Bule Hora University
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SOLID WASTE MANAGEMENT

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Course objective:

- After the completion of this course you will be enabled to identify the **trends, nature, environmental and health** effect and the management of solid waste.

Supportive course objective:

At the end of the course the student will be able to:

- Explain the **historical development of solid wastes**
- Identify the **sources of solid wastes**
- Identify **health problems related** to solid wastes
- Indicate **characteristics and type** of solid waste
- Identify the **solid waste management** as multi disciplinary activity
- Differentiate **methods of solid waste** collection systems

SOLID WASTE









Chapter one
Introduction

- **Definition of terms**
  - ✓ **Waste: is anything that is normally discarded as useless or unwanted.**



Defnition ....

- Wastes are ‘substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.’ (Basel convention)

- It can be defined as ‘any matter, whether solid, liquid, gaseous or radioactive, which is discharged, emitted or deposited in the env’t in such volume, constituency or manner as to cause an alteration of the env’t.’ (US EPA)

Defnition ....

- **Solid waste (also known as refuse):** Anything that is neither liquid nor gas that has to be discarded (Dictionary definition)
  - are all the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted.
- **Municipal solid waste**: It generally implies all the wastes generated in a community with the exception of industrial process wastes and agricultural solid wastes.
- **Ashes**: an incombustible material that remains after a fuel or solid waste has

Defnition ....

- ✓ **Garbage:** Putrescible wastes resulting from the growing, handling, preparing, processing, cooking and consumption of food.

  - It originates from domestic kitchens, stores, markets, restaurants etc.

- ✓ **Rubbish:** Represents all non- putrescible wastes except ash

  - consists of combustible and non-combustible solid wastes

- The term ‘trash’ is often used in the same way but is probably more a subset of rubbish.

Defnition ....

- The combustibles consist of paper, rags, wood, tree branches etc.
- Non-combustibles include material, which can't be burned at 700 - 1100°C. It includes the inorganic portion like tin cans, glass, soil etc.

✓ **Composting**: is the biological decomposition of biodegradable solid waste under controlled predominantly aerobic conditions to a state that is sufficiently stable for nuisance-free storage and handling and is satisfactorily matured for safe use in agriculture.

✓ **Incineration**: mean thermal treatment of waste in an Incinerator.

Defnition ....

- **Recycling**: is the reprocessing of the waste materials for the original purpose or for other purposes including organic recycling but excluding energy recovery.
- **Integrated Waste Management (IWM):** is a system that combines waste streams, waste storage, collection, treatment, and disposal methods, with the objective of achieving env'tal benefits, economic optimization and societal acceptability.

-This will lead to a practical and sustainable waste mgt system for any specific region.

Defnition ....

- **Cleaner Production**: It is the continuous application of an integrated, preventive strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment.

- **Infectious wastes**: are wastes that contain pathogenic organisms such as wastes from hospitals and biological laboratories

Risks and Problems Associated with Solid wastes

- ✓ In early years the impact of solid waste was not as sever as it is now b/c of two basic facts
  - population space ratio
  - complexity of the waste

If solid wastes are not managed properly, there are many negative impacts that may result.

- ➢ Some of the problems of Solid Wastes
- ✓ Sw may cause blockage of drains resulting in flooding & unsanitary conditions

Some of the problems….

- ✓ Promotion of microorganisms that cause diseases
  - The Us public Health service has published the relationship of 22 human diseases to improper solid waste mgt
- ✓ It is a good breeding place for flies, hence causes contamination of food & other fly-borne diseases.
- ✓ It may be a suitable breeding place for **mosquitoes,** causes the problem of mosquito-borne diseases (e.g. malaria, filariasis, etc)
- ✓ Rats find shelter and food in waste dumps,

Some of the problems….

- ✓ Aerosols and dusts can spread fungi and pathogens from uncollected and decomposing wastes.
- ✓ Plastic bags are aesthetically nuisance and cause the death of grazing animals
- ✓ Uncollected wastes degrades the urban env’t
- ✓ Waste collectors face occupational hazards, including strains during lifting, injuries and traffic accidents
- ✓ dangerous items may injure or poison people who sort materials from the wastes
- ✓ Heavy refuse trucks can cause damage to roads affect traffic mov’t

Some of the problems….

- ✓ The leachate from dumps and poorly engineered landfill may contain copper, arsenic, uranium and salts which can cause pollution of water supply
- ✓ landfill gases (like methane) can be explosive, and act as a green house gas, leading to climate change

Methane

- Generated in anaerobic conditions in landfills

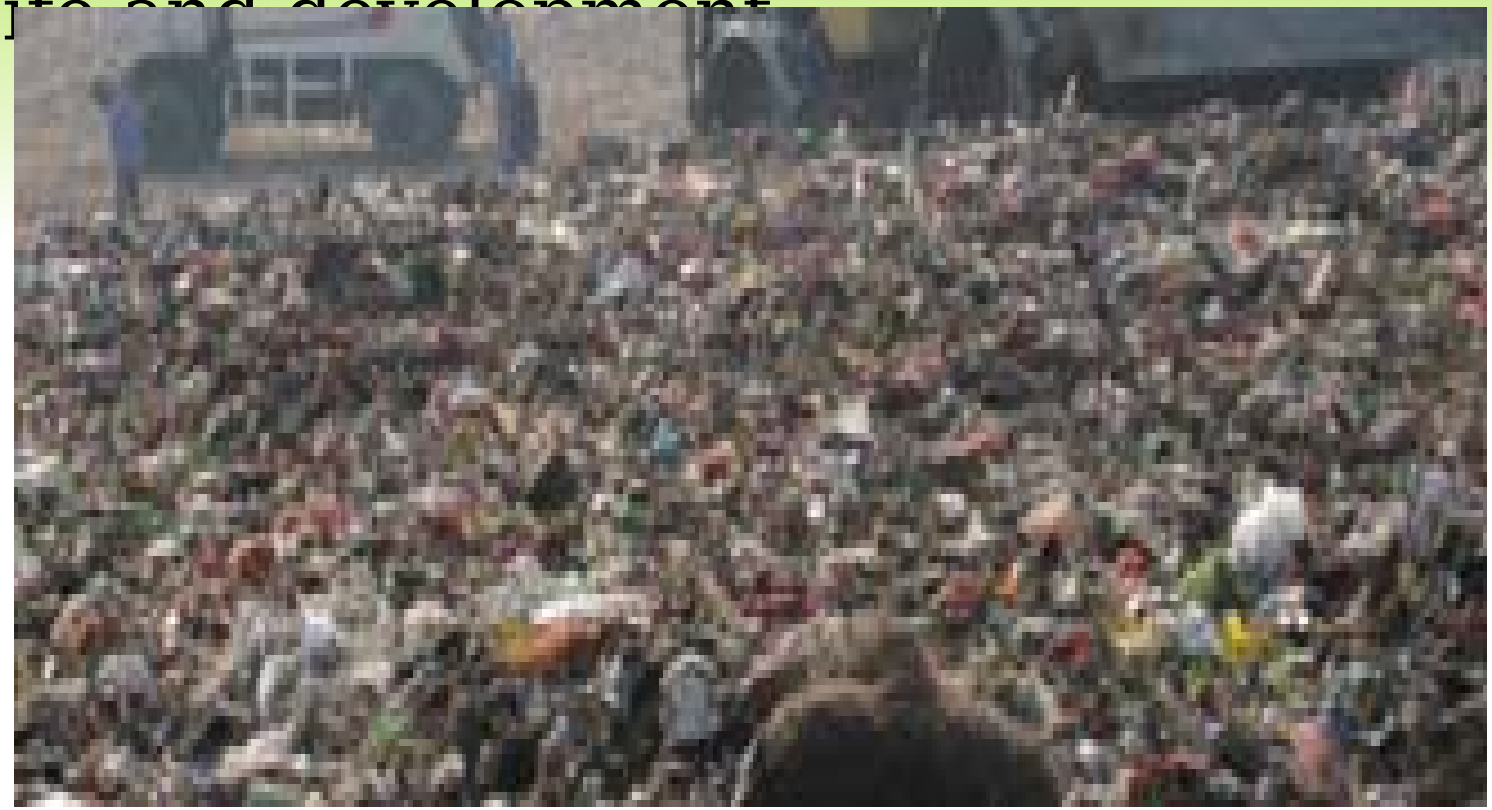
- 21 x global warming potential (GWP) of CO_2

Landfills

- 12%+ global anthropogenic methane

Some of the problems….

- ✓ Unsatisfactory disposal of wastes can cause aesthetic nuisance (smell and appearance), interfere with community life and development



Some of the problems….

- ✓ Fires on disposal sites can causes air pollution, illnesses and reducing visibility ; the products of include dioxins which are



Some of the problems….

- ✓ It Contaminate the soil



Some of the problems….

- ✓ Former disposal sites are very poor foundation to support large buildings.
- ✓ Landfills that receive unprocessed MSW typically remain spongy and continue to settle for decades.
- ✓ Inability to reuse and recycle usable materials results in the wastage and depletion of natural resources

Some of the problems….

- In summary,

Breeding ground for disease carriers	Rats, flies, mosquitoes, cockroaches, pigs, birds and other disease vectors breed in open dumps, waste storage facilities, piles of rotten refuse, etc.
Spread of disease by animals and other vectors, and food	Above vectors transmit diseases and pathogenic bacteria from waste to the households; consumption of meat from animals eating infected waste.
Spread of diseases by direct contact	Neighbourhoods, waste workers, scavengers in developing countries are in direct contact with waste (in case of organised handling, there is a risk of accident). People using recycled materials are also in direct contact with infected materials (not or poorly disinfected).
Air pollution	Fine grained materials, pathogens, decomposition of waste generating greenhouse gases and other gases, dust and smoke from burning, etc. cause pollution at transfer stations, communal bins, dumping sites.
Contaminated water	Leachate and precipitation (may contain metals, organic pollutants, hazardous substance, etc.) from waste piles and open or inadequately protected disposal sites contaminate surface and ground water.
Fire risk	Piles of waste and gas generated by these present a fire risk.
Connection to other services	Blockage of drains and sewers increase workloads to those services.
Environmental pollution	Overall environmental degradation due to contamination of air, water and soil environment via gaseous emission, particulate matter, ash, leachate, piles of unwanted materials, etc.

Historical Development of Waste management

- When early man roamed the Earth, solid waste was the remains from hunting, gathering, and food preparation

-From the days of primitive society, humans and animals have used the resources of the earth to support life and dispose of wastes.

- When man began inhabiting in caves, wastes were piled near entrances, and people move on to another dwelling
- In about 9000 B.C., people began to abandon nomadic life and created permanent communities

Conti....

- Humans advanced from hunters and gatherers to farmers and craftsmen, and became civilized and urbanized.
- Waste quantities increased and began to accumulate for longer periods.
- As a result, wastes became more harmful to health and to natural environments.
- When civilizations arose in Mesopotamia, Egypt, and elsewhere, certain **rules and practices** emerged to encourage some rudimentary programs of waste mgt.
- As early as 8000 to 9000 B.C., dumps were established away from settlements so that wild animals, insects, and odors would not migrate to populated areas .

Conti…

- From 3000 to 1000 B.C., placed their wastes, covered periodically with layers of soil, into large pits, thus operating the first proto-sanitary landfills
- In the Egyptian city (about 2100 B.C.), the wastes were collected and disposed, and ended up in the Nile River
- Around 2000 B.C., Israel provided guidelines as to

  how to manage wastes; instructions for the mgt of human waste are provided in the Bible (Deuteronomy 23:12–13).

Conti…

- In 1500 B.C., an effective composting effort was established in pits
- Many Asian cities collected waste in clay containers which were hauled away
- By 200 B.C., many cities in China employed “sanitary police,” who were responsible for the enforcement of waste disposal laws
- Throwing wastes into the unpaved streets, road ways and vacant land lead to the breeding of rats, with their attendant fleas which cause epidemic of plague, the black death that killed half of the 14th c

Conti…

- In 1906 H.de.B. parson wrote a book entitled “the disposal of municipal refuse”
- It is a basic problem still today and may be even much more complex
- now countries advance technologically, population increased geometrically and the amount is also increasing
- Earlier advanced countries start to haul refuse using carts, followed by

Conti…

- SWM has developed in the developed countries and at most nonexistent in developing countries

- In developed countries such as America and Britain controlled tipping was used in the 1930 and up to the second world war

- sanitary landfill disposal was started in 1950s

Conti…

- Consumption of natural resources at rates higher than can replaced by nature (both renewable and nonrenewable), and the discharge of pollutants in such quantities that their concentrations exceed the natural assimilative capacity of the surrounding environment,
- the two main causes of today's environmental problems.
  - The beginning of industrialization, and
  - The industrialists view to only 'maximize production' has been posed enormous pressure on the

Conti…

- These things herald the importance of a significant change in the whole existing industrial system to make the production and consumption, sustainable or to insure sustainable development.

CHAPTER TWO SOURCES, TYPES AND COMPOSITIONS OF SOLID



Sources and types of solid wastes

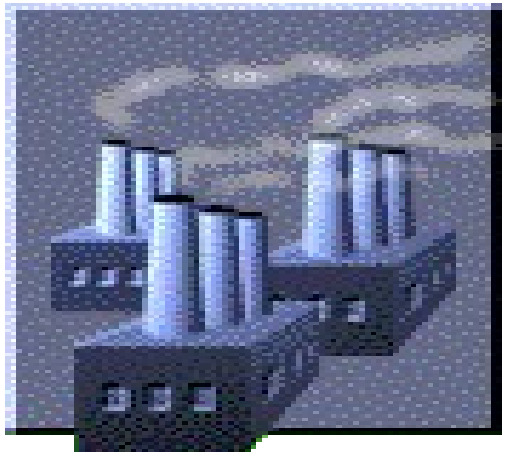
- Knowing the **sources and types** of solid wastes, along with data on the **composition and rates of generation**, is basic to the **design and operation** of the functional elements associated with the management of solid wastes.

- The **sources of solid wastes** are dependent on the **socioeconomic and technological** levels of a society.





