Environmental Studies - Solid and Hazardous Waste Management

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Key Learning Objectives

- Waste generation and composition
- Integrated municipal solid waste management
- Waste hierarchy
- Duties of waste generators
- Classification of municipal solid waste
- Waste sampling and characteristics

MSW Segregation and Disposal

(https://www.google.com/search?q=Municipal+solid+waste+disposal+in+India&client=firefox-b-d&source=lnms&tbm=isch&sa=X&ved=2ahUKEwi4zr3cp737AhWkmOYKHWRECScQ_AUoAXoECAEQAw&biw=1536&bih=704&dpr=1.25)

Municipal Solid Waste (MSW)

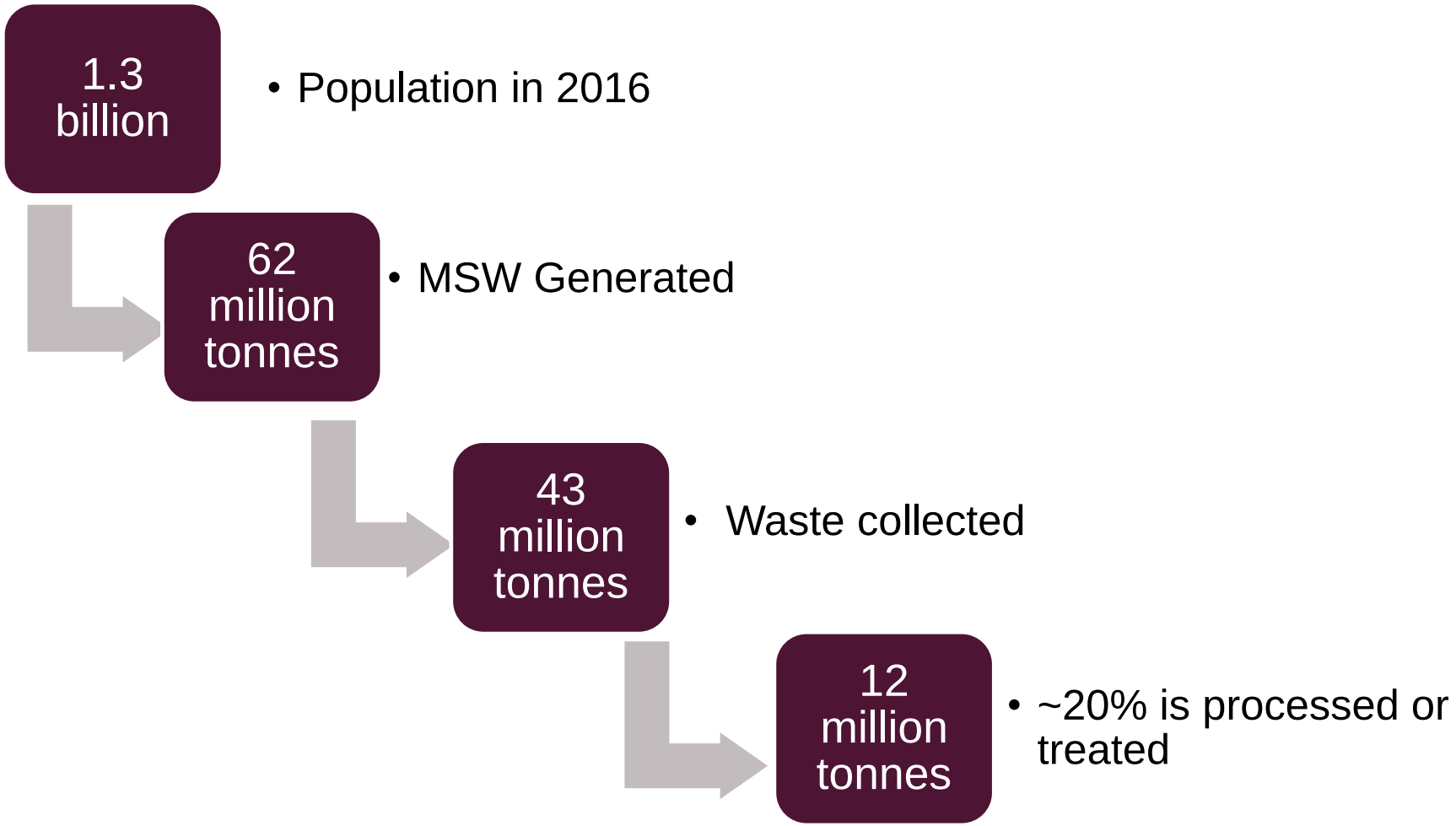
- **The term municipal Solid Waste (MSW) is generally used to describe the non-hazardous waste from a city, town or village.**

- **Solid or semi-solid domestic waste, sanitary, commercial, institutional, catering and market waste and other non residential wastes, street sweepings, silt removed or collected from the surface drains, horticulture waste, agriculture and dairy waste, treated bio-medical waste excluding industrial waste, bio-medical waste and e-waste, battery waste, radio-active waste (Solid Waste Management (SWM), Rules, 2016)**

Important Terms

- **Garbage – Biodegradable matter (e.g., food waste)**
- **Rubbish – Combustible as well as non-combustible fraction and doesn’t include garbage**
- **Trash – Combustible portion of rubbish**

