection is assigned to the lowest social group. More often, the collection crew member accepts the job as a temporary position or stopgap arrangement, while looking for other jobs that are considered more respectable. Apart from this cultural problem, the attitude of some SWM authorities affects collection operation. For example, some authorities still think that the collection of solid waste is mechanical, and therefore, the collection crew does not need any training to acquire special skills. As a result, when a new waste collector starts working, he or she is sent to the field without firm instruction concerning his or her duties, responsibilities and required skills. For an effective collection operation, the collection team must properly be trained. The collection crew and the driver of the collection vehicle must, for example, work as a team, and this is important to maintain the team morale and a sense of social responsibility among these workers. You must also note that the movement of collection crew, container location and vehicle stopping point affect collection system costs. Figure 1.6 highlights the distance the collection crew will have to walk, if it were to serve the farthest point first or serve the point closest to the vehicle:

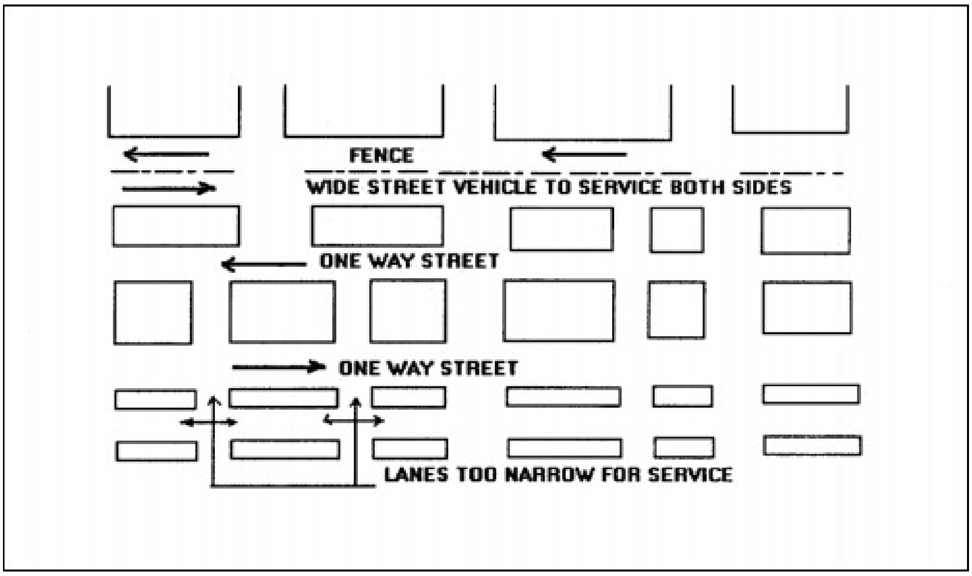


Figure 1.6 Effect of Container Location and Vehicle Stopping

The difference may be one or two minutes per collection stop, but it matters with the number of stops the crew will take in a working shift. Multiplying the minutes by the total number of crew working and labor cost depicts the amount of labor hours lost in terms of monetary value. Generally, familiarity of the crew with the collection area improves efficiency. For example, the driver becomes familiar with the traffic jams, potholes and other obstructions that he or she must avoid. The crew is aware of the location of the containers and the vehicle stops. It is, therefore, important to assign each crew specific areas of responsibility. Working together also establishes an understanding of the strong and weak points of the team members and efficient work sequences. The collection operation must also observe a strict time schedule. Testing of new routes, new gadgets and vehicles is best carried out first in the laboratory and later in a pilot area. Testing of a new sequence using the whole service area could result in disorder and breakdown of the solid waste collection system. Studies show that it takes two hours to recover for every hour of a failed system.

Motion time measurement (MTM) technique

Motion time measurement (MTM) studies are now an integral part of the standard procedure in the development of solid waste collection systems. MTM is a technique to observe and estimate the movement of the collection crew with the help of stopwatches. The results thus gathered are tabulated as shown in Table 1.1 to determine the best sequence of activities that workers must follow in order to complete a repetitive task in the shortest possible time:

	Time		**Odometer (Km)**	**Number of Containers**	**Collection time (Minute Second)**	**Trip time to next Station**
	Arrival	**Departure**				
Garage 1 Station 2 Station . . . 20 Station Last Station Disposal Site Total	:: :: :: :: :: :: :: :: ::	:: :: :: :: :: :: :: :: ::				
Weight	With Load tonne		With Load tonne		With Load tonne	

Source: Phelps, et al., 1995

Table 1.1 MTM Study: Determination of Time, Distance and Number on Containers in Collection Route

MTM also helps in deciding the best combination of equipment to maintain a desired level of output, reduce health problems related to the repetitive work sequence and predict the effects of changes in materials handled. Sophisticated MTM studies involve hidden or open video cameras at different collection stops to record, replay and study the operation sequence of the collection crew. If the crew is conscious of being observed, they tend to work faster and reduce time wastage in unauthorized salvaging and other nonscheduled activities. Once the crew is familiar with the person(s) observing them,it begins to perform more credibly. In studies involving video cameras, therefore, the first two or three hours of observation are often neglected.

7.5.2 Collection vehicle routing

Efficient routing and re-routing of solid waste collection vehicles can help decrease costs by reducing the labour expended for collection. Routing procedures usually consist of the following two separate components:

(iii) Macro-routing: Macro-routing, also referred to as route-balancing, consists of dividing the total collection area into routes, sized in such a way as to represent a day's collection for each crew. The size of each route depends on the amount of waste collected per stop, distance between stops, loading time and traffic conditions. Barriers, such as railroad embankments, rivers and roads with heavy competing traffic, can be used to divide route territories. As much as possible, the size and shape of route areas should be balanced within the limits imposed by such barriers.

(iv) Micro-routing: Using the results of the macro-routing analysis, micro routing can define the specific path that each crew and collection vehicle will take each collection day. Results of micro-routing analyses can then be used to readjust macro-routing decisions. Micro-routing analyses should also include input and review from experienced collection drivers.

Districting is the other method for collection route design. For larger areas it is not possible for one institution to handle it then the best way is to sub divide the area and MSW collection districting plan can be made. This routing will be successful only when road network integrity is good and the regional proximity has been generated. The heuristic (i.e., trial and error) route development process is a relatively simple manual approach that applies specific routing patterns to block configurations. The map should show collection, service garage locations, disposal or transfer sites, one-way streets, natural barriers and areas of heavytraffic flow. Routes should then be traced onto the tracing paper using the following rules:

- Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.
- Total collection plus hauling time should be reasonably constant for each route in the community.
- The collection route should be started as close to the garage or motor pool as possible, taking into account heavily travelled and one-way streets.
- Heavily travelled streets should not be visited during rush hours.
- In the case of one-way streets, it is best to start the route near the upper end of the street, working down it through the looping process.
- Services on dead-end streets can be considered as services on the street segment that they intersect, since they can only be collected by passing down that street segment. To keep right turns at a minimum, (in countries where driving is left-oriented) collection from the dead-end streets is done when they are to the left of the truck. They must be collected by walking down, reversing the vehicle or taking a U-turn.
- Waste on a steep hill should be collected, when practical, on both sides of the street while vehicle is moving downhill. This facilitates safe, easy and fast collection. It also lessens wear of vehicle and conserves gas and oil.
- Higher elevations should be at the start of the route.
- For collection from one side of the street at a time, it is generally best to route with many anti-clockwise turns around blocks.
- For collection from both sides of the street at the same time, it is generally best to route with long, straight paths across the grid before looping anticlockwise.
- For certain block configurations within the route, specific routing patterns should be applied.

Based on the above rules, Figure 1.7 below illustrates a typical collection vehicle routing:

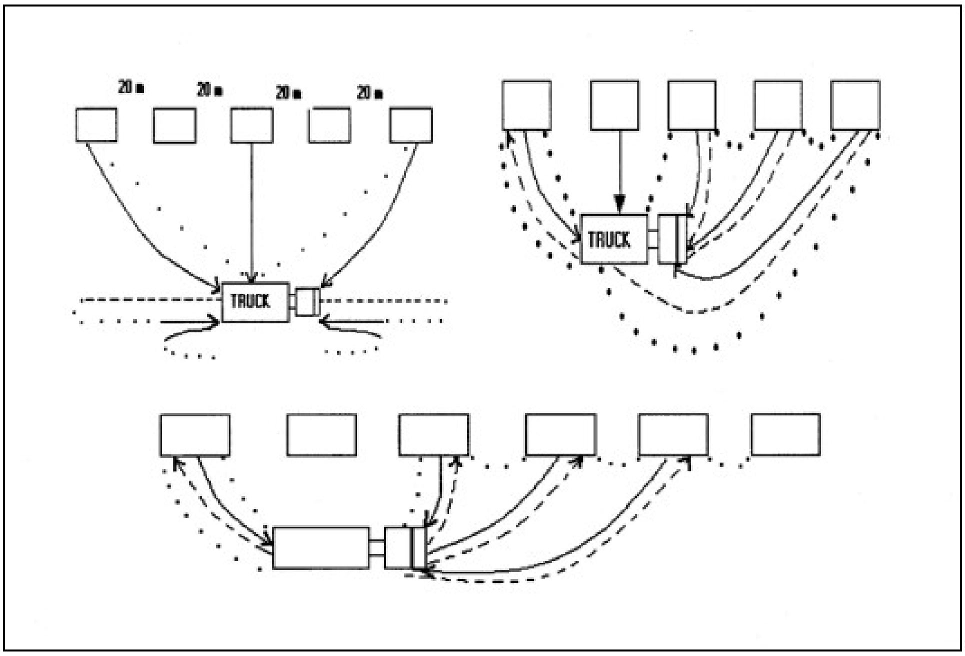


Figure 1.7 Collection Vehicle Route

7.6Transfer Stations

As mentioned earlier in Section, transfer station is a centralized facility, where waste is unloaded from smaller collection vehicles and re-loaded into large vehicles for transport to a disposal or processing site. This transfer of waste is frequently accompanied by removal, separation or handling of waste. In areas, where wastes are not already dense, they may be compacted at a transfer station. The technical limitations of smaller collection vehicles and the low hauling cost of solid waste, using larger vehicles, make a transfer station viable. Also, the use of transfer station proves reasonable, when there is a need for vehicles servicing a collection route to travel shorter distances, unload and return quickly to their primary task of collecting the waste.

Limitations in hauling solid wastes are the main factors to be considered, while evaluating the use of transfer stations. These include the additional capital costs of purchasing trailers, building transfer stations and the extra time, labour and energy required for transferring wastes from collection truck to transfer trailer.

Consider also the following factors that affect the selection of a transfer station:

- Types of waste received.
- Processes required in recovering material from wastes.
- Required capacity and amount of waste storage desired.
- Types of collection vehicles using the facility.
- Types of transfer vehicles that can be accommodated at the disposal facilities.
- Site topography and access.

The main problem in the establishment of a transfer station, however, is securing a suitable site. Stored solid wastes and recyclable materials, if not properly handled, will attract flies and other insect vectors. Odours from the transferred solid wastes will also be a nuisance, if not properly controlled. In addition, the traffic and noise due to small and large collection vehicles, collectors, drivers, etc., invite the resentment of the communities living in the vicinity of transfer stations.

7.6.1 Types

Depending on the size, transfer stations can be either of the following two types:

(iii) **Small to medium transfer stations:** These are direct-discharge stations that provide no intermediate waste storage area. The capacities are generally small (less than 100 tones/day) and medium (100 to 500 tones/day). Depending on weather, site aesthetics and environmental concerns, transfer operations of this size may be located either indoor or outdoor. More complex small transfer stations are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, it includes a recyclable material separation and processing center. The required overall station capacity (i.e., the number and size of containers) depends on the size and population density of the area served and the frequency of collection.

(iv) **Large transfer stations:** These are designed for heavy commercial use by private and municipal collection vehicles. The typical operational procedure for a larger station is as follows:

a. when collection vehicles arrive at the site, they are checked in for billing, weighed and directed to the appropriate dumping area;
b. collection vehicles travel to the dumping area and empty the wastes into a waiting trailer, a pit or a platform;
c. after unloading, the collection vehicle leaves the site, and there is no need to weigh the departing vehicle, if its weight (empty) is known;
d. Transfer vehicles are weighed either during or after loading. If weighed during loading, trailers can be more consistently loaded to just under maximum legal weights and this maximizes payloads and minimizes weight violations.

Designs for larger transfer operations

Several different designs for larger transfer operations are common, depending on the transfer distance and vehicle type. Most designs, however, fall into one of the following three categories:

(iv) Direct-discharge non-compaction station: In these stations, waste is dumped directly from collection vehicle into waiting transfer trailers and is generally designed with two main operating floors. In the transfer operation, wastes are dumped directly from collection vehicles (on the top floor) through a hopper and into open top trailers on the lower floor. The trailers are often positioned on scales so that dumping can be stopped when the maximum payload is reached. A stationary crane with a bucket is often used to distribute the waste in the trailer. After loading, a cover or tarpaulin is placed over the trailer top. However, some provision for waste storage during peak time or system interruptions should be developed. Because of the use of little hydraulic equipment, a shutdown is unlikely and this station minimizes handling of waste.

(v) Platform/pit non-compaction station: In this arrangement, the collection vehicles dump their wastes onto a platform or into a pit using waste handling equipment, where wastes can be temporarily stored, and if desired, picked through for recyclables or unacceptable materials.

The waste is then pushed into open-top trailers, usually by front-end loaders. Like direct discharge stations, platform stations have two levels. If a pit is used, however, the station has three levels. A major advantage of these stations is that they provide temporary storage, which allows peak inflow of wastes to be levelled out over a longer period. Construction costs for this type of facility are usually higher because of the increased floor space. This station provides convenient and efficient storage area and due to simplicity of operation and equipment, the potential for station shutdown is less.

(vi) Compaction station: In this type of station, the mechanical equipment is used to increase the density of wastes before they are transferred. The most common type of compaction station uses a hydraulically powered compactor to compress wastes. Wastes are fed into the compactor through a chute, either directly from collection trucks or after intermediate use of a pit. The hydraulic ram of the compactor pushes waste into the transfer trailer, which is usually mechanically linked to the compactor (EPA, 1995). Compaction stations are used when:

- wastes must be baled for shipment;
- open-top trailers cannot be used because of size restrictions;
- Site topography or layout does not accommodate a multi-level building.

The main disadvantage of a compaction facility is that the facility's ability to process wastes is directly dependent on the operative-ness of the compactor. Selection of a quality compactor, regular maintenance of the equipment, easy availability of spare parts and prompt availability of the service personnel are essential for the station's reliable operation.

7.6.2 Capacity

A transfer station should have enough capacity to manage and handle the wastes at the facility throughout its operating life. While selecting the design capacity of a transfer station, we must, therefore, consider trade-offs between the capital costs associated with the station and equipment and the operational costs. Designers should also plan adequate space for waste storage and, if necessary, waste processing. Transfer stations are usually designed to have 1.5 – 2 days of storage capacity. The collection vehicle unloading area is usually the waste storage area and sometimes a waste sorting area. When planning the unloading area, designers should allow adequate space for vehicle and equipment maneuvering. To minimize the space required, the facility should be designed such that the collection vehicle backs into the unloading position. Adequate space should also be available for offices, employee facilities, and other facility-related activities (EPA, 1995). Factors that should be considered in determining the appropriate capacity of a transfer facility include:

- Capacity of collection vehicles using the facility;
- Desired number of days of storage space on tipping floor;
- Time required to unload collection vehicles;
- Number of vehicles that will use the station and their expected days and hours of arrival;
- Waste sorting or processing to be accomplished at the facility;
- Transfer trailer capacity;
- Hours of station operation;
- Availability of transfer trailers waiting for loading;
- Time required, if necessary, to attach and disconnect trailers from tractors or compactors.

Transfer station capacity can be determined using the following formulae:

- **Pit stations:** Based on the rate at which wastes can be unloaded from collection vehicles:

  C = Pc x (L/W) x (60 x H w/Tc) x F

  Based on rate at which transfer trailers are loaded:

  C = (Pt x N x 60 x H t)/(Tt + B)

- **Direct dump stations:** *C = (Nn x Pt x F x 60 x Hw)/ [((Pt/Pc) x (W/Ln)) x Tc + B]*
- **Hopper compaction stations:** *C = (Nn x Pt x F x 60 x Hw)/[(Pt/Pc x Tc) + B]*
- **Push pit compaction station:** *C = (Np x Pt x F x 60 x Hw)/[(Pt/Pc x W/Lp x Tc) + Bc + B]*

  Where:
  = Station capacity (tonnes/day); Pc = Collection vehicle payload (tonnes); L = Total length of dumping space (feet); Hw = Hours per day that waste is delivered; Tc = Time (in minutes) to unload each collection vehicle; F = Peaking factor (ratio of the number of collection vehicles received during an average 30-minute period to the number received during a peak 30-minute period); Lp = Length of push pit (feet); Np = Number of push pits; Bc = Total cycle time for clearing each push pit and compacting waste into trailer; Pt = Transfer trailer payload (tonnes); N = Number of transfer trailers loading simultaneously; Ht = Hours per day used to load trailers (minutes); B = Time to remove and replace each loaded trailer (minutes); Tt = Time to load each transfer trailer (minutes); Nn = Number of hoppers; Ln = Length of each hopper (feet).

These formulae are useful in estimating the capacity of various types of transfer stations (EPA, 1995) and should be adapted, as necessary, for specific applications.

7.6.3 Viability

Transfer stations offer benefits such as lower collection costs (because crews waste less time travelling to the site), reduced fuel and maintenance costs for collection vehicles, increased flexibility in selection of disposal facilities, opportunity to recover recyclables or compostable at the transfer site and the opportunity to shred or scoop wastes prior to disposal. These benefits must be weighed against the costs to develop and operate the facility.

The classical approach to arrive at the economic viability of operating a transfer station, is to add the unit cost of the transfer station to the cost of hauling using large vehicles, and to compare this cost with the cost of hauling directly to the disposal site using the smaller vehicles that service the collection area. The cost of hauling using small vehicles is the sum of the depreciation cost of the vehicle, driver’s salary, salary of the collection crew (if they are on standby waiting for the vehicle to return to the collection area) and fuel cost. The transfer station cost is the sum of the transfer station's depreciation cost and the operating and maintenance costs divided by the capacity of the station. The cost of using the large vehicle is the sum of the vehicle depreciation, fuel cost and driver’s salary.

The cost-effectiveness of a transfer station depends on the distance of disposal site from the generation area, and a distance of 10 – 15 km is usually the minimum cost-effective distance (Phelps, et al., 1995). The distance between the disposal site and collection area is one of the principal variables in deciding whether to use a transfer station or haul the solid wastes directly from the collection area to the disposal site. Figure 1.8 illustrates the economic analysis involving the effect of the hauling distance on the collection cost:

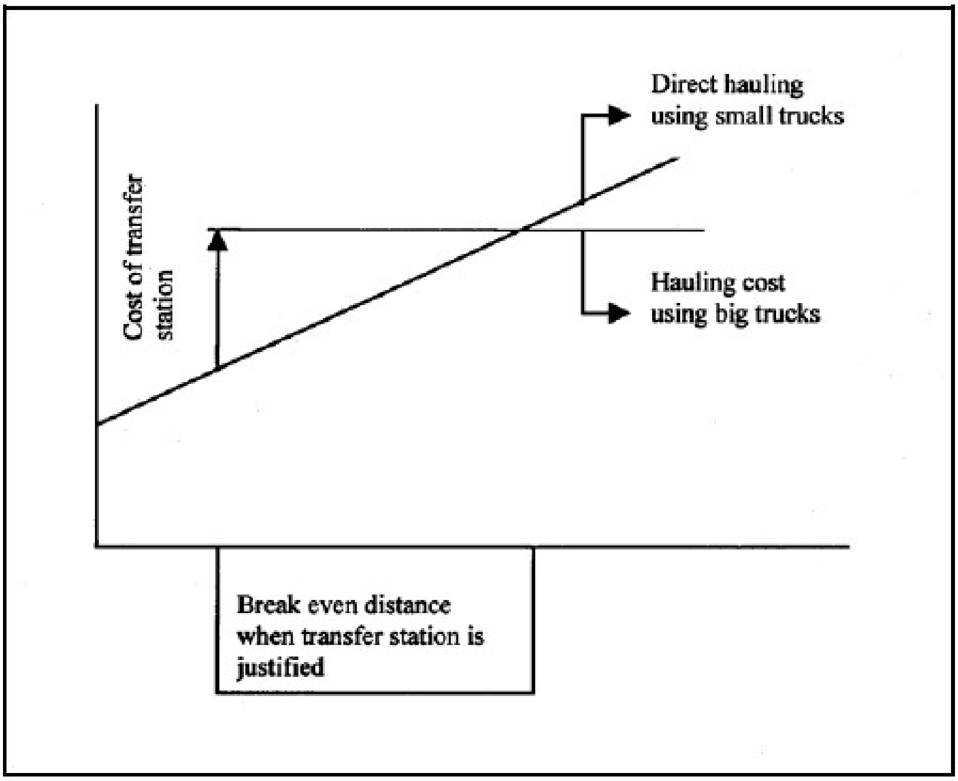


Figure 1.8 Cost Analysis to Determine Viability of Transfer Station

Now, let us consider first the case in which the transfer station is located directly along the hauling route between the disposal site and the collection area. Let the unit cost of hauling using a small vehicle be *Rs. A/m3 km*. The cost of operation, maintenance, and depreciation, loading and unloading at the transfer station be *Rs. B/m3* and the cost of hauling using large vehicles be *Rs. C/m3 km*. If the distance between the collection area and the transfer station is *X km* and the distance between the transfer station and the disposal site is *Y km*, then the distance between the collection area and the disposal site is *X + Y km*. Then, the total cost of hauling the solid wastes from the collection area to the disposal site using a transfer station is:

$$T = 2AX + B + 2CY$$

The factor 2 is added to account for the round trip, which effectively doubles the distance travelled. The total cost of hauling without the transfer station is:

$$T1 = 2A(X + Y)$$

The transfer station is justified, when:

$$T < T1$$

That is, the hauling cost using a transfer station is lower than the direct hauling costs between the collection area and the disposal site. Substituting the values of T and T1 yields:

$$2AX + B + 2CY < 2AX + 2AY$$

or

$$Y > B/(2A - 2C)$$

Note that X cancels out. The distance between the potential transfer station site and the disposal site is the variable to consider. The distance between the collection area and the disposal site is important in deciding the utilisation of a transfer station, if X is equal to zero, in which case the transfer station is located right at the centroid of the collection area. Under normal conditions, the centroid of the collection area has a high land value, and it would be impractical to locate a solid waste transfer station in this area. Figure 3.8 shows the effect of the distance between the potential transfer station site and the disposal site on the hauling cost.

Consider a general case in which the transfer station is located away from the hauling route between the collection area and the disposal site. Let *Z* be the additional distance travelled by the vehicles. The cost *T*, when using a transfer station, is then equal to:

$$T = B + 2AX + 2AZ + 2CY + 2CZ$$

The cost of direct hauling from the collection area to the disposal site remains the same as previously defined. The use of a transfer station is justified, if:

$$B + 2AX + 2AZ + 2CY + 2AZ < 2AX + 2AY$$

or

$$Y > (B + 2CZ + 2AZ)/(2A - 2C)$$

Again, the decision whether or not to use a transfer station is independent of the distance between the collection area and the proposed transfer station.

7.7 Selection of location

Geographic information system (GIS) is a computerize database management system that designed to manage large volumes of spatially distributed data from a variety of sources (Charnpratheep et al., 1997). They are ideal for advanced site-selection studies because they efficiently store, retrieve, analyze, and display information according to user-defined specifications (Kao et al., 1997). GIS has been extensively used to facilitate and lower the cost of the landfill site-selection process (Sener et al., 2006).

GIS often been employed for the siting and placement of facilities (Church, 2002). GIS has emerged as a very important tool for land use suitability analysis (Malczewski, 2004). GIS also can recognize, correlate and analyze the spatial relationship between mapped phenomena, thereby enabling policy-makers to link disparate sources of information, perform sophisticated analysis, visualize trends, project outcomes and strategize long-term planning goals (Malczewski, 2004).

GIS as a box of tools for handling geographical data is very useful, however, the list of tools provided by GIS although impressive is not complete. For example in most GIS packages spatial analytical functionality, lies mainly in the ability to perform deterministic overlay and buffer functions (Carver, 1991). Such abilities whilst ideal for performing spatial searches based on nominally mapped criteria, are of limited use when multiple criteria and targets, such as in the case of landfills selection, are applied (Jeff and Baxter, 1996). The integration of GIS with analytical techniques will be a valuable addition in GIS toolbox. Progress in this area is inevitable and future developments will continue to place increasing emphasis upon the analytical capabilities of GIS (Fotheringham and Rogerson, 1994).

GIS have the capability to handle and simulate the necessary economic, environmental, social, technical, and political constraints. Many of the attributes involved in the process of selection of sanitary landfill sites have a spatial representation, which in the last few years has motivated the predominance of geographical approaches that allow for the integration of multiple attributes using geographic information systems (Kontos et al. 2003; Sarptas et al. 2005; Sener et al. 2006; Gomez-Delgado and Tarantola 2006; Delgado et al. 2008; Chang et al. 2008). Site selection procedures can benefit from the appropriate use of GIS.

Common benefits of GIS include its ability to: (a) capture, store, and manage spatially referenced data; (b) provide massive amounts of spatially referenced input data and perform analysis of the data; (c) perform sensitivity and optimization analysis easily; and (d) communicate model results (Vatalis and Manoliadis 2002).

GIS also provides a spatial framework to land use analysis and it has been recognized as a useful decision support technology. The role of GIS is to generate a set of feasible solutions representing the relative land suitability with respect to any given map layers and to display it. Nevertheless, it does not provide means to deal with multiple decision factors. There has been a recent trend to integrate GIS with other software for better decision making in planning.

7.8 Operation & maintenance

A facility Operations and Maintenance Manual is required for all waste management facilities and systems. The following shall be addressed in detail and as applicable:

- Site security, manpower, supervision, access and signage
- Unacceptable/prohibited activities e.g. no open burning or smoking on-site
- Control systems for nuisance factors including vectors, rodents, scavenging, illegal dumping, malodor, dust and litter
- Procedures for inspection of materials prior to acceptance at the facility.
- Acceptable and unacceptable waste material/waste streams and contingency options
- Contingency and Environmental Emergency plans
- Environmental monitoring program(s)
- Facility/System day-to-day operations protocol /procedures

- Site and equipment maintenance schedule / regime
- Staff/operator training in facility operations, & environmental health and safety Record keeping and Reporting
- Contact information for owner/operator and site managers / supervisors
- On-going Quality Control / Quality Assurance protocol (Plan, do, check, repair/revise/repeat where appropriate).
- A copy of the facility Certificate of Approval

The Operations Management/Maintenance Manual shall be prepared by the owner/operator and approved by the Department. The operation of the facility shall be in compliance with the provisions of the Certificate of Approval and a copy of the Operations Manual is to be kept on site and readily available to staff and regulators.

7.8.1 Environmental Emergency Health and Safety Contingency Plans

The owner/ operator shall have up-to-date contingency plans in place to effectively handle all reasonably forces eable emergencies such as, fire, malodor, flood, power outage, delivery or spillage of hazardous waste/ materials, explosion, leachate leakage, or any other emergency or issue which could result in disruption of facility operations and/or environmental damage. Bound copies of the contingency plan(s) shall be kept at the facility (ies) with the Operations Manual. The plans shall describe appropriate mitigation measures required to prevent damage to the waste management facility and the environment. Employees shall be familiar with the contingency plan(s) and participate in regular practice response exercises. The attendant on site shall be equipped with an effective and quick means of communication for personal safety and to contact first responders (facility owner/operator, fire, police, and medical) in the event of an emergency. An appropriate fire control program shall be in place on a continual basis. The program shall be developed in consultation with the local Fire Department. Fire safety plans, including the comments of the first responder fire department as to the adequacy of the plan, are to be provided to the Department. The Department of Natural Resources shall also be advised in areas where there is a forest fire risk. The contingency plan shall be reviewed annually and revised as needed.

Check your progress

Q1. Explain facility operations and maintenance manual is required for all waste management facilities and systems.

Q2. Illustrate factors that affect the selection of a transfer station.

7.9 Options under Indian conditions.

In India, recently solid waste management systems are assuming larger dimensions in keeping with the Municipal Solid Wastes (Management & Handling) Rules, 2000.

Figure 1.9: Solid Waste in India

Many of the municipalities are taking appropriate actions to improve various component systems like collection of solid waste from generation areas, its transportation to processing and disposal site(s), utilizing the recycling potential of Municipal Solid Waste (MSW) and ultimately disposing of by landfilling.

In view of this, under the sponsorship of Central Pollution Control Board (CPCB), NEERI has carried out the extensive studies to assess the pathways of pollution for various environmental media. Further, a site selection criteria has been developed in the form of guidelines to suit Indian condition in keeping with the findings of the other studies.

The urban solid waste management is an essential municipal service for protection of environment and health of citizens. All the citizens, industries, hospitals and NGOs should co-operate with the municipal authorities to ensure safe management of urban solid waste.

Segregation of inorganic recyclable materials like plastic, glass, metal, papers at the source should be promoted and every effort made to provide collection of these in separate containers or bags in each house.

Solid waste should be collected from each house on a daily basis and transported to the disposal site. Direct transfer of garbage from primary collection carts to covered transportation vehicles should be encouraged.

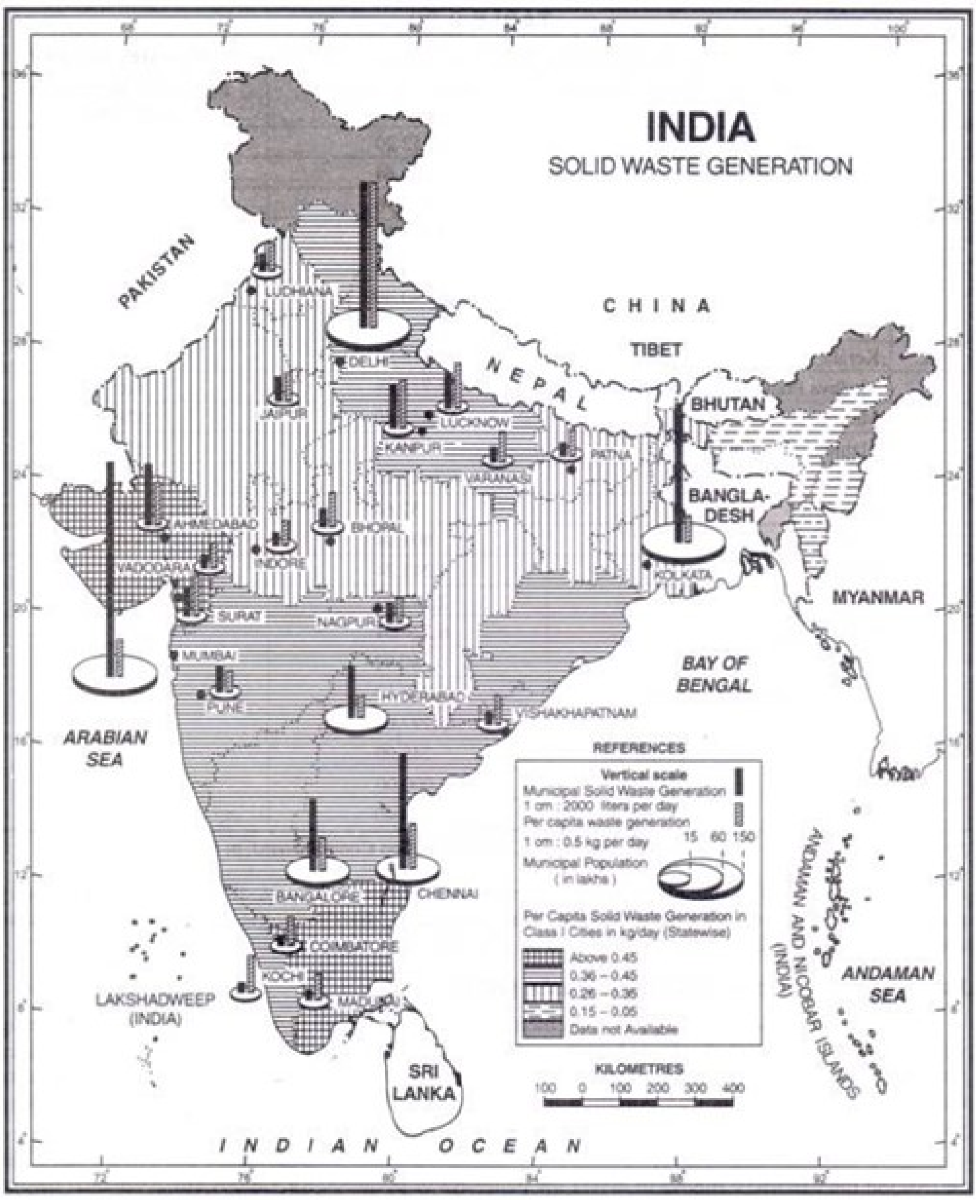


Figure 1.10: Solid Waste Generation in India

Refuse from vegetable and fruit markets should be collected and transported to the composting facilities. Large restaurants/hotels should be encouraged to develop their own onsite treatment facilities.

