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إدارة مخلفات

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Solid Waste Management
CE 556

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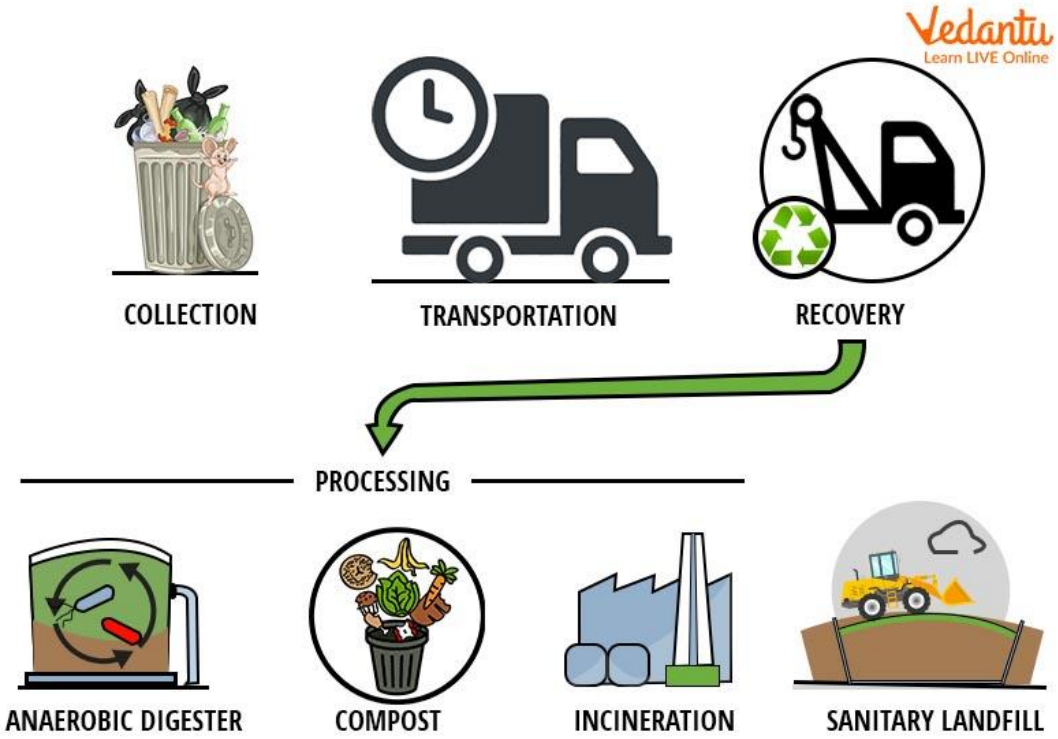
What is solid wastes?

Solid wastes are all the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted.

The term solid waste is encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of agricultural, industrial, and mineral wastes.

Solid waste management

- Waste management is the discipline associated with the control of generation, collection ,transportation and disposal of solid waste in a systematic ,economic and hygienic manner.



Element of Solid Waste Management

The activities associated with the management of solid waste from the point of generation to final disposal has been grouped into Six elements:

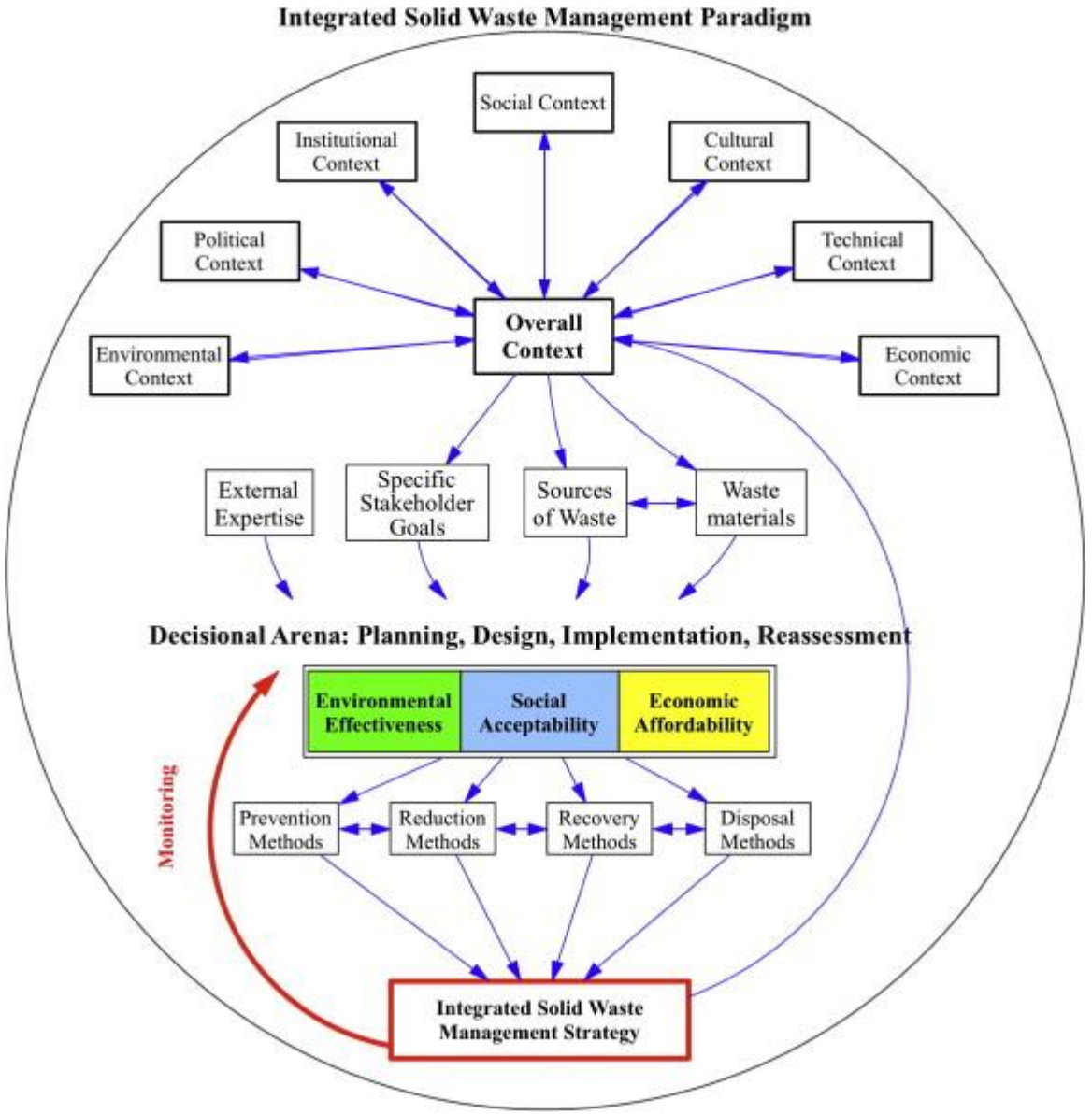
- Generation
- Storage
- Collection
- Transportation and Transfer
- Treatment
- Disposal

Why Waste management

- To prevent contact with humans or their immediate environment.
- The main purpose of waste management is to isolate waste from humans and the environment, and consequently, safeguard individual, family and community health.
- The aesthetic value of a better outlook and a clean physical environment is important for our emotional wellbeing.

Integrated solid waste management

The selection and application of suitable techniques, technologies and management programs to achieve specific waste management objective and goals.



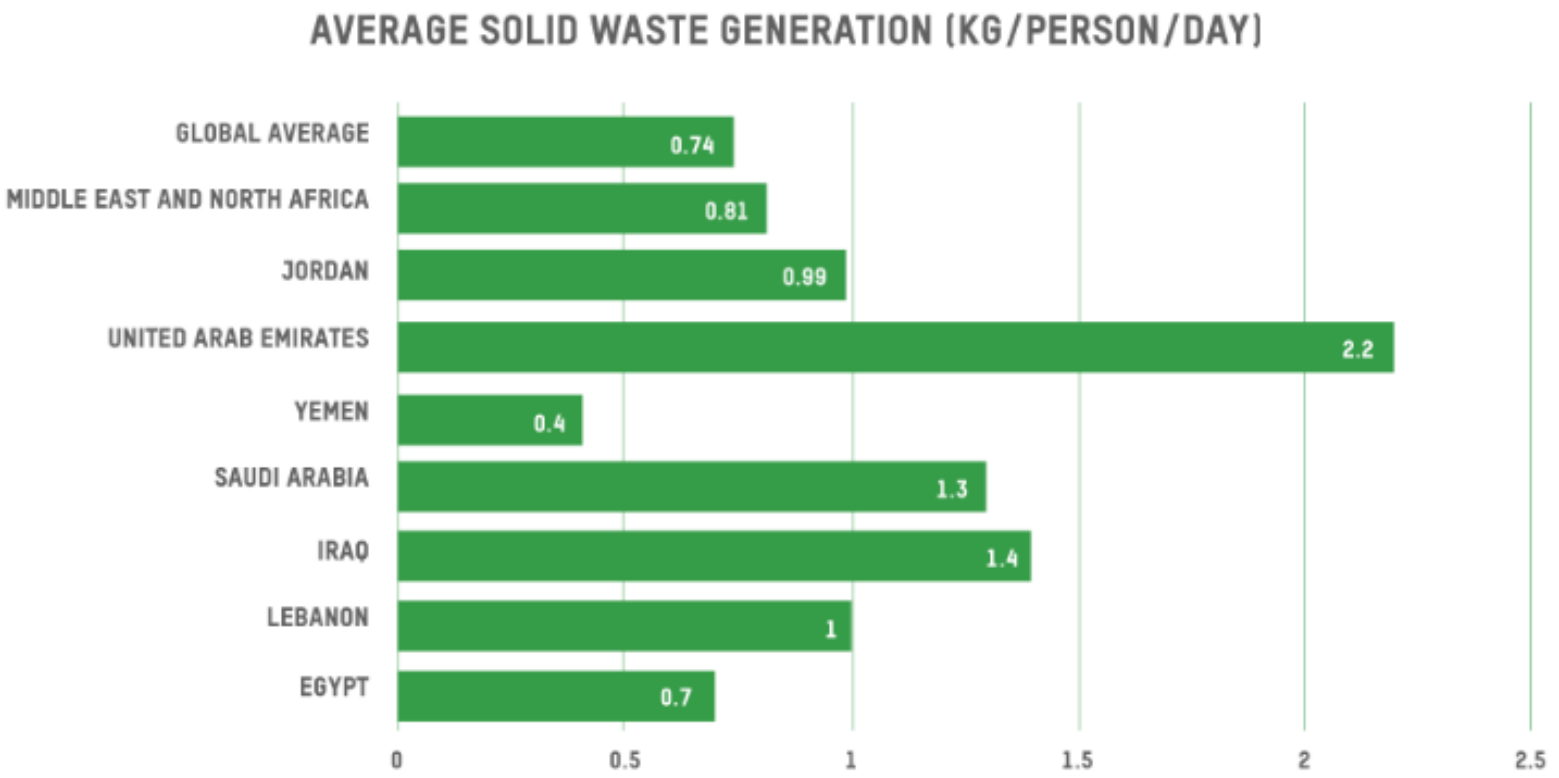
Solid Wastes – Background/ Statistics

- 2.01 billion tons of municipal solid waste is generated every year. (World Bank waste 2.0 report)

- 3.40 billion tones of municipal solid waste is generated by 2050. (Shawn Burke et al., 2018)

- The average generation rate of municipal solid waste in developing countries is 0.3-0.5 kg/person/day.

Jordan’s waste generation compared to other countries?



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- In Jordan, the country currently generates approximately 2.7 million tons of municipal solid waste annually, half of which is generated in the capital alone.

- By 2050, the total annual waste in Jordan is predicted to rise to 6 million tones!!!

- The increase in waste is due in large to the influx of refugees as well as the improved living conditions of the Jordanian people. Absence of a systematic waste management approach often causes unsorted waste, including hazardous waste, to be landfilled.

Cont.

- MSW generation in the U.S. has increased 93% since 1980, to 292M tons per year in 2018. Per capita MSW generation increased by 34% over the same time period, from 3.7 to 4.9 lbs per person per day, comprised to 2.4 in Sweden, 3.6 in Germany, and 2.6 in the U.K. At the 2018 per capita rate, an American weighing 180 lbs generates their own weight in MSW every 37 days.

- 29% of MSW generated in the U.S. is either recycled or composted, 7.6% is sent to waste-to-energy (WTE) incinerator facilities, and the remaining 63.5% is landfilled.

- Packaging, containers, and durable goods made up 48% of MSW in 2018. Most of the remainder was split between nondurable goods, food waste, and yard waste.

Classification of solid waste

- On the base of origin

• residential

• Commercial

• Institutional

• Municipal

• Industrial

• Agricultural

Municipal Solid Waste

- Municipal Solid Waste mainly the household waste include commercial waste and institutional waste.
- its composition depends on factors such as living standard, geographical location, type of housing and seasons.

Agriculture waste

- Wastes and residues resulting from diverse agricultural activities include plant residue and animal waste.
- Food processing waste is considered as agriculture waste
- Some are considered as hazardous waste

Industrial waste

Comprises waste from industrial processes e.g construction, fabrication, manufacturing, refineries, chemical plants

Some of these could also include hazardous waste

Hazardous waste

Wastes or combination of wastes that pose a substantial present or potential hazard to human.

special group of wastes define by certain criteria containing substances causing hazard.

Sometimes hospital waste is also classified as hazardous waste

Cont.

The hazard effect could be due to any or all of following:
Ignitability
Corrosivity
Reactivity
Toxicity
Infectivity

Medical Waste

- Hospital waste includes hazardous and non- hazardous waste.

- Clinical wastes are any waste consist human tissue, blood or other body fluids, excretion include infectious waste.

Domestic or residential

Source	Facilities, activities /location	Type of solid waste
Residential	Single family & multifamily detached dwelling, Low, medium & high-rise apartment, etc.	Food waste, paper, cardboard, plastics, textile, leather, yard waste, wood, glass, tin, cans, aluminum, other metal, ash, street leaves, special waste, household hazardous waste. Special waste: Bulky items, consumer electronics, white goods, yard wastes collected separately, batteries, oil and tires.

Commercial

Source	Facilities, activities /location	Type of solid waste
Commercial	Stores, restaurants, markets, hotel, motel, print shop, service station, auto repair shop.	Paper, cardboard, plastics, wood, food waste, glass, metal, special waste, hazardous waste, ets.

Institutional

Source	Facilities, activities /location	Type of solid waste
Institutional	Schools, hospitals, prisons, governmental centers.	Paper, cardboard, plastics, wood, food waste, glass, metal, special waste, hazardous waste, ets.

Construction and Demolition

Source	Facilities, activities /location	Type of solid waste
Construction and demolition	New construction sites, road repair/renovation sites, razing or building, broken pavement.	Wood, steel, concrete, dirt, etc.

Municipal Services

Source	Facilities, activities /location	Type of solid waste
Municipal service (Excluding treatment facilities)	Street cleaning, landscaping, catch basin cleaning parks and beaches, other recreational areas.	Special waste, rubbish, street sweepings, landscape and tree trimmings, catch basin debris, general waste from parks, beaches and recreational areas.

Treatment plant sites

Source	Facilities, activities /location	Type of solid waste
Treatment plant sites; Municipal incinerators	Water, waster water and industrial treatment processes, etc.	Treatment plant wastes, principally composed of residual sludges.

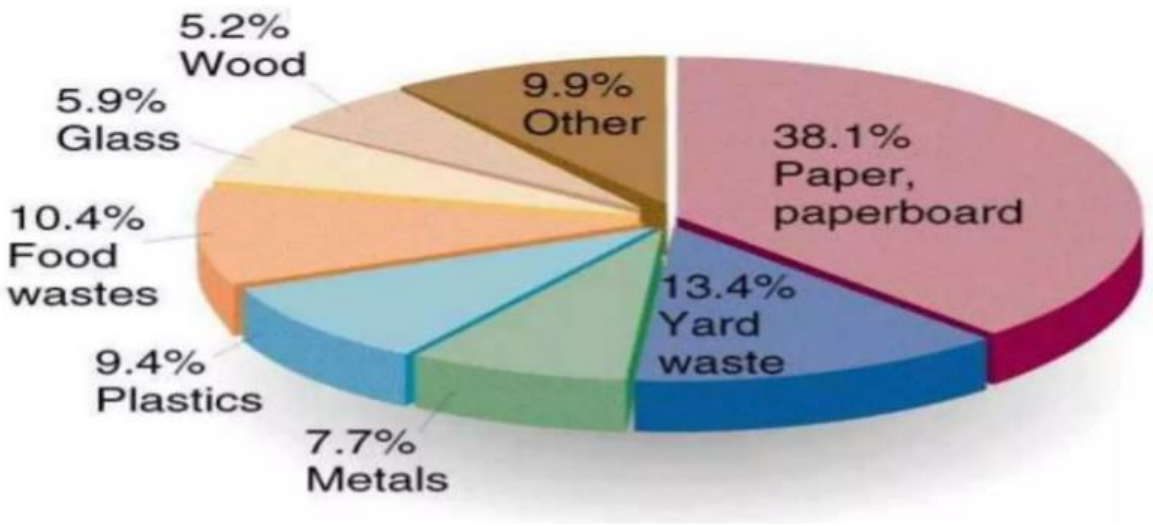
Municipal Solid Waste

Source	Facilities, activities /location	Type of solid waste
Municipal solid waste	All as above	All as above

Industrial

Source	Facilities, activities /location	Type of solid waste
Industrial	Construction, fabrication, ligh & heavy manufacturing, refineries, chemical plants, power plants, demolition, etc.	Industrial process wastes, scrap materials, etc. Non-industrial wastes including food wastes, rubbish, ashes, demolition & construction wastes, special wastes, hazardous waste.