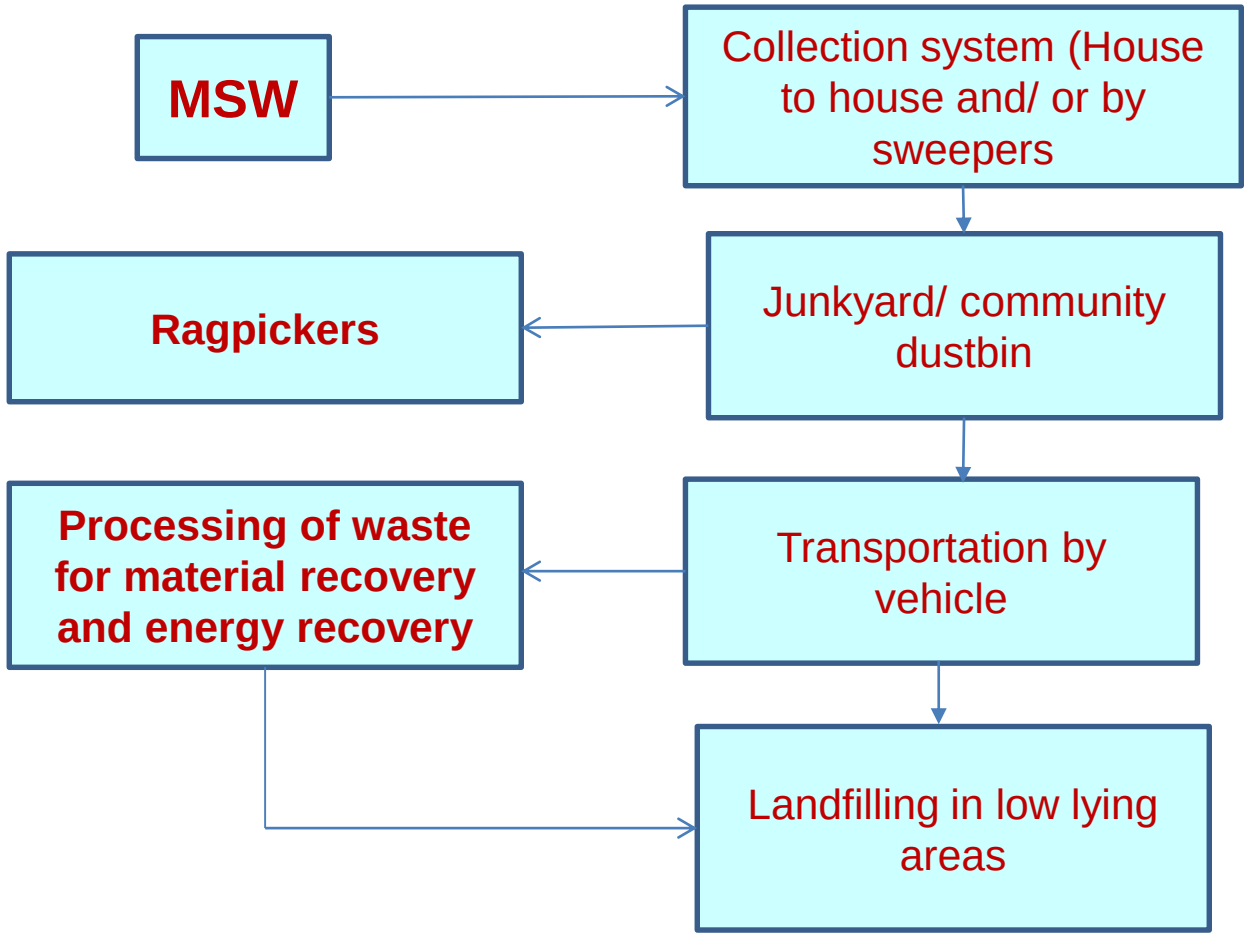
MSW Generation and Disposal in India (CPHEEO, 2016)



Composition of MSW in Different Countries

Type of Waste	Average MSW composition (as % wet basis)				
	USA	UK	China	Thailand	India
	(USEPA, 2009)	(Burnley, 2006)	(Zhang *et al.*, 2010)	(Nithikul *et al.*, 2011)	(NSWAI)
Compostable (Yard trimmings, Food scraps)	27.8	33.2	52.6	42.1	48
Paper	28.2	20.2	6.9	14	8
Plastics	12.3	10.2	7.3	16.2	9
Rubber, leather and textiles	8.3	5	4.7	8.3	-
Metals	8.6	7.3	0.5	0.44	1
Wood	6.5	-	6.9	12.7	-
Glass	4.8	9.3	1.6	2.2	1
Miscellaneous	3.5	16.7	19.5	3.9	33
Moisture content (%)	30 – 40	32.4	56.50	50.8	40-60
Ash content (%)	25 – 35	22.3	19.2	10.8	-
Lower calorific value (MJ/kg)	11.0-12.0	10.1	3.0- 6.7	5.9 - 6.1	3.4 - 4.6

Existing Generalized MSW Management System in India
(Srivastava et al., 2015)



Integrated Solid Waste Management (ISWM)

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

- **It can be viewed as a combination of technologies to tackle waste**

Functional Elements of a Waste Management System

- Waste generation
- Waste handling and separation, storage and processing at the source
- Collection
- Separation, processing and transformation of solid waste
- Transfer and transport
- Disposal

Planning for ISWM (Tchobanoglous et al., 1993)

