MUNICIPAL SOLID WASTE MANAGEMENT

Course: B.E Civil Engineering

Course Code: 01OE 801

Course Module Prepared by

Dr. G.Senthilkumar
Associate Professor
Department of Civil Engineering
Annamalai University

What is solid waste ?

- Solid waste is defined as the unwanted matter which is generated by the society that does not have any economic value from the point of view of first owner.

Why and where it is generated ?

- The consumption of resources is the reason for the generation of waste.
- It is generated in the places where human activities prevail.

Per capita waste generated in India – 0.25 to 2.5 kg/ day

What is solid waste management ?

- It is defined as the discipline associated with control of generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economics, aesthetic, engineering and other environmental considerations.

Goals

- To indicate the direction and desired outcome of solid waste
- It gives overall and explicit purpose to the system or special programs and facilities provided and management particles interns of end result.

Objectives

- To reduce the adverse impact on the environment
- To consider material flow in the society
- Reduction in raw material use
- Reduction in solid waste quality
- Reuse of materials
- Recovery of material and energy
- Day to day solid waste management

Categorization

- Categorization of solid waste can be
  - based on material
  - based on hazard potential
  - based on source of generation

Types of solid waste

- Garbage
- Ashes and residue
- Combustible and non-combustible
- Bulky waste
- Street waste
- Biodegradable and non-biodegradable
- Dead animals
- Abandoned vehicles
- Construction and demolition waste
- Farm waste
- Hazardous waste
- Sewage waste

Sources of solid waste

- Residential
- Commercial
- Industrial
- Municipal services
- Institutional
- Agricultural
- Hospital

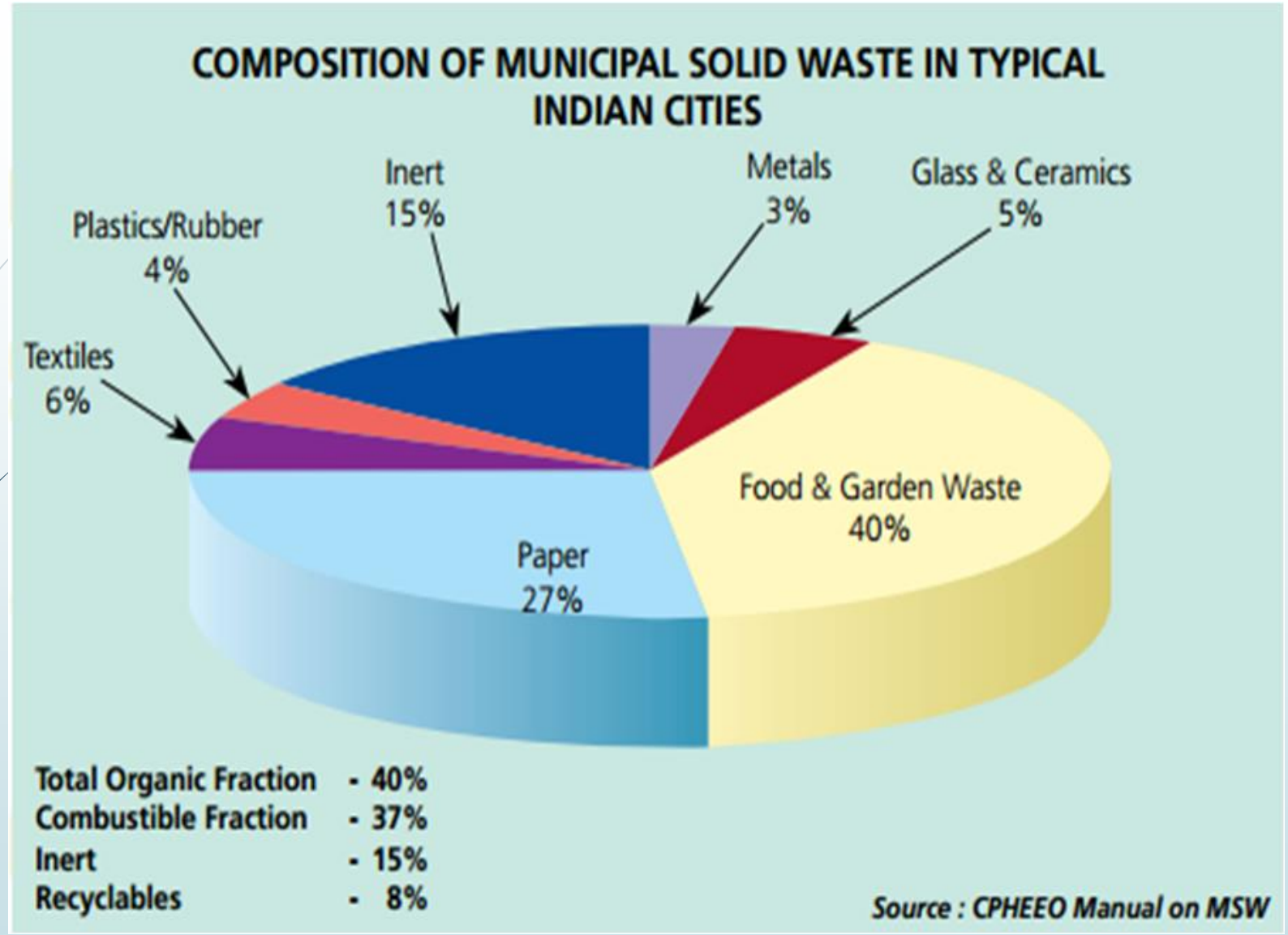
To remember

The quantity, quality and composition of waste depends on the source of waste generation.

Composition of solid waste

The composition of municipal solid waste of India is given below in the table in percentage.

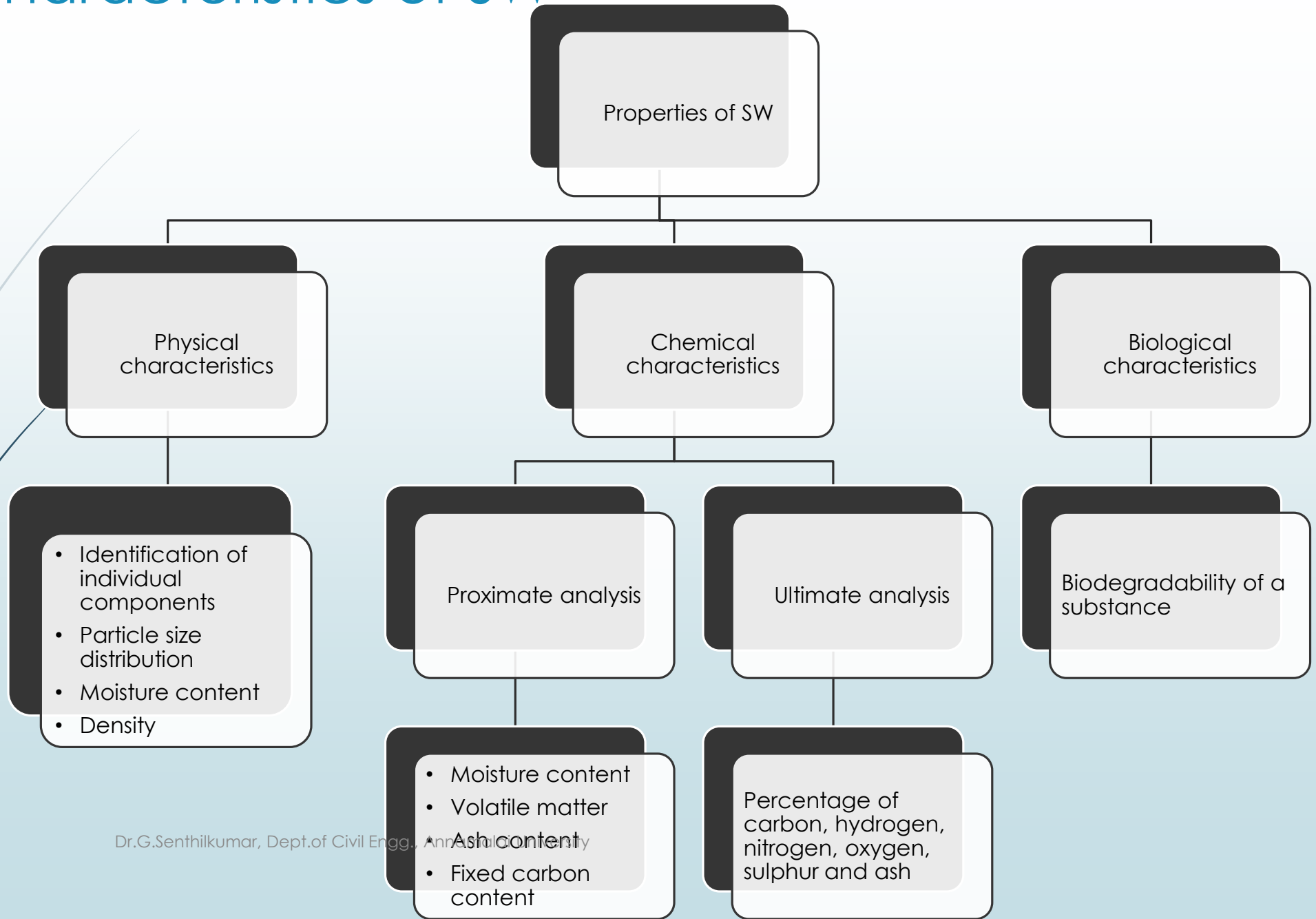
Composition	Low income	Middle income	High income
Organic			
Food waste	40-80	20-65	6-30
Paper	1-10	8-30	20-45
Card board	-	-	5-15
Plastic	1-5	2-6	2-8
Textiles	1-5	2-10	2-6
Rubber	-	-	0-2
Leather	-	-	0-2
Yard waste	1-5	1-10	10-20
Woods	-	-	1-4
Inorganic			
Glass	5	5	8
Aluminium	2	2	-
Inert (ash, dirt, etc,.)	20	15	5


COMPOSITION OF MUNICIPAL SOLID WASTE IN TYPICAL INDIAN CITIES
Inert 15%
Metals 3%
Glass & Ceramics 5%
Plastics/Rubber 4%
Textiles 6%
Food & Garden Waste 40%
Paper 27%
Total Organic Fraction - 40%
Combustible Fraction - 37%
Inert - 15%
Recyclables - 8%
Source : CPHEEO Manual on MSW

Some important definitions

- Rubbish : It consists of tin cans, newspaper, packaging materials, bottles, plastics, and yard trimmings i.e. it consists of both combustible and non-combustible matter excluding garbage.
- Garbage : It is a portion of waste that is biodegradable. The biodegradable waste that is generated from the kitchens, restaurants and markets.
- Trash : It is the combustible portion of the rubbish.
- Discarded materials : The solid waste which remains after the materials are removed for recycling, reuse and composting.
- Reuse : Reusing a product for the same application for which it is originally intended.
- Recycling : A terminology used to represent the processing of recovered material to make them as raw material for new applications.
- Remanufacturing : it is the restoration of the product which has the same characteristics as that of the new one.
- Recovery : Segregation and using the product for other purpose for reusing, recycling, and remanufacturing is called recovery of materials. The recovered materials will have some economic values.
- Refuse : It is the solid waste reject coming out of human practises.
- Litter : The collection of street sweepings at one point is called as litter.

Characteristics of SW



Moisture content

- Moisture content is the water content present in a substance.
- It can be calculated by using the below formula.

Moisture Content

$$MC = \frac{w - d}{w} \times 100$$

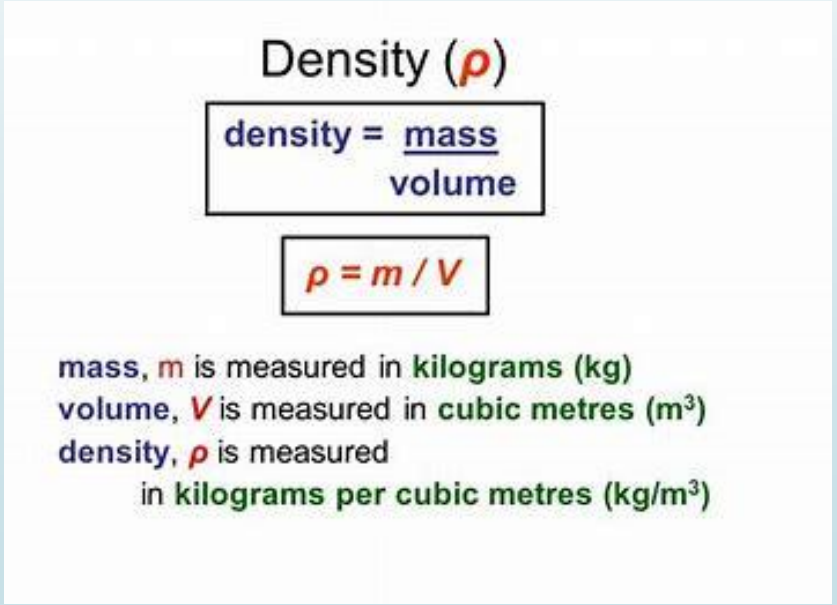
w = wet weight
d = weight after drying

Typical moisture content of MSW

Component	% Range	% Typical
Food waste	50–80	70
Paper	4–10	6
Cardboard	4–8	5
Plastics	1–4	2
Textiles	6–15	10
Rubber	1–4	2
Garden trimming	30–80	60
Wood	15–40	20
Tin cans	2–4	3
Leather	8–12	10
Glass	1–4	2
Non ferrous metals	2–4	2
Dirt, ashes, bricks	6–12	8

