Lecture 1

Introducing Municipal Solid Waste Management

STRUCTURE

OVERVIEW

Due to rapid increase in the production and consumption processes, societies generate as well as reject solid materials regularly from various sectors–agricultural, commercial, domestic, industrial and institutional. The considerable volume of wastes thus generated and rejected is called solid wastes. In other words, solid wastes are the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted. This inevitably places an enormous strain on natural resources and seriously undermines efficient and sustainable development. One of the ways to salvage the situation is through efficient management of solid wastes, and this is the focus of this

Course, Management of Municipal Solid Waste. In the 10 Units that constitute this Course, we will discuss the processes involved in the management of solid wastes–from waste generation to final disposal.

In Unit1, we will describe solid wastes and introduce you to the classification of solid wastes and the functional elements, such as waste generation, storage, collection, transport, processing, recovery and disposal, in the management of solid wastes. In Units 2 to 7, we will explain with the support of case studies each of these functional elements. In Unit 8, we will explain the treatment of solid wastes by incineration and energy recovery from the incineration process. Subsequently, in Unit 9, we will deal with the treatment and management of hazardous (biomedical) wastes. Finally, in Unit10, we will discuss the concept of integrated waste management.

Unit 1 begins with a description and classification of solid wastes. It then touches upon some basics of solid waste management and the need for environmentally sound management practices. It closes with a discussion of the current solid waste management (SWM) scenario in India by presenting the effect of temporal conditions on the quantity of waste generated, analyzing the quantity and composition of urban wastes in nine major cities and describing the currentdisposalmethodsandtheirinfluenceonpublichealthandenvironment.

Before you read any further, note that for the purpose of this Course, we use the terms *solid wastes* and *solid waste* interchangeably.

LEARNINGOBJECTIVES

After completing this Unit, you should be able to:

- classify solid wastes;
- explain the functional elements of SWM;
- assess the current situation of SWM in India.

1.1 CLASSIFICATION OF SOLIDWASTES

Solid wastes are the organic and inorganic waste materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen refuse, paper, appliances, paint cans, batteries, etc., produced in a society, which do not generally carry any value to the first user(s). Solid wastes, thus, encompass both a heterogeneous mass of wastes from the urban community as well as a more homogeneous accumulation of agricultural, industrial and mineral wastes. While wastes have little or no value in one setting or to the one who wants to dispose them, the discharged wastes may gain significant value in another setting. Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated/ disposed is, therefore, essential for the design and operation of the functional elements associated with the management of solid wastes.

Solid wastes are classified on the basis of source of generation and type. We will explain these in Subsections1.1.1 and1.1.2, respectively.

1.1.1 Source-based classification

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

(i) **Residential:** this refers to waste from dwellings, Apartment etc and consists of leftover food, vegetable peels, plastic, clothes, ashes etc.

(ii) **commercial** : This reference to waste consisting of leftover food, glasses, metals, Ashes etc. generated from stores, restaurants, markets, hotels, motels, auto repair shops, medical facilities etc.

(iii) **Institutional:** This mainly consists of paper, plastic, glasses, etc., generated from educational, administrative and public buildings such as schools, colleges, offices, prisons, etc.

(iv) **Municipal:** This includes dust, leafy matter, building debris, treatment plant residual sludge, etc., generated from various municipal activities like construction and demolition, street cleaning, landscaping, etc.

(v) **Industrial:** This mainly consists of process wastes, ashes, demolition and construction wastes, hazardous wastes, etc., due to industrial activities.

(vi) **Agricultural:** This mainly consists of spoiled food grains and vegetables, agricultural remains, litter, etc., generated from fields, orchards, vineyards, farms, etc.

(vii) **Open areas:** this includes wastes from areas such as Streets, alleys, parks, vacant lots, play grounds, beaches, highways, recreational areas, etc.

It is important to define the various types of solid wastes that are generated from various sources (see Sub section1.1.1), which we will do, next.

1.1.2 Type-based classification

Classification of wastes based on types, i.e., physical, chemical, and biological characteristics of wastes, is as follows (Phelps,etal.,1995):

(i) **Garbage:** This refers to animal and vegetable wastes resulting from the handling, sale, 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.

