Solid Waste Management: Introduction, Characteristics and Quantities, generation rates, waste Collection, transportation, segregation, processing, treatment and disposal: Case Studies.

Introduction

Urbanization is now becoming a global phenomenon, but its consequences are more pronounced in developing countries like India. The high rate of population growth, declining opportunities in rural area and shift from stagnant and low paying agricultural sector to more paying urban occupations largely contribute to urbanization.

This unexpected immigration from rural areas has also caused expand of slums and the growth of squatters and informal housing all around the rapidly expanding cities of the developing world. In many cites the rapid population growth has overwhelmed the capacity of municipal authorities to provide even basic services to public. Also this contributes to solid waste generation and unscientific waste handling causes health hazards and urban environment degradation.

Solid Waste (SW)

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

Objective of Solid Waste Management

The objective of solid waste management is to reduce the quantity of solid waste disposed off on land by recovery of materials and energy from solid waste as depicted. This in turn results in lesser requirement of raw material and energy as inputs for technological processes. Such techniques and management programs have to be applied to each and every solid waste generating activity in a society to achieve overall minimization of solid waste, to develop and adopt environmentally sound treatment and disposal methods.

Principles of SW management

Solid Waste Management involves the application of principle of Integrated Solid Waste Management (ISWM) to municipal waste. ISWM is the application of suitable techniques, technologies and management programs covering all types of solid wastes from all sources to achieve the objectives of (a) waste reduction and (b) effective management of waste still produced after waste reduction.

a. Waste reduction

Production as well as product changes have been introduced in many countries, using internal recycling of materials or on-site energy recovery, as part of solid waste minimization schemes.

b. **Effective management of solid wast**e

Effective solid management systems are needed to ensure better human health and safety. They must be safe for workers and safeguard public health by preventing the spread of disease. In addition to these prerequisites, an effective system of solid waste management must be both **environmentally** and **economically sustainable.**

Integrated solid waste management

Integrated Solid Waste Management (ISWM) is a comprehensive waste prevention, recycling, composting, and disposal program. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. It involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills

Classification of SW

Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated or disposed is, therefore essential for the design and operation of the functional elements associated with the management of solid wastes. The municipal solid waste generated is classified as follows,

1. **Source based classification**

   Historically, the sources of solid wastes have been consistent, dependent on sectors and activities, these includes the following sources

   - Residential

     This refers to wastes from dwellings, apartments, single family housing, and mobile home etc., consists of leftover food, vegetable peels, plastic, clothes, ashes etc.,
   - Commercial

     The wastes consisting of leftover food, glasses, metals, ashes, plastic, cardboard, boxes etc., generated from stores, supermarkets, hotels, marriage halls, auto repair shops, shopping malls etc.,
   - Institutional

     This mainly consists of paper, plastic, glasses etc., generated from educational, administrative and public buildings such as office, court, prison, college etc.,
   - Municipal services

     This includes dust, leaf matter, plastic, dead animals etc., and waste generated from various municipal activities like street cleaning, landscaping, cleaning of storm water drains.
   - Industrial

     This includes only the waste materials like plastic, paper, cardboard boxes, and wooden pieces used for packaging purposes. Strictly no processing wastes and hazardous waste are not including from this source.
   - Agricultural

     This includes only the waste material like plastic sheets, left over tins, cans, plastic covers and waste from harvesting process.
   - Open areas

     This consists of wastes from areas such as streets, alleys, parks, vacant lots, playgrounds, beach side, highways and recreational areas, waste will be in the form of paper, plastic etc.,
   - Treatment plant waste

     This includes wastes from water and wastewater facilities inside the city and it contains waste in the form of sludge which comes from various treatment units and plastic bags in which chemicals are received at treatment facility.

2. Type based classification

Classification of wastes based on type's i. e, physical, chemical and biological characteristics of wastes is as follows

- ❖ Garbage
  This refers to animal and vegetable wastes resulting from the handling, sale, and storage, preparation, cooking and serving of food. Garbage comprising these wastes contains putrescible (rotting) organic matter, which produces an obnoxious odour and attracts rats and other vermin. It, therefore, requires special attention in storage, handling and disposal.
- ❖ Ashes and residues
  These are substances remaining from the burning of wood, coal, charcoal, coke and other combustible materials for cooking and heating in houses, institutions and small industrial establishments. When produced in large quantities, as in power-generation plants and factories, these are classified as industrial wastes. Ashes consist of fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass, also small amount of burned and partially burned materials. Since ashes and residues are almost entirely inorganic, they are valuable in landfills.
- ❖ Rubbish
  A broad category of dry goods including boxes, bottles, tin, cans or virtually anything made of wood, metal, glass and cloth. These waste materials can be transformed into new consumer products through a variety of reclamation methods.
- ❖ Combustible and non-combustible waste
  This includes wastes generated from households, institutions, commercial activities etc., excluding food wastes and other highly putrescible material. Typically, while combustible material consists of paper, cardboard, textile, rubber, garden trimmings, etc., non-combustible material consists of such items as glass, crockery, tin and aluminum cans, ferrous and non-ferrous material and dirt
- ❖ Street wastes
  These refer to wastes that are collected from streets, walkways, alleys, parks and vacant plots, and include paper, cardboard, plastics, dirt, leaves and other vegetable matter. Littering in public places is indeed a widespread and acute problem in many countries including India.
- ❖ Biodegradable and non-biodegradable wastes
  Biodegradable wastes mainly refer to substances consisting of organic matter such as leftover food, vegetable & fruit peels, paper, textile, wood, etc., generated from various household and industrial activities. Because of the action of micro-organisms, these wastes are degraded from complex to simpler compounds. Non-biodegradable wastes consist of inorganic and recyclable materials such as plastic, glass, cans, metals, etc.
- ❖ Dead animals
  With regard to municipal wastes, dead animals are those that die naturally or are accidentally killed on the road. Note that this category does not include carcasses and animal parts from slaughter-houses, which are regarded as industrial wastes. Dead animals are divided into two groups – large and small. Among the large animals are

horses, cows, goats, sheep, pigs, etc., and among the small ones are dogs, cats, rabbits, rats, etc. The reason for this differentiation is that large animals require special equipment for lifting and handling when they are removed. If not collected promptly, dead animals pose a threat to public health since they attract flies and other vermin as they decay. Their presence in public places is particularly offensive from the aesthetic point of view as well.

❖ Abandoned vehicles

This category includes automobiles, trucks and trailers that are abandoned on streets and other public places. However, abandoned vehicles have significant scrap value for their metal, and their value to collectors is highly variable. As it has high scrap value the chance of reaching landfill site as solid waste is very less.

❖ Sewage wastes

The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derived from the treatment of organic sludge separated from both raw and treated sewages. The inorganic fraction of raw sewage such as grit and eggshells is separated at the preliminary stage of treatment, as it may entrain putrescible organic matter with pathogens and must be buried without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but is invariably uneconomical. Solid sludge, therefore, enters the stream of municipal wastes, unless special arrangements are made for its disposal.

❖ Bulky wastes

These include large household appliances such as refrigerators, washing machines, furniture, crates, vehicle parts, tyre, wood, trees and branches. Since these household wastes cannot be accommodated in normal storage containers, they require a special collection mechanism.