Density of SW

- The density of the solid waste plays an important role in the solid waste management.
- It is influenced by the geographical location, season of the year, length and time of storage.
- The general formula for density is



Component	Range (kg(m)/m^3)	Typical
Food waste	120-480	290
Paper	30-130	85
Cardboard	30-80	50
Plastics	30-130	65
Textile	30-100	65
Rubber	90-200	130
Leather	90-260	160
Garden trimming	60-225	105
Wood	120-320	240
Miscellaneous organics	90-360	240
Glass	160-480	195
Tin cans	45-160	90
Non ferrous metal	60-240	160
Ferrous metal	120-1200	320
Dirt, ash, brick	320-960	480
MSW (uncompacted)	90-180	130
MSW (compacted)	180-450	300

Proximate analysis

- The proximate analysis includes
  - Moisture – loss of moisture when heated to 105° C for 1 hr.
  - Volatile combustion matter – loss of weight on ignition at 950° C
  - Fixed carbon – residue left after volatile matter is removed
  - Ash – weight of residue after combustion in an open crucible

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

Ultimate analysis

- It involves the determination of percent of C, H, N, O, S and ash.
- It is used to define proper mix of waste material to achieve suitable C/N ratio for biological conservation process
- It also includes the determination of the presence of halogens

Elemental analysis	%
Carbon	47.36
Hydrogen	6.25
Oxygen	39.25
Nitrogen	0.85
Sulfur	0.19
Ash	6.10

Energy content of SW

Component	Range (kJ/kg)	Typical
Food waste	3500-7000	4650
Paper	11600-18600	16750
Cardboard	13950-17450	16300
Plastics	27900-37200	32600
Textile	15100-18600	17450
Rubber	20900-27900	23250
Leather	15700-19800	17450
Garden trimming	2300-18600	6500
Wood	17450-19800	18600
Miscellaneous organics	11600-26000	18000
Glass	100-250	150
Tin cans	250-1200	700
Ferrous metal	250-1200	700
Dirt, ash, brick	2300-11650	7950
MSW	9300-12800	10500

- If the energy values are not available, the approximate value of energy content of MSW can be estimated using the **Modified Dulong equation**.

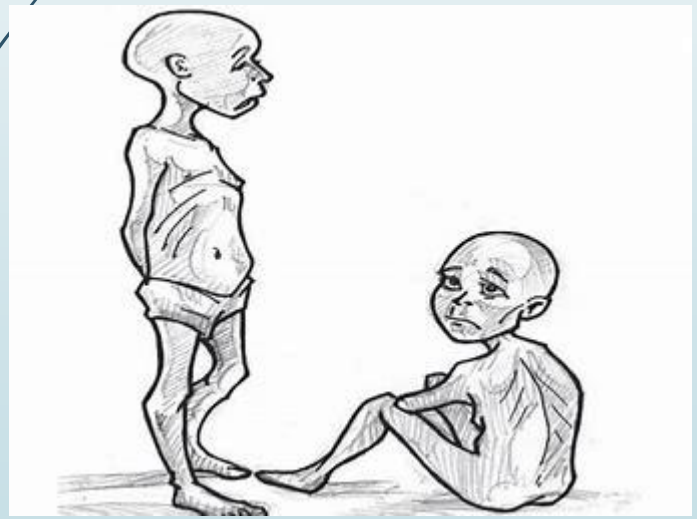
$$Energy\ in\ \left(\frac{kJ}{kg}\right) = 337C + 1428\left[H - \frac{O}{8}\right] + 9S$$

Where,

C is the percentage of carbon,
H is the percentage of hydrogen,
O is the percentage of oxygen, and
S is the percentage of sulphur.

Common illness associated with MSW

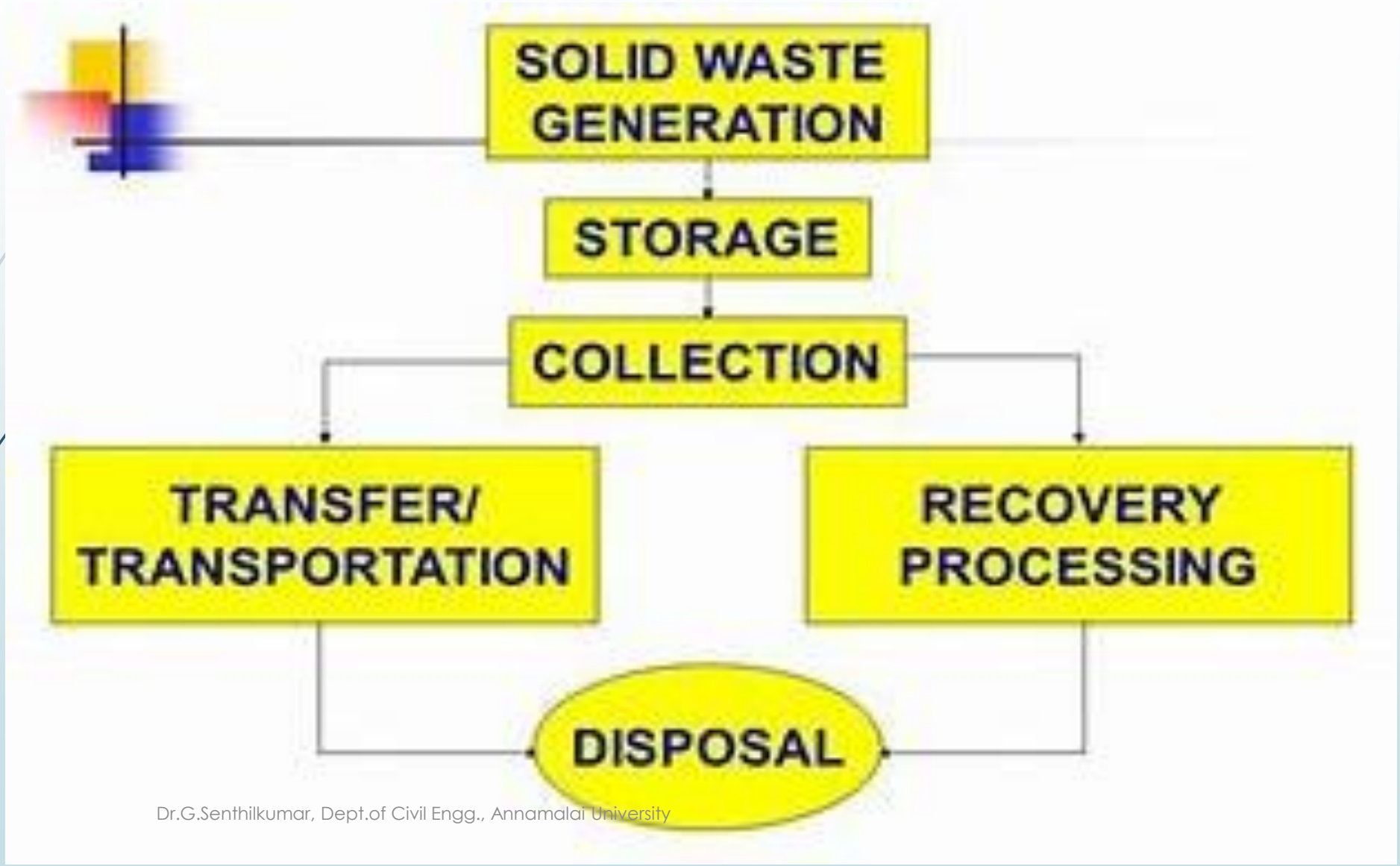
- Tenia versicola, diarrhoea, jaundice, Tenia cruris, cholera, skin diseases, malaria, chicken pox, dysentery and typhoid are few common health hazard for humans.
- The batteries and automobile products posses Hg, Cd, Ni, Ar, Zn, Ba etc., which are highly toxic carcinogenic causing staining of fingers, teeth, hair, general weakness, fatigue and nasal irritation.



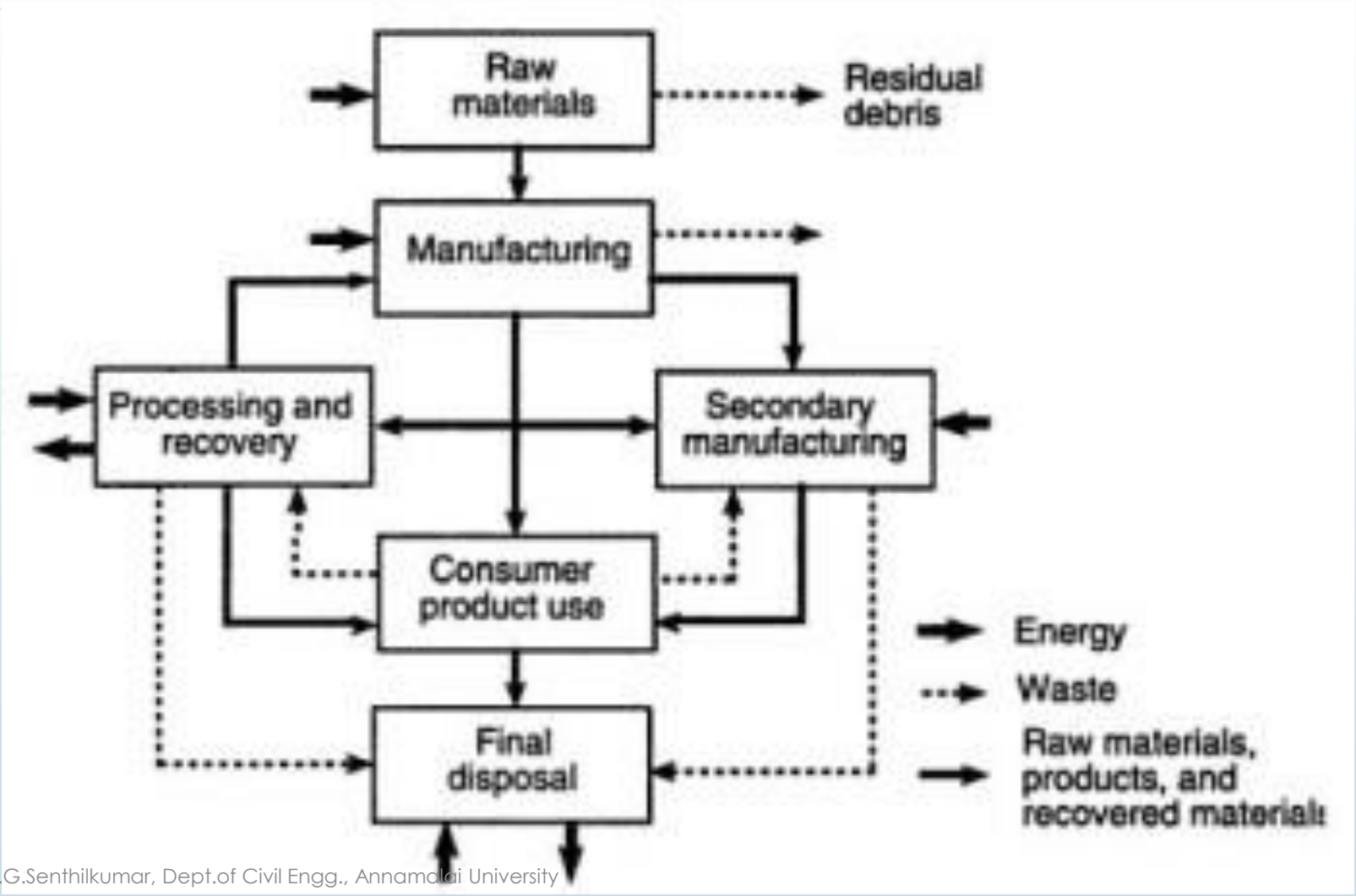
Legal Requirements

- Law of torts
- Indian Penal Code [Chapter XIV- section 268 to 294 A], 1860
- Code of Civil Procedure [Section9,91 to 93], 1908
- Constitution of India [Part 4 & 9], 1950
- Code of criminal procedure [Chapter 10], 1973
- Water (Prevention and control of pollution) Act, 1974
- Air (Prevention and control of pollution) Act, 1981
- Environmental Protection Act [Section 29], 1986
- CRZ Notification,1991
- Hazardous waste (Management and handling) Rules, 1998
- Bio medical waste (Management and handling) Rules, 1998
- Recycled plastics (Management and handling) Rules, 1999
- Municipal solid waste (Management and handling) Rules, 2000
- Solid Waste Management Rules, 2016

Functional elements of SWM



Material flow in society



Storage

- Storage is an important element in the solid waste management.
- Storage is always accompanied by separation process.
- Storage depends on the quality and quantity of waste generated.
- The storage process further depends on:
  - location of bin,
  - size of bin,
  - provision of lid and
  - material of bin.

Basic principles of storage

- Not to throw waste into the neighbour hood area, street, open areas, drains and water bodies.
- Keep biodegradable waste separately in a non corrosive container.
- Keep dry and recyclables in a separate bin.
- Keep all hazardous waste separately.

To make storage effective

- Separating the waste accordingly in different bins.
- Making specific storage plans for households, multi-storeyed buildings, slum locations, institutions, commercial areas, restaurants, hospitals, parks and gardens, markets(vegetable and fruits, fish and meat) and other locations.

The colour of the bin helps in separation of waste.