Sanitary landfills would be the main option for disposal of urban solid waste. The concerned authorities must make adequate provision of land allocated for scientific landfill sites.

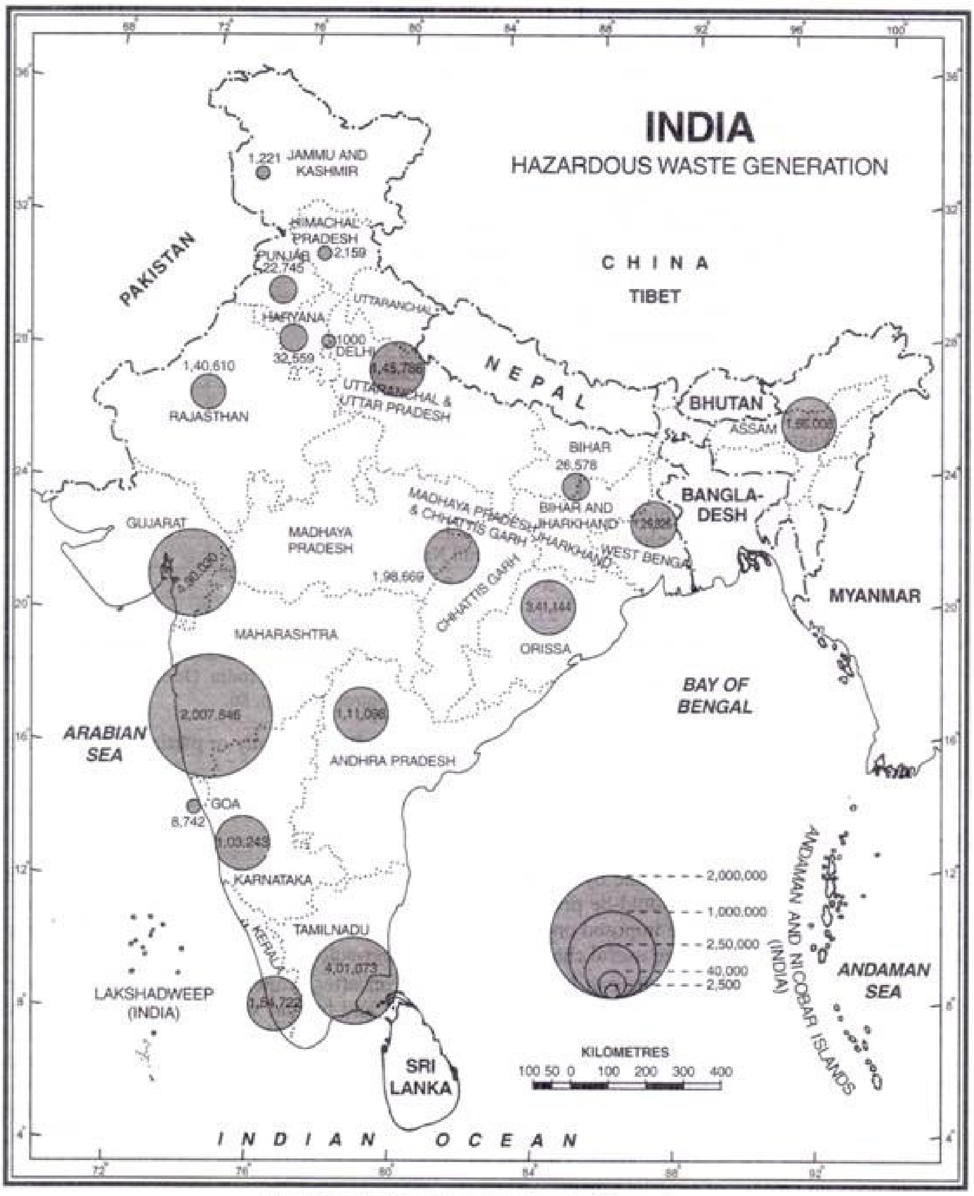


Fig 1.11: Hazardous Waste Generation

Composting along with land disposal on non-compostable are the most preferred options for MSW and could take care of up to 20-30 per cent of municipal solid waste/organic fraction. The urban solid wastes of Indian cities have low calorific value and high moisture content with high percentage of noncombustible materials and hence it is unsuitable for thermal technologies. However, application of technologies such as incineration, palletization and pyrolysis-gasification should be evaluated through research and development and pilot scale studies.

According to latest figures (2004) Delhi is generating about 7,000 metric tonnes of garbage every day and is fast running out of landfill sites. It appears that garbage will soon become the single most important issue for Delhi which requires immediate solution. It is felt that unless a new technology is adopted, there will be no space left for garbage in the next few years.

7.10 Review Questions

Q1. Define the remedies under Indian constitution.

Q2. Illustrate factors that affect the selection of hazardous waste generation at nearer municipal station.

UNIT-VIII Waste Handling And Segregation

Structure

8.0 Introduction

Many components of municipal solid wastes can be reused as secondary material. Among these are papers, cardboard, plastic, glass, ferrous metal, aluminum, and other nonferrous metals. These materials must be separated from MSW before they can be recycled. In this section, material recycling, and separation methods are first briefly presented, followed by bioconversion and refuse derived fuel (RDF) methods.

The waste handling and segregation of solid waste at site, material separation by pick in, screens, float and separator magnets are the major issues .Moreover electromechanical separator and other latest devices for material separation, Waste handling and separation at Commercial and industrial facilities, Storage of solid waste at the sources are handling by modern technology.

The ISWM (Integrated Solid Waste Management) hierarchy of waste management as explained above prioritizes waste minimization (reduction at source and reuse) as the preferred waste management strategy because it is the most effective way to reduce the quantity of waste, the cost associated with its handling, and its environmental impacts.

Waste minimization strategies require policy interventions at the National, State and/or Local level, depending on the type of the intervention (e.g. minimizing use of packaging material, promoting use of refill containers, buy back of reusable or recyclable packing material, introducing a national deposit system on beverage packages) and the scale at which the intervention needs to be initiated for effective implementation. Initiatives which require a behavior change in the community need to be supported by consistent awareness programmes.

Objectives

After studying this unit you should be able to:

- Handling and segregation of solid waste at site
- Material separation by pick in
- Screens, float and separator magnets, electromechanical separator and other latest devices for material separation
- Waste handling and separation at Commercial and industrial facilities Storage of solid waste at the sources.

8.1 Handling and segregation of solid waste at site

The ISWM (Integrated Solid Waste Management) hierarchy of waste management as explained above prioritizes waste minimization (reduction at source and reuse) as the preferred waste management strategy because it is the most effective way to reduce the quantity of waste, the cost associated with its handling, and its environmental impacts.

Waste minimization strategies require policy interventions at the National, State and/or Local level, depending on the type of the intervention (e.g. minimizing use of packaging material, promoting use of refill containers, buy back of reusable or recyclable packing material, introducing a national deposit system on beverage packages) and the scale at which the intervention needs to be initiated for effective implementation. Initiatives which require a behavior change in the community need to be supported by consistent awareness programmes.

Waste Minimization Strategies requiring National or State level interventions or support

- Extended Producer Responsibility (EPR): EPR can be established for wastes like electronics, batteries, packaging and consumer durables by State and National governments. States can take initiatives in this matter; regulations are usually legislated at State and National levels.
- Promotion of voluntary action: Encouraging business groups to reduce volumes of packaging, while maintaining the requisite strength. Example: Godrej has a 'No Packaging Policy' for refrigerators. The company ensures that the packaging, in which the appliance is delivered, is taken back by the supplier and reused.
- Frame rules and bye laws banning use and/or sale of certain types of products and packaging that cannot be reused, repaired, recycled, or composted. With State support, local authorities are enabled to issue and enforce such ordinances
- Developing eco-labelling standards for certain products based on their potential for waste reduction and recycling in respect to the product or connected packaging.

Waste Minimization Initiatives usually requiring ULB Support/Action

- Promoting and implementing awareness and education programs that address different stakeholders: residential, commercial and industrial educational programs, school programs that increase public awareness and participation in at-source waste reduction programs. Campaigns might include promotion of material substitution where possible (e.g. promoting the use of rechargeable batteries instead of single use batteries, buying refills etc.).
- Developing and promoting at-source reduction programs in the community, e.g. domestic composting programs can reduce the volume of food waste, leaves and garden trimmings entering the city level collection system.
- Bans within local authorities' jurisdiction (usually National / State Level authorization required; see above): Replacing non-recyclable / disposable materials and products with recyclables and reusable materials and products (e.g. banning the use of plastic bags).
- Product stewardship and Green Procurement implementing programs whereby the suppliers of a product are responsible for providing a take-back program to promote recycling. Take- back examples are computer monitors, auto oil, batteries, paper, milk pouches, etc. Procurement programs in local governments and businesses should be designed to give preference to recyclable products.
- Local businesses should be encouraged to reward consumers for returning recyclable products/ products which are toxic (e.g. batteries). These initiatives require existing manufacturers' EPR programs (see above).
- Business assistance programs advise businesses how to use materials more efficiently and reduce waste generation.
- Supermarkets & retail stores are often some of the most effective partners for a municipal waste minimization program. These provide a central and consistent point for consumer education, packaging reduction projects and collection of recyclable wastes.
- Promoting materials exchange and reuse programs that divert materials from the waste stream going to landfill (e.g. programs which link sellers of used furniture with potential second hand furniture buyers).
- Establishing incentives for at-source reduction through the principle of "pay as you throw", supported by bye-laws. ULBs can stipulate variable solid waste management charges, based on the quantities being disposed per household/establishment. 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.

MSW should be stored at the source of waste generation till it is collected for disposal by ULB staff or appointed contractors. It is essential to segregate wastes into different fractions, commonly referred to as primary segregation. Segregation of municipal solid waste needs to be linked to primary collection of waste from the door step and given high priority by the ULBs. Unless primary collection of segregated waste is not planned by the ULBs the source segregation by waste generators will be meaningless. The fractions into which the waste has to be segregated should be decided upon by the respective ULB based on the waste characterization, the ULB's capacities and facilities, and other framework conditions (existing kabadi systems, traditions in the community, available space in residential areas and in streets etc.). At a minimum level, indicated as the basic segregation, waste should be segregated by waste generators into two fractions: wet (green container) and dry (bluecontainer) (see figure 1.6). This system is referred to as the 2-bin system. The wet fraction should preferably be used for composting and as many fractions as possible from the dry waste should be sent for recycling.

Figure 2.1: 2-bin system for dry and wet waste

8.1.1 Segregated Collection

Collection of segregated municipal waste from the source of its generation is an essential step in solid waste management. Inefficient waste collection service has an impact on public health and aesthetics of towns and cities. Collection of wet and dry waste separately enhances the potential of cost effective treatment of such wastes and of deriving optimum advantage from the recyclable material fed into the system.

Waste collection service is divided into primary and secondary collection.

Primary collection refers to the process of collecting waste from households, markets, institutions and other commercial establishments and taking the waste to a storage depot/ transfer station or directly to the disposal site, depending on the size of the city and the prevalent waste management system. Secondary collection includes picking up waste from community bins, waste storage depots or transfer stations and transporting it to waste processing sites or to the final disposal site. Primary collection must be introduced both in small and large towns/cities.

Secondary collection systems are necessary in all cities and towns for collection of waste deposited by the waste generators in the community bins or by sanitation workers at the secondary waste storage depots or for onward transportation of waste to processing / disposal facilities.

A well synchronized primary and secondary collection and transportation system is essential to avoid containers' overflow and waste littering on streets. Further, the transport vehicles should be compatible with the equipment design at the waste storage depot in order to avoid multiple handling of wastes and should be able to transport segregated waste. They should also be easy to maintain.

8.1.2 Street Cleaning and Drain Cleaning Material

Street cleaning is an age old fundamental service rendered by municipal authorities in India to ensure clean and hygienic urban conditions. Until recently all domestic and trade waste was being discharged on the streets or street bins and street sweeping was the principal method of waste collection. With the introduction of door to door collection systems in many urban areas, there is a sizeable reduction in the quantity of waste and change in its composition. The street waste should ideally comprise of dust and tree leaves and some litter disposed by citizens on the streets but till such time door to door collection becomes effective, the street sweeping will also include sizeable portions of food waste as well as recyclable waste. Manual sweeping is commonly practiced in India as many streets are congested and narrow road conditions are not conducive for mechanical sweeping. Inefficient waste collection systems coupled with public littering significantly contribute to waste piles in streets.

A wide variety of tools and equipment are available for manual and mechanical sweeping. Municipal authorities must avoid multiple handling of waste by converting traditional handcarts into containerized handcarts to facilitate direct transfer of waste from handcart to a container of collection vehicle. Through the introduction of efficient methods, municipal authorities can achieve significant improvement in quality of service and financial savings. ULBs should determine the frequency of street cleaning based on local conditions for efficiency of staff. Also, the time of street cleaning should be carefully defined to avoid conflicts with traffic, parked vehicles and pedestrians.

In many cities there are open surface drains along the road side, which need to be cleaned on a regular basis to permit free flow of storm/grey water. Solid waste management authorities should ensure that citizens and sweepers do not dispose waste into drains, through training, campaigning, statutory regulations and monetary fines. A further approach to prevent this is to make the same staff responsible for cleaning streets as well as adjacent surface drains up to a depth of 90 cm.

It is very important to ensure that street sweepings and drain cleaning material are not allowed to be mixed with the waste collected from households and commercial establishments as it can seriously hamper treatment and recycling options for the household and commercial wastes and add to the cost of processing of waste.

8.2 Material separation by pick in

Effective recycling relies on effective sorting. With a wide range of sorting technologies on the market today, WMW reviews the options and looks at the issues that are driving the development of new technology.

European citizens will not have failed to notice that the sorting of waste, particularly at a household level, is becoming increasingly important. While the various EU countries currently take different stances on how and which waste to separate, the trend will be to separate as much useful waste as possible and deal with it in the most appropriate manner.

Separating the different elements found in waste streams is essential for enabling the recovery of useful materials, minimizing the amount of material sent to landfill and allowing recyclable materials to find a new incarnation. Companies sort and recycle materials in order to extract value, but those operating in EU Member States are also bound by EU rules and regulations relating to the environment.

In June 2008 MEPs voted to reshape the waste framework directive and the new rules are that each country will have to set and adhere to its own targets on waste. In terms of recycling, the new legislation states that 50% of all household waste and 70% of all construction waste must be re-used or recycled by the year 2020, so the need to make sure sorting processes are as effective and economical as possible is of paramount importance.

8.2.1 Separation technologies

Waste disposal companies dealing with the sorting of materials will commonly use one or more of these five methods:

- Trommel separators/drum screens: These separate materials according to their particle size. Waste is fed into a large rotating drum which is perforated with holes of a certain size. Materials smaller than the diameter of the holes will be able to drop through, but larger particles will remain in the drum.
- Eddy current separator: This method is specifically for the separation of metals. An ‘eddy current’ occurs when a conductor is exposed to a changing magnetic field. Put simply, it is an electromagnetic way of dividing ferrous and non-ferrous metals.
- Induction sorting Material is sent along a conveyor belt with a series of sensors underneath. These sensors locate different types of metal which are then separated by a system of fast air jets which are linked to the sensors.
- Near infrared sensors (NIR) When materials are illuminated they mostly reflect light in the near infrared wavelength spectrum. The NIR sensor can distinguish between different materials based on the way they reflect light.
- X-ray technology X-rays can be used to distinguish between different types of waste based on their density.

Manual sorting

It should also be mentioned that manual sorting of waste is still very much a technique that is used in the world today. Danish company M&J says many of its shredders are bought by companies that want to use them prior to material being sorted by hand on so-called manual picking lines. M&J has shredders that can produce large-sized particles, making it easier for those hand-sorting the waste to do their jobs effectively.

Those companies paving the way in the sorting of waste use the afore mentioned technologies, but are also constantly developing new and more effective methods. In sorting there is a multitude of ways to get the job done. This article aims to provide a flavor of the most common, as well as the most innovative, methods of sorting being used by European waste disposal companies today. We do not have the space to go into detail on every method currently available and in use, but hope this article serves to give an overall impression of the technologies employed in today’s market and their value to society.

Mobile sorting

With today's recycling culture, sorting is surely set to increase. Not all companies can transport the waste to their own plants in order to separate it. Sometimes this work needs to be done on site. Mobile sorting machines are therefore a must, and one company that is leading the way in this field of waste screening is Doppstadt with its SM series of mobile sorters.

The SM series uses drum screens and is adaptable to a variety of uses. There are four different machines to choose from depending on the type and size of waste to be sorted, and each of them includes features designed to make them easy to maintain, keep clean and transport. The rotating drums have rotating brushes to keep them from getting clogged up and are capable of dealing with heavy materials. They employ a patented load-sensing technology which optimizes the flow of material through the drum and the machines benefit from short set-up times as they have hydraulically-folding discharge conveyors. The SM series can sort anything from compost to construction waste and soil to materials excavated from landfill.

Just one example of a use for mobile sorting technology is a plant set up by Cesaro Mac Import in Italy using Doppstadt machinery. As well as a shredding machine this plant makes use of a screening station, SST 1025, with a 40 mm trommel screen. The plant processes waste that is the by-product of paper recycling. This waste comprises paper rejects and sledges. These rejects or foreign fibers can be processed once they are separated and their calorific value is useful. So it is important to use effective technology that can remove this matter from the sludge. The Doppstadt screens in Italy process 550 tonnes of rejects each day.

Enhanced resolution

One of the key features of companies leading the way in today's market is the ability to sort the increasingly diverse range of materials coming through, and deal with them appropriately. Titech, a global company with its headquarters in Norway, has long been aware of this issue and has been spearheading technologies which have now been adopted across the industry. The 15-year-old company sorts a huge range of materials; everything from plastic bottles and WEEE to construction and industrial waste. It places a great deal of importance on research and development. It knows that new materials will be created, but the need to dispose of them correctly will also be paramount. In light of this it uses a diverse range of sensor technology in order to get the purest fractions from every waste stream.

The sensor technologies applied at Titech include: NIR (near infrared), which recognizes different materials based on their spectral properties of reflected light; CMYK (cyan, magenta, yellow, key) sorts paper or carton that has been printed using CMYK; VIS (visual spectrometry) recognizes all colours that are visible and works for both transparent and opaque objects; EM (electromagnetic) sorts metals with electromagnetic properties, as well as sorting metals from non-metals and recovers stainless steel or metallic compounds; RGB sorts specifically in the colour spectrums of red, green and blue for specialized applications and X-ray sorts by recognizing the atomic density of materials. This enables Titech to achieve a high purity level regardless of size, moisture or pollution level.

Another emerging technology is MIR (mid infrared) which works on a similar principle to NIR, but projects light in the mid infrared range onto materials to be analyzed. French company Pellenc ST has been piloting this technology since 2008 as a more efficient way to separate paper and cardboard.

Traditionally, machines have employed the same technology used to sort plastics, i.e. colour sorting methods, to sort paper and cardboard but this results in a much lower level of efficiency. Pellenc ST says that new MIR method brings efficiency levels up to 90% which is an improvement of around 30%.

The range of sensors used at Titech gives us a good indication of the direction the European, and indeed global, sorting market is taking. The company's flagship machines at the moment are the Titech Finder, which can take a high throughput of material and achieve excellent purity, and the TitechPolysort Flake, which can sort smaller particles at extremely high resolution. As many readers will know, Titech has recently expanded its operations by forming a partnership with leading German company CommoDas, which has further increased the range of materials that it is capable of sorting.

German company RTT has been operating since 1990 and is famous for its trademarked. Unisort machines, which have been tailored to specific waste streams. The Unisort CB, for example, salvages circuit boards from WEEE, while the Unisort P can sort a wide range of polymers, papers and more using NIR technology.

The company has always been ahead of the game and its response to the demand for high resolution has been another of its successes. The Unisort Flake deals with waste at a fraction size of 350 mm and can be programmed with specific criteria for every waste stream. As with most sensor sorting machines, the waste is fed in on a conveyor belt under the sensors which then instruct the high-pressure air jets to separate the waste into the appropriate containers.

Compact sorting

So, with the high level of variation in waste streams it usually takes a combination of technologies to separate it all successfully and the stream may also need more than one run through the filtering machine. But these days, customers are increasingly demanding. They want a machine that can separate as much waste as quickly as possible and, with the size of machines also a factor, they are looking for something that takes up the least amount of space.

Enter S+S Separation and Sorting technology GmbH and its Varisort Compact system, which had its grand unveiling at the 2008 IFAT show. This Bavarian company focuses on the detection and separation of contaminants from material streams, and has worked hard to produce a machine that industry professionals would see as a good investment. S+S obviously knows its market. The Varisort machine combines inductive, optical and NIR sensors which can run simultaneously, and its accuracy of detection is impressive sorting up to 500,000 parts per second. It also includes high-speed valves which can process up to 500 switching cycles per second.

Its modest size means it appeals to those companies for whom space is a factor. And it is also impressive to note that its lack of stature has in no way compromised its ability to separate waste. S+S has simply made its shorter conveyor belt faster and the compressed air blasts even more precise in order to make sure the job is done properly. Peter Mayer, Sorting Sales Manager at S+S says 'Because of its outstanding flexibility the Varisort Compact system is ideal for sorting electronic waste. Irrespective of the type of electronic waste that needs to be sorted, the Varisort Compact can always optimally perform the sorting task by employing different sensors.'

For companies that deal with large-scale waste such as WEEE, a compact sorting machine like this can be a godsend. With any recycling technology one must consider that it is only one part of a larger processing system, which usually comprises several machines and takes up a large amount of space.

One cog in a larger wheel

Sorting is, of course, just a single element of the waste disposal/recovery process. But it is a vital part and can come at almost any stage in the life of the waste stream once the material has been discarded. With this in mind the big players in the sorting market have to remain flexible and provide technology that can cope with literally any type of waste. Obviously, technology which is designed to deal with small scale flakes cannot also cope with large scale WEEE or wet agricultural waste, but companies are trying to get as close as they can to developing machines that are multi-purpose and combine technologies to do several different jobs at once.

Check your progress

Q1. What is ISWM (Integrated Solid Waste Management).

Q2. Define Handling and segregation of solid waste at site.

8.3 Screens, float and separator magnets, electromechanical separator and other latest devices for material separation

Component separation is a necessary operation in which the waste components are identified and sorted either manually or mechanically to aid further processing. This is required for the:

- Recovery of valuable materials for recycling;
- Preparation of solid wastes by removing certain components prior to incineration, energy recovery, composting and biogas production.

The most effective way of separation is manual sorting in households prior to collection. In many cities (e.g., Bangalore, Chennai, etc., in India), such systems are now routinely used. The municipality generally provides separate, easily identifiable containers into which the householder deposits segregated recyclable materials such as paper, glass, metals, etc. Usually, separate collections are carried out for the recyclable material. At curbside, separate areas are set aside for each of the recyclable materials for householders to deliver material – when there is no municipal collection system. In case the separation is not done prior to collection, it could be sorted out through mechanical techniques such as air separation, magnetic separation, etc., to recover the wastes.

8.3.1 Air separation

This technique has been in use for a number of years in industrial operations for segregating various components from dry mixture. Air separation is primarily used to separate lighter materials (usually organic) from heavier (usually inorganic) ones. The lighter material may include plastics, paper and paper products and other organic materials. Generally, there is also a need to separate the light fraction of organic material from the conveying air streams, which is usually done in a cyclone separator. In this technique, the heavy fraction is removed from the air classifier (i.e., equipment used for air separation) to the recycling stage or to land disposal, as appropriate. The light fraction may be used, with or without further size reduction, as fuel for incinerators or as compost material. There are various types of air classifiers commonly used, some of which are listed below:

- Conventional chute type: This, as shown in Figure 2.2, is one of the simplest types of air classifiers:

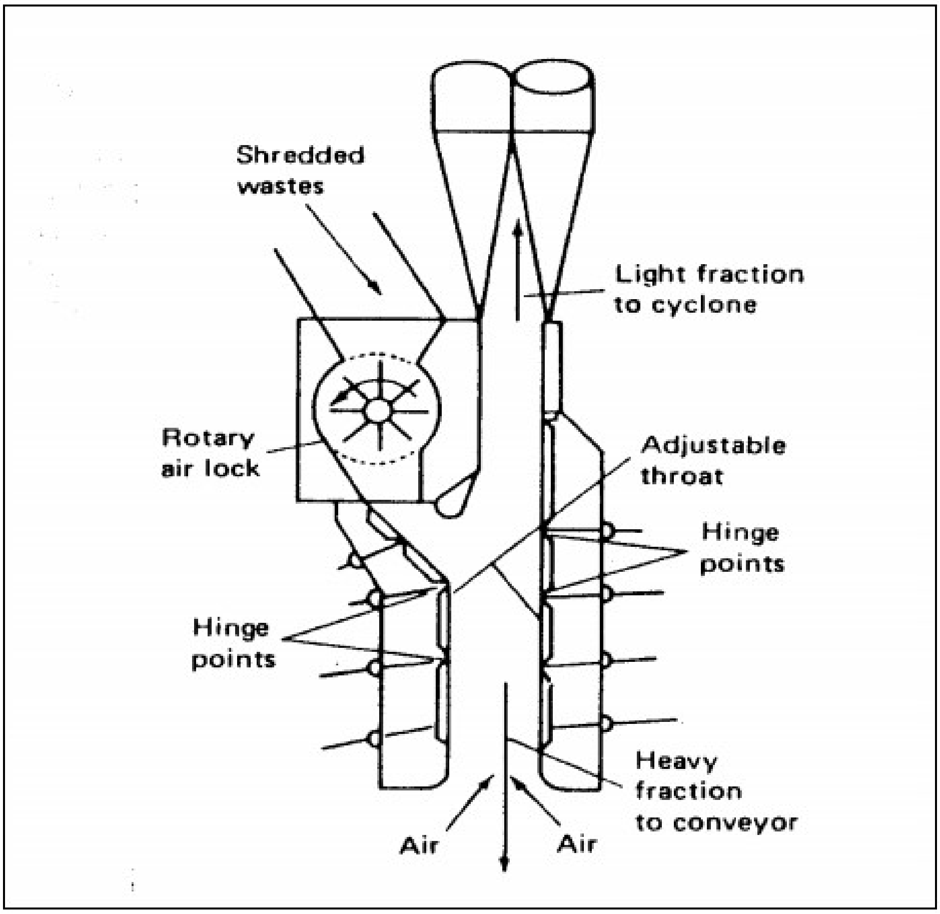


Figure 2.2 Conventional Chute Type

In this type, when the processed solid wastes are dropped into the vertical chute, the lighter material is carried by the airflow to the top while the heavier materials fall to the bottom of the chute. The control of the percentage split between the light and heavy fraction is accomplished by varying the waste loading rate, airflow rate and the cross section of chute. A rotary air lock feed mechanism is required to introduce the shredded wastes into the classifier.

- Zigzag air classifier: An experimental zigzag air classifier, shown in Figure 2.3 below, consists of a continuous vertical column with internal zigzag deflectors through which air is drawn at a high rate:

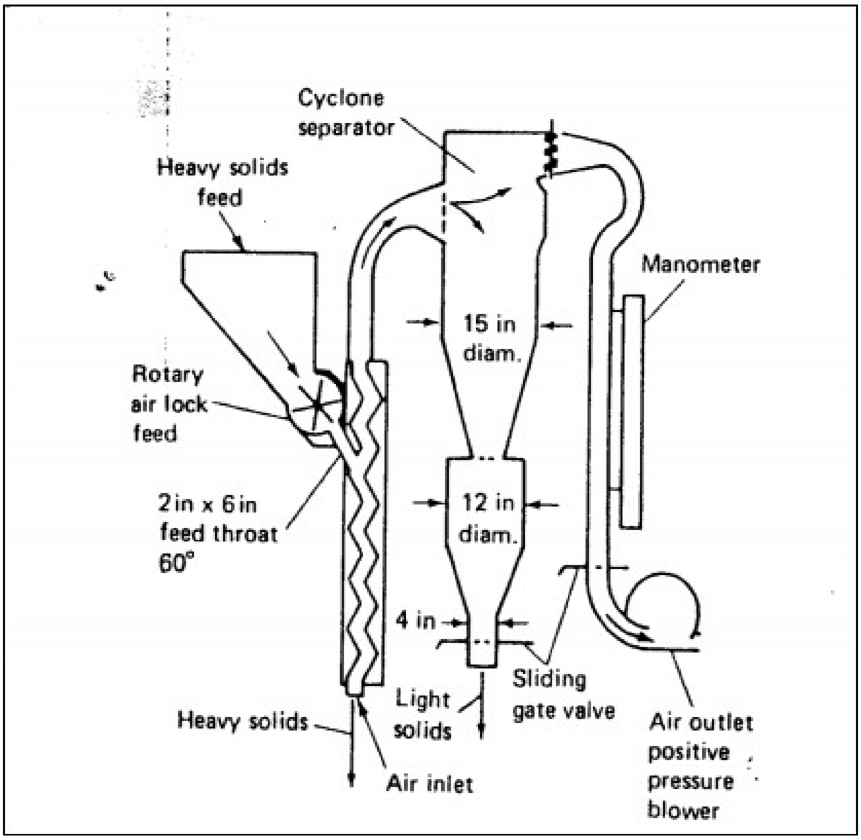


Figure 2.3: Zigzag Air Classifier

Shredded wastes are introduced at the top of the column at a controlled rate, and air is introduced at the bottom of the column. As the wastes drop into the air stream, the lighter fraction is fluidized and moves upward and out of column, while the heavy fraction falls to the bottom. Best separation can be achieved through proper design of the separation chamber, airflow rate and influent feed rate.