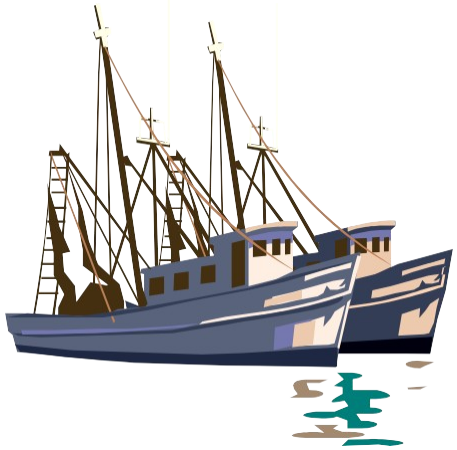


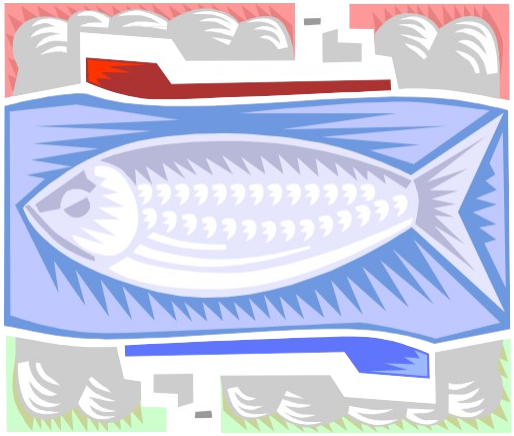


SOURCES…









Types of solid waste

- Solid waste can be classified into different types depending on their source:

1. Residential

This type depend on

- income of the residence (low, medium or high income)
- is in rural, urban, single and multi-family dwellings

Types of solid wastes-

- paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (Bulky items, white goods, batteries), house hold hazardous wastes generated from living households

Types of solid waste

2. Commercial: This depend whether the source is in the urban, sub urban or in rural areas

- The waste from stores, hotels, restaurants, markets, office buildings, shops, etc,

- Types of solid wastes -paper, cardboard, wood, metals, food wastes, glass, plastic, special wastes and hazardous wastes

Types of solid waste

3. Industrial wastes: light and heavy manufacturing, fabrication, construction sites, power and chemical plants

-The nature of the waste depends on the type of industry and kind of raw material involved

Types of solid wastes- house keeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, and special wastes

- There may be toxic and hazardous wastes that have adverse effects to the environment.

Types of solid waste

4. Institutional solid waste: generating from public and government institutions: offices, religious institutes, schools, universities, prisons etc.;.

Types of solid wastes- same as commercial

5. Hospital solid wastes: It consists of both non-hazardous and hazardous waste.

6. Construction and demolition

-New construction sites, road repair, renovation sites,

demolition of buildings

Types of solid wastes- wood, steel, concrete, dirt etc.

CONSTRUCTION WASTE





Polyurethane insulator material marked for removal of the construction site. This material is quite wasteful and alternatives as compressed straw could be better used instead.

Types of solid waste

7. Municipal services

Street cleansing, landscaping, parks, beaches, other recreational areas, water and wastewater treatments

Types of solid wastes-scrap materials, off-specification products, slag, tailings, street swiping

8. Agricultural: due to agricultural activities: food residues, animal dung, crop

Types of solid waste

9. Special waste: are wastes from residential and commercial sources that includes

- Bulky items (like furniture, lamp, bookcases, cabinets etc)
- Consumer electronics (like radio, Tv sets)
- white goods (stoves, refrigerators, dish washers, clothe washers and dryers) and
- other hazardous wastes

Types of solid waste

- Depending on their properties they are categorized into:

1. **BIODEGRADABLE WASTE**

- Biodegradable waste is a type of waste, typically originating from plant or animal sources, which may be degraded by other living organisms.

-Biodegradable waste can be commonly found in municipal solid waste (sometimes called biodegradable municipal waste, or BMW) as green waste, food waste, paper

Types of solid waste

-Other biodegradable wastes include human waste, manure, sewage, sloughterhouse waste.

2.**NON- BIODEGRADABLE WASTE**

-Wastes that cannot be broken down by other living organisms e.g. plastic wastes

Composition of Solid waste

- Is the term used to describe the individual components that make up the solid waste stream and their relative distribution usually based on percentage by weight.
- We need to know the waste composition to evaluate equipment needs, systems, the design and potential of recycling systems, and for planning purposes.
- A full knowledge of the composition of the wastes is an essential element in:

1. The selection of the type of storage and transport methods
2. fostering the optimal design and operation of materials recovery facilities and municipal incinerators;

Composition of...

3. The choice of a suitable method of disposal.
4. The determination of the ev'tal impact exerted by the

   wastes if they are improperly managed.
5. Encourage well - organized and smoothly functioning

   recycling programs.
6. Reduce the amount of waste generated and keep the overall waste management costs low.

SAMPLING PROTOCOLS FOR MSW

- MSW consists of a wide range of materials that vary depending on
  - ✓ the community and its consumers' income and lifestyles,
  - ✓ its degree of industrialization, institutionalism, and commercialism.

In order to compile accurate data, several issues must be addressed

- How to obtain representative samples of the MSW?
- What is the desired sample size?
- How many samples are needed to achieve a desired

1. DIRECT SAMPLING

- Direct sampling is useful on a small scale for obtaining information about MSW composition.
- The direct sampling method involves physically sampling and sorting MSW at the source of generation.
- Although MSW can be extremely heterogeneous, direct sampling is one of the more accurate characterization methods.

- Waste sampling from
  - ✓ single- and multi-family homes,
  - ✓ commercial establishments (restaurants and businesses), and institutions (schools, hospitals) is encouraged, as

Conti....

- Another direct sampling approach is to sample the waste after it has arrived at a centralized collection point or a tipping (i.e., unloading) area.
- This may include a transfer station or disposal facility.
- a sample size of 91 to 136 kg (200 to 300 lb) to be manually sorted at the disposal facility.
- the disadvantage of direct sampling programs based on a limited number of samples is that data may be misleading if unexpected circumstances occurred during

Conti….

- These circumstances could include the delivery of infrequent and exotic wastes, a severe wet or dry season, or errors in sampling methods

- Another disadvantage of direct sampling is that it would be prohibitively expensive for making estimates on a national scale.

2. MATERIAL FLOWS

- This method is useful for estimating waste stream composition and trends on a regional basis.

- The methodology is based on production data (by weight) for materials and products in the waste stream.
- For a particular municipality, inputs and outputs are recorded and compared.

- For example, if a community purchases 500,000 aluminum beverage cans in 1 week, it can be expected that about 500,000 aluminum cans will end up in the waste stream some

•This model is, of course, an oversimplification; and one must also consider that the community is an open system having numerous imports and exports.

3. SURVEYS

- Waste quantity and composition can be estimated by distributing questionnaires to producers of the waste.
- This system typically applies to generators of commercial and industrial wastes, and does not work

VARIABILITY AFFECTING WASTE SAMPLING

- The variation and trends in quantity, composition, and other characteristics of waste are affected by the following factors:
  - » population
  - » affluence/wealth
  - » technology
  - » climate

- It is useful to consider the dynamic nature of the waste generation process according to these four factors.
- Technology may be both an important factor for waste

1. SEASONAL

- To ensure accurate waste generation estimates, wastes should be sampled regularly over a defined period (e.g., one calendar year) to account for seasonal variations.
- The season of the year strongly affects the amounts of yard waste generated,
- Food-processing plants will produce more waste during harvest months.
- More yard waste is produced on weekends; in contrast, more commercial and industrial wastes are produced on weekdays.

- Municipal waste processing and disposal systems must take into account the shifting quantities and composition of waste over the course of a day, a week, or a year.

2. REGIONAL

- Different parts of the country produce markedly different types and amounts of wastes.

3. HOUSEHOLD

- The number of persons per household have a significant influence on waste production
- very low-income households, generate lesser quantity and composition of waste

4. NATIONAL ECONOMY

- There is some correlation between waste generation rates and the overall economy of a country.

Future changes in waste composition

- As more gov’ts adopt waste reduction and recycling programmers there is an impact on the amounts of waste for disposal as well as in the composition of the waste stream
- if all paper and cardboard were recycled, there is a significant decrease in the weight of waste going to the landfill.
- This has implications for future landfill requirements.

CHAPTER THREE

PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF MSW

1. Physical composition of solid wastes

- Knowing the characteristics the physical component of solid waste is important for the following purposes:

  A, for the **selection and operation** of equipment and facilities

  B, to assess the **possibility** for resource of energy recovery

  C, to **design and analyze** disposal

Ways for physical composition Analysis

- **Individual component study**
  - Analyze the components of municipal solid waste by type
  - Sorting and separation of each and every component is necessary
  - Samples each of the heterogeneous refuse of municipal solid waste
  - Should be representative (at all seasons of the year)
  - Statistical produces (representativeness and randomization)

The types (components) of municipal solid waste may be different from country to country by season, economic condition, developmental level, etc

Table 2: typical variation observed in the collected composition of residential municipal solid waste

Waste	Percent by weight	
	Winter season	Summer season
Food waste	11.1	13.5
Paper	45.2	40.0
Plastics	9.1	8.2
Other organics	4.0	4.6
Yard wastes	18.7	24.0
Glass	3.5	2.5
Metals	4.1	3.1
Inert and other wastes	4.3	4.1
	100.0	100.0

Moisture Content

- The moisture content of solid waste is usually expressed in one of two ways

A. In the wet – weight method : is expressed as a percentage of the wet weight of material

B. Dry-weight method, it is expressed as a % age of the dry weight of material.

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

Wet-weight relationship:

- Where: M= wet- weight moisture content, %
- w= initial mass of sample as delivered

Table 3:Typical data on moisture content of municipal solid waste

Component	Moisture Content % by weight	
	Range	Typical
Food wastes	50 -80	70
Paper	4 – 10	6
Card board	4 – 8	5
Plastics	1 – 4	2
Textiles	6 – 15	10
Rubber	1 – 4	2
Leather	8 – 12	10
Garden trimmings	30 - 80	60
Wood	15 - 40	20
Misc. organics	10 - 60	25
Glass	1 – 4	2
Tin cans	2 – 4	3
Nonferrous metals	2 – 4	2
Ferous metals	2 – 6	3
Dirt, ashes, brick, etc	6 – 12	8
MSW	15 - 40	20

Moisture Content….

- To obtain the dry weight, the solid waste material is dried in an oven at 77°C (170 ^{0}F) for 24 hours.

- This temperature and time is used to dehydrate the material completely and to limit the vaporization of volatile materials.

- For most industrial solid wastes, the moisture content will vary from 10 – 35 percent.

Moisture Content….

- The moisture content of municipal solid waste vary depending on
    1. Composition of the waste
    2. The season of the year
    3. Humidity
    4. Weather condition particularly rain

Examples: 1) Estimate the overall moisture content of a sample of MSW as collected, with the typical composition given in the below table

No	Component	% by weight	Moisture content (%)	Dry weight kg
1	Food wastes	9.0	70	2.7
2	Paper	34.0	6	32
3	card board	6.0	5	5.7
4	Plastics	7.0	2	6.9
5	Textiles	2.0	10	1.8
6	Rubber	0.5	2	0.5
7	Leather	0.5	10	0.4
8	Yard wastes	18.5	60	7.4
9	Wood	2.0	20	1.6
10	Glass	8.0	2	7.8
11	Tin cans	6.0	3	5.8
12	Aluminum	0.5	2	0.5
13	Other metals	3.0	3	2.9
14	Dirt, ash, etc	3.0	8	2.8
	Total	**100**		**78.8**

Moisture Content….

Solution

- 1. Step up a computation table to determine the dry weight of the solid waste components using the data in table 3 (based on 100 kg. of as delivered sample).
- The dry weight of solid waste components can be determined using the following relation ship.
- Dry weight in kg = 100 – moisture content X % as delivered weight of 100kg.
- E.g. For food waste = 100 – 70 = 30

Moisture Content….

2. Determine the moisture content using the equation.

$$M = \frac{100 - 78.8}{100} \times 100 = 21.2\%$$

Example 2: - Estimate the moisture content of a solid waste sample with the following composition based on 100 kg of Sample

Component	% By weight
Food wastes	15
Paper	45
Card board	10
Plastics	10
Garden trimmings	10
Wood	5
Tin cans	5
Total	100

Step- 1 set up a computation table to determine the dry mass of the solid-waste sample using the given data.

Component	% By weight	M.C (%)	Dry weight (kg)
Food waste	15	70	4.5
Paper	45	6	42.3
Card board	10	5	9.5
Plastics	10	2	9.8
Garden trimmings	10	60	4.0
Wood	5	20	4.0
Tin cans	5	3	4.9
Total	100		79.0

Moisture Content….

- Step -2) Determine the moisture content using the equation

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

$$M = \frac{100 - 79}{100} X\ 100 = 21\ \%$$

Exercise: Estimate the moisture content for a waste sample with the following composition:

Component	% By weight
Food waste	12
Paper	40
Card board	8
Plastic	4
Garden training	15
Wood	5
Inert (misc.)	16

Initiative Ethi

Density

- it is defined as the weight of the material per unit volume.
- The interest in knowing density of solid waste is to assess the total mass and volume of waste that must be managed.
- The densities of solid waste vary markedly with:
    1. Geographic location
    2. Season of the year
    3. Length of time in storage

Density…

- Great care should be taken in selecting typical weight or density values.

The densities of municipal solid wastes as delivered in compaction vehicles have been found to vary from 178 to 415 Kg/m^3; a typical value is 297 kg/m^3.

2. Chemical composition

- It is important in evaluating **alternative processing and recovery options.**

- For example, the **feasibility of combustion** depends on the **chemical composition** of solid waste.

If solid wastes are to be used as **fuel**, the **four** most important properties to be known are:

A. Proximate Analysis

- Proximate analysis for **combustible components** of municipal solid waste includes the following tests
  - Moisture (loss of moisture when heated to 105 ^{0}c for 1h)
  - Volatile combustible matter (additional loss of weight on ignition at 950 ^{0}c in a covered crucible)
  - Fixed carbon (combustible residue after volatile matter is removed)
  - Ash (weight of residue after combustion in an open crucible

B. Fusing point of ash:

- is defined as the **temperature at** which the ash resulting from the **burning of waste** will form a solid (clinker) by **fusion and agglomeration**.
- Typical **fusion temperature** for the formation of clinker from solid waste ranges from **1100 to 1200°c**.

C. Ultimate analysis:

It involves the determination of the percent of C (carbon), H (hydrogen) O (oxygen), N (nitrogen), S (sulfur) and ash.