Characterization of municipal solid waste



Classification Of Material Comprising Municipal Solid Waste

• Garbage: The animal, fruit or vegetable residues resulting from handling, preparation, cooking, and eating of foods. Because food waste are putrescible, they decompose rapidly, especially in warm weather.

• Rubbish: Combustible and noncombustible solid wastes, excluding food wastes or other putrescible material. Typically, combustible rubbish consists of material such as paper, cardboard, plastics, textiles, rubber, leather, wood, furniture, and garden trimmings. Noncombustible material consists of glass, crockery, tin cans, aluminum cans, ferrous and nonferrous metals, dirt and construction wastes.

• Ashes and Residues: Material remaining from the burning of wood, coal, coke, and other combustible wastes. Ashes and residues are normally composed of fine powdery materials, cinders, clinkers, and small amount of burned and partially burned materials.

Cont.

Demolition and Construction Wastes: Wastes from razed buildings and other structures are classified as demolition wastes. Wastes from the construction, remolding, and repairing of residential, commercial, and industrial buildings and similar structures are classified as construction wastes. These wastes may include dirt, stones, concrete, bricks.

Special Wastes: Wastes such as street sweepings, roadside litter, catch-basin debris, dead animals, abandoned vehicles are classified as special wastes.

Treatment Plant Wastes: The solid and semisolid wastes from water, wastewater, and industrial-waste treatment facilities are included in the classification.

Physical characteristics

- Density: The knowledge of density is important for the design of all elements of the solid waste management systems like storage, transport and disposal. Example for a known volume of the solid waste its density gives us the idea about the requirement of the truck in tonnage. The density varies significantly from source to the disposal site because of handling, change in moisture content, densification due to vibration of movement, disturbance by animals and birds (scavengers) etc.

Physical characteristics

- Moisture Content :Moisture content of the solid waste is expressed as the weight of moisture per unit weight of wet material. Moisture content varies generally from 20 to 45% depending upon the climatic conditions and level of city (income group) etc.

The increase of moisture content increases the weight and thus the cost of transportation and thus the storage section should take care of it.

Chemical Characteristics

- Calorific value: Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kilo calorie per kilogram. The calorific value is determined in the laboratory by Bomb Calorimeter.
- The chemical characteristics of solid waste are determined for assessing the treatment process. Mainly three chemical characteristics are determined, chemical, bio-chemical and toxicological.
- Chemical quantities of solid waste may include pH, nitrogen, phosphorus, and potassium (N-P-K), total carbon, carbon/nitrogen ratio, calorific value.
- Bio-chemical characteristics include carbohydrate, proteins, natural fiber, and biodegradable factor.
- Toxic characteristics include heavy metals, pesticides, insecticides etc.

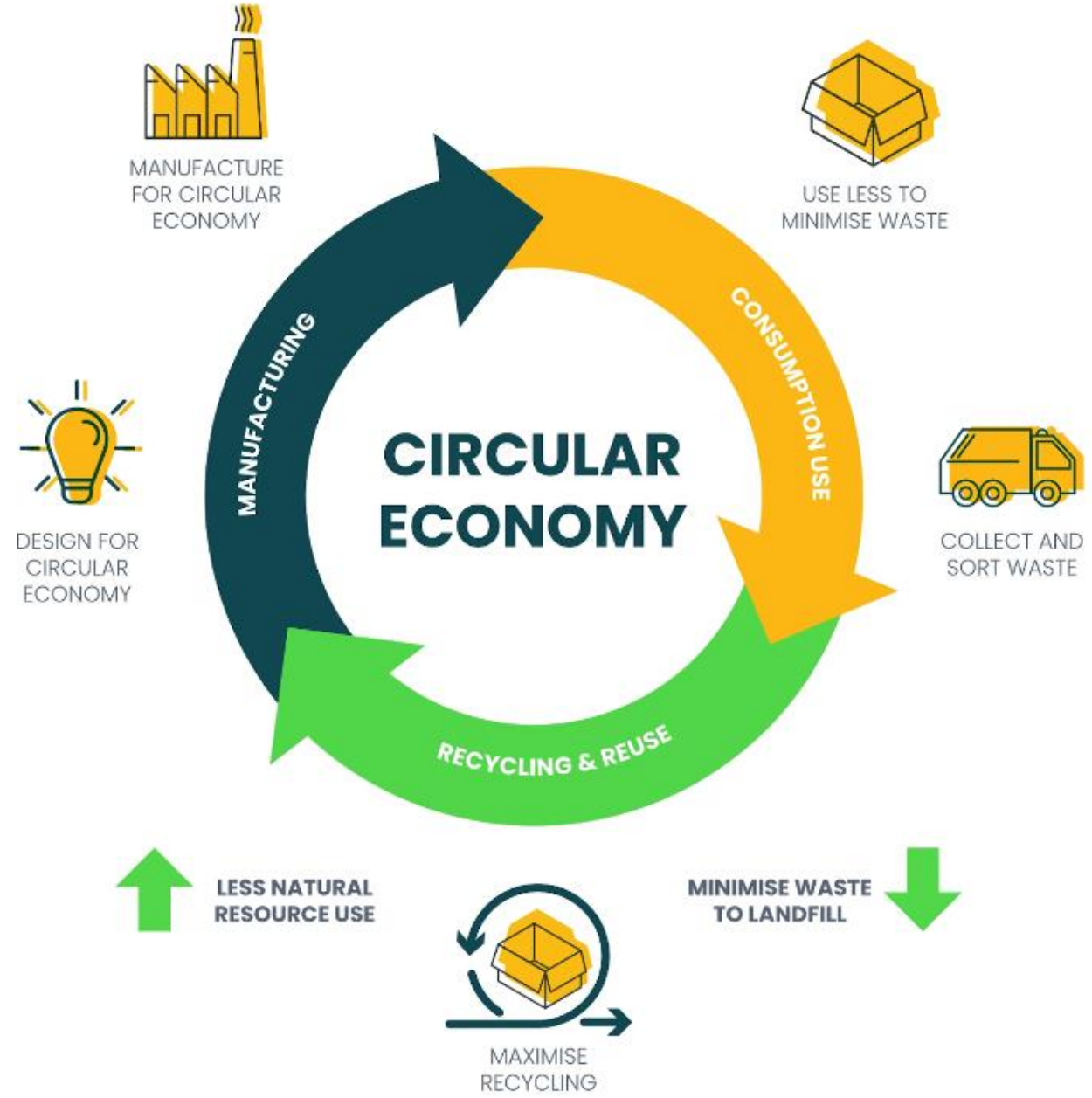
Chemical Characteristics

• Consideration of lipids (fats, oils and grease) should also be done as they are of a very high calorific value (about 38000 Kcal/kg). These days synthetic organic materials like plastic have become a significant component of solid waste accounting for 5-7%. In some countries (India for example) the plastic is non-biodegradable and thus poses a great problem. It chokes the drains and if burnt it produces poisonous gases. The thin plastic sheets and bags are not recycled as the cost of making it dirt & oil free makes the process uneconomical.

• All the above considerations of characteristics are required to design, conceive and assess the most appropriate ways of transportation, the requirements of treatment, extraction of energy and the safe, sanitary way of disposal for the protection of environment

Solid waste Hierarchy

It gives top priority to waste prevention, followed by re-use, recycling, recovery and finally disposal.


MANUFACTURE FOR CIRCULAR ECONOMY
USE LESS TO MINIMISE WASTE
MANUFACTURING
CONSUMPTION USE
CIRCULAR ECONOMY
DESIGN FOR CIRCULAR ECONOMY
COLLECT AND SORT WASTE
RECYCLING & REUSE
LESS NATURAL RESOURCE USE
MINIMISE WASTE TO LANDFILL
MAXIMISE RECYCLING

Characterization of solid waste

Waste Characteristics

Physical Characteristics

Chemical Characteristics

Biological Characteristics

Physical characteristics

- Information and data on the physical composition of solid wastes.
- These are important in the selection and operation of equipment and facilities, and in the analysis and design of disposal facilities.
- Major physical characteristics:

- Density
- Moisture Content
- Waste Particle Size
- Other Physical Characteristics : color ,shape of components, optical property, magnetic properties

Density

- Density of waste, i.e. its mass per unit volume (kg/m^3).
- It is a critical factor in the design of a SWM system i.e. the design of sanitary landfills, storage, types of collection and transport vehicles etc.
- For an efficient operation of landfill, compaction of wastes to optimum density is essential.
- Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density from 100 kg/m^3 to 400 kg/m^3.
- Municipal solid wastes as delivered in compaction vehicles have been found to have an average density of about 300 kg/m^3.
- A waste collection vehicle can drag four times the weight of waste in its compacted state than when it is un-compacted.

Estimation of density of Solid Waste Sample

Example Estimate the density of 1000 kg Solid Waste sample with the following composition

Component	% by mass	Typical density,Kg/m3
Food waste	15	290
Paper	45	85
Cardboard	10	50
Plastics	10	65
Garden wastes	10	105
Wood	5	240
Tin cans	5	90

Component	% by mass	Mass/1000Kg	Typical density,Kg/m3	Total mass
(1)	(2)	(3)	(4)	(5) (3/4)
Food waste	15	150	290	0.52
Paper	45	450	85	5.29
Cardboard	10	100	50	2
Plastics	10	100	65	1.54
Garden wastes	10	100	105	0.95
Wood	5	50	240	0.21
Tin cans	5	50	90	0.56
-	100%	-	-	11.07

Density$= 1000/11.07$

$= 90.33kg/m3$

Problem Estimate the as Discarded density of 500 kg Solid Waste

Component	% by Mass	Typical Density (Kg/m^3)
Food Waste	15	290
Paper	45	85
Cardboard	10	50
Plastic	10	65
Garden Trimmings	10	105
Wood	5	240
Tin Cans	5	90

Moisture content

- Moisture content is defined as the ratio of the weight of water to the total weight of the wet waste.

Moisture content(%) = Wet weight – Dry weight Wet weight ∗ 100

- Moisture increase the weight of solid wastes and thereby, the cost of collection and transport.
- It is a critical determinant in the economic feasibility of waste treatment by incineration because wet waste consumes energy for evaporation of water and in raising the temperature of water vapor.
- A typical range of moisture content is 20 to 40%. However, values greater than 40% are not uncommon.

Typical specific weight and moisture content data for solid waste

Type of waste	Specific weight lb/yd^3		Moisture content % by weight	
	Range	Typical	Range	Typical
Residential uncompacted				
Food wastes (mixed)	220-810	490	50-80	70
Paper	70-220	150	4-10	6
Cardboard	70-135	85	4-8	5
Plastics	70-220	110	1-4	2
Textiles	70-170	110	6-15	10
Residential yard wastes				
Leaves (loose and dry)	50-250	100	20-40	30
Green grass loose and moist	350-500	400	40-80	60
Green grass wet and compacted	1000-1400	1000	50-90	80
Yard waste (shredded)	450-600	500	20-70	50
Yard waste (composted)	450-650	550	40-60	50
Municipal				
In compactor truck	300-760	500	15-40	20
In landfill				
Normally compacted	610-640	760	15-40	25
Well compacted	995-1250	1010	15-40	25

Example Estimate the overall moisture content of a sample of as collected residential MSW with the typical composition given below

Component	weight%	Moisture content, %
Organic Food	9.0	70
Paper	34.0	6.
Cardboard	6.0	5
Plastics	7.0	2
Textiles	2.0	10
Rubber	0-5	2
Leather	0.5	10
Yard wastes	18.5	60
Wood	2.0	20
Misc. organics		
Inorganic Glass	8.0	2
Tin cans	6.0	3
Aluminum	0.5	2
Other metal	3.0	3
Dirt, ash, etc.	3.0	8
Total	100-0	

Based on an as delivered sample weight of 100 lb.

Component	weight%	Moisture content, %	Dry weight,* lb
Organic Food	9.0	70	2.7
Paper	34.0	6.	32.0
Cardboard	6.0	5	5.7
Plastics	7.0	2	6.9
Textiles	2.0	10	1.8
Rubber	0-5	2	0.5
Leather	0.5	10	0.4
Yard wastes	18.5	60	7.4
Wood	2.0	20	1.6
Misc. organics			
Inorganic Glass	8.0	2	7.8
Tin cans	6.0	3	5.8
Aluminum	0.5	2	0.5
Other metal	3.0	3	2.9
Dirt, ash, etc.	3.0	8	2.8
Total	100-0		78.8

Based on an as delivered sample weight of 100 lb.

Moisture content on wet weight $= \frac{100-78.8}{100} \times 100 = 21.2\%$

Particle Size

- The size distribution of solid wastes are important in the recovery of materials especially with mechanical means such as trommel screens and magnetic separators.
- It plays a significant role in the design of mechanical separators and shredders.

Cont.

- The major means of controlling particle size is through shredding.
- Shredding increases homogeneity, increases the surface area/volume ratio and reduces the potential of liquid flow paths through the waste.
- Particle size will also influence waste packing densities.
- Particle size reduction could increase biogas production through the increased surface area available to degradation by bacteria.

Other Properties

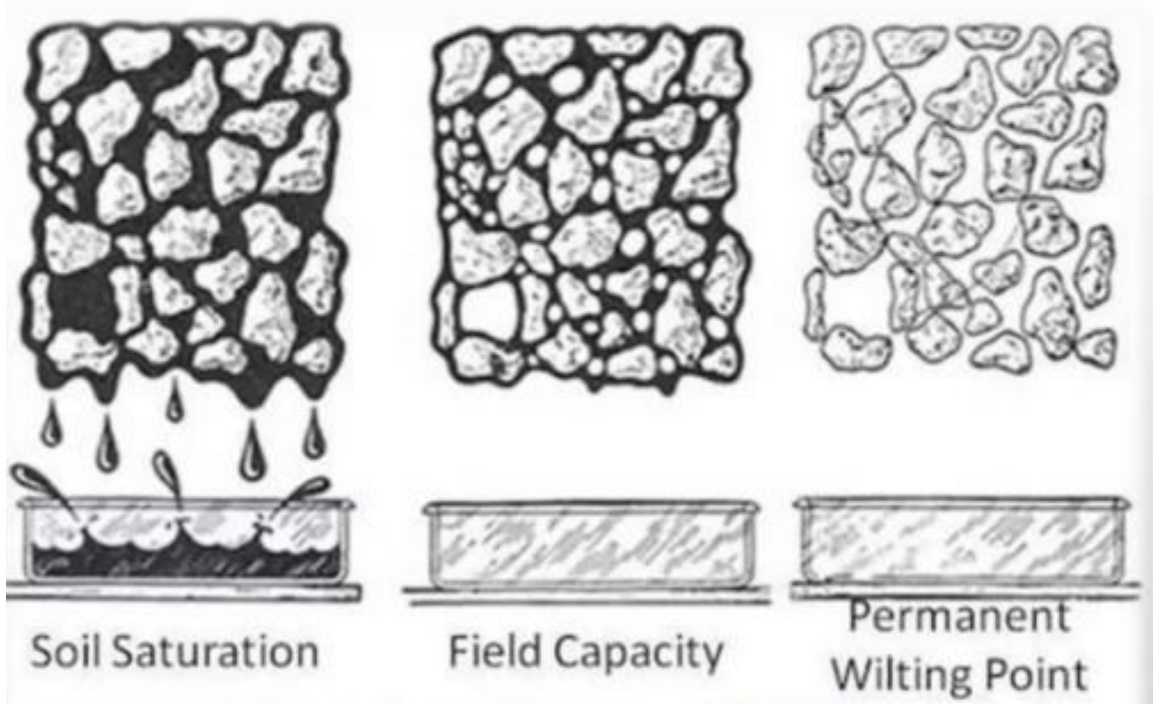
- Optical property can be used to separate opaque materials from transparent substances which majorly contains glass and plastic.

- Shape can be used for segregation as flaky substance will behave differently compared to non-flaky substance.

- Magnetic separators are designed based on the magnetic characteristics of the waste.

Filed Capacity

- The field capacity of waste is the total amount of moisture which can be retained in a waste sample subject to gravitational pull.
- It is used to determine the formation of leachate in landfills.
- It is a critical measure because excess water in field capacity will form leachate.



Chemical Properties

- Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behavior of waste, as it moves through the waste management system.

- To use solid wastes as fuel, or for any other purpose, their chemical characteristics should be known.

Cont.

- Chemical properties includes…
- Lipids
- Carbohydrates
- Proteins
- Natural fibers
- Synthetic organic material (plastics)
- Non-combustibles
- Heating value
- Ultimate analysis
- Proximate analysis

Proximate analysis

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

1. Moisture (loss of moisture when heated to 105°C for 1 h)
2. Volatile combustible matter (additional loss of weight on ignition at 550°C in a covered crucible)
3. Fixed carbon (combustible residue left after volatile matter is removed)
4. Ash (weight of residue after combustion in an open crucible)

Fusing point of ash

- The fusing point of ash is defined as that temperature at which the ash resulting from the burning of waste will form a solid (clinker) by fusion and agglomeration. Typical fusing temperatures for the formation of clinker from solid waste range from 2000 to 2200°F (1100 to 1200°C).