- Black – recyclables
- Yellow – toxic waste
- Red – non biodegradable
- Green - biodegradable

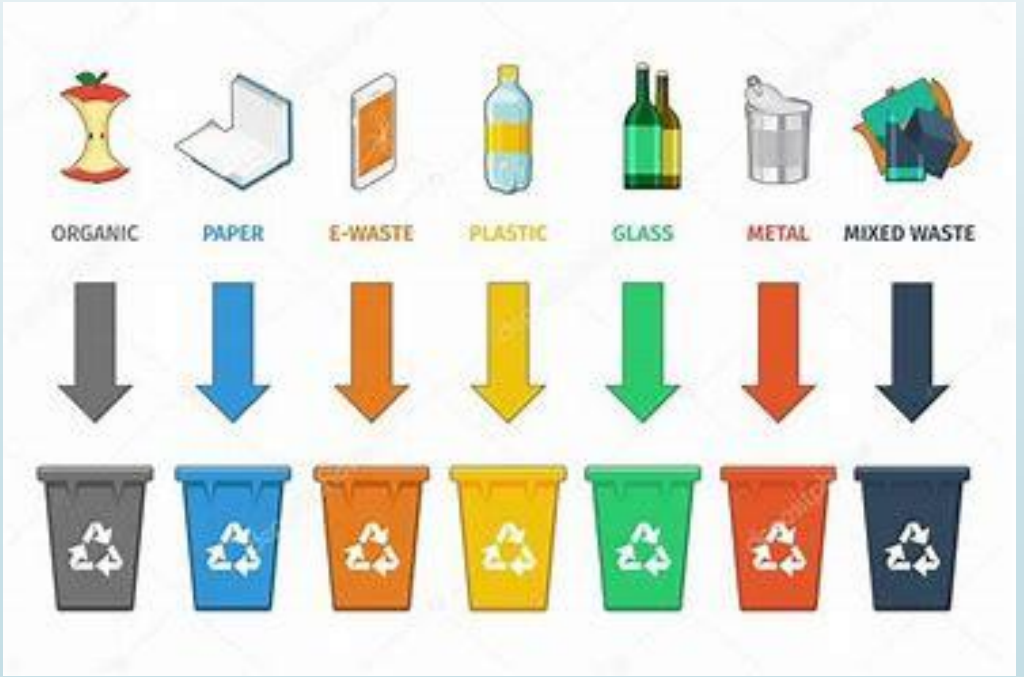
Separation

- Separation is a main process that helps in increasing the efficiency of the solid waste management.
- It is based on the size, nature and mass of the waste generated.
- It can be done in two ways
  - Manual separation
  - Mechanical separation
- It can be done at
  - the site of generation
  - the site of processing

Cont.,

Benefits of segregation of waste

- Waste-to-Wealth
- Reduces waste
- Cleanliness
- Safety and better health
- Cost and time saving in waste management
- Quantum of waste to be land filled will get reduced .



Collection

- Once the waste is segregated and stored the next step is to collect it.
- This term not only includes the gathering or picking up of solid waste from various sources, but also the handling of these wastes to the location where the content of the collection vehicles are emptied.
- This can be done in two stages
  - Primary collection
  - Secondary collection
- Collection form the households in smaller vehicles or a community bin to the small scale collection vehicles is know as the primary collection.
- The secondary collection is receiving waste from the smaller vehicle and transporting it to the point of recovery or disposal.

Collection sites

- The collection is done form the following sites
  - Curb side
  - Alley
  - Set out
  - Set back

Collection frequency

- The frequency of the collection is the number of times the waste is collected.
- The collection frequency depends on the following parameters
  - Number of population
  - Quantity of waste
  - Type (or) composition of waste
  - Capacity of container

Collection frequency

Type of locality	Frequency	
	Class 1 cities (population > 1 lakh)	Class 2 cities (population 50K - 1 lakh)
Residential		
Area with high population density	Once / twice a day	Once a day
Moderate population density	Once / twice a day	Once in 2 days
Low population density	Once in 2 days	Once in 3 days
High income area	Once / twice a day	Once a day
Markets	Once / twice a day	Once a day
Commercial area	Twice a day	Once a day
Industrial area	Once a day	Once a day

Collection type

- Collection system may be classified based on mode of operation, the equipment's used, and types of waste collected.
- Based on the mode of operation system, the collection system is classified as given below
  - Hauled container system
  - Stationary container system

- **Haul container system (HCS)**

- **Stationary container system (SCS)**

Hauled container system

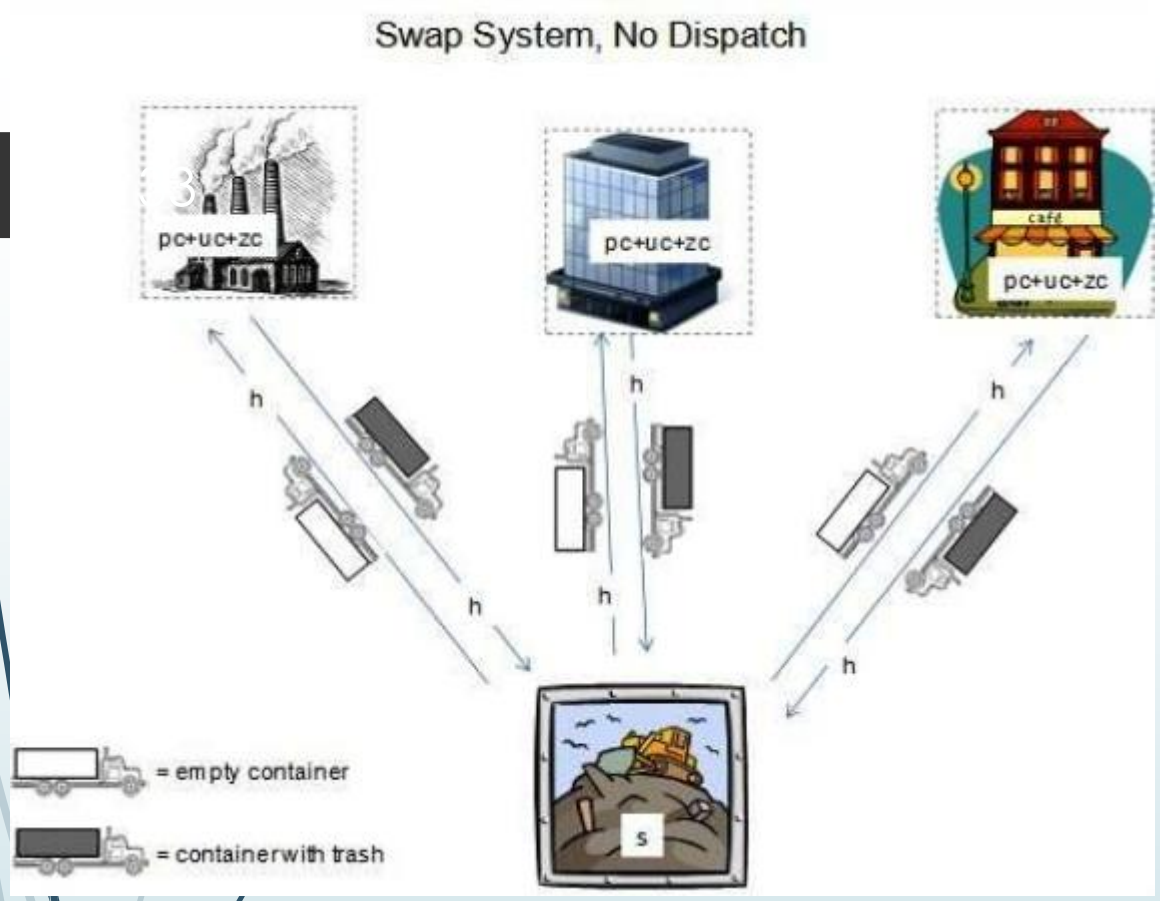
- Container is moved to disposal site
- Used for construction & demolition waste
- High generation rates (open markets)
- One drive and frequent trips
- The vehicles used in this system are
  - Hoist truck
  - Tilt frame container
  - Trash – trailer
- There are two types of HCS
  - Conventional mode
  - Exchange container mode

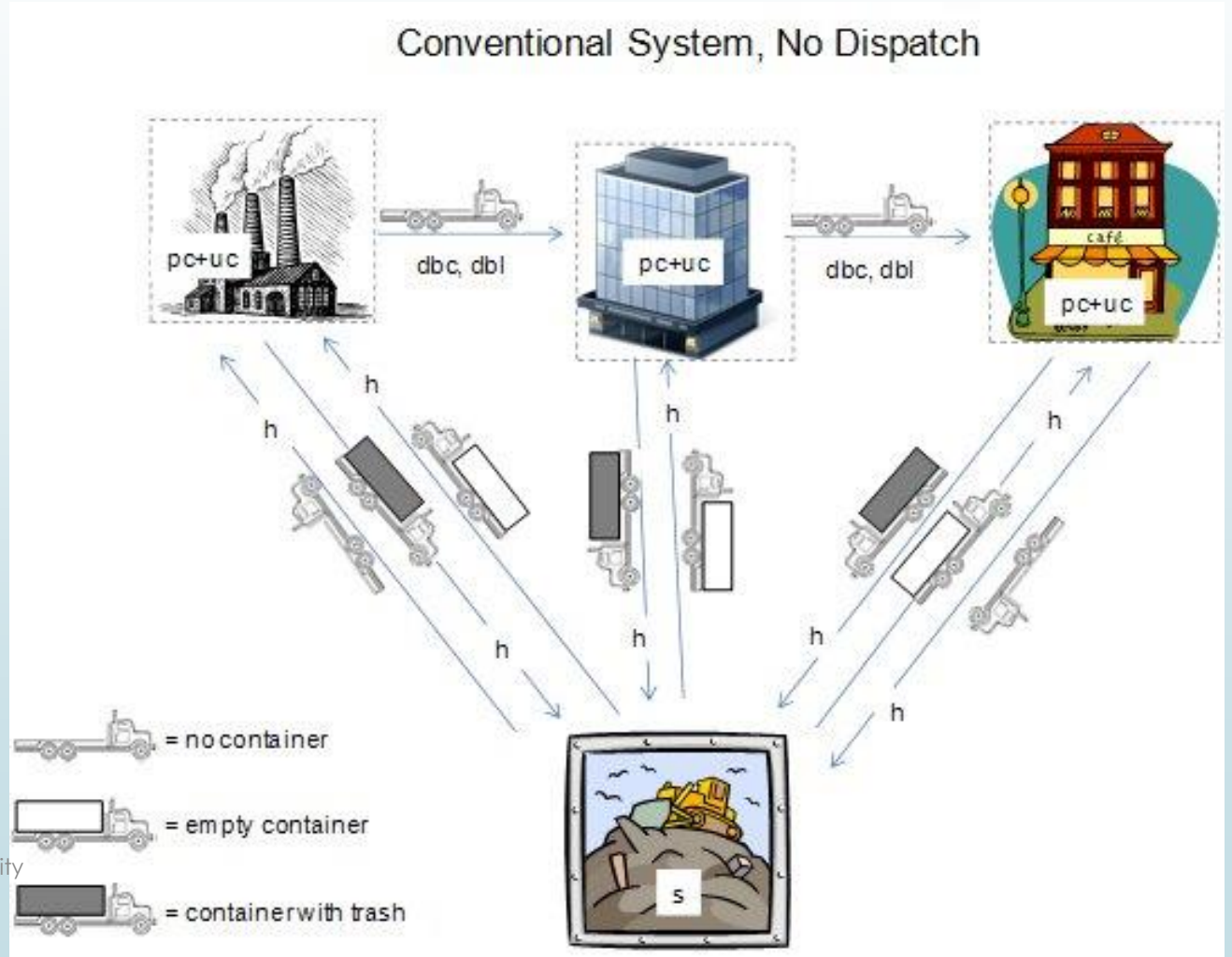
Advantages

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

Disadvantages

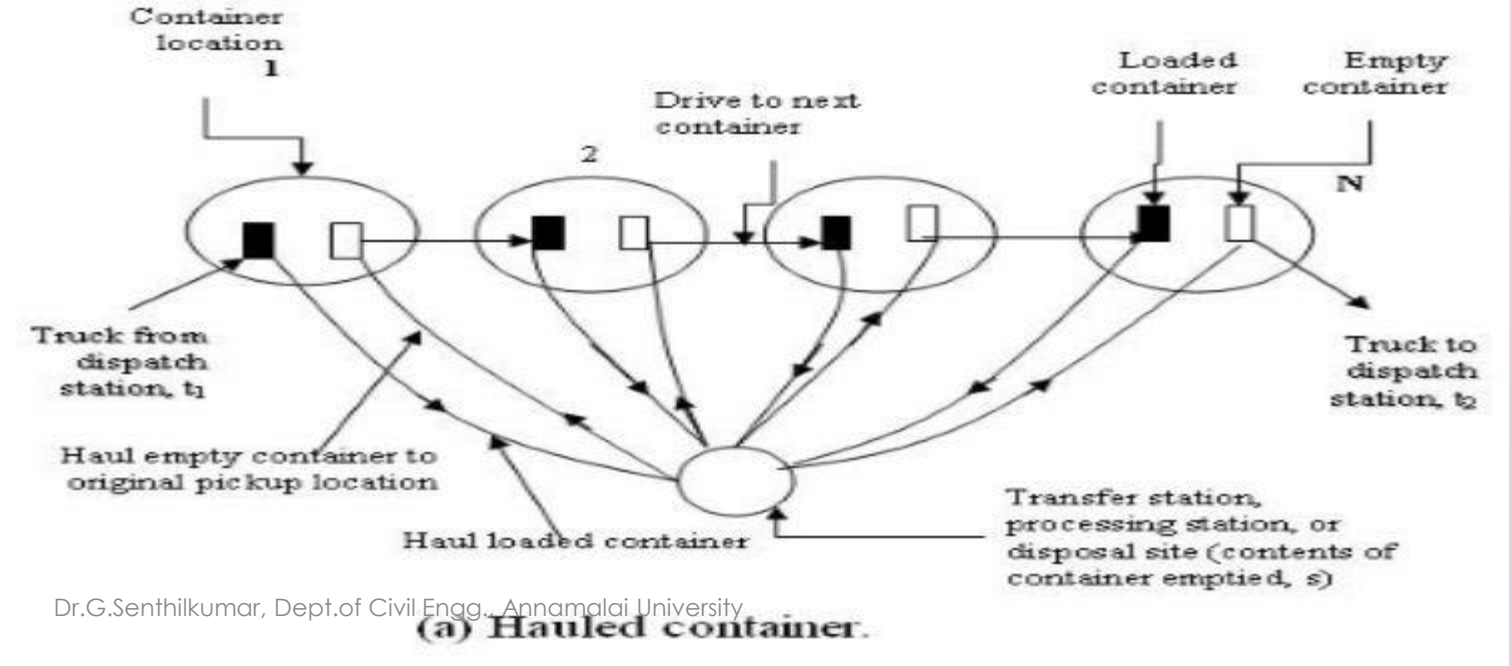
- If the containers are not filled, low utilization rate.