- Open inlet vibrator type: Figure 2.4` below illustrates this type of air classifier:

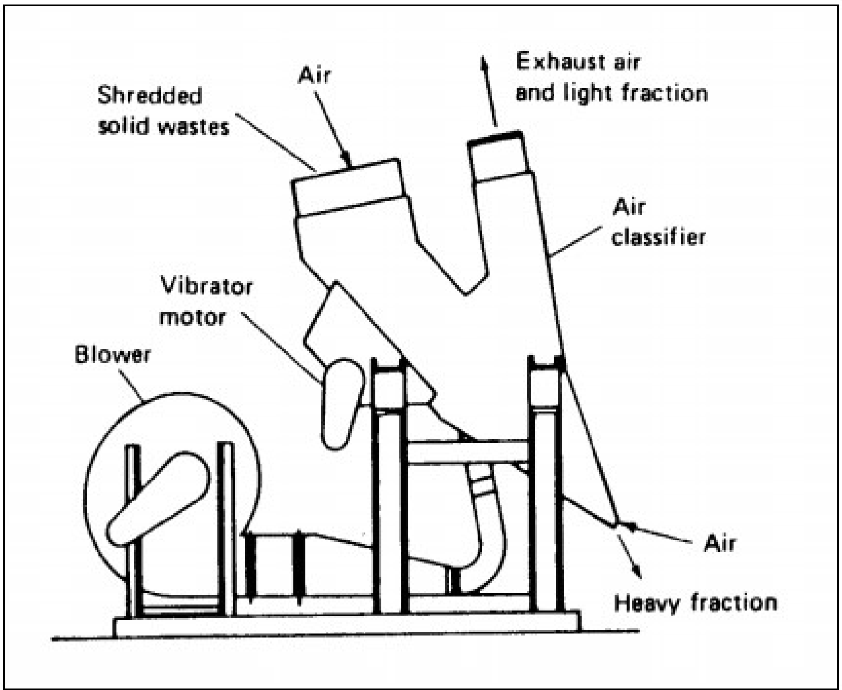


Figure 2.4 Open Inlet Vibrator

In this type of air classifier, the separation is accomplished by a combination of the following actions:

- Vibration: This helps to stratify the material fed to the separator into heavy and light components. Due to this agitation, the heavier particles tend to settle at the bottom as the shredded waste is conveyed down the length of the separator.
- Inertial force: In this action, the air pulled in through the feed inlet imparts an initial acceleration to the lighter particle, while the wastes travel down the separator as they are being agitated.
- Air pressure: This action refers to the injection of fluidizing air in two or more high velocity and low mass flow curtains across the bed. A final stripping of light particles is accomplished at the point where the heavy fraction discharges from the elutriators. It has been reported that the resulting separation is less sensitive to particle size than a conventional vertical air classifier, be it of straight or zigzag design. An advantage ofthis classifier is that an air lock feed mechanism is not required and wastes are fed by gravity directly into the separator inlet.

Selection of air separation equipment

The factors that are to be considered for selecting air separation equipment include the following:

- Characteristics of the material produced by shredding equipment including particle size, shape, moisture content and fiber content.
- Material specification for light fraction.
- Methods of transferring wastes from the shredders to the air separation units and feeding wastes into the air separator.
- Characteristics of separator design including solids-to-air ratio, fluidizing velocities, unit capacity, total airflow and pressure drop.

- Operational characteristics including energy requirement, maintenance requirement, simplicity of operation, proved performance and reliability, noise output, and air and water pollution control requirements.
- Site considerations including space and height access, noise and environmental limitations.

So far, we have studied the separation of solid waste components by air separation. We will next learn about the separation of wastes based on their magnetic properties.

8.3.2 Magnetic separation

The most common method of recovering ferrous scrap from shredded solid wastes involves the use of magnetic recovery systems. Ferrous materials are usually recovered either after shredding or before air classification. When wastes are mass-fired in incinerators, the magnetic separator is used to remove the ferrous material from the incinerator residue. Magnetic recovery systems have also been used at landfill disposal sites. The specific locations, where ferrousmaterials are recovered will depend on the objectives to be achieved, such as reduction of wear and tear on processing and separation equipment, degree of product purity achieved and the required recovery efficiency.

Equipment used for magnetic separation

Various types of equipment are in use for the magnetic separation of ferrous materials. The most common types are the following:

- Suspended magnet: In this type of separator, a permanent magnet is used to attract the ferrous metal from the waste stream. When the attracted metal reaches the area, where there is no magnetism, it falls away freely. This ferrous metal is then collected in a container. Figure 2.5 shows a typical suspended magnet:

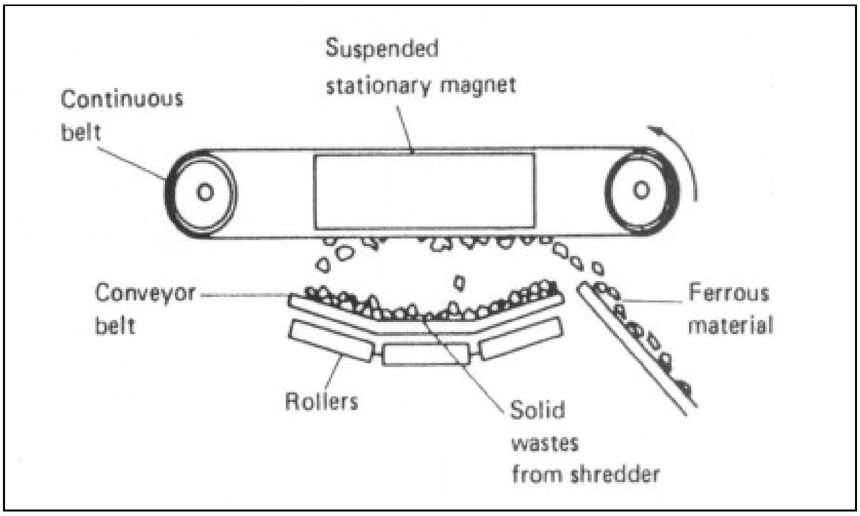


Figure 2.5 Suspended Type Permanent Magnetic Separator

This type of separation device is suitable for processing raw refuse, where separators can remove large pieces of ferrous metal easily from the waste stream.

- Magnetic pulley: This consists of a drum type device containing permanent magnets or electromagnets over which a conveyor or a similar transfer mechanism carries the waste stream. The conveyor belt conforms to the rounded shape of the magnetic drum and the magnetic force pulls the ferrous material away from the falling stream of solid waste. Figure 2.6 illustrates this type of magnetic separator:

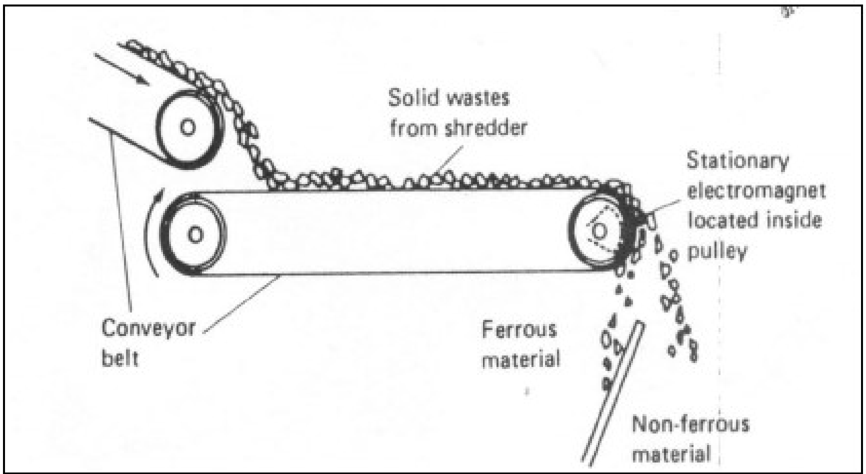


Figure 2.6 Pulley Type Permanent Magnetic Separator

Selection of magnetic separation equipment

We must consider the following factors in the selection of magnetic separation equipment:

- Characteristics of waste from which ferrous materials are to be separated (i.e., the amount of ferrous material, the tendency of the wastes to stick to each other, size, moisture content, etc.)
- Equipment used for feeding wastes to separator and removing the separated waste streams.
- Characteristics of the separator system engineering design, including loading rate, magnet strength, and conveyor speed, material of construction, etc.
- Operational characteristics, including energy requirements, routine and specialized maintenance requirements, and simplicity of operation, reliability, noise output, and air and water pollution control requirements.
- Locations where ferrous materials are to be recovered from solid wastes.
- Site consideration, including space and height, access, noise and environmental limitations.

8.3.3 Screening

Screening is the most common form of separating solid wastes, depending on their size by the use of one or more screening surfaces. Screening has a number of applications in solid waste resource and energy recovery systems. Screens can be used before or after shredding and after air separation of wastes in various applications dealing with both light and heavy fraction materials. The most commonly used screens are rotary drum screens and various forms of vibrating screens. Figures 2.7 shows a typical rotary drum screen:

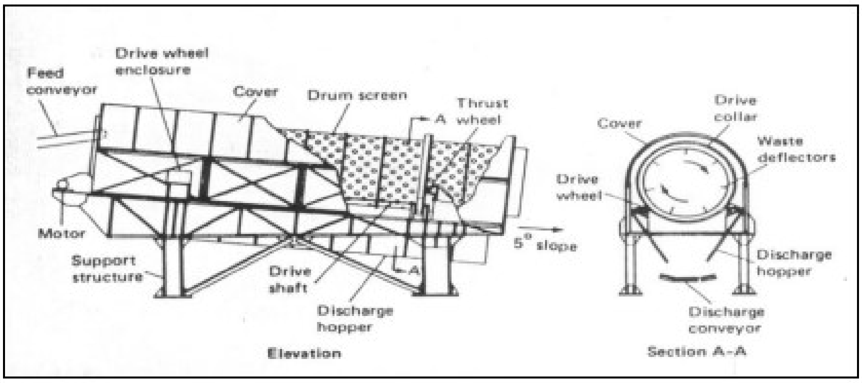


Figure 2.7 Rotary Drum Screen

Note that rotating wire screens with relatively large openings are used for separation of cardboard and paper products, while vibrating screens and rotating drum screens are typically used for the removal of glass and related materials from the shredded solid wastes.

Selection of screening equipment

The various factors that affect the selection of screens include the following:

- Material specification for screened component.
- Location where screening is to be applied and characteristics of waste material to be screened, including particle size, shape, bulk, density and moisture content.
- Separation and overall efficiency.
- Characteristics screen design, including materials of construction, size of screen openings, total surface screening area, oscillating rate for vibrating screens, speed for rotary drum screens, loading rates and length.
- Operational characteristics, including energy requirements, maintenance requirements, and simplicity of operation, reliability, and noise output and air and water pollution control requirements.
- Site considerations such as space and height access, noise and related environmental limitations.

Check your progress

Q1. Define The various factors that affect the selection of screening.

Q2. Illustrate Various types of equipment are in use for the magnetic separation of ferrous materials.

8.4 Waste handling and separation at Commercial and industrial facilities

All waste and recycling generated by a commercial building needs to be stored in appropriate bins or containers with permanent, well-fitting lids. Waste bins and containers should conform to AS 4123 Mobile Waste Containers if the standard is applicable for the selected bin or container type. Waste bins and containers greater than the capacity covered in the Standard (>1,700 L) should be designed to address safety risk. Coloured and labelled bin lids are an important means of correctly identifying what material should go into each bin, therefore replacing or repairing damaged and missing lids should be a priority for those managing the area. Whether they are situated indoors or outdoors, bins should always be in a clean and presentable condition and free of any dirt, accumulated waste or dried liquids. Maintaining bins in a clean and presentable condition will help to encourage appropriate waste and recycling behavior, with users more likely to take care when disposing of waste and avoid or clean up any accidental spills. Waste handling equipment, including balers and compactors, should conform to the relevant design and safety standards. Volume reductions achieved by such compacting and/or baling recyclables and waste offers potentially cost savings through reduced collection requirements

8.4.1 Bin Storage Area– General Considerations

Bin storage areas are where the bins receiving waste and recyclables from across the development are stored. Well-designed bin storage areas eliminate potential issues with conflicting uses of areas as well as minimize the impacts of inappropriately stored bins on local amenity and employee health and safety (Figure 2.8 and Figure 2.9). This is particularly important for commercial operations situated within mixed-use developments. Building and development designs need to incorporate sufficient space to store, in separate bins or containers, the volume of waste and recycling (and potentially organics) likely to be generated during the period between waste collections. Space should also be included for appropriate signage to clearly identify how to use the bins/equipment.

When calculating the likely storage space requirements, consider:

- Waste and recycling generation rates
- Frequency of likely collection
- Suitable waste and recycling storage equipment
- Ability of those depositing waste to access the area
- The likely collection service type, including the access requirements for collection vehicles (such as width and height of gates).

In relation to the design of the storage area, it should have smooth, cleanable and durable floor and wall surfaces that extend up the wall to a height equivalent to any containers held within the area. A further feature could be a bin wash option. It is also suggested that bin storage areas are fitted with doors, gates or roller doors that are durable, self-closing, and lockable and are able to be opened from both inside and outside the storage area. How the bin storage will be serviced is an essential consideration. Bins may be taken and emptied directly from the bin store area, or transported to a separate presentation point where they will be emptied by the service provider. If the storage is located away from the collection point, a responsible individual will be needed to transport separated waste from individual tenancies or areas.

Figure 2.8: Haphazard storage of commercial bins within a rear laneway.

Figure 2.9: Inappropriate and unsafe storage MGBs

8.4.2 Bin Storage Area – Size

The most difficult part of calculating the size of a bin storage area is predicting the collection service that will be needed as businesses expand or as tenancies change. Service requirements should be discussed with waste contractors or consultants and some flexibility needs to be built into the design to provide for future needs. The design of the building can incorporate flexibility by:

- Identifying suitable waste storage and collection point locations that would enable onsite collection in the future
- Keeping waste storage areas clear of potential obstacles that would limit bin size. For example, fixed structures to separate individual bins or bays should be avoided as bin sizes and/or configurations may change

- Designing access paths and doorways greater than the minimum width requirements to allow for potential changes in bin size. For example, installing double doors on a waste storage area would allow easy movement of either MGBs or bulk bins should either system be installed
- Sizing bin storage areas to allow for a potential increase in waste generation from the development, for example, if the building is expanded or its use is changed.

8.4.3 Bin Storage Area – Design

When designing the bin storage area, there are some general consideration, the areas need to:

- Be constructed in accordance with the requirements of the Building Code of Australia
- If enclosed, have a separate ventilation system to comply with AS 1668 – The use of mechanical ventilation and air-conditioning in buildings.

Bin storage areas should not affect the aesthetics of a development and should blend in with the surrounding buildings and landscape (Figure 2.9). Aside from aesthetics, locating storage areas out of sight of the public can reduce the chance of vandalism (as bins are less accessible) and reduce the impact of noise and odour.

Figure 2.9: These bins are easily accessible, but highly visible from the roadway. A bin store would help to minimize their impact on local amenity.

It is essential to provide an adequate area to enable waste and recycling (and organics collected) bins to be kept separate within the storage area (Figure 2.10). However, bin storage areas that are too large may encourage bulky items to be dumped. The storage area should be designed for easy access and maneuvering of bins to allow trouble-free cleaning. It is also important to consider the access requirements for maintenance and servicing. Other services and appliances, such as electrical meter boards, gas meters or conduits, should not be located in bin storage areas as they may be damaged during collection or cleaning.

Figure 2.10: Appropriate storage of bins.

Check your progress

Q1. Define Bin storage areas.

Q2. Illustrate Bin storage area designing in your local municipality.

8.5 Storage of solid waste at the sources.

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. While wastes have little or no value in one setting or to the one who wants to dispose them, the discharged wastes may gain significant value in another setting. Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated/ disposed is, therefore, essential for the design and operation of the functional elements associated with the management of solid wastes.

8.5.1 Source-based classification

Historically, the sources of solid wastes have been consistent, dependent on sectors and activities (Tchobanoglous, et al., 1977), and these include the following:

(viii) Residential: This refers to wastes from dwellings, apartments, etc., and consists of leftover food, vegetable peels, plastic, clothes, ashes, etc.

(ix) Commercial: This refers to wastes consisting of leftover food, glasses, metals, ashes, etc., generated from stores, restaurants, markets, hotels, motels, auto-repair shops, medical facilities, etc.

(x) Institutional: This mainly consists of paper, plastic, glasses, etc., generated from educational, administrative and public buildings such as schools, colleges, offices, prisons, etc.

(xi) Municipal: This includes dust, leafy matter, building debris, treatment plant residual sludge, etc., generated from various municipal activities like construction and demolition, street cleaning, landscaping, etc. (Note, however, in India municipal can typically subsume items at (i) to (iii) above).

(xii) Industrial: This mainly consists of process wastes, ashes, demolition and construction wastes, hazardous wastes, etc., due to industrial activities.

(xiii) Agricultural: This mainly consists of spoiled food grains and vegetables, agricultural remains, litter, etc., generated from fields, orchards, vineyards, farms, etc.

(xiv) Open areas: this includes wastes from areas such as Streets, alleys, parks, vacant lots, playgrounds, beaches, highways, recreational areas, etc.

8.5.2 Type-based classification

Classification of wastes based on types, i.e., physical, chemical, and biological characteristics of wastes, is as follows (Phelps, et al., 1995):

(xiii) Garbage: This refers to animal and vegetable wastes resulting from the handling, sale, and storage, preparation, cooking and serving of food. Garbage comprising these wastes contains putrescible (rotting) organic matter, which produces an obnoxious odour and attracts rats and other vermin. It, therefore, requires special attention in storage, handling and disposal.

(xiv) Ashes and residues: These are substances remaining from the burning of wood, coal, charcoal, coke and other combustible materials for cooking and heating in houses, institutions and small industrial establishments. Whenproduced in large quantities, as in power-generation plants and factories, these are classified as industrial wastes. Ashes consist of fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass. Since ashes and residues are almost entirely inorganic, they are valuable in landfills.

(xv) Combustible and non-combustible wastes: These consist of wastes generated from households, institutions, commercial activities, etc., excluding food wastes and other highly putrescible material. Typically, while combustible material consists of paper, cardboard, textile, rubber, garden trimmings, etc., non-combustible material consists of such items as glass, crockery, tin and aluminum cans, ferrous and non-ferrous material and dirt.

(xvi) Bulky wastes: These include large household appliances such as refrigerators, washing machines, furniture, crates, vehicle parts, tires, wood, trees and branches. Since these household wastes cannot be accommodated in normal storage containers, they require a special collection mechanism.

(xvii) Street wastes: These refer to wastes that are collected from streets, walkways, alleys, parks and vacant plots, and include paper, cardboard, plastics, dirt, leaves and other vegetable matter. Littering in public places is indeed a widespread and acute problem in many countries including India, and a solid waste management system must address this menace appropriately.

(xviii) Biodegradable and non-biodegradable wastes: Biodegradable wastes mainly refer to substances consisting of organic matter such as leftover food, vegetable and fruit peels, paper, textile, wood, etc., generated from various household and industrial activities. Because of the action of micro-organisms, these wastes are degraded from complex to simpler compounds. No biodegradable wastes consist of inorganic and recyclable materials such as plastic, glass, cans, metals, etc. Table 2.1 below shows a comparison of biodegradable and non-biodegradable wastes with their degeneration time, i.e., the time required to break from a complex to a simple biological form:

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

Table 2.1 Biodegradable and Non-Biodegradable Wastes: Degeneration Time

From Table 2.1, we can easily deduce the environmental consequences associated with non-biodegradable wastes such as plastics, glass, etc.

(xix) Dead animals: With regard to municipal wastes, dead animals are those that die naturally or accidentally killed on the road. Note that this category does not include carcasses and animal parts from slaughter-houses, which are regarded as industrial wastes. Dead animals are divided into two groups – large and small. Among the large animals are horses, cows, goats, sheep, pigs, etc., and among the small ones are dogs, cats, rabbits, rats, etc. The reason for this differentiation is that large animals require special equipment for lifting and handling when they are removed. If not collected promptly, dead animals pose a threat to public health since they attract flies and other vermin as they decay. Their presence in public places is particularly offensive from the aesthetic point of view as well.

(xx) Abandoned vehicles: This category includes automobiles, trucks and trailers that are abandoned on streets and other public places. However, abandoned vehicles have significant scrap value for their metal, and their value to collectors is highly variable.

(xxi) Construction and demolition wastes: These are wastes generated as a result of construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. They consist mainly of earth, stones, and concrete, bricks, lumber, roofing and plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream.

(xxii) Farm wastes:These wastes result from diverse agricultural activities such as planting, harvesting, production of milk, rearing of animals for slaughter and the operation of feedlots. In many areas, the disposal of animal waste has become a critical problem, especially from feedlots, poultry farms and dairies.

(xxiii) Hazardous wastes: Hazardous wastes are those defined as wastes of industrial, institutional or consumer origin that are potentially dangerous either immediately or over a period of time to human beings and the environment. This is due to their physical, chemical and biological or radioactive characteristics like ignitability, corrosively, reactivity and toxicity. Note that in some cases, the active agents may be liquid or gaseous hazardous wastes. These are, nevertheless, classified as solid wastes as they are confined in solid containers. Typical examples of hazardous wastes are empty containers of solvents, paints and pesticides, which are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous wastes may cause explosions in incinerators and fires at landfill sites. Others such as pathological wastes from hospitals and radioactive wastes also require special handling. Effective management practices should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them harmless.

(xxiv) Sewage wastes: The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derived from the treatment of organic sludge separated from both raw and treated sewages. The inorganic fraction of raw sewage such as grit and eggshells is separated at the preliminary stage of treatment, as it may entrain putrescible organic matter with pathogens and must be buried without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but is invariably uneconomical. Solid sludge, therefore, enters the stream of municipal wastes, unless special arrangements are made for its disposal.

Table 2.2 below summarizes our discussion of waste classification based on sources of generation and their types:

	Type	Description	Sources
Solid Wastes	Garbage	Food waste: wastes from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meat.	Households, institutions and commercial concerns such as hotels, stores, restaurants, markets, etc.
	Combustible and non–combustible	Combustible (primary organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings, etc.	
		Non-combustible (primary inorganic) metals, tin, cans, glass bottles, crockery, stones, etc.	
	Ashes	Residue from fires used for cooking and for heating building cinders	
	Bulky wastes	Large auto parts, tyres, stoves, refrigerators other large appliances, furniture, large crates, trees, branches, stumps, etc.	Streets, sidewalks, alleys, vacant lots, etc.
	Street wastes	Street sweepings, dirt, leaves, etc.	
	Dead animals	Dogs, cats, rats, donkeys, etc.	
	Abandoned vehicles	Automobiles and spare parts	
	Construction and demolition wastes	Roofing, and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc.	Construction and demolition sites.
	Industrial wastes	Solid wastes resulting from industry processes and manufacturing operations, such as, food processing wastes, boiler house cinders, wood, plastic and metal scraps, shavings, etc	Factories, power plants, etc.
	Hazardous wastes	Pathological wastes, explosives, radioactive materials, etc.	Households, hospitals, institutions, stores, industry, etc.
	Animal and agricultural wastes	Manure, crop residues, etc.	Livestock, farms, feedlots and agriculture
	Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

Table 2.2 Classification of Solid Wastes

8.6 Review Questions

Q1. Define biodegradable & non biodegradable waste.

Q2. What are Hazardous wastes.

Q3. Illustrate sewage waste in local Municipal Corporation.

UNIT-IX Processing of Solid Waste

Structure

9.0 Introduction

Management of solid waste may be defined as the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes based on scientific principles. This includes all technological, financial, institutional and legal aspects involved to solve the whole spectrum of issues related solid wastes. The SWM processes differ depending on factors such as socio-economic status, degree of industrialization, social development (e.g., education, literacy, healthcare etc.), life style and quality of life of a location. In addition regional, seasonal and economic differences influence the SWM processes.

The Processing of solid waste is biggest challenge in India .quantity of MSW generated is increasing rapidly due to increasing population and change in lifestyle. The current MSW crisis should be approached holistically; while planning for long term solutions, focus on the solving the present problems should be maintained. The Government and local authorities should work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. While this is being achieved and recycling is increased, provisions should be made to handle the non-recyclable wastes that are being generated and will continue to be generated in the future. Policy to include waste-pickers in the private sector must be introduced to utilize their low cost public and environmental service and to provide better working conditions to these marginalized populations

Objectives

After studying this unit you should be able to:

- Processing of solid waste at residence
- Processing of solid waste at Commercial and industrial site.

9.1 Processing of solid waste at residence

Management of solid waste may be defined as the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes based on scientific principles. This includes all technological, financial, institutional and legal aspects involved to solve the whole spectrum of issues related solid wastes. The SWM processes differ depending on factors such as socio-economic status, degree of industrialization, social development (e.g., education, literacy, healthcare etc.), life style and quality of life of a location. In addition regional, seasonal and economic differences influence the SWM processes. There are various functional elements associated with the management of solid wastes such as segregation, collection, processing and disposal.

(iii) Major Functional Elements

Waste generation: Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted into goods for consumption. The source of waste generation determines quantity, composition and waste characteristics.

Waste storage: Storage of waste after collection and before transportation to the processing/disposal site is an important functional component. The time of storage depends on the type of waste. For example, the biodegradable waste cannot be stored for long in a storage container because of its putrescible nature. There are many options for storage like plastic containers, conventional dustbins (of households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc.

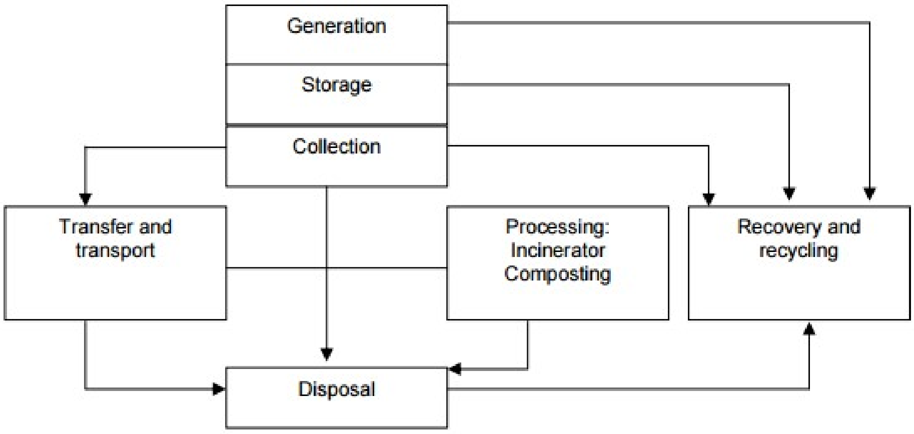
Waste collection: Collection refers to mainly two aspects; collection from the source of generation to the next collection point and collection from that point to the large vehicles for transportation or to the transfer stations and finally to the processing plant/disposal area. Collection depends on the number of containers, frequency of collection, types of collection services and routes. Collection is done either directly through the municipal services to franchised services or contracts. Recently, collection of waste from the source to the next step is carried out by Self Help Groups (SHGs) in many cities in India, which is very common in the state of Kerala.

Transfer and transport: This functional element involves:

- The transfer of wastes from smaller collection vehicles to larger ones at transfer stations.
- The subsequent transport of the waste to disposal sites

Processing: Processing of waste is the most important functional component of SWM system, which leads to various types of resource recovery, recycling, energy generation, production of organic manure, etc.

Disposal of final rejects: Disposal of final rejects after resource recovery is one of the important functional components of SWM system. This is mainly achieved through construction of engineered sanitary landfill. Engineering principles are followed to confine the wastes to the smallest possible area, reduce them to the lowest particle volume by compaction at the site and cover them after each day’s operation to reduce exposure to vermin



Flow chart of a typical SWM system with its functional elements and linkages

(iv) <u>Factors to be considered in SWM planning</u>

There are many factors influencing the SWM planning (Phelps et al., 1995), such as:

Quantity and characteristics of wastes: The quantity of wastes generated generally depends on the income level of a family, as higher income category tends to generate larger quantity of wastes, compared to low-income category. The quantity ranges from about 0.25 to about 0.65 kg per person per day, indicating a strong correlation between waste production and per capita income. One of the measures of waste composition (and characteristics) is density, which ranges from 150 kg/m3 to 600 kg/m3 . Proportion of paper and packaging materials in the waste largely account for the differences. When this proportion is high, the density is low and vice versa. The wastes of high density reflect a relatively high proportion of organic matter and moisture and lower levels of recycling.

Climate and seasonal variations: Climate has a major influence in SWM planning. In cold climates, drifting snow and frozen ground interfere with landfill operations, and therefore, trenches must be dug in summer and cover material stockpiles for winter use. Tropical climates, on the other hand, are subject to sharp seasonal variations from wet to dry season, which cause significant changes in the moisture content of solidwaste, varying from less than 50% in dry season to greater than 65% in wet months. Collection and disposal of wastes in the wet months are often problematic. High temperatures and humidity cause solid wastes decompose far more rapidly than in colder climates.

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 possible, door-to-door collection of solid wastes is comparatively easy using large compactor vehicle or smaller vehicle. Added to this is the problem of urban sprawl in the outskirts (of the cities) where population is growing at an alarming rate. Problems of solid waste storage and collection are most acute in such areas.

Management and technical resources: Solid waste management, to be successful, requires wide spectrum of work force in keeping with demands of the system. The best system for a region is one which makes full use of indigenous crafts and professional skills and/or ensures that training programs are in place to provide a self-sustaining supply of trained work force.

9.2 Processing of solid waste at Commercial and industrial site.

Commercial wastes are those produced from businesses such as food and drink establishments, shops, banks and by public administration offices. These wastes contain similar materials to residential waste, although the proportions may vary. For example, a restaurant will produce more food waste than a normal household and an insurance office will produce more paper and less food waste.

There are also many industrial facilities in Ethiopia that process agricultural products such as cotton, flour, hides and skins. Other important industries include plastic and resin manufacturing, textiles, cement, metallurgical, foods, general chemicals and pharmaceuticals. All these industries manufacture useful products and contribute to the country's economy but, at the same time, they can also be a major contributor to the country's solid waste and pollution problems.

The composition of the waste produced by industry depends very much on the nature of the industry concerned. For example, animal hide processing produces large amounts of biodegradable waste (animal parts), while the construction industry produces a lot of excavated soil, rock and demolition waste (bricks, stones, wood, glass, etc.). For this reason, industrial waste is usually processed and disposed of by the industry itself, often using specialized technologies. As explained in previous section, these wastes can be classed as either hazardous or non-hazardous depending on the inherent dangers associated with their physical and chemical properties.

Industrial and commercial organizations only produce a small proportion of a city's waste. Because of this, less attention is given to these wastes and the amounts produced are not known accurately. However, for urban WASH workers, it is useful to understand the characteristics of the solid waste generated from these sources in order to:

- advise workers on the potential health and environmental hazards of handling the solid waste
- give advice on the transportation, treatment, and disposal systems needed
- develop precautions and procedures to protect people during collection and disposal
- Understand and determine which of the solid wastes generated in any particular industry can be managed along with the household and commercial wastes.

9.9 REVIEW QUESTIONS

Q1.Define the processing of Commercial wastes are those produced from businesses such as food and drink establishments, shops, banks and by public administration offices.

Q2. Examine the industrial waste processing in your city.

BLOCK –IV

Disposal of Municipal Solid Waste and Hazardous Solid Waste

Block-IV Disposal of Municipal Solid Waste and Hazardous Solid Waste

OVERVIEW

Civilization began & developed around river banks. Things were manageable at those times as people lived in harmony with nature. Industrialization changed everything. At the end of the 19^{th} century the industrial revolution saw the rise of the world of consumers. Concentrated population packets developed at and around industrial area. Rapid Urbanization process posed many challenges before planning authorities. Government, local administration tried & is trying their level best to provide all basic amenities to this population. While doing so, one difficult challenge before administration is to manage waste generated by this large population. Solid waste generation is a continually growing problem at global, regional and local levels. Solid wastes are those organic and inorganic waste materials produced by various activities of the society, which have lost their value to the first user. Improper disposal of solid wastes pollutes all the vital components of the living environment (i.e., air, land and water) at local and global levels. The problem is more acute in developing nations than in developed nations, as their economic growth as well as urbanization is more rapid. There has been a significant increase in MSW (municipal solid waste) generation in India in the last few decades. This is largely because of rapid population growth and economic development in the country. Due to rapid growth of urban population, as well as constraint in resources, the management of solid waste poses a difficult and complex problem for the society and its improper management gravely affects the public health and degrades environment. The population of Mumbai grew from around 8.2 million in 1981 to 12.3 million in 1991, registering a growth of around 49%. On the other hand, MSW generated in the city increased from 3200 tonnes per day to 5355 tonnes per day in the same period registering a growth of around 67% (CPCB 2000). This clearly indicates that the growth in MSW in our urban centers has outpaced the population growth in recent years. This trend can be ascribed to our changing lifestyles, food habits, and change in living standards. Waste referred as rubbish, trash, garbage, or junk is unwanted or unusable material. According to European councils' directive "Waste is any substance or object which the holder discards or intends or is required to discard." Waste if it is hazardous or toxic, it could even be a harbinger of disease and death, not just for living beings, but for all that sustains life, for example, water, air, soil and food. Solid waste can be defined as any solid or semi-solid substance or object resulting from human or animal activities, discarded as useless or unwanted. It is an extremely mixed mass of wastes, which may originate from household, commercial, industrial or agricultural activities. Solid waste is a broad term, which encompasses all kinds of waste such as Municipal Solid Waste (MSW), Industrial Waste (IW), Hazardous Waste (HW), Bio-Medical Waste (BMW) and Electronic waste (E-waste) depending on their source & composition. It consists of organic and inorganic constituents which may or may not be biodegradable. On one hand, the recyclable components of solid waste could be useful as secondary resource for production processes. On the other hand, some of its toxic and harmful constituents may pose a danger if not handled properly. Source reduction, recycling and composting, waste-to-energy conversion facilities, and land filling are the four basic approaches to waste management. In this bock we will learn about Combustion and energy recovery of municipal solid waste, effects of combustion, undesirable effects of Combustion. Landfill: Classification, planning, sitting, permitting, landfill processes, landfill design, landfill operation, use of old landfill. Differentiate sanitary land fill and incineration as final disposal system for solid waste.