Ultimate analysis of solid waste components

- The ultimate analysis of a waste component typically involves the determination of the percent C(carbon), H(hydrogen), O(oxygen), N(nitrogen), S(sulfur), and ash. Because of the concern over the emission of chlorinated compounds during combustion, the determination of halogens is often included in an ultimate analysis. The results of the ultimate analysis 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 the ultimate analysis of the combustible components in residential MSW Percent by weight (dry basis)

Organic	Carbon	Hydrogen	Oxyge	Nitrog	sulfur	Ash
Food wastes	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	5.0
Plastics	60.0	7.2	22.8	—	—	10.0
Textiles	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
Yard wastes	47.8	6.0	38.0	3.4	0.3	4.5
Wood	49.5	6.0	42.7	0.2	0.1	1.5
Inorganic						
Glass	0.5	0.1	0.4	<0.1	—	98.9
Metals	4.5	0.6	4.3	<0-1	—	90.5
Dirt, ash, etc.	26.3	3.0	2.0	0.5	0.2	68.0

Lipids

- This class of compounds includes fats, oils and grease and the principal sources of lipids are garbage, cooking oils and fats.
- Lipids have high heating values, about 38,000 KJ/Kg, which makes them suitable for energy recovery.
- Since lipids become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition.
- Though they are biodegradable, the rate of biodegradation is relatively slow because lipids have a low solubility in water.

Carbohydrates

- These are found primarily in food and yard wastes, which encompass sugar and polymer of sugars (e.g., Starch, cellulose, etc.) With general formula (CH2O)X.
- Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane.
- Decomposing carbohydrates attract flies and rats and therefore, should not be left exposed for long duration.

Proteins

- These are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH_2).
- They are mainly found in food and garden wastes. The partial decomposition of these compounds can result in the production of amines that have unpleasant odors.

Natural Fibers

- These are found in paper products, food and yard wastes that are resistant to biodegradation.
- They are a highly combustible solid waste, having a high proportion of paper and wood products, they are suitable for incineration.

Heating Value

- An evaluation of the potential of waste as a fuel for incineration, requires a determination of its heating value expressed as kilojoules per kilogram (kj/kg).

- The heating value is determined experimentally using the bomb calorimeter test, in which the waste of specified quantity is heated at constant temperature of 25C.

Example

Determine the Energy Value of a Typical Municipal Solid Waste With an Average Composition Shown in the Table

Component	weight%	Moisture content, %	Dry weight.* lb
Organic Food	9.0	70	2.7
Paper	34.0	6.	32.0
Cardboard	6.0	5	5.7
Plastics	7.0	2	6.9
Textiles	2.0	10	1.8
Rubber	0-5	2	0.5
Leather	0.5	10	0.4
Yard wastes	18.5	60	7.4
Wood	2.0	20	1.6
Misc. organics			
Inorganic Glass	8.0	2	7.8
Tin cans	6.0	3	5.8
Aluminum	0.5	2	0.5
Other metal	3.0	3	2.9
Dirt, ash, etc.	3.0	8	2.8
Total	100-0		78.8

Based on an as delivered sample weight of 100 lb.

Solution

1- Determine the total energy content using the data given in the table. The necessary computations are presented below.

Component	Solid wastes Ib	Energy Btu/Ib	Total energy Btu
Organic			
Food wastes	9.0	2,000	18,000
Paper	34.0	7,200	244,800
Cardboard	6.0	7,000	42,000
Plastics	-7.0	14,000	98,000
Textiles	2.0	7.500	15,000
Rubber	0-5	10.000	5,000
Leather	0.5	7,500	3,750
Yard wastes	18.5	2,800	51,800
Wood	2.0	8,000	16,000
Inorganic			
Glass	8.0	60	480
Tin cans	6.0	300	1,800
Aluminum	0.5	—	-
Other metal	3.0	300	900
Dirt, ashes, etc.	3.0	3.000	9.000
Total	100.0	506.530	

2- Determine the as discarded energy content per Ib of waste

$$Energy\ content = 505{,}530\ Btu/100Ib = (5065\ Btu/Ib) = (11{,}782\ kJ/kg)$$

Synthetic Organic Materials (Plastic)

- They are highly resistant to biodegradation and therefore, are objectionable and of special concern in SWM.
- Plastics have a high heating value, about 32,000 KJ/KG, which makes them very suitable for incineration.
- But, polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas. This increases corrosion in the combustion system and is responsible for acid rain..

Table (1) Typical Data on Ultimate Analysis of the Combustible Components in Municipal Solid Wastes

Component	Percent by weight (dry basis)					
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
Food wastes	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	5.0
Plastic	60.0	7.2	22.8	-	-	10.0
Textiles	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	1.5
Dirt, ashes, brick etc.	26.3	3.0	2.0	0.5	0.2	68.0

Table (2)Typical physical composition of a solid waste

Component	Percent by mass
Food waste	15
Paper	40
Cardboard	4
Plastics	3
Textile	2
Rubber	0.5
Leather	0.5
Garden trimming	12
Wood	2
Glass	8
Tin cans	6
Non ferrous materials	1
Ferrous materials	2
Dirt, ashes, Bricks	4
Total	100

Table (3)Typical chemical composition of a solid waste

Component	Value, percent Typical
Moisture	20
Volatile matter	53
Fixed carbon	7
Glass, metal, ash	20

Biodegradability of organic waste components

- Volatile solids (VS) content, determined by ignition at 550 ^{o}C, is often used as a measure of the biodegradability of the organic components.

- The use of VS in describing the biodegradability of the organic components is misleading, as some of the organic constituents are highly volatile but low in biodegradability(e.g., Newsprint and certain plant trimmings).

- Alternatively, the lignin content of a waste can be used to estimate the biodegradable fraction, using the following relationship: BF = 0.83 – 0.028 LC

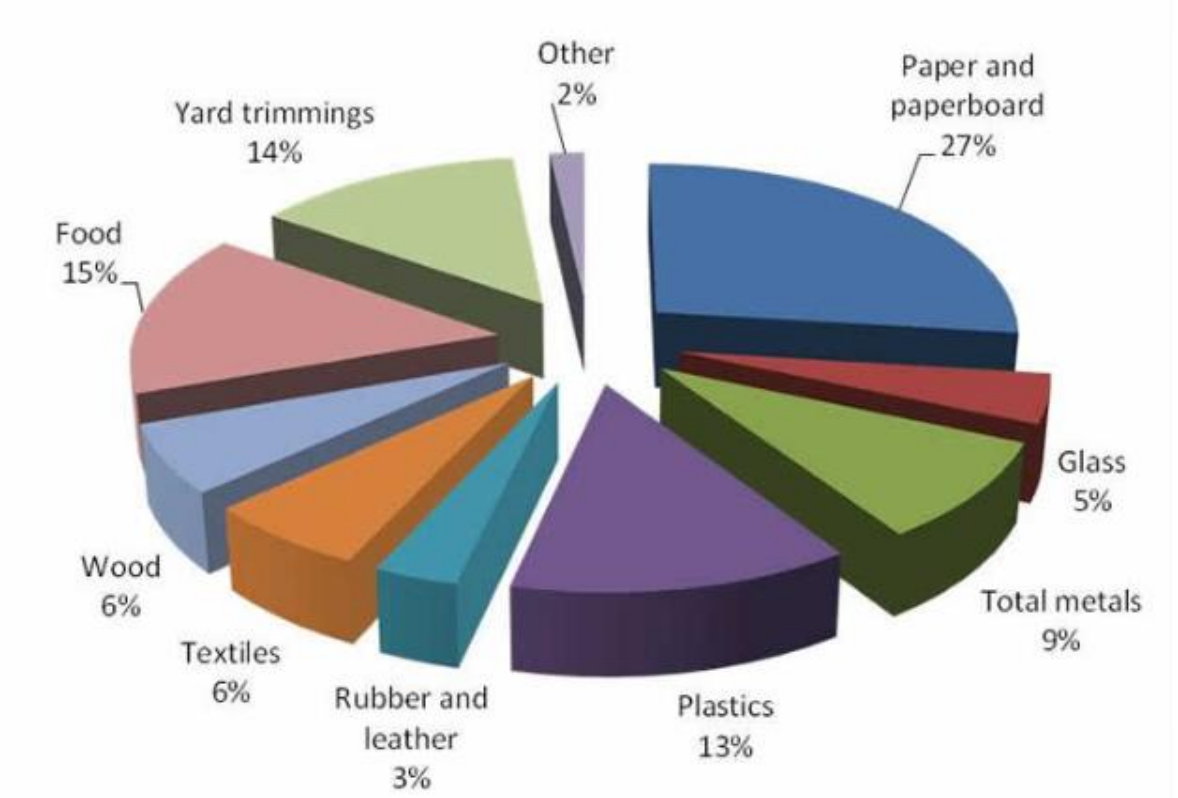
- Wastes with high lignin contents are significantly less biodegradable.

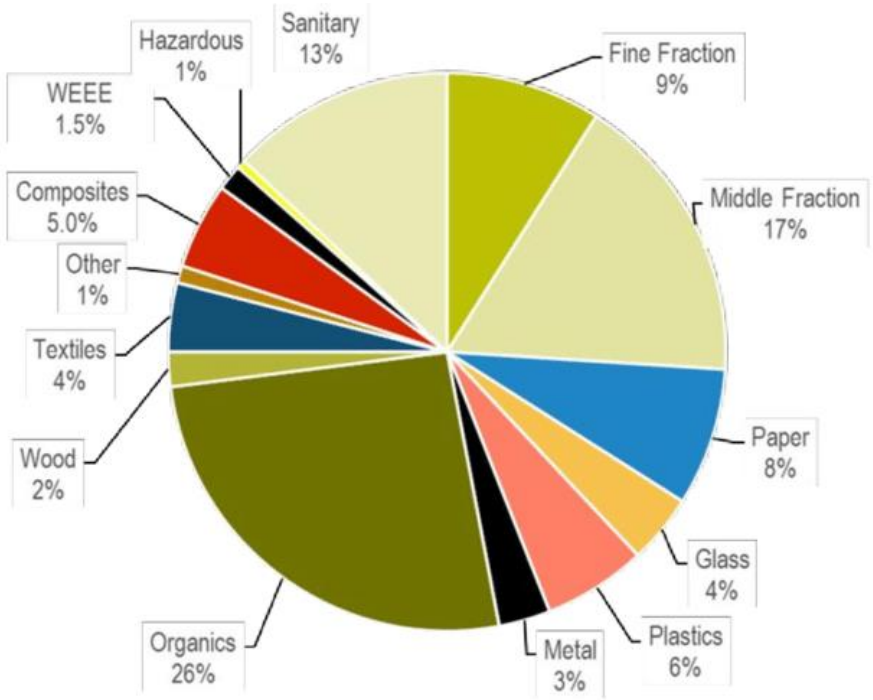
Cont.

- Organic components (excluding plastic, rubber, and leather) can be classified as follows:

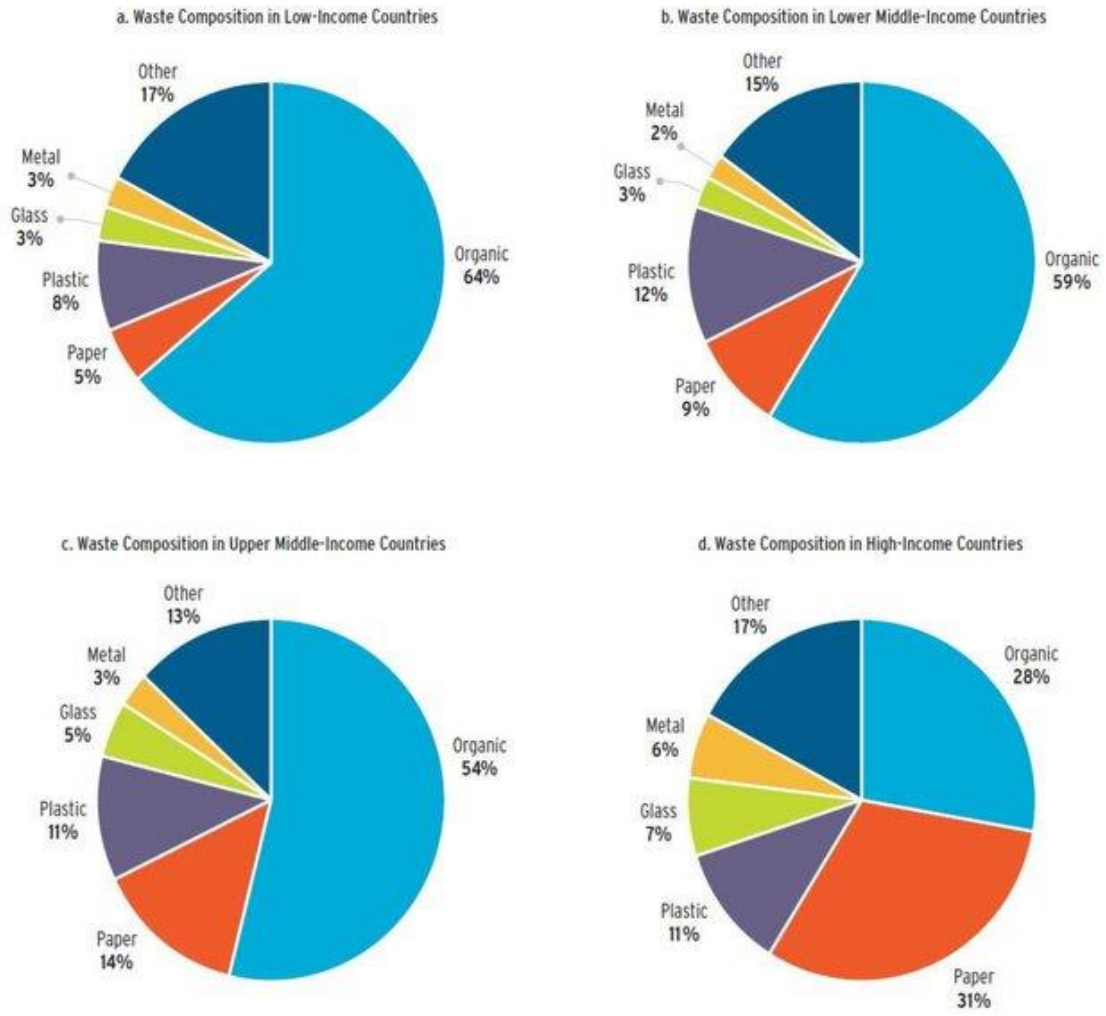
1. water soluble constituents, such as sugars, starches, amino acids, and various organic acids
2. Hemicelluloses, a condensation product of five and six carbon sugars
3. cellulose, a condensation product of six carbon sugars glucose
4. Fats, oils, and waxes, which are esters of alcohols and long-chain fatty acids
5. lignin, a polymeric material containing aromatic rings with methyoxyl groups (- OCH3)’
6. Lignocellulose = lignin + cellulose
7. Proteins, which are composed of chains of amino acids

The composition of municipal waste varies greatly from country to country and changes significantly with time.





Municipal Waste Composition

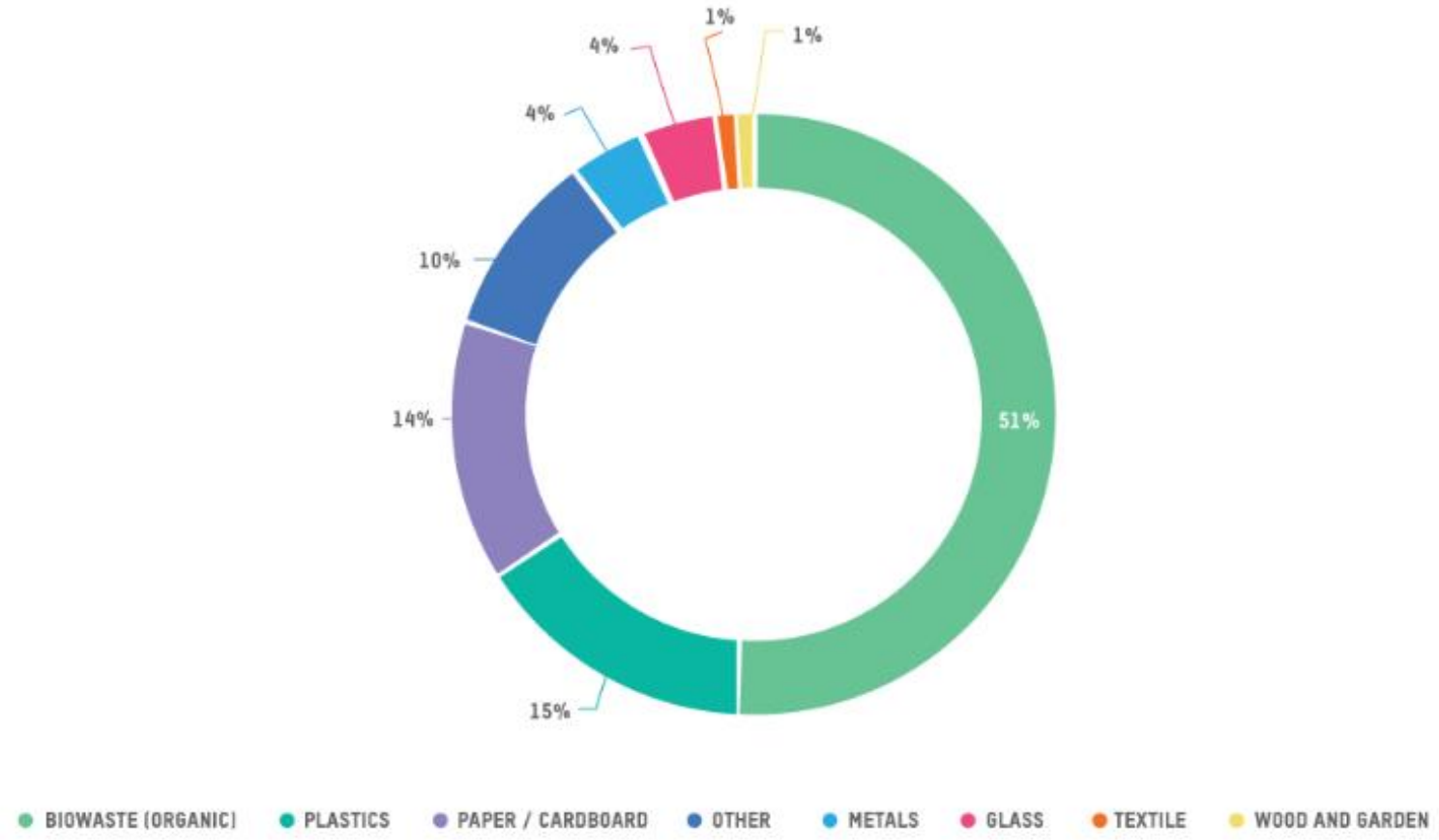


Waste composition per income level. Source: World Bank, 2012

Typical Distribution of Components in residential MSW for Low-, middle- & upper-income countries excluding recycled materials

Sr. No	Component	LIC	MIC	UIC
1	Organic			
	Food waste	40-85	20-65	6-30
	Paper	1-10	8-30	20-45
	Cardboard	1-10	8-30	5-15
	Plastics	1-5	2-6	2-8
	Textiles	1-5	2-10	2-6
	Rubber	1-5	1-4	0-2
	Leather	1-5	1-4	0-2
	Yard Wastes	1-5	1-10	10-20
	Wood	1-5	1-10	1-4
	Mis.organics	-	-	-
2	Inorganic			
	Glass	1-10	1-10	4-12
	Tin cans			2-8
	Aluminium	1-5	1-5	0-1
	Other metal			1-4
	Dirt,ash etc	1-40	1-30	0-10

MSW composition in Jordan



Solid waste analysis- Why?