The results are used to characterize the chemical composition of the organic matter in

Table 4: Typical data on ultimate analysis of the combustible components in municipal solid waste Percent by weight (dry basis)

Component	C	H	O	N	S	Ash
Food waste	48.0	6.4	37.6	2.6	0.4	5.0
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Card board	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
Misc organics	48.5	6.5	37.5	2.2	0.3	5.0
Dirt, ashes, brick, etc	26.3	3.0	2.0	0.5	0.2	68.0

D. Energy content:

- the energy content of the organic components in municipal solid waste can be determined;
  - By using a full scale boiler as a calorimeter
  - By using a laboratory bomb calorimeter
  - By calculation if the elemental composition is known

Energy values as discarded basis may be converted to a dry basis by using:

$$\frac{KJ}{Kg}(dry\ basis) = \frac{KJ}{Kg}(as\ discarded)\left(\frac{100}{100 - \%\ moisture}\right)$$

The corresponding equation for a dry ash-free basis is:

$$\frac{KJ}{Kg}(dry\ ashfree\ basis) = \frac{KJ}{Kg}(as\ discarded)\left(\frac{100}{100 - \%\ moisture - \%\ ash}\right)$$

Table 5: Typical data on inert residue and energy content of municipal solid wastes

Component	Inert residue (after complete combustion.) %		Energy, KJ/kg (as discarded basis)	
	Range	Typical	Range	Typical
Food wastes	2-8	5	3,5000-7,000	4,650
Paper	4-8	6	11,600-18,600	16,750
Cardboard	3-6	5	13,950-17,450	16,300
Plastics	6-20	10	27,900 –37,200	32,600
Textiles	2-4	2.5	15,100 –18,600	17,450
Rubber	8 - 20	10	20,900 – 27,900	23, 250
Leather	8 – 20	10	15,100 –19,800	17,450
Garden trimmings	2 -6	4.5	2,300 – 18,600	6,500
Wood	0.6-2	1.5	17,450-19,800	18,600
Misc. organics	2-8	6	11,000- 26,000	18,000
Glass	96-99	98	100 - 250	150
Tin cans	96-99	98	250 – 1,200	700
Non–ferrous metals	90–99	96	-	-
Ferrous metals	94 – 99	98	250 – 1,200	700
Dirt, ashes, bricks, etc	60 - 80	70	2,300 – 11, 650	7,000
MSW	-	-	9,300 – 12, 800	10,500

Example:

Estimate the energy content of a solid waste sample with the composition given below

SOLUTION: Step -1) set up a computation table to determine the total as discarded energy content of the solid

Component	Percent by weight	Energy KJ/Kg	Total energy, KJ (Based on 100-Kg sample)
Food waste	15	4,650	69,750
Paper	45	16,750	753,750
Card board	10	16,300	163,000
Plastics	10	32,600	326,000
Garden trimmings	10	6,500	65,000
Wood	5	18,600	93,000
Tin cans	5	700	3,500
Total	100		1,474,000

Conti…

Step 2) Compute the unit energy content

$$\text{Energy content} = \frac{1{,}474{,}000\ \text{KJ}}{100Kg} = 14{,}740\ \text{KJ/kg}$$

Step 3) Determine the energy content on a dry basis

a) Moisture content is 21.0 percent (as calculated)

b) The energy content on dry basis is :

$$\frac{KJ}{Kg}(dry\ basis) = 14{,}740\frac{KJ}{Kg}\left(\frac{100}{100-21.0}\right) = 18658$$

Step 4) Determine the energy content on an ash –free dry basis

a) Assume the ash content is equal to 5%

$$\frac{KJ}{Kg}(dry\ ashfree\ basis) = 14{,}740\ \frac{KJ}{Kg}\left(\frac{100}{100-21.0-5}\right) = 19919$$

If energy values are not available, approximate energy values for the individual waste material can be determined by using the equation known as "modified Dulong formula & the data on tables

$$\frac{KJ}{Kg} = 337C + 1428\left(H_2 - \frac{1}{8}O_2\right) + 93S + 23N \quad \text{.....Dulong equation}$$

Where: C = carbon, in percent by weight

H = Hydrogen in percent by weight

O = Oxygen in percent by weight

S = Sulfur in percent by

3. Biological properties of MSW

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

An alternative is the **lignin content** can be used to determine **biodegradability**:

The organic fraction of most MSW can be classified

1. water soluble constituents such as **sugars, starches**
2. Hemi-cellulose :- a condensation product of 5-6 carbon sugar
3. Cellulose:- a condensation product of 6 carbon sugar glucose
4. Fats, oils, and waxes that are Easters of alcohols and long chain fatty acids
5. **Legnin**, lingo cellulose and proteins
    - Legnin ia a ploymetric material containing aromatic rings with methoxyl group (-OCH_3)

1. Bio-degradability of organic waste components

- VS, volatile solids, ignition at **550ºC** is often used as a measure of the **biodegradability** of the organic fraction.
- The use of VS in describing the bio-degradability of the **organic content**
- Use of the **lignin content** of a waste to estimate the biodegradable fraction
- **BF = 0.83 - 0.028 LC ; where, BF=** biodegradable fraction, 0.83 & 0.028= empirical constant, **LC**= lignin content of the VS expressed as a % of dry weight

2. Production of odors

- Odors can be develop when SW are:
  - Stored for **long periods** of time onsite in transfer station and in land fills
  - **Odor** is more significant in **warm climates**
  - Significant **odor formation** in anaerobic decomposition
  - Eg. Sulfates sulfides hydrogen sulfide

3. Fly breeding

- It is an important consideration mainly in **summer** (hot climates)
- **Fly breeding** is dependant on onsite storage time.
- The life history of the CHF from egg to adult can be described as follows.
  - Eggs develop- 8-12hrs
  - 1st stage of larva period 20hr
  - 2nd stage of larva period 24hrs
  - Pupal stage 4-5
  - Total **9-11 days**

Physical, Chemical and Biological Transformations

A. Physical Transformations

- **Component separation**

Separating identifiable matter from the commingled MSW.

- Used to:
  - **Recover** usable material
  - **Remove** contaminants
  - **Improve** specifications for the separated material
  - **Remove** hazardous waste
  - **Recover energy** and conversion products

- **Mechanical Volume Reduction (Densification)**

  - The initial volume is reduced usually by force or pressure.

  - Compaction, baling.

- **Mechanical size reduction**
  - Purpose:
  - **reduce size**
  - create a more **uniform product**
  - Size reduction does not necessarily mean **volume reduction**, shredded paper occupies more volume than the parent material
  - **Shredding, grinding, milling**

B. Chemical Transformations

1.) Combustion (Incineration)

- Combustion is the chemical reaction of oxygen with organic materials, to produce oxidized compounds with the emission of light and heat.

- Results in gasses, ashes and heat, highly **exothermic**.

2.) Pyrolysis (Destructive Distillation)

- The splitting of organics by thermal cracking and condensation in an oxygen-free atmosphere into **gaseous, liquid and solid fractions.**
- Highly **endothermic**.
- Equation $\longrightarrow$

  $$\mathbf{3(C_6H_{10}O_5) \longrightarrow 8H_2O + C_6H_8O + 2CO + CH_4 + H_2 + 7C}$$

- In which:
  - $\mathbf{C_6H_{10}O_5}$ is cellulose
  - the gases are $\mathbf{CO + CH_4 + H_2}$
  - the tar and/or oil stream is $\mathbf{C_6H_8O}$

3.) Gasification

- Partial combustion of a **carbonaceous fuel** to generate a **combustible fuel gas** rich in **carbon monoxide, hydrogen and methane.**

- The **fuel gas** can then be combusted.

C. Biological Transformations

- Used to:
  - Reduce weight and volume
  - To produce compost
  - To produce methane
- Principal MOs:
  - bacteria
  - fungi
  - yeasts
  - actinomycetes
- Aerobic composting, biological decomposition
- Anaerobic digestion yields methane.

CHAPTER – 4

ENGINEERING PRINCIPLES OF SOLID WASTE MANAGEMENT

By Gedeno K.

Topic Outline

1. **Engineering Principles of Solid Waste Management**
   - Integrated Solid Waste Management
   - Functional Elements of Solid Waste Management
   - Waste reduction and materials recovery
2. **Disposal options of solid wastes**
   - Composting
   - Sanitary Landfill Planning, Design, And Operation
   - Incineration
   - Other Disposal Options :(Indiscriminate

Introduction

- What is ISWM?

- What do you think is the current practice of municipal solid waste management in our country?

Introduction

Typical considerations in SWM

- Protecting community health and safety.
- Protecting the natural environment.
- Complying with federal and regional laws.
- Protecting and conserving natural and cultural resources.
- Contributing to the economic development of the community.

Definition of ISWM

- ISWM refers to the strategic approach to sustainable management of solid wastes covering all sources and all aspects:
  - Generation,
  - Segregation,
  - Transfer & Transport,
  - Processing & recovery,
  - Treatment, and
  - Final disposal in an integrated manner, with an emphasis on maximizing resource use efficiency
- ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions

What is ISWM?

- ISWM proposes to take a comprehensive approach across all types of solid waste streams and involves the use of a range of different options.
- It is a system developed from generation to disposal and builds around the other management steps encompassing all types of solid wastes.
- The selection of the most appropriate waste management systems and sustainable technologies are also needed to deliver an optimum and sustainable ISWM system.
- In combination with economic and social considerations, this approach would help


Integrated Sustainable Waste Management
STAKEHOLDERS
Local Authorities
NGOs / CBOs
Service users
Private informal sector
Private formal sector
Donor agencies
WASTE SYSTEM ELEMENTS
Generation & Separation
Collection
Transfer & Transport
Treatment & Disposal
Reduction
Re-use
Recycling
Recovery
Process time
Sustainability
ASPECTS
Technical
Environmental / Health
Financial / Economic
Socio-cultural
Institutional
Policy / Legal / Political

What is ISWM…

- **Thus, for the management of solid waste, the following is the preferred hierarchy of approaches**
  - **Reduction at source** - meaning incorporation of the tenets of waste management at every stage of consumption from design, manufacture, purchase, or use of materials to reduce the amount or toxicity of waste generated.
  - **Environmentally suitable reuse and recycling** - to conserve natural resources and energy through

A comprehensive MSWM system includes

- Setting policies; developing and enforcing regulations;
- Planning and evaluating municipal SWM activities by system designers, users, and other stakeholders;
- Using waste characterisation studies to adjust systems to the types of waste generated;
- Physically handling wastes and recoverable

MSWM cont…

- Marketing recovered materials to brokers or to end- users for industrial, commercial, or small-scale manufacturing purposes;
- Establishing training programs for MSWM workers;
- Carrying out public information and education programs;
- Identifying financial mechanisms and cost recovery systems;

MSWM cont…

- Establishing prices for services, and creating incentives;
- Managing public sector administrative and operations units; and
- Incorporating private sector businesses, including informal sector collectors, processors, and entrepreneurs.

Methods for integrating a waste system

- Planners can work toward integrated systems in a number of ways
  - The first task is to ***consider all aspects*** of the formal part of the waste system **within one framework** and to produce a plan based on the objectives of the entire system.
    - One of the foundations of the framework for modern, ISWM systems is the solid waste management **hierarchy**

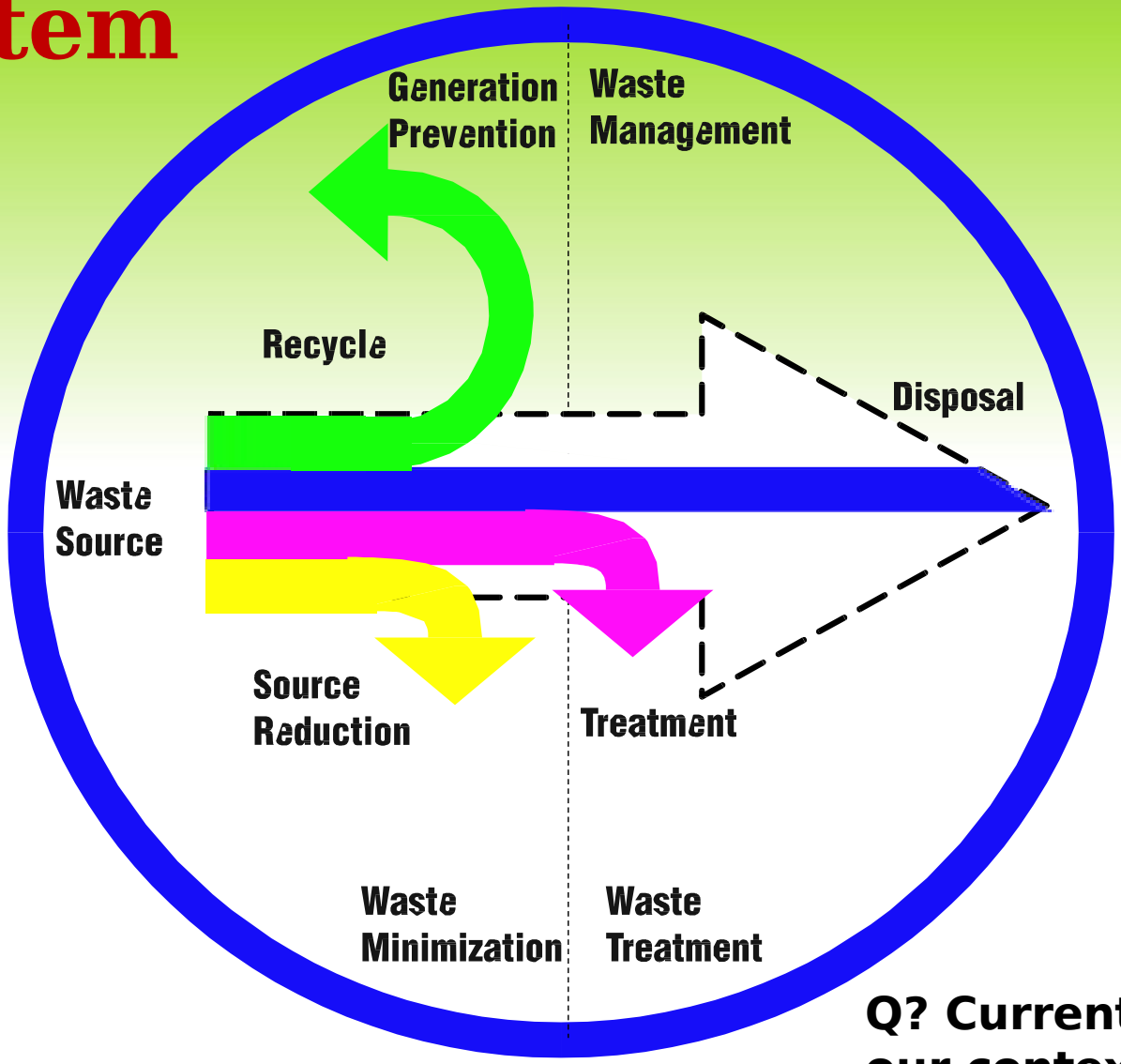
Method cont…

- Second, ***Putting all administration and staffing issues*** and waste-related functions **under the same division or agency**

- A third way of **facilitating coordination and assessing trade-offs among all aspects** of a waste management system is to ***create integrated financial structures***