Classification of solid waste

Type	Description	Sources
Garbage	Food waste: wastes from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage and sale of meat.	Households, institutions and commercial concerns such as hotels, stores, restaurants, markets etc.,
Combustible and non-combustible	Combustible (primary organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings etc.,	
	Non-combustible (primary inorganic) metals, tin, cans, glass, bottles, crockery, stones etc.,	
Ashes	Residue from fires used for cooking and for heating, building cinders	
Bulky wastes	Large auto parts, tyres, used refrigerators and other large appliances, furniture's etc.,	
Street wastes	Street sweepings, dirt, leaves, branches, stumps etc.,	Streets, alleys, vacant places, sidewalks etc.,
Dead animals	Dogs, cats, rats, donkeys etc.,	
Abandoned vehicles	Automobile and spare parts	

Industrial wastes	Wood, plastic, paper, packaging materials, scraps, ferrous and non-ferrous items.	Small scale industries
Agricultural wastes	Crop residue, plastic sheets, used fertilizer bags, can and tins	Livestock, farms, agriculture lands
Sewage treatment residue	Coarse screening grit, treated sludge from primary and secondary tanks	Wastewater treatment plants
Construction and demolition wastes	Roofing and sheathing scraps, broken concrete, plaster, wire, insulation materials etc.,	Construction and demolition sites

Approximate degeneration time of various SW

Category	Type of waste	App. Time to degenerate
Biodegradable	Organic waste such as vegetables, leftover food etc.,	A week or two
	Paper	10-30 days
	Cotton cloth	2-5 months
	Woolen items	1 year
	Wood	10-15 years
Non-biodegradable	Tin, Aluminum and other metal items such as cans	100-500 years
	Plastic Bags	1 million years
	Glass	Undetermined

Properties of Solid Waste

Information on the properties of solid wastes is important in evaluating alternative equipment needs, systems and management programs and plans, especially with respect to the implementation of disposal and resource and energy recovery options.

Physical properties of SW

Important physical properties/characteristics of MSW include Density, Moisture content, Particle size, Filed capacity and Hydraulic conductivity of compacted waste.

1. Density

Density is a useful parameter in waste characterization as it provides information for predicting storage volume, including as-discarded at a residence or commercial facility, after compaction in a collection truck and after compaction within a landfill site. It is expressed as mass per unit volume (kg/m3). A reduction in volume by 75% is achieved through normal compaction equipment, so that an initial density of 100kg/ m3 may readily be increased to 400 kg/m3. Significant changes in the density occur as waste moves from sources to disposal site, as a result of severing, handling, wetting and drying by the weather and vibration during transport. Density is critical in the design of sanitary landfill as well as for storage, collection and transport of wastes. Efficient operation of landfill requires compaction of wastes to optimum density. Raw wastes range in density from about 115 to 180 kg/m3. This low density is partly a function of the shape of the material in the waste stream. Paper, packaging materials, tin cans contain large void spaces which greatly decrease the density. If these materials are crushed the density sharply increases. The typical density of each component of MSW is shown in the table below.

Typical densities for SW components

Component	**Range (kg/ m3)**	**Typical (kg/ m^3)**
Food wastes	120-480	290
Paper	30-130	85
Cardboard	30-80	50
Plastics	30-130	65
Textiles	30-100	65
Rubber	90-200	130
Leather	90-260	160
Garden trimming	60-225	105
Wood	120-320	240
Misc. organics	90-360	240
Glass	160-480	195
Tin cans	45-160	90
Nonferrous metals	60-240	160
Ferrous metals	120-1200	320
Dirt, ashes, bricks etc.,	320-960	480

2. Particle size

The size and size distribution of the component materials in solid wastes are an important consideration in the recovery of materials, especially with mechanical means such as trommel screens and magnetic separators. Size distribution is measured by passing samples of MSW over a series of screens, beginning with a coarse screen and continuing down to a fine screen. The size of a waste component may be defined by one or more of the following measures:

$$S_c = l$$

$$S_c = \left(\frac{l + w}{2}\right)$$

$$S_c = \left(\frac{l + w + h}{3}\right)$$

$$S_c = (l \times w)^{\frac{1}{2}}$$

$$S_c = (l \times w \times h)^{\frac{1}{3}}$$

Where, S_c = size of component, in (mm)
L = length, in (mm)
W = width, in (mm)
H= height, in (mm)

The major means of controlling particle size is through shredding. Shredding increases homogeneity increases the surface area/volume ratio and reduces the potential for preferential liquid flow paths through the waste. Particle size will also influence waste packing densities, and particle size reduction (by shredding) could increase biogas production through the increased surface area available to degradation by bacteria. But the smaller particles allow higher packing density which decrease water movement, bacterial movement and the bacterial access to substrate. MSW tends to stratify vertically when mixed, with smaller and denser components migrating to the bottom of a pile and lighter, bulkier objects migrating to the top. Such stratification has implications for efficient combustion on a travelling grate in a boiler or for materials separation in a MRF.

3. Moisture content

Moisture content is defined as the ratio of the weight of water (wet weight -dry weight) to the total weight of the wet waste. It is useful in estimating heat content, landfill sizing and transportation requirements. A typical range of moisture content is 20 to 45%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 45% are not uncommon. The typical data on the moisture content for the solid waste components given in Table below. Moisture increases the weight of the solid waste and therefore the cost of collection and transport increases. Consequently, waste should be insulated from rain or other extraneous water source. Moisture content is critical determinant in the economic feasibility of waste treatment by incineration. During incineration energy must be supplied for evaporation of water and raising the temperature of vapor. Therefore, at the site waste should be insulated from rainfall or other extraneous water. The moisture percentage is calculated using the formula:

$$\mathbf{M = (w-d)/w*100}$$

Where, M = moisture content, %
w = initial weight of sample as derived, kg
d = weight of sample after drying at 105 degree Celsius, kg

Typical data on moisture of SW components

Component	**Range (%)**	**Typical (%)**
Food wastes	50-80	70
Paper	4-10	6
Cardboard	4-8	5
Plastics	1-4	2

Textiles	6-15	10
Rubber	1-4	2
Leather	8-12	10
Garden trimming	30-40	60
Wood	15-40	20
Misc. organics	10-60	25
Glass	1-4	2
Tin cans	2-4	3
Nonferrous metals	2-4	2
Ferrous metals	2-6	3
Dirt, ashes, bricks etc.,	6-12	8

4. Field capacity

The field capacity of solid waste is the total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity. The field capacity of waste materials is of critical importance in determining the formation of leachate in landfills. Water in excess of the field capacity will be released as leachate. The field capacity varies with the degree of applied pressure and the state of decomposition of the waste.

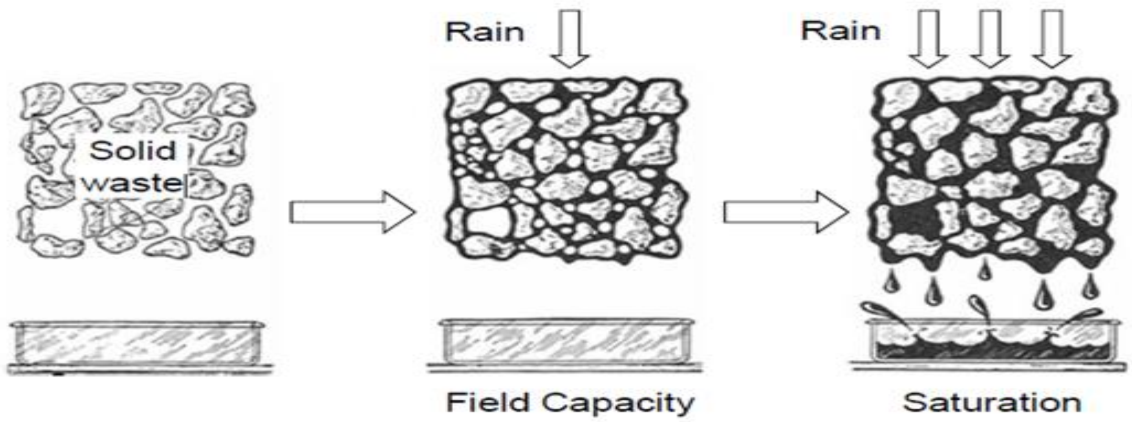


Figure: Schematic to illustrate the field capacity in solid waste

5. Hydraulic conductivity of compacted waste

The hydraulic conductivity, designated K, of compacted waste is a physical property that strongly influences the movement of liquids (especially leachate) and gases in a landfill. Dense and compacted wastes tend to resist rainfall infiltration and promote runoff from a landfill cell. In contrast, paper and yard waste, by virtue of having large particles and therefore large void space, exhibit little resistance to rainfall infiltration.