ISWM plan is a local activity

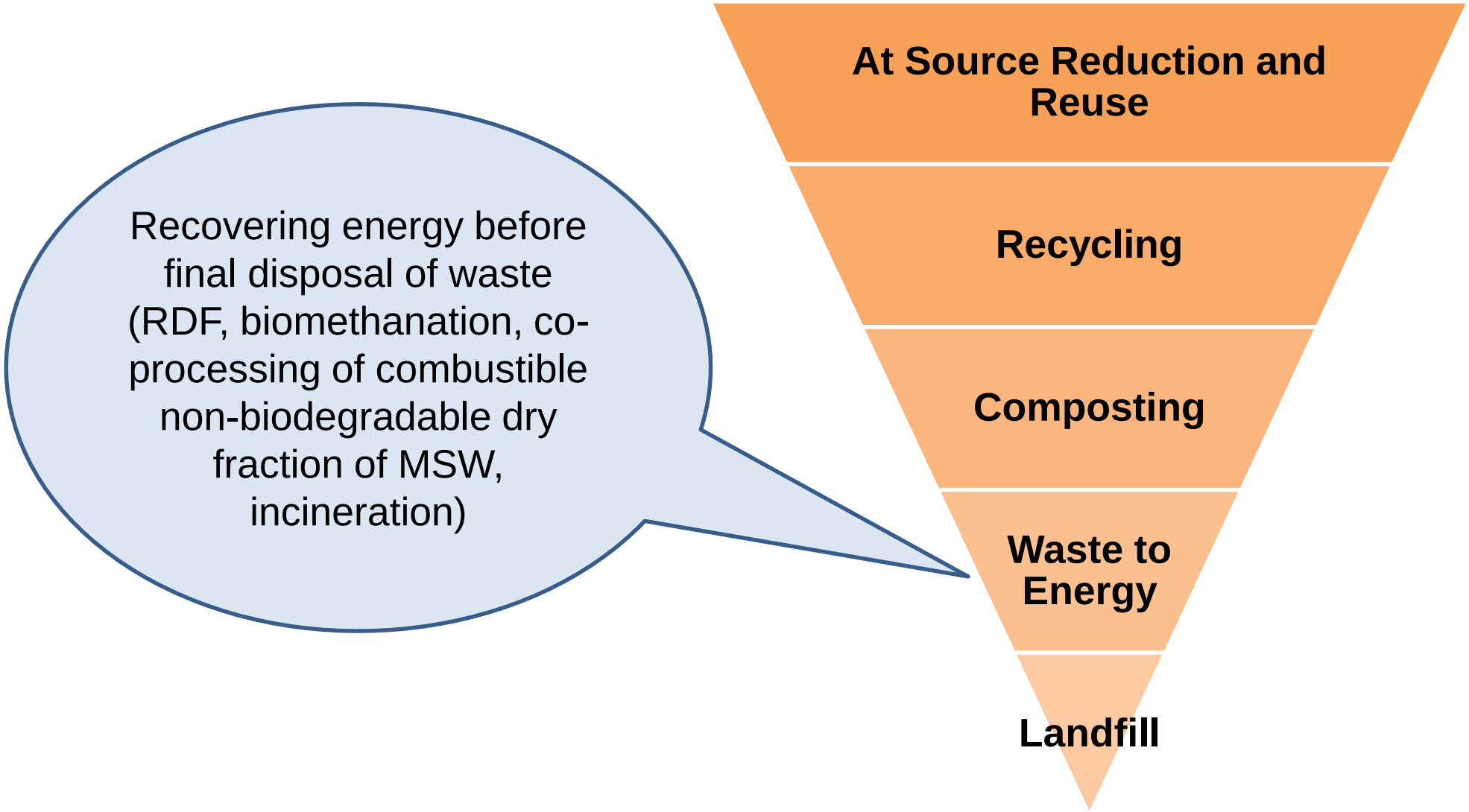
- ✓**Proper mix of alternatives and technologies**
- ✓**Flexibility in meeting future changes**
- ✓**Monitoring and evaluation**

Operation of Solid Waste Management Systems

(Tchobanoglous et al., 1993)

- **Management issues**
  - ✓ **Setting workable but protective regulatory standards**
  - ✓ **Improving scientific methods for the interpretation of data**
  - ✓ **Identification of hazardous and toxic consumer products requiring special waste management units**
  - ✓ **Paying for improved waste management units**
  - ✓ **Designating land disposal units at or near large urban centers**
  - ✓ **Establishing and maintaining more qualified managers to develop and operate waste management units**
- **Future challenges and opportunities**
  - ✓ **Changing consumption habits**
  - ✓ **Volume reduction at source**
  - ✓ **Safer landfills**
  - ✓ **Development of new technologies**

Waste Hierarchy (CPHEEO, 2016)



Solid Waste Management Rules

- **Title:** Solid Waste Management Rules, 2016

- **Scope:** Solid or semi-solid domestic waste, sanitary waste, commercial waste, institutional waste, catering and market waste and other non residential wastes, street sweepings, silt removed or collected from surface drains, horticulture waste, agriculture and dairy waste, treated bio-medical waste