- It provides a basic data on which management system is planned, designed and operated
- Changes/Trends in composition & quality of wastes are known – Future Planning.
- Selection of equipment & appropriate technology
- Indicates the amount and type of material suitable for processing, recovery and recycling.
- Assist designers & manufacturers in the production of vehicle and equipment suitable for future needs

Solid waste composition

- Composition- Individual components that makes up the solid.
- Usually based on percent by weight.
- Important in evaluating equipment needs, systems, management programs and plans
- The residential and commercial waste- 50-75%
- The actual percentage distribution will depend on:

1. Extent of construction and demolition activities

2. Types of water & wastewater treatments used 3. Extent of municipal services provided.

Determination of solid waste composition

- Because of the heterogeneous nature of solid wastes, determination of the composition is not an easy task.
- Strict statistical procedures are difficult, if not impossible, to implement. For this reason, a more generalized field procedure, based on common sense and random-sampling techniques, has been developed for determining composition.
- 1. Unload a truck of wastes in a controlled area away from other operations.
- 2. Quarter the waste load
- 3. Select one of the quarters and quarter that quarter
- 4. Select one of the quartered quarters and separate all of the individual components of the waste into preselected component such as those listed in above table.
- Place the separated components in a container and weight
- 6. Determine the weight percentages of each component by mass

Methods Used to Estimate SW Quantities of solid waste

- Estimates A residential area consisting of 1500 houses has an average of four residents per house. For estimating the quantity of solid waste generated, the following observations were made at disposal site for a period of one week.

Type of Vehicle	Number of trips	Volume (m^3)	Specific Weight (kg/m^3)	Total Weight (Kg)
I	10	15	300	45,000
II	8	2	150	2,400
III	25	0.50	100	1,250
			Total (Kg/week)	48,650

Cont.

The unit generation rate,

$$= \frac{\text{Total quantity of wastes}}{\text{No. of houses X Residents per House X Days}}$$

$$= \frac{48{,}650}{1500 \text{ X } 4 \text{ X } 7}$$

= 1.1583 Kg/capita/day

Methods Used to Estimate Waste Quantities

- Load-count analysis

In this method, the number of individual loads and the corresponding waste characteristics (types of waste, estimated volume) are noted over a specified time period.

- Weight-volume analysis

The use of detailed weight-volume data obtained by weighing and measuring each load will certainly provide better information on the specific weight of the various forms of solid wastes at a given location.

- Materials mass balance analysis:

The only way to determine the generation and movement of solid wastes with any degree of reliability is to perform a detailed materials balance analysis for each generation source, such as an individual home or a commercial or industrial activity. In some cases, the materials balance method of analysis will be required to obtain the data needed to verify compliance with statemandated recycling programs.

Example

From the following date, estimate the unit waste disposal rate per week for a residential area consisting of 1200 homes. The average occupancy is 3.5 persons per home. The observation location is a local transfer station that receives all of the wastes collected for disposal. The observation period was one week.

- Number of compactor truck loads = 9
- Average size of compactor truck = 20 yd^3
- Number of flatbed loads = 7
- Average flatbed volume = 2 yd^3
- Number of loads from individual residents' private cars and trucks = 20
- Estimated average volume per domestic vehicle = 8 ft^3

Step 1: Setup a computation table to estimate the total weight of waste disposed during this week.

Waste Source	Number of Loads	Average Volume, yd^3	Specific Weight, $lb/yd^{3\dagger}$	Total Weight, lb
Compactor Truck	9	20	500	90,000
Flatbed Truck	7	2	225	3,150
Private Vehicle	20	0.3	150	900
			Total, lb/week =	**94,050**

† based on estimates of average vehicle volume and weight

Step 2: Determine the unit waste disposal rate

$$\text{Unit or Per Capita Disposal Rate} = \frac{94{,}050 \text{ lb/wk}}{(200 \text{ homes})(3.5 \text{ persons/home})(\quad \text{days/wk})}$$

$$\boxed{\text{Unit or Per Capita Disposal Rate} = 3.2 \frac{\text{lb}}{\text{capita} \cdot \text{day}}}$$

Solid waste reduction, reuse and recycling

I. Reduce: Buy only what you need because a better way to reduce waste is by not creating it.

II. Reuse: If you have to acquire goods, try getting used ones or obtaining substitutes.

III. Recycle: When discarding your waste, find ways to recycle it instead of letting it go to landfill.

Source reduction

- The USEPA defines source reduction as the design, manufacture, purchase or use of materials to reduce their quantity or toxicity before they reach the waste stream.

- The National Recycling Coalition (NRC) define source reduction as “any action that avoids the creation of waste by reducing waste at the source, including redesigning of products or packaging so that less material is used; making voluntary or imposed behavioral changes in the use of materials; or increasing durability or re-usability of materials.”

Cont.

- Whenever a consumer or establishment takes part in an activity that reduces the amount and/or toxicity of waste which otherwise would have been generated, they are participating in source reduction.

- The USEPA considers source reduction the highest priority method for addressing solid waste issues.

Cont.

- Several terms are often used to mean source reduction. These include:

- Waste reduction
- Waste prevention
- Waste minimization
- Pollution prevention
- Precycling
- Source Reduction

Source reduction

- In recent years source reduction, also known as waste prevention, has been gaining more attention around the world.
- The goal of a source reduction program is to decrease the amount and toxicity of material that must be managed by preventing its generation in the first place.
- Thus, source reduction is distinguished from other forms of solid waste management, such as recycling and yard waste collection, because it eliminates and/or facilitates the need to manage waste.

Cont.

- The primary routes of source reduction are:

- Decreasing or eliminating the amount or toxicity of material used in the manufacture and packaging of products.
- Redesigning products for increased life span, reusability, and repairability.
- Changing purchasing decisions to favor those products that have minimized residual toxicity and waste associated with them.
- Modifying patterns of consumption and material use in a way that reduces the amount and toxicity of waste generated .

Ways to reduce the amount of waste you create

- Only buy what you need, and use what you buy
- Buy loose fruit and vegetables and avoid items that are heavily packaged
- Sign up to paperless billing or banking
- Buy products with refillable packaging
- If you are able, try home composting your food waste
- Use refillable water bottles and coffee cups
- Buy secondhand clothing and consider hiring clothing
- Have a go at replacing buttons and mending faulty zips or fallen hems rather than buying new clothing
- Buy items that will have a longer life than disposable items, such as rechargeable batteries and use real crockery and cutlery for your parties instead of disposable ones

Table 1. How Long Does It Take to Decompose (EPA, 2013a)

Paper towel	2–4 weeks	Plastic bag	10–20 years
Newspaper	6 weeks	Plastic film container	20–30 years
Apple core	2 months	Tin can	50 years
Waxed milk carton	3 months	Rubber boot sole	50–80 years
Plywood	1–3 years	Styrofoam plastic cup	50 years
Wool sock	1–5 years	Aluminum can	80–200 years
Cigarette butt	1–5 years	Plastic beverage bottle	450 years
		Monofilament fishing line	600 years
		Glass bottle	1 million years

Effects of source reduction

- There are both economic and environmental advantages to source reduction, primarily the reduction in pollution and cost of solid waste management and disposal.

- In addition, source reduction activities can result in changes to the composition of solid waste.

Economics

1. In a study of solid waste management in New York City it was found that $300 million was spent for waste collection per year, $50 million for disposal, and slightly less for recycling, while only $1 to 2 million was invested in waste prevention programs.

2. However, a 9 percent reduction in the solid waste stream would save an estimated $90 million in collection and disposal costs annually.

Cont.

3. Choosing to refurbish, reuse, and repair an item can represent a substantial savings over disposal.

4. Choosing products for reusability also has long-term cost benefits; for example, when a restaurant or cafeteria switches to reusable utensils and dishware, there is no longer a need to reorder disposable products continually.

5. Regular maintenance and repair increases the lifetime that an item is in service and reduces the need to dispose of and replace that item.

Environmental

1. Many environmental benefits are associated with waste and toxicity reduction, primarily the reduced need for natural resources, less energy and pollution from avoided processing/reprocessing of materials, and a reduction in the amount of material sent to landfills and waste combustion facilities.

2. Greenhouse gases, such as NOx, CO_2, and CH_4, are released when energy is expended to mine raw materials, transport and process those materials, manufacture products, transport those products, and finally collect and dispose of the residual waste after the product's useful life has ended.

Cont.

3. Activities such as deposit and refund systems for beverage containers have been shown to reduce litter and increase the recovery rate for these materials to more than 80 percent in most places.

4. Because of the complexities associated with predicting a product or materials impact on the environment, a measurement known as life-cycle assessment (LCA) can be used (U.S. EPA, 1993).

Cont.

5. The process of LCA is used to assess a product or material's overall environmental footprint on the earth by considering the effects of the following processes:

- Choice of and extraction of raw materials
- Transport and processing of those materials
- Manufacture of products from those materials
- Use of those products
- Fate at end of life

Environmental benefits

- Other environmental benefits include:	Reduced pollution from trucks and disposal.
	Less resource depletion from excess packaging not generated.
	Economic development of cities reuse and repair industries
	Reduced need for landfill capacity.

Waste Reuse

- Reuse is the second preferred waste management option after waste reduction. Reuse is the practice of using a material over and over again in its current form. The essence of reuse is that it preserves some or all of the energy and materials that went into making an item. Society has long embraced the practice of reuse by finding alternate uses for an item rather than disposing or recycling it. Some common examples include donating used household items like books, magazines, clothing, kitchen wares, etc. It may also include using empty food containers to store leftovers or reusing plastic grocery sacks to line trash containers or pick up after pets.

Cont.

- Reuse is to use again or more than once reuse materials and items so that they have longer life spans and don’t get thrown away after the first use. Many items found around the home can be used for different purposes. So before you throw those items away, think about how they can be reused.

How to reuse

- Carrier bags and twist ties

Carrier bags can be reused in the shops or as bin bags around the house. Paper bags make useful wrapping paper and twist ties can be used to secure loose items together, such as computer wires.

Cont.

- Newspaper, cardboard and bubble wrap

Make useful packing material when moving house or to store items.

- Old clothes

Can be made into other textile items such as cushion covers.

- Scrap paper

Can be used to make notes and sketches. Don't forget to recycle it when you no longer need it.

Cont.

- Old tires

Can be given to your local petrol station where they will be recycled. Or you could make a tire-swing by tying a strong rope around a tire and attaching it to a tree.

- Used wood

Can be used in woodcrafts for making objects such as a spice rack or a bird table. Alternatively, it could be used as firewood.

What is recycling?

- Recycling turns materials that would otherwise become waste into valuable resources and generates a host of environmental, financial, and social benefits. After collection, materials (e.g., glass, metal, plastics, and paper) are separated and sent to facilities that can process them into new products and materials.

- Recycling is the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products. Recycling can benefit your community, the economy, and the environment

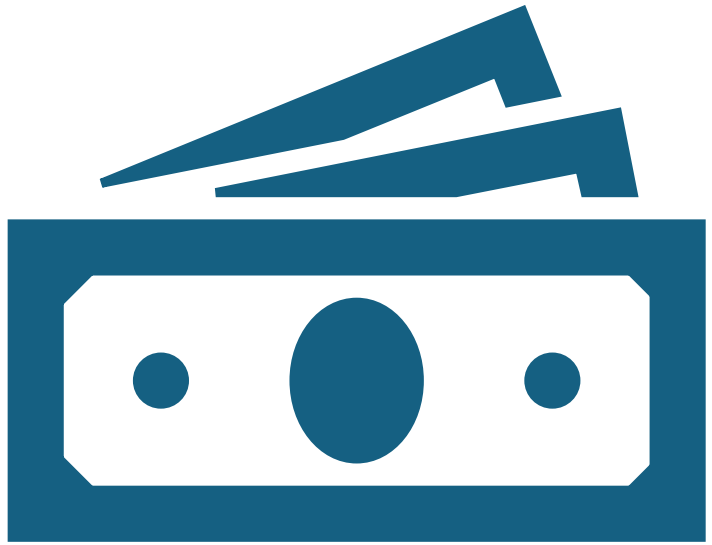
Recycling Benefits

- Following are some benefits for recycling solid waste:

- Economic
- Environmental
- Employee Morale
- Corporate Image
- Compliance

Economic

- Reduced waste disposal fees.
- Revenues from recycling commodities.



Recycling environmental benefits

- The environmental benefits include:

- Reduced energy consumption.
- Reduced pollution.
- Conservation of natural resources.
- Extension of valuable landfill capacity.
- Stimulates the development of greener technologies.
- Prevents emissions of many greenhouse gases and water pollutant.

Employee morale

- Employees morale improves when they see the company taking steps to reduce waste through recycling
- This heightened morale could increase employee enthusiasm, productivity and more waste prevention measures
- Some companies use recycling revenues for employee recreation (I.e. picnics, holiday parties etc.)

Corporate Image

- When customers and the surrounding neighborhoods see that the company is environmentally conscious, it creates a favorable image of the company.
- An enhanced corporate image might attract customers
- Surveys show that more and more consumers consider a firm's environmental record when making purchasing decisions

Compliance

- Reducing solid waste through recycling can also mean compliance with local or state solid waste regulations.
- Some communities also restrict the amount or types of waste accepted at solid waste management facilities
- By implementing an aggressive recycling program, your business can help ensure compliance with these requirements

Deciding what to recycle

Certain materials are either banned or restricted from disposal facilities, such as:

- Tires.
- Green Waste (yard trimmings)
- Appliances
- Used Oil
- Scrap Metal
- Auto Batteries
- Contact your landfill to find a listing of restricted materials and how these materials can be disposed

Deciding What to Recycle

- In some municipalities, businesses are required to recycle certain commodities such as:
- Cafes and restaurants might be required to recycle glass
- Office buildings might be required to recycle office paper, newspaper and cardboard
- Hotels, restaurants, food courts, grocery stores, hospitals, and food manufacturers who generate large volumes of food waste might be required to recycle food waste
- You should contact your local solid waste regulator to determine what materials you must recycle

Cont.

- The following liquids may be recycled and reused on your premises in most areas with special equipment:

- Solvents
- Antifreeze
- Frying oil

Recyclable waste… Where do they go?

- Many towns and municipalities offer recycling services that pick-up materials like paper, plastic and cardboard from the curb.

<u>Where do these materials go after pickup?</u>

Material Recovery Facility (MRF)

• Once recyclables are picked up from the curb on trash day, they are generally transported to a material recovery facility.

Recyclable Materials

Recyclable Materials include plastic containers and bottles and fiber materials such as phonebooks and newspapers.

- Plastic bags are more difficult to recycle and are not accepted at most MRFs because they create problems during processing.
- The first step in recycling is proper separation and sorting of materials curbside, so the individual who recycles has an important responsibility

At the MRF

- At an MRF, trucks drop off load of recyclables in the receiving area.
- The trash and non-recyclable items are removed from the recycling process and the clean recyclables are sorted.
- Bags of materials are broken open, and a conveyor transports the recyclables to a sorting line.
- There, MRF staff manually sort out the different types of materials into various holding bins.
- The recyclables are then transported via an incline conveyor into a baler, which crushes the materials together and binds them with wire bands.
- The bales are then stored in stacks for shipment.