Loose samples of MSW have a hydraulic conductivity value of $15x10^{-5}$ m/s, while dense baled waste may have a K of $7x10^{-6}$ m/s. The K value for shredded waste ranges from 10^{-4} to 10^{-6} m/s. Since MSW is very heterogeneous, these values serve only as an assumption and will be varying.

Chemical properties

Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behavior of waste, as it moves through the waste management system. Information on the chemical properties of the components that constitute MSW is important in (i) Improving leachate properties and groundwater contamination; (ii) Evaluating alternative solid waste processing and recovery options; (iii) Information about trace element composition; and (iv) Assessing the feasibility of MSW combustion directly affected by chemical composition. The four most important properties to be known are:

1. **Ultimate analysis**
   The ultimate analysis of a material is defined as its total elemental analysis, i.e., the percentage of each individual element present. It typically involves the determination of the percent C(carbon), H(hydrogen), O(oxygen), N(nitrogen), S(sulfur), and ash. The results of the ultimate analysis are typically used to characterize the chemical composition of the organic fraction of MSW. This helps in assessing the suitability of the waste as fuel and predicting emissions from combustion and also used to define proper mix of MSW materials to achieve suitable nutrient ratios (C/N) for biological conversion processes such as composting. The majority of MSW is composed of C, H and oxygen. The ash fraction is the residual remaining after combustion and is inorganic although some organics may remain as well. Ash can impact significant environmental and public health effects if improperly managed. Data on the ultimate analysis of individual elements are presented in the table Sulphur is not a component of any solid waste category, except perhaps building materials and yard waste. Nitrogen occurs mainly in food waste, grass clippings and textiles.

Table: Typical data after the ultimate analysis of the waste materials found in MSW

	% by Wt (dry basis)					
Component	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
Organic						
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Plastics	60.0	7.2	22.8	—	—	10.0
Food Wastes	48.0	6.4	37.6	2.6	0.4	5.0
Yard Wastes	47.8	6.0	38.0	3.4	0.3	4.5
Textiles	55.0	6.6	31.2	4.6	0.15	2.5
Rubber	78.0	10.0	—	2.0	—	10.0
Wood	49.5	6.0	42.7	0.2	0.1	1.5
Inorganic						
Glass	0.5	0.1	0.4	<0.1	—	98.9
Metals	4.5	0.6	4.3	<0.1	—	90.5
Dirt, ash	26.3	3.0	2.0	0.5	0.2	68.0
MSW	15–30	2–5	12–24	0.2–1.0	0.02–0.1	—

2. Proximate analysis

Proximate analysis is more specific compared with ultimate analysis and is used to estimate the capability of MSW as a fuel. Proximate analysis includes following tests,

1. Moisture content, determined by loss of moisture after heating at 105-degree C for 1 h
2. Volatile combustible matter, the additional loss of weight after ignition at 950 degree C for 7 min in a covered crucible (oxygen is excluded)
3. Fixed carbon, the combustible residue left after volatile matter is removed; ignition at 600 to 900-degree C
4. Ash, the weight of residue after combustion in an open crucible

- Moisture content and ash represent the non-combustible component of the MSW
- Moisture is undesirable in MSW as it adds weight to the fuel without adding to the heating value and in addition, it affects the heat release from the fuel
- Similarly, ash adds weight without providing heat energy and also furthermore ash retains heat when removed from the furnace; as a result potentially useful heat is lost to the environment
- Volatile matter and fixed carbon content are the preferred indicators of the combustion capability of MSW.
- Volatile matter is the portion of MSW converted into gas as the temperature increases
- Fixed carbon is the solid carbon residue that has settled on the furnace grates after Solid waste is heated and the volatile matter is expelled
- A waste or fuel with a high proportion of fixed carbon requires a longer retention time on the furnace grates to achieve complete combustion than a waste or fuel with a low proportion of fixed carbon

$$\textit{Fixed carbon}\ [\%] = 100\ [\%] - \textit{moisture}\ [\%] - \textit{ash}\ [\%] - \textit{volatile matter}\ [\%]$$

The limitation of proximate analysis is that it does not provide an indication of possible pollutants emitted during combustion. These data are determined by conducting ultimate analysis. Proximate analysis data for the MSW components are presented in the table below.

Table: Typical proximate analysis of MSW components

	Proximate analysis (% by wt)			
Waste Type	Moisture	Volatiles	Fixed Carbon	Noncombustable (ash)
Food mixed	70.0	21	3.6	5.0
Paper mixed	10.2	76	8.4	5.4
Newspapers	6.0	81	11.5	1.4
Cardboard	5.2	77	12.3	5.0
Plastics mixed	0.2	96	2	2
Polyethylene	0.2	98	<0.1	1.2
Polystyrene	0.2	99	0.7	0.5
PVC	0.2	87	10.8	2.1
Textiles	10	66	17.5	6.5
Yard wastes	60	30	9.5	0.5
Wood mixed	20	68	11.3	0.6
Glass	2			96–99
Metals	2.5			94–99
Domestic MSW	10–40	30–60	3–15	10–30

3. Fusing point of ash

It is the temperature at which the ash from the combustion of waste forms clinker by fusion and agglomeration which provides information about softening and melting conditions Typical fusing temperatures for the formation of clinker from solid waste range from 2000 to 2200°F (1100 to 1200°C).

4. Energy content

The heating value of waste is a measure of the energy released when it is burned.
It can be estimated by:
(i) Combusting samples in a boiler and measuring the heat output
(ii) Using lab scale bomb calorimeter
(iii) Calculation from elemental composition (ultimate analysis)
The heat generated by the combustion of a material in a calorimeter is determined by using the formula:

$$\mathbf{U = Cv\Delta T/M}$$

U= heat value (cal/g)
Cv= heat capacity of the calorimeter (cal/degree C)
ΔT= rise in temperature (degree C)
M= mass of material, grams

Typical data for energy content and inert residue for the components of MSW are reported in the table below.

Table: Typical data on inert residue and energy content of MSW

Component	Inert Residue %		Heating Value (kJ/kg)	
	Range	Typical	Range	Typical
Food wastes	2-8	5	3500-7000	4500
Paper	4-8	6	11500-18500	16500
Cardboard	3-6	5	14000-17500	16000
Plastics	2-20	10	28000-37000	32500
Textiles	2-4	2.5	15000-20000	17500

Component	Inert Residue %		Heating Value (kJ/kg)	
	Range	Typical	Range	Typical
Rubber	8-20	10	21000-28000	18500
Leather	8-20	10	15000-20000	17500
Garden trimmings	2-6	4.5	2300-18500	6500
Wood	0.6-2	1.5	17500-20000	18500
Glass	96-99	98	120-240	140
Tin cans	96-99	96	240-1200	700
Nonferrous metals	90-99	96	240-1200	700
Ferrous metals	94-99	98	240-1200	700
Dirt, ash, bricks, etc.	60-80	70	2300-11500	7000
Municipal solid waste			9500-13000	10500

- Energy values may be converted to a dry basis by using the equation below:

kJ/kg (dry basis)= k/J (as discarded)* (100/(100-%moisture))

- Similarly the corresponding equation on an ash free dry basis is given by:

kJ/kg (ash free dry basis)= k/J (as discarded)* (100/(100-%ash-%moisture))

- If energy values are not available, approximate values may be determined by using *modified Dulong formula*

kJ/kg= 337C+1428(H-0.125O)+93S+23N

Biological properties

The most important biological characteristic of the organic fraction of MSW is that almost all of the organic components can be converted biologically to gases and relatively inert organic and inorganic solids. The production of odours and the generation of flies are also related to the putrescible nature of the organic materials found in MSW (e.g., food wastes).