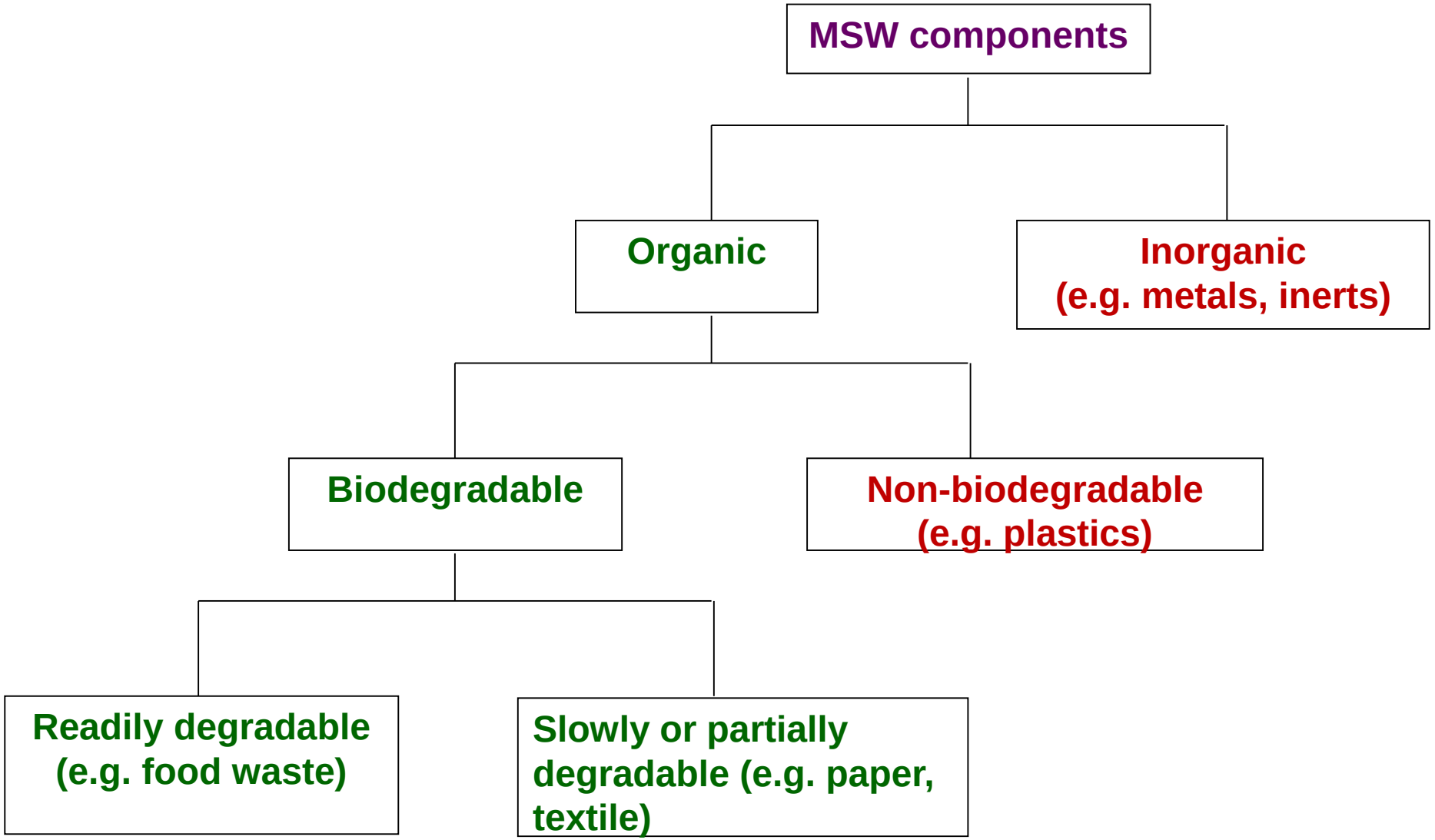
- **Excluding** industrial waste, bio-medical waste, e-waste, battery waste, radioactive waste

- **Waste Hierarchy:** Priority order in which waste should be managed. Emphasis on Prevention, Reduction, Reuse, Recycling, Recovery and Disposal

Duties of Waste Generators (Solid Waste Management Rules, 2016)

- **Segregate and store** the waste generated in three streams: bio-degradable, non-biodegradable and domestic hazardous wastes and handover these to authorised waste pickers
- **Should not burn or bury** the solid waste on streets, open public spaces or in the drain or water bodies
- All waste generators should pay **user fee** for solid waste management
- To organise a **gathering of more than hundred persons** at any unlicensed place, intimate the local body, at least three working days in advance and ensure segregation at source and handing over of waste
- Every **street vendor** shall keep suitable containers for storage of waste generated during the course of his activity
- All gated communities and institutions with more than 5,000 m^2 area, hotels and restaurants should ensure segregation. The bio-degradable waste shall be processed, treated and disposed off through **composting or bio-methanation** within the premises

Classification of MSW



Adverse Impacts of Unsustainable Waste Disposal

- **Health impacts**

✓**Can cause direct and indirect impacts**

- **Environmental impacts**

✓**Soil**

✓**Water**

✓**Air**

Health Impacts

- Improperly operated incineration plants cause air pollution
- Improperly managed and designed landfills attract insects and rodents that spread disease
- Landfill sites should be well lined and walled to ensure that there is no leakage into the nearby ground water sources
- Disposal of health-care wastes require special attention since it can create major health hazards, such as Hepatitis B and C, through wounds caused by discarded syringes
- Certain chemicals if released untreated, e.g. cyanides, mercury, and polychlorinated biphenyls are highly toxic and exposure can lead to disease or death
- Coloured plastics are harmful as their pigment contains heavy metals that are highly toxic

MSW Sampling and Characteristics

Some Important Information required about MSW

- Types and quantities
- Rates at which various types of material will arrive
- Properties of MSW (as received)
- Temporal and seasonal variation in MSW property
- Changes in property during processing
- The properties which makes the MSW of economic value
- The forecast trends to assist designers and manufacturers in the production of vehicles and equipment suitable for future needs

MSW Sampling (CPHEEO, 2016)

- Due to heterogeneous nature of waste, the method by which sample is collected and the number of samples to be collected is critical.
- A large number of samples will improve accuracy however, it may be costly and time consuming.
- For sample collection, the sampling site should be such which covers a large fraction of population.
- Sampling points should be distributed uniformly as per the area such as residential, commercial, institutional etc.
- Method of quartering is used to collect a representative sample. The general protocol is as follows:

✓ In this method, around 10 kg of MSW is collected from each of the 10 points from inside and outside the heap.