UNIT-X Combustion and energy recovery of solid waste

Structure

10.0 Introduction

In Unit 7, we discussed the recovery of energy through composting and bio gasification. Yet another means of energy recovery is thermal treatment of solid wastes, which is also regarded as pre-treatment of waste prior to final disposal. Thermal treatment includes both the burning of mixed MSW (municipal solid waste) in incinerators and the burning of selected parts of the waste stream as fuel. In this Unit (i.e., Unit 8), we will deal with incineration and energy recovery. We will begin the Unit with an introduction to the process and objectives of incineration. Then, we will take up the issues that are to be considered while planning an incineration facility. We will, subsequently, discuss. Various incineration technologies such as mass burning system, refuse derived fuel (RDF) system, modular incineration and fluidized bed incineration. Then, we will explain energy generation, i.e., generation of steam and electricity, and cogeneration of steam and electricity. Emission of air pollutants being a major concern of incineration facilities, and we will also discuss the various gaseous pollutants and their control measures (equipment). Finally, we will discuss the environmental impacts of incineration on land, water and aesthetics.

Objectives

After studying this unit you should be able to:

- Discuss incineration processes;
- List the objectives of incineration;
- Plan an incineration facility;
- Explain various incineration technologies;
- Identify emissions from incinerators and their control;
- Estimate the energy generation potential of wastes;
- Assess the environmental impacts of incineration.

10.1 Incineration: An Introduction

Incineration is a chemical reaction in which carbon, hydrogen and other elements in the waste mix with oxygen in the combustion zone and generates heat. The air requirements for combustion of solid wastes are considerable. For example, approximately 5000 kg of air is required for each tonne of solid wastes burned. Usually, excess air is supplied to the incinerator to ensure complete mixing and combustion and to regulate operating temperature and control emissions. Excess air requirements, however, differ with moisture content of waste, heating values and the type of combustion technology employed. The principal gas products of combustion are carbon dioxide, carbon monoxide, water, oxygen and oxides of nitrogen.

Many incinerators are designed to operate in the combustion zone of 900°C – 1100°C. This temperature is selected to ensure good combustion, complete elimination of odors and protection of the walls of the incinerator. Incinerator systems are designed to maximize waste burn out and heat output, while minimizing emissions by balancing the oxygen (air) and the three "Ts", i.e., time, temperature and turbulence. Complete incineration of solid wastes produces virtually an inert residue, which constitutes about 10% of the initial weight and perhaps a larger reduction in volume. The residue is generally landfilled.

The incineration facility along with combustion of waste emits air pollutants (i.e., fine particulate and toxic gases), which are an environmental concern, and, therefore, their control is necessary. Other concerns relating to incineration include the disposal of the liquid wastes from floor drainage, quench water, scrubber effluents and the problem of ash disposal in landfills because of heavy metal residues. By optimising the combustion process, we can control the emission of combustible, carbon-containing pollutants (EPA 1989 and 1995). Oxides of nitrogen and sulphur, and other gaseous pollutants are not considered a problem because of their relatively smaller concentration Having introduced you to incineration, we will touch upon the combustion of various elements of waste materials and the objectives of incineration in Subsections 8.1.1 and 8.1.2, respectively.

10.1.1 Combustion of waste material

Table 10.1 shows the major elements that constitute solid wastes and the end products of combustion

Table 10.1

Major Elements of Solid Wastes Elements	Combustion Process	**End Products (Gases)**
Carbon (C)	Carbon dioxide (CO_2)	
Hydrogen (H)	Water (H_2O)	
Oxygen (O)		
Nitrogen (N)	Nitrogen (N_2)	
Sulphur (S)	Sulphur dioxide (SO_2), other gaseous compounds and ash	

Table 10.2 gives the information about several components of solid waste mixtures on the basis of proportion:

Table 10.2

Ultimate Analysis of Combustible Component Percent by Weight (dry basis)						
Component	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulphur**	**Ash**
Food waste	48.0	6.4	37.6	2.6	0.4	5.0
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Cardboard	44.0	5.9	44.6	0.3	0.2	6.0
Plastic	60.0	7.2	22.8	--	--	10.0
Textile	55.0	6.6	31.2	4.6	0.15	2.5
Rubber	78.0	10.0	--	2.0	--	10.0
Leather	60.0	8.0	11.6	10.0	0.4	10.0
Garden trimmings	47.8	6.0	38.0	3.4	0.3	4.5
Wood	49.5	6.0	42.7	0.2	0.1	1.
Dirt, ash, brick, etc.	26.3	3.0	2.0	0.5	0.2	68.0

Energy value (BTU/lb) = 145.4 C + 620 (H – 1/8 O) + 41S

WhereC, H, O, and S are in percent by weight (dry basis) and can be converted to KJ/kg by: **BTU/lb x 2.326 = KJ/kg**

10.1.2 Incineration objectives

The purpose of incineration is to combust solid wastes to reduce their volume to about one-tenth, without producing offensive gases and ashes (Phelps, et al., 1995). That is to say, incineration of solid wastes aims at the following (McDougall, et al., 2001):

Volume reduction: Depending on its composition, incineration reduces the volume of solid wastes to be disposed of by an average of 90%. The weight of the solid wastes to be dealt is reduced by 70 – 75%. This has both environmental and economic advantages since there is less demand for final disposal to landfill, as well as reduced costs and environmental burdens due to transport, if a distant landfill is used.

Stabilisation of waste: Incinerator output (i.e., ash) is considerably more inert than incinerator input (i.e., solid wastes), mainly due to the oxidation of the organic components of the waste stream. This leads to a reduction of landfill management problems (since the organic fraction is responsible for landfill gas production) and the organic compounds present in landfill leachate.

Recovery of energy from waste (EFW): This represents a valorisation method, rather than just a pre-treatment of waste prior to disposal. Energy recovered from burning the wastes is used to generate steam for use in on-site electricity generation or export to local factories or district heating schemes. Combined heat and power plants increase the efficiency of energy recovery by producing electricity as well as utilising the residual heat. Solid waste incineration can replace the use of fossil fuels for energy generation. As a large part of the energy content of solid wastes comes from truly renewable resources (e.g., biomass), there should be a lower overall net carbon dioxide production than that from burning fossil fuels, since carbon dioxide is absorbed in the initial growing phase of the biomass.

Sterilization of waste: This is of primary importance in the incineration of clinical or biomedical waste. Incineration of solid wastes will also ensure destruction of pathogens prior to final disposal in a landfill.

The prevalence of incineration practice and the actual approach that it takes vary across regions and reflect the relative importance attached to the different objectives discussed. Volume reduction for both environmental and economic reasons and sterilization of waste has historically been the important objectives of incineration. Due to the growing concern over the production of landfill gas and the organic compounds in leachate from landfill receiving untreated waste, it is likely that the future will see more emphasis on using incineration for stabilizing wastes for subsequent landfilling. Landfill gas and leachate arise principally from the organic fraction of solid wastes, which will be effectively converted to gases and mineralized ash by incineration

Now, we discuss the planning aspects pertaining to siting and sizing an incineration facility.

10.2 Planning an Incineration Facility

Incineration of solid wastes is becoming an increasingly important aspect of solid waste management, as communities look for alternatives to rapidly filling landfills (or disappearing landfill sites). Modern incineration facilities are no longer simple garbage burners. Instead, they are designed to produce steam and electricity and can be used as a complement to source reduction, recycling and composting programmes. However, strategic long- term planning is essential for developing a successful incineration facility. In other words, it is important to develop an understanding of a variety of issues in the planning process, including the following:

(i) **Facility ownership and operation:** One of the first planning decisions that local officials make is about the entity that will actually own the facility and oversee its operation. This decision is based largely on the amount of financial risk the community is willing to assume and the time and resources available. Some of the procurement options, in this context, are:

Full service approach: In this system, the community specifies only the process type and the performance required, and hires a (single) firm to design, construct and operate the plant.

Merchant plants: In this type of system, in which waste is accepted on weight basis, a private firm designs, constructs, owns and operates the facility.

Turnkey approach: In this system, a single company designs and builds the plant, according to the communities' specifications, and the community or a different contractor owns and operates the plant.

(ii) **Energy market:** Waste incineration facilities differ from most government services in that they generate a product as well as energy, which are sold for revenue. Steam and electricity are the energy products at incineration facilities, depending on the particular design.

(iii) **Marketing steam:** The primary end uses of steam from waste incineration facilities are industrial and institutional heating and cooling systems. Marketing of steam products involves identifying these industries and institutions within the region. Industrial and institutional steam users include textile, paper and pulp, food processing, leather, chemical producers, hospitals, etc. Planning must include proper backup to guarantee a consistent supply and steam demand variation (often caused by changing seasons).

(iv) **Marketing electricity:** Incineration facilities generating electricity are referred to as *co-generators* as they provide electricity in addition to that generated by the local electric utility. Besides the plant that uses the electricity generated for its operation, customers for electricity include nearby industries and public, and private utilities. It must be equipped to give a consistent supply and must compete with other co-generators in selling energy.

(v) **Facility siting:** Siting the incineration facility is one of the most important tasks to be undertaken and a variety of social and technical hurdles have to be negotiated. The important aspects in this context are the following:

Effect on residents: Residents will be concerned with the health effects associated with incinerator plant, decreased property value and increased traffic (e.g., due to truck movement).

Environmental impact: Incineration has the potential to create a variety of environmental concerns like air, water and noise pollution and ash disposal

Development plans: It is important to evaluate future land use plans at the possible site.

Proximity to waste source: Transportation cost is one of the most significant expenditures in waste management system.

Proximity to energy market: The energy products will have to be delivered to buyers. The location of power line must be considered.

Logistic concerns: Area zoning and access route must be considered.

Residual ash disposal: Access to a secure landfill is necessary.

(vi) **Facility sizing:** Proper plant sizing results from careful evaluation of a wide variety of criteria such as:

Waste supply: This is the most fundamental sizing factor and measures are usually taken to guarantee a waste supply for the facility. Waste flow control ordinances are often used to ascertain the quantity of waste. When properly planned, waste flow control can benefit both incineration facility and alternative waste management programme, by diverting the relevant portions of the waste stream (e.g., recyclables to the recycling programme and combustibles to incineration facility).

Alternative waste management programme: In addition to waste flow control agreements, future source reduction, recycling and composting programmes are directly related to facility design. When sizing the incineration facility, it is important, therefore, to account for the type and amount of materials that will be diverted from the facility.

Waste stream characteristics: Good combustion depends on the accuracy of waste stream data. Planning of incineration facility requires waste stream assessment to develop an accurate picture of the quantity and composition of the waste stream. From a technical standpoint, the waste stream data will be used to ascertain the heating value of the waste, which helps in plant operation

Planning for facility disruption: Accounting for downtime is an important facility planning criteria. Most incineration facilities are designed to operate continuously (i.e., 24 hours a day), but both scheduled (e.g., maintenance) and unscheduled (e.g., equipment failure) downtime situations are likely to occur. Storage space must be available for the waste that continues to arrive during downtime. If these capabilities are not built into the system, provisions must be made to send waste to a landfill or an alternative facility.

Facility financing: Depending upon the procurement approach selected, incineration facility will require extensive financing agreements.

Time frame: The time required to plan, develop and construct a facility will vary, but at least 5 to 8 years are required to bring a new facility from the early planning stages to in-service.

Long-term planning within the local government is the key for successful facility design and operation. By understanding all issues and dedicated workforce, waste combustion can become a positive component of waste management system (EPA 1989 and 1995).

10.3 Incineration Technologies

The four incineration technologies covered in this section are mass burning system, refuse derived fuel system, modular incineration and fluidised bed incineration. The two most widely used and technically proven incineration technologies are mass-burning incineration and modular incineration. Fluidised-bed incineration has been employed to a lesser extent, although its use has been expanding and experience with this relatively new technology has increased. Refuse-derived fuel production and incineration has also been used, with limited success. Some facilities have been used in conjunction with pyrolysis, gasification and other related processes that convert solid waste to gaseous, liquid, or solid fuel through thermal processing (UNEP 1996). In Subsections 8.3.1 to 8.3.4, we will discuss the four incineration technologies.

10.3.1 Mass-burning system

Mass-burning systems are the predominant form of MSW incineration. A mass-burn facility typically consists of a reciprocating grate combustion system and a refractory-lined, water-walled steam generator. Mass-burn systems generally consist of either two or three incineration units ranging in capacity from 50 to 1,000 tonnes per day. That is to say, the facility capacity ranges from about 100 – 150 to 2,000 – 3,000 tonnes per day. These facilities can accept refuse that has undergone little preprocessing other than the removal of oversized items. Although this versatility makes mass-burn facilities convenient and flexible, local programmes to separate household hazardous wastes (e.g., cleaners and pesticides) and recover certain materials (e.g., iron scrap) are necessary to help ensure environmentally viable incineration and resource conservation.

Because of the larger facility size, an incineration unit is specially designed to efficiently combust the waste to recover greater quantities of steam or electricity for revenue. To achieve this greater combustion and heat recovery efficiency, the larger field-erected incinerators are usually in-line furnaces with a grate system. The steam generator generally consists of refractory-coated water wall systems i.e., walls comprised of tubes through which water circulates to absorb the heat of combustion. In a water wall system, the boiler is an integral part of the system wall, rather than a separate unit as is in a refractory system.

Mass-burning of waste can also be achieved by the use of a rotary kiln. Rotary kilns use a turning cylinder, either refractor or water wall design, to tumble the waste through the system. The kiln is reclined, with waste entering at the high elevation end and ash and non-combustibles leaving at the lower end.

The waste intake area usually includes a tipping floor, pit, crane and sometimes conveyors. Trucks enter the tipping floor and tip their wastes either onto the floor itself, or directly into the pit. When wastes are tipped onto the floor, a front-end loader or a bulldozer is used to push them into the pit or onto a conveyor. From a feed chute, MSW is continuously fed to a grate system, which moves the waste through a combustion chamber using a tumbling motion. A travelling or reciprocating grate may follow rotary combustors to further complete combustion.

At least two combustor units are included to provide a level of redundancy and to allow waste processing at a reduced rate during periods of scheduled and unscheduled maintenance. Mass-burn facilities today generate a higher quality of steam (i.e., pressure and temperature), which is then passed through a turbine generator to produce electricity or through an extraction turbine to generate electricity as well as provide process steam for heating or other purposes. Figure 10.1 below illustrates a typical mass-burn facility:

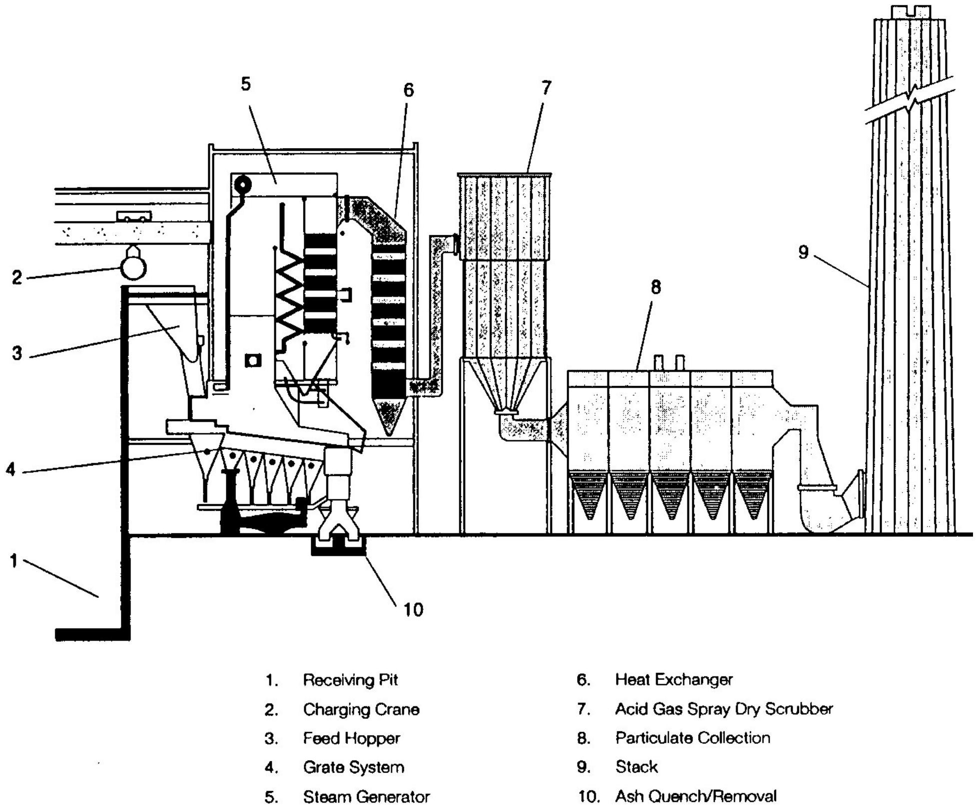


Figure 10.1 Typical Mass-Burn Facility

10.3.2 Refuse derived fuel (RDF) system

Refuse-derived fuel (RDF) refers to solid wastes in any form that is used as fuel. The term RDF, however, is commonly used to refer to solid waste that has been mechanically processed to produce a storable, transportable and more homogeneous fuel for combustion. RDF systems have two basic components: RDF production and RDF incineration.

RDF production facilities make RDF in various forms through material separation, size reduction and pelletising. Although RDF processing has the advantage of removing recyclables and contaminants from the combustion stream, on an average, capital costs per tonne for incineration units that use RDF are higher than for other incineration options. RDF production plants like mass-burn incinerators characteristically have an indoor tipping floor. Instead of being pushed onto a pit, the waste in an RDF plant is typically fed onto a conveyor, which is either below grade or hopper fed. In some plants, the loader doing the feeding will separate corrugated and bulky items, like carpets.

Once on the conveyor, the waste travels through a number of processing stages, usually beginning with magnetic separation. The processing steps are tailored to the desired products, and typically include one or more screening stages, using trammel or vibrating screens, shredding or hammer milling of waste with additional screening steps, pelletising or baling of burnable wastes, and, depending on the local recycling markets and the design of the facility, a manual separation line. A typical RDF facility scheme is given in Figure 10.2 below:

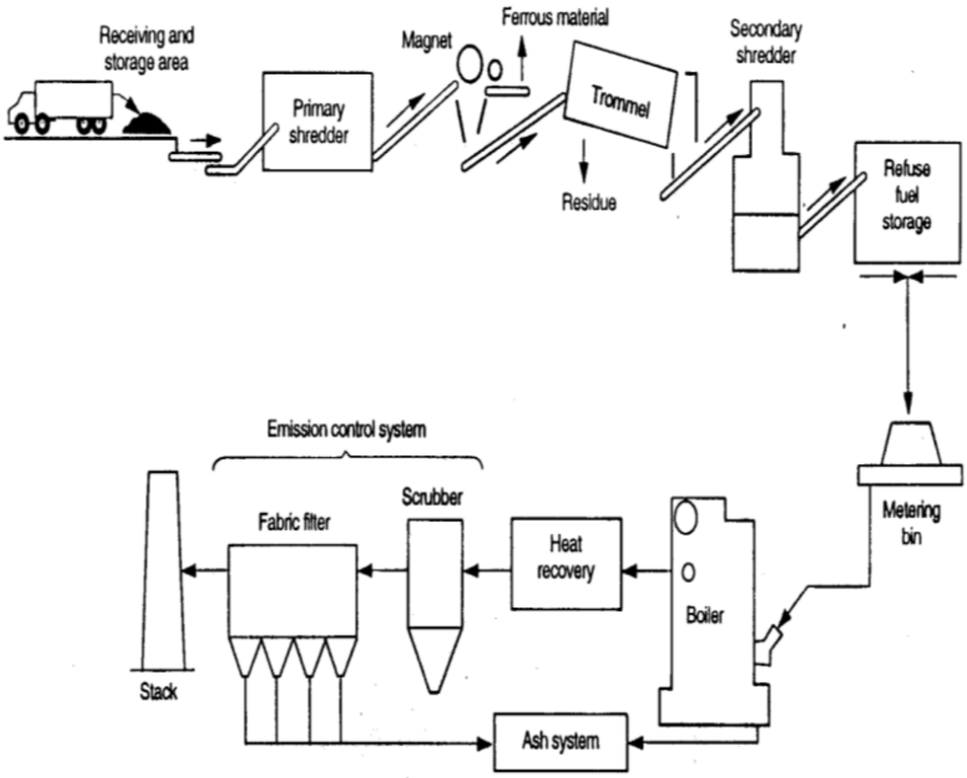


Figure 10.2 Typical Simplified RDF Facility

There are two primary types of systems in operation, and these are:

(i) **Shred-and-burn systems:** Shred-and-burn systems are the simplest form of RDF production. The process system typically consists of shredding the MSW to the desired particle size that allows effective feeding to the combustor and magnetic removal of ferrous metal, with the remaining portion delivered to the combustor. There is no attempt to remove other non-combustible materials in the MSW before combustion. This, in essence, is a system with minimal processing and removal of non-combustibles.

(ii) **Simplified process systems:** This is a system that removes a significant portion of the non-combustibles. A simplified process system involves processing the MSW to produce an RDF with a significant portion of the non-combustibles removed before combustion. The MSW process removes more than 85% of the ferrous metals, a significant percentage of the remaining non-combustible (i.e., glass, nonferrous metals, dirt, sand, etc.), and shreds the material to a nominal particle top size of 10 to 15 cm to allow effective firing in the combustion unit

Depending on the type of combustor to be used, a significant degree of separation can be achieved to produce a high-quality RDF (i.e., low ash), which typically results in the loss of a higher percentage of combustibles when compared to systems that can produce a low-quality fuel (i.e., slightly higher ash content) for firing in a specially designed combustor. These types of systems recover over 95% of the combustibles in the fuel fraction.

10.3.3 Modular incineration

Modular incinerator units are usually prefabricated units with relatively small capacities between 5 and 120 tonnes of solid waste per day. Typical facilities have between 1 and 4 units with a total plant capacity of about 15 to 400 tonnes per day. The majority of modular units produce steam as the sole energy product. Due to their small capacity, modular incinerators are generally used in small communities or for commercial and industrial operations.

Their prefabricated design gives modular facilities the advantage of a shorter construction time. Modular combustion systems are usually factory-assembled units consisting of a refractory-lined furnace and a waste heat boiler. Both units can be pre-assembled and shipped to the construction site, which minimises field installation time and cost. Adding modules or units, installed in parallel can increase facility capacity. For example, a 200 tonne-per-day facility may consist of 4 units, a 50-tonne-per-day consists of 2 units and a 100 tonne-per-day consists of 1 unit. The number of units may depend on the fluctuation of waste generation for the service area and the anticipated maintenance cycle of the units.

Modular incinerators employ a different process from that of mass-burn incinerators, typically involving two combustion chambers, and combustion is typically achieved in two stages.

The first stage may be operated in a condition in which there is less than the theoretical amount of air necessary for complete combustion. The controlled air condition creates volatile gases, which are fed into the secondary chamber, mixed with additional combustion air, and under controlled conditions, completely burned. Combustion temperatures in the secondary chamber are regulated by controlling the air supply, and when necessary, through the use of an auxiliary fuel. The hot combustion gases then pass through a waste heat boiler to produce steam for electrical generation or for heating purposes. The combustion gases and products are processed through air emission control equipment to meet the required emission standards.

In general, modular incineration systems are a suitable alternative and may, for smaller-sized facilities, be more cost-effective than other incinerators. But modular incineration has become less common, partly due to concerns over the consistency and adequacy of air pollution controls.

10.3.4 Fluidised-bed incineration

Fluidised-bed incineration of MSW is typically medium scale, with processing capacity from 50 to 150 tonnes per day. In this system, a bed of limestone or sand that can withstand high temperatures, fed by an air distribution system, replaces the grate. The heating of the bed and an increase in the air velocities cause the bed to bubble, which gives rise to the term *fluidised*. There are two types of fluidised-bed technologies, viz., bubbling bed and circulating bed. The differences are reflected in the relationship between air flow and bed material, and have implications for the type of wastes that can be burned, as well as the heat transfer to the energy recovery system.

Unlike mass-burn incinerators, fluidised-bed incinerators require front-end pre-processing, also called fuel preparation. They are generally associated with source separation because glass and metals do not fare well in these systems and also they can successfully burn wastes of widely varying moisture and heat content, so that the inclusion of paper and wood, which are both recyclable and burnable, is not a crucial factor in their operation (and thus paper can be extracted for higher-value recycling).

Fluidised-bed systems are more consistent in their operation than mass burn and can be controlled more effectively to achieve higher energy conversion efficiency, less residual ash and lower air emissions. In general, however, these systems appear to operate efficiently on smaller scales than mass-burn incinerators, which may make them attractive in some situations. For this reason, fluidised-bed technology may be a sound choice for high-recycling cities in developing countries when they first adopt incineration.

Let's see Indian Scenario in adopting incineration technology

Indian scenario in selection of Incineration technology

The absence of a well planned, scientific system of waste management (including waste segregation at source) coupled with ineffective regulation leading to waste burning. The left-over waste at the dumping yards generally contains high percentage of inerts (>40%) and of puterscible organic matter (30-60%). It is common practice of adding the road sweepings to the dust bins. Papers and plastics are mostly picked up and only such fraction which is in an unrecoverable form remains in the refuse. Paper normally constitutes 3-7% of refuse while the plastic content is normally less than 1%. The calorific value on dry weight basis (High Calorific Value) varies between 800-1100 k-cal/kg. Self sustaining combustion cannot be obtained for such waste and auxiliary fuel will be required. Incineration, therefore, has not been preferred in India so far. The only incineration plant installed in the country is at Timarpur, Delhi way back in the year 1990 has been lying inoperative due to mismatch between the available waste quality and plant design. This made the government of Delhi to assure increased efforts in segregation of household MSW at source collection. However, with the growing problems of waste management in the urban areas and the increasing awareness about the ill effects of the existing waste management practices on the public heath, the urgent need for improving the overall waste management system and adoption of advanced, scientific methods of waste disposal, including incineration, is imperative.

Out of most recent Waste to energy technologies adopted in India such as Biomethanation, landfill with gas recovery, gasification/pyrolysis, incineration and composting; incineration is selected as last option.

Check your progress

Q1. Define undesirable effects of Combustion.

Q2. Illustrate Refuse-derived fuel (RDF) refers to solid wastes.

10.4 Energy Recovery

Most of the MSW incineration currently practice energy recovery in the form of steam, which is used either to drive a turbine to generate electricity or directly for heating or cooling. In the past, it was common to simply burn MSW in incinerators to reduce its volume and weight, but energy recovery has become more prevalent (EPA 1989 and 1995).

In waste-to-energy (WTE) plants, heat from the burning waste is absorbed by water in the wall of the furnace chamber, or in separate boilers. Water when heated to the boiling point changes to steam. At this point, the steam is used either for heating or to turn turbines to generate electricity. The amount of energy recovered from waste is a function of the amount of waste combusted, energy value of the waste stream and the efficiency of the combustion process (UNEP 1996). The three basic types of waste-to-energy incineration are:

(i) **Generation of electricity:** Electricity is the most common form of energy produced and sold from WTE facilities constructed today. By directing the steam produced from a WTE system through a turbine generator, electricity can be produced and sold. A process flow diagram of an electrical generation system is shown in Figure 10.3:

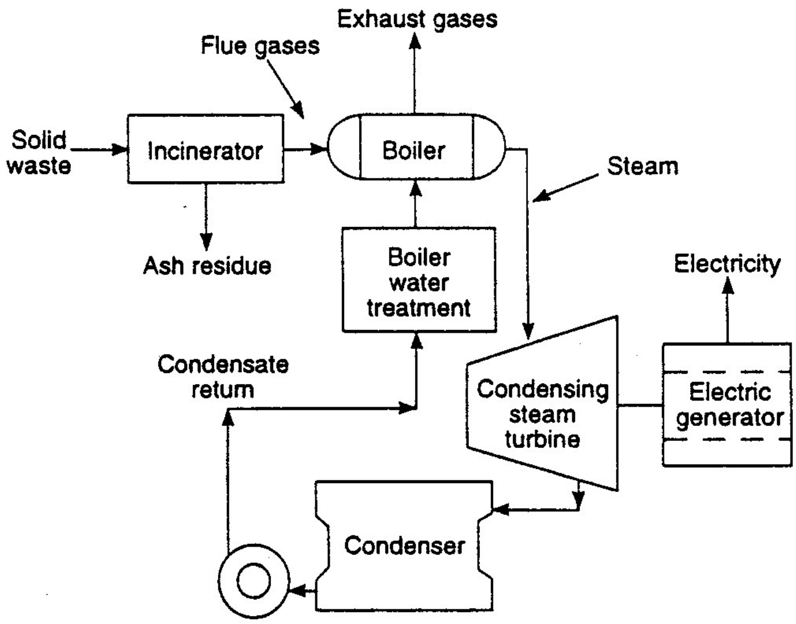


Figure 10.3 Incinerator and Electrical Generation System

Since electric utilities can receive power 24 hours a day and are usually very stable financially, public utilities have attractive markets for power produced from WTE systems. Of the electricity produced in incineration facilities, about one-fifth is used at the facility for general operations, and the remainder is sold to public and private utilities or nearby industries. In many countries, utilities provide a stable market for electricity generated from incinerators. The availability of purchasers and rates for electricity sales will, however, vary by region.

(ii) **Steam generation**: Steam is used widely in a variety of industrial applications. Steam generated in incineration facilities can also be used directly by a customer for manufacturing operations. Steam generated in an incinerator is supplied to a customer through a steam line, and a separate line sometimes returns the condensed steam. It can be used to drive machinery such as compressors, for space heating and generating electricity. Industrial plants, dairies, cheese plants, public utilities, paper mills, tanneries, breweries, public buildings and many other businesses use steam for heating and air conditioning.

When assessing potential markets for steam, it is important to consider a market's proximity to the WTE facility and the quantity of steam produced. Proximity is important because steam cannot usually be economically transported more than one or two miles. The WTE facility, therefore, should be as close as possible to the potential market. The advantages of transmitting steam over a long distance to an end user must be weighed against energy losses that will occur in transmission. Installation of a pipeline connecting the facility and the customer can also be prohibitively expensive in certain circumstances. High-temperature hot water may be an option for overcoming the transmission limitation for steam.

Anticipated steam quantity and quality are interrelated parameters, and must be carefully projected when assessing steam markets. The prospective user will most likely have an existing process requiring steam at a specific temperature and pressure. The quantity of steam produced from a given amount of waste will decrease, as the steam temperature and pressure increase, but the equipment using the steam will operate more efficiently. To ensure the continuing availability of high quantity and quality steam, supplementary fuels, such as natural gas, may occasionally be used, but this will result in an increase in the operating costs.