Swap System, No Dispatch
pc+uc+zc
pc+uc+zc
café
pc+uc+zc
h
h
h
h
h
h
S
= empty container
= containerwith trash


Conventional System, No Dispatch
pc+uc
dbc, dbl
pc+uc
dbc, dbl
café
pc+uc
h
h
h
h
h
h
h
h
S
= no container
= empty container
= containerwith trash

Conventional mode (HCS)

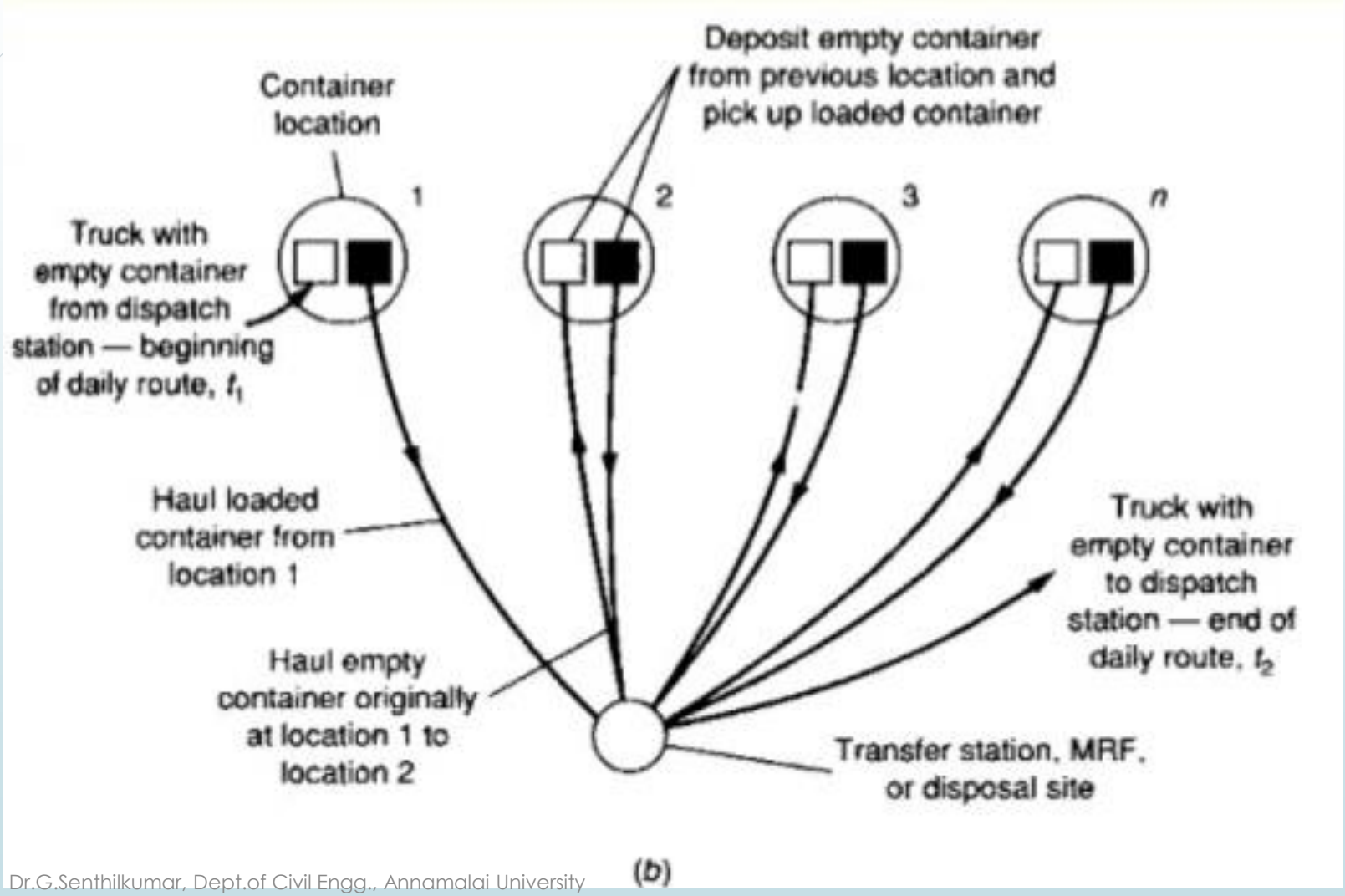
- In this method the truck goes empty form the garage to the first pick up point.
- It collects the filled container and drives to the disposal point to dispose the waste, after which it returns to the same point to keep the empty container.
- Then it drives to the next site to collect the filed container



(a) Hauled container.

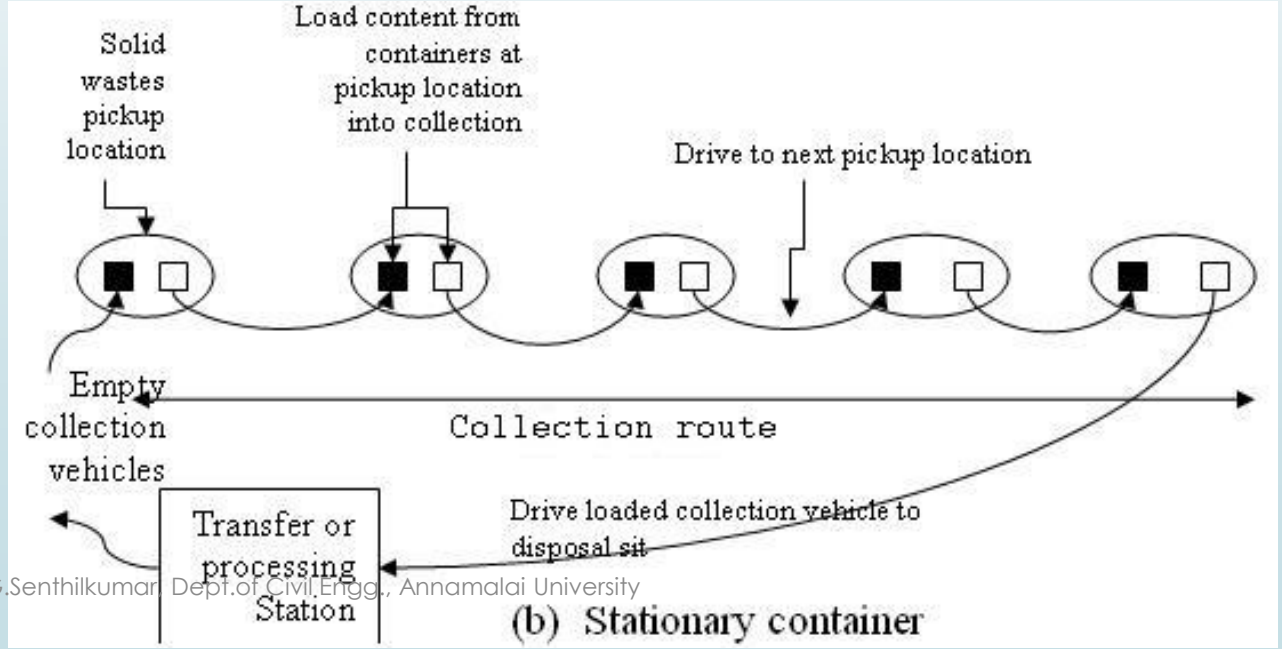
Exchange container method(HCS)

- In this method the truck goes with an empty container form the garage to the first pick up point.
- It exchanges the empty container with the filled container and drives to the disposal point to dispose the waste, after which it returns to the next collection point to keep the empty container.
- In the next collection site, it exchanges the filled with the empty container, and this process continues till the last collection point.
- After emptying the container from last collection point, it travels to the garage with the empty container.
- The advantage in this system compared to that of conventional method is that the number of trips is reduced and the container is cleaned every day.


Container location
Deposit empty container from previous location and pick up loaded container
1
2
3
n
Truck with empty container from dispatch station — beginning of daily route, t_1
Haul loaded container from location 1
Haul empty container originally at location 1 to location 2
Truck with empty container to dispatch station — end of daily route, t_2
Transfer station, MRF, or disposal site
(b)

Stationary container system

- Container remains at site (residential and commercial)
- May be manually or mechanically loaded
- Container size and utilization are important
- This of two types
  - Mechanically loaded collection
  - Manually loaded collection.



Advantages

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

Disadvantages

- System is not flexible in terms of picking up bulky goods.
- Wastes e.g. demolition, that make damage the relatively delicate mechanisms.
- Large volume generations may not have room for storing large containers.

Routing

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

Routing

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

Analysis of Collection Systems

To determine

- Capacity of vehicle
- Number of vehicle required
- Crew size
- Labor required
- Length of workday/week

Look at: (divide collection into specific tasks)

- Pick up time
- Haul time
- At site time
- Off route time
- Container capacity, waste volume generated
- Vehicle compaction factor

Analysis of Collection Systems

- to develop design data and relationship that can be used universally
- to evaluate both the variables associated with collection activities and the variables related to the particular location
- The activities involved in the collection of solid wastes can be resolved into four unit operations
  - Pickup (Phcs)
  - Haul (h)
  - At-site (s)
  - Off-route (W)

Pickup (Phcs)

- 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

Pickup (Pscs)

- time spent loading the vehicle, beginning with the first container and ending when the last container has been loaded

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

At-site (s)

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

Off-Site (W)

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

Formulae

$$Thcs = Phcs + s + a + bx$$

Where,

a is empirical haul constant (hr/trip)

b is empirical haul constant (hr/km)

$$Phcs = Pc + Uc + dbc$$

Where,

Pc is time required to pick up loaded container (hr/trip)

Uc is time required to unload container (hr/trip)

dbc is average time spent driving between container location (hr/trip)

$$Nd = \frac{[\,(1-w)H - (t_1 + t_2)]}{Phcs + s + a + bx}$$

Where,

t_1 is the time from garage to first container location (hr/day)

t_2 is the time from last container location to garage (hr/day)

Transfer station

- A transfer station is an intermediate station between the final disposal and the collection point in order to increase the efficiency of the system as collection vehicles and crew remain closer to route.
- The construction of transfer station requires more attention. The following should be consider while selecting the location for a transfer station
  - It should not be in highly traffic area. The route provided for load and unload the waste should be clear.
  - It should not be near populated or residential area.
- Other factors that affect the selection of transfer station
  - Type of waste received
  - Processed used for recovery of materials
  - The amount of waste to be stored
  - Type of collection vehicle and transfer vehicle used
  - Site topography and access

The types of the transfer station can be classified based on the size

- Small (capacity less that 100 tonnes/day)
- Medium (capacity between 100 to 500 tonnes/day)
- Large (capacity more than 500 tonnes/day)

The components and requirement for a transfer station

- Arrivals and scales
- Tipping, processing and reloading
- Facility
- Basic equipment
- Staffing