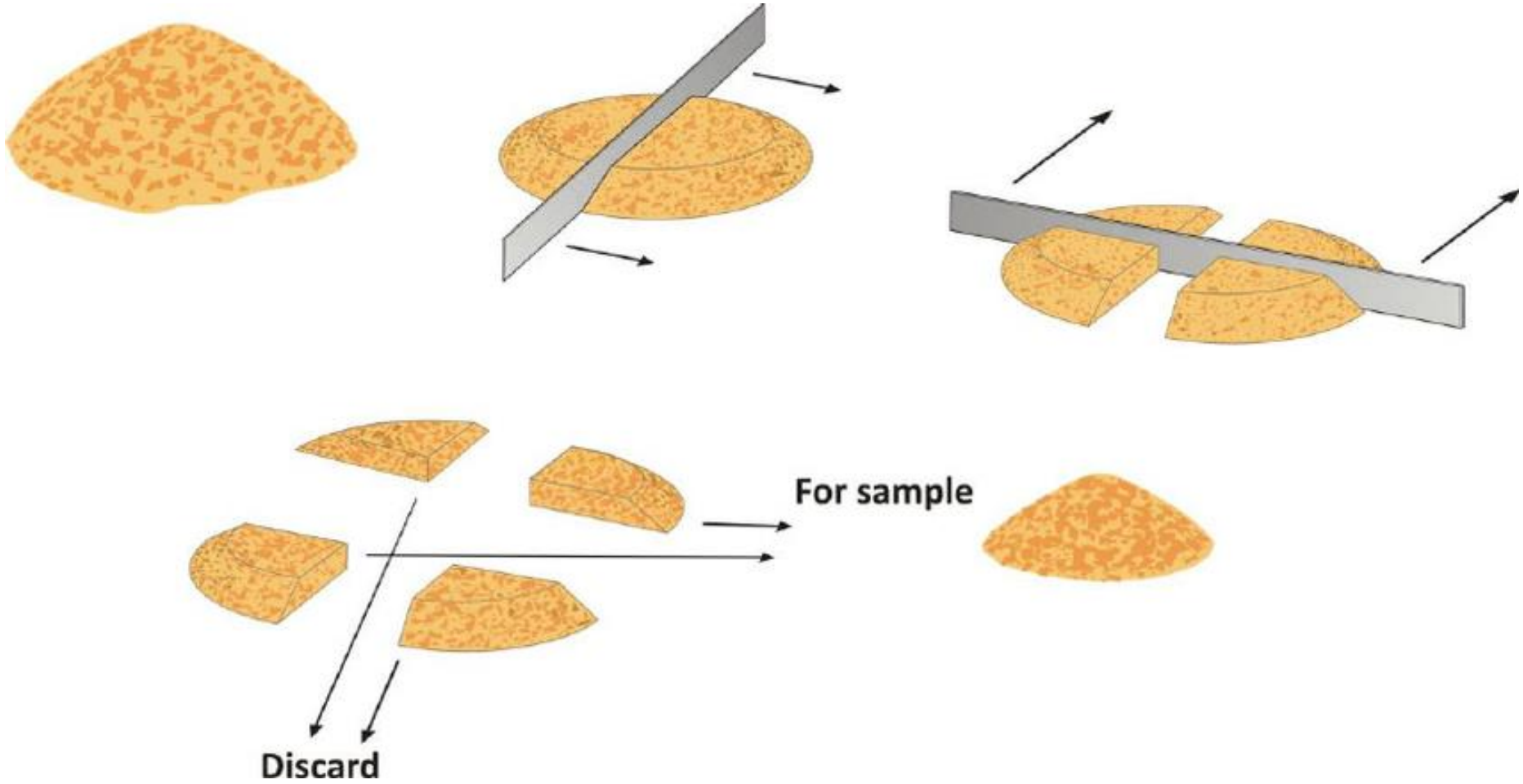
✓ The waste is mixed thoroughly and the coning and quartering method can be used to first divide the sample into four segments, the diagonally opposite of which are rejected.

✓ Its quantity is reduced to a size which can be handled in the laboratory.

✓ Typically, the samples collected are sealed in double plastic bags (~10-12 kg per bag).

Coning and Quartering Method for Waste Sampling

(https://www.researchgate.net/figure/The-coning-and-quartering-method-can-be-used-to-first-divide-the-sample-into-four_fig4_283496833)



Physical Properties of MSW

- **Specific weight**

✓ **It can vary from 180 – 415 kg/m^3 with an average of around 300 kg/m^3.**

- **Moisture content**
- **Particle size and size distribution**
- **Field Capacity**

✓ **Total amount of moisture which can be retained in a waste sample**

- **Permeability or hydraulic conductivity**

✓ **Dense baled waste has a permeability of 7x10^{-6} m/s while loose samples may have 15x10^{-5} m/s**

✓ **Typically the hydraulic conductivity of waste will be 10^{-5} m/s but it depends upon the density**

✓ **Since MSW is heterogeneous, the permeability is not isotropic.**

✓ **$K_0 = C.d^2$, $K = K_0.\gamma/\mu$**

Chemical Properties of MSW

- **Proximate analysis**

✓**Moisture**

✓**Volatile combustible matter**

✓**Fixed carbon**

✓**Ash content**

- **Ultimate analysis**

✓**C, H, O, N, S and ash**

✓**The determination of halogens can also be included in the analysis**

Chemical Properties of MSW……

- **Energy content**

✓**HHV and LHV**

✓The higher heating value (also known gross calorific value or gross energy) of a fuel is defined as the amount of heat released by a specified quantity (initially at 25°C) once it is combusted and the products have returned to a temperature of 25°C, which takes into account the latent heat of vaporization of water in combustion products

✓The lower heating value (also known as net calorific value) of a fuel is defined as the amount of heat released by combusting a specified quantity (initially at 25°C) and it assumes the latent heat of vaporization of water in the reaction products is not recovered.