(iii) **Co-generation:** Co-generation refers to combined production of steam and electricity and can occur in two ways. If the energy customer requires steam conditions (pressure and temperature) that are less than the incineration plant's design specifications, a turbine-generator is used to produce electricity and thus reduce steam conditions to appropriate levels for the customer. If the steam purchaser cannot accept all the steam produced by the facility, the excess can be converted to electricity. In co-generation, high-pressure steam is used first to generate electricity; the steam leaving the turbine is then used to serve the steam users. Co-generation (Figure 8.4) provides greater overall energy efficiency, even though the output of the major energy product – whether electricity or steam – may be less than that generated by producing one type of energy alone.

Co-generation allows flexibility, so that seasonal variations in steam demand can be offset by increases in electricity production, and can provide the project a financial base by selling electricity, should the steam customer become unavailable.

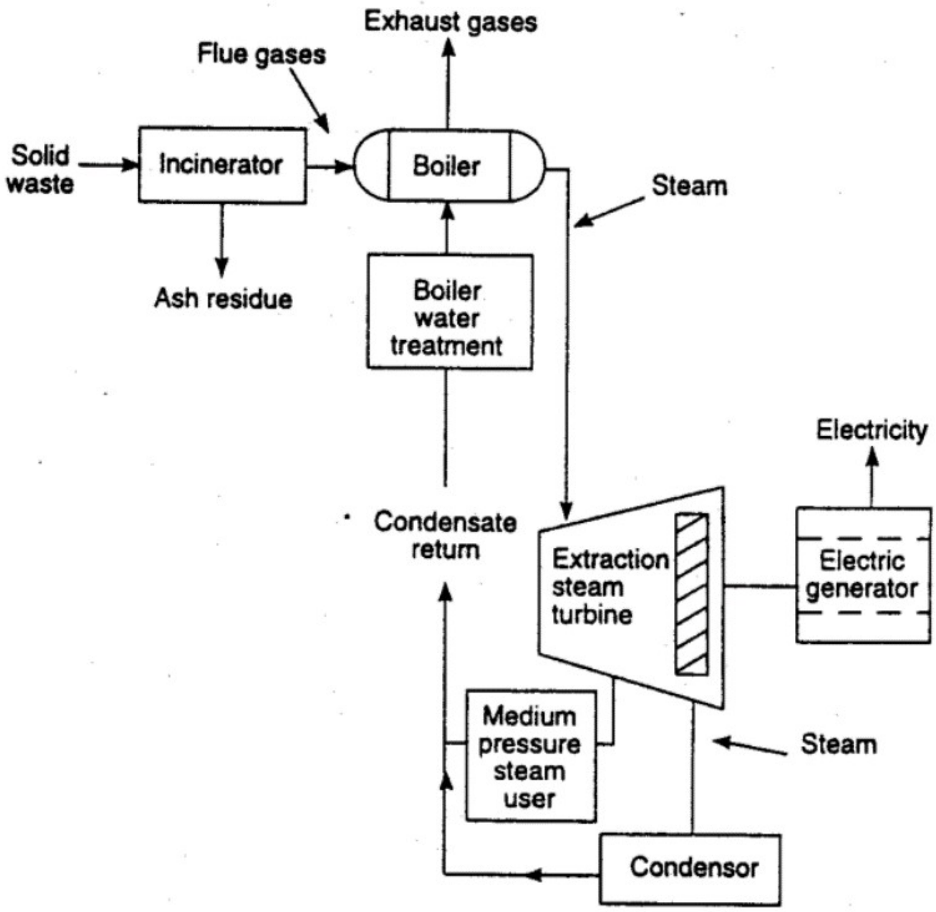


Figure 10.4 Co-generation System for Producing Electricity and Steam

10.5 Air Emission and Its Control

The operation of the combustion process plays an important role in the formation of pollutants, which are carbon monoxide, NOx (oxides of nitrogen), hydrocarbons and other volatile organic compounds. It also produces gaseous stream containing dust, acid gases (HCl, SOx, HF), heavy metals and traces of dioxins (McDougall, et al., 2001). The majority of modern incinerators, however, produce less particulate and gaseous pollutants than their predecessors. Also, emissions from incinerators are controlled by a combination of measures that use both the pollution prevention approach and various control equipment. We will describe the main gaseous pollutants and their control measures, respectively, in Subsections 8.5.1 and 8.5.2.

10.5.1 Gaseous pollutants

The various gaseous pollutants formed due to incineration processes are:

Carbon dioxide (CO_2): This is one of the main products of incineration, and the other main product is water. At low concentrations, CO_2 has no short-term toxic or irritating effect, as it is abundant in the atmosphere and necessary for plant life and is not generally considered a pollutant. Nevertheless, due to the high increase in global concentration of CO_2, it has been recognised as one of the gases responsible for global warming.

Carbon monoxide (CO): An incomplete combustion of carbon due to the lack of oxygen forms CO. This gas is toxic, as it reacts with the haemoglobin in the blood, causing a decrease of available oxygen to the organisms. This lack of oxygen produces headache, nausea, suffocation and eventually death. Carbon monoxide in the flue gas and is used to monitor the incomplete combustion of the other emissions, such as un-burnt hydrocarbons and provide information on the performance of the incinerator.

Sulphur oxides (SOx): The emission of SOx is a direct result of the oxidation of sulphur present in solid waste, but other conditions such as the type of incinerator used and its operating conditions also influence its production. Approximately 90% of SOx emissions are SO_2 and 10% are SO_3. In the atmosphere, most of the SO2 is transformed into SO_3, which leads to the production of H_2SO_3 (sulphurous acid) and H_2SO_4 (sulphuric acid), increasing the acidity of rain. At high concentrations, it causes eye, nose and throat irritation, and other respiratory problems.

Nitrogen oxides (NO_x): This is predominantly formed during the incineration process. However, they oxidise to NO_2 in the atmosphere. NO_x is formed from two main sources – thermal NO_x and fuel NO_x. In thermal formation, the oxygen and nitrogen react in the air. Fuel NO_x is formed during the reactions between oxygen and nitrogen in the fuel. Nitrogen oxides are important, as they participate in several processes in atmospheric chemistry. They are precursors of the formation of ozone (O_3) and preoxy acetal nitrate (PAN). These photochemical oxidants are responsible for smog formation and cause acid rain.

Particulates: This is formed during the combustion process by several mechanisms. The turbulence in the combustion chambers may carry some ash into the exhaust flow. Other inorganic materials present in the waste volatilise at combustion temperature and later condense downstream to form particles or deposits on ash particles. The main component of fly ash is chemically inert silica; but it may also contain toxic metal and organic substances.

Hydrochloric acid (HCl): Hydrochloric acid results from the high concentration of chlorine containing materials (e.g., some type of plastics like polyvinyl chloride) in solid waste. Chlorine easily dissolves in water to form HCl. Its presence in the gaseous state may increase the acidity of local rain and ground water, which can damage exposed and unprotected metal surfaces, erode buildings and may affect the mobilisation of heavy metals in soil.

Hydrogen fluoride (HF): Hydrogen fluoride is more toxic and corrosive than HCl, although its presence in the emissions from solid waste incinerators occurs in much smaller quantities. It is formed due to the presence of trace amounts of fluorine in the waste.

Heavy metals (Hg, Cd, Pb, Zn, Cu, Ni, Cr): Solid waste contains heavy metals and metallic compounds in the combustible and incombustible fractions. During the incineration process, metals may vaporise directly or form oxides or chlorides at high temperatures in the combustion zone. They condensate over other particles and leave the incineration process in the flue gas.

Dioxins and furans: Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) have been detected in the emissions from solid waste incinerators. Dioxins can be formed in all combustion processes, where organic carbon, oxygen and chlorine are present, although the processes by which they are formed during incineration are not completely understood. The concern over dioxins and furans has increased after a number of animal studies have shown that for some species, they are carcinogenic and highly toxic, even at very low levels of exposure.

10.5.2 Gas-cleaning equipment

The technologies employed to carry out the necessary flue gas cleaning include:

Electrostatic precipitators (ESP): These are used for particle control. ESP use electric forces to move the particle flowing out of the gas stream on to the collector electrodes. The particles get a negative charge, when they pass through an ionised field. The electric field that forces the charged particles to the walls comes from discharged electrodes maintained at high voltage in the centre of the flow lane.

When particles are collected, they must be carefully removed to avoid their entry into the gaseous stream. This is achieved by knocking them loose from the plates and by intermittent and continuous washing with water. The removal efficiency is more than 99% with a low-pressure drop. Particle size and other physical characteristics such as gas stream temperature, flue gas volume, moisture content, gas stream composition, particle composition and particle surface characteristics affect the performance of the equipment. ESP's come in one- or two-stage designs and can have different configurations: plate wire, flat plate and tubular. These configurations can be wet or dry, depending on the method of dust collection.

Fabric filters: In fabric filtration, the gas flows through a number of filter bags placed in parallel, leaving the dust captured by the fabric. Extended operation of fabric filters requires periodic cleaning of the cloth surface. After a new fabric goes through a number of cycles of use and cleaning, it forms a residual cake of dust that becomes the filter medium, which is responsible for highly efficient filtering of small particles that characterises fabric filter. They are widely accepted for controlling particulate matter.

The type of cloth fabric limits the temperature of operation of fabric cloth: cotton is least resistant (82C) while fabric glass is the most resistant (277C). This temperature requirement makes the use of a cooling system necessary for the gas, before it enters the equipment, but it is also necessary that the temperature of the exhaust gas stream be maintained above the dew point because liquid particles block the pores in the fabric very quickly. The major difference between different configurations of fabric filters is the cleaning method used during operating cycles such as shaker, reverse-air and pulse-jet cleaning

Scrubbers: Scrubbers are used to control particulate matter and acid gases leaving the incinerator. Particulates and gases are removed from the gas stream mainly by absorption and adsorption. The particles are moved to the vicinity of the water droplets and collide with each other. The particles adhere to the liquid media and precipitate to the bottom of the unit containing the dust particle from the gas phase. In addition to removing entrapped particulate matter, scrubbers can also remove gases by absorption and adsorption. Any other type of particulate control equipment does not possess this capability of scrubber. It can remove particles of size 0.1 to 200m efficiently. The various types of scrubbers can be dry, semi-dry or wet, depending on the composition of flue gas.

10.6 Environmental Concerns

Undesirable effects of Combustion

In Section **10**.5, we discussed the various air pollutants emitted from an incinerator and their control equipment. Apart from air pollution, there are other environmental concerns related to incineration (EPA 1989 and 1995), some of which are touched upon below:

(i) **Water pollution:** Wastewater in an incineration facility can be generated in various forms. These include tipping floor runoff system wash water, ash quench water and water from pollution control systems. These systems also deal with normal problems experienced by all large industrial facilities, including sanitary wastewater disposal and surface-water runoff. For most incineration facilities, wastewater can be recycled in a closed-loop system. In these systems, water from floor drains, ash dewatering, water softener recharge and other process wastewaters are collected and stored in a tank. This water is then reused for ash quenching. Sanitary waste can be directed to municipal sewer systems. In some cases, regulatory authorities may require that the waste stream be pretreated before discharge.

(ii) **Land-retained pollution:** Land-retained pollutants originate as stack or fugitive emissions and are of increasing concern. Bioaccumulation and subsequent ingestion from food is an indirect exposure route resulting from land-retained emissions. To provide better understanding of land-retained pollutants, it may be desirable to establish baseline contaminant levels, before incineration plant construction so that changes in those levels throughout the plant's operating lifetime can be monitored.

(iii) **Residue disposal:** An incineration facility and its emission control system produce a variety of residues such as large quantity of bottom ash, the unburned and not burnable materials discharged from the incinerator at the end of the burning cycle. The process also produces a lighter emission known as fly ash. Fly ash consists of products in particulate form, which are either produced as a result of the chemical decomposition of burnable materials or are unburned (or partially burned) materials drawn upward by thermal air currents in the incinerator and trapped in pollution control equipment. Fly ash normally comprises only a small proportion (ranging from 10 to 20%) of the total volume of residue from an incineration facility.

Constituents in both ash and scrubber product vary, depending on the materials burned. In systems burning a homogeneous fuel such as coal, oil, or tires, the level of pollutants in residues may be relatively constant. Systems burning a more heterogeneous mixture, such as municipal, industrial, or medical waste may experience wide swings in the chemical composition of residues. The major constituents of concern in municipal waste combustion ash are heavy metals, particularly lead, cadmium and mercury. These metals may impact human health and the environment; if improperly handled, stored, transported, disposed of or reused.

(iv) **Noise pollution:** Truck traffic is the greatest source of noise pollution in incineration plant operations. Well-maintained and responsibly operated trucks will help minimise this problem. Local ordinances may restrict truck traffic to certain hours of the day and to specified truck corridors. Under these conditions, noise pollution should not be a significant factor. Noise resulting from plant operations and air handling fans associated with the combustion and emission control equipment is also a potential problem. Noise levels are likely to be the highest in front of waste tipping floor doors, ash floor doors and the vicinity of air emission stacks. Walls, fences, trees and landscaped earthen barriers can serve to reduce noise levels.

(v) **Aesthetic impact:** Proper site landscaping and building design can help minimize or prevent negative aesthetic impacts. Such impacts are much less problematic, if the facility is sited in an industrial area and not adjacent to residential or commercial districts. Local zoning ordinances may ensure that aesthetic impacts are minimized. Keeping the process building at negative pressure can prevent undesirable odours from escaping outside of the building. Also, the use of internal air for combustion in the plant processes will destroy most odours.

Some facilities may emit visible steam or vapor plumes. Smoke, resulting from improper conditions in the combustion chamber, can also be problematic. Air emission stacks and cooling towers may also be unappealing anomalies in the skyline of some areas. If external lights on buildings prove objectionable to neighbors, perimeter lights (on stands) directed towards the plant may be preferable

Check your progress

Q1.Define Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in solid waste.

Q2. Illustrate Undesirable effects of Combustion.

10.7 Landfill

The safe and reliable disposal of municipal solid waste (MSW) and solid waste residues is an important component of integrated waste management. Solid waste residues are waste components that are not recycled, that remain after processing at a materials recovery facility, or that remain after the recovery of conversion products and/or energy. Historically, solid waste has been placed on or in the surface soils of the earth or deposited in the oceans. Ocean dumping of municipal solid waste was officially abandoned in the United States in 1933. *Landfill* is the term used to describe the physical facilities used for the disposal of solid wastes and solid waste residuals in the surface soils of the earth. Since the turn of the last century, the use of landfills, in one form or another, has been the most economical and environmentally acceptable method for the disposal of solid wastes, both in the United States and throughout the world. Today, landfill management incorporates the planning, design, operation, environmental monitoring, closure, and post closure control of landfills. Although many landfills have been constructed in the past with little or no thought for the long-term protection of public health and the environment, the focus of this chapter is modern land filling practice. In the past 20 years, practices have changed substantially so that recently constructed landfills have overcome the problems formerly associated with “dumps.”

Land filling is the term used to describe the process by which solid waste and solid waste residuals are placed in a landfill. In the past, the term *sanitary landfill* was used to denote a land filling which the waste placed in the landfill was covered at the end of each day’s operation. Today, *sanitary landfill* refers to an engineered facility for the disposal of MSW designed and operated to minimize public health and environmental impacts. Landfills for individual waste constituents such as combustion ash, asbestos, and other similar wastes are known as *mono-fills.* Landfills for the disposal of hazardous wastes are called *secure landfills.* Those places where waste is dumped on or into the ground in no organized manner are called *uncontrolled land disposal sites* or *waste dumps.*

In developing countries, the implementation of improved land disposal practices is progressing at varying rates dependent upon the available resources and national regulatory standards. The need to improve land disposal practices is being forced along by consolidating populations, where rural residents are moving to cities resulting in rapid urban population growth. This has created an ever increasing need for better solid waste disposal practices. In anumber of instances, less than adequate disposal practices have resulted in accidents that have led to loss of life. Large, uncontrolled dumps in urban areas are also a significant source of air pollution and water contamination and, as such, over time these facilities will need to beclosed and replaced with landfills that meet conventional standards.

10.7.1 Landfill Classification

The landfill classification system divides landfills into two classes, with different levels of environmental protection and minimum requirements for each class, covering siting, design and operational characteristics. The two classes are as follows.

- **Class A landfills** meet, or are consistent with, the site selection and design standards outlined in the Centre for Advanced Engineering's *Landfill Guidelines* (2000). These landfills are sited in areas that reduce the potential for adverse environmental effects, have engineered systems designed to provide a degree of redundancy for leachate containment, and collect landfill leachate and landfill gas.
- **Class B landfills** are existing landfills that do not meet the site selection and design standards outlined in the Centre for Advanced Engineering's *Landfill Guidelines* (2000) and are consented to accept general domestic and commercial waste. These landfills have limited or no engineered systems designed to collect landfill leachate or gases, and may be in areas that pose a risk to the environment (e.g. sited over highly permeable sands and/or gravels, active faults, or floodplains).

The landfill classification system allows some level of flexibility. For instance, there may not be sufficient low-permeability clay regionally available to allow the cost-effective design of a landfill that is clearly equivalent to the suggested landfill designs outlined in the CAE Landfill Guidelines. However, it may be possible to design the landfill in such a way that it provides a level of containment equivalent to those designs.

Landfills that do not clearly meet the requirements outlined in the CAE Landfill Guidelines have the option of showing that the selected combination of siting and design provide an equivalent level of containment. In all cases, Class A landfills must meet a number of minimum design and siting requirements.

The decision process for waste acceptance is outlined in Figure 10.5, but the following points should be noted.

- The landfill classification system applies to municipal waste landfills - it does not include industrial monofills. Waste acceptance criteria for industrial monofills should be determined through the resource consent process under the Resource Management Act 1991.
- Cleanfill sites are covered by the Guide to the Management of Cleanfills and can accept wastes meeting the Ministry's cleanfill definition. Cleanfills should have an existing resource consent to accept clean fill material, or meet the conditions of a relevant permitted activity rule in a regional plan.
- The majority of existing landfills do not meet the Class A standard, although the majority of refuse in New Zealand is disposed to sites that are likely to meet Class A. The inclusion of Class B acknowledges the existence of older-style tips or landfills and the need to control waste disposal at these sites. It is unlikely that new landfills would be consented unless they meet the Class A landfill standard.
- It is recognized that there is an increasing demand for sites that accept construction and demolition wastes. The acceptable standard for these sites depends on the range of wastes being accepted at the site. In practice this varies widely, and it is recommended that the acceptable standard be developed on a site-by-site basis.

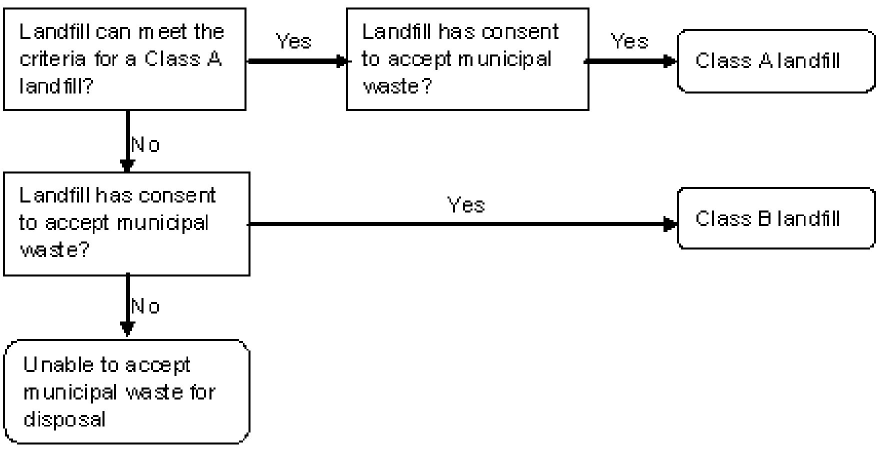


Figure 10.5: Landfill classification

Figure 10.5 shows that if a landfill can meet the criteria for Class A landfills *and* has a consent to accept municipal waste, then it is a Class A landfill. If a landfill cannot meet the criteria for Class A landfills but has a consent to accept municipal waste, then it is a Class B landfill.

10.7.2 Landfill planning, sitting & permitting

Amec Foster Wheeler offers a results-oriented approach to waste management. Amec Foster Wheeler designs systems that combine innovation with proven methods of waste management, treatment and disposal. Amec Foster Wheeler's concepts are driven by market requirements and regulatory compliance, while reducing liability and costs. Not only are waste management solutions relevant, they are easy to understand and implement.

Amec Foster Wheeler's team includes specialists in planning, environmental science, engineering, geology, hydrogeology, chemistry, biology, environmental management, economics and social development. The staff is highly qualified and experienced in teamwork within interdisciplinary settings. Our expertise has been successfully demonstrated at the local, national and international level.

Waste management planning

- Policy, program and system evaluation
- Feasibility studies
- Waste management master plans
- Waste inventories
- Geographic information system (GIS) capability
- Economic and financial analyses
- Risk management Market evaluation
- Database development

Facility sitting and permitting

- Public involvement program
- Hydrogeological and geotechnical investigations
- Land use and zoning issues
- Waste facility impact screening and assessment
- Regulatory compliance, approvals and permits
- Hearings and expert advice

Collection and transportation

- Waste handling and storage

- Waste consignment
- Collection productivity and routing
- Transfer system planning and design

Waste reduction, reuse and recycling

- Waste minimization program development
- Education and incentive programs
- Industrial and commercial waste audits
- Technology reviews
- System assessment
- Recycling and processing facility design
- Troubleshooting

Landfill engineering

- Municipal landfill design
- Industrial landfill design
- Liner/cover design
- Leachate collection and treatment systems
- Landfill gas assessment and control
- Drainage and infrastructure design
- Operation plans
- Closure, post-closure and remedial action plans

Energy recovery

Landfill gas recovery

- Waste to energy incinerator design
- Refuse derived fuel (RDF) facility design
- Cogeneration facility design

Engineering design and construction management

- Construction documents bid documents
- Bid request and evaluation
- Vendor and contractor selection
- Construction supervision

- Quality assurance testing
- Cost tracking

Assessment and monitoring

- Contaminant transport modeling
- Monitoring program development and execution
- Field services
- Laboratory services
- Compliance audits
- Performance reviews
- Liability assessments
- Waste contractor assessments.

10.7.3 Landfill processes

Landfills can be thought of as active waste treatment plants, where biochemical processes act on and degrade landfilled solid waste causing settlement of the landform and creating landfill gases and leachate.

Landfill gas (LFG) is a powerful greenhouse gas, but proper control measures can prevent or at least minimize emissions to the atmosphere, and utilization systems can convert LFG into electricity. Until 2006, LFG was the largest single contributor to renewable energy in the UK.

Our research has involved the investigation of fundamental landfill processes, through carefully controlled experiments on waste mechanics, degradation and settlement through to the development of coupled numerical models.

Waste Mechanics and settlement

The Landfill Directive requires that wastes are subjected to pre-treatment prior to landfilling, in part to reduce the biological content of household waste. One form of treatment, known as mechanical-biological treatment or MBT, typically involves shredding or grinding of wastes prior to accelerated aerobic (often referred to as composting) or anaerobic degradation. We have undertaken research into the mechanical properties of the residual wastes from these processes which may have very different properties to untreated wastes in terms of their mechanical behavior (which impacts on the physical stability of landfills and hence their risk of landslides and pollution), the amount of gas and fluid which will be produced and the timescales over which gas and fluid production will occur.

The effect that MBT treatment has on the mechanical strength of the residual waste stream was investigated at a fundamental level by investigating the effect that individual particles and shapes of particles has on waste mechanics. Experiments into waste strength were undertaken using shear box apparatus, and purpose built anaerobic reactors where the waste was subject to a constantly applied load were used to investigate waste settlement, degradation and gas generation.

10.7.4 Landfill design

Once a suitable site has been selected, the design stage may commence. This section sets the outcomes and suggested measures for achieving these outcomes. All designs must be verified by a RPEQ in accordance with the Queensland Professional Engineers Act 2002.

Liner systems

The principal functions of a landfill liner system are to limit contaminant migration to groundwater and to control landfill gas migration. This is achieved by the landfill liner slowing the vertical and lateral seepage of leachate to allow collection and removal by the leachate collection system, and to contain landfill gas within the landfill for appropriate collection. The liner may also attenuate contaminants in leachate seeping through the liner. A further function of the liner is to control infiltration of groundwater. The primary design objective of the liner and leachate collection system is to protect the environmental values of groundwater. This includes limiting the size of any attenuation zone that extends beyond the boundary of the premises. The outcomes of the hydrogeological risk assessment, stability risk assessment and landfill gas risk assessment will influence the containment design features; however it will generally comprise, but not be limited to, a combination of the following components in Table 2.

Table 2: Liner system components and functions

Component	Function
Subgrade	To provide a well consolidated firm platform for the installation of the subsequent lining materials which will protect them from excessive strains, potentially resulting in failure of the materials, and to ensure that the drainage system drains effectively throughout the life of the landfill.
Clay	A low permeability clay layer in a lining system retards water movement and absorbs exchangeable cations. Some of the properties of the soil measured to determine its suitability as a low permeability liner are particle size distribution and plasticity (described by the soil plasticity index) and cation exchange capacity. A key consideration is the potential for desiccation and subsequent cracking.
Geosynthetic Clay Liner (GCL)	To provide a low permeability layer to limit contaminant migration, reduce water ingress into the landfill and to control landfill gas migration. They are generally used as a compliment with clay in the lining

	system. The assessment for the suitability of a GCL in a lining system should consider water and gas flow, contaminant transport and stability including the assessment of hydraulic conductivity, gas permeability, chemical compatibility, diffusion and shear strength.
Geomembrane	To limit contaminant migration, reduce water ingress into the landfill and control landfill gas migration. Key properties to consider when selecting a geomembrane include thickness, strength, the ability to resist or accept stress and deformation, tensile strength, puncture resistance, slope stability-interface friction, long term mechanical performance, durability and resistance to degradation.
Geotextile	Installed to protect the integrity of a geomembrane. It minimizes the risk of the geomembrane being damaged/punctured during construction and operation of the landfill, and minimizes the strains in the geomembrane, and hence the risk of future punctures forming due to environmental stress cracking.

10.7.5 Leachate collection system

The design objectives of the leachate collection system are to ensure that it is:

- Able to drain leachate sufficiently well so that the leachate head above the liner is minimized
- Appropriately sized to collect the estimated volume of leachate (predicted by water balance models)
- Resistant to chemical attack, and physical, chemical and biological clogging
- Able to withstand the weight of waste and the compaction equipment without crushing
- Able to be inspected and cleaned by readily available video inspection and pipe-cleaning equipment.
- Designed to be sufficiently robust to function and perform as required for the expected landfill life cycle.

A leachate collection system typically comprises a high-permeability drainage layer (coarse aggregate or Geosynthetic), perforated collection pipes, a sump where collected leachate is extracted from the landfill, and geotextiles to protect any geomembrane and prevent clogging of the drainage layer. The liner is sloped into the leachate collection pipes which in turn are sloped to the leachate collection sump.

Leachate collection systems can fail in less than a decade, in several known ways including when:

- They clog with silt or mud
- Micro-organisms clog the pipes
- Precipitation from chemical reactions block the pipes
- The pipes are damaged during installation or early in the filling of the landfill
- The pipes are weakened by chemical attack (acids, solvents, oxidizing agents, or corrosion) and are crushed.

Due to the above, adequate controls need to be considered to mitigate failure of the leachate collection system. Where applicable, measures (such as monitoring points) must be installed to demonstrate that leachate depth across the landfill liner is minimized.

10.7.6 Landfill operation

Daily landfill operations have the potential to give rise to short and long term environmental pollution issues. The purpose of this section is to provide guidance on the day to day landfill operational management requirements.

The key landfill operational management areas to be covered in this section are:

- Waste checking and acceptance
- Waste placement, compaction and cover
- Environmental management and control measures
- Waste disposal monitoring and record keeping.

Table 3: Landfill operations

Outcome	Suggested Measure
Waste Checking and Acceptance	
To ensure that only allowed wastes are deposited at the landfill.	• Landfill operator to ensure that non-conforming waste is not disposed of at the landfill site. • Provide signs advising the types of wastes allowed at the site. • Implement a procedure to deal with the dumping of non-conforming waste at the landfill site. • Ensure that the landfill is staffed at all times it is open for the receival of waste. • Conduct random inspections and sampling of waste loads. • Train landfill staff to recognise conforming and non-conforming waste.
Waste Placement and Compaction	
To place waste in a manner that is mechanically stable and controls litter, vectors and other pest species, and that maximises the degree of compaction.	• Maintain an active tipping area that is as small as possible. • Place waste so that all unconfined faces are mechanically stable and capable of retaining cover material. • Compact all waste deposited in the landfill. • Keep covering waste to maintain the active tipping area at less than 30 metres x 30 metres. • Place wastes at the base of each lift and compact wastes in layers of less than 2 metres. • Avoid unconfined waste slopes with gradients steeper than 2 horizontal to 1 vertical unit. • Undertake surveys to monitor density being achieved and assess compaction efficiency.
Waste Cover	
To ensure that wastes are covered appropriately to mitigate against any environmental or health impacts.	• Cover the waste, at least daily (or otherwise agreed frequency), with soil, or another suitable cover material, for all sites that accept putrescible waste and maintain the cover. • Close cracks in old, exposed cover layers to contain landfill gas and odour. • Use 0.3 metres of soil, where soil is used as cover. • Avoid creating low-permeability confining layers in the landfill by partial removal of low-permeability cover material prior to placement of wastes in that location. • Stockpile sufficient cover material at the tipping face. • Do not use acid sulfate soil as daily cover.
Litter	
To keep the landfill and surrounding environment in a litter free condition.	• Minimise the size of the tipping area. • Use litter screens to control litter. • Deposit waste in areas of the landfill that are sheltered from the wind. • Establish contingency plans to deal with extreme events that cause gross litter problems. • Use an appropriate daily cover to reduce litter.
Odour	

10.7.7 Use of old landfill

Old landfills often seem to be a problem, with planners seeing only risks and difficulties. How can this be changed? European partners on the SufalNet project have developed a model strategy for examination, aftercare and redevelopment of landfills

In March last year the European Commission decided to start legal action against 14 European Member States for inadequately transposing the EU's legislation on the landfilling of waste into their national law. This followed a similar course of action initiated against seven Member States in December 2006. The action in question was a first 'warning'.Whilst political warnings are likely to have an impact in the political world, the occurrence of natural warnings, arguably, has a broader and more immediate resonance.

On 15 September 1979 in the Dutch city of Lekkerkerk, the main drinking water pipeline burst. 'An enormous fountain sprouted metres high and lifted the pavement' commented the Chairman of the residents' association. 'The pipeline had turned black and was blistered. It looked like prawn crackers.' It turned out that the new housing estate had been built on an old landfill and the waste and pollution had damaged the plastic main pipeline. The local and national governments decided to sanitize this site completely. Almost 300 families were evacuated. Most of the landfill, 1600 barrels with chemical waste and the surrounding polluted soil were dug out. The houses had been built on piles, which made digging under them possible and allowed backfilling under and around the houses with clean soil. This was the first major environmental disaster in the Netherlands and it gave impetus to further and more rapid development and implementation of Dutch legislation on soil pollution.

This occurrence highlights both a problem and a solution. There are numerous landfills across developed and developing nations. Some have high levels of control, exploiting the landfill gas produced and effectively managing the leachate. Others are more rudimentary. In many cases, scope exists for remediation and redevelopment.

Continuing the story from the burst water pipeline in Lekkerkerk, this article explores Dutch experience in this matter and integrates work undertaken within the European SufalNet project on landfill redevelopment.

North Brabant

With Lekkerkerk in mind, plans were made to prevent similar unpleasant surprises. The authorities of North Brabant needed to know where old landfills were located, and if there were any other disasters waiting to happen. In the late 1990s, a project was initiated to make an inventory of all landfills throughout the province. Over 1200 sites were investigated. Local people, including local administrations, were asked about the size, depth, height and kind of waste dumped, plus the period it was in use. All these information were gathered and a priority list was made.

As a next step, all of the bigger landfills (600 landfills over 1000 m2) were visited once again and groundwater samples were taken. A monitoring system was set up. In a period of over 15 years, groundwater samples were taken at least three times. In 2007, all data on each landfill were evaluated and the risks assessed. In North Brabant all 600 old landfills have now been examined; and the wealth of information accumulated has provided a platform for redevelopment work.