An operating transfer station

Volume reduction

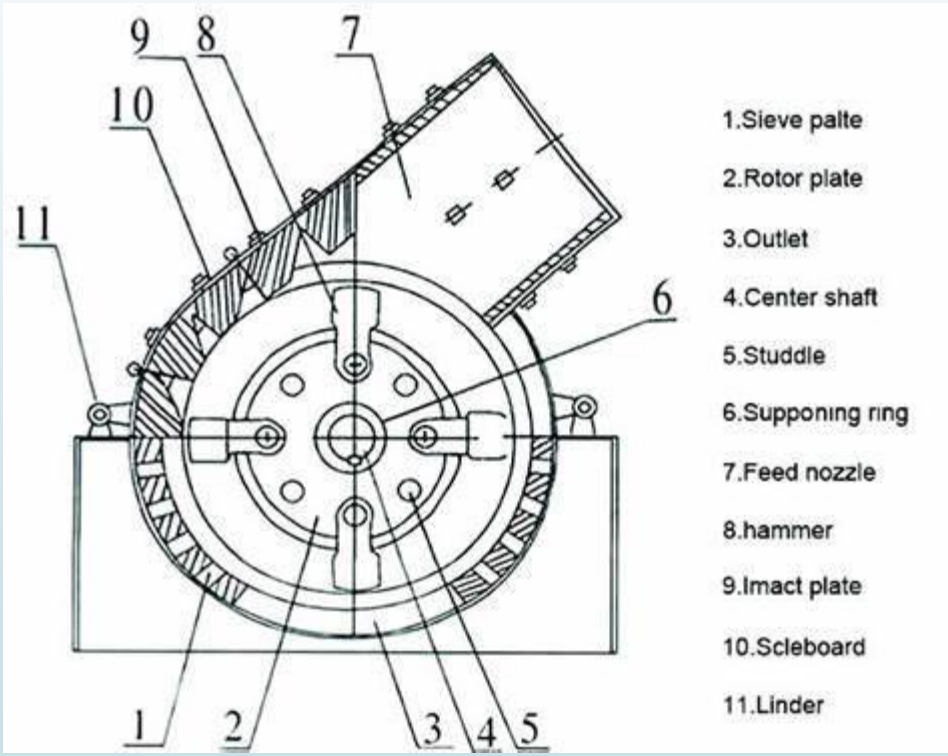
- Solid waste volume reduction can take place at several points in the waste management process.
- Volume reduction is the process of reducing the size of the solid waste.
- It can be done by using either one of the following methods
  - Physical or mechanical volume reduction
  - Chemical volume reduction
  - Thermal volume reduction
  - Biological volume reduction
- Volume reduction can be done
  - At source
  - At central location

- The volume reduction at source can be done by burning, home composting, garbage grinders, compactors, wet pulverising, and pulping.
- The volume reduction at central source can be done by using baling equipment like hammermill, rasps, grinders, presser, shredders, chipper, compactor, incinerator etc,.
- The method of volume reduction depends on the type of waste that needs to be processed.
- Volume reduction has both merits and demerits.
- Merits of volume reduction
  - Reduction in quantity of material
  - Increased life of landfill
  - Economically viable waste management system
- Demerits of volume reduction
  - Poor quality of recyclable materials
  - Difficulty in segregation and sorting
  - Bio-degradable material

Physical volume reduction

- The process of physical volume reduction includes the following methods
  - Compressive force
  - Tensile force
  - Shear force

Hydraulic car compactor



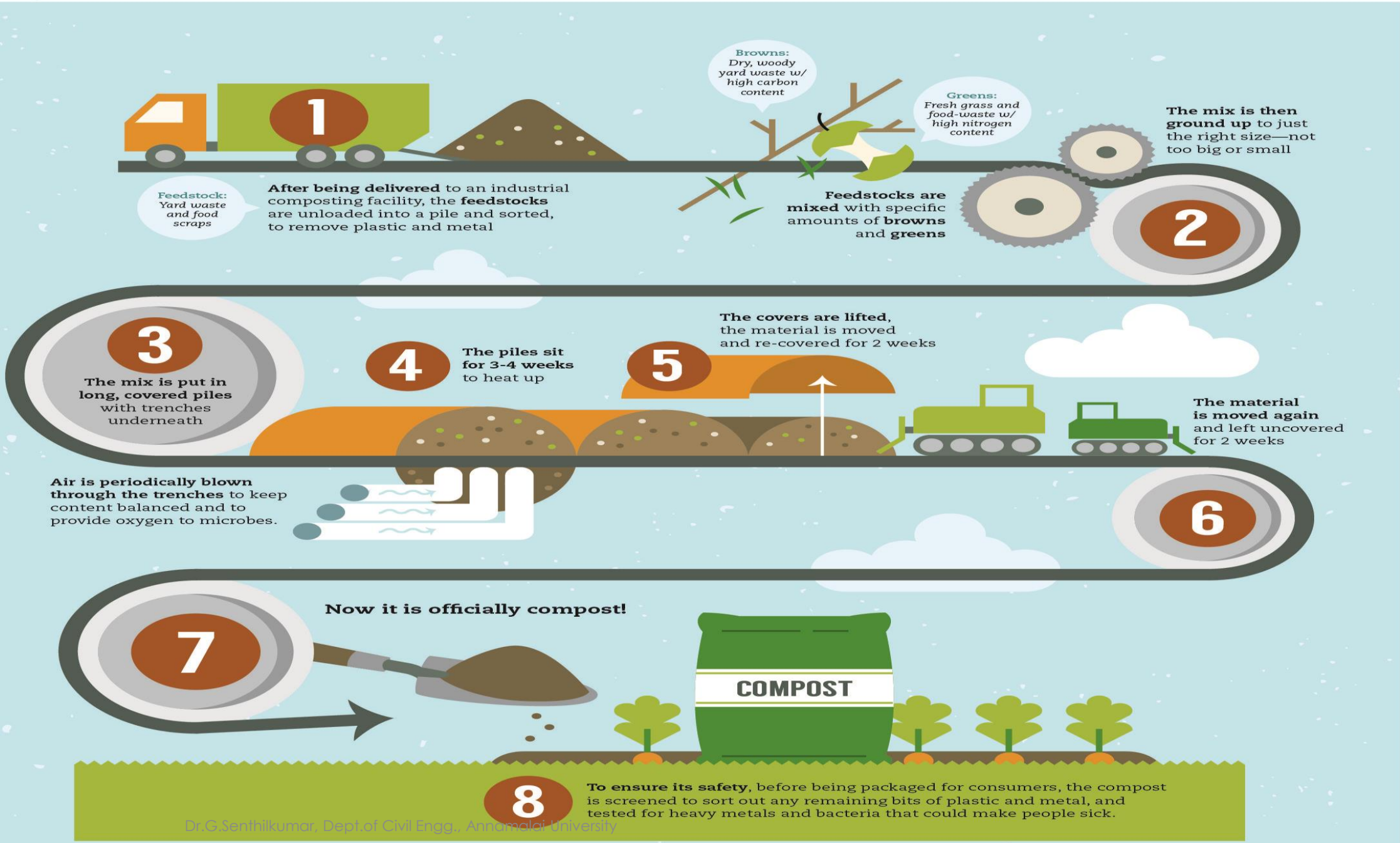
Hammer mil cross section

chemical volume reduction

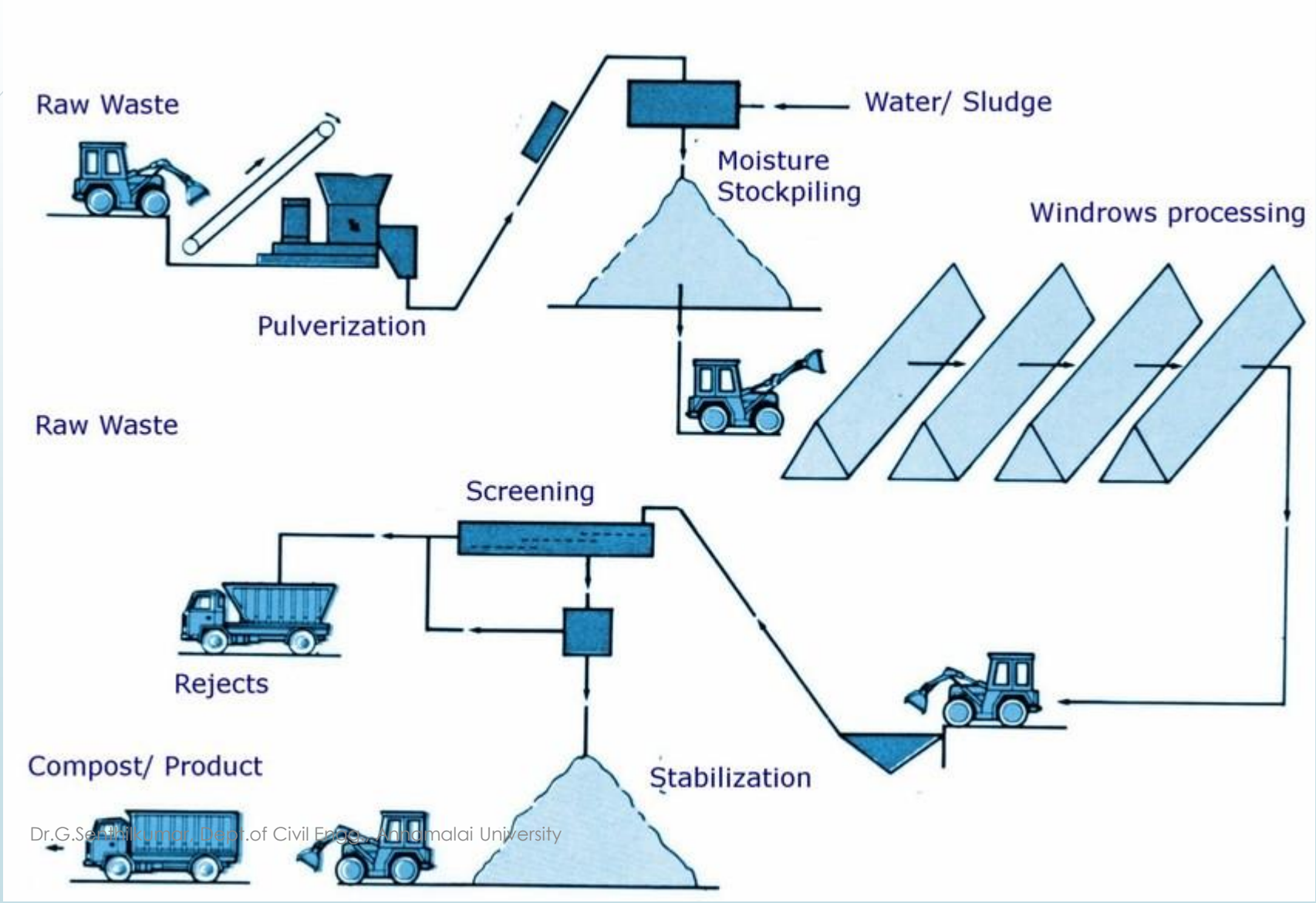
- The process of chemical volume reduction involves the usage of chemicals which is a secondary pollutant.
- It can only be adopted when there is no other option available for the treatment of waste.
- This process is generally adopted to treat the industrial waste.
- It is not that very advisable since one form of waste is converted into another form.

Biological volume reduction

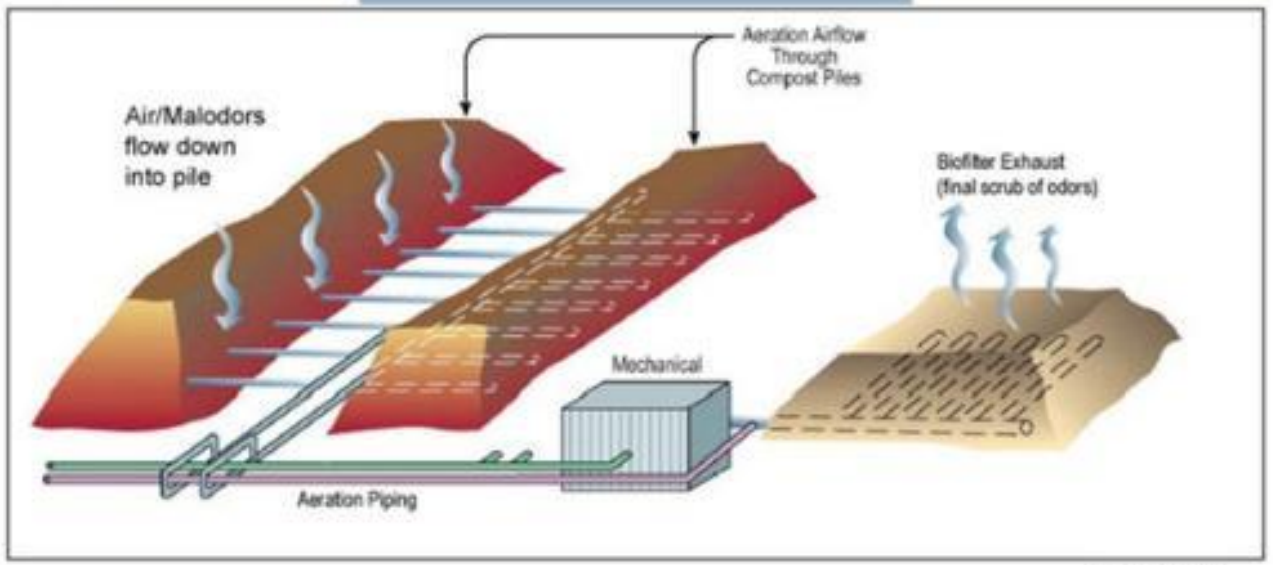
- The biological volume reduction process refers to the composting of bio-degradable waste under aerobic or anaerobic conditions.
- The process of composting can be done both at source and at centralized location.
- The composting process can be done at large scale by using the following methods
  - Windrow composting
  - Aerated static pile composting
  - In vessel composting system
  - Vertical composting reactor
  - Horizontal composting reactor
  - Rotating drum


1
Feedstock: Yard waste and food scraps
After being delivered to an industrial composting facility, the feedstocks are unloaded into a pile and sorted, to remove plastic and metal
Browns: Dry, woody yard waste w/ high carbon content
Greens: Fresh grass and food-waste w/ high nitrogen content
Feedstocks are mixed with specific amounts of browns and greens
2
The mix is then ground up to just the right size—not too big or small
3
The mix is put in long, covered piles with trenches underneath
4
The piles sit for 3-4 weeks to heat up
5
The covers are lifted, the material is moved and re-covered for 2 weeks
The material is moved again and left uncovered for 2 weeks
6
Air is periodically blown through the trenches to keep content balanced and to provide oxygen to microbes.
7
Now it is officially compost!
COMPOST
8
To ensure its safety, before being packaged for consumers, the compost is screened to sort out any remaining bits of plastic and metal, and tested for heavy metals and bacteria that could make people sick.