  – For example, use disposal fees to finance

Waste management system



Q? Current practice in our context

Waste management hierarchy

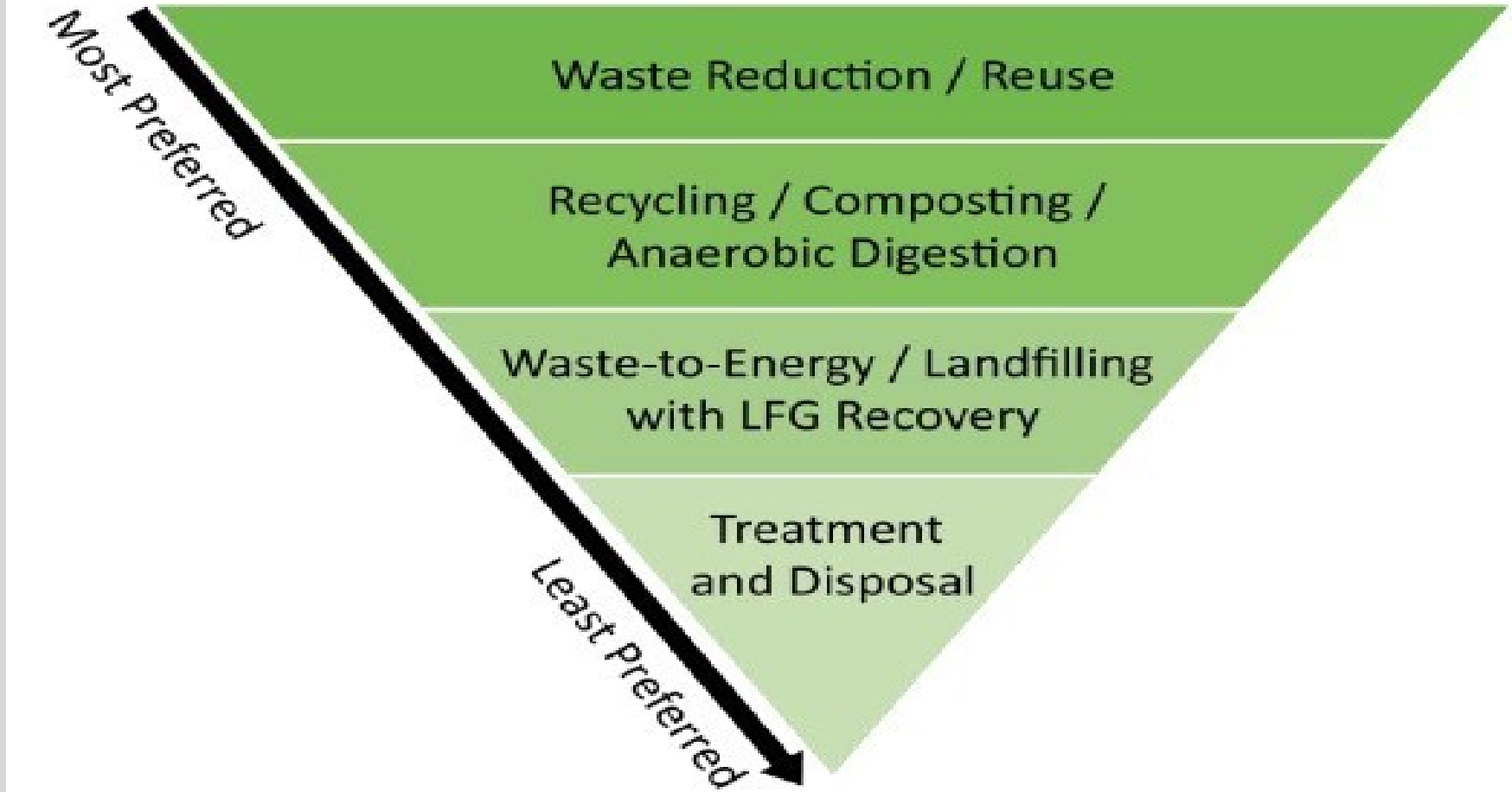


Figure 1-4. Preferred Components of Integrated Solid Waste Management

Waste management hierarchy cont…

- The purpose of the waste management hierarchy is to make waste management practices as environmentally sound as possible

- The hierarchy is a useful policy tool for conserving resources, for dealing with landfill shortages,

- For minimising air and water pollution, and for protecting public

Major Components of Integrated Solid Waste Management

- To address the waste management challenges, cities and relevant government entities have focused on developing and implementing a variety of ISWM strategies to tackle the long-term management of waste.

- The primary elements of ISWM are:
  - Waste reduction
  - Reuse
  - Recycle and

Waste reduction

- Also referred to as:
  - Source reduction,
  - Waste avoidance or
  - Waste prevention

- Waste reduction aims to change the way products are made and used to minimize waste generation

Waste reduction cont…

- Waste reduction has the two-fold benefit
  - ***Reducing raw material inputs and all of the cost*** and energy savings encompassed by this reduction, and
  - ***Reducing the volume*** of waste that needs ***to be managed*** and disposed of properly
- Waste reduction conserves resources; reduces SWD costs and pollution.

Examples of waste reduction

- Reduce office paper by establishing electronic data base
- In manufacturing industries using quality raw materials
- Redesign packaging to eliminate excess material while maintaining strength
- Work with customers to design and implement a packaging return program

Reuse

- Reusing products rather than discarding them after a single use
- It is repeated use of items prior to disposal and/or repair the item
- **Benefits**
  - Reuse conserves raw materials,
  - reduces energy consumption and transportation, reduce emissions, and
  - results in SWD cost savings and reduced gas emissions

Examples of reuse

- Reuse office furniture and supplies, such as interoffice envelopes, file folders, and paper
  - Use durable house furniture and other products
  - Use durable packaging materials
  - Others?....

Recycling

- Recycling involves the collection of used materials and the reprocessing or remanufacturing of these materials into usable products or materials

- Recycling can be accomplished by separate collection of recyclable materials from households and businesses

- Recycling materials such as metals, paper, plastics and wood saves gas emissions by reducing the amount of solid waste requiring disposal and providing a substitute for virgin raw materials in

Benefits of recycling

- Reduce environmental degradation
- Making money out of waste (the case of urban agriculture, informal waste collectors)
- Considerable saving in cost due to transportation and disposal
- Energy cost
- Do you think that we Ethiopians practice recycling?

Benefits of recycling…

- **Savings through recycling:**

-When Al is re-smelted: considerable saving in cost

-Making paper from waste saves 50% energy

-Every tone of recycled glass saves energy equivalent to 100 litres of oil

Examples of recycling

- Manufacturing card board and other paper from used paper
- Manufacturing plastic bags or bottles from used plastic wastes
- **Example:** Addis Ababa manufacture of plastic conduits from waste plastics
  - Paper recycling in Addis Ababa
- Manufacturing furniture or other materials from scrapped metals or wood
- Manufacturing glass from scrapped glass

Material sorted for Recycling



Materials Recovery

Technological Options

1

- **Bio-chemical conversion**
  - Composting
  - Bio-methanation

2

- **Thermo-chemical Conversion**
  - Pyrolysis & Gasification
  - Plasma Pyrolysis
  - Refuse Derived Fuel (RDF)

Examples of Recovery

- **Composting**
  - uses the natural decomposition of organic matter, such as food and yard wastes
  - Compost is a humus-like material that can be added to soils to increase fertility, aeration and nutrient retention
  - Small-scale or backyard composting can be used as a method of managing

Examples of recovery cont…

- Anaerobic Digestion
  - Involves the conversion of biodegradable organic matter to energy by microorganisms in the absence of oxygen.
  - The biogas produced in the digestion process is a mixture of methane and carbon dioxide and can be used as a fuel source for heating or electricity production

Examples of recovery cont…

- **Waste-to-Energy**
  - Also referred to as waste combustion or incineration
  - it is the controlled combustion of wastes in a modern furnace equipped with pollution controls that produces steam or electricity
  - It is an effective means for converting waste to energy and significantly reduces the volume of waste and the proportion of organic matter that is placed in a landfill, which in turn reduces the production rates

Benefits of ISWM

- Lower costs of overall waste management;
- Less environmental pollution (of soil, water & air);
- Conservation of raw materials;
- Conservation of resources, since appropriate planning doesn’t allow inappropriate investments;
- Better coordination between urban services;

Benefit cont…

- More active citizens who contribute to urban development;
- People that are more satisfied with the service provided and thus less inclined to subversive activities;
- Built of a Better image of a city/region;
- Fewer health hazards;
- Better cost management and higher cost recovery

FUNCTIONAL ELEMENTS OF WASTE MANAGEMENT SYSTEM

Introduction

- The **problem associated with the management** of solid wastes in today's society are complex because of
  - the **quantity and diverse** nature of the wastes,
  - the **development of sprawling** urban areas,
  - the **funding limitations** for public services
  - the **impacts of technology**, and **the**

Con't

- Indiscriminate dumping of **solid waste and failure of the collection system** in a populated community would soon cause many **health problems**.
  - **Odors, flies, rats, roaches, crickets, wandering dogs and cats, and fires** would dispel and
  - remaining doubts of the importance of proper solid waste storage, collection and disposal.

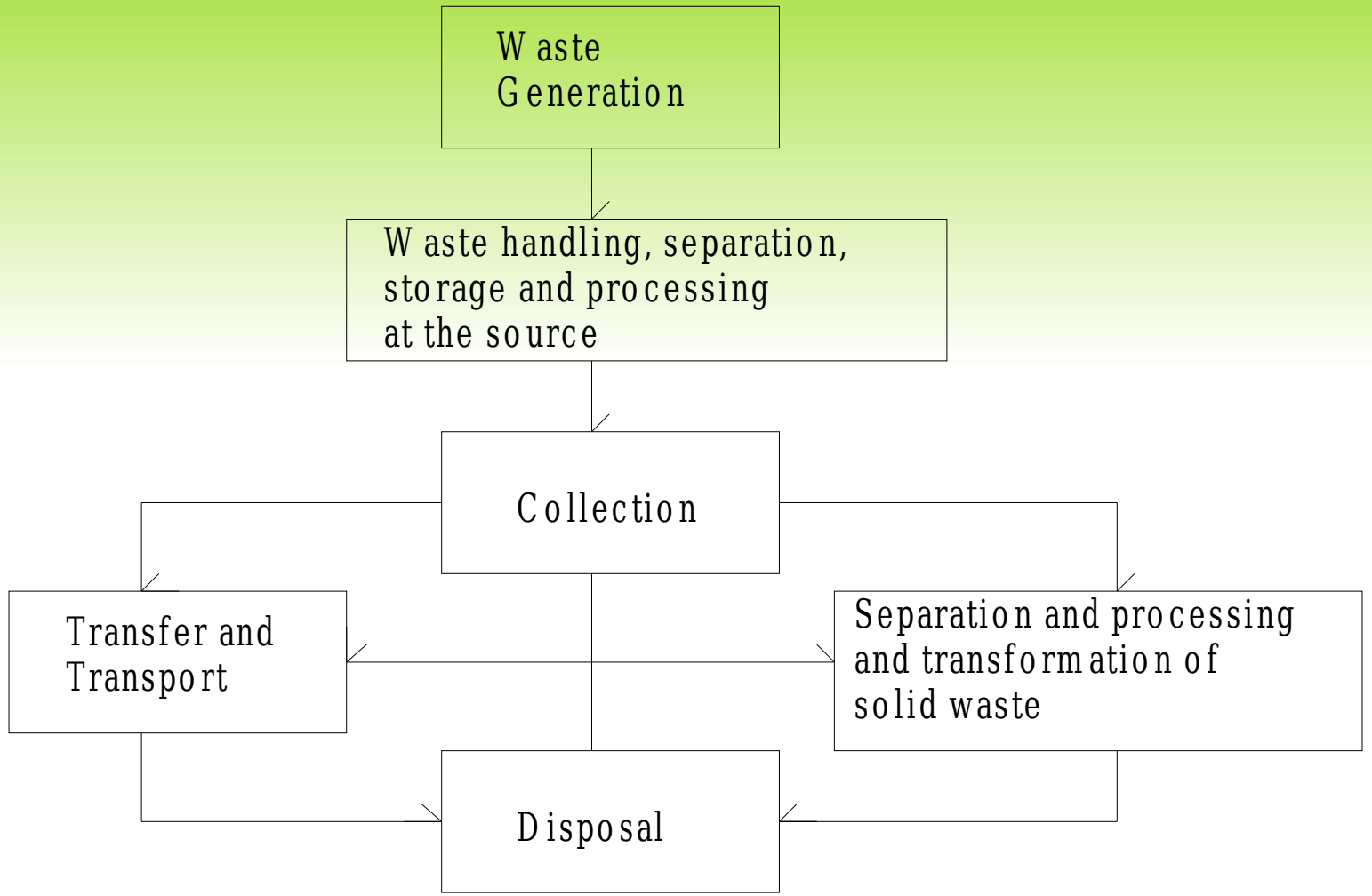
Con't

- The activities involved with the **management of solid wastes** from the **point of generation to final disposal** have been grouped into **six functional elements**:

  1) **Waste generation:**
  2) **On-site handling, storage, and processing**:
  3) **Collection:**
  4) **Transfer and transport:**
  5) **Processing and recovery**: and
  6) **Disposal.**

Con't

Functional elements of MSWMS



1. Solid Waste Generation

- It encompasses **activities** in which materials are identified as **no longer being of value** and are either **thrown away or gathered** together for disposal
- It is important in waste generation to note that there is an **identification step** and that this **step varies** with each individual waste.
- **Knowledge of the quantities** of solid wastes generated, separated for recycling, and collected for further processing or disposal is of **fundamental**

Con't

- **Expression of unit generation**
  - In addition to knowing the **source and composition** of solid waste, it is equally important to have **uniform units of expression.**
  - **universally accepted units for**:
  - Household waste (**kg/capita/day**)
  - Commercial waste (**kg/x/day** , where x can be **m^2** of floor area of commercial establishment, the number of employees, etc.)
  - Institutional waste (**kg/x/day,** where x can be the number of students, m^2 of the area of park or public place, number of visitors

Con’t

- Market waste (**kg/x/day**, where x can be the **number of market lots**, m^2 of floor area, dollar in sales, etc.)
- Industrial waste (**kg/x/day**, where x can be **unit volume**, m^2 of floor area, **the number of employees**, etc.)
- street sweeping waste (**kg/km/day**)
- drain cleaning waste (**kg/km/day**)
- total waste (**kg/capita/day**)

Con't

Methods used to estimate Waste Quantities

- Waste quantities are usually estimated on the basis of data gathered by
  - **conducting** a waste characterization study,
  - using **previous** waste generation data or
  - some combination of the **two** approaches
- **Methods commonly used to assess solid waste quantities are**
  - **1. load-count analysis,**

Con't

- **Load-Count Analysis.**
  - In this method, the number of individual loads and the **corresponding waste characteristics** (types of waste, estimate volume) are noted over a specified time period.
  - If scales are available, **weight data** are also recorded.
  - It may estimate the **vehicular capacity** and the **number of vehicles** of that capacity.

Con't

- **Weight-Volume Analysis.**
  - Both **weight & volume** data can be obtained by **weighing and measuring** each load.
  - The use of volume as a measure of quantity is **misleading** as the quantity is different for lose and compacted piles.
  - **Weight records** are necessary in the transport of SW
  - **Volume and weight** are equally important with respect to the capacity

Con't

- **Materials Mass Balancer Analysis.**
  - We can have a **good degree of reliability** to determine waste by **performing detailed materials balance analysis.**
  - In some cases, the **materials balance method** of analysis will be required to obtain the data needed to verify compliance with **state-mandated recycling** programs.

Con't

- **Preparation of Materials Mass Balances.**
  - The approach to be followed in the preparation of a material mass balance analysis is as follows.
  - **First, draw a system boundary** around the unit to be studied.
  - **Second**, identify all the activities that **cross or occur within the boundary and affect** the generation of wastes.
  - **Third**, identify the **rate of waste generation** associated with each of these activities.