In North Brabant aftercare is primarily the responsibility of the owner of the landfill. The risk assessment done also provided owners with advice on aftercare measures. In about 70% of cases the cover layer was not sufficient to protect humans, animals or plants on the landfill from potential harm. The advice in most cases is to make the cover layer thicker. The province has also given the general advice not to use groundwater from shallow wells.

Since 2004 about 30 landfills have been redeveloped in some way in North Brabant. Some of the smaller examples have been remodelled as parks and playgrounds in new housing estates. The Gulbergen estate is developed on one of the region's biggest landfills and offers an interesting first case study.

The Gulbergen Estate

Halfway between the cities Eindhoven and Helmond lies a large regional landfill of about 50 hectares. The first waste was dumped here in 1958, the last in 2005. In total 10 million m2 of municipal and solid waste is dumped here, leaving the resulting mound at about 40 metres high above ground level. Twenty-one surrounding municipalities have formed a co-operative public organization known as SRE (Samenwerkingsverband Regio Eindhoven) which has purchased 450 ha land, around and including the old landfill site, to create the Gulbergen estate.

On the landfill-site a golf course with 36 holes (20 ha), a hillside elevator, footpaths and bicycle routes and an outdoor centre for sports (climbing, skiing, bob-run) are constructed. Within a few years, the remainder of the site will be covered with a top liner. Meanwhile, on the surrounding estate there is a zoo, a recreational area (restaurants, hotel, congress centre, museum), an area for outdoor festivals, fairs, horse-jumping (40 ha) plus more footpaths and bicycle routes. The SRE spend E34 million to create Gulbergen estate, with E9 million spend by third parties. In the future, the estate will be financially independent the budgets for aftercare and redevelopment are strictly separate.

Why make the effort?

Old and abandoned landfills are a potential risk to the environment. It is vital that we understand the nature of this risk and take steps to protect the environment. An examination strategy developed within the European SufalNet project (SufalNet being an acronym for the 'Sustainable use of former and abandoned landfills network') helps us to do so.

Due to the growth of cities and villages, old landfills are often surrounded by residential or industrial areas. The space taken by the landfill is usually not used in any way. It seems easier to plan around the landfill than to incorporate the landfill in any new development plans. SufalNet believes this is a missed chance.

By redeveloping old landfill sites (and any other brownfield site), green fields are saved. On a local level this sometimes does not seem to be a big issue, but on a European scale things look different. The total space taken by old landfills is about 300,000 ha! Not using this space means using green fields for development of residential and industrial areas and losing 300,000 ha of nature. Can we afford that?

Risks

Old landfills can cause a risk in several ways. When rain or groundwater percolate through the waste material, the leachate often pollutes surrounding soil and groundwater. Landfill gas, produced by bacteria in the waste, can escape from the landfill. These gasses can cause fires or damage plants growing on the landfill. The waste material itself can cause a risk when the cover layer on the landfill is too thin, mixed with waste or polluted. Polluted soil is often used to cover landfills. These risks can be ecological or human risks depending on the current use of the site and the possibility and probability of contact with the waste, leachate or landfill gas.

1.7 Summary

Incineration is a chemical reaction by which carbon, hydrogen and other elements in the waste combine with oxygen in the combustible air and generate heat. In this Unit, we discussed the objectives and issues to be considered while planning an incineration facility. In this context, we discussed the various incineration processes and technologies such as mass burn, refuse derive fuel, modular incineration and fluidised bed incineration. We said that the product of incineration is heat that can be utilised for the generation of steam and electricity. We also pointed out that the amount of energy recovered is a function of the amount of waste combusted, the energy value of the waste stream and the efficiency of the combustion process. We then discussed energy generation. We also discussed the various air pollutants emitted out of an incineration facility and the equipment used for their control namely scrubbers, electrostatic precipitators and fabric filters. Finally, we listed some of the impacts of incinerators on the environment.

The Institute for Electrical and Electronic Engineers developed an Ethernet standard known as IEEE Standard 802.3. This standard defines rules for configuring an Ethernet network and also specifies how the elements in an Ethernet network interact with one another. By adhering to the IEEE standard, network equipment and network protocols can communicate efficiently.

1.8 Review Questions

Q1. Define The design objectives of the leach ate collection system.

Q2. What are Daily landfill operations.

Q3.llustrate Landfill planning, sitting & permitting in waste management.

Q4. Define the use of landfills around your locality.

UNIT-XI Biochemical processes

Structure

11.0 Introduction

Most chemical changes in a cell result from chains and cycles of biochemical reactions, with each step controlled by a separate, specific enzyme

Metabolism is the totality of the chemical reactions which occur within a cell, and can be divided into various types. Anaerobic digestion was practiced in the 10th Century for heating baths in Assyria by biogas, gas produced by the breakdown of organic matter. In the 17th century, Jan Baptita Van Helmont of Belgium discovered that decaying organic matter produces flammable gas. In 1808, the British chemist Sir Humphry Davy discovered that methane gas was present in cow manure. The first known plant to use anaerobic digesters built in a leper colony in Bombay, India in 1859. Anaerobic digestion occurs when organic material decays in an oxygen-free or low oxygen environment. Anaerobic methane recovery occurs in bio-digesters, where organic matter is digested, and produces a fuel called biogas. Anaerobic digestion is a natural process in which bacteria convert organic materials into biogas. It occurs in marshes and wetlands, and in the digestive tract of ruminants. The bacteria are also active in landfills where they are the principal process degrading landfilled food wastes and other biomass. Biogas can be collected and used as a potential energy resource.

11.1 Biochemical processes

Most chemical changes in a cell result from chains and cycles of biochemical reactions, with each step controlled by a separate, specific enzyme

Metabolism is the totality of the chemical reactions which occur within a cell, and can be divided into two types:

- *Anabolic reactions* involve the synthesis of complex molecules from simpler ones and usually require energy to form new bonds (endergonic)
- *Catabolic reactions* involve the breakdown of complex molecules into simpler ones and usually release energy from breaking bonds (exergonic)

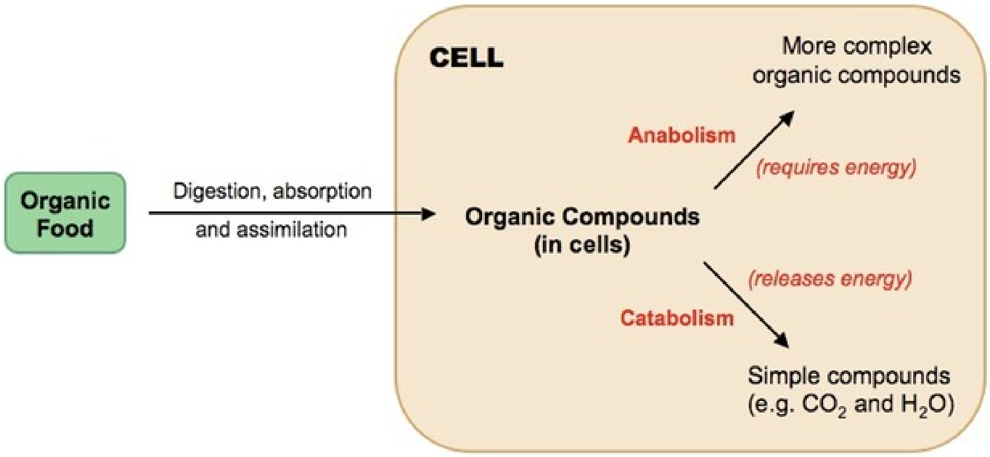
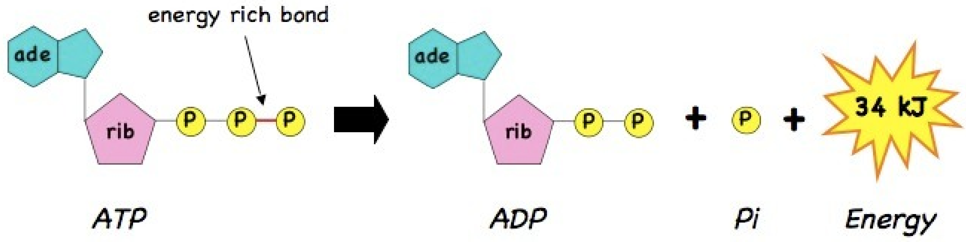


Figure 2.1 Overview of Metabolism

Energy Transformations

- Energy in living cells is stored and released in the chemical form of ATP (adenosine triphosphate)
- ATP is made up of an RNA nucleotide (base = adenine) bonded to two additional phosphate groups (three in total)
- These additional phosphates are connected by high energy bonds that release a large amount of free energy when hydrolysed
- The energy released from the hydrolysis of ATP (into ADP + P_i) can be used by the cell to fuel biochemical processes



- ATP can be synthesised by the transmembrane enzyme ATP synthase (via both photosynthesis and cell respiration)
- Photosynthesis uses light energy to synthesise ATP, which is then hydrolysed in order to synthesise organic molecules (anabolic reaction)
- Cell respiration breaks down organic molecules to release energy which is used to synthesise ATP for use in cell processes (catabolic reaction)

Functions of ATP

ATP provides an immediate source of energy when hydrolysed and functions as the energy currency of the cell

Biochemical processes that utilise ATP include:

- **Growth and repair:** Increase cell size and replace damaged tissue requires ATP
- **Movement:** The contraction of muscle fibres in order to generate movement in organisms requires ATP
- **Nerve transmissions:** The generation and transmission of a nerve impulse (action potential) requires ATP
- **Active transport:** Moving molecules against their concentration gradient, or by cytosis, requires ATP
- **Biosynthesis of macromolecules:** Building complex organic molecules from simpler subunits (anabolism) requires ATP
- **Emission of light:** Some cells may be capable of luminescence, and this process requires ATP

11.2 Methane generation by anaerobic digestion

Anaerobic digestion was practiced in the 10th Century for heating baths in Assyria by biogas, gas produced by the breakdown of organic matter. In the 17th century, Jan Baptita Van Helmont of Belgium discovered that decaying organic matter produces flammable gas. In 1808, the British chemist Sir Humphry Davy discovered that methane gas was present in cow manure. The first known plant to use anaerobic digesters built in a leper colony in Bombay, India in 1859. Anaerobic digestion occurs when organic material decays in an oxygen-free or low oxygen environment. Anaerobic methane recovery occurs in bio-digesters, where organic matter is digested, and produces a fuel called biogas. This process conserves nutrients and reduces pathogens in organic matter. David House states in his book, 1000 lbs of human waste can produce 0.6 cubic meters of biogas. Today, Germany converts half of their biogas generated from sewage sludge digestion to fuel cars. However, the most common use for anaerobic digestion is on farms and in waste water treatment plants.

Anaerobic digestion occurs when organic material is broken down by bacteria in four major processes: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Hydrolysis is the process in which carbohydrates, proteins, fats are converted to sugars, fatty acids, and amino acids. Acidogenesis is the process in which the sugars, fatty acids, and amino acids are converted to carbon dioxide, ammonia, and carbonic acids. Acetogensis is the process which creates acetic acid and carbon dioxide. The final process, methanogenesis, is when biogas is formed. Biogas contains a mixture methane and carbon dioxide gases. The extracted methane can provide a fuel for heat and electricity.5 Figure 2-2: Anaerobic Digestion Phases shows a summary the anaerobic digestion processes.

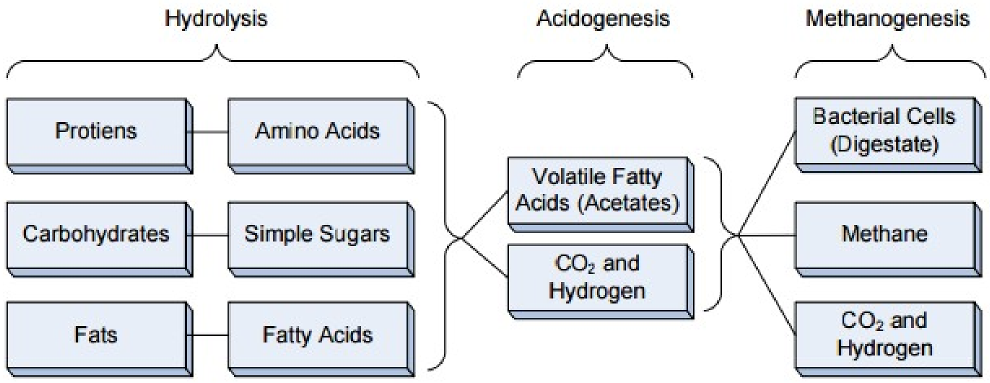


Figure 2-2: Anaerobic Digestion Phases

There are two common types of digesters used for anaerobic treatment: batch and continuous. Batch digesters are the simpler of the two because the material is loaded in the digester and then allowed to digest. Once the digestion is complete, the effluent is removed and the process is repeated.

In a continuous digester, organic material is regularly fed into the digester with the constant loading and unloading of effluent. The material moves through the digester either mechanically or by the force of the new feed pushing out digested material. There are three types of continuous digesters: vertical tank systems, horizontal tank or plug-flow systems. Continuous digesters are most common for large-scale operations. Temperature is carefully controlled in anaerobic digestion systems. There are two common environments for anaerobic digesters: thermophilic and mesophilic. The difference between the two environments is the temperature at which the organic material, or sludge, is digested. Thermophilic digestion operates around 50 to 60 °C (120 to 140 °F). The quick breakdown of sludge allows digester volume to be small, relative to mesophilic systems. The average digestion time is approximately three to five days. Thermophilic digestion require more insulation and more heat energy and are more sensitive to incoming materials and temperature changes, compared to the mesophilic digestion system. Mesophilic digestion operates around 35 to 40 degrees °C (95 to 105 °F). The average digestion time is 15 to 20 days. Mesophilic is more common in wastewater treatment plants because thermophilic treatment due to cost and more energy is required to have more sophisticated control & instrumentation, as a thermophilic system would need.

There are three common types of anaerobic systems: farm based, food processing and centralized systems. Farm based systems are typically designed for manure from one farm, or the manure from several nearby small farms. Figure 2-3 Food processing systems are typically on the same scale as farm-based systems. Centralized systems involve materials from many farms and food processing plants. Each type of anaerobic system will have different gas productions due to the difference in the feedstock for the digesters demonstrates how different waste materials affect biogas production.

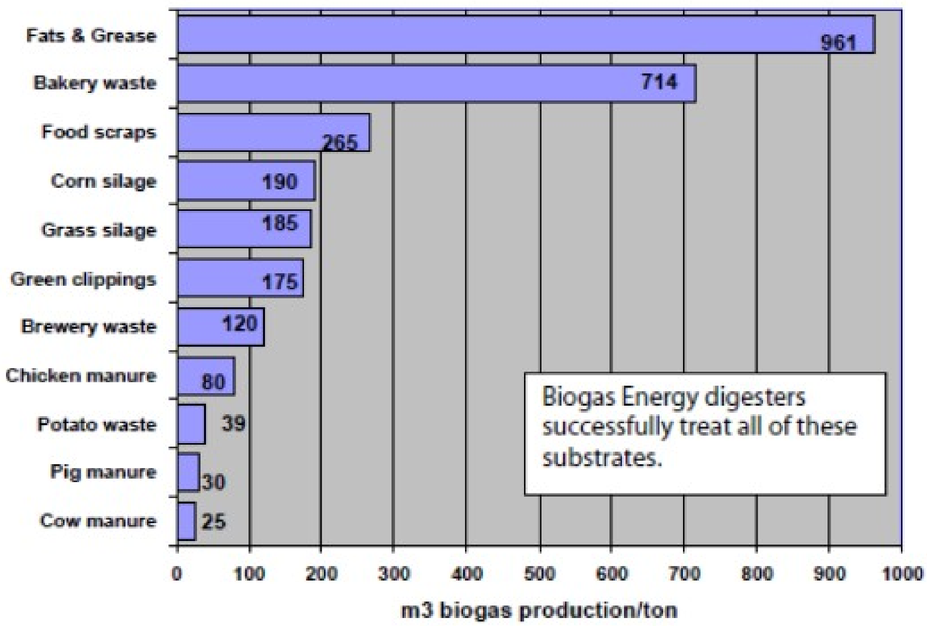


Figure 2-3: Biogas Production by Feedstock

Due to its small input and local needs, lower cost components that involve lower levels of control may be used. Farm-based systems have been successfully operated throughout North America, with the first one built in 1979, located at Mason Dixon Farms, in Gettysburg,Pennsylvania.10 Food processing sites may be similar to farm-based systems. They also may be designed for removing organic matter from wastewater. Food processing systems will likely be sized to meet either the heating requirements of the facility, or to manage the byproducts produced onsite or from several food processing facilities. Many farm-based systems provide sufficient heat and/or power for the farm, to provide a surplus power to local electrical lines. Centralized systems involve materials from many farms and food processing plants.

Other materials, such as source-separated organics, are often added to boost gas production. Often the digestate is immediately transferred to remote field storages to allow for easier handling for land application. In many instances, heat from the centralized system is used nearby at another commercial facility or residences.

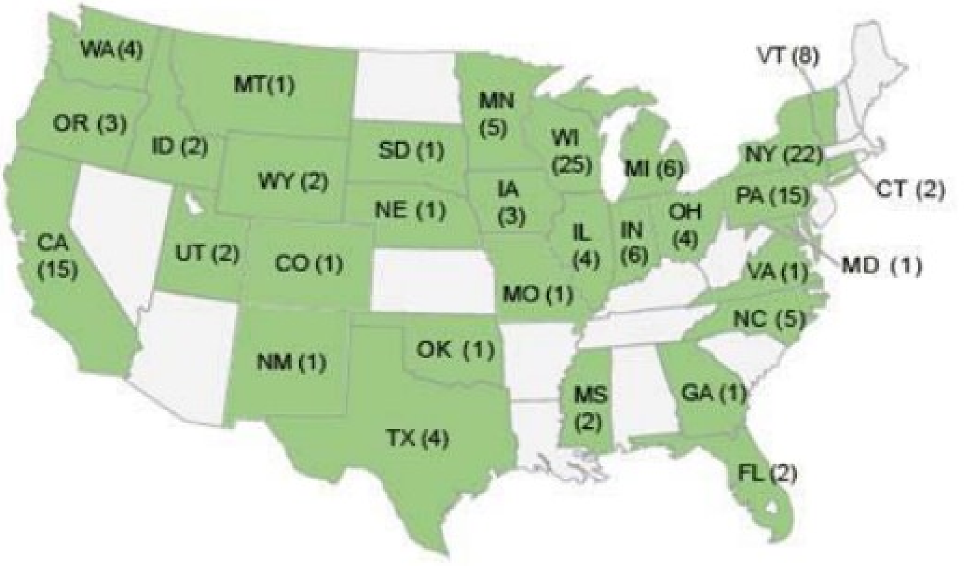


Figure 2-4: Livestock Farms with Anaerobic Digesters

According to the EPA, as of April 2010 there were 151 operating anaerobic digesters on commercial livestock farms. Figure 2-4 shows the number of farms with anaerobic digester by state, Appendix A.2 contains a complete list of digesters, locations and operations. Of the 151 operational digesters, 130 capture the biogas to generate electrical or thermal energy. Table 2-1 lists the energy generation and methane emission reduction of these 151 agricultural anaerobic digesters. One major issue that is not factored in here is the reduction of fossil fuels. Every unit of biogas used to generate heat or electricity reduces the amount of fossil fuels consumed.

Table 2-1: Impact of Agricultural Anaerobic Digesters

Impact of Agricultural Anaerobic Digesters	
Electricity Generation using Biogas	340,000,000 MWh
Other Energy Project using Biogas	52,000 MWh
Methane Emission Reduction	45,000 tonnes/year
• Equivalent CO_2 Reduction	944,000 tonnes/year

<u>Methane and Biogas</u>

Methane is a colorless, non-poisonous, odorless, and flammable gas with a wide distribution in nature. Methane (CH_4 Figure 2-5) has a molecular weight of 16.04 containing 74.87% carbon and 25.13% hydrogen. It's also a major component of the outer planets of our solar system as well as cooking fuel. Methane is also used in the manufacturing of hydrogen, hydrogen cyanide, ammonia, formaldehyde.

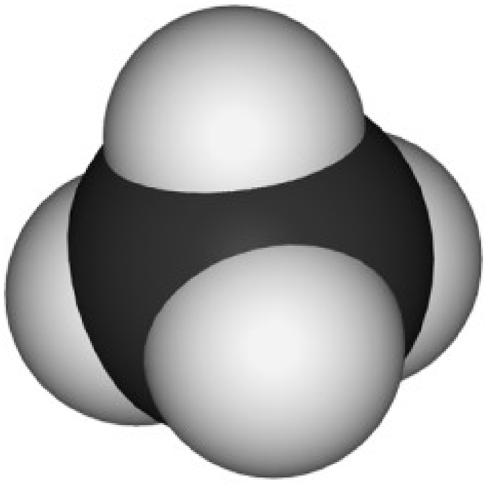


Figure 2-5: Methane Molecule

Methane is a primary component of natural gas that contains a mixture containing approximately 75% methane, 15% ethane (C_2H_6), and 5% other hydrocarbons. Methane is a potent greenhouse gas; it absorbs infrared radiation that would normally escape. Methane can also trap heat 20 times more effectively than carbon dioxide over a 100 year period. Landfills, coal mining, biomass burning, and waste water treatment are human influenced sources of methane production. Methane is also produced from the anaerobic digestion of organic matter,whether this occurs in a man-made anaerobic digester or underwater in a swamp to produce swamp gas. Biogas is technical terminology for the gas that is produced from anaerobic digestion. Typically, the gas is comprised of approximately 60-80% methane, 20-40% carbon dioxide and often contains traces of gases such as hydrogen sulfide, ammonia and hydrogen.

Production of Biogas by Anaerobic Digestion

Anaerobic digestion is a natural process in which bacteria convert organic materials into biogas. It occurs in marshes and wetlands, and in the digestive tract of ruminants. The bacteria are also active in landfills where they are the principal process degrading landfilled food wastes and other biomass. Biogas can be collected and used as a potential energy resource. The process occurs in an anaerobic (oxygen-free) environment through the activities of acid- and methane-forming bacteria that break down the organic material and produce methane (CH_4) and carbon dioxide (CO_2) in a gaseous form known as biogas. Dairy manure waste consists of feed and water that has already passed through the anaerobic digestion process in the stomach of a cow, mixed with some waste feed and, possibly, flush water. The environmental advantages of using anaerobic digestion for dairy farm wastes include the reduction of odors, flies, and pathogens as well as decreasing greenhouse gas (GHG) and other undesirable air emissions. It also stabilizes the manure and reduces BOD. As large dairies become more common, the pollution potential of these operations, if not properly managed, also increases. The potential for the leaching of nitrates into groundwater, the potential release of nitrates and pathogens into surface waters, and the emission of odors from storage lagoons is significantly reduced with the use of anaerobic digestion. There may also be a reduction in the level of VOC emissions.

Elements of Anaerobic Digestion Systems

Anaerobic digester systems have been used for decades at municipal wastewater facilities, and more recently, have been used to process industrial and agricultural wastes (Burke, 2001). These systems are designed to optimize the growth of the methane-forming (methanogenic) bacteria that generate CH_4. Typically, using organic wastes as the major input, the systems produce biogas that contains 55% to 70% CH_4 and 30% to 45% CO_2. On dairy farms, the overall process includes the following:

- Manure collection and handling. Key considerations in the system design include the amount of water and inorganic solids that mix with manure during collection and handling,
- Pretreatment. Collected manure may undergo pretreatment prior to introduction in an anaerobic digester. Pretreatment—which may include screening, grit removal, mixing, and/or flow equalization—is used to adjust the manure or slurry water content to meet process requirements of the selected digestion technology. A concrete or metal collection/mix tank may be used to accumulate manure, process water and/or flush water. Proper design of a mix tank prior to the digester can limit the introduction of sand and rocks into the anaerobic digester itself. If the digestion processes requires a thick manure slurry, a mix tank serves a control point where water can be added to dry manure or dry manure can be added to dilute manure. If the digester is designed to handle manures mixed with flush and process water, the contents of the collection/mix tank can be pumped directly to a solids separator. A variety of solids separators, including static and shaking screens are available and currently used on farms.
- Anaerobic digestion. An anaerobic digester is an engineered containment vessel designed to exclude air and promote the growth of methane bacteria. The digester may be a tank, a covered lagoon (Figure 2-6), or a more complex design, such as a tank provided with internal baffles or with surfaces for attached bacterial growth. It may be designed to heat or mix the organic material. Manure characteristics and collection technique determine the type of anaerobic digestion technology used. Some technologies may include the removal of impurities such as hydrogen sulfide (H2S), which is highly corrosive.
- By-product recovery and effluent use. It is possible to recover digested fiber from the effluent of some dairy manure digesters. This material can then be used for cattle bedding or sold as a soil amendment. Most of the ruminant and hog manure solids that pass through a separator will digest in a covered lagoon, leaving no valuable recoverable byproduct.
- Biogas recovery. Biogas formed in the anaerobic digester bubbles to the surface and may accumulate beneath a fixed rigid top, a flexible inflatable top, or a floating cover, depending on the type of digester. The collection system, typically plastic piping, then directs the biogas to gas handling subsystems.
- Biogas handling. Biogas is usually pumped or compressed to the operating pressure required by specific applications and then metered to the gas use equipment. Prior to this, biogas may be processed to remove moisture, H_2S, and CO_2, the main contaminants in dairy biogas, in which case the biogas becomes biomethane. (Partial removal of contaminants, particularly H_2S, will yield an intermediate product that we refer to in this report as partially upgraded biogas). Depending on applications, biogas may be stored either before or after processing, at low or high pressures.
- Biogas use. Recovered biogas can be used directly as fuel for heating or it can be combusted in an engine to generate electricity or flared. If the biogas is upgraded to biomethane, additional uses may be possible. Anaerobic digestion is a complex process that involves two stages, as shown in the simplified schematic in Figure 2-7. In the first stage, decomposition is performed by fast-growing, acidforming (acidogenic) bacteria. Protein, carbohydrate, cellulose, and hemicellulose in the manure are hydrolyzed and metabolized into mainly short-chain fatty acids—acetic, propionic, and butyric—along with CO_2 and hydrogen (H_2) gases. At this stage the

decomposition products have noticeable, disagreeable, effusive odors from the organic acids, H_2S, and other metabolic products.

Figure 2-6 A dairy farm anaerobic digestion system\

In the second stage, most of the organic acids and all of the H_2 are metabolized by methanogenic bacteria, with the end result being production of a mixture of approximately 55% to 70% CH_4 and 30% to 45% CO_2, called biogas. The methanogenic bacteria are slower growing and more environmentally sensitive (to pH, air, and temperatures) than the acidogenic bacteria. Typically, the methanogenic bacteria require a narrow pH range (above 6), adequate time (typically more than 15 days), and temperatures at or above 70° F, to most effectively convert organic acids into biogas. The average amount of time manure remains in a digester is called the hydraulic retention time, defined as the digester volume divided by daily influent volume and expressed in days.

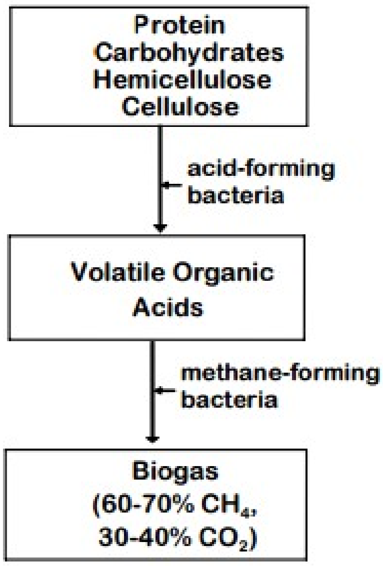


Figure 2-7 Simplified process of biogas production

Anaerobic Digestion Technologies Suitable for Dairy Manure

Numerous configurations of anaerobic digestershave been developed, but many are not likely to be commercially applicable for California dairy farms. This section briefly describes the three digester t most suitable for California dairies: ambienttemperature covered-lagoon, complete-mix, and plug-flow digesters. Table 2-2 provides the operating characteristics of these manure digester technologies.

Table 2-1 Characteristics of Anaerobic Digesters Suitable for On-Farm Use

Digester Type	Technology Level	Concentration of Influent Solids (%)	Allowable Solids Size	Supplemental Heat Needed?	HRT [a] (days)
Ambient-temperature covered lagoon	low	0.1 – 2	fine	no	40+
Complete mix	medium	2.0 – 10	coarse	yes	15+
Plug flow	low	11.0 – 13	coarse	yes	15+

[a] HRT = Hydraulic Retention Time = digester volume/daily influent volume

Ambient-Temperature Covered Lagoon

Properly designed anaerobic lagoons are used to produce biogas from dilute wastes with less than 2% total solids (98% moisture) such as flushed dairy manure, dairy parlor wash water, and flushed hog manure. The lagoons are not heated and the lagoon temperature and biogas production varies with ambient temperatures. Coarse solids such as hay and silage fibers in cow manure must be separated in a pretreatment step and kept out of the lagoon. If dairy solids are not separated, they float to the top and form a crust. The crust will thicken, which will result in reduced biogas production and, eventually, infilling of the lagoon with solids. Unheated, unmixed anaerobic lagoons have been successfully fitted with floating covers for biogas recovery for dairy and hog waste in California. Other industrial and dairy covered lagoons are located across the southern USA in warm climates. Ambient temperature lagoons are not suitable for colder climates such as those encountered in New York or Wisconsin.

Complete-Mix Digester

Complete-mix digesters are the most flexible of all digesters as far as the variety of wastes that can be accommodated. Wastes with 2% to 10% solids are pumped into the digester and the digester contents are continuously or intermittently mixed to prevent separation. Complete-mix digesters are usually aboveground, heated, insulated round tanks. Mixing can be accomplished by gas recirculation, mechanical propellers, or circulation of liquid.

Plug-Flow Digester

Plug-flow digesters are used to digest thick wastes (11% to 13% solids) from ruminant animals. Coarse solids in ruminant manure form a viscous material and limit solids separation. If the waste is less than 10% solids, a plug-flow digester is not suitable. If the collected manure is too dry, water or a liquid organic waste such as cheese whey can be added. Plug-flow digesters consist of unmixed, heated rectangular tanks that function by horizontally displacing old material with new material. The new material is usually pumped in, displacing an equal portion of old material, which is pushed out the other end of the digester.

Factors Influencing Anaerobic Digestion Efficiency

Digesters can function at ambient temperatures in warmer climates such as California, but with a lower biogas output than heated digesters. In some applications and in colder environments, digesters are heated. The optimal ranges for anaerobic digestion are between 125 to 135° F (thermophilic conditions) and between 95 to 105° F (mesophilic conditions). Anaerobic digestion under thermophilic conditions generates gas in a shorter amount of time than anaerobic digestion under mesophilic conditions. However, a higher percentage of the gross energy generated is required to maintain thermophilic conditions within the reactor. The extra heat is either extracted from the gross waste heat recovery in an engine or recovered from effluent. Covered lagoons have seasonal variation in gas production due to the variation in ambient temperature. Gas production from complete-mix and plug-flow digesters are impacted less by ambient temperature variation since they are usually heated. On an annual basis, gas production from complete-mix and plug-flow digesters tends to be higher than for ambient-temperature covered lagoons because a higher percentage of solids entering complete-mix and plug-flow digesters is converted to biogas and the higher operating temperatures favor greater microbial activity. Gas production in all these digesters is dependent on hydraulic retention time.