The organic fraction of MSW (excluding plastics, rubber and leather) can be classified as:

- Water-soluble constituents - sugars, starches, amino acids and various organic acids
- Hemicellulose - a product of 5 and 6-carbon sugars glucose - Cellulose - a product of 6-carbon sugar glucose
- Fats, oils and waxes - esters of alcohols and long-chain fatty acids
- Lignin - present in some paper products
- Lignocellulose - combination of lignin and cellulose
- Proteins - amino acid chains

1. **Biodegradability of organic waste components**

- Volatile solids (VS)content, determined by ignition at 550°C, is often used as a measure of the biodegradability of the organic fraction of MSW
- The use of VS in describing the biodegradability of the organic fraction of MSW is misleading, as some of the organic constituents of MSW are highly volatile but low in biodegradability (e.g., newsprint and certain plant trimmings)

Alternatively, the lignin content of a waste can be used to estimate the biodegradable fraction, using the following relationship:

BF=0.83-0.028LC

Where,

BF= biodegradable fraction expressed on a volatile solids(VS) basis

0.83= empirical constant , 0.028=empirical constant

LC=lignin content of the VS expressed as a percent of dry weight

For practical purposes, the principal organic waste components in MSW are often classified as rapidly and slowly decomposable.

Data on biodegradable fraction of selected organic waste components based on lignin content

Component	Volatile solids (VS), percent of total solids (TS)	Lignin content (LC), percent of VS	Biodegradable fraction (BF)
Food wastes	7-15	0.4	0.82
Paper			
Newsprint	94	21.9	0.22
Office paper	96.4	0.4	0.82
Cardboard	94	12.9	0.47
Yard wastes	50-90	4.1	0.72

2. Production of odour

- Odors can develop when solid wastes are stored for long periods of time on-site between collections, in transfer stations, and in landfills
- The development of odors in on-site storage facilities is more significant in warm climates. Typically, the formation of odors results from the anaerobic decomposition of the readily decomposable organic components found in MSW.
- For example, under anaerobic (reducing) conditions, sulfate can be reduced to sulfide (S-2), which subsequently combines with hydrogen to form hydrogen sulfide. It can be illustrated by the following reactions.

$$\underbrace{2CH_3CHOHCOOH}_{\text{Lactate}} + \underbrace{SO_4^{2-}}_{\text{Sulfate}} \rightarrow \underbrace{2CH_3COOH}_{\text{Acetate}} + \underbrace{S^{2-}}_{\text{Sulfide ion}} + H_2O + CO_2$$

$$4H_2 + SO_4^{2-} \rightarrow S^{2-} + 4H_2O$$

$$S^{2-} + 2H^+ \rightarrow H_2S$$

- The sulfide ion can also combine with metal salts that may be present, such as iron, to form metal sulfides

$$S^{2-} + Fe^{2+} \rightarrow FeS$$

- The black color of solid wastes after anaerobic decomposition in a landfill is primarily due to the formation of metal sulfides.
- The biochemical reduction of an organic compound containing sulfur radical can lead to the formation of malodorous compounds such as methyl mercaptan and amino butyric acid. The reduction of methionine, an amino acid, serves as an example.

$$\underbrace{CH_3SCH_2CH_2CH\,(NH_2)\,COOH}_{\text{Methionine}} \rightarrow \underbrace{CH_3SH}_{\text{methyl mercaptan}} + \underbrace{CH_3CH_2CH_2\,(NH_2)\,COOH}_{\text{amino butyric acid}}$$

The methyl mercaptan can be hydrolyzed biochemically to methyl alcohol and hydrogen sulfide as follows.

$$CH_3SH + H_2O \rightarrow CH_4OH + H_2S$$

3. Breeding of flies

In the summertime and during all seasons in warm climates, fly breeding is an important consideration in the onsite storage of wastes. Flies can develop in less than two weeks after the eggs are laid. The knowledge on breeding of flies is very important in MSW management to control over human diseases.

The life history of the common house fly from egg to adult can described as follows.

Eggs develop	8 to 12 hours
First stage of larval period	20 hours
Second stage of larval period	24 hours
Third stage of larval period	3 Days
Pupal stage	4 to 5 days
Total	9 to 11 days

Waste Stream Assessment

- Waste stream assessment (WSA) is a means to determine the basic aspects of quantity (i.e., the amount of waste generated in the community, both in terms of weight and volume), composition (i.e., the different components of waste stream) and sources of wastes.
- The information relating to these basic aspects of wastes is vital for making decisions about the SWM system, finance and regulations. Put differently, an assessment of waste stream is essential in the analysis of short and long term problems within the local waste management system.
- It also helps in targeting waste management activities and setting goals for different elements of a waste management plan.
- Waste stream assessment, however, is not a one-time activity. It is a continuous and dynamic process, because the characteristics of wastes differ depending on the regions, communities, seasons

Importance of Waste Quantities

- In determining compliance with federal and state waste diversion programs
- In selecting specific equipment
- In designing of waste collection routes
- In selecting Materials recovery facilities and disposal facilities

Measure and Methods used to assess SW Quantities

- Volume and weight are used for the measurement of solid waste quantities
- But, the use of volume as a measure of quantity can be misleading
- To avoid confusion, solid waste quantities should be expressed in terms of weight
- Weight is the only accurate basis for records because tonnages can be measured directly, regardless of the degree of compaction
- Helps during hauling waste over highways
- 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
2. Weight-volume analysis
3. Materials-balance analysis

Load-Count Analysis

- The number of individual loads and the corresponding waste characteristics (types of waste, estimated volume) are noted down over a specified time period.
- It might be at transfer station or at disposal site
- The total mass and mass distribution by composition is determined using average density data for each waste category
- Unit generation rates are determined by using the field data and necessary published data.

Weight-Volume Analysis

- This method of analysis is similar to the pervious method with the added feature that the mass/weight of each load is also recorded.
- Vehicles are weighed when they enter the disposal sites loaded, and exit the sites empty
- The weighing of loaded and unloaded vehicles is accomplished with a weighing scale or weighbridge

Sample data sheet for a weight survey

Generator			Weight/Volume				Self-Haul Wastes							
							Self-Haul Vehicles					Waste Categories		
Residential	Commercial	Industrial	Gross Weight (kg)	Tare Weight (kg)	Capacity of Vehicle (m^3)	Volume of Waste (%)	Pickup Truck	Other Truck	Automobile	Handcart	Other	Yard Waste	C&D[a]	Other[b]
Recorded by: ______________								Date: ______________						

[a] C&D = Construction and demolition debris.
[b] "Other" - describe.

