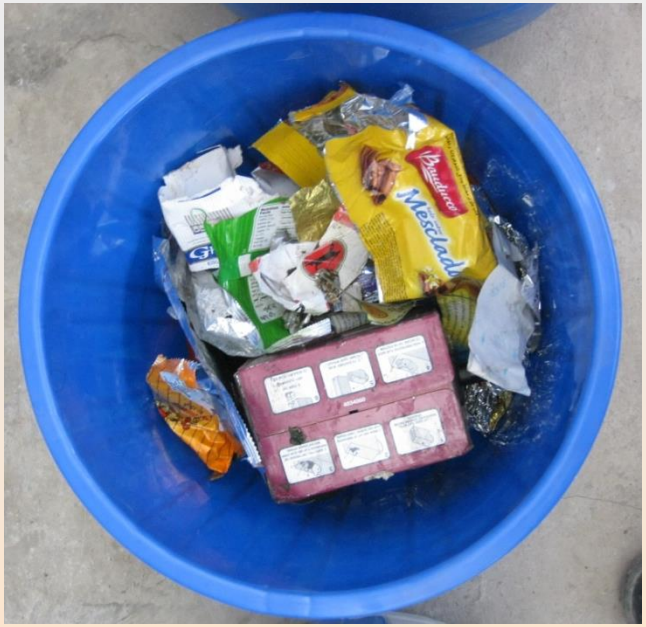
# Solid Waste Management

# Waste

- *Solid waste:* Any material that is thrown away or discarded as useless and unwanted.
- *Municipal Solid Waste* (MSW): Solid wastes other than hazardous and radioactive materials.

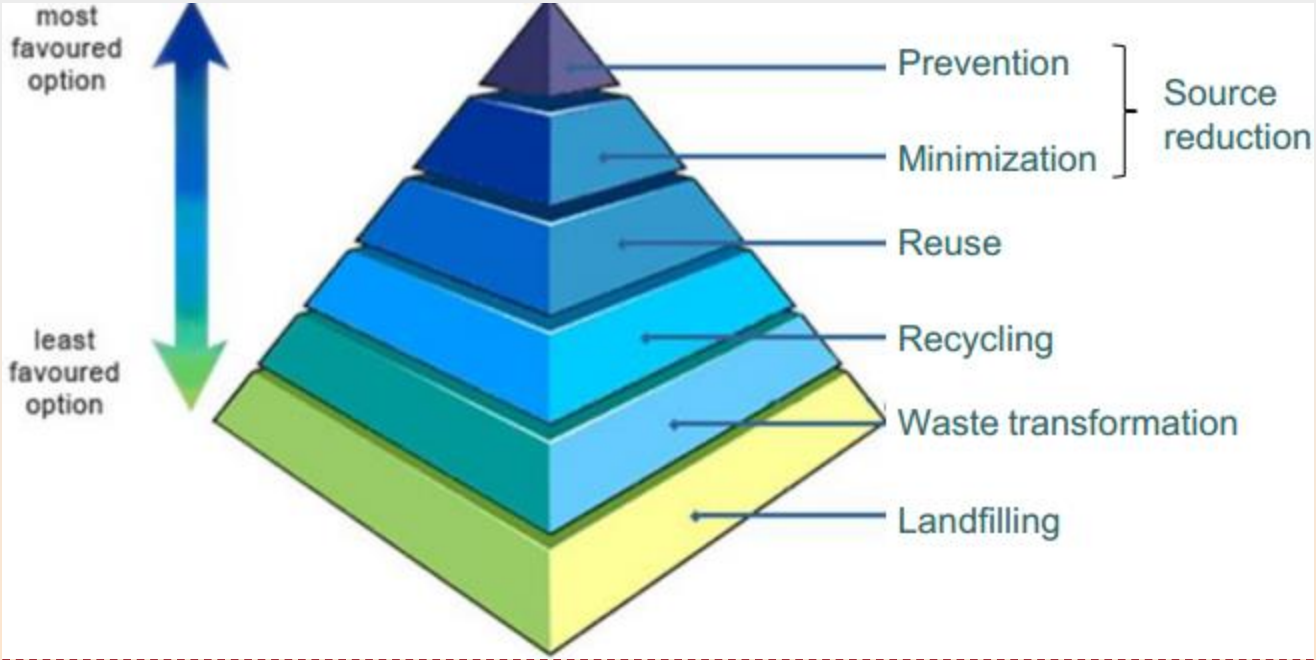




SOLID WASTE MANAGEMENT
ACTIVITIES
INFRASTRUCTURE
Planning
Design
Financing
Construction
Operation
Collection
Transport
Processing
Recycling
Disposal

# Integrated Solid Waste Management

- *ISWMM can be defined as the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals*



# Sources of Solid Wastes

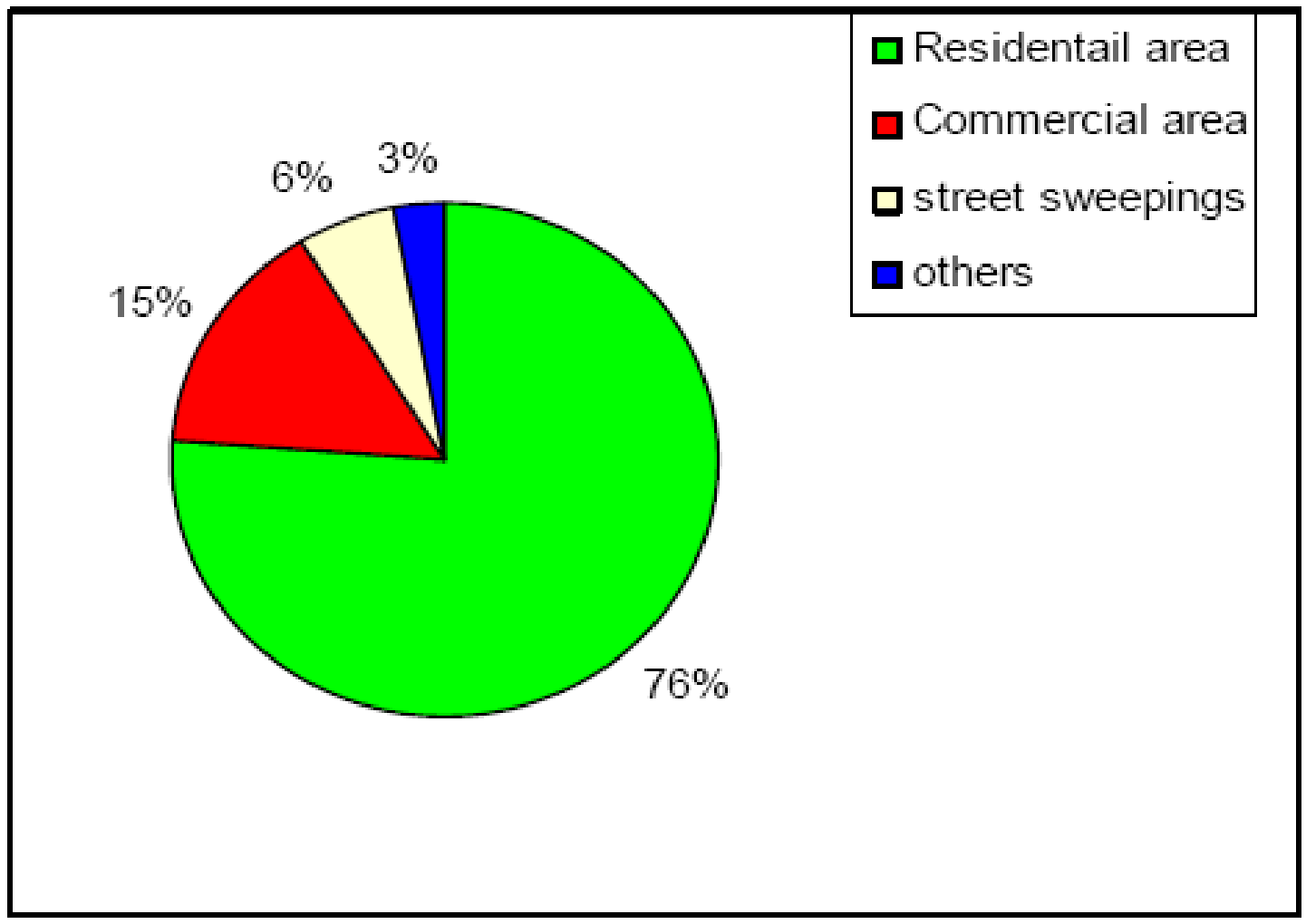
- Residential
- Commercial
- Institutional
- Industrial
- Construction and Demolition
- Agricultural
- Mining wastes
- Treatment Plant Sites