(ii) **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. Since ashes and residues are almost entirely inorganic, they are valuable in landfills. (We will discuss land fills in Unit 4.)

(iii) **Combustible and non- combustible wastes:** These consist of wastes generated from house holds, 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.

(iv) **Bulky wastes:** These include large house hold appliances such as refrigerators, washing machines, furniture, crates, vehicle parts, tyres, wood, trees and branches. Since these house hold wastes can not be accommodated in normal storage containers, they require a special collection mechanism.

(v) **Street wastes:** These refer to wastes that are collected from streets, walk ways, alleys, parks and vacant plots, and include paper, card board, plastics, dirt, leaves and other vegetable matter. Littering in public places is indeed a wide spread and acute problem in many countries including India, and a solid waste management system must address this menace appropriately.

(vi) **Bio degradable and non-bio degradable wastes:** *Biodegradable wastes* mainly refer to substances consisting of organic matter such as left over food, vegetable and fruit peels, paper, textile, wood, etc., generated from various house hold 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. Table1.1 below shows a comparison of biodegradable and non-biodegradable wastes with their degeneration time, i.e., the time required to break from a complex to a simple biological form:

Table1.1

Biodegradable and Non-Biodegradable Wastes: Degeneration Time

Category	Type of waste	Approximate time taken to degenerate
Biodegradable	Organic waste such as vegetable and fruit peels, leftover foodstuff, etc.	A week or two.
	Paper	10–30 days
	Cotton cloth	2–5 months
	Woollen items	1 year
	Wood	10–15 years
Non-biodegradable	Tin, aluminium, and other metal items such as cans	100–500 years
	Plastic bags	One million years
	Glass bottles	Undetermined

FromTable1.1,we can easily deduce the environmental consequences associated with non-biodegradable wastes such as plastics, glass, etc., which we will discuss later in Unit 6.

(vii) **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.

(viii) **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.

(ix) **Construction and demolition wastes:** These are wastes generated as a result of construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. They consist mainly of earth, stones, concrete, bricks, lumber, roofing and plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream.

(x) **Farm wastes:** These wastes result from diverse agricultural activities such as planting, harvesting, production of milk, rearing of animals for slaughter and the operation of feed lots. In many areas, the disposal of animal waste has become a critical problem, especially from feed lots, poultry farms and dairies.

(xi) **Hazardous wastes:** *Hazardous wastes* are those defined as wastes of industrial, institutional or consumer origin that are potentially dangerous either immediately or over a period of time to human beings and the environment. This is due to their physical, chemical and biological or radioactive characteristics like ignitability, corrosivity, reactivity and toxicity. Note that in some cases, the active agents maybe liquid or gaseous hazardous wastes. These are, nevertheless, classified as solid wastes as they are confined in solid containers. Typical examples of hazardous wastes are empty containers of solvents, paints and pesticides, which are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous wastes may cause explosions in incinerators and fires at land fill sites. Others such as pathological wastes from hospitals and radioactive wastes also require special handling. Effective management practices should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them harmless. We will discuss hazardous wastes in detail in Unit 9.

(xii) **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 egg shells 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, de watered sludge is useful as as oil conditioner but is invariably uneconomical. Solid sludge, therefore, enters the stream of municipal wastes, unless special arrangements are made for its disposal.

Table 1.2 below summarizes our discussion of waste classification based on sources of generation and their types:

Table 1.2
Classification of Solid Wastes

	Type	Description	Sources
Solid Wastes	Garbage	Food waste: wastes from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage, and sale of produce and 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, stoves, refrigerators other large appliances, furniture, large crates, trees, branches, stumps, etc.	Streets, sidewalks, alleys, vacant lots, etc.
	Street wastes	Street sweepings, dirt, leaves, etc.	
	Dead animals	Dogs, cats, rats, donkeys, etc.	
	Abandoned vehicles	Automobiles and spare parts	
	Construction and demolition wastes	Roofing, and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc.	Construction and demolition sites.
	Industrial wastes	Solid wastes resulting from industry processes and manufacturing operations, such as, food processing wastes, boiler house cinders, wood, plastic and metal scraps, shavings, etc	Factories, power plants, etc.
	Hazardous wastes	Pathological wastes, explosives, radioactive materials, etc.	Households, hospitals, institutions, stores, industry, etc.
	Animal and agricultural wastes	Manure, crop residues, etc.	Livestock, farms, feedlots and agriculture
	Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