Environmental Impacts of Anaerobic Digestion

The environmental impacts of on-farm anaerobic digestion depend on the manure management system that the digester amends or replaces as well as the actual use of the biogas produced. Typically, the anaerobic digestion of dairy manure followed by flaring of biogas, combustion of biogas for electricity, or production and use of biomethane as fuel can provide a number of direct environmental benefits. These include:

- Reduced GHG emissions
- Potential reduction of VOC emissions
- Odor control
- Pathogen and weed seed control
- Improved water quality

One potentially negative environmental impact of anaerobic digesters that combust the biogas is the creation of nitrogen oxides (NOx), which are regulated air pollutants and an ozone precursor. Nitrogen oxides are created by combustion of fuel with air. Combustion of dairy biogas or any other methane containing gas (whether in a flare, reciprocating or gas turbine engine, or a boiler) will emit NOx. The emission rate varies but is generally lowest for properly engineered flares and highest for rich burn reciprocating (piston) engines. NOx emissions are controlled by using lean burn engines, catalytic controls or microturbines. The latter two methods are fouled by the high sulfur content of biogas, and the H_2S must be scrubbed to prevent the swift corrosion of these devices.

Reduced Greenhouse Gas Emissions

The use of anaerobic digestion to create biogas from dairy manure can reduce GHG emissions in two distinct ways. First, when used in combination with a manure management system that stores manure under anaerobic conditions, it can prevent the release of CH4, a greenhouse gas, into theatmosphere. Second, the biogas or biomethane generated by the anaerobic digestion process can replace the use of fossil fuels that generate GHGs.

The biogas generated from anaerobic digestion contains about 60% CH_4. It is this component, methane (which is also the main component of natural gas), that can produce energy. In addition to being an energy resource, however, CH_4 is also a GHG with 21 times the global warming potential, by weight, of CO_2. Globally, CH_4 constitutes 22% of anthropogenic GHG emissions in terms of carbon equivalents. In the USA, CH_4 contributes 10% of anthropogenic GHG emissions and 10% of the CH_4 is derived from animal manure. Thus animal manure produces approximately 1% of all anthropogenic GHG emissions in the USA.

Most of the Central Valley dairies store manure in large lagoons under anaerobic conditions. Manure stored in anaerobic conditions produces the bulk of the GHG emissions from animal waste. The methanogenic bacteria that thrive in this environment produce CH_4, which is released into the atmosphere. If the lagoon is covered or the manure is digested in another type of digester, the CH_4 can be captured and combusted. This destroys the CH_4 and releases CO_2. Since each unit of CH_4 has 21 times the global warming potential of CO_2, 21 units of GHG are eliminated and 1 unit is created for each unit of CH_4 that is captured and combusted, creating an overall net gain of 20 units. This benefit will occur as long as the methane is combusted—whether the biogas is flared, used to generate electricity, or upgraded to biomethane and then combusted to produce energy. This benefit is in addition to the benefit when energy created by this renewable fuel replaces energy created by combusting a fossil fuel.

A good proportion of dairy manure in Southern California is stored aerobically. Methanogenic bacteria do not thrive in aerobic conditions and thus manure that is stored in corrals or piles where it is exposed to the air produces, very little CH_4. Since manure stored in this manner releases little CH_4, putting it into an anaerobic digester produces no significant reduction in CH_4 emissions, although there may be some nitrous oxide (N_2O) reductions. Also, if the anaerobic digester has any significant leakage, emissions of CH_4 may actually be higher than they would be using aerobic (dry) storage alone.

Reduced Volatile Organic Compound Emissions

Volatile organic compounds, in combination with NOx and sunlight, produce ozone, the primary element in smog and a critical air pollutant. Thus VOCs are an ozone precursor and are regulated by State and federal law. In California, VOCs are often called reactive organic gases (ROG).

VOCs are an intermediate product generated by methanogenic bacteria during the transformation of manure into biogas. It is expected that the total volume of VOCs generated is related to the total volume of CH_4 produced, but the more effective the methanogenic decomposition, the lower the VOCs as a percentage of the biogas. VOCs are created by enteric fermentation (the digestion process of the cow) and released primarily through the breath of the cow. They are also produced by the anaerobic decomposition of manure. A well designed and managed anaerobic digester may reduce VOCs by more completely transforming them into CH_4. Some fraction of the remaining VOCs in the biogas should be eliminated through the combustion of the biogas.

For its emission inventory, the California Air Resources Board (CARB) uses an emission factor for dairy cows of 12.8 lb of VOCs per cow per year. (This emission factor is based on a single 1938 study, which measured CH_4 emissions from a cow but did not measure VOC emissions.) Based on this emission factor, dairies are a significant source of VOC emissions and a major contributor to ozone in the San Joaquin Valley. The CARB has not determined the portion of VOC emissions that is generated by manure-holding lagoons.

Increased Nitrogen Oxide Emissions

When biogas or any fuel is combusted in an internal combustion engine it produces NOx, a air pollutant as well as a precursor to ozone and smog.

For reciprocating engines the main NOx production route is thermal, and is strongly temperature dependent. Internal combustion engines can produce a significant amount of NOx. Maximum NOx formation occurs when the fuel mixture is slightly lean, i.e. when there is not quite enough oxygen to burn all the fuel. Lean-burn engines typically have lower NOx formation than stoichiometric or rich-burn engines because more air dilutes the combustion gases, keeping peak flame temperature lower. Gas turbines and microturbines also produce a very low level of NOx because peak flame temperatures are low compared to reciprocating engines. A system to flaregas, if properly engineered, will generate a substantially lower level of NOx than an uncontrolled reciprocating engine.

Dairy anaerobic digesters that burn biogas for electricity typically use reciprocating internal combustion engines; microturbines have not been used successfully because impurities in the biogas corrode the engines. When there is enough biogas to support a lean-burn engine, NOx can be kept relatively low. The Inland Empire Utility Agency in Chino, California uses 700 to 1,400 kilowatt (kW) engines to combust biogas and has kept NOx production below 50 ppm, which meets BACT for waste gas as proposed by CARB in its guidance document to California air districts as required under SB 1298 (CARB, 2002, p.4). For smaller applications (capacity of less than 350 kW), there are no lean-burn waste-gas reciprocating engines available in the USA; consequently, NOx formation at these facilities can be expected to be much higher.

There are several catalytic conversion technologies for reducing NOx emissions which can be used on rich- and lean-burn engines that use natural gas, but the impurities in dairy biogas will substantially shorten the life of the catalytic NOx controls. If the H2S content of the biogas is reduced to a very low level before introduction to the engine, the emissions from the scrubbed dairy biogas will not degrade catalytic controls or microturbines as quickly. One California dairy has installed a H2S scrubbing system and a catalytic emission control device on its engine. Initial tests are promising, but it is too soon to know if this will be a reliable solution.

If biogas is upgraded to biomethane, the selective catalytic reduction technologies used for natural gas engines can be used to keep NOx formation at acceptable levels. Biomethane will not corrode microturbines and electricity generated in microturbines from biomethane has a very low accompanying NOx formation.

Control of Unpleasant Odors

According to anecdotal reports, most of the approximately 100 anaerobic digesters processing animal manure in the USA were built to address odor complaints from neighbors. As more housing is built in formerly rural areas of California's Central Valley, complaints about odors from dairies increase. Most of the odor problem comes from H_2S, VOC, and ammonia (NH_3) emissions from dairy manure. While hard to measure objectively, these odors are perceived as a serious environmental problem by residents in proximity to dairy farms. Fortunately, anaerobic digestion is a good method for controlling these odors, particularly if used in conjunction with a system that will scrub the H_2S from the biogas.

Control of Pathogens and Weed Seeds

Digesters that are heated to mesophilic and thermophilic levels are very effective in denaturing weed seeds and reducing pathogens. Pathogen reduction is greater than 99% in a 20-day hydraulic retention time, mesophilic digester. Thermophilic temperatures essentially result in the complete elimination of pathogens. Covered-lagoon digesters, which operate at ambient temperatures, have a more modest effect on weed seeds and pathogens.

Improved Water Quality

An anaerobic digester will have minimal effect on the total nutrient content of the digested manure. However, the chemical form of some of the nutrients will be changed. A digester decomposes organic materials, converting approximately half or more of the organic nitrogen (org-N) into NH3-N. Some phosphorus (P) and potassium (K) are released into solution by decomposing material. A minimal amount of the P and K will settle as sludge in plug flow and complete mix digesters. However 30% to 40% of the P and K are retained in covered-lagoon digesters in the accumulated sludge. Dissolved and suspended nutrients are of lesser concern as they will flow through the digester.

The anaerobic digestion process is an effective way to reduce high BOD in the effluent. Biological oxygen demand is a measure of the amount of oxygen used by microorganisms in the biochemical oxidation of organic matter; BOD concentrations in dairy wastewater are often 25 to 40 times greater than those in domestic wastewater. Anaerobic processes can remove 70% to 90% of the BOD in high-strength wastewater at a lower cost, in terms of both land and energy inputs, than aerated systems.

Check your progress

Q1. What are processes of reduction of green house gas emission?

Q2. Define the Production of Biogas by Anaerobic Digestion**.**

11.3 Composting and other biochemical Processes

The presence of mixed organic substrates is a prerogative of composting. More specifically, according to its etymological meaning, composting (from the Latin compositum, meaning mixture) refers to a biodegradation process of a mixture of substrates carried out by a microbial community composed of various populations in aerobic conditions and in the solid state. Microbial transformation of pure substrates goes under the name of fermentation or biooxidation, but not composting.

The exothermic process produces energy in the form of heat, which results in an increase of the temperature in the mass. A spontaneous process, therefore, passes through a thermophilic phase, which is preceded and followed by two mesophilic phases. During composting there is a temporary release of phytotoxins (intermediary metabolites, ammonia, etc.). At the end of the process, this phytotoxicity is completely overcome and the final product is beneficial to plant growth. The composting process leads to the final production of carbon dioxide, water, minerals, and stabilized organic matter (compost). The process starts with the oxidation of easily degradable organic matter; this first phase is called decomposition. The second phase, stabilization, includes not only the mineralization of slowly degradable molecules, but also includes more complex processes such as the humification of ligno-cellulosic compounds.

From a technical point of view, the composting process is stopped at a phase in which the organic matter still is present in a relatively large quantity (more than 50% of the starting amount); otherwise the process would continue, environmental conditions permitting, until all of the organic components are completely mineralized.

The main product is called compost, which may be defined as the stabilized and sanitized product of composting, compatible and beneficial to plant growth. Compost has undergone:

- An initial, rapid stage of decomposition;
- A stage of stabilization; and
- An incomplete process of humification.

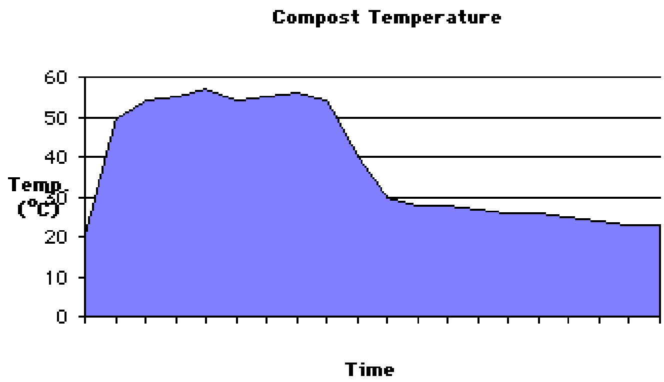
The transformation of fresh organic matter into compost is carried out mainly for three reasons:

- To overcome the phytotoxicity of fresh non-stabilized organic matter;
- To reduce the presence of agents (viruses, bacteria, fungi, parasites) that are pathogenic toman, animals, and plants to a level that does not further constitute a health risk;
- To produce an organic fertilizer or a soil conditioner, recycling organic wastes and biomass.

Many adjectives have been used for compost; some of them are correct, such as: aerobic, solid state, hygienized, and quality. Some others are in contradiction with the definition of compost and include: anaerobic, fresh, liquid state, etc., and thus should be avoided.

The Phases of Composting

In the process of composting, microorganisms break down organic matter and produce carbon dioxide, water, heat, and humus, the relatively stable organic end product. Under optimal conditions, composting proceeds through three phases: 1) the mesophilic, or moderate-temperature phase, which lasts for a couple of days, 2) the thermophilic, or high-temperature phase, which can last from a few days to several months, and finally, 3) a several-month cooling and maturation phase.



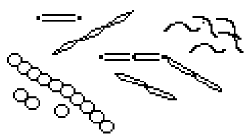
Different communities of microorganisms predominate during the various composting phases. Initial decomposition is carried out by mesophilic microorganisms, which rapidly break down the soluble, readily degradable compounds. The heat they produce causes the compost temperature to rapidly rise.

As the temperature rises above about 40°C, the mesophilic microorganisms become less competitive and are replaced by others that are thermophilic, or heat-loving. At temperatures of 55°C and above, many microorganisms that are human or plant pathogens are destroyed. Because temperatures over about 65°C kill many forms of microbes and limit the rate of decomposition, compost managers use aeration and mixing to keep the temperature below this point.

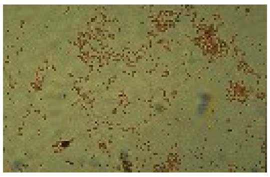
During the thermophilic phase, high temperatures accelerate the breakdown of proteins, fats, and complex carboydrates like cellulose and hemicellulose, the major structural molecules in plants. As the supply of these high-energy compounds becomes exhausted, the compost temperature gradually decreases and mesophilic microorganisms once again take over for the final phase of "curing" or maturation of the remaining organic matter.

Bacteria

Bacteria are the smallest living organisms and the most numerous in compost; they make up 80 to 90% of the billions of microorganisms typically found in a gram of compost. Bacteria are responsible for most of the decomposition and heat generation in compost. They are the most nutritionally diverse group of compost organisms, using a broad range of enzymes to chemically break down a variety of organic materials.



Bacteria are single-celled and structured as either rod-shaped bacilli, sphere-shaped cocci or spiral-shaped spirilla. Many are motile, meaning that they have the ability to move under their own power. At the beginning of the composting process (0-40°C), mesophilic bacteria predominate. Most of these are forms that can also be found in topsoil.



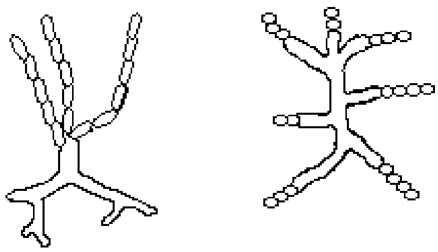
As the compost heats up above 40°C, thermophilic bacteria take over. The microbial populations during this phase are dominated by members of the genus Bacillus. The diversity of bacilli species is fairly high at temperatures from 50-55°C but decreases dramatically at 60°C or above. When conditions become unfavorable, bacilli survive by forming endospores, thick-walled spores that are highly resistant to heat, cold, dryness, or lack of food. They are ubiquitous in nature and become active whenever environmental conditions are favorable.

At the highest compost temperatures, bacteria of the genus *Thermus* have been isolated. Composters sometimes wonder how microorganisms evolved in nature that can withstand the high temperatures found in active compost. *Thermus* bacteria were first found in hot springs in Yellowstone National Park and may have evolved there. Other places where thermophilic conditions exist in nature include deep sea thermal vents, manure droppings, and accumulations of decomposing vegetation that have the right conditions to heat up just as they would in a compost pile.

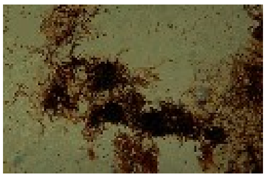
Once the compost cools down, mesophilic bacteria again predominate. The numbers and types of mesophilic microbes that recolonize compost as it matures depend on what spores and organisms are present in the compost as well as in the immediate environment. In general, the longer the curing or maturation phase, the more diverse the microbial community it supports.

Actinomycetes

The characteristic earthy smell of soil is caused by actinomycetes, organisms that resemble fungi but actually are filamentous bacteria. Like other bacteria, they lack nuclei, but they grow multicellular filaments like fungi. In composting they play an important role in degrading complex organics such as cellulose, lignin, chitin, and proteins. Their enzymes enable them to chemically break down tough debris such as woody stems, bark, or newspaper. Some species appear during the thermophilic phase, and others become important during the cooler curing phase, when only the most resistant compounds remain in the last stages of the formation of humus.

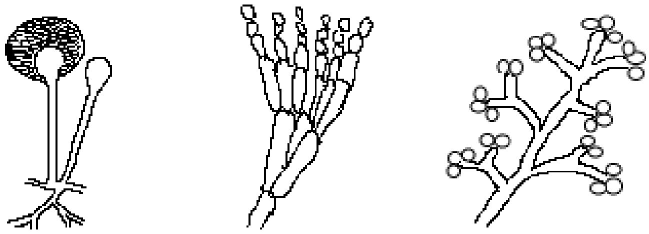


Actinomycetes form long, thread-like branched filaments that look like gray spider webs stretching through compost. These filaments are most commonly seen toward the end of the composting process, in the outer 10 to 15 centimeters of the pile. Sometimes they appear as circular colonies that gradually expand in diameter.



Fungi

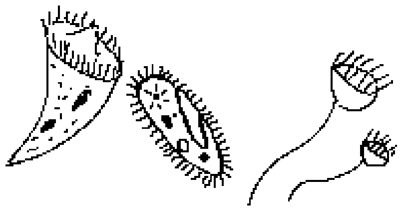
Fungi include molds and yeasts, and collectively they are responsible for the decomposition of many complex plant polymers in soil and compost. In compost, fungi are important because they break down tough debris, enabling bacteria to continue the decomposition process once most of the cellulose has been exhausted. They spread and grow vigorously by producing many cells and filaments, and they can attack organic residues that are too dry, acidic, or low in nitrogen for bacterial decomposition.



Most fungi are classified as saprophytes because they live on dead or dying material and obtain energy by breaking down organic matter in dead plants and animals. Fungal species are numerous during both mesophilic and thermophilic phases of composting. Most fungi live in the outer layer of compost when temperatures are high. Compost molds are strict aerobes that grow both as unseen filaments and as gray or white fuzzy colonies on the compost surface.

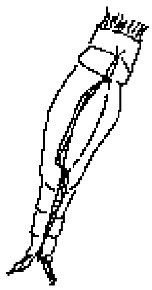
Protozoa

Protozoa are one-celled microscopic animals. They are found in water droplets in compost but play a relatively minor role in decomposition. Protozoa obtain their food from organic matter in the same way as bacteria do but also act as secondary consumers ingesting bacteria and fungi.



Rotifers

Rotifers are microscopic multicellular organisms also found in films of water in the compost. They feed on organic matter and also ingest bacteria and fungi.



11.4 Summary

In economically developing countries, constraints related to economics, technology, and qualified personnel have narrowed the choice of acceptable solid waste management, treatment, and disposal options. Viable options include minimisation, recycling, composting, incineration, and sanitary landfilling. Composting is the option that, with few exceptions, best fits within the limited resources available in developing countries. A characteristic that renders com posting especially suitable is its adaptability to a broad rangeof situations, due in part to the flexibility ofits requirements. As a result, there is a composting systemfor nearly every situation; i.e., simple systems forearly stages of industrial development to relatively complex, mechanised systems for advanced industrial development.

The compost option affords the many advantages of biological systems: lower equipment and operating costs; in harmony with the environment; and results in a useful product. On the other hand, composting is sometimes attributed with disadvantages often associated with biological systems -- namely, a slow reaction rate and some unpredictability. Regarding the attributed disadvantages, slow reaction rate may be justified, in that retention times are in terms of weeks and months. However, the attribution of unpredictability is not justified. If all conditions are known, applied, and maintained, the course of a given process will be predictable. Among the major prerequisites for successful composting are a satisfactory understanding and application of the basic principles of the process. Without this understanding, inadequacies of design and operation are practically inevitable. An understanding of the biology rests upon a knowledge of the basic principles of the process. Such a knowledge enables a rational evaluation of individual compost technologies and utilisation of those technologies. An obvious benefit of the knowledge is the ability to select the system most suited to an intended undertaking. An accompanying benefit is the ability to critically evaluate claims made on behalf of candidate systems.

11.5 Review Questions

Q1. Define bacteria, fungus & protozoan's involved in the process.

Q2. Illustrate the phase of composting?

UNIT-XII Hazardous solid waste

Structure

12.0 Introduction

In Units 1 to 8, we discussed the management of solid waste and its functional elements, which include storage, collection, transport, waste disposal, processing, recycling, biological conversion of waste and incineration with energy recovery in the context of non-hazardous wastes. In view of the substantial threat present and potential – hazardous wastes pose to human health, or living organisms in general, they ought to be handled, treated and managed differently, and this issue is discussed in the present Unit. In this Unit, we will first identify

and classify hazardous wastes, and then discuss their functional elements namely generation, storage and collection, transfer and transport, processing and disposal. Subsequently, we will discuss the various physical, chemical, thermal and biological treatments to reduce the impact of hazardous wastes on public health and the environment. We will close the Unit by explaining some of the techniques for hazardous waste minimisation and pollution prevention and touching upon the prevailing hazardous waste management practices in India .In this chapter we will learn Hazardous solid waste Definition, identification and classification of hazardous solid waste. Characteristics: Hazardous waste toxicity, reactivity, infectiousness, flammability, radioactivity, corrosiveness, irritation, bio-concentration, genetic activity, explosiveness

Objectives

After studying this unit you should be able to:

- Identify and classify hazardous wastes.
- Explain the techniques of hazardous waste management, treatment and minimization.
- Describe the physical, chemical, thermal and biological methods of treating hazardous waste.
- Adopt waste minimization and pollution prevention techniques.

12.1 Hazardous Waste: Identification And Classification

Hazardous wastes refer to wastes that may, or tend to, cause adverse health effects on the ecosystem and human beings. These wastes pose present or potential risks to human health or living organisms, due to the fact that they:

- Are non-degradable or persistent in nature;
- Can be biologically magnified;
- Are highly toxic and even lethal at very low concentrations.

The above list relates only to the intrinsic hazard of the waste, under uncontrolled release, to the environment, regardless of quantity or pathways to humans or other critical organisms (i.e., plants and animals). The criteria used to determine the nature of hazard include toxicity, phytotoxicity, genetic activity and bio-concentration. The threat to public health and the environment of a given hazardous waste is dependent on the quantity and characteristics of the waste involved. Wastes are secondary materials, which are generally classified into six categories as inherently waste: like materials, spent materials, sludges, by-products, commercial chemical products and scrap metals. Solid wastes form a subset of all secondary materials and hazardous wastes form a subset of solid waste. However, note that certain secondary materials are not regulated as wastes, as they are recycled and reused.

Figure 9.1 illustrates the relationship among secondary materials, solid wastes and hazardous wastes.

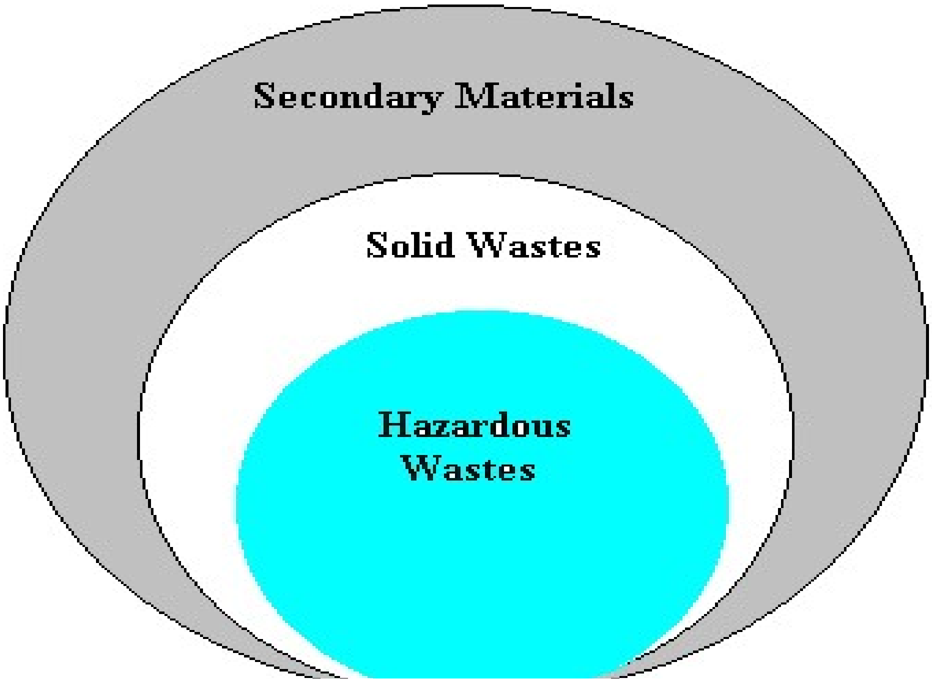


Figure 9.1Secondary Materials, Solid and Hazardous Wastes: Relationship

12.1.1 Identification

By using either or both of the following criteria, we can identify as to whether or not a waste is hazardous:

(i) The list provided by government agencies declaring that substance as hazardous.

(ii) Characteristics such as ignitibility, corrosively, reactivity and toxicity of the substance.

Let us now explain these two criteria

Listed hazardous wastes (priority chemicals)

A specific list showing certain materials as hazardous wastes minimises the need to test wastes as well as simplifies waste determination. In other words, any waste that fits the definition of a listed waste is considered a hazardous waste. Four separate lists cover wastes from generic industrial processes, specific industrial sectors, unused pure chemical products and formulations that are either acutely toxic or toxic, and all hazardous waste regulations apply to these lists of wastes. We will describe these wastes, classified in the F, K, P, and U industrial waste codes, respectively, below

http://www2.kumc.edu/safety/kdhehw/hwg1_10.html#SectionIV):

F-list: The F-list contains hazardous wastes from non-specific sources, that is, various industrial processes that may have generated the waste. The list consists of solvents commonly used in degreasing, metal treatment baths and sludges, wastewaters from metal plating operations and dioxin containing chemicals or their precursors. Examples of solvents that are F-listed hazardous wastes, along with their code numbers, include benzene (F005), carbon tetrachloride (F001), cresylic acid (F004), methyl ethyl ketone (F005), methylene chloride (F001), 1,1,1, trichloroethane (F001), toluene (F005) and trichloroethylene (F001). Solvent mixtures or blends, which contain greater than 10% of one or more of the solvents listed in F001, F002, F003, F004 and F005 are also considered F-listed wastes

K-list: The K-list contains hazardous wastes generated by specific industrial processes. Examples of industries, which generate K-listed wastes include wood preservation, pigment production, chemical production, petroleum refining, iron and steel production, explosive manufacturing and pesticide production.

P and U lists: The P and U lists contain discarded commercial chemical products, off-specification chemicals, container residues and residues from the spillage of materials. These two lists include commercial pure grades of the chemical, any technical grades of the chemical that are produced or marketed, and all formulations in which the chemical is the sole active ingredient. An example of a P or U listed hazardous waste is a pesticide which is not used during its shelf-life and requires to be disposed in bulk. The primary distinction between the two lists is the quantity at which the chemical is regulated. The P-list consists of acutely toxic wastes that are regulated when the quantity generated per month, or accumulated at any time, exceeds one kilogram (2.2 pounds), while U-listed hazardous wastes are regulated when the quantity generated per month exceeds 25 kilograms (55 pounds). Examples of businesses that typically generate P or U listed wastes include pesticide applicators, laboratories and chemical formulators

Characteristics of hazardous wastes

The regulations define characteristic hazardous wastes as wastes that exhibit measurable properties posing sufficient threats to warrant regulation. For a waste to be deemed a characteristic hazardous waste, it must cause, or significantly contribute to, an increased mortality or an increase in serious irreversible or incapacitating reversible illness, or pose a substantial hazard or threat of a hazard to human health or the environment, when it is improperly treated, stored, transported, disposed of, or otherwise mismanaged.

In other words, if the wastes generated at a facility are not listed in the F, K, P, or U lists, the final step to determine whether a waste is hazardous is to evaluate it against the following 4 hazardous characteristics:

(i) **Ignitability** (EPA Waste Identification Number D001): A waste is an ignitable hazardous waste, if it has a flash point of less than 60 ^{o}C; readily catches fire and burns so vigorously as to create a hazard; or is an ignitable compressed gas or an oxidiser. A simple method of determining the flash point of a waste is to review the material safety data sheet, which can be obtained from the manufacturer or distributor of the material. Naphtha, lacquer thinner, epoxy resins, adhesives and oil based paints are all examples of ignitable hazardous wastes

(ii) **Corrosivity** (EPA Waste Identification Number D002): A liquid waste which has a pH of less than or equal to 2 or greater than or equal to 12.5 is. Considered to be a corrosive hazardous waste. Sodium hydroxide, a caustic solution with a high pH, is often used by many industries to clean or degrease metal parts. Hydrochloric acid, a solution with a low pH, is used by many industries to clean metal parts prior to painting. When these caustic or acid solutions are disposed of, the waste is a corrosive hazardous waste.

(iii) **Reactivity** (EPA Waste Identification Number D003): A material is considered a reactive hazardous waste, if it is unstable, reacts violently with water, generates toxic gases when exposed to water or corrosive materials, or if it is capable of detonation or explosion when exposed to heat or a flame. Examples of reactive wastes would be waste gunpowder, sodium metal or wastes containing cyanides or sulphides.

(iv) **Toxicity** (EPA Waste Identification Number D004): To determine if a waste is a toxic hazardous waste, a representative sample of the material must be subjected to a test conducted in a certified laboratory. The toxic characteristic identifies wastes that are likely to leach dangerous concentrations of toxic chemicals into ground water.

12.1.2 Classification

From a practical standpoint, there are far too many compounds, products and product combinations that fit within the broad definition of hazardous waste. For this reason, groups of waste are considered in the following five general categories:

(i) **Radioactive substance:** Substances that emit ionising radiation are radioactive. Such substances are hazardous because prolonged exposure to radiation often results in damage to living organisms. Radioactive substances are of special concern because they persist for a long period. The period in which radiation occurs is commonly measured and expressed as *half-life*, i.e., the time required for the radioactivity of a given amount of the substance to decay to half its initial value. For example, uranium compounds have half-lives that range from 72 years for U232 to 23,420,000 years for U236. The management of radioactive wastes is highly controlled by national and state regulatory agencies. Disposal sites that are used for the long-term storage of radioactive wastes are not used for the disposal of any other solid waste.

(ii) **Chemicals:** Most hazardous chemical wastes can be classified into four groups: synthetic organics, inorganic metals, salts, acids and bases, and flammables and explosives. Some of the chemicals are hazardous because they are highly toxic to most life forms. When such hazardous compounds are present in a waste stream at levels equal to, or greater than, their threshold levels, the entire waste stream is identified as hazardous.

(iii) Biomedical wastes: The principal sources of hazardous biological wastes are hospitals and biological research facilities. The ability to infect other living organisms and the ability to produce toxins are the most significant characteristics of hazardous biological wastes. This group mainly includes malignant tissues discarded during surgical procedures and contaminated materials, such as hypodermic needles, bandages and outdated drugs. This waste can also be generated as a by-product of industrial biological conversion processes.

(iv) **Flammable wastes:** Most flammable wastes are also identified as hazardous chemical wastes. This dual grouping is necessary because of the high potential hazard in storing, collecting and disposing of flammable wastes. These wastes may be liquid, gaseous or solid, but most often they are liquids. Typical examples include organic solvents, oils, plasticisers and organic sludges.

(v) **Explosives:** Explosive hazardous wastes are mainly ordnance (artillery) materials, i.e., the wastes resulting from ordnance manufacturing and some industrial gases. Similar to flammables, these wastes also have a high potential for hazard in storage, collection and disposal, and therefore, they should be considered separately in addition to being listed as hazardous chemicals. These wastes may exist in solid, liquid or gaseous form.

vi) Household hazardous wastes: Household wastes such as cleaning chemicals, batteries, nail polish etc in MSW constitute hazardous waste. Especially batteries contain mercury which are alkaline which is dangerous enough to kill people. Generic household hazardous material include non chlorinated organic, chlorinated organic, pesticides, latex paint, oil based paints, waste oil, automobile battery and household battery.

12.2 HAZARDOUS WASTE MANAGEMENT

Hazardous waste management, as is the case with non-hazardous solid waste management, which we studied earlier, consists of several functional elements. We will discuss these elements in Subsections 9.2.1 to 9.2.5.