The Don’ts

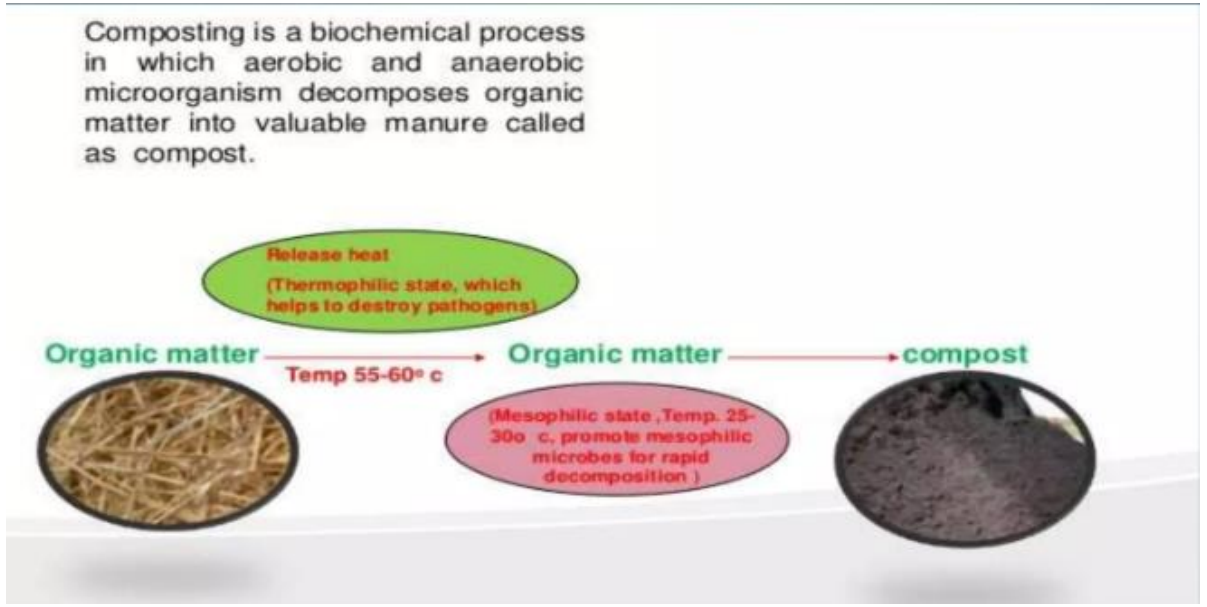
- Materials that are not recyclable must be separated from the waste stream because they can create problems in the recycling process.
- Some examples of non-recyclable materials include aluminum foil, Styrofoam, food wraps, ceramic and clay pots, porcelain, light bulbs and fabrics.

Chapter Four

Composting and incineration of municipal solid wastes

Composting

- It is an aerobic, biological process which uses naturally occurring microorganisms to convert biodegradable organic matter into a humus-like product(COMPOST).
- Composting is the biological reclamation of organic materials by natural decomposition process.
- Examples: decay of fallen leaves in forests, decay of wood in a stand and animal carcasses decaying in a preserve.



Raw Organic material → Microorganisms + Oxygen → Compost

Cont.

- **Composting** speeding up the natural decay process.
- A compost pile or bin allows you to control
  - Air (oxygen)
  - Water
  - Food
  - Temperature

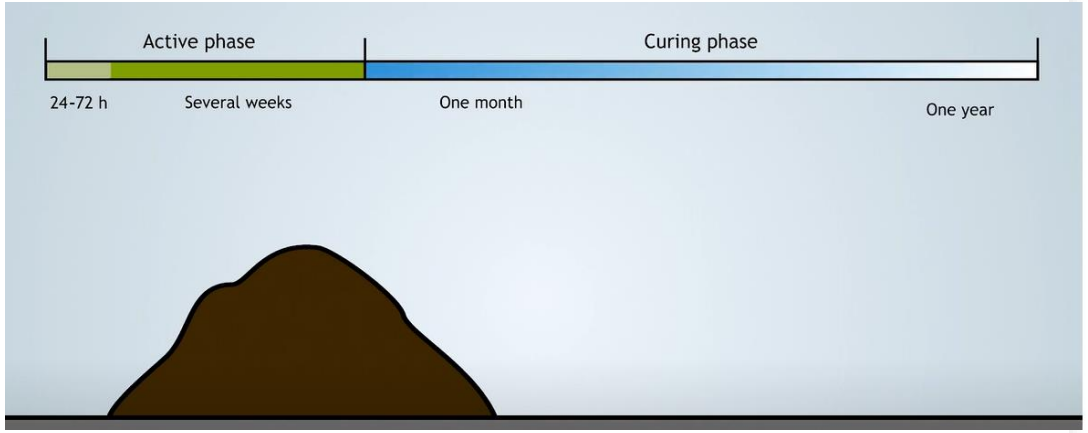
By managing these factors, you can speed up the otherwise slow natural decay process

Biological Process of Composting

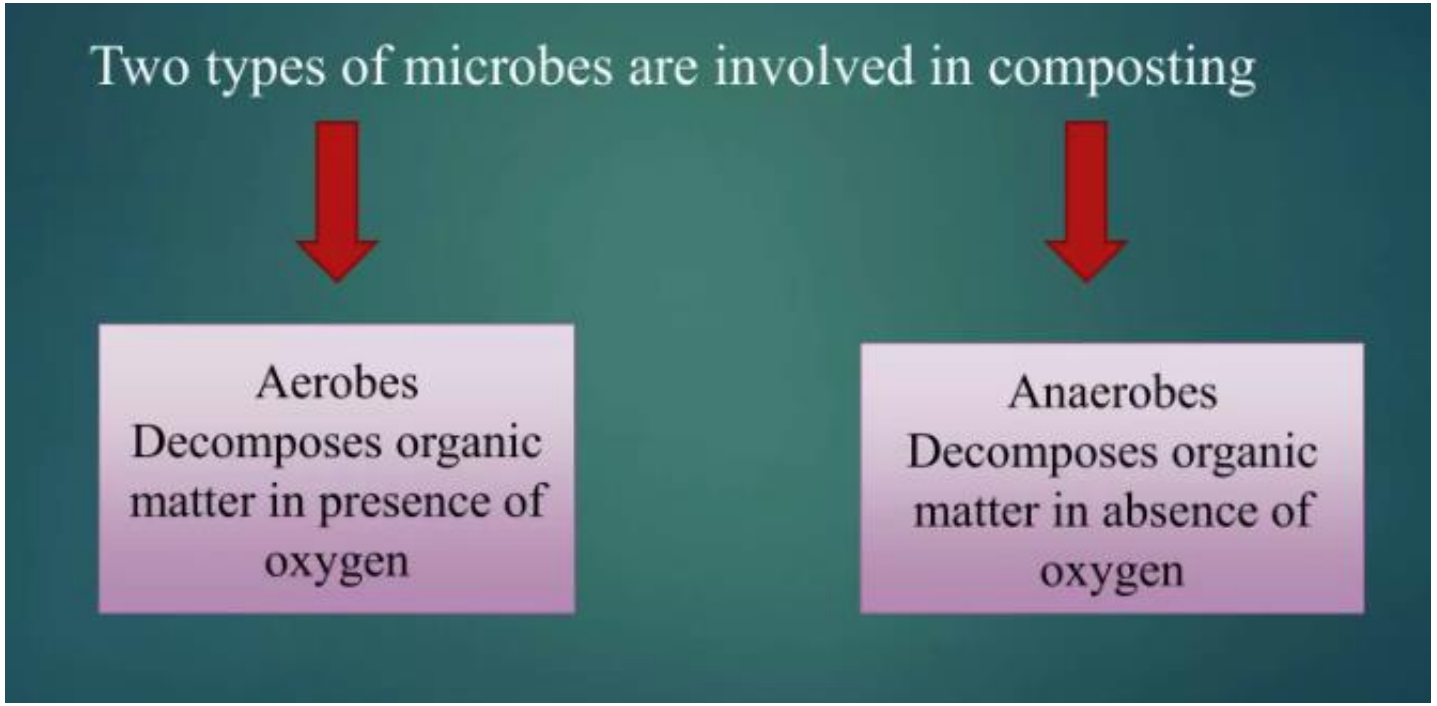
- Microorganisms + OM -------> H_2O + CO_2 + Heat + Humus

There are three phases under optimal conditions

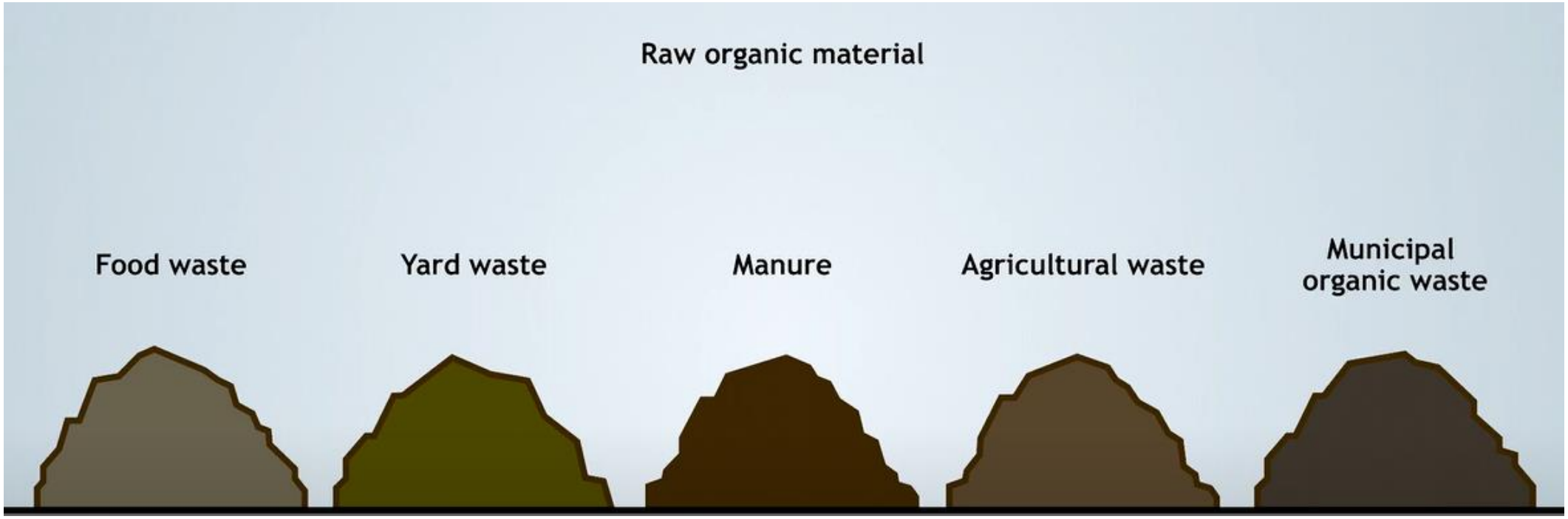
1) Mesophilic - lasts couple of days (~40^oC)
2) Thermophilic - can last a few days (55^oC–65^oC)
3) Several-month cooling and maturation phase

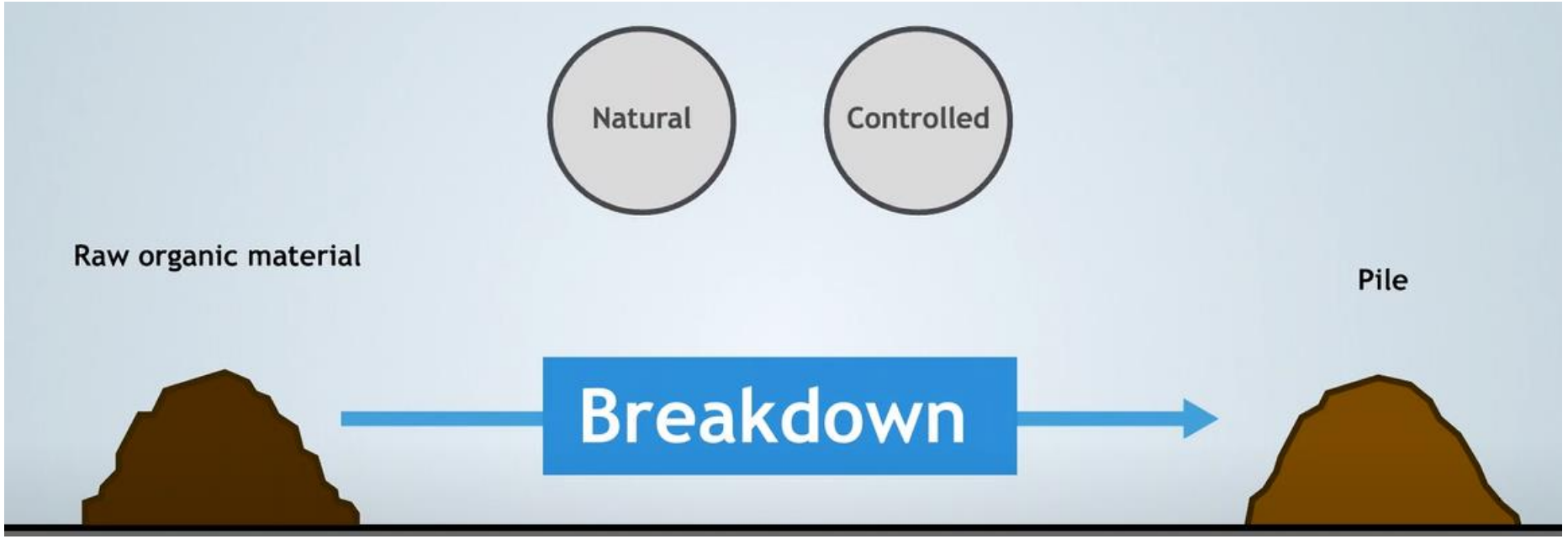


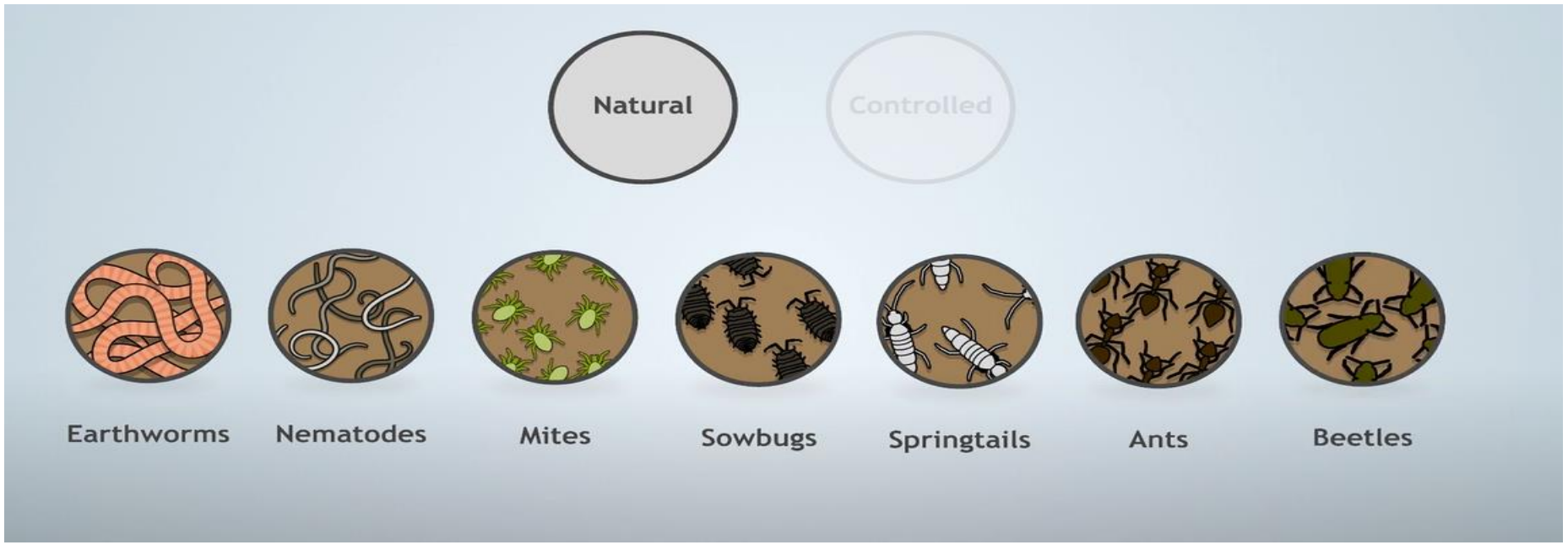
Microorganisms involved in composting



Raw organic material

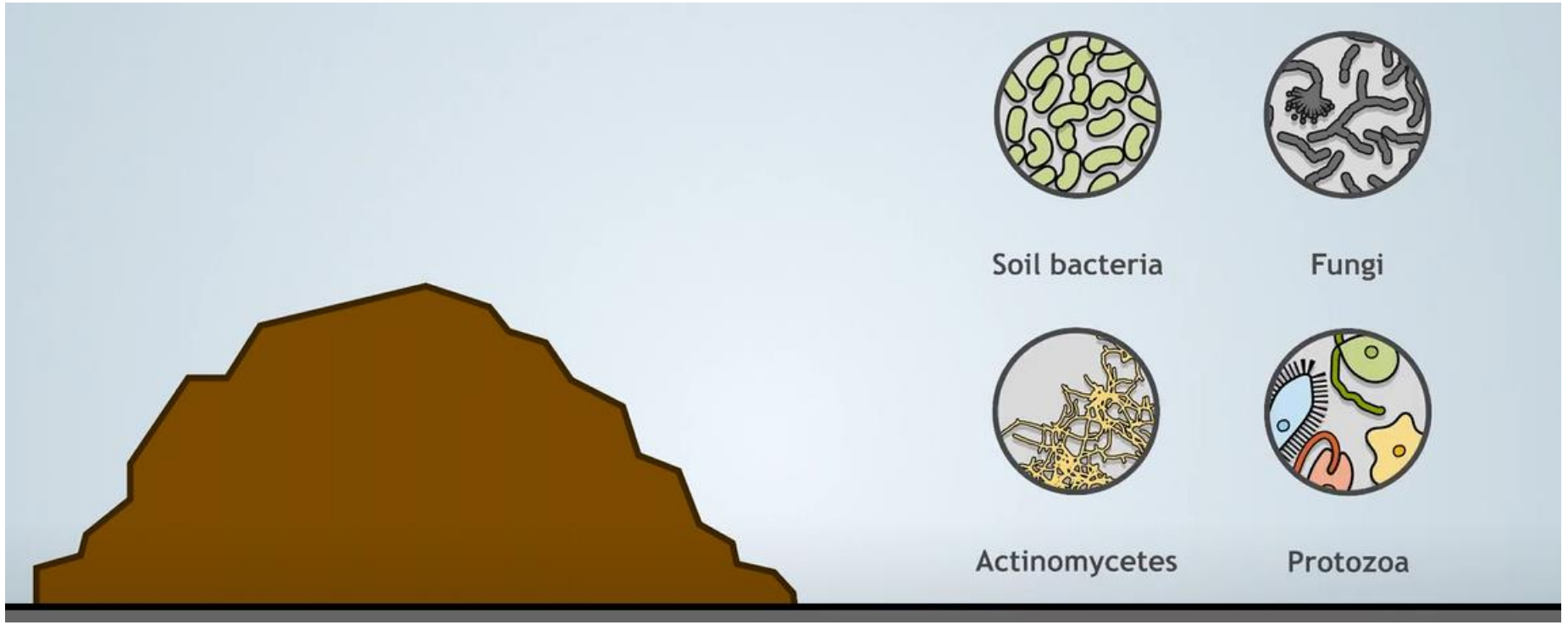



Natural
Controlled
Raw organic material
Pile
Breakdown


Natural
Controlled
Earthworms
Nematodes
Mites
Sowbugs
Springtails
Ants
Beetles

Principles of Composting

- Composting is the controlled decomposition of organic matter.
- Rather than allowing nature to take its slow course, a composter provides an optimal environment in which decomposers can thrive.
- To encourage the most active microbes, a compost pile needs the correct mix of the following ingredients: • Carbon, Nitrogen (from composting materials) • Oxygen (from the air) • Water



Factors affecting composting

- Feedstock and Nutrient Balance
- Particle Size
- Moisture Content
- Oxygen Flow
- Temperature

Feedstock and Nutrient balance

- Composting, or controlled decomposition, requires a proper balance of “green” organic materials and “brown” organic materials.