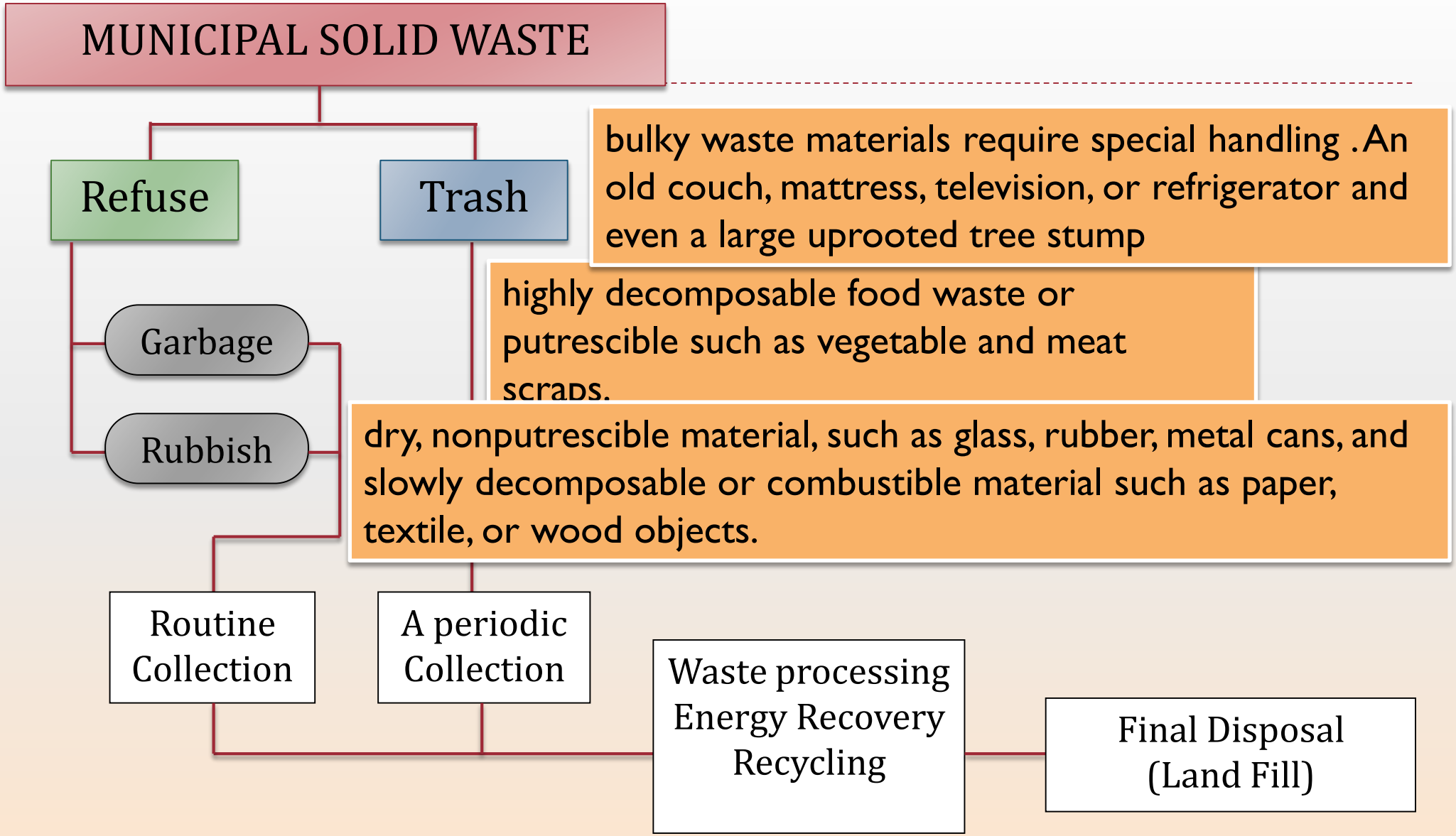
MSW

# Source of Solid Wastes

| Source | Typical Waste Generators | Types of Solid Wastes |
|---|---|---|
| **Residential** | Single and multifamily dwellings | Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes). |
| **Industrial** | Light and heavy manufacturing, fabrication, construction sites, power and chemical plants | Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes. |
| **Commercial** | Stores, hotels, restaurants, markets, office buildings, etc. | Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes. |
| **Institutional** | Schools, hospitals, prisons, government centers. | Same as commercial |
| **Construction & Demolition** | New construction sites, road repair, renovation sites, demolition of buildings | Wood, steel, concrete, dirt, etc. |
| **Municipal services** | Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants. | Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge. |
| **Manufacturing Processes** | Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing. | Industrial process wastes, scrap materials, off-specification products, slay, tailings. |
| **Agricultural** | Crops, orchards, vineyards, dairies, feedlots, farms. | Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides). |

# Addis Ababa Waste




MUNICIPAL SOLID WASTE
Refuse
Trash
bulky waste materials require special handling .An old couch, mattress, television, or refrigerator and even a large uprooted tree stump
Garbage
highly decomposable food waste or putrescible such as vegetable and meat scraps.
Rubbish
dry, nonputrescible material, such as glass, rubber, metal cans, and slowly decomposable or combustible material such as paper, textile, or wood objects.
Routine Collection
A periodic Collection
Waste processing Energy Recovery Recycling
Final Disposal (Land Fill)

# Characteristics of MSW

- gross composition
- moisture content
- density
- particle size
- chemical composition

# Composition of MSW

- Distribution for components in MSW vary with location, season & economic condition
- Because of heterogeneous nature of MSW, determination of its composition is not easy.
- Generalized field procedures, based on common sense and random sampling techniques are used.

# Composition of MSW

- To obtain a sample for analysis, a truckload from a typical weekday is first quartered.
- One part is selected for additional quartering until a sample size of about 100 kg is obtained
- Sample is then separated manually and each component Paper & cardboard, Food wastes, Yard wastes, Metal, Glass, Plastic, Ashes, dirt & Other rubbish is placed in separated containers.
- Finally , weighed and weights are recorded

| Components | Weight % of the total |
|---|---|
| Paper and cardboard | 41 |
| Food wastes | 17 |
| Yard wastes | 10 |
| Metal | 7 |
| Glass | 5 |
| Plastic | 5 |
| Ashes, dirt | 8 |
| Other rubbish | 7 |

# Moisture Content of MSW

- Percentage of wet weight in the MSW
- May vary between 15 and 30% (usually 20%)
- Analysis Procedure
  - Weigh the aluminum dish
  - Fill the dish with SW sample and re-weigh
  - Dry SW+dish in the oven for at least 24hrs at 77°C (170°F)
  - Remove the dish from the oven, allow to cool and weigh and record
  - Calculate the moisture content (M) as

$$M = \frac{w-d}{w} \times 100\%$$

$M$ = moisture content, percent,
w = initial, wet weight of sample, and
$d$ = final, *dry* weight of sample.

# Typical components of solid waste

| Components | Weight % of the total | Moisture (% by weight) | |
|---|---|---|---|
| | | Range | Typical |
| Paper and cardboard | 41 | 4-10 | 7 |
| Food wastes | 17 | 50-80 | 70 |
| Yard wastes | 10 | 30-80 | 60 |
| Metal | 7 | 2-6 | 3 |
| Glass | 5 | 1-4 | 2 |
| Plastic | 5 | 1-4 | 2 |
| Ashes, dirt | 8 | 6-12 | 8 |
| Other rubbish | 7 | 5-30 | 20 |

# Example

- The following are the particular of solid waste generated. Determine the total moisture content on wet and dry basis.

| Components | % M/M | % water |
|---|---|---|
| Paper | 40 | 6 |
| Cardboard | 33 | 6 |
| Glass | 5 | 0.5 |
| Others | 22 | 60 |

# Solution

| Components | % M/M | % water | For 100 kg moisture |
|---|---|---|---|
| Paper | 40 | 6 | 2.4 |
| Cardboard | 33 | 6 | 1.98 |
| Glass | 5 | 0.5 | 0.025 |
| Others | 22 | 60 | 13.200 |
| Total | 100 | | 17.605 |

Assuming we have 100 kg solid waste the last column shows the moisture content in weight.

Thus, % moisture on wet basis = 17.605 %

And % moisture on dry basis = $\frac{17.605}{100-17.605} = 21.37\%$

# Collection

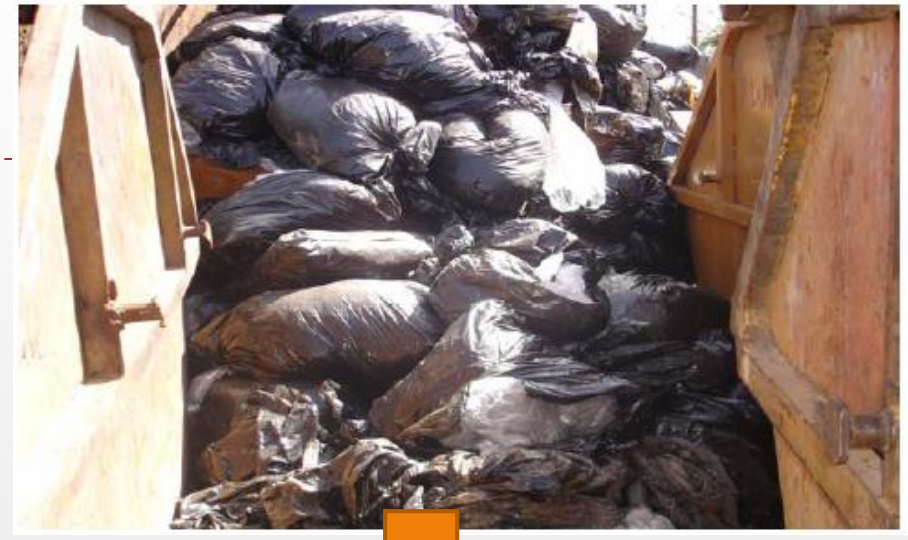
- includes not only the gathering or picking up of SW from various sources, but also the hauling to the location where the contents of the collection vehicles are emptied.
- Collection accounts for 50-90% of the budget of MSW management system
- Trucks that carry hydraulic rams to compact the refuse to reduce its volume.
- Collections are facilitated by the use of containers that are emptied into the truck with a mechanical or hydraulic mechanism.

# Collection System Types

- Hauled Container System (HCS)
  - the containers used for the storage of wastes are hauled to a materials recovery facility (MRF), transfer station, or disposal site,
  - emptied, and returned to either their original location or some other location.
- Stationary Container System (SCS)
  - Container remains at site (residential and commercial)