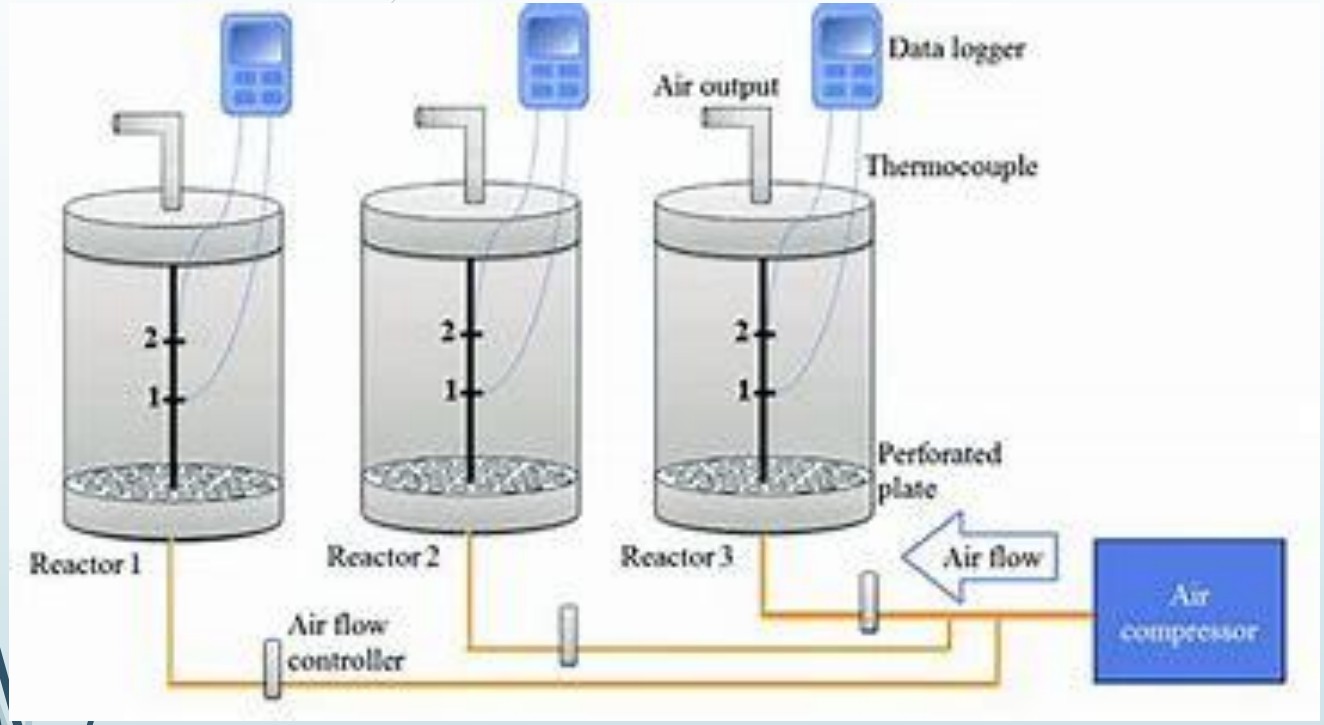
Windrow composting



Aerated Static Pile Schematic



Vertical composting



Rotating drum

Thermal volume reduction

- The process of burning the solid waste involves the chemical reaction due to the heat applied.
- This method of destruction was believed to be the most effective way of handling the municipal solid waste.
- The thermal destruction process can be done by using the following the methods.
  - Open burning
  - Incineration
  - Pyrolysis
  - Gasification
  - Plasma Arc gasification

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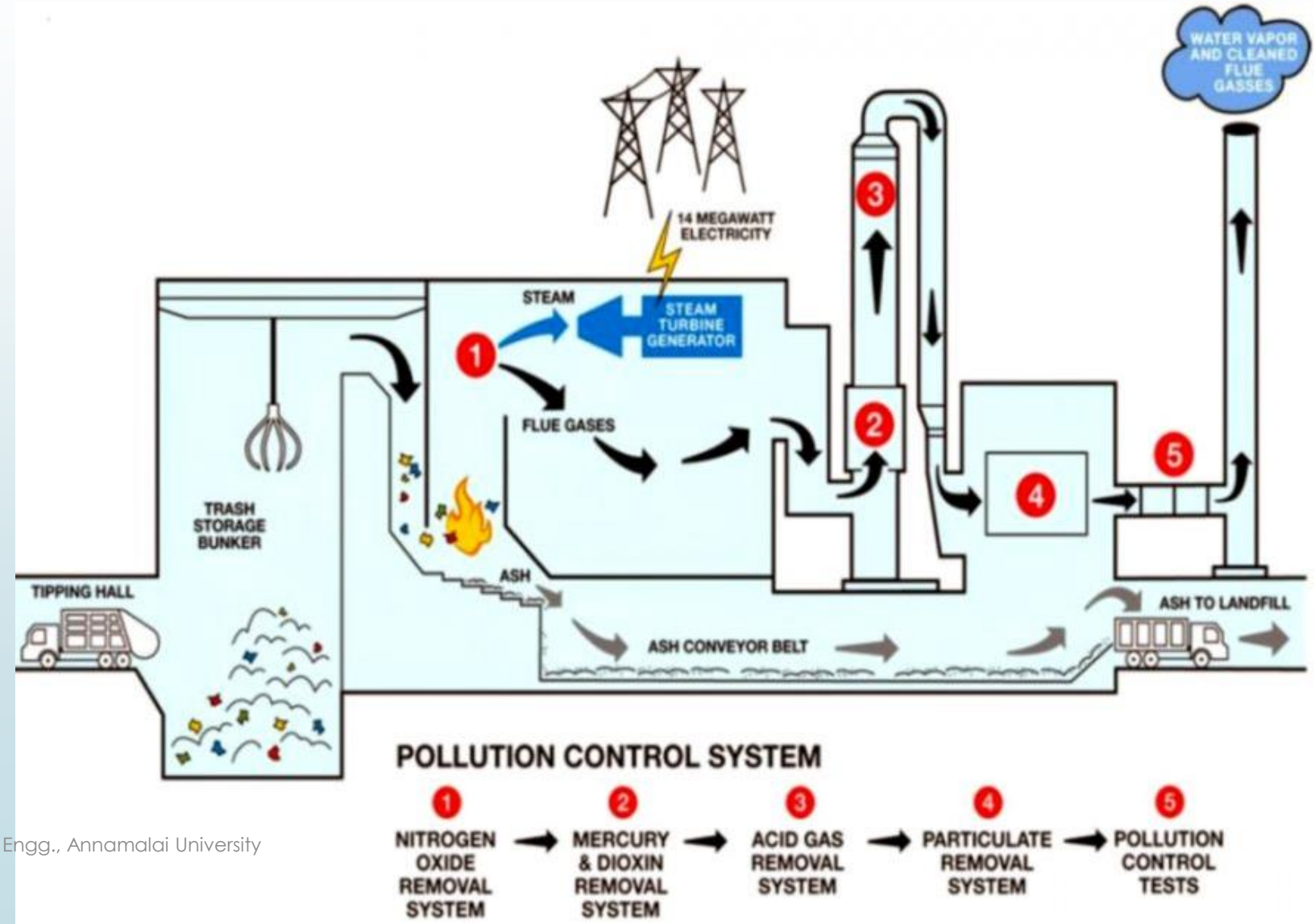
Open burning

- Open burning is the most common process of solid waste destruction then and now.
- Since the temperature generated in this process is not high enough for complete combustion, this creates a nuisance o the environment.
- This type of destruction is banned in most of the developed and developing countries.

Incineration

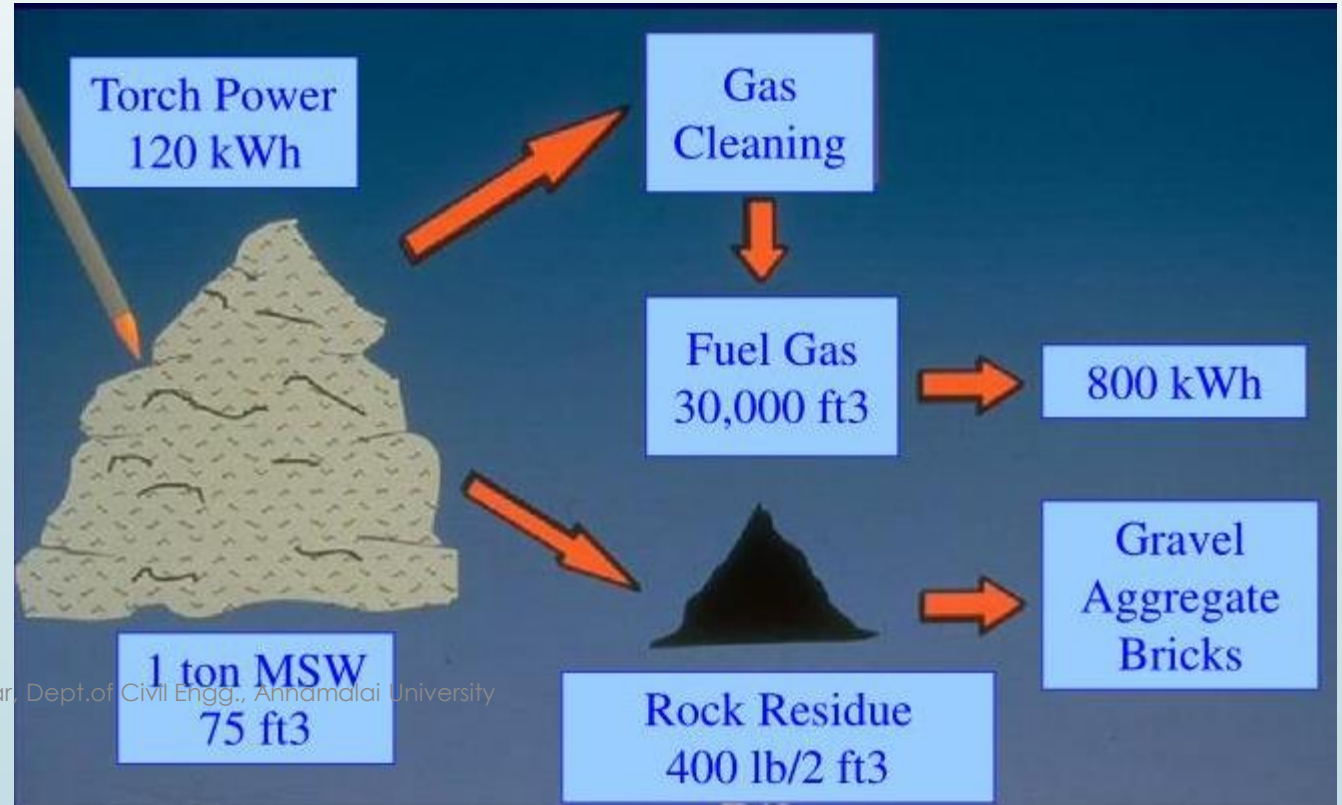
- It is a chemical reaction in which carbon, hydrogen and other elements in the waste mix with oxygen in the combustion zone and generates heat.
- It is a controlled process in which the waste is burnt and converted into gases and residue containing a little or no combustible material.
- The working temperature of incineration plant varies from 900˚C to 1100˚C
- The types of incineration methods are
  - Mass burning system
  - Modular incineration
  - Fluidized- bed incinerator
  - Multiple hearth incinerator
  - Rotary kiln incinerator
  - Liquid injection incinerator
  - Catalytic combustion incinerator
  - Waste-gas flare incinerator
  - Direct flame incinerator