- “Green” organic material includes grass clippings, food scraps, and manure, which contain large amounts of nitrogen.

- “Brown” organic materials includes dry leaves, wood chips, and branches, which contain large amounts of carbon but little nitrogen.

- Obtaining the right nutrient mix requires experimentation and patience. It is part of the art and science of composting.

Cont.

- Composting will be most rapid if the decomposers are fed a mix of carbon rich and nitrogen rich materials.

- Carbon rich organic wastes are known as “browns”

- Nitrogen rich organic wastes are known as “greens

Cont.

- Browns High carbon materials such as Leaves (30-80:1) Straw (40-100:1) Paper (150-200:1) Sawdust (100-500:1) Animal bedding mixed with manure (30-80:1)

- Greens High nitrogen materials such as Vegetable scraps (12-20:1) Coffee grounds (20:1) Grass clippings (12-25:1) Manure • Cow (20:1) • Horse (25:1) • Poultry (10:1), with litter (13-18:1) • Hog (5-7:1)


Browns
• Decay very slowly
• Coarse browns can keep pile aerated
• Tend to accumulate in the fall
• Tie up nitrogen in soil if not fully composted
• May need to stockpile until can mix with greens
Greens
• Decay rapidly
• Poor aeration – may have foul odors if composted alone
• Tend to accumulate in spring and summer
• Supply nitrogen for composting
• Best composting if mixed with browns

Material	C:N Ratio
Vegetable wastes	12-20:1
Alfalfa hay	13:1
Cow manure	20:1
Apple pomace	21:1
Leaves	40-80:1
Corn stalks	60:1
Oat straw	74:1
Wheat straw	80:1

Particle Size

- Grinding, chipping, and shredding materials increases the surface area on which microorganisms can feed.

- Smaller particles also produce a more homogeneous compost mixture and improve pile insulation to help maintain optimum temperatures.

- If the particles are too small, however, they might prevent air from flowing freely through the pile. Pile may need to be turned more often.

Moisture Content

- Microorganisms living in a compost pile need enough moisture to survive.

- Water is the key element that helps transports substances within the compost pile and makes the nutrients in organic material accessible to the microbes.

- Organic material contains some moisture in varying amounts, but moisture also might come in the form of rainfall or intentional watering.

Oxygen Flow

- Turning the pile, placing the pile on a series of pipes, or including bulking agents such as wood chips and shredded newspaper all help aerate the pile.

- Aerating the pile allows decomposition to occur at a faster rate than anaerobic conditions.

- Care must be taken, however, not to provide too much oxygen, which can dry out the pile and impede the composting process.

Temperature

- Microorganisms require a certain temperature range for optimal activity.
- Certain temperatures promote rapid composting and destroy pathogens and weed seeds.
- Microbial activity can raise the temperature of the pile’s core to at least 140° F.
- If the temperature does not increase, anaerobic conditions (i.e., rotting) occur.
- Controlling the previous four factors can bring about the proper temperature.

Criteria for composting

- C : N ratio - 25-35 : 1
- Particle size - 50 mm
- Moisture content - 50-60%
- Air flow - 0.6-1.8 m3/day/kg
- Temperature - 55°C - 60°C, for 1st 3 days
- Agitation - Periodic turning at 15 days interval
- Heap size - Any length, 1.5 m high, 2.5m wide
- Activators - Microbial organisms.

Taking care of your compost pile

- The most rapid composting is achieved by

- Adding mixed browns + greens.
- Regularly turning (mixing) the compost pile.
- Controlling water content.
- When pile no longer heats after mixing, allow it to cure (stand without mixing) for at least 4 weeks before using the compost.

When is compost finished?

- Compost is mature when:

- The color is dark brown.
- It is crumbly, loose, and humus-like.
- It has an earthy smell.
- It contains no readily recognizable feedstock.
- The pile has shrunk to about 1/3 of its original volume.

Aerobic composting takes time.

Generally, aeration and humidity are usually the two key factors influencing the amount of time required to create finished compost.

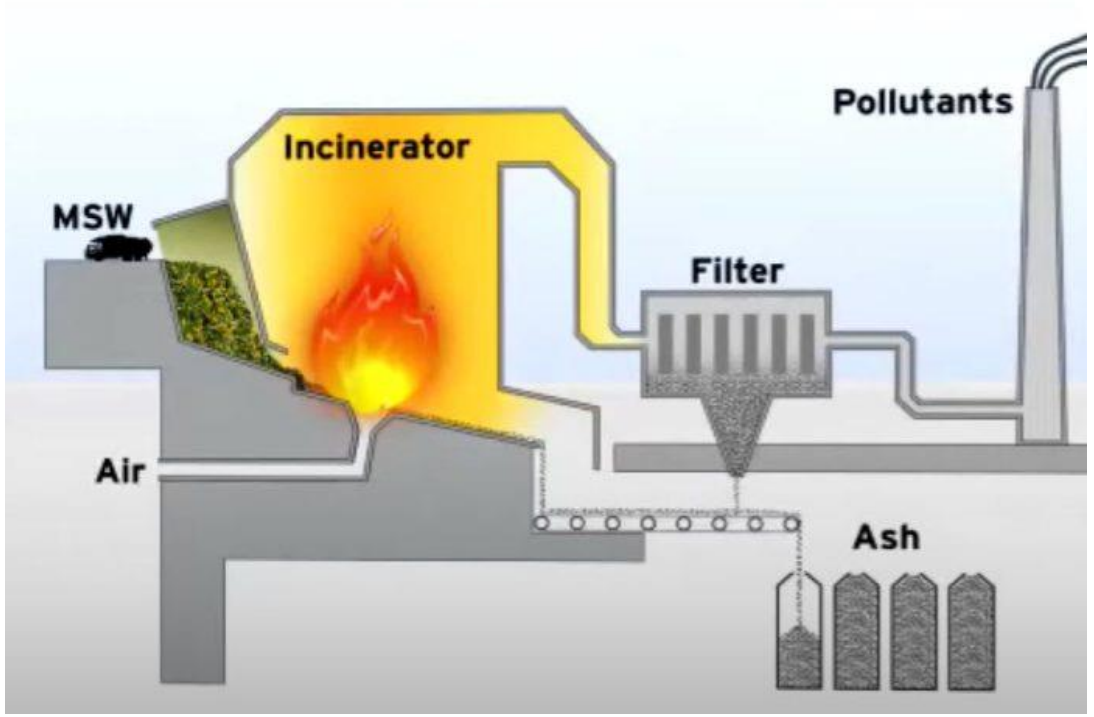
Where should I put my compost pile?

- Shaded area will help prevent drying out in summer
- Avoid areas that will interfere with lawn and garden activities.
- Adequate work area around the pile
- Area for storage
- Water available

- **One teaspoon of good garden soil to which compost has been** added contains
- 100 million bacteria
- 800 feet of fungal threads

Incineration

- A waste treatment technology, which includes the combustion of waste for recovering energy, is called as “incineration”.
- Incineration coupled with high temperature waste treatments are recognized as thermal treatments.
- Incineration of waste materials converts the waste into ash, flue gas and heat.
- Incineration reduces the mass of the waste from 95 to 96 percent.



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- The purpose of incineration is to combust solid wastes to reduce their volume to about one- tenth, without producing offensive gases and ashes. That is to say, incineration of solid wastes aims at the following:

• 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 with 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.

• Stabilization 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.

Cont.

- Recovery of energy from waste (EFW): Energy recovered from burning the wastes is used to generate steam for use in onsite 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 utilizing the residual heat. Solid waste incineration can replace the use of fossil fuels for energy generation.

- 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.

Advantages

- Volume Reduction: Incineration significantly reduces the volume of waste by up to 95%. This is quite beneficial in densely populated areas with limited landfill space.

- Energy Recovery: Modern incinerator facilities can be equipped to capture the heat generated during combustion. This heat can then be used to run turbines and generators that create electric power, providing a form of waste-to-energy scheme.

- Waste Destruction: Incineration can effectively destroy pathogens and harmful toxins in certain waste streams. This helps to reduce the risk of public health risks and environmental contamination.

- Landfill Diversion: By diverting waste from landfills, incineration can help conserve landfill space and reduce the environmental impact of landfills.

- Reduced Reliance on Fossil Fuels: When used for energy generation, waste incineration can partially offset the need for fossil fuels, potentially leading to lower greenhouse gas emissions. However, this depends on the efficiency of the incineration process.

Disadvantages

- **Air Pollution:** Burning waste releases various pollutants into the air such as particulate matter, nitrogen oxides, and harmful toxins like dioxins. These pollutants can contribute to several health problems.
- **Ash Disposal:** The incineration process does not eliminate waste entirely. It creates ash residue, which can contain concentrated heavy metals and other toxins. This ash requires careful management and disposal in special landfills. This disposal adds another layer of complexity.
- **Greenhouse Gas Emissions:** Although incineration can sometimes offset reliance on fossil fuels for energy generation, it still releases greenhouse gases during the burning process. This can contribute to climate change, especially if the waste stream contains a lot of plastic.

Cont.

- **Disincentive for Reduction and Recycling:** Some argue that readily available incineration facilities can discourage efforts to reduce waste generation and prioritize recycling. If there's a convenient way to burn waste for energy, there might be a reduction in the focus on waste minimization or recycling.

Hazardous Waste

What is Waste

- A material, substance, or by-product , eliminated or discarded as no longer useful or required after the completion of a process.

OR

- Any unwanted or discarded material we produce that is may be a solid or a liquid or gas. It may be toxic or may be not .

Hazardous waste

- Hazardous waste means wastes solid, sludge, liquids, and containerized gases other than radioactive and infectious wastes which, by reason of their chemical activity or toxic, explosive, corrosive, or other characteristics cause danger or likely will cause danger to health or to the environment, whether alone or when they come in contact with other waste.

Cont.

- Hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Examples include drain cleaners, oil paint, motor oil, antifreeze, fuel, poisons, pesticides, herbicides and rodenticides, fluorescent lamps, lamp ballasts, smoke detectors, medical waste, some types of cleaning chemicals, and consumer electronics (such as televisions, computers, and cell phones).

Source of hazardous waste

Hazardous waste is generated from many sources, ranging from industrial manufacturing process wastes .it may come in many forms, including liquids, solids gases, and sludges. It includes

- Clinical wastes.
- Waste oils/water, hydrocarbons/water mixtures, emulsions.

Cont.

- Wastes from the production, formulation and use of resins, latex, plasticizers, glues/adhesives.
- Wastes resulting from surface treatment of metals and plastics.
- Residues arising from industrial waste disposal operations.
- Wastes which contain certain compounds such as: copper, zinc, cadmium, mercury, lead and asbestos.
- Household waste; or Residues arising from the incineration of household waste.

Household hazard waste

- Examples:
- Cleaning products – Oven cleaners, toilet cleaners, bleach, and ammonia
- Paint based products – Paint thinners, stains, wood preservatives
- Gardening and pest control products – Pesticides and rodenticides
- General Products – Batteries, glues
- Automotive products – Gasoline, motor oil, solvents, brake fluid, antifreeze
- E-Waste – Cellphones, personal computers, i-pods, laptops

Difference between Toxic & Hazardous waste

- According to EPA, toxic waste is only waste “that is harmful or fatal to living organisms when absorbed or ingested”. Hazardous waste is the lower level of potentially harmful substances, toxic is higher. Hazardous waste can be but isn't necessarily toxic. All toxic waste is hazardous.

- The EPA describes toxic waste as any chemical waste material “… that is harmful or fatal to living organisms when absorbed or ingested.”

Toxic vs. Hazardous

- Occupational Safety and Health Administration (OSHA)
  - The toxicity of a substance is its ability to cause harmful effects.
  - All chemicals can cause harm.
  - When only a very large amount of the chemical can cause damage, the chemical is considered to be relatively non-toxic. When a small amount can be harmful, the chemical is considered toxic.

  - So Hazardous waste may be sometimes toxic But toxic waste always be Hazardous waste

Concern about hazardous waste

- Cause of mass life and material damage and loss (disability, death, fire, explosion).
- Cause of environmental damages: water, solid and air pollution (under ground and surface drinking water).
- Cause of potential increased chemical bioaccumulation that is hard for biodegradability (chlorine containing chemicals).
- Cause of long-term irreversible health risks.
- High concern of trans-boundary movement of toxic waste.
- Cause of massive toxic health damages

Health affects

- Acute – Meaning they act immediately like producing a cough, watery eyes, nausea, etc.

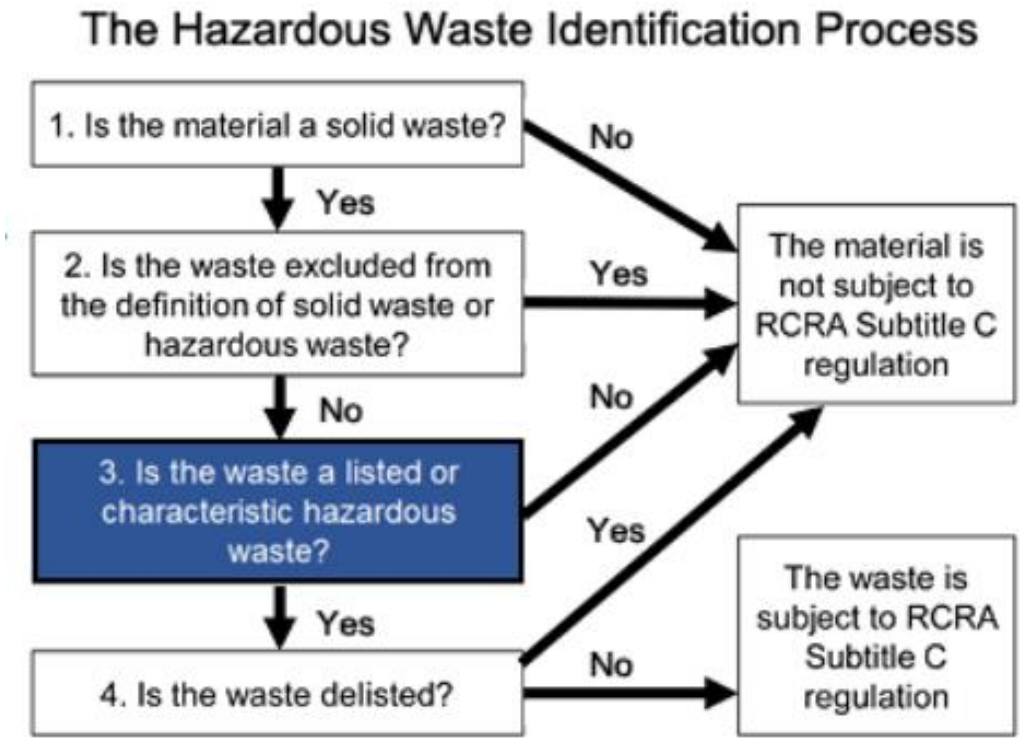
- Chronic Affects – Meaning the effect they have is long term and sometimes cumulative. X-ray exposure, noxious cleaning chemicals, etc.

How to classify whether the waste is Hazardous or not?

- Using defined list of criteria (as specified by US-EPA).
- Identifying components of Waste.
- Based on Characteristics of Waste.
- Reviewing literature about the inherent characteristics of Waste

Cont.

- According to Resource Conservation & Recovery Act (RCRA), waste is classified as hazardous if it meets any of the following criteria:
- It exhibits an identified characteristics: - Ignitibility , Corrosivity, Reactivity, Toxicity (characteristic waste)
- It is on a list of specific wastes that are considered by EPA to be hazardous (listed waste)



Cont.

Listed waste are based on Pedigree (e.g., history, background, derivation)

VS.