# Hauled container systems

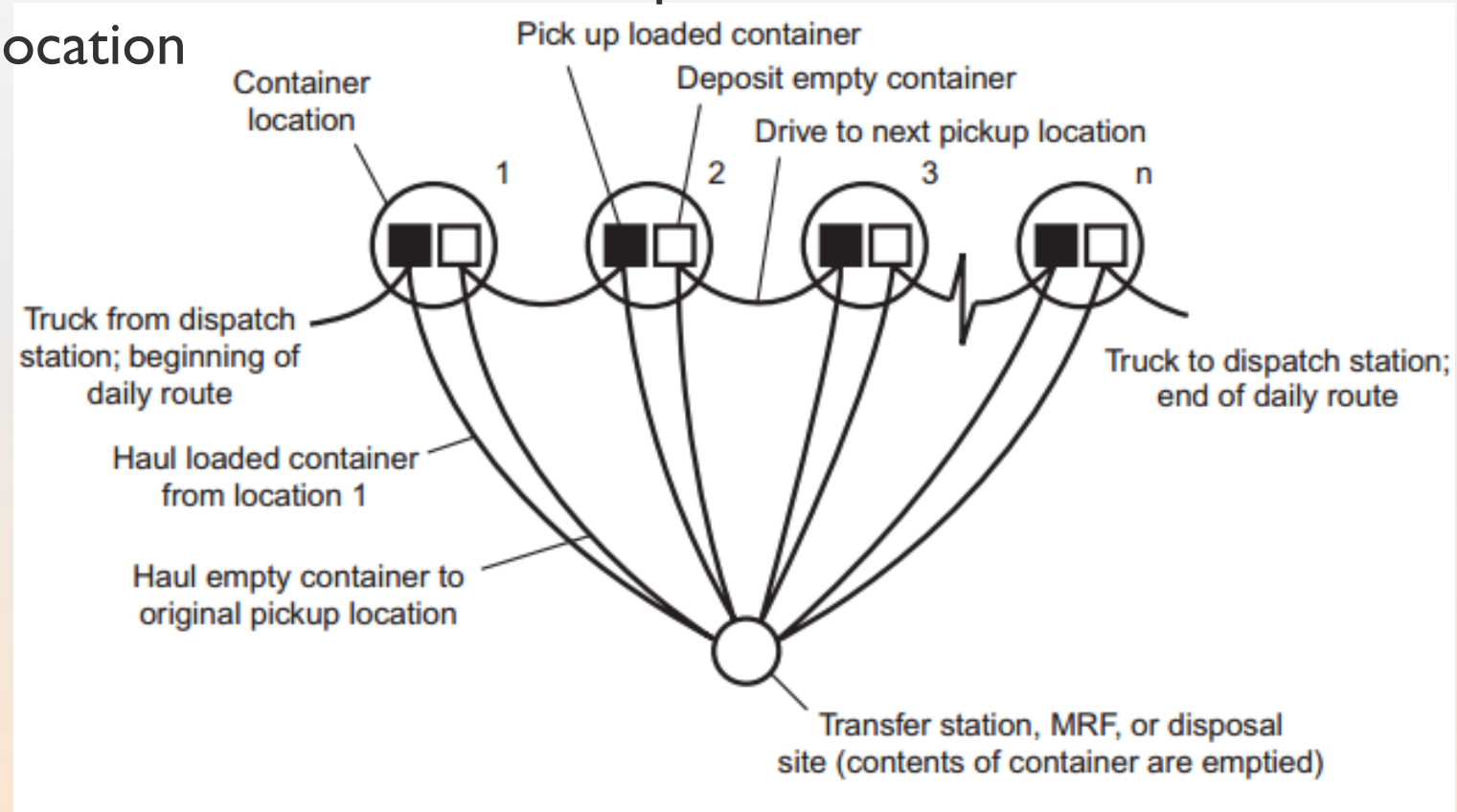
- ideally suited for the removal of wastes from sources where the rate of generation is high
- High generation rates (construction & demolition waste)
- One truck but require a round trips
- types of hauled container systems:
  - hoist truck
  - tilt-frame container, and
  - trash-trailer
- eliminate spillage associated with multiple smaller containers



# Hauled container systems

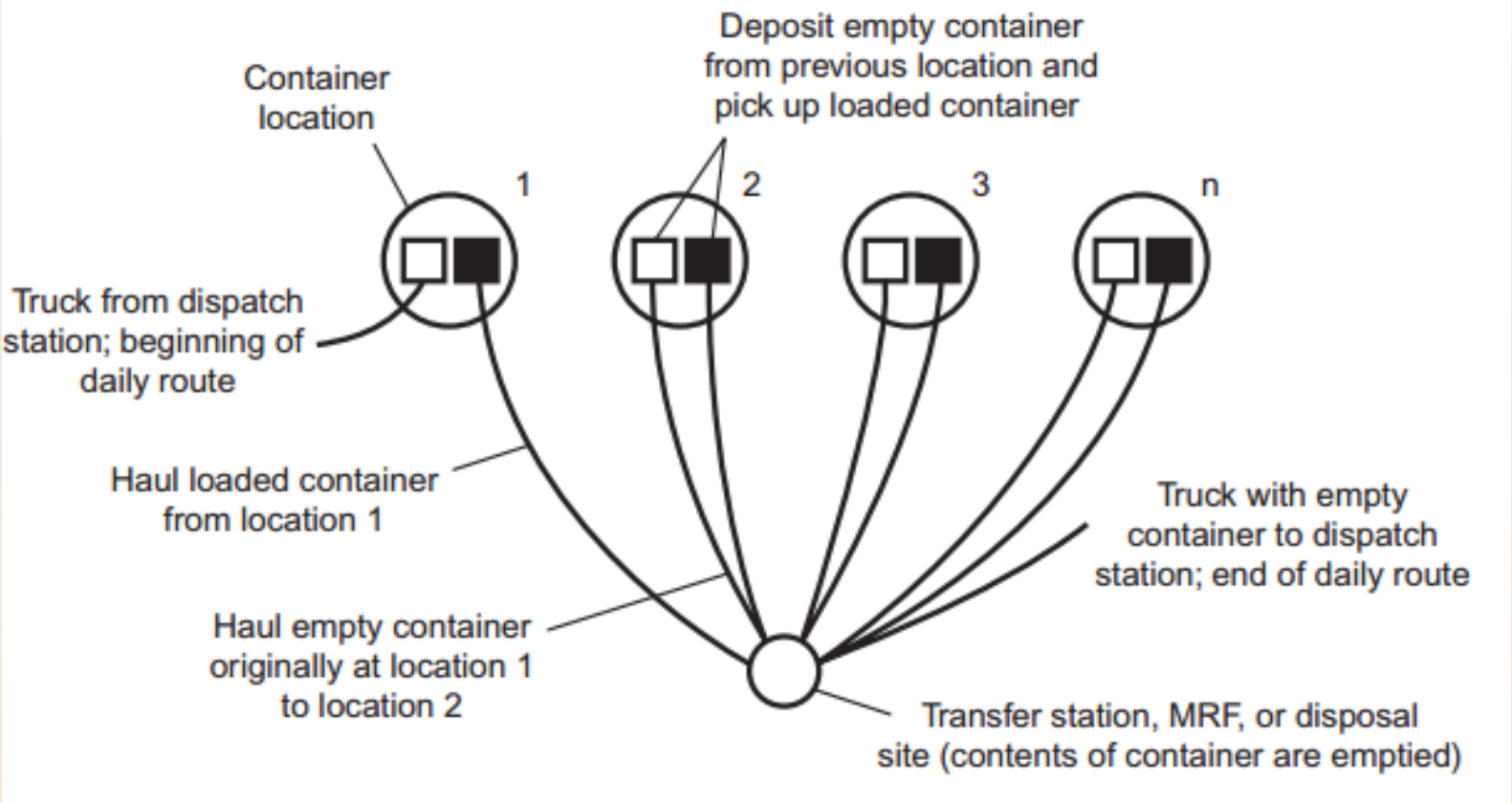
## Conventional mode

- The container hauled off to the disposal area and returned to the original location



# Hauled container systems

Exchange container mode: start with an empty container



# Hauled container systems

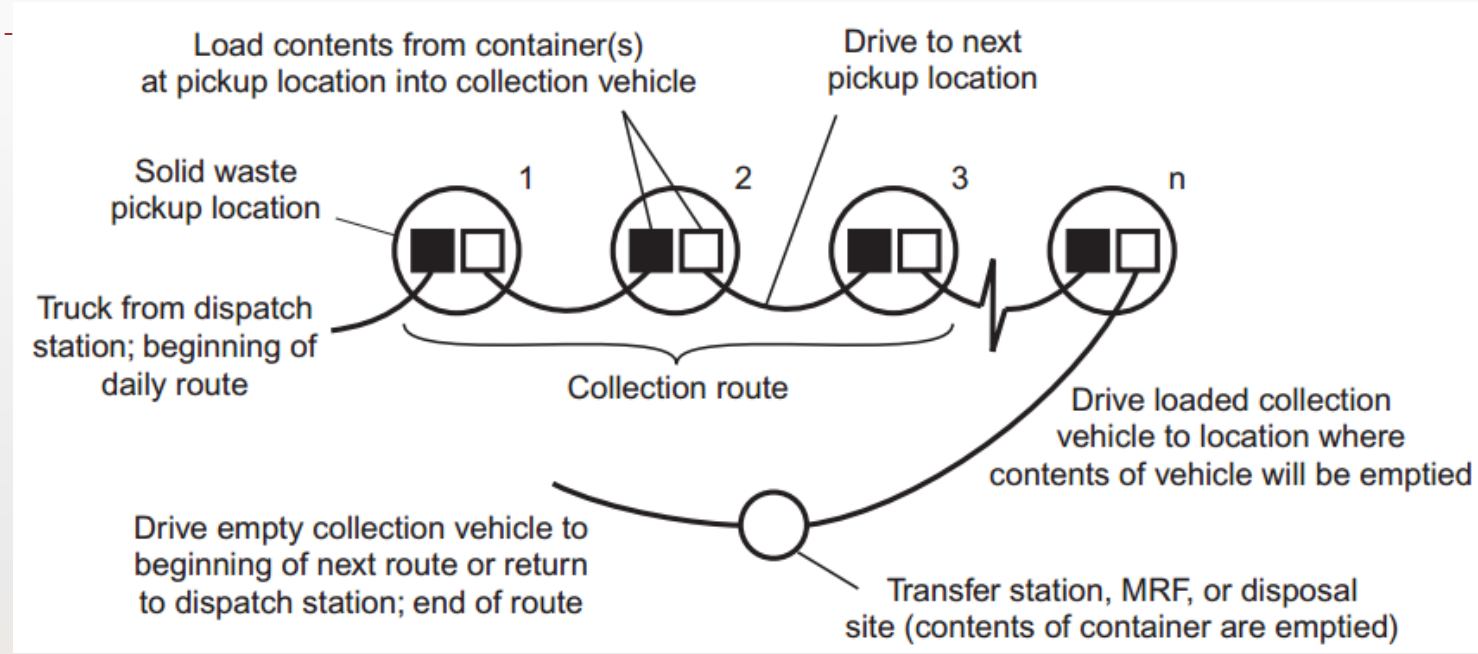
- Advantages:
  - Useful when generation rate is high and containers are large
  - eliminate spillage associated with multiple smaller containers
  - Flexible. Need more capacity, use a larger container

- Disadvantage:
  - If the containers are not filled, low utilization rate.