1.2 SOLID WASTE MANAGEMENT (SWM)

Solid waste management (SWM) is associated with the control of waste generation, its storage, collection, transfer and transport, processing and disposal in a manner that is in accordance with the best principles of public health, economics, engineering, conservation, aesthetics, public attitude and other environmental considerations.

Put differently, the SWM processes differ depending on factors such as economic status (e.g., the ratio of wealth created by the production of primary products to that derived from manufactured goods, per capita income, etc.), degree of industrialization, social development (e.g., education, literacy, healthcare, etc.) and quality of life of a location. In addition, regional, seasonal and economic differences influence the SWM processes. This, therefore, warrants management strategies that are economically viable, technically feasible and socially acceptable to carry out such of the functions as are listed below (http://ces.iisc.ernet.in/energy/SWMTR/TR85.html):

- Protection of environmental health.
- Promotion of environmental quality.
- Supporting the efficiency and productivity of the economy.
- Generation of employment and income.

SWM has socio-economic and environmental dimensions. In the socio-economic dimension, for example, it includes various phases such as waste storage, collection, transport and disposal, and the management of these phases has to be integrated. In other words, wastes have to be properly stored, collected and disposed of by co-operative management. In addition, poor management of wastes on the user side such as disposing of wastes in the streets, storm water drains, rivers and lakes has to be avoided to preserve the environment, control vector-born diseases and ensure water quality/resource.

Against this background, we will study in Sub section 1.2.1 SWM system.

1.2.1 SWM system

A SWM 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. The functional elements that constitute the system are:

(i) **Waste generation:** Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted in to goods for consumption. The source of waste generation, as we touched upon earlier in Section1.1, determines quantity, composition and waste characteristics (see Unit 2 for details). For example, wastes are generated from house holds, commercial areas, industries, institutions, street cleaning and other municipal services. The most important aspect of this part of the SWM system is the identification of waste.

(ii) **Waste storage:** Storage is a key functional element because collection of wastes never takes place at the source or at the time of their generation. The heterogeneous wastes generated in residential areas must be removed within 8 days due to shortage of storage space and presence of biodegradable material. On site storage is of primary importance due to aesthetic consideration, public health and economics involved. 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. We shall discuss waste storage in detail in Unit 3.

(iii) **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.

Note that the solution to the problem of hauling is complicated. For instance, vehicles used for long distance hauling may not be suitable or particularly economic for house-to-house collection. Every SWM system, therefore, requires

An individual solution to its waste collection problem, and we will explain this in Unit 3.

(iv) **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. We will discuss these in Unit 3.