Con't

Rate of accumulation of materials with the system boundary = Rate of flow of materials into the system boundary − [Rate of flow of materials out the system boundary + Rate of generation of waste materials with in the system boundary]

accumulation = In flow − [out flow + Generation]

Solid Waste Generation Rates con't…

- It estimates the **amount of waste created** by **residences or businesses** over a certain amount of time (day, year, etc.).
- Waste generation includes **all materials discarded**, whether or not they are later **recycled or disposed** in a landfill.
- It can be used to estimate **the impact of new developments** on the **local waste stream**.
- it may be useful in providing a **general level of information** for **planning**

Variation in Generation Rates

- The quantities of solid waste generated vary **daily, weekly, monthly and seasonally.**
- Information on the variations to be expected in the peak residential waste generation rate usually peak during **Christmas holiday** season and during spring house cleaning days.
- In general, as the **size of the waste source increases** (e.g. from individual residences to a community) the **variation in the peak day, week and month**

Factors that affect waste generation rates.

A. Source Reduction and Recycling.

- Decrease **unnecessary or excessive packing**.
- Develop and use products with **greater durability and reparability.**
- Substitute **reuse-able products** for disposable single use products e.g. plastic cups and plates can be replaced by reuse-able plates and cups.
- Increase the **recycled materials** content of products.
- Develop **rate structure** that encourage generators to produce less waste

Con't

B. public Attitudes and legislation.

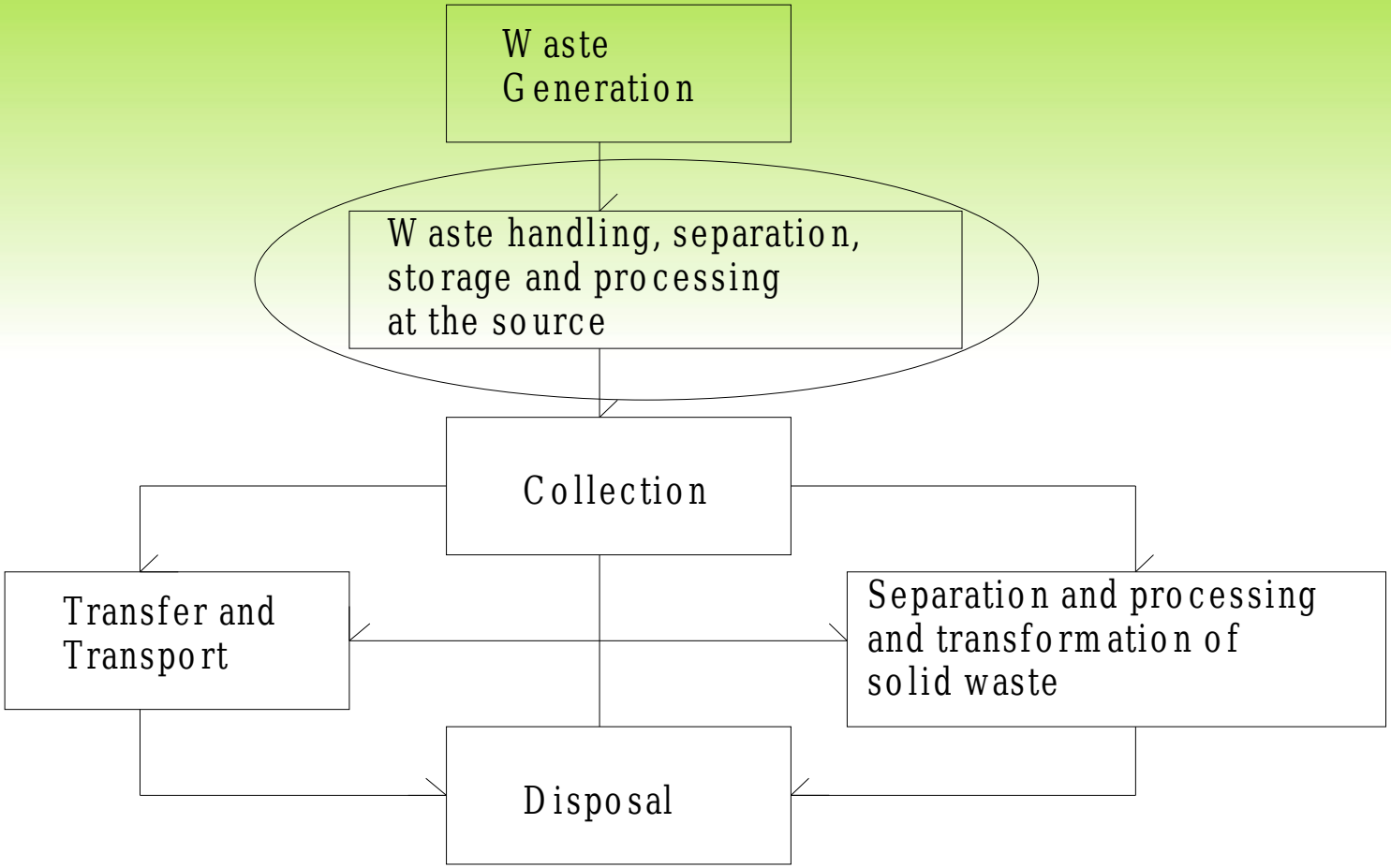
- Significant reductions of solid wastes generated occur **when and if people are willing** to change like:
  - of their **own volition** (one's power to decide/choose/control).
  - their habits and lifestyles to **conserve natural resources**.
- A program of **continuing education** is essential in bringing about a change in public attitudes.
- The most important factor affecting the generation of certain types of wastes is the **existence of local, state and federal regulations** concerning the use of specific materials.
- Price **difference (5-10%)** for recycled material is

Con't

C. Geographic and physical factors

- Geographic location like different influence both the amount of certain types of solid wastes generated and the time period over which the wastes are generated.
- **Season of the year** e.g. during winter the **consumption of charcoal and wood** is more.
- **Harvesting time** is vary from one location to the other location
- **Frequency of collection**

Waste handling and separation, storage and processing at the source



Con't

- It is the **second** of the six functional elements in the sold waste management system.
- this element can have a significant effect
  - on the **characteristics of the waste**,
  - on **subsequent functional elements**,
  - on **public health and on public attitudes** concerning the operation of the waste management system,
  - it is important to understand the activities in this step/ element.

Con't

- **Handling** refers to activities associated with MSW **before** they are placed in a **collection container.**
  - May also include handling of the **collection container** to and from the collection point.
- Handling process vary depending on the:
  - **Types of waste material** that are separated for **re-use and recycling.**
  - The **extent to which these materials** are **separated** from the waste stream

Separation and Recycling:

- The separation of solid waste components including wastepaper, cardboard, aluminum cans, glass and plastic containers at the sources of generation is one of the **most positive and effective** way to achieve the **recovery and reuse of materials.**
- Some homeowners **store the separated** components **within the home**, periodically transferring the accumulated wastes to **large containers** used for the storage of these materials between collections.
- Some owners prefer to take them directly in the containers used for **storage of these materials**

Con't

- In some collection systems, mixed wastes are placed in a **variety of storage containers** with little or no standardization.
- In other systems, mixed wastes are placed in a **large containers** equipped with wheels.
- In both of these systems, the **homeowner or tenants** are responsible for **transporting the containers** filled with wastes to the **street curb for collection**.
- In some residences, **waste compactors** are being used to reduce the volume of the waste to be collected.

Storage of solid wastes at the source:

- Factors that must be considered in the **onsite storage of solid** wastes include:
- **the effect of storage on the waste components;**
- **the type of container to be used**
- **the container location;**
- **public health and aesthetics**

A. Effects of storage on waste components:

- An important consideration at the onsite storage of wastes is the effects of storage itself on the characteristics of the waste being stored.

- These effects of storing waste include:
  - a) **microbiological decomposition**
  - **b) the absorption of fluids**
  - **c) the contamination of waste components.**

B. Types of containers:

- To a large extent, the **types and capacities** of the containers used depend on
  - the **characteristics and types** of solid wastes to be collected,
  - the **type of collection system** in use,
  - the **collection frequency** and
  - the **space available** for the placement of containers.

Con't

- **Garbage and refuse** should be collected and stored in properly designed and constructed **water-proof garbage cans, made from galvanized iron sheet** or **plastic materials.**
  - They should have **tight-fitting covers**.
  - They must be of such size that when full they can be **lifted easily by one man.**
  - They should be located in **a cool place on platforms** at least **30 centimeters** above ground level.
  - The dustbins must be covered after **use,**

Con’t

- Containers should be
  - **water tight,**
  - **rust resistant,**
  - **with tight fitting covers,**
  - **fire-resistant,**
  - **adequate in size,**
  - **light in weight** with side handles and washable

Con't

- ***Containers sizes:*** Consideration should be given for the size of the loaded container that must be hauled to the collection vehicle or to the disposal site. Therefore container size for :
  - Ash can be up to **80-128 liters**,
  - mixed refuse should not exceed **120-128 liters**,
  - rubbish can be up to **200 liters**,
  - kitchen waste **40 liters** and
  - garbage is **40-80 liters**.

Con't

- **Galvanized metal** is preferable for garbage storage because it is resistant to corrosion.
- **Plastic cans** are light in weight but are easily damaged by rats, crack by ultraviolet light.
- **Bulk containers** are recommended where large volumes of refuse are generated such as hotels, restaurants, apartment houses and shopping centers.
- **Temporary and disposable containers** such as paper bags, cardboard boxes, plastic containers and bags and wooden boxes are routinely used **as temporary and disposable containers** of accumulated

Con't

C. Containers storage locations:

- In low dwellings
  - at the sides or at rear (back-garden) of the house;
  - in alley (path/area between two houses) ;
  - in or next to the garage
- In high dwellings
  - Basement **storage or outdoor** storage.

Con't

D. Public Health and Aesthetics: relates to **on-time collection** to avoid the spread of diseases by vectors, etc

- Typically, proper sanitation involves:
  - the use of containers with tight lids.
  - the periodic washing of the containers as well as of the storage areas.
  - the periodic removal of biodegradable materials (usually within less than 8 days), which is especially important in areas with warm climates.

Aesthetics:

- must be pleasing to the eye (containers must

Con't

Processing of solid wastes at residential area

- Waste processing is used to:
  - 1) **Reduce the volume**
  - **2) Recover usable materials**
  - **3) Alter (change)** the physical form of the solid wastes.
- The most common onsite processing operations used at low-rise detached residential dwellings include: **Food waste grinding, Component separation, Compaction, **

Con't

 Backyard incineration, once a common processing technique (still practice in Gondar) used to **reduce the volume of waste**, is no longer allowed in most urban areas.

 Grinding of food waste: Commonly used in developed countries. These (grinders) are used primarily for wastes from the preparation, cooking and serving of foods (not used for bones and bulky items).

- Functionally, grinders render the material that passes through them suitable for

Con't

- **Compaction:** Two types for residential areas are
  - 1) Small (individual) home apartment compaction units.
  - 2) Large compactors used to compact wastes from a large number of apartment.
  - Compactors can reduce the original volume of wastes placed to them by up to 70%.
- **Compositing:** During 1970's home compositing as a means of recycling organic materials increased in popularity. In backyard compositing individual home owner develop some method of compositing yard wastes.

3. Collection of Solid Wastes

- The term collection includes
  - the **gathering or picking up** of solid wastes from the various sources, and
  - the **hauling of these wastes** to the location where the content of the collection vehicles are emptied.
  - The **unloading of the collection** vehicle is also considered part of the collection operation. (hauling means - to carry goods in a vehicle).

Con't

- Collection of solid waste is an urban area is **difficult and complex** because:
  - The generation of waste takes place in **every where.**
  - the **mushroom** like development of suburbs all over the country.
  - As the pattern of waste generation become more diffuse and the **total quantity of waste increases**, the **logistics of collection become complex**.
  - **High costs of fuel and labor** e.g. generally **50-80%** of money used in

Con't

Types of collection services:

- **From low-rise detached dwellings:**
- The most common types of residential collection service for low-rise detached dwellings include:
  - **1) Curb,**
  - **2) Alley.**
  - **3) Setout-setback,**
  - **4) Setout**.

Con't

- In **curb service,**
  - the homeowner/person living in that house is **responsible** for placing the container to be emptied at the curb on collection day and for returning the empty containers to their location until the next collection.
- In **Alley** (path, area covered or surrounded by bushes/plants etc.),
  - where alleys are part of the basic layout of a city or a given residential area. Alley storage of containers used for

Con't

- In **Setout-setback service,**
  - containers are setout from the homeowner's property and setback after being emptied by **additional crews** with collection vehicles.

- **Setout service**
  - It is essentially the same as setback-setout service, except that the homeowner is responsible for returning the containers to their storage location.

Con't

- **Manual methods for the collection of residential waste include**
  - ►the **direct lifting and carrying** of loaded containers to the collection vehicle for emptying.
  - ►the **rolling of loaded containers** on their rims to the collection vehicle for emptying.
  - ►the **use of small lifts** for rolling loaded containers to the collection vehicle

Con't

- **From low and medium-rise apartments:**
  - **Curbside** collection service is common.
  - In these apartments **maintenance staff** is responsible for carrying the containers mechanically or manually to curbside collection.
- **From high-rise apartments:**
  - Large container collection system is used commonly.

Con't

- **From commercial –industrial facilities:**
  - Both manual and mechanical means are used to collect waste.
  - To avoid traffic congestion during the day, solid waste in many large cities are collected in the late evening and early morning hours.
  - Two-three collectors with one driver in a crew collect the wastes.
  - Plastic bags, cardboard boxes, disposable containers are used for manual collection in curb type collection system.
  - Movable containers are also used to avoid

Types of collection systems

- According to the mode of operation, collection systems have been classified into two categories:

A. Hauled containers systems(HCS):

- The containers used for the storage of waste are hauled to the disposal site, emptied and return to either original location or some other location.
- These HCS are ideally suited for the removal of wastes from sources where the rate of generation is high, because relatively large containers are used.
- Use of large containers reduces handling

Con't

- This system (HCS) requires only one truck and driver to accomplish the collection cycle, each container picked up requires a round trip to the disposal site.
- There are three main types of hauled container systems:
  - **Hoist truck:** large capacity of mechanically loaded collection vehicles.
  - **Tilt-frame container system**: Use tilt frame-loaded vehicles and large containers, often called drop or debris boxes.
  - **Trash-trailer:** Good for heavy rubbish, such as sand, timber, metal scrap

Con't

B. Stationary container systems:

- In this type the collection container is **stationary.**
- They are not carried over to disposal site for emptying.
- These are of two types:
  - 1. System in which mechanically loaded collection vehicles are used
  - 2. System in which manually loaded collection vehicles are used.

Con't

- The **activities** involved in the collection of solid wastes can be resolved into 4 unit operations:

1. **Pick up:**

- Refers to the time spent driving to the next container after an empty container has been deposited,
- the time spent picking up the loaded container and
- the time required to redeposit the container after its contents have been emptied.

Con't

2. Haul:

- Represents the **time** required to reach the disposal site starting after a container whose contents are to be emptied has been loaded on the truck plus
- the time spent after **leaving** the disposal site until the truck arrives at the location where the empty container is to be deposited.

Con't

3. At-site:

- The unit operation at-site(s) refers to the time spent at the location where the contents of the container are unloaded and includes
- the time spent waiting to unload as well as the time spent unloading the waste from the container or collection vehicles.

4. Off-site: Includes the time spent on activities that are non-productive from the point of view of the overall collection system.