12.2.1 Generation

Hazardous wastes are generated in limited amounts in a community and very little information is available on the quantities of hazardous waste generated within a community and in various industries. Hazardous waste generation outside the industry is irregular and very less in amount, rendering the waste generation parameter meaningless. The only practical means to overcome these limitations is to conduct a detailed inventory and measurement studies at each potential source in a community. As a first step in developing a community inventory, potential sources of hazardous waste are to be identified. The total annual quantity of hazardous waste at any given source in a community must be established through data inventory completed during onsite visits.

Table 9.1 below presents a list of hazardous waste generation sources:

Table 9.1

Common Hazardous Wastes: Community Source

Waste Category	**Sources**
Radioactive substances	Biomedical research facilities, colleges and university laboratories, offices, hospitals, nuclear power plants, etc.
Toxic chemicals	Agricultural chemical companies, battery shops, car washes, chemical shops, college and university laboratories, construction companies, electric utilities, hospitals and clinics, industrial cooling towers, newspaper and photographic solutions, nuclear power plants, pest control agencies, photographic processing facilities, plating shops, service stations, etc.
Biological wastes	Biomedical research facilities, drug companies, hospitals, medical clinics, etc.
Flammable wastes	Dry cleaners, petroleum reclamation plants, petroleum refining and processing facilities, service stations, tanker truck cleaning stations, etc.
Explosives	Construction companies, dry cleaners, ammunition production facilities, etc.

In addition to the sources listed, the spillage of containerised hazardous waste must also be considered an important source. The quantities of hazardous wastes that are involved in spillage are usually not known. The effects of spillage are often spectacular and visible to the community. Because the occurrence of spillage cannot be predicted, the potential threat to human health and environment is greater than that from routinely generated hazardous wastes

12.2.2 Storage and collection

Onsite storage practices are a function of the types and amounts of hazardous wastes generated and the period over which generation occurs. Usually, when large quantities are generated, special facilities are used that have sufficient capacity to hold wastes accumulated over a period of several days. When only a small amount is generated, the waste can be containerized, and limited quantity may be stored. Containers and facilities used in hazardous waste storage and handling are selected on the basis of waste characteristics. For example : Corrosive acids or caustic solutions are stored in fiberglass or glass-lined containers to prevent deterioration of metals in the container. Great care must also be exercised to avoid storing incompatible wastes in the same container or locations. Figures 9.2 and 9.3 show typical drum containers used for the storage of hazardous waste:

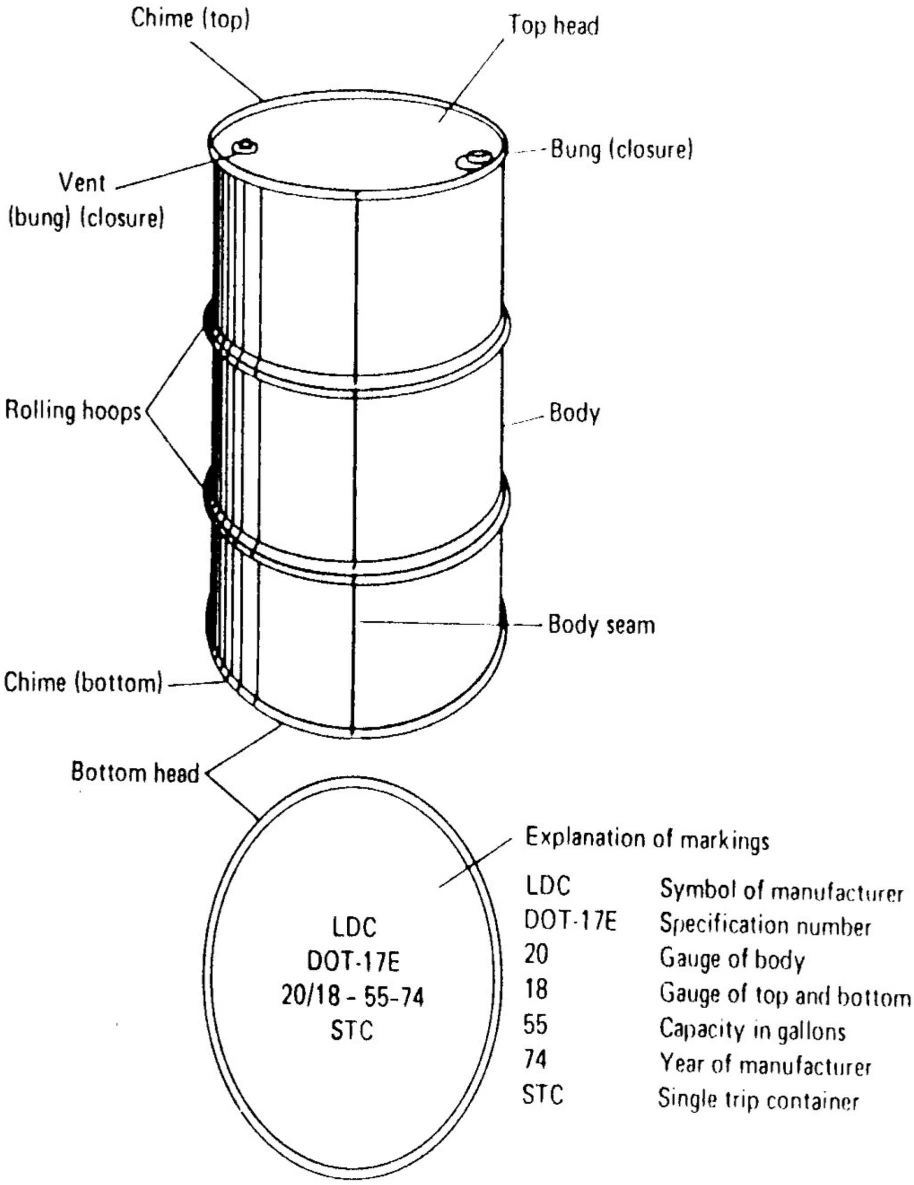


Figure 9.2 Light-Gauge Closed Head Drum

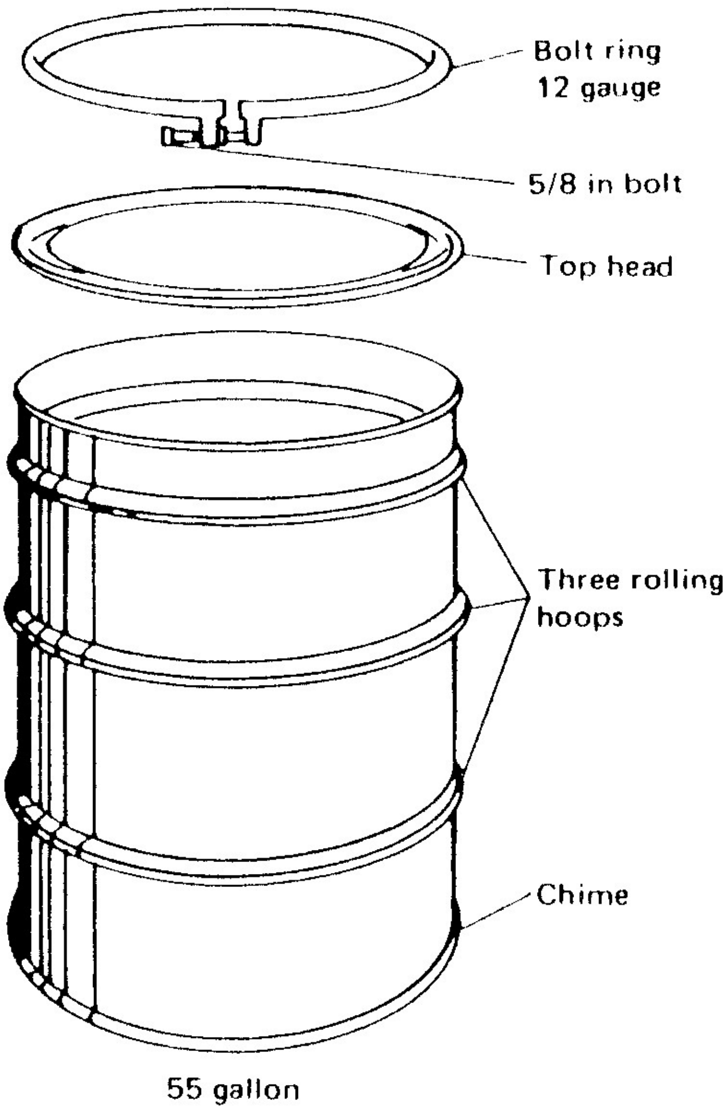


Figure 9.3 Light-Gauge Open Head Drum

The waste generator, or a specialised hauler, generally collects the hazardous waste for delivery to a treatment or disposal site. The loading of collection vehicles is completed in either of the following ways:

(i) Wastes stored in large-capacity tanks are either drained or pumped into collection vehicles;

(ii) Wastes stored in sealed drums or sealed containers are loaded by hand or by mechanical equipment onto flatbed trucks.

The stored containers are transported unopened to the treatment and disposal facility. To avoid accidents and the possible loss of life, two collectors should be assigned when hazardous wastes are to be collected. The equipment used for collection vary with the waste characteristics, and the typical collection equipment are listed in Table 9.2 below:

Table 9.2

Equipment for Collection of Hazardous Waste

Waste Category	**Collection equipment and accessories**
Radioactive substances	Various types of trucks and railroad equipment depending on characteristics of wastes; special marking to show safety hazard; heavy loading equipment to handle concrete-encased lead containers.
Toxic chemicals	Flatbed trucks for wastes stored in drums; tractor-trailer tank truck combination for large volumes of wastes; railroad tank cars; special interior linings such as glass, fibreglass or rubber.
Biological wastes	Standard packers' collection truck with some special precautions to prevent contact between wastes and the collector; flatbed trucks for wastes stored in drums.
Flammable wastes	Same as those for toxic chemicals, with special colourings and safety warning printed on vehicles.
Explosives	Same as those for toxic chemicals with some restriction on transport routes, especially through residential areas.

12.2.3 Transfer and transport

The economic benefits derived by transferring smaller vehicle loads to larger vehicles, as discussed for non-hazardous solid waste in Unit 3, are equally applicable to hazardous wastes. However, the facilities of a hazardous waste transfer station are quite different from solid waste transfer station. Typically, hazardous wastes are not compacted (i.e., mechanical volume reduction) or delivered by numerous community residents. Instead, liquid hazardous wastes are generally pumped from collection vehicles and sludge or solids are reloaded without removal from the collection containers for transport to processing and disposal facilities.

It is unusual to find a hazardous waste transfer facility, where wastes are simply transferred to larger transport vehicles. Some processing and storage facilities are often part of the material handling sequence at a transfer station. For example, neutralisation of corrosive wastes might result in the use of a lower-cost holding tank on transport vehicles. As in the case of storage (see Subsection 9.2.3 above), great care must be exercised to avoid the danger of mixing incompatible wastes.

12.2.4 Processing

Processing of hazardous waste is done for purposes of recovering useful materials and preparing the wastes for disposal.

Processing can be accomplished on-site or off-site. The variables affecting the selection of processing site include the characteristics of wastes, the quantity of wastes, the technical, economical and environmental aspects of available on-site treatment processes and the availability of the nearest off-site treatment facility (e.g., haul distance, fees, and exclusions). The treatment of hazardous waste can be accomplished by physical, chemical, thermal or biological means. Table 9.3 below gives the various individual processes in each category:

Table 9.3

Hazardous Waste Treatment Operations and Processes

Operation/Processes	Functions performed$	Types of wastes*	Forms of waste#
Physical Treatment			
Aeration	Se	1, 2, 3, 4	L
Ammonia stripping	VR, Se	1, 2, 3, 4	L
Carbon sorption	VR, Se	1, 3, 4, 5	L,G
Centrifugation	VR, Se	1, 2, 3, 4, 5	L
Dialysis	VR, Se	1, 2, 3, 4	L
Distillation	VR, Se	1, 2, 3, 4, 5	L
Electro dialysis	VR, Se	1, 2, 3, 4, 6	L
Encapsulation	St	1, 2, 3, 4, 6	L,S
Evaporation	VR, Se	1, 2, 5	L
Filtration	VR, Se	1, 2, 3, 4, 5	L,G
Flocculation/Settling	VR, Se	1, 2, 3, 4, 5	L
Flotation	Se	1, 2, 3, 4	L
Reverse osmosis	VR, Se	1, 2, 4, 6	L
Sedimentation	VR, Se	1, 2, 3, 4, 5	L
Thickening	Se	1, 2, 3, 4	L
Vapour scrubbing	VR, Se	1, 2, 3, 4	L
Chemical Treatment			
Calcination	VR	1, 2, 5	L
Ion exchange	VR, Se, De	1, 2, 3, 4, 5	L
Neutralisation	De	1, 2, 3, 4	L
Oxidation	De	1, 2, 3, 4	L
Precipitation	VR, Se	1, 2, 3, 4, 5	L
Reduction	De	1, 2	L
Solvent extraction	Se	1, 2, 3, 4, 5	L
Sorption	De	1, 2, 3, 4	L
Thermal treatment			
Incineration	VR, De	3, 5, 6, 7, 8	S, L, G
Pyrolysis	VR, De	3, 4, 6	S, L, G
Biological Treatment			
Activated sludges	De	3	L
Aerated lagoons	De	3	L
Anaerobic digestion	De	3	L
Anaerobic filters	De	3	L
Trickling filters	De	3	L
Waste stabilisation pond	De	3	L

Source: Tchobanoglous, et al., (1977, 1993)

*$ Functions: VR= volume reduction; Se = separation; De = detoxification; St = storage; * Waste types: 1= inorganic chemical without heavy metals; 2 = inorganic chemical with heavy metal; 3 = organic chemical without heavy metal; 4 = organic chemical with heavy metal; 5= radiological; 6 = biological; 7= flammable and 8= explosive; # Waste forms: S=solid; L= liquid and G= gas*

12.2.5 Disposal

Regardless of their form (i.e., solid, liquid, or gas), most hazardous waste is disposed off either near the surface or by deep burial. Table 9.4 shows the various hazardous waste disposal methods:

Table 9.4

Hazardous Wastes Disposal and Storage Methods

Operation/Process	Functions performed$	Types of wastes*	Forms of waste#
Deep well injection	Di	1, 2, 3, 4,5,6,7	L
Detonation	Di	6, 8	S, L, G
Engineered storage	St	1, 2, 3, 4, 5,6,7,8	S, L, G
Land burial	Di	1, 2, 3, 4, 5,6,7,8	S, L
Ocean dumping	Di	1, 2, 3, 4, 7, 8	S, L, G

Source: Tchobanoglous, et al., (1977 and 1993)

*$ Functions: Di= disposal; St = storage; * Waste types: 1= inorganic chemical without heavy metals; 2 = inorganic chemical with heavy metal; 3 = organic chemical without heavy metal; 4 = organic chemical with heavy metal; 5= radiological; 6 = biological; 7= flammable and 8= explosive.*

 # Waste form: S=solid; L= liquid and G= gas

Although, controlled landfill methods have been proved adequate for disposing of municipal solid waste and limited amounts of hazardous waste, they are not suitable enough for the disposal of a large quantity of hazardous waste, due to the following reasons:

Possible percolation of toxic liquid waste to the ground water;

Dissolution of solids followed by leaching and percolation to the ground water;

Dissolution of solid hazardous wastes by acid leachate from solid waste, followed by leaching and percolation to the ground water;

Potential for undesirable reactions in the landfill that may lead to the development of explosive or toxic gases;

Volatilization of hazardous waste leading to the release of toxic or explosive vapors to the atmosphere;

Corrosion of containers with hazardous wastes.

We must, therefore, take care both in the selection of a hazardous waste disposal site and its design. In general, disposal sites for hazardous wastes should be separate from those for municipal solid wastes. As hazardous wastes can exist in the form of liquids, sludges, solids and dusts, a correct approach for co-disposal for each of the hazardous wastes should be determined. To avoid the co-disposal of incompatible wastes, separate storage areas within the total landfill site should be designated for various classes of compatible wastes (Phelps, et al., 1995).

Liquid wastes are usually stored in a tank near the site and can be introduced into the landfill by means of trenches or lagoons, injection or irrigation. Sludges are also placed in trenches. During disposal of lightweight wastes, the disposal area must be kept wet to prevent dust emissions. Hazardous solid waste characterized by a high degree of impermeability as such must not be disposed of over large areas. When containerised wastes are to be disposed of, precautions must be taken to avoid the rupturing of containers during the unloading operation and the placement of incompatible waste in the same location. To avoid rupturing, the containers are unloaded and placed in position individually. The covering of the containers with earth should be monitored and controlled carefully to ensure that a soil layer exists between each container and the equipment placing the soil does not crush or deform the container.

While designing a landfill site for hazardous waste, provision should be made to prevent any leachate escaping from landfill site. This requires a clay liner, and in some cases, both clay and impermeable membrane liners are used. A layer of limestone is placed at the bottom of the landfill to neutralise the pH of leachate. A final soil cover of 25 cm or more should be placed over the liner. The completed site should be monitored continuously, both visually and with sample wells

Hazardous waste options

A three stage hierarchy of options for handling hazardous wastes are:

1) The top tier includes in plant options such as process manipulation, recycle and reuse options that reduce the production of hazardous waste in the first place. It also contains most desirable options.

2) Middle stage highlights processes that convert hazardous waste to less hazardous or non hazardous substances that include

a) Incineration

b) Land treatment

c) Ocean and atmospheric assimilation

d) Chemical, physical and biological treatments

e) Thermal treatments

3) Last stage which is least preferred or desirable tier that is perpetual storage cheapest alternative. Few process include landfill, underground injection, arid region unsaturated zone, surface impoundments, salt formations and waste piles.

12.3 HAZARDOUS WASTE TREATMENT

In Section 9.2, we discussed the various elements of hazardous waste management such as generation, storage and transport, transfer and transport, processing and disposal. Processing is mainly done to recover useful products and to prepare waste for disposal. But prior to disposal, hazardous wastes need appropriate treatment, depending on the type of waste. The various options for hazardous waste treatment can be categorised under physical, chemical, thermal and biological treatments. We will discuss these options, in Subsections 9.3.1 to 9.3.3.

12.3.1 Physical and chemical treatment

Physical and chemical treatments are an essential part of most hazardous waste treatment operations, and the treatments include the following (Freeman, 1988):

(i) **Filtration and separation:** Filtration is a method for separating solid particles from a liquid using a porous medium. The driving force in filtration is a pressure gradient, caused by gravity, centrifugal force, vacuum, or pressure greater than atmospheric pressure. The application of filtration for treatment of hazardous waste fall into the following categories:

Clarification, in which suspended solid particles less than 100 ppm (parts per million) concentration are removed from an aqueous stream. This is usually accomplished by depth filtration and cross-flow filtration and the primary aim is to produce a clear aqueous effluent, which can either be discharged directly, or further processed. The suspended solids are concentrated in a reject stream.

Dewatering of slurries of typically 1% to 30 % solids by weight. Here, the aim is to concentrate the solids into a phase or solid form for disposal or further treatment. This is usually accomplished by cake filtration. The filtration treatment, for example, can be used for neutralisation of strong acid with lime or limestone, or precipitation of dissolved heavy metals as carbonates or sulphides followed by settling and thickening of the resulting precipitated solids as slurry. The slurry can be dewatered by cake filtration and the effluent from the settling step can be filtered by depth filtration prior to discharge.

(ii) **Chemical precipitation:** This is a process by which the soluble substance is converted to an insoluble form either by a chemical reaction or by change in the composition of the solvent to diminish the solubility of the substance in it. Settling and/or filtration can then remove the precipitated solids. In the treatment of hazardous waste, the process has a wide applicability in the removal of toxic metal from aqueous wastes by converting them to an insoluble form. This includes wastes containing arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium and zinc. The sources of wastes containing metals are metal plating and polishing, inorganic pigment, mining and the electronic industries. Hazardous wastes containing metals are also generated from cleanup of uncontrolled hazardous waste sites, e.g., leachate or contaminated ground water.

(iii) **Chemical oxidation and reduction (redox):** In these reactions, the oxidation state of one reactant is raised, while that of the other reactant is lowered. When electrons are removed from an ion, atom, or molecule, the substance is oxidised and when electrons are added to a substance, it is reduced. Such reactions are used in treatment of metal-bearing wastes, sulphides, cyanides and chromium and in the treatment of many organic wastes such as phenols, pesticides and sulphur containing compounds. Since these treatment processes involve chemical reactions, both reactantsare generally in solution. However, in some cases, a solution reacts with a slightly soluble solid or gas.

There are many chemicals, which are oxidising agents; but relatively few of them are used for waste treatment. Some of the commonly used oxidising agents are sodium hypochlorite, hydrogen peroxide, calcium hypochlorite, potassium permanganate and ozone. Reducing agents are used to treat wastes containing hexavalent chromium, mercury, organometallic compounds and chelated metals. Some of the compounds used as reducing agents are sulphur dioxide, sodium borohydride, etc. In general, chemical treatment costs are highly influenced by the chemical cost. This oxidation and reduction treatment tends to be more suitable for low concentration (i.e., less than 1%) in wastes.

(iv) **Solidification and stabilisation:** In hazardous waste management, solidification and stabilisation (S/S) is a term normally used to designate a technology employing activities to reduce the mobility of pollutants, thereby making the waste acceptable under current land disposal requirements. Solidification and stabilisation are treatment processes designed to improve waste handling and physical characteristics, decrease surface area across which pollutants can transfer or leach, limit the solubility or detoxify the hazardous constituent. To understand this technology, it is important for us to understand the following terms:

Solidification: This refers to a process in which materials are added to the waste to produce a solid. It may or may not involve a chemical bonding between the toxic contaminant and the additive.

Stabilisation: This refers to a process by which a waste is converted to a more chemically stable form. Subsuming solidification, stabilisation represents the use of a chemical reaction to transform the toxic component to a new, non-toxic compound or substance.

Chemical fixation: This implies the transformation of toxic Contaminants to a new non-toxic compound. The term has been misused to describe processes, which do not involve chemical bonding of the contaminant to the binder.

Encapsulation: This is a process involving the complete coating or enclosure of a toxic particle or waste agglomerate with a new substance (e.g., S/S additive or binder). The encapsulation of the individual particles is known as micro-encapsulation, while that of an agglomeration of waste particles or micro-encapsulated materials is known as macro-encapsulation.

In S/S method, some wastes can be mixed with filling and binding agents to obtain a dischargeable product. This rather simple treatment can only be used for waste with chemical properties suitable for landfilling. With regard to wastes with physical properties, it changes only the physical properties, but is unsuitable for landfilling. The most important application of this technology, however, is the solidification of metal-containing waste. S/S technology could potentially be an important alternative technology with a major use being to treat wastes in order to make them acceptable for land disposal. Lower permeability, lower contaminant leaching rate and such similar characteristics may make hazardous wastes acceptable for land disposal after stabilisation.

(v) **Evaporation:** Evaporation is defined as the conversion of a liquid from a solution or slurry into vapour. All evaporation systems require the transfer of sufficient heat from a heating medium to the process fluid to vaporise the volatile solvent. Evaporation is used in the treatment of hazardous waste and the process equipment is quite flexible and can handle waste in various forms – aqueous, slurries, sludges and tars. Evaporation is commonly used as a pre-treatment method to decrease quantities of material for final treatment. It is also used in cases where no other treatment method was found to be practical, such as in the concentration of trinitrotoluene (TNT) for subsequent incineration.

(vi) **Ozonation:** Ozone is a relatively unstable gas consisting of three oxygen atoms per molecule (O3) and is one of the strongest oxidising agentsknown. It can be substituted for conventional oxidants such as chlorine, hydrogen peroxide and potassium permanganate. Ozone and UV radiations have been used to detoxify industrial organic wastes, containing aromatic and aliphatic polychlorinated compounds, ketones and alcohols.

12.3.2 Thermal treatment

The two main thermal treatments used with regard to hazardous wastes are:

(i) **Incineration:** Incineration can be regarded as either a pre-treatment of hazardous waste, prior to final disposal or as a means of valorising waste by recovering energy. It includes both the burning of mixed solid waste or burning of selected parts of the waste stream as a fuel. The concept of treating hazardous waste is similar to that of municipal solid waste (see Unit 8).

(ii) **Pyrolysis:** This is defined as the chemical decomposition or change brought about by heating in the absence of oxygen. This is a thermal process for transformation of solid and liquid carbonaceous materials into gaseous components and the solid residue containing fixed carbon and ash. The application of pyrolysis to hazardous waste treatment leads to a two-step process for disposal. In the first step, wastes are heated separating the volatile contents (e.g., combustible gases, water vapour, etc.) from non-volatile char and ash. In the second step volatile components are burned under proper conditions to assure incineration of all hazardous components (Freeman, M. H. et al., 1988).

To elaborate, pyrolysis is applicable to hazardous waste treatment, as it provides a precise control of the combustion process. The first step of pyrolysis treatment is endothermic and generally done at 425 to 760C. The heating chamber is called the pyrolyser. Hazardous organic compounds can be volatilised at this low temperature, leaving a clean residue. In the second step, the volatiles are burned in a fume incinerator to achieve destruction efficiency of more than 99%. Separating the process into two very controllable steps allows precise temperature control and makes it possible to build simpler equipment. The pyrolysis process can be applied to solids, sludges and liquid wastes. Wastes with the following characteristics are especially amenable to pyrolysis:

- Sludge material that is either too viscous, too abrasive or varies too much in consistency to be atomised in an incinerator.
- Wastes such as plastic, which undergo partial or complete phase changes during thermal processing.
- High-residue materials such as high-ash liquid and sludges, with light, easily entrained solids that will generally require substantial stack gas clean up.
- Materials containing salts and metals, which melt and volatilise at normal incineration temperatures. Materials like sodium chloride (NaCl), zinc (Zn) and lead (Pb), when incinerated may cause refractory spalling and fouling of the heat-exchanger surface.

12.3.3 Biological treatment

On the basis of the fact that hazardous materials are toxic to living beings, it is not uncommon for some to assume that biological treatment is not possible for hazardous wastes. This assumption is untenable, and, in fact, we must aggressively seek biological treatment in order to exploit the full potential of hazardous wastes in terms of removal efficiency and cost (Freeman, et al., 1988). Against this background, let us now list some of the techniques used for biological treatment of hazardous waste:

(i) **Land treatment:** This is a waste treatment and disposal process, where a waste is mixed with or incorporated into the surface soil and is degraded, transformed or immobilised through proper management. The other terminologies used commonly include land cultivation, land farming, land application and sludge spreading. Compared to other land disposal options (e.g., landfill and surface impoundments), land treatment has lower long-term monitoring, maintenance and potential clean up liabilities and because of this, it has received considerable attention as an ultimate disposal method. It is a dynamic, management-intensive process involving waste, site, soil, climate and biological activity as a system to degrade and immobilise waste constituents.

In land treatment, the organic fraction must be biodegradable at reasonable rates to minimise environmental problems associated with migration of hazardous waste constituents. The various factors involved in the operation of the system are as follows

Waste characteristics: Biodegradable wastes are suitable for land treatment. Radioactive wastes, highly volatile, reactive, flammable liquids and inorganic wastes such as heavy metals, acids and bases, cyanides and ammonia are not considered for land treatment. Land treatability of organic compound often follows a predictable pattern for similar type of compounds. Chemical structure, molecular weight, water solubility and vapour pressure are few of the characteristics that determine the ease of biodegradation.

Soil characteristics: The rate of biodegradation and leaching of waste applied, the availability of nutrients and toxicants to microorganisms and the fate of hazardous waste constituents are determined largely by application rate as well as the soil's chemical and physical characteristics or reaction. Principal soil characteristics affecting land treatment processes are pH, salinity, aeration, moisture holding capacity, soil temperature, etc. Some of the characteristics can be improved through soil amendments (e.g., nutrients, lime, etc.), tillage or through adjustments of loading rate, frequency, etc., at the time of waste application.

Microorganisms: Soil normally contains a large number of diverse microorganisms, consisting of several groups that are predominantly aerobic in well-drained soil. The types and population of microorganisms present in the waste-amended soil depend on the soil moisture content, available oxygen, nutrient composition and other

Characteristics. The key groups of the microorganisms present in the surface soil are bacteria, actinomycetes, fungi, algae and protozoa. In addition to these groups, other micro and macro fauna, such as nematodes and insects are often present.

Waste degradation: Conditions favourable for plant growth are also favourable for the activity of soil microorganisms. The factors affecting waste degradation that (may be adjusted in the design and operation of a land treatment facility) are soil pH (near 7), soil moisture content (usually between 30 to 90 %), soil temperature (activity decreases below 10C) and nutrients.

(ii) **Enzymatic systems:** Enzymes are complex proteins ubiquitous in nature. These proteins, composed of amino acids, are linked together via peptide bonds. Enzymes capable of transforming hazardous waste chemicals to non-toxic products can be harvested from microorganisms grown in mass culture. Such crude enzyme extracts derived from microorganisms have been shown to convert pesticides into less toxic and persistent products. The reaction of detoxifying enzymes are not limited to intracellular conditions but have been demonstrated through the use of immobilised enzyme extracts on several liquid waste streams. The factors of moisture, temperature, aeration, soil structure, organic matter content, seasonal variation and the availability of soil nutrients influence the presence and abundance of enzymes.

(i) **Composting:** The principles involved in composting organic hazardous wastes are the same as those in the composting of all organic materials (See Unit 8), though with moderate modifications. The microbiology of hazardous wastes differs from that of composting in the use of inoculums. The reaction is that certain types of hazardous waste molecules can be degraded by only one or a very few microbial species, which may not be widely distributed or abundant in nature. The factors important in composting of hazardous wastes are those that govern all biological reactions. The principal physical parameters are the shape and dimensions of the particles of the material to be composted and the environmental

(ii) Factors of interest in an operation are temperature, pH, available oxygen, moisture, and nutrient availability.

(iii) As we studied in Unit 7, the compost technology can be divided into two broad classes – windrow (open pile) and in-vessel (enclosed), and the former may be further subdivided into turned and forced aeration (static pile). Composting, by no means, is a panacea for the hazardous waste problem. When considering the future of hazardous waste composting needs, attention must be paid to the advantages and disadvantages inherent in composting as compared to those inherent in physical, chemical and thermal method of waste treatment.

(iv) **Aerobic and anaerobic treatment:** Hazardous materials are present in low to high concentration in wastewaters, leachate and soil. These wastes are characterised by high organic content (e.g., up to 40,000 mg/l total organic carbon), low and high pH (2 to 12), elevated salt levels (sometimes, over 5%), and presence of heavy metals and hazardous organics. Hazardous wastes can be treated using either aerobic or anaerobic treatment methods.

(v) In aerobic treatment, under proper conditions, microorganisms grow. They need a carbon and energy source, which many hazardous wastes satisfy, nutrients such as nitrogen, phosphorus and trace metals and a source of oxygen. Some organisms can use oxidised inorganic compounds (e.g. nitrate) as a substitute for oxygen. Care is to be taken such that all the required nutrients and substances are supplied in sufficient quantities. Temperature and pH must be controlled as needed and the substances that are toxic to the organisms (e.g., heavy metals) must be removed.

Anaerobic treatment is a sequential biologically destructive process in which hydrocarbons are converted, in the absence of free oxygen, from complex to simpler molecules, and ultimately to carbon dioxide and methane. The process is mediated through enzyme catalysis and depends on maintaining a balance of population within a specific set of environmental conditions. Hazardous waste streams often consist of hydrocarbons leading to higher concentrations of chemical oxygen demand (COD). Depending upon the nature of waste, the organic constituents may be derived from a single process stream or from a mixture of streams.

The treatability of the waste depends upon the susceptibility of the hydrocarbon content to anaerobic biological degradation, and on the ability of the organisms to resist detrimental effect of biologically recalcitrant and toxic organic and inorganic chemicals. The metabolic interactions among the various groups of organisms are essential for the successful and complete mineralization of the organic molecules. Various parameters such as the influent quality, the biological activity of the reactor and the quality of the reactor environment are monitored to maintain efficient operating conditions within the reactor.

12.7 REVIEW QUESTIONS

Q.1. What is hazardous waste substance?

Q.2. Define aerobic & anaerobic treatment.