Characteristic waste are based on chemistry (e.g., physical properties)

Categories of Hazardous waste

- Characteristic wastes.
- Listed wastes.
- Universal wastes.
- Mixed wastes

Classification of hazardous waste

1. Listed Waste by US Environmental Protection Agency (US-EPA)
    - F-List
    - K-List
    - P-List and,
    - U-List
2. Characterized Waste
    - a) Ignitability
    - b) Corrosivity
    - c) Reactivity d)
    - Toxicity
3. Universal Waste
    - a) Batteries
    - b) Pesticides
    - c) Equipment containing mercury
    - d) Lamps containing mercury
4. Mixed Waste: Radioactive + Hazardous
5. E-Waste: Electrical Waste, Electronic Waste

Characterized waste - Ignitability

•Ignitibility (D 001) : The potential of waste material to cause a fire during storage, transport, disposal or treatment (example – used organic solvent, waste oil)

A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:

(1) It is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume and has flash point less than 60 °C (140 °F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM Standard D 93–79 or D 93–80 (incorporated by reference, see §260.11), or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D 3278–78 (incorporated by reference, see §260.11).

Ignitability

- A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:

(2) It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.

(3) It is an ignitable compressed gas and oxidizer.

EPA assigned D001 as the waste code for ignitable hazardous wastes.

Corrosivity

- Wastes that are hazardous due to the corrosivity characteristic include aqueous wastes with a pH of less than or equal to 2, a pH greater than or equal to 12.5 or based on the liquids ability to corrode steel.
- When a liquid corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.250 inch) per year at a test temperature of 55°C (130°F) , it is considered corrosive.
- EPA assigned D002 as the waste code for corrosive hazardous wastes.

Reactivity

- Wastes that are hazardous due to the reactivity characteristic may be unstable under normal conditions, may react with water, may give off toxic gases and may be capable of detonation or explosion under normal conditions or when heated.
- EPA assigned D003 as the waste code for reactive hazardous wastes.

Toxicity

- Wastes that are hazardous due to the toxicity characteristic are harmful when ingested or absorbed. Toxic wastes present a concern as they may be able to leach from waste and pollute groundwater.

- The toxicity of a waste is determined by the Toxicity Characteristic Leaching Procedure (TCLP) (SW-846 Test Method 1311).

- EPA assigned wastes codes D004 through D043 that correspond to a contaminant and its associated TCLP concentration.

Listed wastes
US-EPA: list of hazardous waste

- Hazardous Waste categorized by US Environmental Protection Agency (EPA):
- F-List: Wastes on this list are created from common manufacturing and industrial processes. Because these wastes are produced in multiple industries, they are known as “non-specific source waste.”
- K-List: Wastes, including sludge or wastewater, from a selection of specific industries, such as petroleum refining or pesticide manufacturing, are included on this list. Since we know the industry, they are produced in, they are called “source-specific wastes.”
- P-list and U-list: Wastes on this lists are commercial chemical products being discarded in their unused form. They become hazardous when discarded.

Listed wastes

- EPA designates more than 450 listed wastes which are specific substances or classes of substances known to be Hazardous.

Industry and EPA Hazardous Waste Number	Description	Hazard Code*
F001	The following spent halogenated solvents used in degreasing: Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; all spent solvent mixtures/blends used in degreasing containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those solvents listed in F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures	(T)
K001	Bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol	(T)
F002	The following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane, and 1,1,2-trichloroethane; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those listed in F001, F004, or F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures	(T)
K002	Wastewater treatment sludge from the production of chrome yellow and orange pigments	(T)

Each substance in every group or list is assigned an EPA hazardous waste number.
For example, in U-type list Acetophenone U004

In k-type list Wastewater treatment sludge from the production of chrome yellow and orange pigments K002

To indicate its reason for listing a waste, EPA assigns a hazard code to each waste listed on the F and K list. An explanation of each of the codes is below:

(T) - Toxic Waste
(H) - Acute Hazardous Waste
(I) - Ignitable Waste
(C) - Corrosive Waste
(R) - Reactive Waste
(E) - Toxicity Characteristic Waste

Hazardous Waste No.	Chemical Abstract No.	Substance**
P001	[1]81-81-2	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenylbutyl)-, & salts, when present at concentrations greater than 0.3%
P001	[1]81-81-2	Warfarin, & salts, when present at concentrations greater than 0.3%
P002	591-08-2	Acetamide, -(aminothioxomethyl)-
P002	591-08-2	1-Acetyl-2-thiourea
P003	107-02-8	Acrolein
P003	107-02-8	2-Propenal
P004	309-00-2	Aldrin
P004	309-00-2	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa-chloro-1,4,4a,5,8,8a,-hexahydro-, (1alpha,4alpha,4abeta,5alpha,8alpha,8abeta)-
P005	107-18-6	Allyl alcohol

Hazardous waste management

- EPA is responsible for regulating hazardous waste under a Federal statute known as the Resource Conservation and Recovery Act (RCRA). This Act requires that all hazardous waste shipped off-site be tracked from "cradle-to-grave" using a manifest (paper or electronic) that provides information about the generator of the waste, the facility that will receive the waste, a description and quantity of the waste (including the number and type of containers), and how the waste will be routed to the receiving facility.

- EPA regulates hazardous waste under the Resource Conservation and Recovery Act to ensure these wastes are managed in ways that protect human health and the environment.

HW Generators

- A generator is any person who produces a hazardous waste as listed or characterized in part 261 of title 40 of the Code of Federal Regulations (CFR).
- Recognizing that generators produce waste in different quantities, EPA established three categories of generators in the regulations:

- very small quantity generators : generate 100 kilograms or less per month of hazardous waste or one kilogram or less per month of acutely hazardous waste.
- small quantity generators : generate more than 100 kilograms, but less than 1,000 kilograms of hazardous waste per month.
- large quantity generators : generate 1,000 kilograms per month or more of hazardous waste or more than one kilogram per month of acutely hazardous waste.
- The volume of hazardous waste each generator produces in a calendar month determines which regulations apply to that generator.

HW Storage

- Till disposal for recycling/ treatment/ land filling, HWs are to be stored onsite in bags/ containers in a covered area.

- Storage permitted for a period not exceeding 90 days – SPCB (State Pollution Control Board)may extend the storage period, in case of:

i. Small generator, generating HW up to 10 TPA (million ton per annum).

ii. Recyclers, preprocessors and facility operators up to 6 months of their annual capacity.

iii. Generators who do not have access to any TSDF (Treatment Storage and Disposal Facility) in the concerned State.

iv. Wastes which need to be specifically stored for development of a process for its recycling, reuse.

HW Transporter

- Subtitle C of the Resource Conservation and Recovery Act (RCRA) defines a hazardous waste transporter as any person engaged in the off-site transportation of the hazardous waste within the United States. Off-site transportation of hazardous waste includes shipments from a hazardous waste generator's facility or property to another facility for treatment, storage, or disposal (TSDF).

- EPA keeps track of hazardous waste transporters by requiring each transportation company to obtain an EPA ID number. A transporter is forbidden from transporting hazardous waste if they do not have an ID number.

Cont.

- Unlike generator EPA ID numbers, which are site-specific, transporter ID numbers are assigned to the transportation company as a whole. This means that each individual truck uses the number issued to the company's headquarters location and does not receive its own unique number.
- EPA's hazardous waste manifest system is designed to track hazardous waste from the time it leaves the generator facility where it was produced, until it reaches the off-site waste management facility that will store, treat or dispose of the hazardous waste. The manifesting responsibilities vary depending on the mode of transportation (highway, water, rail or air).

Cont.

TSDF is the final link in the cradle to grave HW system

- Treatment : Any process that may change the characteristics or composition of HW so as to render it less hazardous, or that is capable of volume reduction or resource recovery.
- Storage: the temporary holding of HW prior to treatment or disposal.
- Disposal: the deposit of HW so that it might either safely reenter the environment or be safely and securely disposed

Treatment of hazardous waste

- There are five types by which the hazardous waste can be treated:-

1. Physical treatment.
2. Chemical treatment.
3. Thermal treatment.
4. Biological treatment.
5. Disposal method.

Physical treatment

Physical processes enable different waste components to be separated or isolated, either for re-use or for appropriate further treatment or disposal.

Some physical processes on-site eg sedimentation, while other are off-site.

On-site treatment reduces:

1. volumes needing.
2. transport costs.

Physico- chemical processes

- Off-site treatment allows for dedicated waste handling and treatment systems.
- Should provide:

- Waste receiving station.
- Storage facilities for wastes awaiting treatment.
- Treatment areas for number and variety of processes used.
- Storage and disposal facilities for treatment residues eg reaction products, filter cake and wastewater.
- Storage for treated wastes to be incinerated, where appropriate.
- Laboratory services.
- Trained personnel

Treatment residue

- All physico-chemical treatment processes generate residues which may:

- Be hazardous wastes themselves.
- Be more concentrated than original waste.
- Be suitable for recycling.
- Require further treatment.
- Need to be landfilled

Physical processes

- Many different physical treatment processes.
- Most are simple and low-cost.
- Choice depends on physical form of waste and its characteristics.

- Options include:

- Separation·
- Sedimentation·
- Flotation·
- Drying·
- Evaporation·
- Sludge dewatering·
- Filtration

Separation

Examples of separation techniques:

- Sieving and screening - for dry materials of different particle size.
- Distillation - to separate liquids.
- Use of washing medium - to extract contaminants from soils or soluble components from solid wastes

Adsorption

Adsorbents	Application
Activated carbon	Solvent recovery Elimination of odours Gases purification
Alumina	Drying of gases and liquids
Bauxite	Treatment of petroleum fractions Drying of gases and liquids
Molecular sieves	Selective removal of contaminants from hydrocarbons
Silica gel	Drying and purifying gases

Sedimentation

- Used to separate particles held in suspension in a liquid which is principally aqueous.
- Uses gravity.
- May require mechanical or manual stirring.
- Suitable for a wide range of hazardous wastes such as:
  - Metals in wastewater.
  - Neutralized acids and alkalis containing suspended metal hydroxides.
  - Metals that have been precipitated.

- Sludges may need further screening, drying or dewatering.
- Separated liquid may need further treatment

Sedimentation

Flotation

- Relies on the natural behavior of particles less dense than water.

- Is suitable for a range of waste types eg oil/water separation.

- Efficiency can be improved by blowing air through the liquid.

✓ size of air bubbles should be varied according to waste type.

Drying and evaporation

- May be needed after sedimentation.

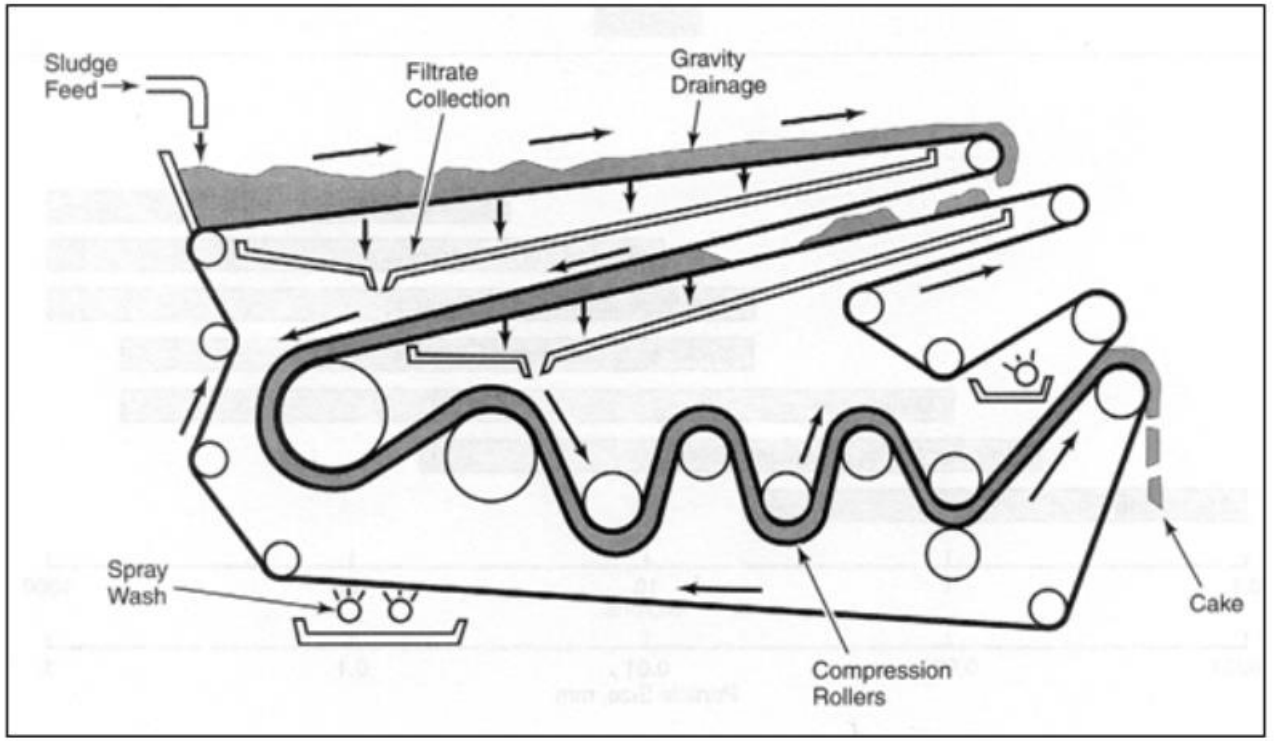
- Options include:

✓Sludge drying beds.

✓Centrifugal separation.

✓Filtering and pressing

Drying and evaporation - Example



Dewatering sludge

Filtration and separation

Filtration is the method for separating solid particles from a liquid using a porous medium. The application of filtration of treatment of hazardous waste fall into the following categories:-

- Clarification:-method in which suspended solid particles are less than 100ppm and the aim is to produce a clear aqueous effluent, which can be discharged directly or further processed.

- De watering:- in this method the slurry is concentrated by the removal of liquids to form a solid.

Chemical treatment

- Chemical processes rely on chemical reactions to transform hazardous wastes into less hazardous substances, using the chemical properties of the waste itself to effect the transformation.
- Use a chemical to treat a chemical.

✓need details of waste composition and reactivity.

✓need qualified staff to:

- Assess waste composition.
- Monitor chemical reaction.
- check reaction results.

- Options include:·

✓Reduction and oxidation·

✓Neutralization·

✓Precipitation.

Chemical oxidation and reduction

- Reduction/oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorite's, chlorine, and chlorine dioxide.
- In these reactions the oxidation state of one reactant is raised, while the other reactant is lowered.

E.g.:- this kind of treatment is used for the waste of:

1. Sulphide.
2. Cyanide.
3. Many organic wastes such as pesticides and phenols.

Chemical oxidation and reduction

Some common oxidising and reducing reagents

Oxidising reagents

- Sodium or calcium hypochlorite
- Hydrogen peroxide
- Chlorine
- Potassium permanganate
- UV
- Ozone

Reducing reagents

- Ferrous sulphate
- Sodium sulphite
- Sulphuric acid
- Iron
- Aluminium
- Zinc
- Sodium borohydride

Oxidation in practice

- Enables avoidance of harmful side reactions.
- Needs expert design, careful operation to be safe.
- Cost effective.
- Enables avoidance of harmful side reactions.
- Commonly used for cyanides.
- Easiest oxidizing reagents: sodium or calcium hypochlorite

Reduction in practice

- Commonly used for chromates and chromic acids from chromium plating and tanning industries.

Cr VI reduced to Cr III then removed by precipitation.

- Common reducing reagents:

  ferrous sulphate sodium sulphite/sulphuric acid.

Chemical Oxidation and reduction

- Oxidation reduction methods provide another important chemical treatment alternative for hazardous wastes. One important chemical redox treatment involves the oxidation of cyanide wastes from metal finishing industry, using chlorine in alkali solution. In this reaction CN- is first converted to a less toxic cyanate. Further chlorination oxidises the cyanate to simple carbondioxide and nitrogen gas.

$$NaCN + Cl_2 + 2NaOH \rightarrow NaCNO + 2NaCl + H_2O \ldots\ldots\ldots\ldots$$

$$2NaCNO + 3Cl_2 + 4NaOH \rightarrow 2CO_2 + N_2 + 6NaCl + 2H_2O \ldots$$

Cont.

- Important redox treatment process is the reduction of hexavalent chromium Cr(VI) to trivalent chromium Cr(III) in large electroplating operations. Sulphur dioxide is used as the reducing agent and the reactions are as follows.

$$3SO_2 + 3H_2O \rightarrow 3H_2SO_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$2CrO_3 + 3H_2SO_3 \rightarrow Cr_2(SO_4)_3 + 3H_2O \ldots\ldots$$

Cont.

A large variety of oxidizable contaminants in wastewater and sludges are oxidized by ozone which can be generated on site by an electrical discharge through dry air or oxygen.

$$(CH_2O) + 2[O] \rightarrow CO_2 + H_2O \ldots.$$

$$CH_3CHO + [O] \rightarrow CH_3COOH \ldots.$$

Neutralization

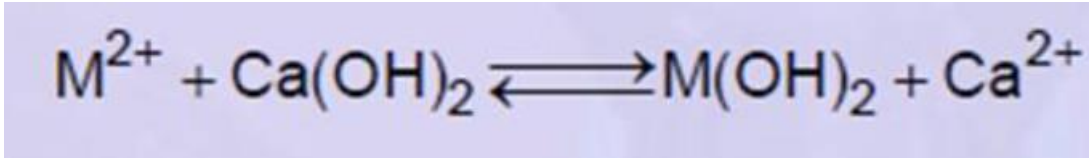
- Used for wide variety of acidic and alkaline wastes.
- Acid wastes are neutralized by alkalis, and vice versa.
- Used to treat liquid wastes, sludges and gases.
- Reactions must be laboratory tested to control pH, identify complementary reagents.
- Neutralized liquid usually sent for sedimentation

Precipitation

- Causes soluble substances to become less soluble/insoluble.
- Often used in combination with other treatment processes eg reduction, neutralization.
- Effective treatment for wastewater containing toxic metals which arise in metal-plating and finishing industry, and mining.
- Calcium hydroxide (lime) most widely used reagent

Cont.