✓**Experimentally determined by bomb calorimeter**

✓**By calculation**

➢**Modified Dulong formula**

Heating value (kJ/kg) = 337C + 1419(H – 0.125O) + 93S + 23N

where C, H, O, N and S are in mass percent

- **Essential nutrients and other elements**

Biodegradability of Organic Waste Components

- Volatile solids determined at 550°C are often used a measure of biodegradability.
- For better measurement, lignin content of a waste is determined to estimate the biodegradability of waste.

  Biodegradable fraction = 0.83 – 0.028.(LC)

  LC = Lignin content of the VS expressed as a percent of dry weight
- Typical biodegradability values for food waste, newsprint, office paper and card board are 0.82, 0.22, 0.82 and 0.47, respectively.

Waste Handling, Separation for Recycling and Processing

- **Waste handling refers to the activities associated with managing solid wastes until they are placed in the containers used for their storage before collection**
- **Depending upon the collection service, handling may also be required to move the loaded containers to the point where they are stored between collections.**
- **The separation of various components can be performed to enhance recycling and reuse at source of generation**
- **Different strategies needs to be adopted depending upon the dwellings and building types which are of three types: Low rise, medium rise and high rise**
- **Backyard composting is one of the major methods for recycling wet waste at source**

Factors to be Considered in the Onsite Storage of Waste

- **Effects of storage on waste components**
  - ✓ **Biological decomposition**
  - ✓ **The absorption of fluids**
  - ✓ **The contamination of waste components**
- **Types of containers**
- **Container storage locations**
- **Public health and aesthetics**

Centralized and Decentralized MSWM Systems (CPHEEO, 2016)

	Centralized	Decentralized
Advantages	• Economies of scale • Single monitoring point • High-end technology and better environmental controls	• Lower level of mechanization • Can be a tailored solution • Reduces cost of collection, transportation and disposal
Limitations	• Large land requirement • Limited funds and limited experience of urban local bodies • High risk for failure if environmental controls are not in place	• Suitable land availability in neighbourhood • Shortage of trained and qualified staff • Periodic check on product quality • Financial viability

Need for Transfer Operations

- **Transfer and transport operations become a necessity when haul distances to available processing centres or disposal sites increase so that direct hauling is no longer economically feasible.**
- **The factors that tend to make use of transfer operations attractive include**

✓ **The occurrence of illegal dumping due to excessive haul distances**

✓ **The location of disposal sites relatively far from collection routes**

✓ **The use of small capacity collection vehicles**

✓ **The existence of low-density residential service areas**

Classification of Transfer Stations

- **Direct discharge**

✓ **Waste from the collection vehicle is directly emptied into the vehicle to be used to transport them to a place of final disposition.**

- **Storage discharge**

✓ **Wastes are either emptied into a storage pit or onto a platform and then loaded into transport vehicle by various types of equipment.**

- **Combined direct and storage discharge**

✓ **These are facilities that service a broader range of users**

Segregated Collection and Transportation (CPHEEO, 2016)

- **Primary collection**

✓ **It refers to the waste collection from households, markets, institutions and other commercial establishments and transferring the waste to a intermediate place or final disposal site**

- **Secondary collection**

✓ **It refers to the waste collection from community bins or other intermediate locations and transferring to final disposal or processing site**

Type of Collection Services (Tchobanoglous, 1993)

- **Curbside or alley pick up**

✓ **The quickest and most economical point of collection is from curb side or alleys using standard containers.**

✓ **The crews simply empty the container placed on curb into the collection vehicles.**

✓ **Aesthetically many citizens object to unsightly appearance of solid waste containers on the street.**

- **Set out, set back collection**

✓ **Set out crew carries the full containers from residential storage location to the curb or alley before the collection vehicle arrives and set back after emptying into collection vehicle.**