Material-Balance Analysis

- The only way to determine the generation and movement of SW with any degree of reliability is to perform a detailed materials mass balance analysis for each generation source
- In some cases, it will be required to obtain the data needed to verify compliance with state-mandated recycling programs

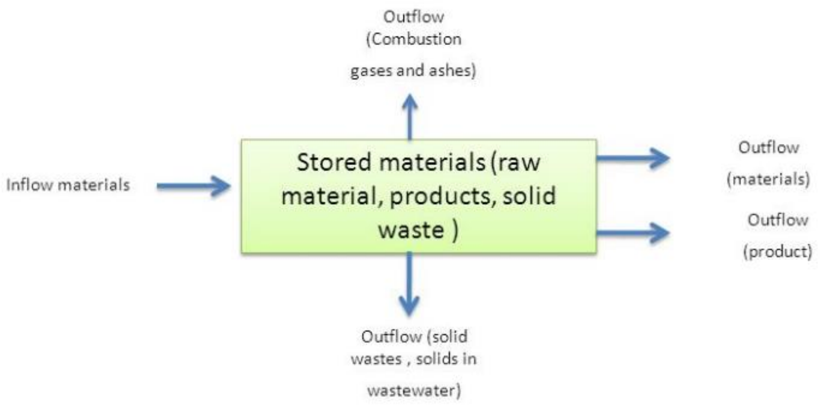
Preparation of Materials Mass Balances:

1. Draw a system boundary around the unit to be studied
2. Identify all the activities that cross or occur within the boundary and affect the generation of waste
3. Identify the rate of waste generation associated with each of these activities
4. Use the appropriate mathematical relationship and determine the quantity of waste generated, collected and stored

➢Materials Mass Balance Analysis

- Simplified word statement

Accumulation = inflow – outflow + generation



General word statement:

Rate of accumulation of materials within the system boundary = Rate of flow of materials into the system boundary - Rate of flow of materials out of the system boundary + Rate of generation of waste materials within the system boundary

Symbolic representation

$$dM/dt = \Sigma M_{in} - \Sigma M_{out} + r_w$$

Where,

dM/dt = rate of change of the weight of material stored (accumulated) within the study unit, lb/d

ΣM_{in} = sum of all the materials flowing into study unit, lb/d

ΣM_{out} = sum of all the materials flowing out of study unit, lb/d

r_w= rate of waste generation, lb/d

Solid Waste Management System

As the expenses for environmental management are multi-tiered, and future events are difficult to forecast with assurance, the risks in the future and associated costs can be minimized and eliminated by choosing appropriate preventive measures. Therefore it is necessary to have a MSW management system where the community generates solid waste.

A Municipal Solid Waste management system refers to a combination of various functional elements associated with the management of solid wastes. The system, when put in place, facilitates the collection and disposal of solid wastes in the community at minimal costs while preserving public health and ensuring little or minimal adverse impact on the environment.

Solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing and disposal of solid wastes in a manner that is accord with the best principles of public health, economics, engineering, conservation, aesthetics and other environmental considerations.

Functional Elements of SW Management

The activities associated with the management of municipal solid wastes from the point of generation to final disposal can be grouped into the six functional elements. In figure 1.1 it shows the interrelationship of functional elements comprising of solid waste management system.

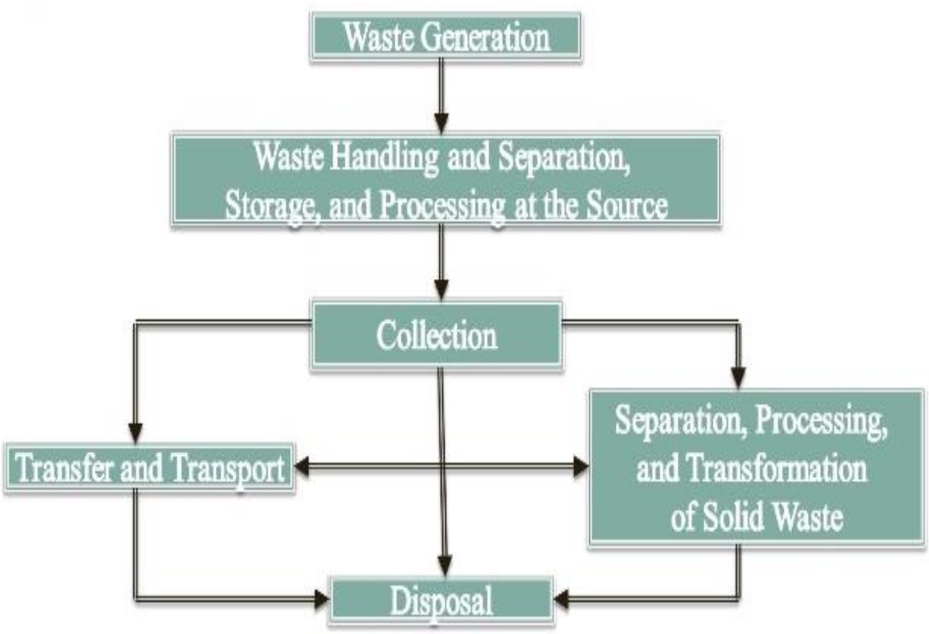


Figure 1.1: Interrelationship of Functional elements comprising of SWM system

1. Waste generation

Waste generation encompasses activities in which materials are identified as no longer being of value (in their present form) and are either thrown away or gathered together for disposal. Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted into goods for consumption. At present, waste generation is an activity that is not very controllable and in the future, however, more control is likely to be exercised over the generation of wastes. The source of waste generation determines quantity; composition and waste characteristics. For example, wastes are generated from households, commercial areas, institutions, street cleaning and other municipal services in the form of paper, plastic, cardboard, food waste etc.,. The most important aspect of this part of the SWM system is the identification of waste.

2. **Waste handling and separation, storage and processing at the source**

This is a key functional element because collection of wastes never takes place at the source or at the time of their generation. Waste handling and sorting involves the activities associated with management of wastes until they are placed in storage containers for collection and also encompasses the movement of loaded containers to the point of collection. The sorting of waste components is an important step in the handling and storage of solid waste at the source. For example, the best place to separate waste materials for reuse and recycling is at the source of generation. On-site storage is of primary importance because of public health concerns and aesthetic consideration. The cost of providing storage for solid wastes at the source is normally borne by the household in the case of individuals, or by the management of commercial and industrial properties. Some of the options for storage are plastic containers, conventional dustbins (of households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc. Obviously, these vary greatly in size, form and material. Processing at the source involves activities such as backyard waste composting, volume reduction; alter the physical form of solid waste by the waste generator.

3. **Waste collection**

This includes gathering of wastes and hauling them to the location, where the collection vehicle is emptied, which may be a transfer station (i.e., intermediate station where wastes from smaller vehicles are transferred to larger ones and also segregated), a processing plant or a disposal site. Collection depends on the number of containers, frequency of collection, types of collection services and routes. Typically, collection is provided under various management arrangements, ranging from municipal services to franchised services, and under various forms of contracts. The collection of separated and not separated waste in an urban area is difficult and complex because the generation of residential and commercial wastes takes place in every home, apartments and shops.

4. **Transfer and transport**

This functional element involves the transfer of wastes from smaller collection vehicles, where necessary to overcome the problem of narrow access lanes, to larger ones at transfer stations the subsequent transport of the wastes, usually over long distances, to disposal sites. The factors that contribute to the designing of a transfer station include the type of transfer operation, capacity, equipment, accessories and environmental requirements.

5. **Separation, processing and transformation of solid waste**

The recovery of sorted materials, processing of solid waste and transformation of solid waste that occurs primarily in locations away from the source of waste generation are encompassed by this functional element. Sorting of commingled (mixed) wastes usually occurs at a materials recovery facility, transfer stations, combustion facilities, or at the disposal sites. Sorting often includes the separation of bulky items, separation of waste components by size using screens, manual separation of waste components, and separation of ferrous and non-ferrous metals. But selecting any recovery process is a function of economics, i.e., cost of separation versus the recovered materials products. The processing of solid waste is required to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling and some of the important processing technique includes compaction, thermal volume reduction, incineration etc., and also the organic fraction of MSW can be transformed by a variety of biological and thermal processes. The selection of a given set of processes will depend on the waste management objectives to be achieved.