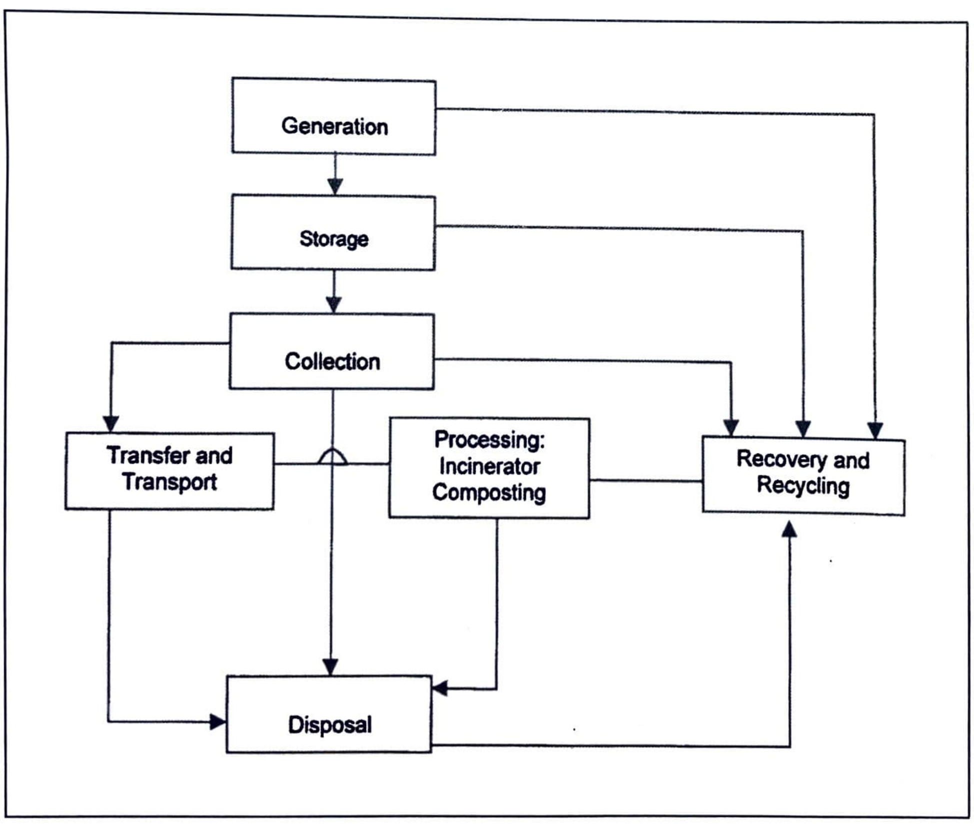
(v) **Processing:** Processing is required to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling. The important processing techniques include compaction, thermal volume reduction, manual separation of waste components, incineration and composting. We will discuss the various functions involved in waste processing in detail in Unit 5.

(vi) **Recovery and recycling:** This includes various techniques, equipment and facilities used to improve both the efficiency of disposal system and recovery of usable material and energy. Recovery involves the separation of valuable resources from the mixed solid wastes, delivered at transfer stations or processing plants. It also involves size reduction and density separation by air classifier, magnetic device for iron and screens for glass. The selection of any recovery process is a function of economics, i.e., costs of separation versus there covered-material products. Certain recovered materials like glass, plastics, paper, etc., can be recycled as they have economic value. We will discuss the various aspects of recovery and recycling, respectively, in Units 6 and 7.

(vii) **Waste disposal:** Disposal is the ultimate fate of all solid wastes, be they residential wastes, semi-solid wastes from municipal and industrial treatment plants, incinerator residues, composts or other substances that have no further use to the society. Thus, land use planning becomes a primary determinant in the selection, design and operation of landfill operations. A modern sanitary land fill is a method of disposing solid waste without creating a nuisance and hazard to public health. 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. One of the most important functional elements of SWM, therefore, relates to the final use of the reclaimed land.

In Figure1.1 below, we show you a typical SWM system with its functional elements and linkages:

Figure1.1
Typical SWM System: Functional Elements



You must, however, note that all the elements and linkages shown in Figure 1.1 need not necessarily be always present in a SWM system. Being generic in its form, this system is applicable to all regions, irrespective of their relative state of development (Tchobanoglous,etal.,1977).

1.2.2 ESSWM and EST

We must recognize that each functional element discussed in Sub section 1.2.1 is closely inter connected to minimize adverse impact of wastes on the environment and to maximize the ecosystem carrying capacity. To derive optimal benefits from this, we must apply environmentally sound solid waste management (ESSWM). This is an integrated approach for controlling and preserving the resources, both in quantity and quality. To improve environmental quality and achieve sustainable development, it is necessary we use EST–environmentally sound technologies (Matsumoto,etal.,2000). We will describe ESSWM and EST, next.

Environmentally sound solid waste management (ESSWM)

In any waste or resource management system, we must pay attention to the interaction between human activities and the ecosystem. We have to recognize that human activities including consumption of goods/ services, production of wastes, etc., have a serious impact on the carrying capacity of the ecosystem. This in turn affects human health, as the environment deteriorates. The fundamental principles of ESSWM, which take into account economic and social issues along with environmental impact consideration, include the following:

- To ensure sustainable development of the ecosystem and human environment.
- To minimize the impact of human activities on the environment.
- To minimize the impact on the environment and maximize the ecosystem's Carrying capacity.
- To ensure the implementation of ESSWM through environmentally sound technologies.