Con't

- The time spent on off-route activities may be **subdivided** into **two categories: necessary and unnecessary**:
- Necessary off-route activities includes:
  - Time spent checking in and out in the morning and the end of the day.
  - Time lost due to unavoidable congestion.
  - Time spent on equipment repairs, maintenance and so on.
- Unnecessary off-route activities include:
  - time spent on lunch in excess
  - unauthorized coffee break
  - Talking to friends and the like activities

Con't

Frequency of solid waste collection:

- It depends on
  - ►**the quantity of solid waste,**
  - ► **time of year,**
  - ► **socioeconomic status of the area served,**
  - ► **municipal or contractor responsibility**.

Con't

- In **business areas, government offices**, **refuse** including garbage is generally collected **daily** except holidays.
- In **residential areas**, **twice-a-week** for refuse collection during **warm** months of a year and
  - **once a week** at other times should be maximum permissible interval.
- Slum areas usually require at least **twice-a-week** collection.
- The provision of frequent collection service is important in the **prevention of fly breeding** in garbage

Collection Routes:

- Once **labor and equipment** requirements have been determined,
- collection routes must be laid out so that both
  - **Collectors and**
  - **Equipment** are used effectively.

Con't

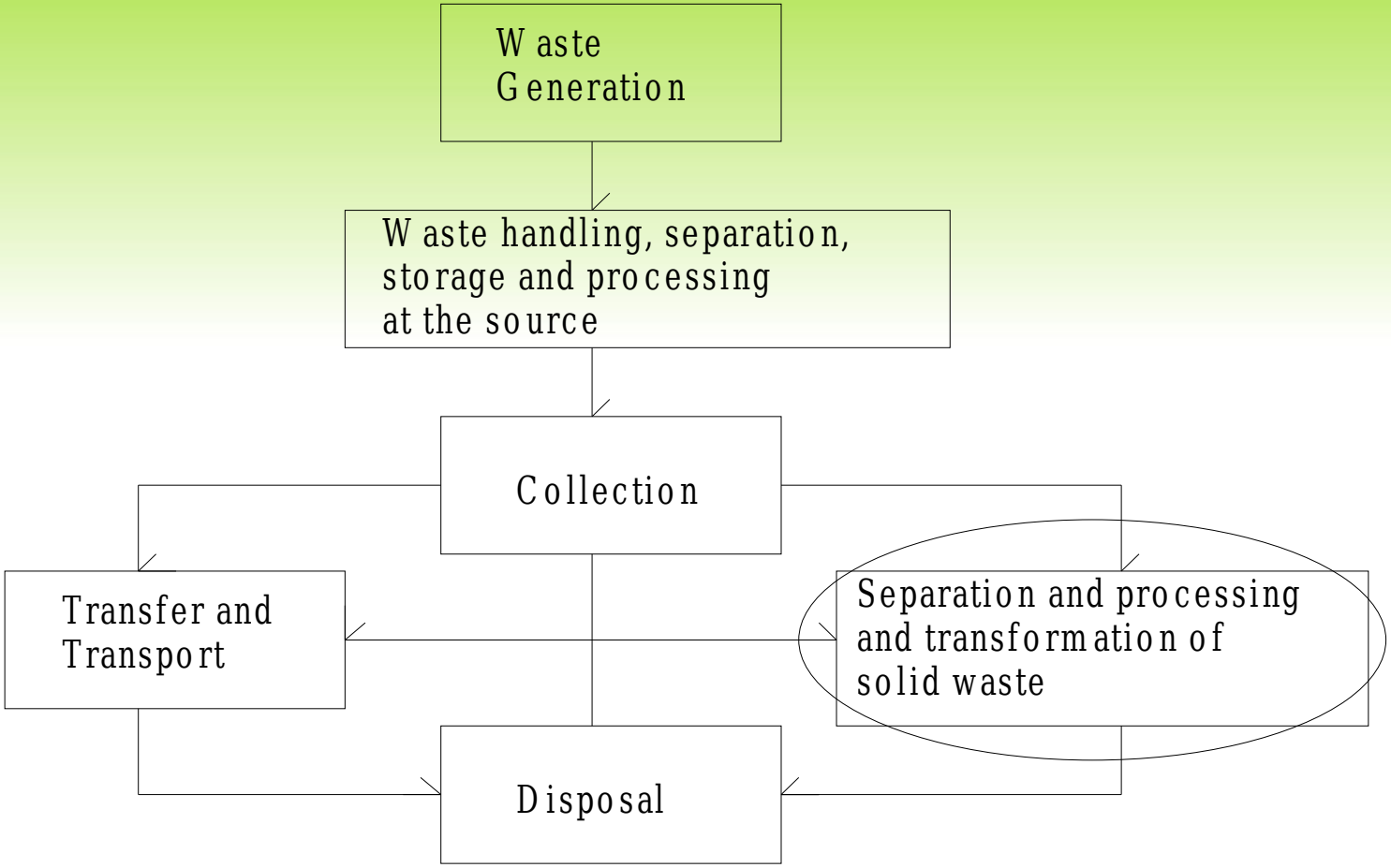
- The general steps involved in establishing collection routes include
  - **A) Preparation of location maps**
  - **B) Data analysis and as required, preparation of information summary tables.**
  - **C) Preliminary layout of routes.**
  - **D) Evaluation of the preliminary routes and**
  - **E) the development of balanced routes by successive trials**.

Con't

- **Routing system of Collection:**
- ***Micro routing*:**
  - The routing of a vehicle within its **assigned collection zone.**
  - It concerned with how to route a track through a series of one or two way streets so that the total distance traveled is **minimized**.
- ***Macro-routing*:**
  - Large scale routing to **the disposal site** and
  - the establishment of the **individual route boundaries**.

Separation and processing and transformation of solid waste…

It is 4th functional element of SWM



Con't

- It used to recover **source-separated materials**.
- The further separation and processing of wastes that have been source separated, as well as the separation of commingled wastes, usually occur at
  - **materials recovery facilities** (MRF) or
  - at large integrated **materials recovery/transfer facilities** (MR/ TF's).

Con't

A MR/TF's may include:

- a **drop-off center**
- a **material separation facility**,
- **compositing**
- **bioconversion** of wastes,
- the production of **refuse-derived fuel and**
- **a transfer and transport** facility.

Con't

- transformation processes are used to
  - reduce the **volume and weight** of waste requiring disposal and
  - to recover **conversion products and energy**.
- The most commonly used chemical transformation process is
  - **energy in the form of heat**.
- The most commonly used biological transformation process is
  - **aerobic compositing**.

Transfer and Transport

- **It is 5th functional elements of SWM**
- It refers to the **means, facilities and appurtenances** (law/responsibilities) used
  - **to effects the transfer of wastes from one location to another, usually more distant location.**
- It involves **small collection vehicles** for transfer of wastes to **larger vehicles** that are used to transport the waste over **extended distances** either to MRFs or to disposal sites.

Con't

- It becomes a necessity,
- When **haul distances** to available processing centers or disposal sites increase
  - direct hauling is **no longer** economically feasible.
- When processing centers or disposal sites are **sited in remote locations** and
    - **cannot be reached directly** by **highway.**

Con't

- Additional factors that tend to make the use of transfer operations attractive include

1. The occurrence of illegal dumping due to excessive haul distances.
2. The location of disposal sites relatively far from **collection routes** (typically more than 10 min.)
3. The use of small-capacity collection vehicles.
4. The existence of low density residential service areas.
5. The use of a hauled container system with relatively small containers for the collection

Con't

Types of transfer stations:

I. May be classified into **three general** types:

1. Direct load
2. Storage load
3. Combined direct – load and discharge load

Con't

II. With respect to throughout capacity (the **amount of material** that can be transferred and hauled).

1. Small < 100 ton/d
2. Medium –100-500 ton/d
3. Large > 500 ton/d.

Direct – load transfer stations:

- The wastes in the collection vehicles are emptied directly
  - into the **vehicle** to be used to transport them to a place of final disposal or
  - into **facilities** to compact the wastes into transport vehicles or
  - into **waste bales** that are transported to disposal site.

Storage – load transfer station:

- In these stations: wastes are emptied directly into a **storage pit** from which they are loaded into transport vehicles by various types of auxiliary equipment.
- It is designed with a capacity to store waste typically **1-3 days**.

Combined direct – load and discharge – load transfer station:

- In some transfer stations, both direct – load and discharge – load methods are used.
- Usually these are multipurpose facilities that service a brooder range of users than a single – purpose facility.
- It can also have a material recovery operation.

Con’t

- **Transport means and methods:**
  - **motor vehicles, rail roads and ocean** going vessels are the principal means.
  - **Pneumatic and hydraulic** systems have also been used.

Con't

Vehicles used for hauling on high ways should satisfy the following requirements:

1. Wastes must be transported **at minimum cost**
2. Wastes must be **covered** during the haul operation
3. Vehicles must be designed for **highway traffic**
4. Vehicles capacity must be such that the **allowable weight limits** are not exceeded.
5. Methods used for **unloading** must be

Con't

Rail road transport:

- One of the largest **rail haul operations currently** in use.
- Operationally 25 to 28 tons of waste is compacted into a 40ft, sealed shipping container mounted on a trailer chassis.

Water transport:

- In some parts in England, **river barges** are used to transport wastes.

Con't

Pneumatic and Hydraulic Transport:

- Both low – **pressure air and vacuum** conduit transport systems have been used .
- The most common used in **high – density – apartments or commercial** activities to a central location.
- The largest **pneumatic system** was installed in the US.

Con't

- **pneumatic systems** are more complex than hydraulic systems because of complex control valves and ancillary mechanisms that are required.

- The need to use blowers or high-speed turbines further complicates the installation from a maintenance standpoint.

Con't

- **Hydraulic transport** is now commonly used for the transport of a **portion of food wastes** (where home grinders are used).
- One of the major problems with this method is that ultimately the water or wastewater used for transporting the wastes must be **treated**.
- Hydraulic systems may be practical in areas where proper **preprocessing and post processing facilities** are incorporated into the treatment system.
- Usually, such applications are limited to areas with **high population densities**

Transfer Station Design Requirement:

Important factors that must be considered in the design of transfer stations include.

1. The type of **transfer operation** to be used.
2. **Storage and throughout capacity** requirements
3. **Equipment and accessory** requirements
4. **Sanitation requirements**

Con't

- The key issue from a design standpoint in whether waste **recovery operations** will be incorporated into the **transfer station facility**.

- If **waste recovery** is to be accomplished at the transfer station, then an **adequate area** must be **available** for the collection vehicles to unload.

Con’t

 The **types and amounts of equipment** required **vary with the capacity** of the station.

- In pit type storage
  - load transfer station, **one or more tractors** are required to break up the wastes.
- Other facilities like **lunch room, meeting rooms, offices, locker room, showers and toilets** should be provided.
- Facilities for providing **equipment maintenance** may also be incorporated.

Con't

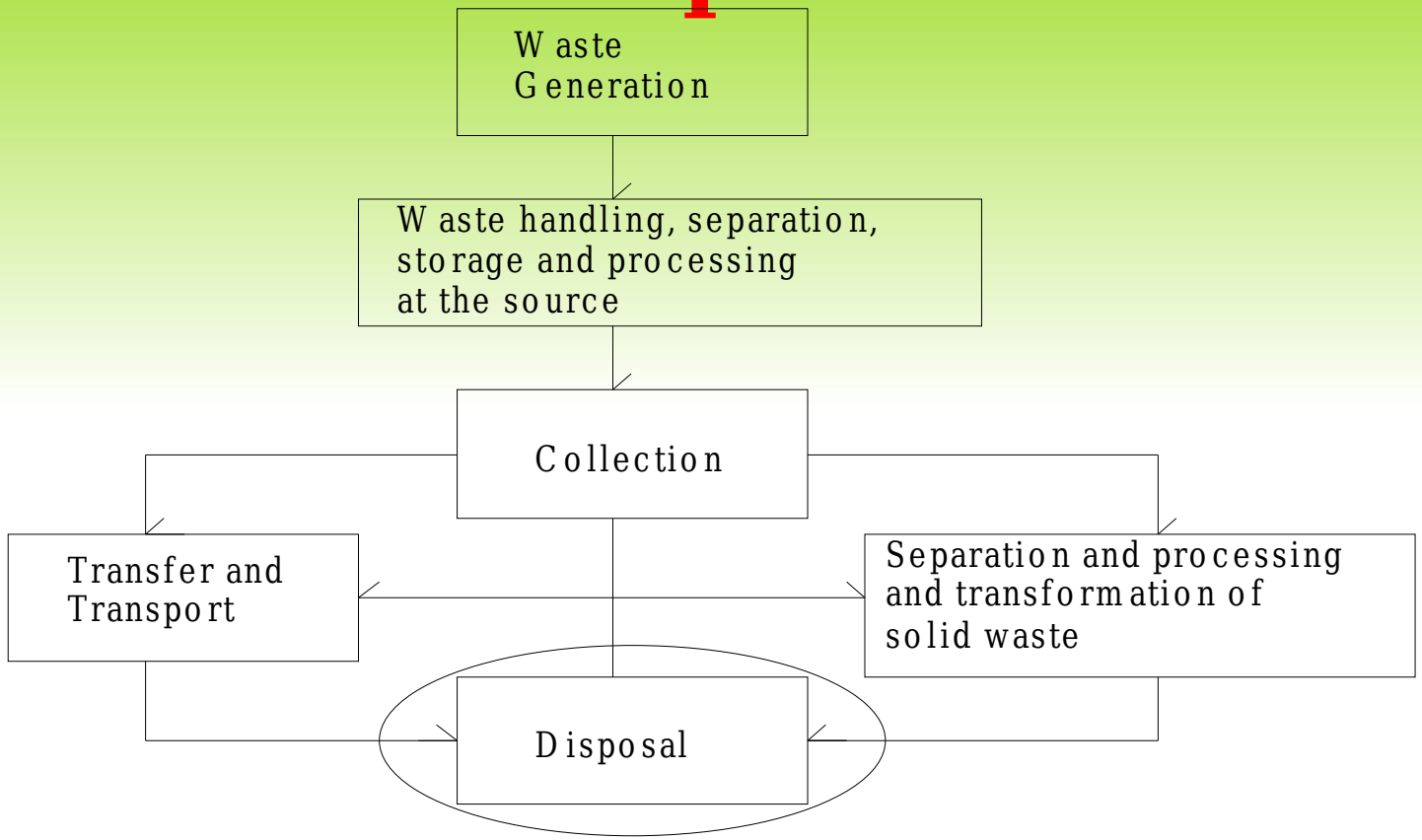
 ***Health and safety*:**

- Health and safety issues at transfer stations are related to **dust inhalation**.
- **Overhead water sprays** are used to keep the dust down in the storage area of storage – load transfer station.
- To prevent dust – inhalation, workers should **wear dust masks.**
- For reasons of safety, **the public** should not be allowed to **discharge wastes** directly into the pit at large storage – load transfer stations.