- **Backyard Method**

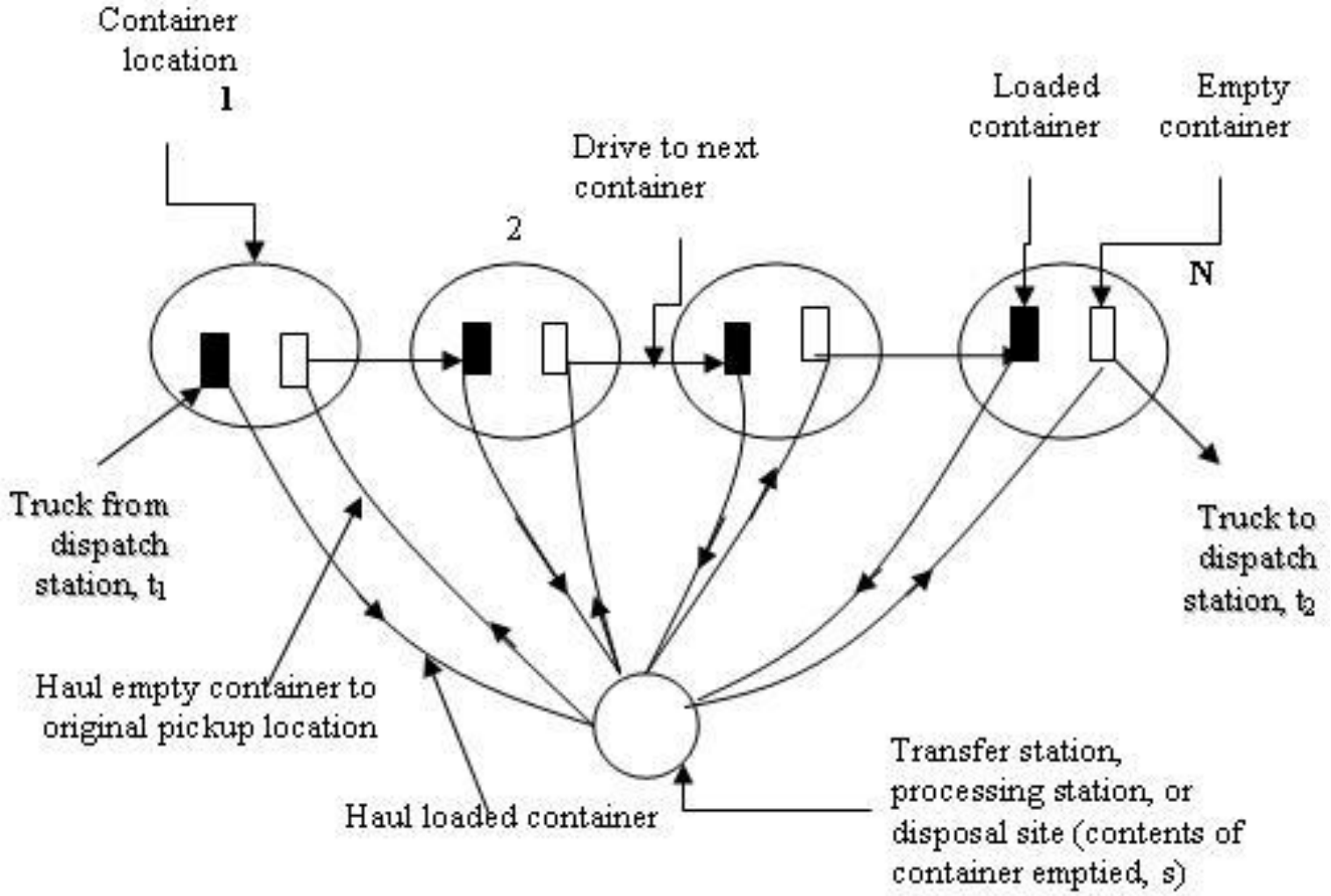
✓ **Crew brings the bin from the property and empties into the collection vehicle.**

✓ **Convenient to homeowners**

Hauled Container System

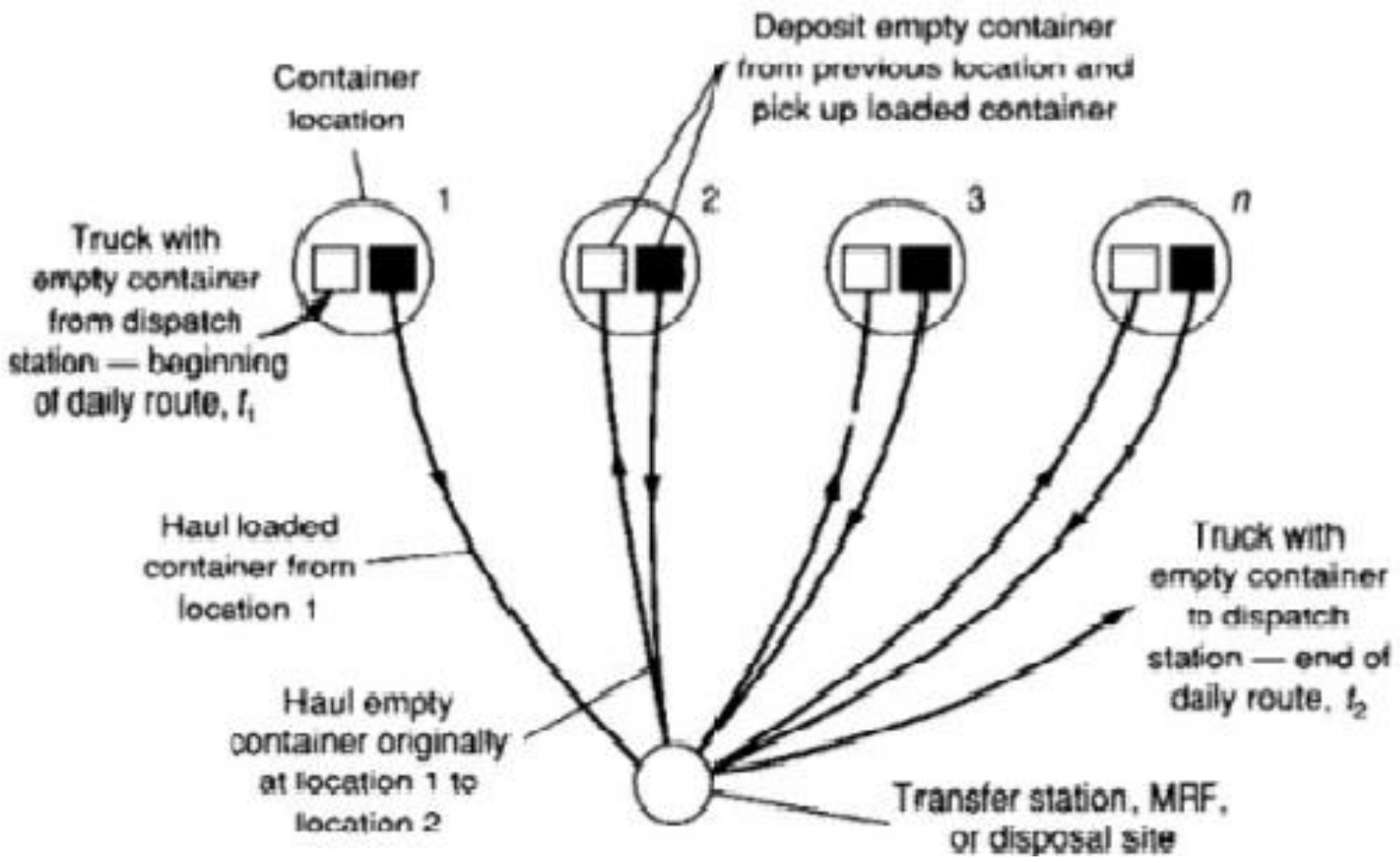
- **Such systems suited for the places where waste generation rate is high because large containers are used.**
- **The use of large containers reduces handling time as well as unsightly accumulation and unsanitary conditions.**
- **Hauled container systems have the advantage of requiring one truck and only one driver (and a cleaner if needed only) to complete one cycle, each container picked up requires a round trip to the disposal site.**