6. **Waste disposal**

The final functional element in the solid waste management system is disposal. Today the disposal of wastes by landfilling or uncontrolled dumping is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a landfill site, residual materials from Materials Recovery Facilities (MRFs), residue from the combustion of solid waste, rejects of composting, or other substances from various solid waste-processing facilities. A municipal solid waste landfill plant is an engineered facility used for disposing of solid wastes on land or within the earth's mantle without creating nuisance or hazard to public health or safety, such as breeding of rodents and insects and contamination of groundwater. Generally, engineering principles are followed to confine the wastes to the smallest possible area, reduce them to the lowest particle volume by compaction at the site and cover them after each day's operation to reduce exposure to vermin.

Factors affecting solid waste management system

Many factors influence the decision-making process in the implementation of a SWM system. Some of the factors that need to be considered in developing a SWM system are listed below:

1. **Quantity and characteristics of waste**

   The quantities of wastes generated generally depend on the income level of a family, as higher income category tends to generate larger quantity of wastes, compared to low-income category. The quantity ranges from about 0.25 to about 2.3 kg per person per day, indicating a strong correlation between waste production and per capita income. One of the measures of waste composition (and characteristics) is density, which ranges from 150 kg/m3 to 600 kg/m3. Proportion of paper and packaging materials in the waste largely account for the differences and when this proportion is high, the density is low and vice versa. The wastes of high density reflect a relatively high proportion of organic matter and moisture and lower levels of recycling.

2. **Climatic and seasonal variations**

   There are regions in extreme north and south, where temperatures are very low for much of the year. In cold climates, drifting snow and frozen ground interfere with landfill operations, and therefore, trenches must be dug in summer and cover material stockpiled for winter use. Tropical climates, on the other hand, are subject to sharp seasonal variations from wet to dry season, which cause significant changes in the moisture content of solid waste, varying from less to high temperatures and humidity cause solid wastes to decompose far more rapidly than they do in colder climates because of this frequency of waste collection in high temperature and humid climates should, therefore, be higher than that in cold climates. In sub-tropical or desert climate, there is no significant variation in moisture content of wastes (due to low rainfall) and low production of leachate from sanitary landfill. But high winds and windblown sand and dust, however, cause special problems at landfill sites. While temperature inversions can cause airborne pollutants to be trapped near ground level.

3. **Physical characteristics of an urban area**
In urban areas (i.e., towns and cities), where the layout of streets and houses is such that access by vehicles is possible and door-to-door collection of solid wastes is the accepted norm either by large compaction vehicle or smaller vehicle. The picture is, however, quite different in the inner and older city areas where narrow lanes make service by vehicles difficult and often impossible. Added to this is the problem of urban sprawl in the outskirts (of the cities) where population is growing at an alarming rate. Access ways are narrow, unpaved and tortuous, and therefore, not accessible to collection vehicles. Problems of solid waste storage and collection are most acute in such areas.

4. **Financial and foreign exchange constraints**
Solid waste management accounts for sizeable proportions of the budgets of municipal corporations. This is allocated for capital resources, which go towards the purchase of equipment's, vehicles, and fuel and labour costs. Typically, 10% to 40% of the revenues of municipalities are allocated to solid waste management. In regions where wage rates are low, the aim is to optimize vehicle productivity. The unfavorable financial situation of some countries hinders purchase of equipment and vehicles, and this situation is further worsened by the acute shortage of foreign exchange. This means that the balance between the degree of mechanization and the size of the labour force becomes a critical issue in arriving at the most cost-effective solution.

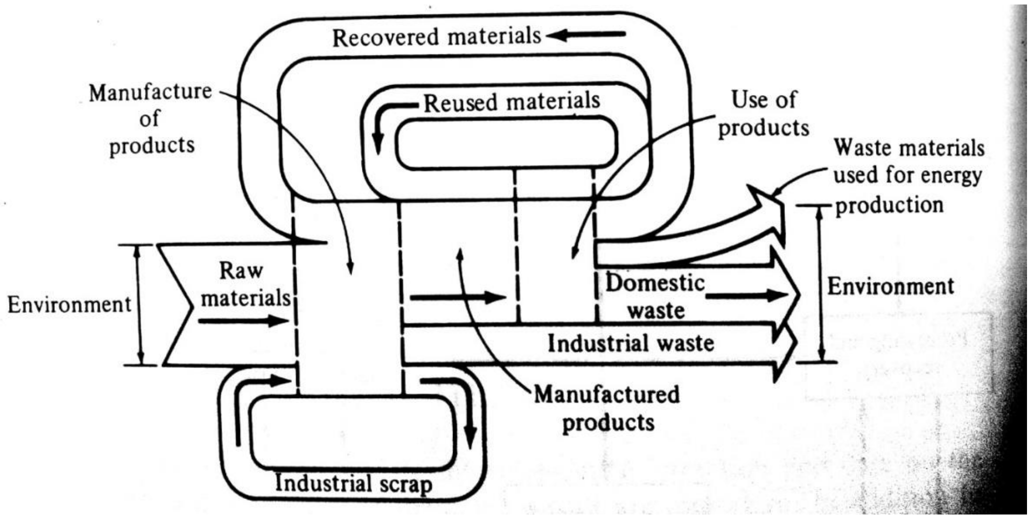
5. **Cultural constraints**
In some regions, long-standing traditions preclude the intrusion of waste collection on the precincts of households, and therefore, influence the collection system. In others, where the tradition of caste persists, recruits to the labour force for street cleaning and handling of waste must be drawn from certain sections of the population, while others will not consent to placing storage bins in their immediate vicinity. Social norms of a community more often than not over-ride what many may consider rational solutions. Waste management should, therefore, be sensitive to such local patterns of living and consider these factors in planning, design and operation.

6. **Management and technical resources**
Solid waste management, to be successful, requires a wide spectrum of workforce in keeping with the demands of the system. The best system for a region is one which makes full use of indigenous crafts and professional skills and/or ensures that training programmes are in place to provide a self-sustaining supply of trained workforce to deal with functional elements of solid waste management system.

Waste Generation

Solid waste generation rates estimate 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. Waste generation rates for residential and commercial activities can be used to estimate the impact of new developments on the local waste stream Determination of the generation rate of solid waste is important to obtain data in order to determine waste volume and for subsequent solid waste management.

Material Flow and Waste Generation



Flow of materials and Waste generation in a technological society *(From Vesilind and Rimer)*

Historically, waste management has been an engineering function. It is related to the evolution of a technological society, which, along with the benefits of mass production, has also created problems that require the disposal of solid wastes. The flow of materials in a technological society and the resulting waste generation are illustrated schematically in the above figure **(a)**. Wastes are generated during the mining and production of raw materials, such as the tailings from a mine or the discarded husks from a cornfield. After the raw materials have been mined, harvested, or otherwise procured, more wastes are generated during subsequent steps of the processes that generate goods for consumption by society from these raw materials. It is apparent from the diagram in Fig. 1.1 that the most effective way to ameliorate the solid waste disposal problem is to reduce both the amount and the toxicity of waste that is generated, but as people search for a better life and a higher standard of living, they tend to consume more goods and generate more waste. Consequently, society is searching for improved methods of waste management and ways to reduce the amount of waste that needs to be landfilled.