# Stationary container system (SCS)

- the container used to store waste remain at the point of generation; except when moved to curb or other location to be emptied.
  - Types include:
    - Mechanically-loaded system
    - Manually-loaded collection vehicle(more common)

# Stationary container system (SCS)




Advantages:

- vehicle does not travel to disposal area until it is full yielding higher utilization rates

Disadvantages:

- not flexible in terms of picking up bulky goods
- Wastes e.g. demolition, that make damage the relatively delicate mechanisms

The activities involved in the collection of solid wastes can be resolved into four unit operations

I. Pickup
   - $P_{HCS}$
     - time spent driving to the next container
     - the time spent picking  up the loaded container
     - time required to re-deposit the container after it has been emptied
   - $P_{SCS}$
     - time spent loading the vehicle, beginning with the first container and ending when the last container has been loaded

II. Haul (h)

- HCS- The time required to reach the location where the waste will be emptied
- SCS - The time required to reach the location where the full vehicle will be emptied and continuing until the truck arrives at the location

III. At-site (s)

- The time spent at the site (landfill, transfer station) where the system is unloaded (including waiting time)

IV. Off-Site (W)

- Non-productive activities (Check in, check out, meeting, breaks)
- Typically 15%

- Equations for Analysis a hauled Container System

$$T_{hcs} = (P_{hcs} + s + h)/(1-W)$$

  - The time required for a trip is the sum of the pickup time, the time on site and the haul time
  - W = off route factor, fraction

- The haul time may be expressed as:

$$h = a + bx$$

  - where x is distance
  - h is essentially a function of the distance traveled.

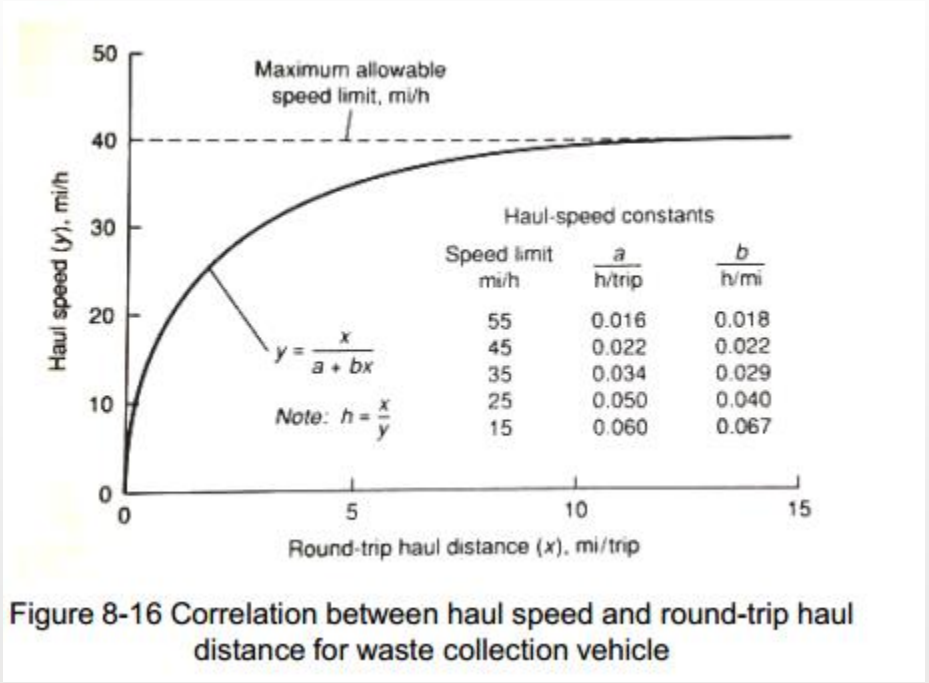



Figure 8-16 Correlation between haul speed and round-trip haul distance for waste collection vehicle

- The pickup time may be expressed as follows:

$$P_{hcs} = pc + uc + dbc$$

where pc = **p**ickup the container

uc = **u**nload the container and

dbc = **d**rive between containers

# Collection routes

- Path established by
  - Trial and error
  - Computer
  - Heuristic methods (common sense)

Steps

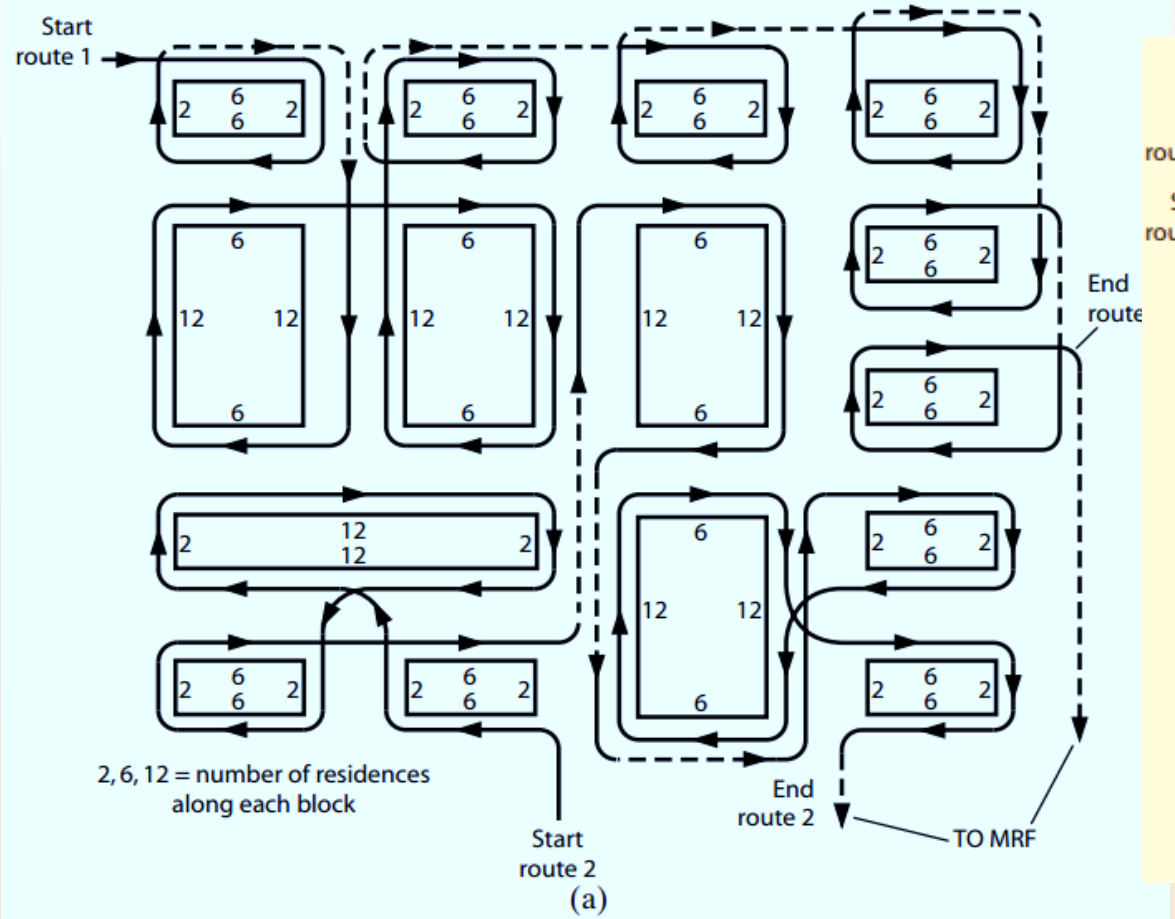
- Define collection area
- Assign disposal sites if more than one
- Establish daily collection zones - collection area divided into sections for daily service established based on compacted volume
- Balance daily vehicle assignments (districting)
- Route vehicles within daily districts
  - Location maps with pertinent info; sources, volume, containers
  - Layout preliminary routes

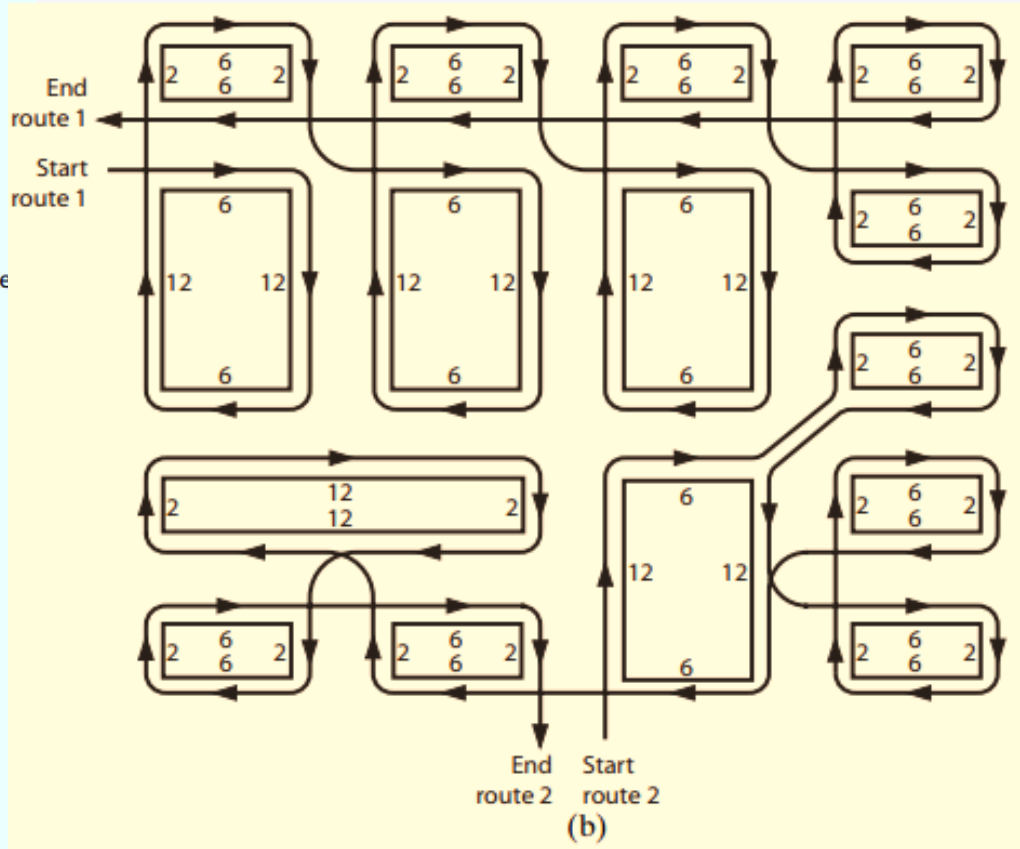
# Collection routes

Rules

- Begin and end near arterial streets
- Start at top of hills
- Work toward disposal site
- Work in congested areas during non-rush hours
- Large quantities first
- Routes should not overlap (minimum deadheading)