Hauled Container System (HCS) (Conventional Mode)



(a) Hauled container.

Hauled Container System (HCS)
(Exchange Container Mode)



Stationary Container System (SCS)

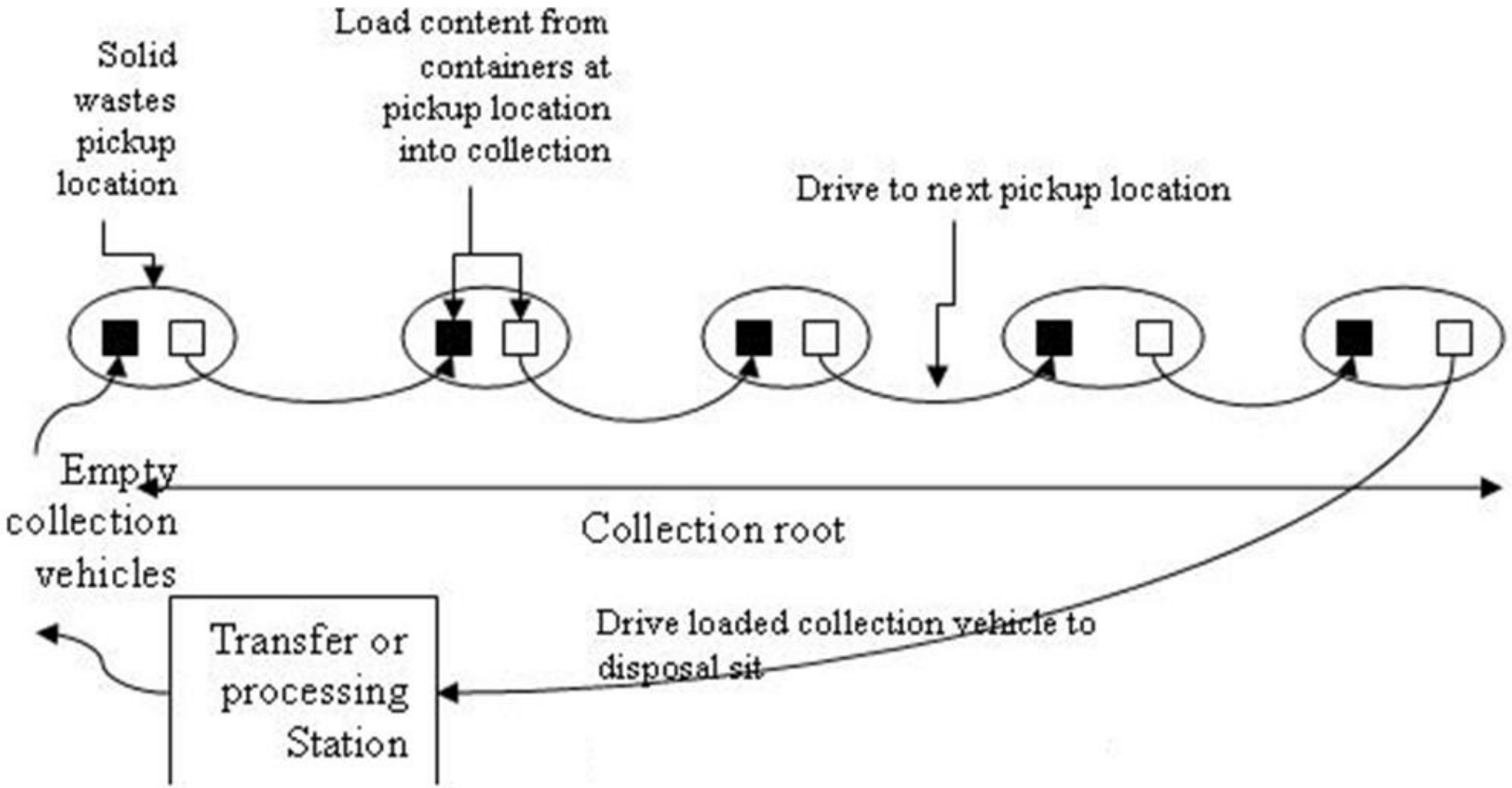
- **These may be used to collect all types of waste.**
- **These can be of two types:**

✓ **Mechanically loaded collection vehicles**

✓ **Manually loaded collection vehicles**

- **The personnel requirements for the stationary collection system will vary depending upon the type of system.**
- **For mechanical systems, a driver and one helper are used. Occasionally, two helpers may be used.**
- **For manual collection system, 1 – 3 collectors may be used.**

Stationary Container System



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Thank you

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