The generalized flow of materials and the generation of solid waste in society can be quantified relatively as shown in the above figure **(a)**. To satisfy the principle of conservation of mass the input must equal the output. Clearly, if a reduction in the usage of raw materials is to occur either the input or output must be reduced. Raw materials usage can be reduced most effectively by reducing the quantity of municipal and industrial waste. For example to meet EPA millage restrictions American cars are now (1984) on the average, 20 % smaller than they were in the late 1950's and early 1960's. This reduction in size as also reduced the demand for steel by about 20%. The reduced demand for steel as in turn resulted in less mining for the iron ore used to make steel. While most people would agree that its desirable to reduce the usage of raw materials is decreased jobs in those industries also are decreased. With this prelude the following points explains about control of waste in a technological society.

Resource optimization: Minimizing the amount of waste produced by organizations or individuals goes hand-in-hand with optimizing their use of raw materials.

Reuse of scrap material: Scraps can be immediately re-incorporated at the beginning of the manufacturing line so that they do not become waste products.
Improved quality control and process monitoring: Steps can be taken to ensure that the number of reject batches is kept to a minimum. This is achieved by increasing the frequency of inspection and the number of points of inspection.
Waste exchanges: This is where the waste product of one process becomes the raw material for a second process. Waste exchanges represent another way of reducing waste disposal volumes for waste that cannot be eliminated.
Ship to point of use: This involves making deliveries of incoming raw materials or components direct to the point where they are assembled or used in the manufacturing process to minimize handling and the use of protective wrappings or enclosures.

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. For example, universally accepted units for:
• Household waste (kg/capita/day)
• Commercial waste (kg/x/day where x can be m2 of floor area of commercial establishment, unit volume or dollar in sales, the number of employees, etc.)
• Institutional waste (kg/x/day where x can be the number of students, m2 of the area of park or public place, number of visitors, etc.)
• Market waste (kg/x/day where x can be the no. of market lots, m2 of floor area, dollar in sales, etc.)
• Industrial waste (kg/x/day where x can be unit volume or dollar of production output, m2 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)

Factors that affect Waste Generation Rates

There are several factors, which affect the present as well as the future waste quantity and composition and some of which are listed below:

- **Source reduction:** Waste reduction may occur through the design, manufacturing and packaging of the products with minimum toxic content, minimum volume of materials and/or longer useful life. Waste reduction may also occur at household, commercial and industrial facility through selective buying patterns. Some ways in which source reduction can be achieved like, decrease unnecessary or excessive packaging, develop and use products with greater durability and reparability (e.g., more durable appliances and tires), Use fewer resources (two sided copying).
- **Geographic location:** The influence of geographic location is related primarily to different climates that can influence both the amount of certain types of solid wastes generated and the collection operation. For instance, substantial variations in the amount of yard and garden wastes generated in various parts of India are related to the climate. To illustrate, in the warmer southern areas, where the growing season is considerably longer compared to the northern areas, yard wastes are collected in considerably larger quantities and over a longer period of time.

- **Seasons:** Seasons of the year have implications for the quantities and composition of certain types of solid wastes. For example, the growing season of vegetables and fruits affect the quantities of food wastes.
- **Collection frequency:** A general observation is that in localities, where there are ultimate collection services, more wastes are collected. Note that this does not mean that more wastes are generated. For example, if a homeowner has access to only one or two containers per week, due to limited container capacity, he or she will store newspapers or other materials in some specified storage area. However, the same homeowner will tend to throw them away, if there is access to unlimited container services. In this latter situation, the quantity of waste generated may actually be the same but the quantity collected, as it relates to the frequency of collection, is considerably different.
- **Population diversity:** The characteristics of the population influence the quantity and composition of waste generated. The amount of waste generated is more in low-income areas compared to that in high-income areas. Similarly, the composition differs in terms of paper and other recyclables, which are typically more in high-income areas as against low income areas.
- **Extent of salvaging and recycling:** The existence of salvaging and recycling operation within a community definitely affects the quantity of wastes collected.
- **Public attitude:** Significant reduction in the quantity of solid waste is possible, if and when people are willing to change – on their own volition – their habits and lifestyles to conserve the natural resources and to reduce the economic burden associated with the management of solid wastes.
- **Legislation:** This refers to the existence of local and state regulations concerning the use and disposal of specific materials and is an important factor that influences the composition and generation of certain types of wastes. The Indian legislation dealing with packing and beverage container materials is an example.

On-Site Handling, Storage and Processing

- Onsite means these functions are concerned with solid waste at the place where the waste is generated
- This part includes a description and discussion of the handling and separation, storage and processing of the waste materials at the source
- If not properly managed can have a significant effect on the characteristics of the waste, on subsequent functional elements, on public health.
- Refers to the activities associated with managing solid wastes until they are placed in the containers used for storage before collection or return to drop-off & recycling centers
- Vary depending on the types of waste materials that are separated for reuse and recycling
- Separation of solid waste components is one of the most positive & effective way to achieve recovery and reuse
- Depending on the collection type handling may also required to move the loaded container to the collection point and back to the container location

Waste Handling & Separation at Residential Dwellings

For the purpose of handling and separation of wastes, the residential dwellings are classified as:

(a) Low rise buildings (< 4 stories)

1.. Single family detached

2.. Single family attached

(b) Medium rise buildings (4-7 stories)
(c) High rise buildings (> 7 stories)

At Low –Rise Detached Dwellings

- Residents or tenants are responsible for placing solid waste, recyclable materials around their dwelling in storage containers.
- Waste components separated are placed in one large containers.
- Recyclable materials separated are placed in special containers or bags.
- In some residents, waste compactors are used to reduce the volume and placed in containers or sealed plastic bags
- And also transporting the filled containers to the street curb for collection

At Low and Medium Rise Apartments

- Handling are same as low rise dwellings
- But waste storage location and collection may be different.
- Typical solid waste storage locations include

- basement storage
- outdoor storage
- sometimes compactor storage

Basement storage:

- A basement storage room or area is provided for storage of SW
- Containers used for recycling are located within or next to the solid waste storage area
- Residents carry their waste and recyclable materials to the storage area and deposit
- The maintenance staff is responsible for transporting the containers to street for curbside collection
- In many apartments the maintenance crew is responsible for collection of waste and recyclable materials left outside of the doorway

Outdoor Storage:

- In many low and medium-rise apartments, large waste storage containers are located outdoor
- The large containers are emptied mechanically using collection vehicles equipped with unloading mechanisms.
- Containers used for recycling located within the outdoor storage area
- Residents carry their waste and recyclable materials to the storage area and deposit in appropriate containers
- In some apartments, maintenance staff responsible for above or collect from a utility room located on each floor

At High Rise Apartments

Methods of handling involves one or more of the following:

1. Wastes are picked up by building maintenance personnel (or) porters from the various floors and taken to the basement (or) service area
2. Wastes are taken to the basements or service area by tenants

3. Vertical chutes (usually circular) with openings provided on each floor
4. Wastes are bagged and placed or discharged by the tenants in specially designed vertical chutes (usually circular) with openings provided on each floor
5. Waste discharged in chutes are collected in large containers, compacted into large containers or baled directly
6. Recyclable materials may be put outside in the hall or entry way for pickup or carried by tenants to service area located on each floor for pickup
7. The entrance to the chute is usually located in the service area
8. Bulky items are carried by maintenance crew and also for handling the compressed waste and any other waste or recyclable materials that tenants bring to the service areas

Waste handling & separation at Commercial facilities

- Placed in relatively medium/large containers mounted on rollers and once filled, these removed by service elevators
- From that emptied into:

1. Large storage containers
2. Compactors used in conjunction with the storage containers
3. Stationary compactors that can compress the materials into bales or into specially designed containers
4. Other processing equipment

- No adequate provision for on-site storage of solid wastes and recyclable materials in some buildings and creates handling problems