# Collection routes



# Example

- A residential area of about 40 ha contains 400 single-family residences and 8 ha with multiple-family units housing 400 people. With two curb-side pickups per week, how many trips on each collection day would one packer truck need to make to serve this area if its capacity is 5 tones? Assume four residents per single-family unit and the residential per capital waste generation as1.1 kg/day)

# Solution

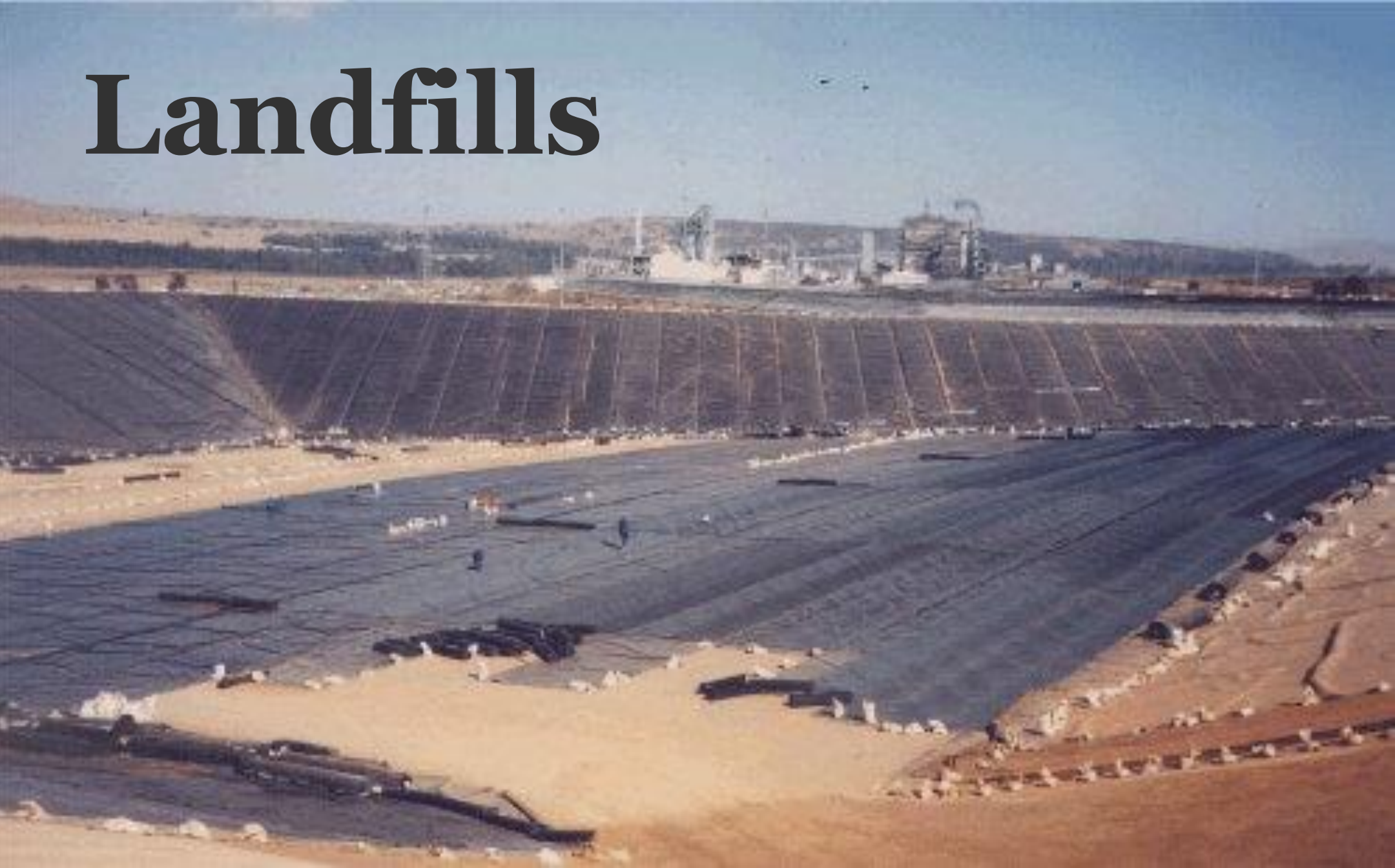
- *Population served:*
  - Single family at 4 residents per unit = 1600 people
  - Multiple family at 50 residents per hectare = 400 people
- Total = 2000 people
- *Waste quantity:* Assume the residential per capital waste generation is 1.1 kg/day. Then the amount each collection day is

$$2000 \times 1.1 \times 7/2 = 7700 \text{ kg} = 7.7 \text{ tones}$$

# Solid Waste Processing

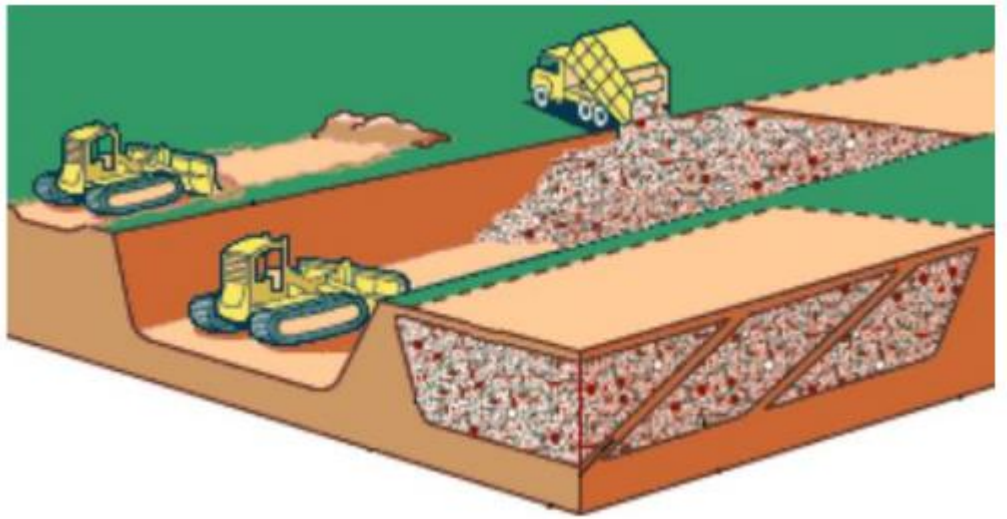
- Advantages
  - reduces the volume and weight
  - changes its form and improves its handling characteristics.
  - to recover natural resources and energy in the waste material for reuse, or recycling.
- The most widely used municipal waste treatment processes include
  - *incineration, shredding, pulverizing (glass crushing), baling (compressed into desk-sized blocks),* and *composting.*

# Landfills



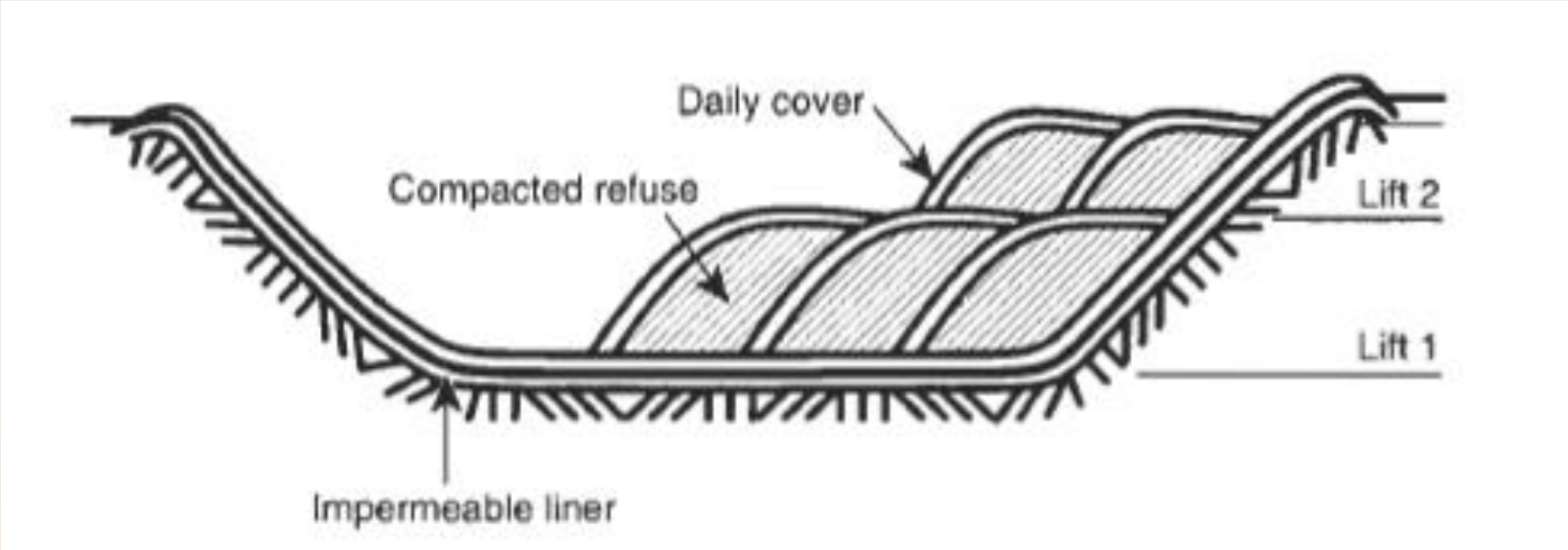
# Landfills

- A modern landfill is not a dump; it is an engineered facility used for disposing of solid wastes on land without creating nuisances or hazards to public health or safety, such as the breeding of rats and insects and the contamination of groundwater.