- This technique can be applied to almost any liquid waste stream containing a precipitable hazardous constituent. By properly adjusting pH, the solubility of toxic metals can be decreased, leading to the formation of a precipitate that can be removed by settling and filtration.
- Quite often lime [Ca(OH)2] or caustic soda is used for precipitation of the metal ions as metal hydroxides. For example, the following reaction suggests the use of lime to precipitate the metal as hydroxide.



Cont.

- Sodium carbonate also has been used to precipitate metals as hydroxides ($Fe(OH)_3 \bullet XH_2O$), carbonates ($CdCO_3$), basic carbonate salts ($2PbCO_3 \bullet Pb(OH)_2$).Carbonate ion hydrolyses in water to give hydroxide ion.

Thermal treatment

- Thermal treatment = destruction of hazardous waste by thermal decomposition.
- Thermal treatment methods include:
- Incineration - complete combustion using excess oxygen.
- Gasification - incomplete combustion in the partial absence of oxygen.
- Pyrolysis - thermal decomposition in the total absence of oxygen

Cont.

- Suitable for organic wastes.

- Thermal treatment processes:
- Require high capital investment.
- Are highly regulated
- Need skilled personnel.
- Require high operating and safety standards.
- Have medium to high operating costs

Example of calorific value

Mixed waste from plant cleaning operations	10,000 - 30,000 kj/kg
Wastewater	5,000 kj/kg
	(0 - 10,000kj/kg depending on organic content)
Industrial sludge	1,000 - 10,000 kj/kg
Paints and varnishes	>20,000 kj/kg
Chlorinated hydrocarbons	5,000 - 20,000 kj/kg

For comparison, MSW = ~10,000kj/kg

Combustion

- Requires: addition of excess air mechanical mixing of waste
  even distribution and aeration of waste.
- Behavior of waste during combustion varies according to its heat value and its form.
- Some low CV wastes burn easily = straw.
- Some low CV wastes are difficult to burn = wet sludges.
- Some high CV wastes burn easily = tank bottoms.
- Some high CV wastes are difficult to burn = contaminated soils, certain plastics.
- Certain wastes change their physical characteristics during combustion

Pyrolysis

- Thermal decomposition process which takes place in the total absence of oxygen.

- Products of pyrolysis:
- combustible gases.
- mixed liquid residue.

- Advantages:
- Low operating temperature.
- No need for excess air so less flue gas.
- By-products are combustible.

Gasification

- Incomplete combustion in the partial absence of oxygen.
- Enables efficient destruction of hazardous waste at lower temperatures than incineration.
- Thermal destruction is ensured by a combination of high-temperature oxidation followed by high temperature reduction.
- Products: useful gases eg hydrogen, carbon monoxide

Biological treatment of hazardous wastes:

- Biological processes are in general, the most cost-effective techniques for treating aqueous waste streams containing organic constituents.
- The physical and chemical properties of the compound influence its biodegradability.
- With appropriate organisms and under right conditions, even phenol which is considered to be biocidal can be degraded.
- The microorganism must be allowed to acclimate to the waste to be treated prior to routine operation of the process.
- Even some compounds which were considered as bio refractory may be degraded by microorganisms adapted to their biodegradation.

Cont.

- In aerobic waste treatment, hazardous wastes such as chemical processes wastes, and land fill leachates can be degraded by aerobic microorganisms such as bacteria and fungi in the presence of oxygen.
- In anaerobic waste treatment, microorganisms degrade different organic wastes in the absence of oxygen. During the process H2S is generated which precipitates toxic heavy metal ions as their sulfides.

Cont.

- Some pesticide is degraded by properly acclimated pseudomonas.
- The relatively highly chlorinated PCBs are degraded by anaerobic bacteria under less anaerobic condition.
- These products can be further decomposed
- To increase the biodegradability of the hazardous wastes, the pH of the medium should be adjusted to an optimum value of 6-9 and the oxygen level should be high.
- Concentrations of soluble inorganics in the hazardous wastes should be kept low so that enzymatic activity is not inhibited.
- Trace concentrations of inorganics may be partially removed from the liquid waste stream during the biological treatment, because of adsorption onto the microbial cell coating.

Land treatment

- Land treatment is a waste management practice in which waste materials are mixed with or applied to the soil surface.

- Land treatment of hazardous wastes involves controlled application of the waste onto the soil surface.

- The objectives of land treatment are the biological and chemical degradation of organic waste constituents and the immobilization of inorganic waste constituents.

- Land treatment differs from land fills in that with land treatment, the assimilative capacity of the soil is used to detoxify, immobilize, and degrade all or a portion of the applied waste. Land fills are containments that store hazardous wastes and control the migration of wastes or by-products from the land fill sites. Liners are not required with land treatment.

Cont.

- Hazardous wastes should not be placed in a land treatment site unless the waste can be made less hazardous or nonhazardous by the reactions occurring in the soil.

- Hazardous-waste land treatment is the controlled application of hazardous waste on the aerobic soil horizon, accompanied by continued monitoring and management in order to alter the physical, chemical and biological characteristics of the waste and to render the waste less hazardous.

Cont.

- Land treatment of wastes is accomplished by mixing the wastes with soil under appropriate conditions.
- Important microorganisms like bacteria, including those from the genera, agrobacterium, Arthrobacter, bacillus, flavobacterium, pseudomonas are involved in biodegradation.
- In addition, actinomycetes and fungi are all involved in the biodegradation of wastes.
- Bacterial cultures may develop through acclimation over long periods of time, and which are able to degrade these normally recalcitrant compounds.
- Land treatment is applicable to petroleum refining wastes, biodegradable organic chemical wastes including organochlorine compounds. However, it is not suited to the treatment of waste containing acids, bases, toxic inorganic compounds, salts, heavy metals and excessively soluble volatile and flammable organic compounds.

Surface impoundments

A surface impoundment is a man-made excavation, diked area, or natural topographic depression designed to hold an accumulation of liquid wastes. The construction is similar to that described for land fills in that bottom walls should be impermeable to liquids and provision must be made for leachate collection. Proper geological siting and construction with floors and walls composed of low-permeability soil and clay are important in preventing the pollution, since the chemical and mechanical challenges to the liner materials in surface impounds are severe.

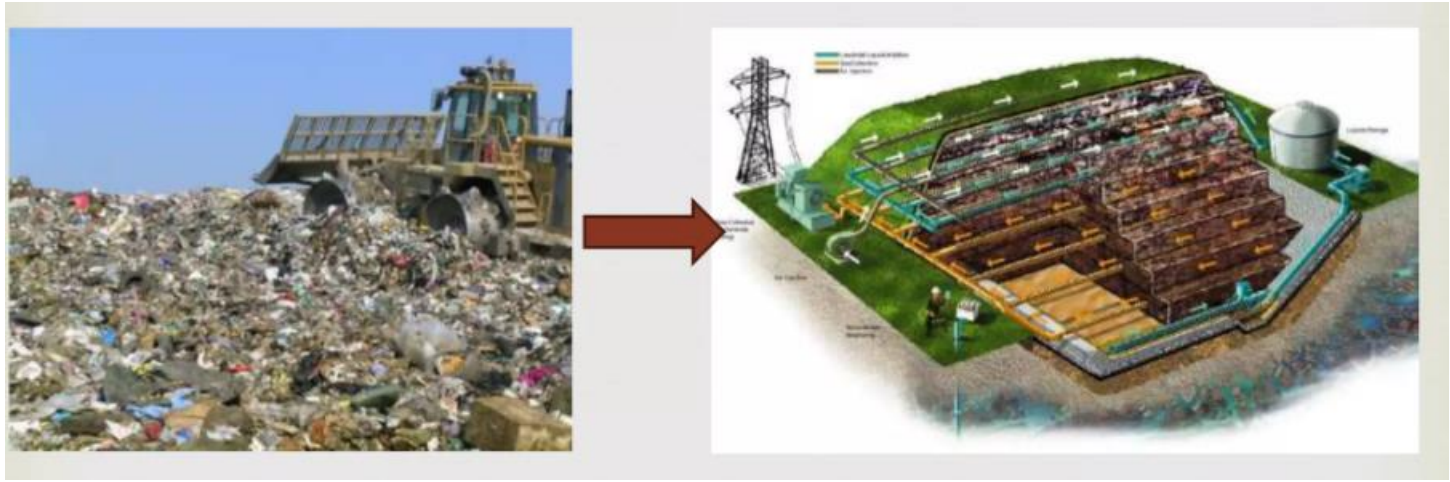
Landfill

Landfill

- Is an engineered method for land disposal of solid and hazardous waste.
- Landfilling is the term used to describe the process by which solid waste is placed in the landfill.
- Landfills for individual waste constituents such as combustion ash, asbestos and other similar wastes are known as monofills.
- Landfills for the disposal of hazardous wastes are called secure landfills.

Principle of landfills

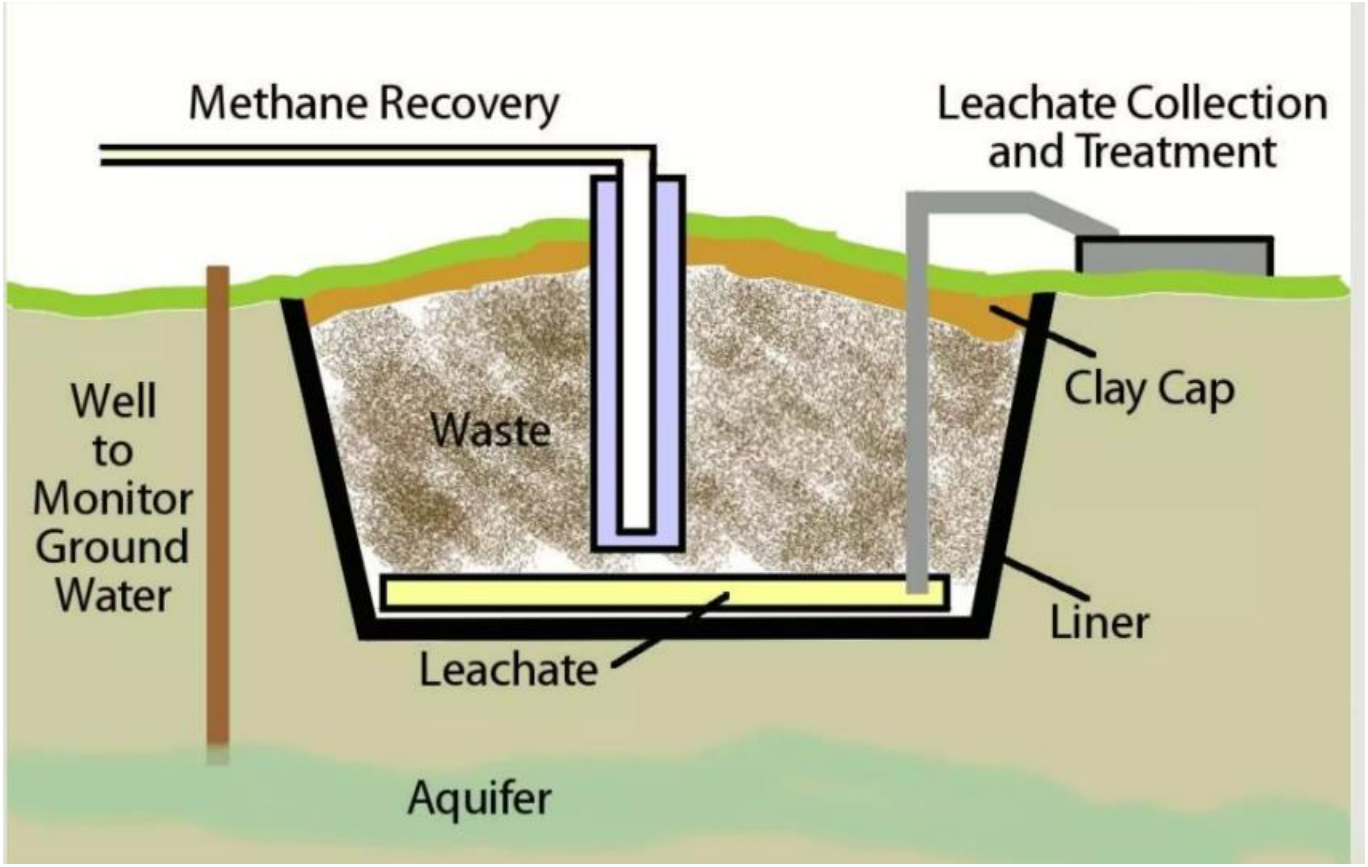
- Purpose of landfilling is to bury/ alter the chemical composition of the waste so that they do not pose any threat to environment/public health.
- Landfills are usually made up of cells in which a discrete volume of waste is kept isolated from adjacent waste cells by a suitable barrier.
- The term cell is used to describe the volume of material placed in a landfill during one operating period.



Difference between dump and landfills

- **A dump** is an open hole in the ground where trash is buried and where animals often swarm. They offer no environmental protection and are not regulated.
- **A landfill** is a carefully designed and monitored structure that isolates trash from the surrounding environment (e.g., groundwater, air, rain). This isolation is accomplished with the use of a bottom liner and daily covering of soil.

Essential components of landfills



Why landfill is important

- To prevent contamination of waste into the surrounding environment, especially groundwater due to open dumping.
- Some materials can not be recycled, used for energy or composted.
- Increasing population resulting in increase in waste.

Site selection process

- The suitability of a landfill site is determined by

- Its size/area/volume.

- Technical and environmental factors.

- Climate and hydrological conditions.

- It requires a development of a working plan, description of site location, operation, engineering work and site restoration.

- People are reluctant to allow construction of new landfill, thus siting approval authority is important.

Advantages of Landfilling

- In addition to provide an option for waste management, it also serves to improve/ reclaim poor quality land.

- It raises the ground elevation/surface grade of the site. Completed landfills have been converted to municipal parks, playgrounds, golf courses, community land use projects.

- It is the most economical alternative for SW disposal which accounts for its frequent application.

- Other disposal methods are not entirely safe and efficient throughout the year.

Cont.

- Incineration is a costly process; residue requires ultimate disposal on land.
- Composting is a seasonal option.
- It is not possible to reclaim and recycle all SW material.
- Thus landfilling is the most convenient option.

Disadvantages

- Difficult to find suitable site within economically feasible distance.
- It is not possible to build a completely safe and secure SW landfill. Some of the pollutants may escape in the environment in the form of leachate.
- Potential harm to public health due to air, soil, water and noise pollution.
- Damage to local ecosystem.
- Public oppose.

What happens to the waste in Landfill

- Designed to bury waste in layers of soil.
- Compacting the layers to reduce volume.
- Slowdown of waste decomposition with minimal amounts of oxygen and moisture.
- Finally covering them with soil each day so as to minimize human health and environmental problems.
- And for careful filling, monitoring and maintenance while they are active and for up to 30 years after they are closed

Characteristics of Landfill

1. solid waste is placed in a suitably selected and prepared (lined) landfill site in a carefully prescribed manner.

2. the waste material is spread out and compacted with appropriate heavy machinery.

3. The waste is covered each day with a layer of compacted soil.

4. Most important feature of modern sanitary landfill design is the technology used to prevent GW pollution.

5. It relies on containment rather than treatment.

Important aspects of landfill process

The feasibility of land disposal of solid waste depends on many factors

- Type of solid waste.
- Quantity of waste.
- Characteristics of waste.
- Laws and regulations.
- Soil and site characteristics.

Cont.

Total capacity and design life of a new landfill depend on

- Size.
- Topography of the site.
- Rate of refuse generation.
- The degree of refuse compaction.
- The amount of daily soil cover adds 20% of overall fill volume, it must be considered for evaluation of capacity of landfill.

Landfill operation

- The gases found in land fills include air, ammonia Carbon-monoxide, hydrogen, sulfide, methane, nitrogen.

- Carbon monoxide and methane are the principal gases produced from anaerobic decomposition .

- It involves three steps:

    - Enzyme mediated transformation.

    - Bacterial conversion for intermediate compounds .

    - Bacterial conversion of intermediate compounds to low molecular weight compounds.

Landfill Settling Process

Primary consolidation

- Substantial amount of settling occurs at this stage.
- It is caused by weight of the waste layers, truck movements, bulldozers , mechanical compactors.
- After this stage aerobic degradation of waste occurs.

Secondary compression

- Rate of settling is much lower than first stage.
- Settling occurs through compression.

Decomposition

- It is the degradation process
- Organic material is converted to gas and leachate.
- Settling rate increases as compared to secondary stage, but with the passage of time it gradually decreases.
- It continues till the organic matter is degraded.

Leachate collection system

- Leachate may be defined as the liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it.

- The rate of seepage of leachate from the bottom of a landfill is estimated by Darcys law.

- The use of clay has favored in reducing the leachate percolation .

Cont.

- It is a mixture of organic degradation products, liquid waste and rainwater.
- It has high organic carbon content, high concentrations of nitrogen and is usually slightly acidic.
- The most hazardous products of such leachate are four major types of constituents: soluble organic matters, inorganic components, heavy metals, and xenobiotic organic compounds.

Landfill gas

- In most of the cases as the anaerobic decomposition of the wastes predominates the decomposition process the gases obtain are Carbon dioxide and methane.

- Carbon dioxide as result of its density will move towards the groundwater which can lower the pH of the groundwater and increases the hardness and mineral content in the ground water.

Gas venting system

- The lateral movement of gases produced in a landfill Can be controlled by installing vents made of materials that are more permeable than surrounding soil.

- The spacing of vents depends on width of waste cells but usually varies from 18 to 60 m.