Location of Transfer stations:

- It Should be located:_
  1. As near as possible to the **weighted center** of the individual solid waste production areas to be served.
  2. With in **easy access of major arterial highway** **rout**es as well as near secondary or supplemental means of transportation.
  3. Where there will be a **minimum of public and environmental objection** to the transfer operations.
  4. Where **construction and operation** will be most economical.

Several methods of solid waste disposal



Con’t

- Ordinary open dumping;
- Controlled tipping /burial
- Hog feeding
- Incineration

- Sanitary landfill
- Compositing
- Grinding and discharge into sewers
- Recycling
- Dumping into water bodies
- Disposal of corpses.

1.Open Dumping

- Street sweepings, ashes and non combustible rubbish are suitable for open dumping.
- Garbage and any other mixed solid wastes are not fit or suitable because of nuisance and health hazard creation.
- SW is spread over a large area,
  - providing sources of food and shelter for **flies, rats and other vermin**.
- It causes
  - unsightly odor and smoke,
  - nuisance and hazards

Con't

- Carefully selected rubbish must be
  - disposed in order to prevent fire accidents that might occur.
- The location of open dumping must be
  - carefully chosen so that there will be a minimum chance of complaints from near by residents.

Con't

- **Advantages:**

1. It can take care of all types of solid wastes except garbage.
2. It causes less health problems if proper site is selected.
3. It needs less labor and supervision

- **Disadvantage:**

1. It attracts
   - flies,
   - mosquitoes and
   - other insects as well as
   - stray dogs, rats and other animals

Con't

- The **following points** should be considered before selection and locating sites for open dumping:

1. Sources of water supply and distance from it.
2. Direction of wind.
3. Distance from nearest residents, nearby farm areas and main land.
4. Distance that flies and rodents can travel from disposal site to living quarters

2. Controlled Tipping /burial:

- Indiscriminate dumping of garbage and rubbish creates favorable conditions for **fly breeding, shelter and food for rodents, nuisances** etc.
- To avoid such problems, **garbage and rubbish** should be disposed of under sanitary conditions.
- One of the methods is **burying garbage and rubbish** under controlled conditions.
- **Controlled or engineered burial** is known as **controlled Tipping or sanitary landfill system**.

Con’t

- This can be done by **digging shallow trenches**,
  - laying down the generated waste in an orderly manner,
  - **compacting the waste** manually or mechanically and
  - **covering with adequate depth** of earth or ash at the end of each day’s work (**22cm depth**).
- The process is repeated each day systematically at appropriate locations.

Con't

- If properly done, this system can prevent fly – breeding, rodent shelter, mosquito –breeding and nuisances.
- It can be applied in areas where **appropriate land** is **available** for such practice.
- This system can be considered an adaptation of what is technically called **the sanitary landfill system**.

: 3. HOG FEEDING

- The feeding of garbage to hogs.
- But there is surprising high incidence of trichinosis among hogs.
- Trichinosis spread through nematodes, from digestive system its effects the skeletal muscles.
- The Trichinosis worm is easily killed only at a temperature of **58ºC**.
- Refrigeration at - 35^{0}C for a period of 30 days will also kill the larva.
- **Pickling, salting and smoking** also **kill the larva** when done thoroughly.

Con’t

- Garbage feeding is **profitable** if properly handled.
- While **garbage** is the most potential valuable element or component of solid waste,
- it is the most difficult to **handle in a sanitary manner and**
- It is responsible for the majority of **nuisances and health hazards** associated with the disease.

Con't

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- While **garbage** is the most potential valuable element or component of solid waste,
- it is the most difficult to **handle in a sanitary manner and**
- It is responsible for the majority of **nuisances and health hazards** associated with the disease.
- To use garbage for hog feeding,
  - it has to be cooked at a temperature of 100ºC for 30 minutes just to be on safe side.

4.Grinding and Discharge in to sewer lines

- Methods for the disposal of garbage into sewers:

1. House hold grinders:
   - To grind the kitchen wastes (except bones) for their easy disposal and transport with waste water.
   - But it may lead to an **increase of solids** in **sewage treatment plants.**

Con’t

2. Municipal grinding stations:

- central grinding stations are used/installed at **convenient points** along sewer system .
- These are used to **avoid blockage of sewers** but care should be taken from **accumulated garbage**,
- increases in **>50% of suspended solids** and **more consumption of water.**

Dumping into water bodies:

- The old method of disposal,
- presently **not used** commonly, rarely used in some areas near to **bank of rivers, seashores**.
- How this methods in "**Addis Ababa**"
- It affects marine life.
- Ultimately **effect humans** through food chain e.g.
- Minimata disease in Japan spread due to consumption of mercury contaminated fishes.

Disposal of Dead Bodies:

- **Embalming:**
  - This **delays** the decay process of dead bodies by **injection of preservatives.**
- **Cremating:**
  - **Burning of dead bodies** is practiced in certain religion.
  - Considered to be **best sanitary method**.
  - In addition, it helps in **conservation of land**.
  - Not acceptable in Ethiopia.
- Disposal into water bodies:
- Ground burial: common, old and traditional method.
  - Minimum depth for such a method is **2**

Thermal processes or Incineration

- It is a particularly desirable for large quantities of **organic hazardous wastes**,
- it ensures **high efficient destruction** of most organic wastes,
- at the same time producing only minimal quantities of **undesirable air emissions** which can be controlled.

Con’t

- **Advantages**
- It reduce the volume of wastes
- Incinerators offer **detoxification** of
  - all combustible **carcinogens,**
  - **mutagens and**
  - **teratogens.**
- Numerous other hazardous wastes detoxified by incineration included **pathological wastes**,

Con’t

- the **elimination of long-term odors** .
- **energy** can be recovered.
- **Reduction of leachates** from waste landfills
- It easy to manage **potential air emissions** at a **central location** as opposed to **widely dispersed landfill locations.**

Disadvantage

- The initial capital investment cost is higher
- It requires highly trained operators, qualified supervisory and operating personnel.
- It needs regular maintenance
- It requires regular supervision to ensure reliable operations, even under the most adverse climatic and process conditions.

Con't

- The emission of odors,
  - particulate matter and
  - hazardous gaseous substances must be controlled
    - so as to keep these undesirable air pollutants (HCL, CO, SO_2, NO_x, Heavy metals, ashes) from being emitted into the atmosphere.

Con't

- In an incinerating System
  - the thermal destruction of hazardous waste can be carried out, typically above **1600ºF**.
- The temperature of operation to initiate thermal destruction of hazardous waste is known as threshold temperature.

Types of Incinerators:

Mass Burn Incineration

- It is used for the treatment and disposal of **municipal solid waste** throughout the world.
- The economic viability depends on **the recovery of energy**.
- Of the particular importance the '**fuel' properties** of the waste, ash, moisture content, volatile content and elemental analysis.

Con’t

- **Moisture content** is important since ignition will not occur if the material is wet and
  - moisture also **diminishes** the gross **calorific value of fuel.**
- The **ash content** is important since a **high ash percentage** will **lower** the calorific value of the waste and
  - must be **removed and disposed of** after combustion.

Con’t

- The incinerator may be divided in to **5 main areas**:

1. Waste delivery, bunker and feeding system:
2. Furnace
3. Heat recovery
4. Pollution control
5. Energy recovery via district heating and feeding system.

Other Types of Incinerators

- **Fluidised Bed Incinerators**:
- used for a wide variety of wastes, including
  - **municipal solid waste,**
  - **sewage sludge,**
  - **hazardous wastes (HW),**
  - **liquid and gaseous wastes.**

Con't

- Fluidised beds consist of
  - a **bed of sand particles** contained in a refractory – lined chamber through which the primary combustion air is blown from below;
  - the sand particles are hence **fluidized** by adjusting **the air flow**.

Starved Air Incinerators or Pyrolytic Incinerators:

- are **two stage** combustion type incinerators
- are widely used for clinical waste incineration and also for some industrial wastes.
- The temperature of the pyrolytic section are of the order of **700-800°C**,
  - since a high proportion of the heat generated is used in the **endothermic pyrolytic process**.
- These gases will then pass at a temperature of **1000-1200°C** which completes the combustion process by combusting the hydrogen, carbon monoxide and

Con't

- The two stage combustion process inhibits the formation of NO_x.
- The relatively **long residence time** with in the **secondary chamber plus the high temperature** of over 1000^0C will
  - **destroy** any dioxins and PCBs that are contained in the secondary gases.
- The **ash** is finally discharged at the rear of the incinerator into a water trough.

Con't

- The two stages consist of a **pyrolytic stage and a combustion stage.**
- The advantages of the **starved air incinerator** are a more controlled combustion process leading to **lower release of volatile organic compounds and CO.**

- In addition the **low combustion air flow** which also reduces **other particulate – borne pollutants** such as **heavy metals, dioxins and furans**.

Rotary kiln Incinerators

- is a two stage incineration type,
- but the first stage is usually operated in the oxidative mode,
- i.e., with about **50-200%** excess air, rather than the **semi-pyrolytic mode**.

Con't

- used for a wide variety of wastes, including
  - municipal solid waste,
  - sewage sludge,
  - industrial waste,
  - & hazardous waste.
- However, they are most common for the treatment of hazardous and industrial wastes.

Con't

- the primary chamber of the rotary kiln is consisting of
  - an inclined **cylinder lined with ceramic** material
  - which rotates at rates which can vary between
  - two revolutions per minutes to **six revolutions per hour**
  - depending on the **type of waste and type of** rotary kiln.
- The size of the rotary kiln can be from **1-6m diameter** and from **4-20m in length**.
- The **kiln** is rotated by a series of rollers on which the kiln is located.
- The waste is fed to the front end and ignited by a **burner**.

Con't

- The kiln normally operates at between **900 and 1100^{0}C,**
- but the 'slagging type' of rotary kiln operates at temperatures up to 1500^{0}C.
- The high temperature of the 'slagging type' kiln allows
  - the formation of a **molten slag of the ash**, and
  - whole drums of waste can be incinerated as the metal drums will

Con’t

- The presence of **molten slag** absorbs **particulate matter**, including heavy metals.
- The **ash or molten slag** exists from the kiln into a quench pit.
- The **molten ash forms** a glass-like material which is less susceptible to leaching of the dissolved metals.

Con’t

- The gases from the primary rotary kiln pass to the secondary chamber where excess air conditions with auxiliary burners serve to burn out completely the combustible **gases, vapours, tars and soot.**

- The rotary kiln combines a **long residence time and a high temperature**, which allows the **complete combustion of complex hazardous** wastes.

Pyrolysis

- Pyrolysis is
  - the thermal degradation of organic waste in the **absence of oxygen** to produce a **carbonaceous char, oils and combustible gases**.
  - Relatively low temperatures are used, in the range **400-800°C.**

Con’t

- The gases produced from waste pyrolysis are mainly
  - **CO_2,**
  - **hydrogen,**
  - **methane and**
  - **lower concentrations of other hydrocarbon gases**.

Con’t

- A wide variety of pyrolysis technologies have been investigated for the pyrolysis of waste materials like
  - fluidized beds,
  - fixed bed reactors,
  - rotary kilns, &
  - vacuum pyrolysis.

Gasification:

- It differs from pyrolysis in that oxygen in the form of **air, steam or pure oxygen** is reacted at high temperature with the available carbon in the waste to produce a **gas, ash and a tar product**.

- Partial combustion occurs to produce heat, and the reaction proceeds **exothermically** to produce a low to medium calorific value fuel gas.

Con't

- The operating temperatures are relatively high compared with pyrolysis,
  - at 800-1100^{0}C with air gasification, and
  - 1000 – 1400^{0}C with oxygen.
- Calorific values of the product gas are
  - low for air gasification, in the region of 4-6mJ/m^3 and
  - medium about 10-15 mJ/m^3, for oxygen gasification.

Con't

- During the gasification process, 5 principal reactions occur:
- $C+O_2 \rightarrow CO_2$ exothermic
- $C+H_2O \rightarrow CO + H_2$ endothermic
- $C + CO_2 \rightarrow 2CO$ - do –
- $C + 2H_2 \rightarrow CH_4$ exothermic
- $CO + H_2O \rightarrow CO_2 + H_2$

Con't

- The heat to sustain the process is derived from the exothermic reactions, whereas the combustible components are primarily generated by the endothermic reactions.
- When a gasifier is operated at atmospheric pressure with air as the oxidant, the end products of the gasification are a low-btugas typically containing (by volume) 10% CO_2, 20% CO, 15% H_2 and 2% CH_4 with the balance being N_2.

Con’t

- Gasifer types:
  - Vertical fixed bed,
  - horizontal fixed bed,
  - fluidized bed,
  - multiple hearth and
  - rotary kiln.
- First three have been widely used.

LAND FILLING OR LAND DISPOSAL

- is an important component of integrated waste management.

- Solid waste residues are not recycled, that remain
  - after processing at a material recovery facility, or
  - after the recovery of conversion products or energy.

Con't

- Historically:
- SW has been placed in the **soil in the earth surface** or deposited in the oceans.

- **Ocean dumping** is banned in many parts of world
- it is argued that wastes in the land/landfills could be used as **fertilizers** to increase the productivity of land.

Con't

Definition of terms:

LAND FILLS:

- are the **physical facilities** used for the disposal of residual solid wastes in the earth.
- Landfills for the disposal of hazardous wastes are called secure landfills.
- A **sanitary landfill** is also sometimes identified as a solid waste management unit.

Con't

- **In the past,**
  - sanitary landfills referred/used to denote a landfill in which the waste placed in the landfill was covered at **the end of each day's operation**.

- **Today,**
  - sanitary landfill refers to an engineered facility for the disposal of MSW **designed and operated** to minimize **public health and environmental impacts**

Con't

Land filling:

- Is the process by which **residual solid waste** is placed in landfill.
- It includes
  - monitoring of the incoming waste stream,
  - placement and compaction of the waste and
  - installation of landfill environmental monitoring &

Con't

- **Cell:**
  - Is used to describe the volume of material placed in a landfill during one operating period, usually one day.
  - It includes the solid waste deposited and the daily cover material surrounding it.
- **Daily cover:**
  - Usually consists of 6-12 inches of native soil or alternative materials at the end of the each operating period.

Con’t

- The purpose of daily cover are
  - to control the **blowing** of waste materials;
  - to prevent **rats, flies and other disease vectors** from entering or exiting the landfill; and
  - to control the entry of water into the landfill during operation.

Con't

- **Lift:**
  - Is a **complete layer of cells** over the active area of the landfill.
  - Typically, landfills are **comprised of a series** of lifts.
- **Bench or Terrace:**
  - Is commonly used where the **height of the** landfill will exceed 50-70 ft, to maintain the slope **stability** of the landfill, for the placement of surface water drainage channels, and for the location of landfill gas recovery piping.

Con't

- **The final lift(final cover layer):**
  - Includes the cover layer.
  - It is applied to the entire landfill surface after all land filling operations are complete.
  - It usually consists of **multiple layers of soil** and or geomembrane materials designed to
    - enhance surface drainage,
    - intercept percolating water, and
    - support surface vegetation.