# Sanitary Landfills

- Designed, controlled and managed disposal sites for MSW spread in thin layers, compacted, and covered with a fresh layer of soil each day to minimize pest, aesthetic, disease, air pollution, and water pollution problems

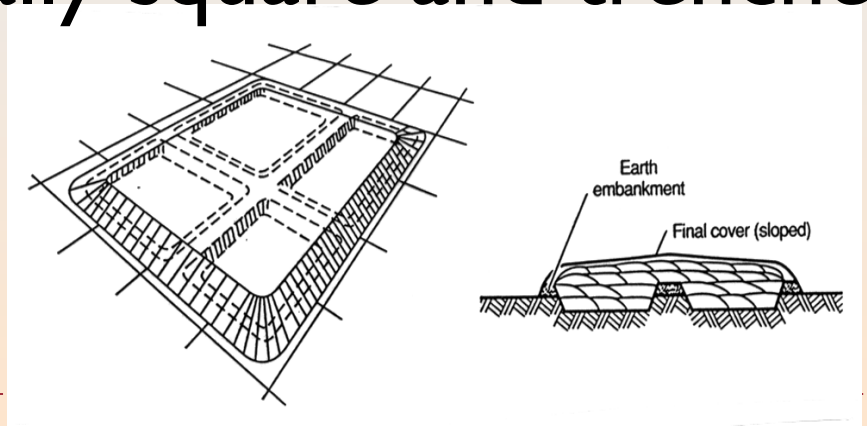


# Common Landfill Methods

- Trench Method
- Area Method
- Canyon Depression Method

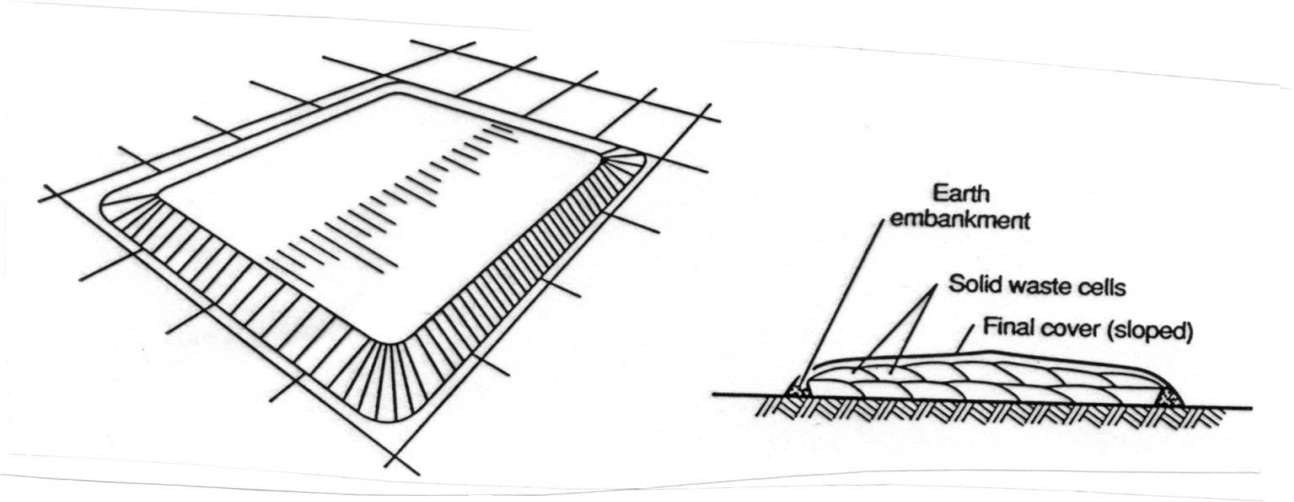
# Trench Method

- It is ideally suited to areas where an adequate depth of cover material is available at the site and where water table is not near the surface.
- The soil excavated is used for daily and final cover.
- Excavated cells are typically square and trenches are long ditches.



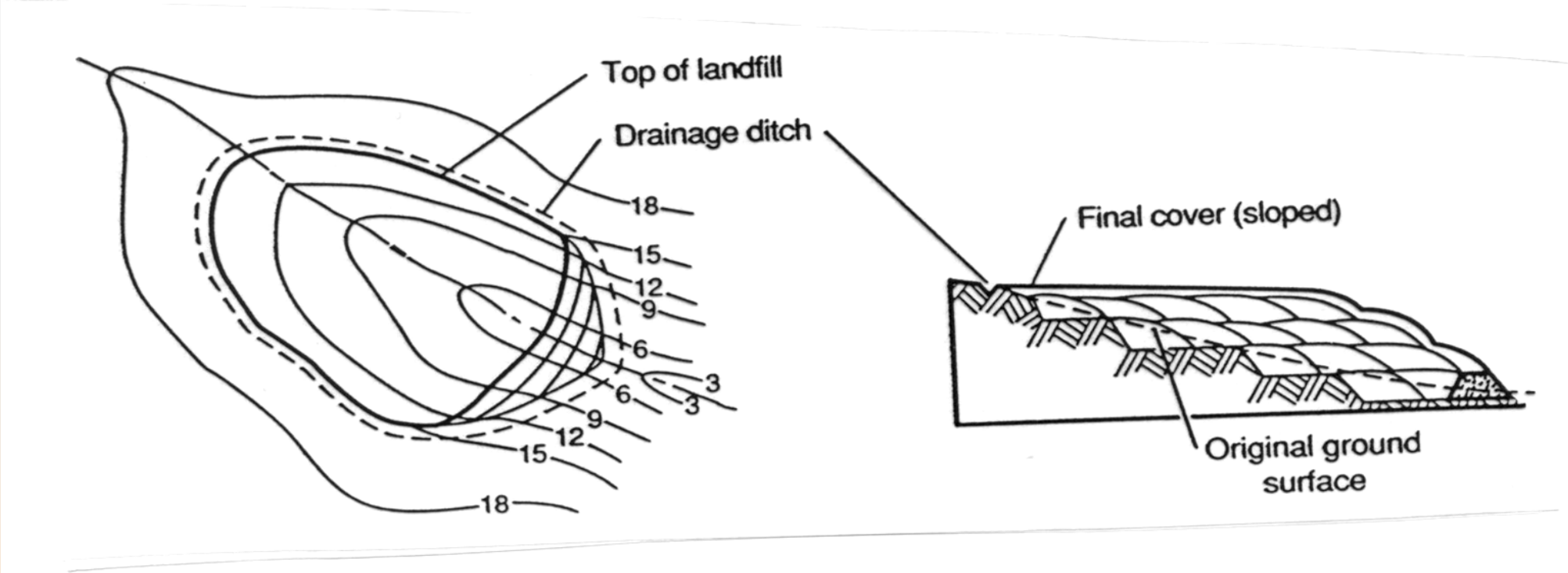
# Area Method

- It is used when the terrain is unsuitable for excavation.
- High-groundwater conditions necessitate the use of this type.
- Cover material must be hauled by truck or earthmoving equipment from adjacent land or from borrow-pit areas.
- Compost produced from MSW can be used as intermediate cover material.



# Canyon Depression Method

- filling in a hole, ravine, quarry that already exists
- Canyons, ravines, dry borrow pits, and quarries are used.
- Control of surface drainage often is critical factor in the development of canyon/depression sites.
- Filling for each lift starts at the head end of the canyon and ends at the month, so as to prevent the accumulation of water behind the landfill.
- Cover material is excavated from the canyon walls or floor before the liner is installed.


Top of landfill
Drainage ditch
18
15
12
9
6
3
6
3
9
12
15
18
Final cover (sloped)
Original ground surface

# Landfill gases

- Carbon dioxide and Methane
- **Volume of gas produced**
  - methane fermentation process:

$$C_aH_bO_cN_d + nH_2O \rightarrow m\,CH_4 + s\,CO_2 + d\,NH_3 = z\,C_5H_7O_2N + \text{energy}$$

**Biodegradable organic matter**

**bacterial cells**

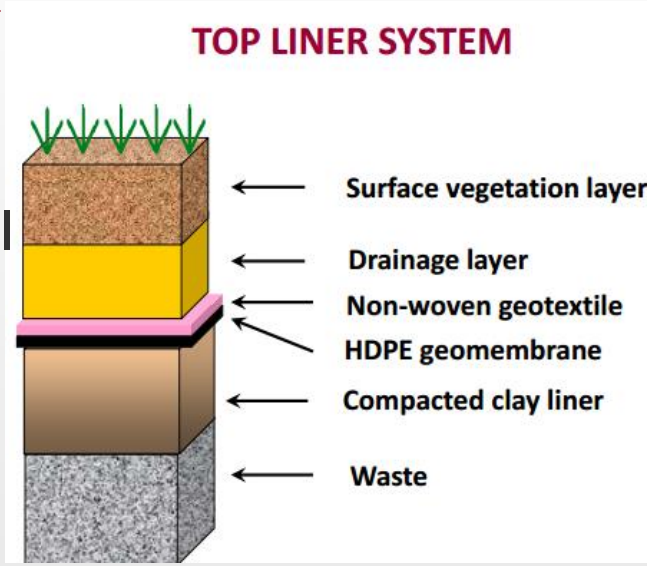
- where
  - $n = (4a - b - 2c + 3d)/4$
  - $\mathrm{m} = (4a + b - 2c - 3d)/8$
  - $\mathrm{s} = (4a - b + 2c + 3d)/8$
- Under ideal conditions, the gases generated from a landfill should be either vented to the atmosphere or, in larger landfills, collected for the production of energy.

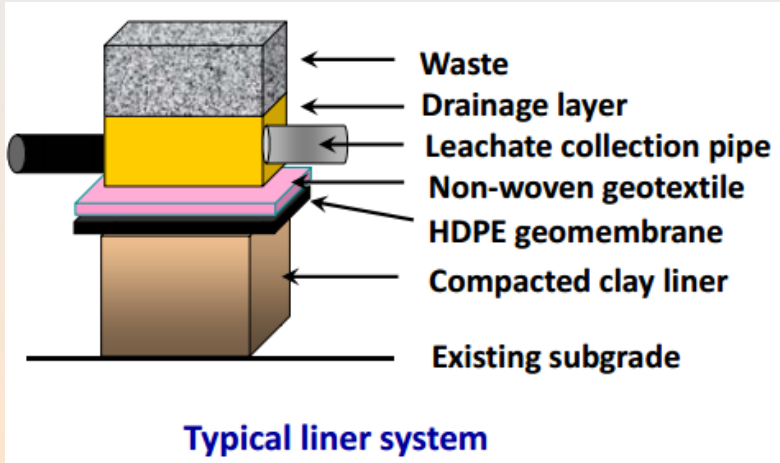
# Leachate

- The liquid produced during decomposition, as well as
- water that seeps through the groundcover and works its way out of the refuse