Storage of Solid Wastes at the Source

- The first phase to manage solid waste is at home level
- It requires facilities for temporarily storing of refuse on the premises
- The waste should normally be stored at the source of waste generation till collected for its disposal
- Individual house holders (or) tenants have responsibility for onsite storage of solid waste

<u>Factors to be considered in the on-site storage of solid waste</u>

1. The effects of storage on the waste components.
2. Type of container to be used
3. The location of containers
4. Public health and aesthetics
5. The collection method and time

1. The effects of storage on the waste components

An important consideration in the onsite storage of wastes are the effects of storage itself on the characteristics of the waste being stored.

a. Microbiological decomposition

- Food and other waste placed in containers immediately start microbiological decomposition (putrefaction) as a result growth of bacteria and fungi
- For extended period of time, flies start breed and odours

b. The contamination of waste components

- Major waste components contaminated by small amount of waste like motor oils, cleaners and paints and it reduces the value of individual components for recycling

c. The absorption of fluids

- Waste components have initial moisture contents are stored together, paper will absorb moisture from food waste and garden trimmings.
- Degree of absorption depends on time the waste stored until collection
- If stored more than a week in enclosed container, the moisture distributed throughout the waste .

2. Type of container to be used

The types and capacities of containers depends on

- characteristics and types of solid waste to be collected
- the type of collection system in use
- the collection frequency
- the space available for placement of containers.

Low-Rise Dwellings- Manual Curbside waste collection

- Manual curbside waste collection service at low rise detached residential dwellings
- Containers should be light enough to be handled easily by one collector when they are full
- In general, the upper weight limit should be between 40 -65 lb
- Choice of container materials depends on the preferences of the home-owner
- Temporary and disposable containers such as paper bags, cardboard boxes, plastic containers and bags are used
- Under normal circumstances, these are removed along with the waste and loading is difficult
- Container liners are used (paper or plastic)
- Difficulty during separation at the site



Low-Rise Dwellings- Mechanized Curbside waste collection

- Improved collection systems / methods
- Containers are designed specifically to work with the container- unloading mechanism attached to the collection vehicle

- These containers vary in size from about 75 gals to 120 gals, with 90 gal being the most common
- Although the containers look bulky and difficult to handle by the residents, they are designed so that easily tilted back and move to its source



Low and Medium Rise Apartments

- In low rise apartment complex a number of storage containers have been used
- Individual plastic or galvanized metal containers and large portable or fixed containers
- When apartment is grouped in close proximity, large containers are placed in a common area
- Containers enclosures are covered and equipped with rollers for easy movements
- The container for recyclable materials depend on the waste type



High- Rise Apartments

- Solid waste chutes are available, separate storage containers are not used
- In some older medium and high rise apartments without chutes, waste is stored in containers on the premises between collections
- Most common means of storage for wastes accumulated from individual apartments include:

1. Enclosed storage containers with compaction equipment
2. Large open top containers for un-compacted waste and bulky items
3. Large open top containers for recycled waste


Storage at commercial facilities

- The type of containers used for commercial facilities will depend on methods used for collecting waste produced at various location and space available
- Typically, large open top containers are used for un-separated wastes

- Containers equipped with compactor are widely used
- Selection on containers size depends on the amount of waste generated

3. **Container storage location**

- Containers storage locations depend on the type of dwellings or commercial or any other, available space and access to collection services
- At low-rise detached dwellings containers are usually placed at the sides or rear of the house, next to garage or some common location specifically designated for that purpose
- At the basement in some low rise and medium rise apartments
- Outdoor storage containers at the end of the streets for residential areas
- The container location at commercial areas will be worked out jointly between the building owners and public or private collection agency.

4. **Public Health and Aesthetics**

- Less space at residential buildings, as a result- they can have significant public health and aesthetic impacts
- Vermin and insects that often serves as potential disease vectors
- Production of odor by decomposition process
- Periodic cleaning and removal of biodegradable waste
- Odor can be controlled by having containers with lids or can be sprayed with a masking deodorant as a temporary expedient

TYPES OF CONTAINERS

Based on usage mobility

i) Stationary containers: These are used for contents to be transferred to collection vehicles at the site of storage.

(ii) Hauled containers: These are used for contents to be directly transferred to a processing plant, transfer station or disposal site for emptying before being returned to the storage site.

2. Based on size/requirement

(i) Small containers

(ii) Large containers

Characteristics of a well-designed container

- A container for manual handling by one person should not weigh more than 20 kg, or else it may lead to occupational health hazards such as muscular strain, etc.
- Containers should not have rough or sharp edges, and preferably have a wheel to facilitate mobility

- They should be covered to prevent rainwater from entering (which increases the weight and rate of decomposition of organic materials) into the solid wastes
- The container body must be strong enough to resist and discourage stray animals and scavengers from ripping it as well as withstand rough handling by the collection crew and mechanical loading equipment
- Containers should be provided with a lifting bar, compatible with the hoisting mechanism of the vehicle
- The material should be light and easy to clean

On-Site Processing of Solid Waste

On-site waste processing is used to:

1. Reduce the volume
2. Recover usable materials
3. Alter the physical form of the solid waste

Most common onsite processing operations

- Food waste grinding
- Component separation
- Compaction
- Incineration (fireplaces)
- Composting

Food waste grinders:

- The amount of food waste has been increasing dramatically over the last several decades & some estimates indicate that as much as 40% of food in the US is thrown away
- Home grinders are used primarily for waste from the preparation, cooking & serving foods, and they cannot be used for large bones or other bulky items
- Render the material that passes through grinder suitable for transport through the sewer system
- Organic material added to sewage has resulted in overloading many treatment facilities
- It is possible to increase the time period between collections pickups because wastes that might readily decay are not stored
- Enhance biogas production through increasing food surface area in anaerobic digestion
- Minimize waste disposal costs by grinding up organic waste and sending it to be composted

Separation of waste

- The sorting or separation of waste materials into newspapers, aluminum cans, and glass and others by hand at the household is one of the most positive ways to achieve the recovery and reuse materials
- Using reusable products, instead of their disposal equivalents, reduce the amount of materials that are to be managed as wastes. An example of product reuse is the reusable shopping bag.

Compaction of waste

- Waste compaction is the process of compacting waste, reducing it in size
- Within the past few years, a number of small compactors designed for home use have appeared on the market for compaction of loose paper and cardboard
- The use of home compactors may also help subsequent processing operations
- Should compact carefully with same kind of waste product to achieve more profit from reselling of recovered products
- Problems because of compaction



Incineration of waste

- In the past burning of combustible waste was a common practice in their backyard
- Now, backyard burning is banned in most of the countries
- Elimination of backyard burning significantly increased the quantity of paper, cardboard, plastic and yard waste collected
- Later this can be utilized for reuse or recycle


Composting of waste

- The process of natural decomposition is very important to one type of waste disposal
- Composting is a form of waste disposal where organic waste decomposes naturally with the help of micro organisms
- Compost is organic matter that has been decomposed in a process called composting
- Compost is rich in nutrients. It is used, for example,
  in gardens, landscaping, horticulture, urban agriculture and organic farming. The compost itself is beneficial for the land in many ways, including as a soil conditioner, a fertilizer, addition of vital humus or humic acids, and as a natural pesticide for soil
- Oldest technique for the processing of organic waste
- It is an effective way of reducing volume and altering the physical composition of solid wastes. While at the same time producing useful by-product
- Backyard composting- material placement, occasional watering and turning
- Number of additives are available to enhance the composting process
- Co-composting is a technique that processes organic solid waste together with other input materials such as dewatered fecal sludge or sewage sludge