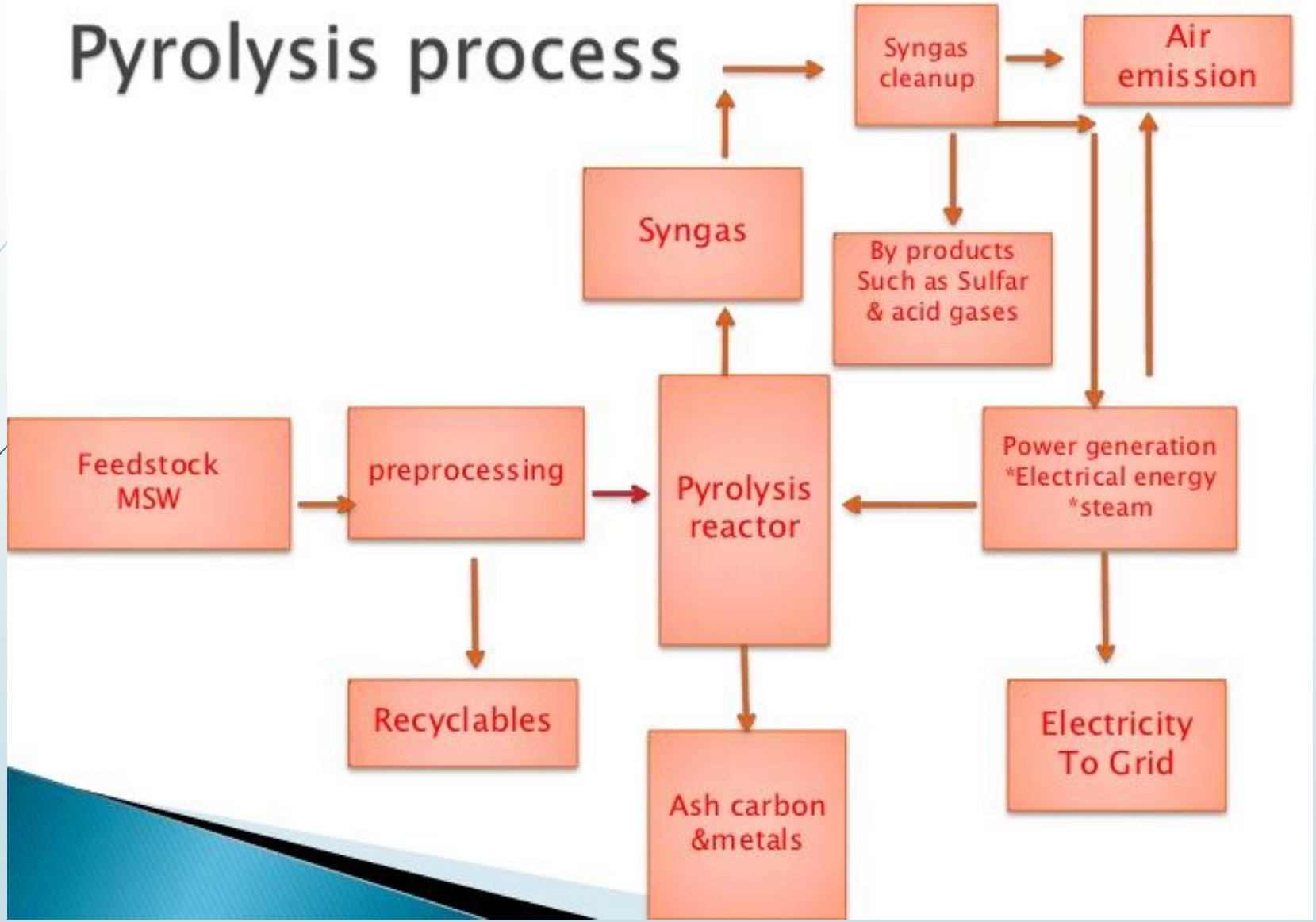
- The process of incineration causes air pollution, thus the following air pollution controlling equipment should be taken
  - Electrostatic precipitator
  - Fabric filters
  - scrubbers



Pyrolysis

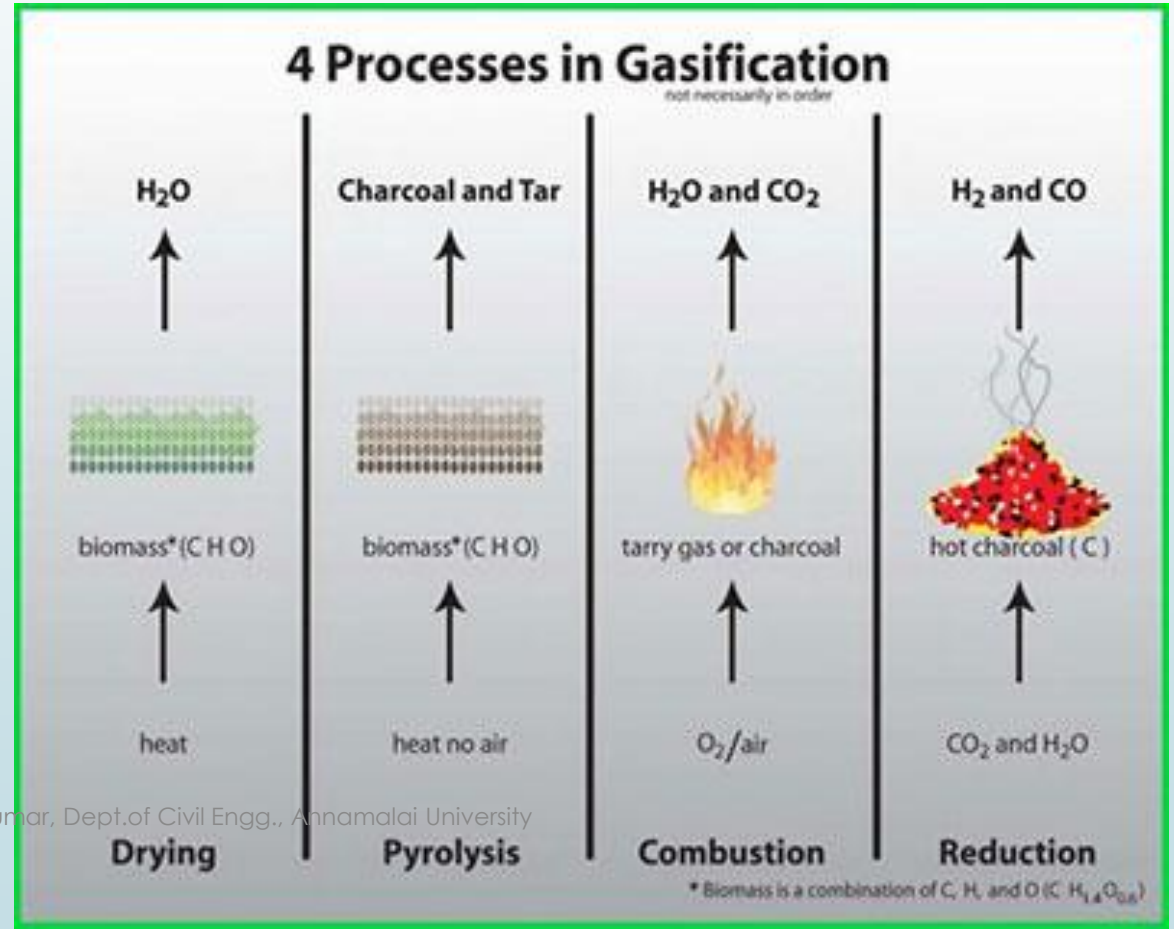
- It is the thermal decomposition of organic material at elevated temperature in the absence of oxygen.
- It involves the simultaneous change of chemical composition and irreversible physical change.
- The working temperature is 1200˚F to 2200˚F
- The end product of this method is black carbon.



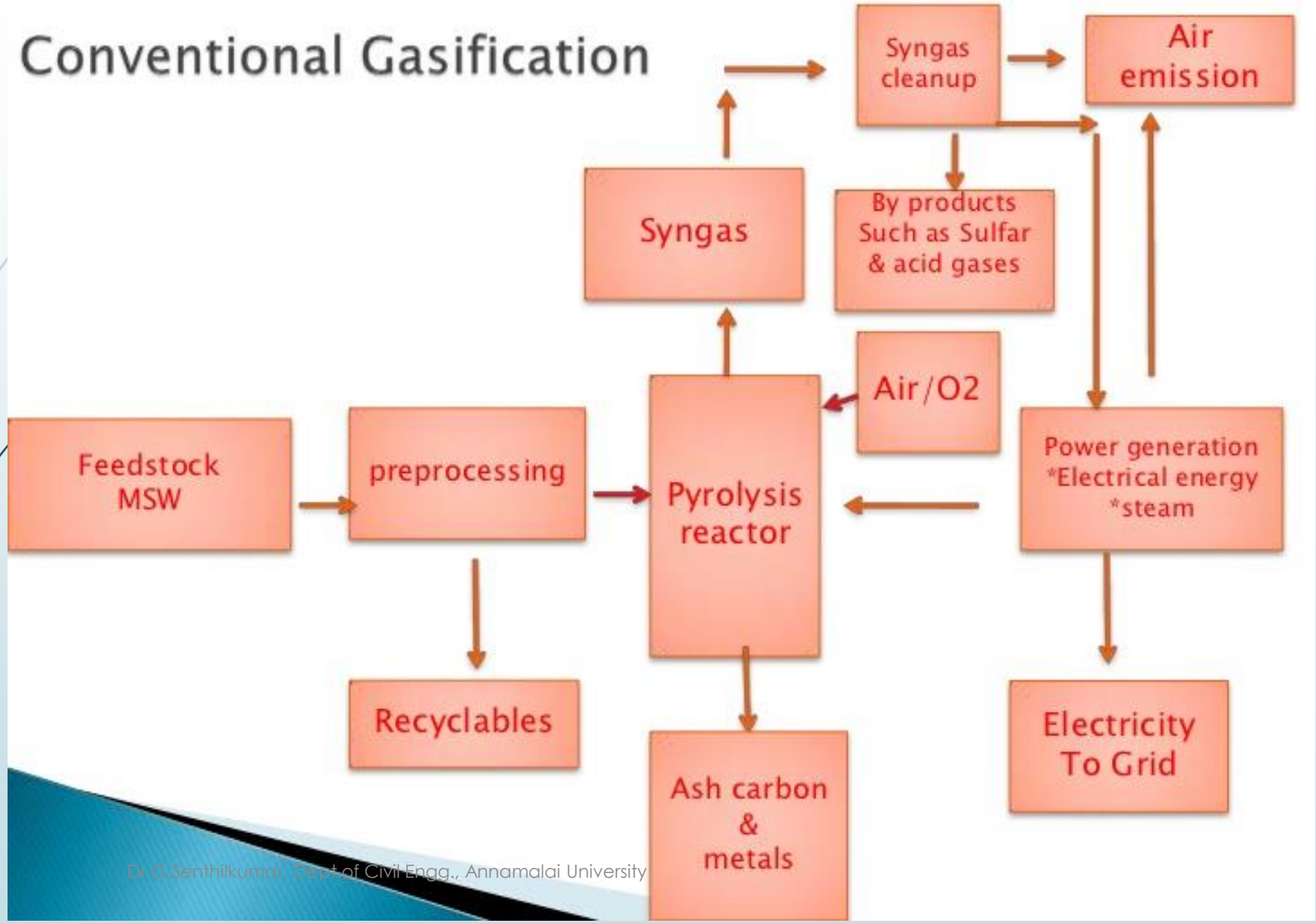

Pyrolysis process
Syngas cleanup
Air emission
Syngas
By products Such as Sulfar & acid gases
Feedstock MSW
preprocessing
Pyrolysis reactor
Power generation *Electrical energy *steam
Recyclables
Ash carbon &metals
Electricity To Grid

Gasification

- It is the process which converts the carbonaceous products into syngas using limited supply of air (oxygen).
- The temperature range is between 1450˚F to 3000˚F. Steam may also be sometimes injected into the reactor to promote CO and H_2.