# Components of landfill

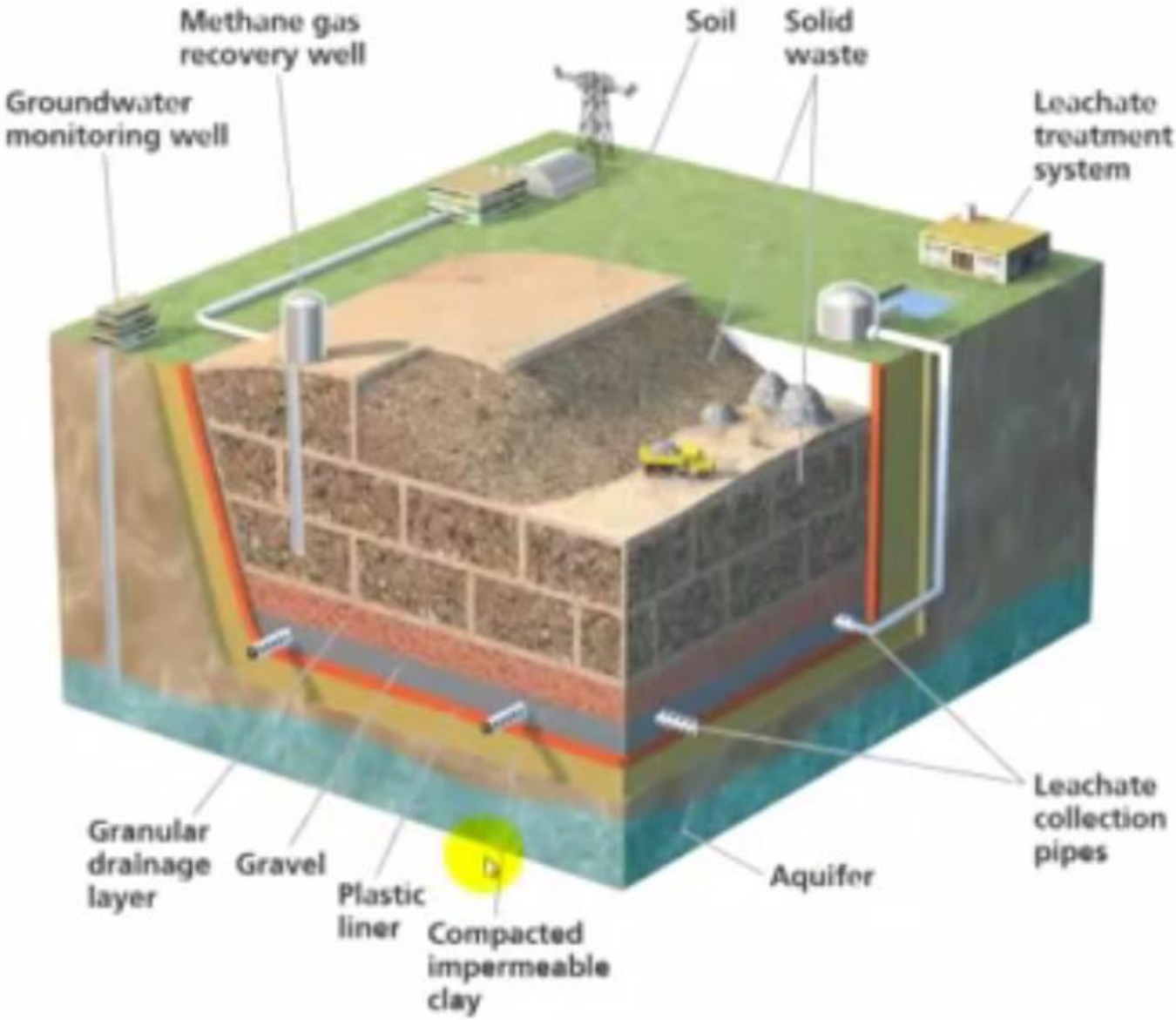
- **Bottom and side liner system**
  - Geomembrane, geosynthetic clay liner, geotextiles
  - Helps to prevent contamination of surrounding water & soil
- **Leachate collection and removal system**
  - Helps to prevent build up of leachate head on the liner
  - drain the leachate effectively outside for treatment
- **Gas collection and removal system**
  - Helps to generate energy
  - Flared under controlled condition
- **Top liner system**
  - Prevent infiltration water
  - Support surface vegetation
  - Enhance surface drainage




Typical liner system

# Sanitary landfill




**"Sanitary"** because waste is buried or piled up so as to avoid contamination of the environment

# Landfill site location

- Factors that must be considered in evaluating potential sites
  - Location restrictions
  - Haul distance
  - Available land area
  - Site access
  - Soil conditions and topography
  - Climatologic conditions
  - Surface water hydrology
  - Geologic and hydrogeologic conditions
  - Local environmental conditions
  - Ultimate use of completed landfills

# Example

- Imagine a town where 10000 households each generating 50L of MSW per day. What would this MSW occupy in a landfill? Assume that 10% of volume is occupied by the final cover. Assume that the MSW has a loose density of 120kg/$m^3$ and a compacted density of 600kg/$m^3$

## Solution

- $Mass_{loose} = Mass_{compacted}$
- $V_{loose\text{-}MSW} * D_{loose\text{-}MSW} = V_{compacted\text{-}MSW} * D_{compacted\text{-}MSW}$
- $V_{loose\text{-}MSW} = 10000\ ca * 50\ L/ca.day * m^3 / 1000\ L$
- $V_{loose\text{-}MSW} = 500\ m^3/day$
- $V_{compacted\text{-}MSW} = (500\ m^3/day * 120\ kg/m^3) / 600\ kg/m^3$
- $V_{compacted\text{-}MSW} = 100\ m^3/day$
- $V_{landfill} = V_{compacted\text{-}MSW} * (1+10\%)$
- $V_{landfill} = 110\ m^3/day$

# Example

Addis Ababa municipality has a landfill site which is 15 m high and encompasses 40 hectare (assume a rectangular solid) and has been in operation since January 2003. Records show they do about 0.2kg/capita.day. Assume 4:1 cover (4/5 waste and 1/5 soil). Estimate the average population that the landfill has been serving assuming a flat population curve. (the MSW compacted density= 600 kg/m3)

# Example

- Solution:
  - Total volume = 15 m x 40 hectare x 10,000 $m^2$/hectare

    = 6,000,000 $m^3$
  - Volume of waste = 6,000,000 $m^3$ x 4/5 (ratio of waste to the total)

    = 4,800,000 $m^3$
  - Weight of waste = 4,800,000 $m^3$ x 600 kg/$m^3$
  - Weight of waste = 2,880,000,000 kg

- Population = 2,880,000,000 kg x cap.day/0.2 kg x 1 year/365 days x 1/16 years

  = 2465754

# Reuse, Recycling, and Resource Recovery

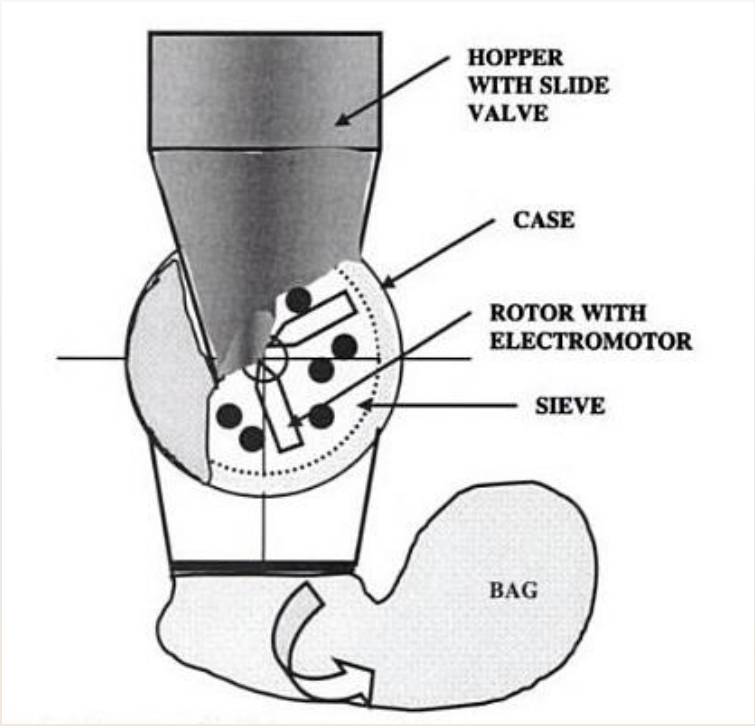
- ***Redefining solid waste as a resource and using it to produce usable goods***
- ***Reuse:*** voluntary continued use of a product for a purpose for which it may not have been originally intended.
- ***Recycling:*** is the collection of a product by the public and the return of this material to the industrial sector.
- ***Recovery:*** the waste is collected as mixed refuse, and then the materials are removed by various processing steps.

# Recovery

- Shredding
- Screens
- Air Classifiers
- Magnets

# Shredding

- Size reduction, or *shredding*, is brute force breaking of particles of refuse by swinging hammers in an enclosure.
- *two* types of shredders : the vertical and horizontal hammermills.
- The specific energy W required to reduce a unit weight of material 80% finer than some diameter $L_F$ to **a** product 80% finer than some diameter Lp, where both $L_F$ and $Lp$ are in micrometers (pm), is expressed as