Con’t

- **Leachate:**
  - It is the liquid that collects at the bottom of the landfill.
  - In deep landfills, it is often collected at intermediate points.
  - it is a result of the percolation of precipitation, uncontrolled runoff and irrigation water into the landfill.

Con't

- It also includes **water initially** contained in the waste as well as **infiltrating ground** water.
- It contains a wide variety of **chemical constituents** derived
  - From the **solubility of the materials** deposited in the landfill and
  - from the products of **the chemical and biochemical reactions**

Con't

- **Landfill gas:**
  - Is the **mixture of gases** found within a landfill.
  - The bulk of landfill gas consists of CH_4 and CO_2, the principal products of the anaerobic decomposition of the biodegradable organic fraction of the MSW in landfill.
  - Other gases include **atmospheric nitrogen, oxygen, ammonia and trace organic** compounds.

Con't

Landfill liners:

- are the materials (both natural and manufactured) that are used to line the bottom area and below-grade sides of the landfill.
- It usually consists of layers of compacted clay and/or geomembrane material designated to prevent migration of landfill leachate and landfill gases.

Con't

- **Landfill control facilities:**
  - include liners, **landfill leachate collection and extraction systems**,
  - **landfill gas collection and extraction systems** and
  - **daily and final** cover layers.
- **Environmental monitoring:**
  - involves the activities, associated with **collection and analysis of water and air samples**, that are used to monitor the **movement of landfill gases and leachate** at the landfill site.

Con't

- **landfill closure**:
  - Is the term used to describe the steps that must be taken to **close and secure** a landfill site once the **filling operation has been completed**.

- ***Post closure*:**
  - care refers to the activities associated with the **long-term monitoring and maintenance** of the completed landfill (typically 30-50 years).

Con't

Sanitary landfill:

- It is an **effective and proven** method for a permanent disposal of refuses.
- It can be used in any community where **sufficient suitable land is available** and
- for cities of **less than 100,000 population** because sufficient land is more likely to be available in these areas.

Con’t

This method of SW disposal consists basically of four steps:

1. **Depositing of refuse** in planned and controlled manner.
2. **Compacting the refuse** in thin layer to reduce its volume.
3. **Covering the refuse** with a layer of earth.
4. **Compacting the earth cover**.

Con't

- Refuse will be well compacted in **1.8 – 3.7 meter** layers.
- The fill should not exceed more than **1.8 – 2.4 meter in depth** and
- each day's accumulation of refuse should be sealed with **0.6 meter of cover**, and
- the entire fill finally sealed with 0.67 meter of soil.

Con’t

Site selection for sanitary landfills:

It should based on:

- ✓ Distance from the **sources of waste**
- ✓ Availability of **suitable access roads and bridges**.
- ✓ Type of **soil for seal** (covering) – sand or soil is most desirable. Avoid rock and clay soil.
- ✓ Avoid **contact** to **the water table** in order to prevent water contamination.
- ✓ **No obstruction** of normal drainage channels.

Con’t

- Avoid areas subjected to **flooding**.
- **Available land areas**.
- Avoid **main traffic arteries** by truck.
- Impact of processing and resource recovery.
- Soil condition and topography.
- Geologic and hydrologic condition.
- Surface water hydrology
- Local climatic /environmental conditions.

Con’t

Final selection of a disposal site usually based on the result of:

- → Preliminary study
- → Engineering design
- → Cost situations
- → Environmental Impact Assessment

Con’t

Location of sanitary landfill construction:

1. **30 meter** from all property lines
2. **152 meter** from all residences.
3. **152 meter** from all wells.
4. **61meter** from normal boundaries of springs, lakes and other bodies of water

Con't

Preparation of the site for land filling:

- → Existing site drainage must be modified to route any **run off away from the intended landfill** area.
- → Drainage of the landfill area itself must be modified to route **water away from the initial fill** area.
- → Construction of **access roads and weighing** facilities and
- → **installation of fences**.

Con't

- **Next step** in the development of a landfill is
  - the **excavation and preparation** of the landfill bottom and subsurface sides.
  - Modern landfills typically are **constructed in sections.**
  - Working by sections allows
    - only a small part of the **unprotected landfill surface** to be exposed to **precipitation** at any time.

Con't

- Excavated material can be stockpiled
  - on unexcavated **soil near the active area** and
  - the problem of precipitation collecting in the excavation is minimized.

- Where the entire bottom of the landfill is
  - **lined** at once,
  - provision must be made to **remove storm water** runoff from the portion

Con’t

- To minimize costs,
  - it is desirable to obtain **cover materials** from the landfill site whenever possible.
- **Vadose Zone** (zone between **ground surface** and permanent **ground water**) and

- **ground water monitoring** equipment is installed before the **landfill liner** is laid down.

Con’t

- The landfill bottom is shaped
  - to provide **drainage of leachate**, and
  - a **low-permeability liner** is installed.
- **Leachate collection** and **extraction facilities** are placed **with in or on top** of the liner.
- Typically, the **liner extends up** the excavated walls of the landfill.

Con’t

- Horizontal gas recovery trenches may be
  - installed at **the bottom of the landfill**, particularly if emissions of volatile organic compounds (VOCs).
- To **minimize** the release of VOC’s
  - **a vacuum** is applied and air is drawn through the completed portions of the landfill.

Con’t

- The gas that is removed must be
  - **burned under controlled conditions** to destroy the VOC’s.
- Before the fill operation begins,
  - a **soil beam** is constructed at the down ward side of the planned fill area.
  - It serves as a **wind break** to control blowing materials.

Con’t

- **Methods of sanitary landfill construction:**
  - Basically, there are **two methods** and
  - the choice will be made according to **the surrounding land available.**

Con't

1. **Area method:**
   - It is a method where solid waste is **dumped, spread, compacted and covered** with **covering materials.**
   - **Enough cover** should be excavated to provide a **1.8meter layer daily** and a final layer of **7.3 meter**, compacted well
     - to eliminate breeding by **rodents, flies and other vermin**.

Con’t

2. Trench method:

- Trench method is used when level ground is available.
- There are three variations of trench method. These are:

Con't

A. Single progressive trench:

- The trench is dug for **one day's** solid waste, and **cover material** is obtained by trenching.

B. Sing trench: One single trench is dug.

- Excavated material is placed on both sides for use as a cover.

C. Dual trench:

- One trench is dug on the length of the site and refuse is dumped into it.
- Cover materials come from parallel trench excavated two or more meters from the first trench depending on the

Con’t

Compaction of Sanitary landfills

- The objectives of compaction in the method are to:

1. Reduce settlement problem
2. Prevent fire
3. Eliminate odor
4. Kill flies
5. Conserve trench space
6. Provide a solid field for truck travel and future use.

Con't

Methods to obtain the best compaction

1. Spread refuse thinly and mix garbage with refuse.
2. Hard materials from old furniture leftover, building materials and other bulky materials should be buried **deep**
   - to eliminate rat shelters.

Con't

- Increase the cover of refuse when the fill is complete (**7.3 meter**) and daily base 1.8 meter.
- **Continuous maintenance program** should be carried out
  - to ensure repair crack, erosions and depressions of the surface and side slope.
- Much **steeper** than a 1% slope should be avoided because
  - it encourages erosion

Con't

- → A **separate trench or bit** may be desirable
  - for disposal of **small dead animals, spoiled food stuffs and other large quantities** of untraceable materials.
- → Generally, the **rate of decomposition** of refuse in a landfill prevents
  - the **reuse** of the same location for many years.

- In some areas, decomposition of

Con't

- **Reactions occurring in land fills:**
  - **Biological reactions:**
  - are those involving the **organic material** that lead to the **evolution of landfill gases and eventually liquids**.
  - The biological decomposition process usually proceeds **aerobically** for some short period.
  - **CO_2** is the principal gas produced.

Con't

- Once the O_2 availability has been consumed,
  - the decomposition become **anaerobic** and
  - the organic matter is converted to
    - **CO_2,**
    - **CH_4 and**
    - **trace amounts** of **ammonia and hydrogen sulfide**.

Con’t

Chemical Reactions:

- include **dissolution and suspension** of landfill materials and
- biological conversion products in the **liquid** percolating through the waste,
- **evaporation and vaporization** of chemical compounds and water into the evolving landfill gas,
- **sorption** of volatile and semi-volatile organic compounds in to the landfill materials,

Con’t

- **dehalogenation and decomposition** of organic compound, and
- **oxidation and reduction reactions** affecting metals and the solubility of metal salts
- **chemical reactions** between certain organic compounds and clay liners,
  - which may alter the structure and permeability of the liner material.

Con't

Physical Reactions:

- The important changes in landfills are
  - the lateral diffusion of gases and
  - emission of landfill gases
  - movement of leachate and into underlying soils and
  - settlement caused by consolidation and decomposition of landfill material.
- As gas is evolved with in a landfill, internal **pressure** may build, causing the landfill cover to **crack and leak**.

Con't

- **Water entering** the landfill through
  - the **cracking/leaking cover** may enhance the gas production rate causing still **more cracking**.
- Escaping landfill gas may carry
  - trace **carcinogenic and teratogenic.**
  - landfill gas usually has **high methane** content,
    - there may be a **combustion or explosion hazard.**

Con’t

Concern with the land filling of solid wastes:

- The uncontrolled release of landfill gases
  - that might migrate off-site which cause odor and other potentially dangerous conditions.
- The impact of uncontrolled discharge of landfill gases
  - on the **green house** effect in the atmosphere.

Con’t

- The uncontrolled release of **leachate**
  - that might migrate down to underlying **ground water or to surface waters.**
- The **breeding and harboring of disease vectors**
  - in improperly managed landfills.
- The health and environmental impacts
  - associated with **the release of the trace gases**, arising from the **hazardous materials** that were often placed in landfills in the past.

Con't

Composition of Land fill Gas

- **Percent of components** vary with **the age of land fill.**

Component	**Percent (dry volume basis)**
Methane	45-60
Carbon dioxide	40-60
Nitrogen	2-5
Oxygen	0.1-1.0

Con’t

- Sulfides, disulfides, mercaptants etc 0-1.0
- Ammonia 0.1-1.0
- Hydrogen 0-0.2
- Carbon monoxide 0-0.2
- Trace constituents 0.01-0.6
  - (about > 116 organic compounds were found in land fill gas)

Con’t

Some trace constituents are

- Acetone, Benzene,
- chlorobenzene, chloroform,
- ethylene bromide, ethylene dichloride,
- ethylene oxide, ethyl benzene,
- methyl ethylketone, trichloroethylene,
- toluene, vinyl chloride,
- styrenes, xylenes.

Con’t

- The occurrence of significant concentrations of VOCs (Volatile organic compounds) is
  - associated with **older landfills** that accepted **industrial and commercial wastes** containing VOCs.

- In **newer landfills** in which the disposal of hazardous waste has been banned,
  - the concentration of **VOCs** in the landfill

Con’t

Management of landfill gas:

- Typically, landfill gases that have been recovered
  - for the **recovery of energy** in the form of electricity (5MW) or both.
- Another point is the separation
  - the **methane in landfill gas** has been suggested as an alternative to the production of **heat and electricity.**

Con't

Flaring of landfill gases:

- A common method of treatment for landfill gases is thermal destruction i.e.

$$\xrightarrow{O_2}$$

- CH_4, VOCs ----→ CO_2, SO_2, oxides of nitrogen

  Burn and other related gases.

Con't

- concern over air pollution, modern flaring facilities are designed to meet rigorous operating specification to
  - ensure effective destruction of VOCs and
  - other similar compounds that may be present in the landfill gas.
- E.g. A typical requirement might be a minimum combustion temperature of $1500^{0}F$ and a residence time of 0.3 to 0.5s.

Con’t

- **Composition of leachate:**
  - liquid that has percolated through solid waste
  - Leachate from landfills usually contains extracted, dissolved and suspended materials, some of which may be harmful.
  - The chemical composition of leachate will vary greatly depending on **the age of landfill** and the events preceding the time of sampling.

Con’t

Composition of leachate from new and mature landfills.

Constituent New landfill (<2 year)mg/L Mature landfill (>10 years) mg/L

- BOD_5 2000-30,000 100-200
- COD 3000-60,000 100-500
- TSSs 200-2,000 100-400
- pH 4.5-7.5 6.6-7.5
- Organic nitrogen 10-800 80-120
- Total hardness ($CaCO_3$) 300-10,000 200-500

Con't

- If a leachate sample is collected during the **acid phase of decomposition** the pH value will
  - be low and
  - the concentration of BOD_5,
  - COD,
  - nutrients and
  - heavy metals will be high.

Con't

- On the other hand if a leachate sample is collected during the methane formation fermentation phase,
  - the pH will be in the range from 6.5-7.5 and
  - the BOD_5, COD, nutrients and heavy metals will be lower.
  - The concentration of heavy metals will be lower because most metals are **less soluble** at neutral pH values.

Con't

- *Organic constituents*:
  - phenols, COD, Total organic carbon (TOC), Volatile acids, Tannins, lignin's, ether (oil/grease), chlorinated hydrocarbons.
- *Inorganic constituents:*
  - suspended solids (S.S), total dissolved solids (TDS), chloride, sulfate, phosphate, Nitrate – N, Nitrite N, Ammonia – N, Sodium, potassium, calcium, magnesium,
- *Heavy metals:*
  - Pb, Cu, Ni, Cr, Zn, Cd, Fe, Mn, Hg, Ba, Mg, As, Cyanide, F, Selenium

Con't

- In general, **heavy metals** are removed by
  - ion **exchange reactions** as leachate travels through the soil while
  - **trace organics** are removed by **adsorption** primarily.
- The ability of soil to retain heavy metals found in leachate is
  - a function of the **cation exchange capacity** (CEC) of the soil.

Con't

- **Landfill field capacity:**
  - water entering the landfill may appear as leachate.
  - Both the waste material and the cover material are capable of **holding water** against the pull of gravity.
- The **quantity of water** that can be held against the pull of gravity is referred to as ***field capacity.***
- The potential quantity of leachate is the amount of moisture within the landfill in excess of landfill field capacity.

Advantages:

- relatively **economical and acceptable** method.
  - **Initial investment** is low
- The system is flexible;
- It enables the **reclaiming of depression** and **sub-marginal lands** for **use and benefits** of community.
- Completed landfill areas can be used for **agricultural and other purposes.**
- **Unsightliness, health hazards and the nuisance of open dumping** can be eliminated

Disadvantages:

- Sometimes **suitable land with in economical hauling** distance may not be available.
- Relatively **large areas of land** are required due to **slow decomposition of refuse**.
- An adequate supply of **good earth cover** may not be readily accessible.
- If not properly located, seepage from landfills into **streams** may increase the chance for **stream pollution.**

Composting (reading assignment)

- It is an aerobic process, and the end product is the partially decomposed organic fraction.
- It is often promoted as a natural process of SWM.

Fundamental of compositing:

- Aerobic microorganisms extract energy from the organic matter through a series of exothermic reactions that break the material down to simpler materials.

REFERENCE BOOKS

- Solid waste management lecture note by Takele Tadesse
- Environmental Engineering by J.A Salvato, 1982
- Integrated solid waste management Engineering Principles & management issues, 1983
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THE END