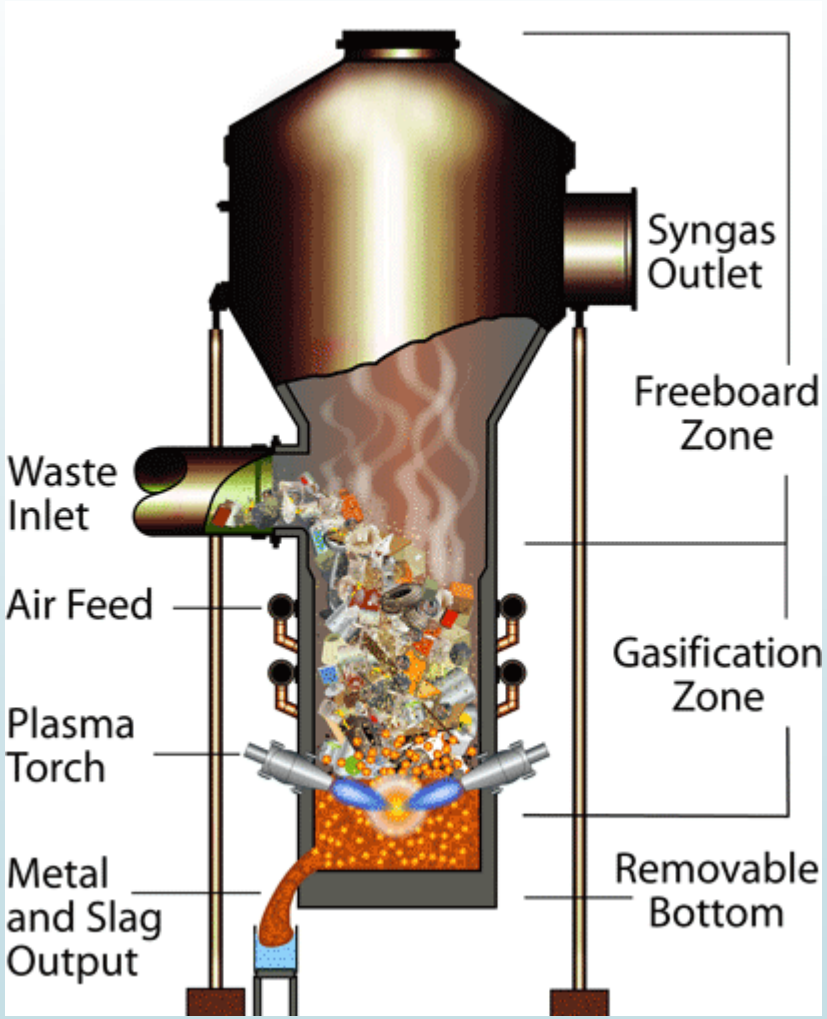


Conventional Gasification

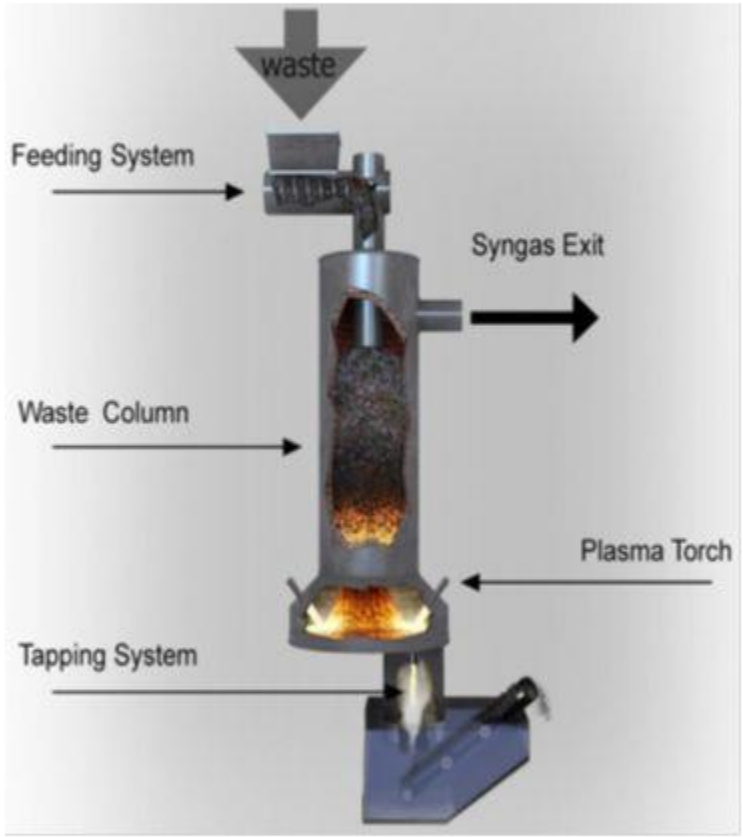


Plasma Arc Gasification

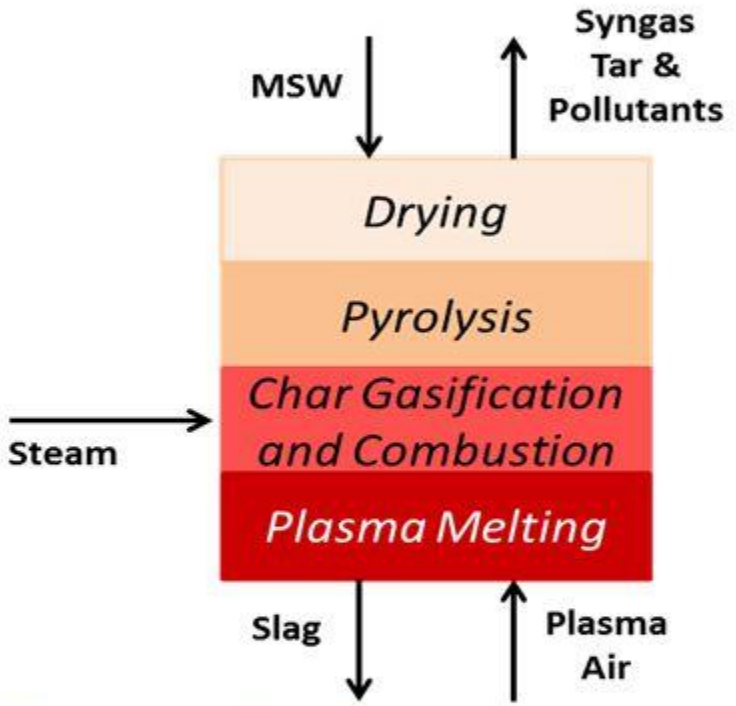
- It is a high temperature pyrolytic process which converts the organics of the solid waste into syngas, inorganic residues and minerals.
- The by-product is a rocky glass material known as vitrified glass is made.
- The temperature range is between 7200˚F to 12,600˚F. It is produced by using an electric arc in a torch where the gas is converted into plasma.



Plasma Gasification Furnace



(source: Zhang et al., 2012)



(source: Zhang et al., 2013)

Secured landfill

- Landfilling is of two types based on the waste dumped in it.
  - Sanitary landfill
  - Secured landfill
- The sanitary landfill is for dumping the municipal solid waste where as the secured landfill is for the hazardous waste.
- The process of landfilling has been proved to be hazardous to the nature and steps are been taken for the process of reclamation.
- The landfill construction and maintenance plays a major role. The laws laid by the Central Pollution Control Board should be followed properly.

- The following should be considered while designing and constructing the landfill
  - Characterization of waste
  - Design of impervious liner
  - Reclamation of leachate
  - Construction of landfill
  - Operation of landfill
  - Environmental monitoring
- The major elements of landfills are
  - HDPE liner
  - Leachate collection well and pipe network
  - Earth moving machineries
  - Site office
  - Workshop
  - Green belt

- The green belt of minimum 10m around the landfill is recommended by the CPCB.
- It acts as a natural barrier by protecting from noise, air, water and land pollution.

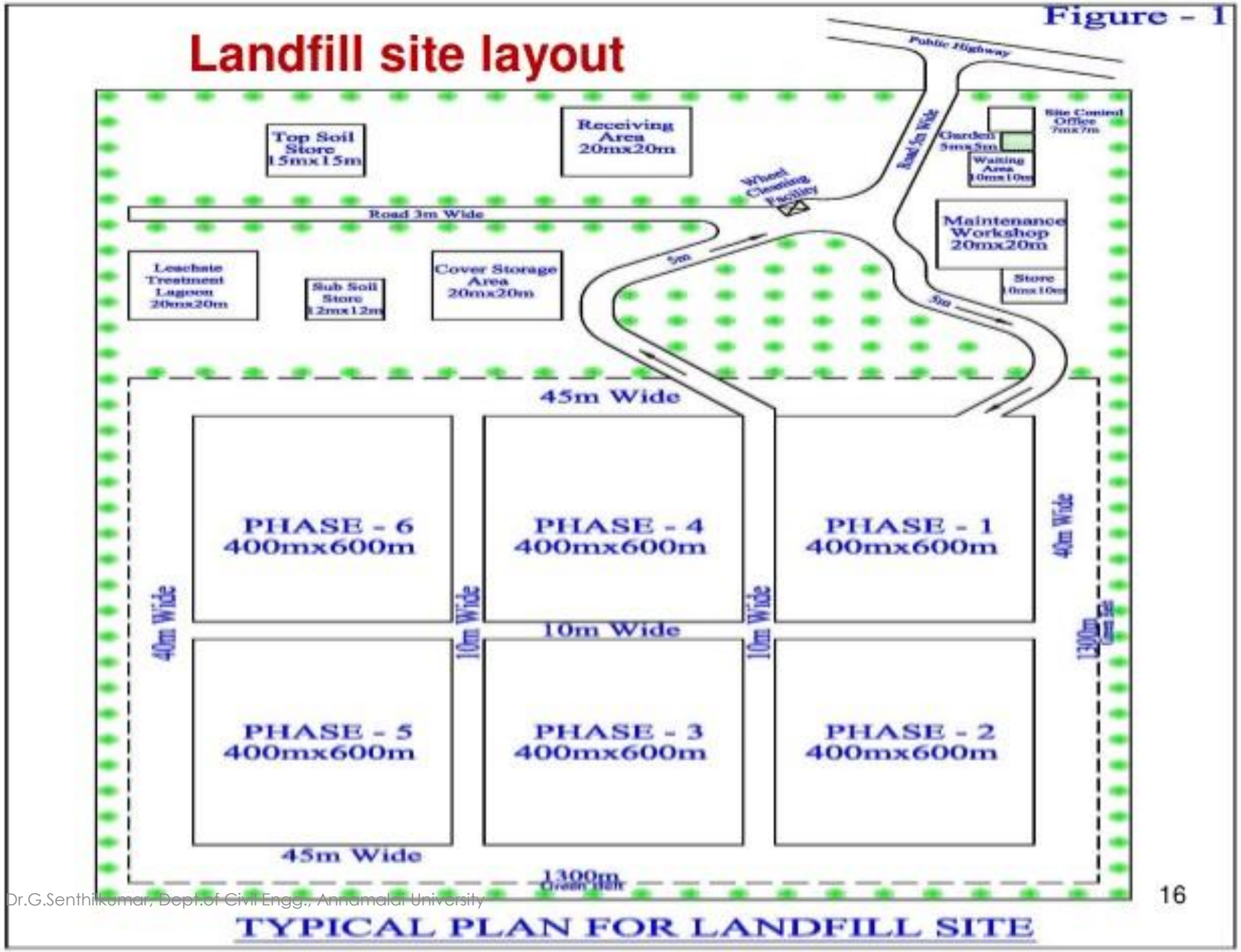
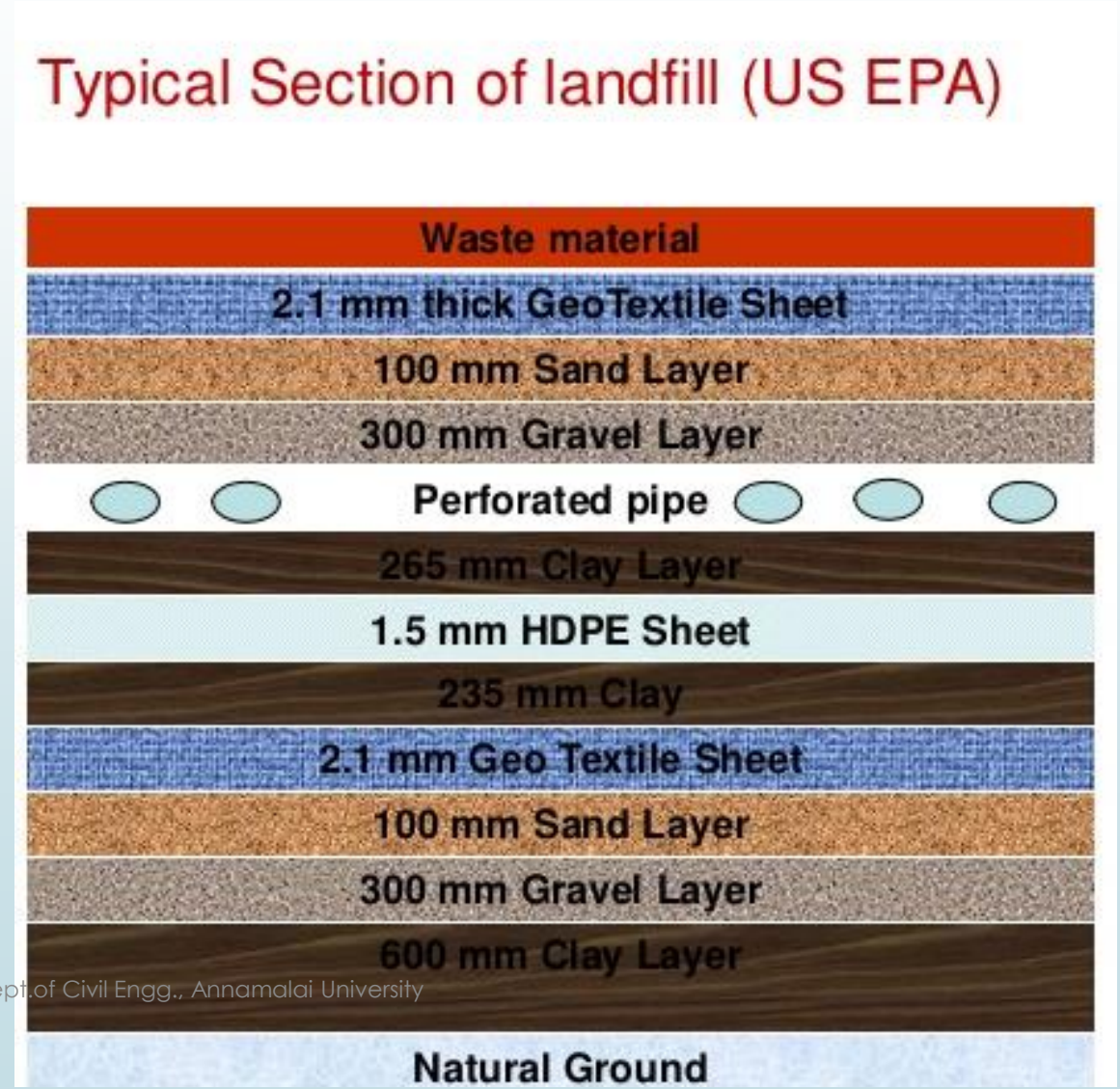


Figure - 1
Landfill site layout
Public Highway
Top Soil Store 15mx15m
Receiving Area 20mx20m
Road 5m Wide
Site Control Office 7mx7m
Garden 5mx5m
Waiting Area 10mx10m
Wheel Cleaning Facility
Road 3m Wide
Maintenance Workshop 20mx20m
Store 10mx10m
Leachate Treatment Lagoon 20mx20m
Sub Soil Store 12mx12m
Cover Storage Area 20mx20m
5m
5m
45m Wide
PHASE - 6 400mx600m
PHASE - 4 400mx600m
PHASE - 1 400mx600m
40m Wide
10m Wide
10m Wide
40m Wide
10m Wide
PHASE - 5 400mx600m
PHASE - 3 400mx600m
PHASE - 2 400mx600m
45m Wide
1300m
1300m
TYPICAL PLAN FOR LANDFILL SITE
16

- Landfill liner plays an important role as a barrier that protects the nearby land from the pollution.
- Thus a proper thick liner should be laid.



Secure Landfills