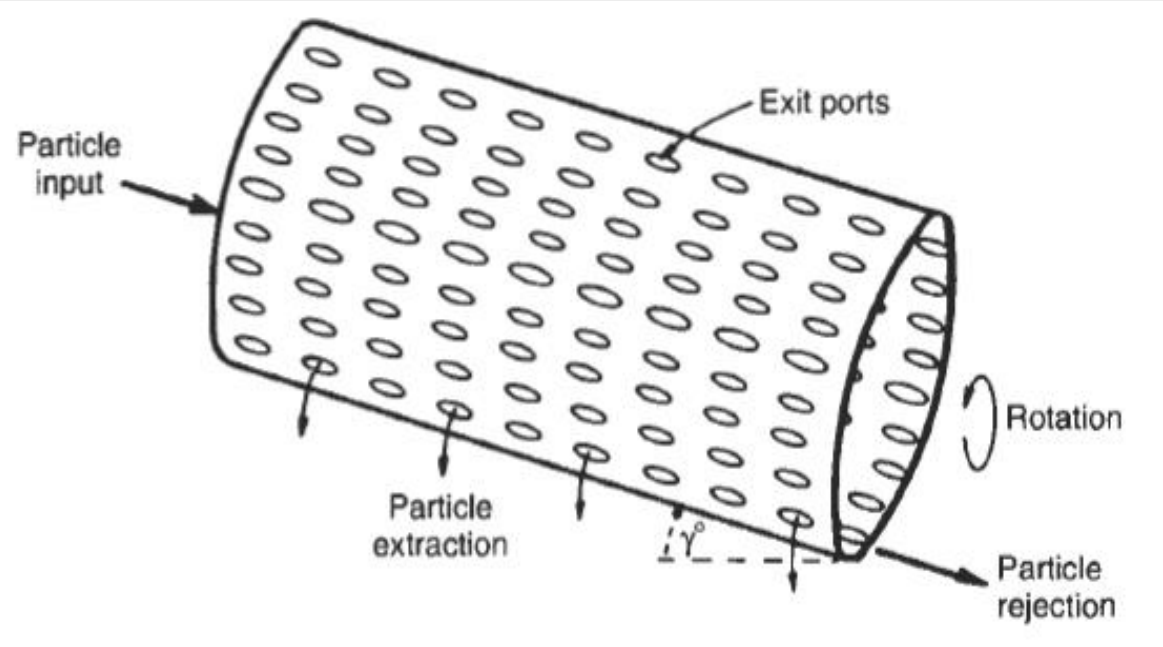



$$W = 10W_i\left[\frac{1}{\sqrt{L_p}} - \frac{1}{\sqrt{L_F}}\right]$$

$W_i$ Bond *work index*
*function of the material processed*

# Screens

- Screens separate material solely by size and do not identify the material by any other property.
- *Trommel screen*

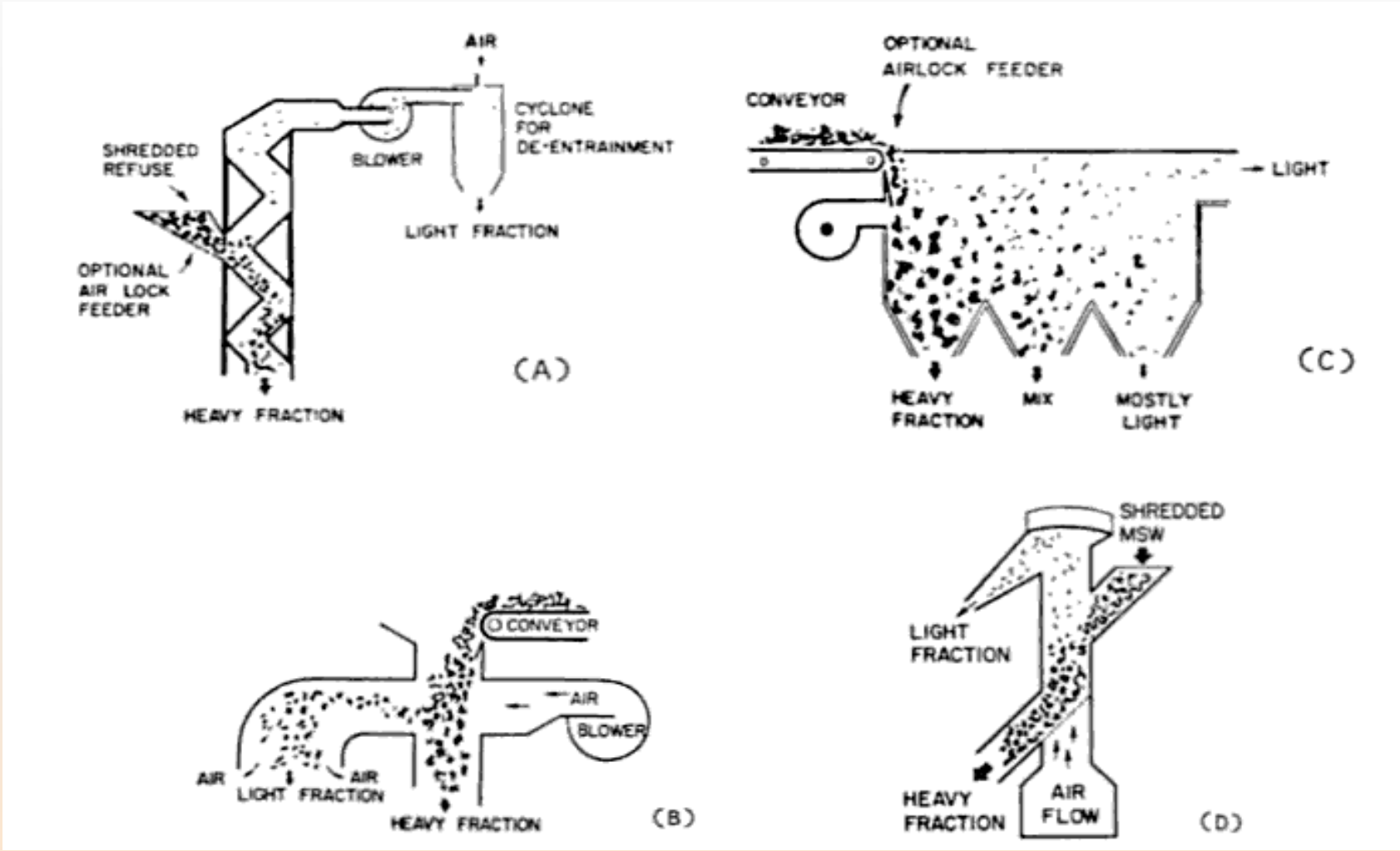



- *Cascading*
- *Cataracting*
- *Centrifuging*

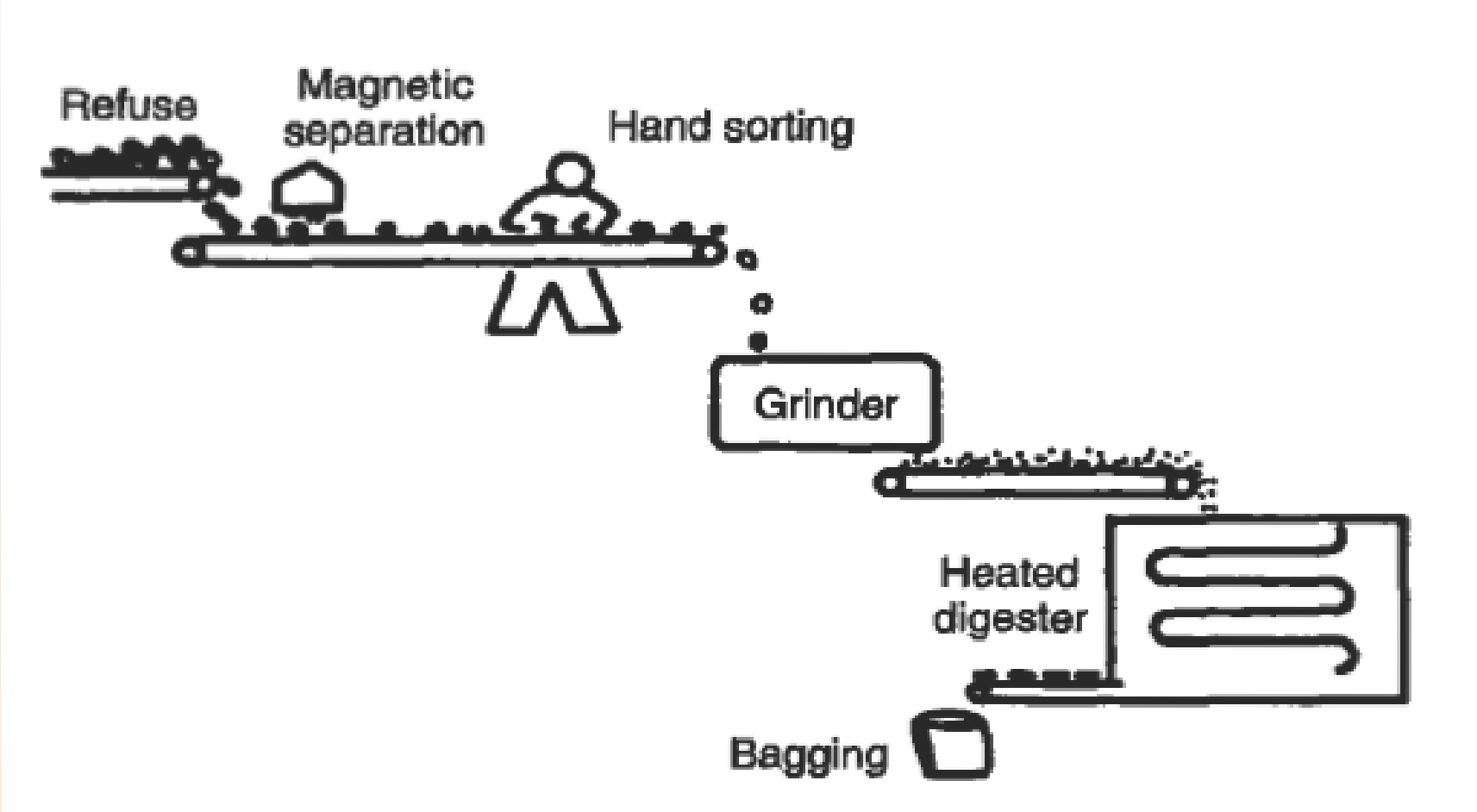
$$\mu_c = \sqrt{\frac{g}{4\pi^2 r}}$$

# Air Classifiers

- Materials separated by their aerodynamic properties.
- Heavier, most inert (metals, glass, dense plastics, rubbers, stones, and organics)
- Lighter combustible (paper, film plastic, fabric, and some wood)
- terminal settling velocity difference
  - The fraction escaping with the air stream is the product or *overflow,*
  - the fraction falling out the bottom is the reject or *underflow.*


AIR
SHREDDED REFUSE
BLOWER
CYCLONE FOR DE-ENTRAINMENT
LIGHT FRACTION
OPTIONAL AIR LOCK FEEDER
HEAVY FRACTION
(A)
OPTIONAL AIRLOCK FEEDER
CONVEYOR
LIGHT
HEAVY FRACTION
MIX
MOSTLY LIGHT
(C)
CONVEYOR
AIR
BLOWER
AIR
AIR
LIGHT FRACTION
HEAVY FRACTION
(B)
SHREDDED MSW
LIGHT FRACTION
HEAVY FRACTION
AIR FLOW
(D)

# Magnets


Refuse
Magnetic separation
Hand sorting
Grinder
Heated digester
Bagging

# Centralized Recycling Flowsheet