Environmentally sound technologies (EST)

EST refers to cost effective and energy efficient technologies, which generally

Perform better on the environment, as they do not pollute the ecosystem's vital Components such as air, land or water and consider the reuse, recycling or recovery of wastes. EST can be categorized broadly as follows:

- **Hard EST**: This includes equipment, machines and other infrastructure with their material accessories to handle waste products and monitor/ measure the quality of air, water and soil.

- **Soft EST**: This supports and complements hard technologies and include *nature-based technologies and management tools.* Nature-based technologies include processes and mechanisms nature uses within a specific ecosystem and its carrying capacity, while management tools include system and procedures, policy and regulatory frame works, and environmental performance standards and guidelines.

Note that, as implied above, hard and soft technologies complement one another to achieve the goal.

EST is selected based on the following generic criteria, the indicators of which may vary depending on the regions in which they are implemented:

- **Affordability:** This means low investment, reasonableness, maintenance-free and durability.

- **Validity:** This refers to effectiveness, easy operation and maintenance.

Sustainability: This means low impact, energy saving and cultural acceptability.

Examples of EST for collection and transfer of Waste

Set-out container is one of the major factors that most collection system depends on. This is usually a paper or plastic bag, or a metal or plastic garbage or kraft paper bags in a metal or wooden frame. Set-out containers of rural areas include bags, pots, plastic or paper bags, cane baskets, concrete or brick vats, urns, boxes, clay jars, or any kind of container available.

Non-compact or trucks are more efficient and cost-effective than compact or trucks in small cities and in areas where wastes tend to be very dense and have

Little potential for compaction. The use of lighter, more energy-efficient box-trucks, vans, and dump trucks can be appropriate for sparsely populated areas, where the main constraint on collection efficiency is distance.

Transfer trailers or compacting vehicles can carry larger volumes of MSW than regular collection trucks, which allow them to travel longer distances carrying more waste. This lowers fuel costs, increases labour productivity, and saves on vehicle wear.

1.2.3 Factors affecting SWM system

Many factors influence the decision-making process in the implementation of a SWM system (Phelps,etal.,1995). Some of the factors that need to be considered in developing a SWM system are listed below:

(i) **Quantities and characteristics of wastes:** 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 2.3kg 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 150kg/m^3 to 600kg/m^3. Proportion of paper and packaging materials in the waste largely account for the differences. 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.

(ii) **Climate and seasonal variations:** There are regions in extreme north (>70° N Latitude) and south(>60° S Latitude), where temperatures are very low
For much of the year. In cold climates, drifting snow and frozen ground interfere with land fill operations, and therefore, trenches must be dug in summer and cover material stock piled 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 than

50% in dry season to greater than 65% in wet months. Collection and disposal of wastes in the wet months are often problematic.

High temperatures and humidity cause solid wastes to decompose far more rapidly than they do in colder climates. The 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 rain fall) and low production of leachate from sanitary land fill. High winds and wind blown sand and dust, however, cause special problems at land fill sites. While temperature inversions can cause air borne pollutants to be trapped near ground level, land fill sites can affect ground water by altering the thermal properties of the soil.

(iii) **Physical characteristics of an urban area:** In urban areas (i.e., town sand 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 sèrvice by vehicles difficult and often impossible. Added to this is the problem of urban sprawl in the out skirts (of the cities) where population is growing at an alarming rate. Accessways 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.

(iv) **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 equipments, vehicles, and fuel and labour costs. Typically, 10% to 40% of their venues of municipalities are allocated to solid waste management. In regions where wage rates are low, the aim is to optimize vehicle productivity. The unfavourable 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.

(v) **Cultural constraints:** In some regions, long-standing traditions preclude the intrusion of waste collection on the precincts of house holds, 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 never 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.

(vi) **Management and technical resources:** Solid waste management, to be successful, requires a wide spectrum of work force 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 work force.