The wastes generated in solid state as a result of various human activities and normally discarded as useless or unwanted material are known as *solid waste*. Solid waste consists of highly heterogeneous mass of discarded materials from residential, commercial, industrial, agricultural and mining activities. Depending on the sources, solid wastes can be broadly classified into three types— 1. Municipal Solid Waste (MSW), 2. Bio-medical Solid Waste (BSW) and 3. Industrial Solid Waste (ISW).

(1) MUNICIPAL SOLID WASTE (MSW)

Municipal solid wastes are generated from residential, commercial and institutional activities along with waste from street sweepings. In India, MSW generation varies from 0.2 kg/capita/day to 0.5 kg/capita/day depending on the population of the cities. In metropolitan cities, MSW generation is 0.5 kg/capita/day. The per capita waste generation depends on various factors like increased commercial activities, standard of living etc. The per capita quantitie of MSW in Indian urban areas are given in Table 13.1.

Table 13.1 Per capita quantity of municipal solid wastes in Indian urban areas

Population range (in million) (kg/capita/day)	Average per capita MSW production (kg)
0.1–0.5	0.21
0.5–1.0	0.25
1.0–2.0	0.27
2.0–5.0	0.35
2.0–5.0	0.35
>5.0	0.50

As per studies by Central Pollution Control Board, the quantities of municipal solid waste generation in the major metropolitan cities are given in Table 13.2. This shows that Mumbai produces highest quantity of MSW (300 tonnes/day) among the Indian metro cities.

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Table 13.2 Municipal solid waste generation in major Indian metropolitan cities

City	Municipal solid waste (tonnes/day)	Per capita waste (kg/day)
Ahmedabad	1,683	0.585
Bangalore	2,400	0.484
Chennai	3,124	0.657
Delhi	4,000	0.475
Kolkata	3,692	0.383
Kanpur	1,200	0.640
Lucknow	1,010	0.623
Mumbai	5,355	0.436
Visakhapatnam	300	0.400

Composition of MSW

The average composition of MSW consists of 30 to 40% organic matter, 30 to 40% fine materials, paper (5%), metal (1%), glass (1%) and plastics (1%). The materials like plastic, metals, glass and paper can be recycled. The actual composition of municipal solid waste varies demographically and the composition ranges are:

Paper 3.0–6.43%; metals, 0.33–0.80%; glass, 0.35–0.94%, (on dry weight basis). The calorific value of India's solid waste varies from 800 to 1000 kcal/kg.

Collection and Disposal of MSW

The solid wastes generated in individual household are normally transferred to a community bin. House-to-house collection by municipal agencies is done in many cities. But most of the cities and towns are old and having narrow winding roads which pose problems to the vehicles in reaching the individual houses for waste collection. Hence, house-to-house collection system is not in practice in most parts of India. In our country, community-bin system is most widely used where storage bins, owned and maintained by municipal bodies, are provided at frequent intervals at the intersection or along the roadside. Citizens keep their wastes in these bins. The solid wastes, collected from different community bins, are then transported to the disposal site by a fleet of vehicles by the municipal bodies. The disposal sites are usually a low-lying area on the outskirts of the city.

Sanitary Landfill

Miscellaneous refuse materials are those from household, hotels, stores, markets, restaurants, etc. (*e.g.*, food wastes, vegetables and animal wastes, paper, cardboard, wood, boxes, rubber, leather, plastics, tin cans, crockery glass, metals, etc.) ashes (from fires used for cooking, heating buildings, etc.), dead animals, industries and agricultural fields, etc. In the developed countries, e.g., USA it is a common practice for each household to burn the bulk of waste in a backyard incinerator. Mainly food scraps, bottles and combustible articles are contained in packets for collection by municipality. The percentage of paper, rubber, leather, plastics, metals and glass increases considerably with increasing industrialization in developed countries compared to developing countries because of wide application of these materials in their daily lives.

Most of the solid waste is dumped on land in heaps in uncontrolled manner in developing countries. Some waste is used for land filling in abandoned quarries or mines. The developed countries prefer the second method, *viz.* incineration (see next section). Industrial wastes are treated in treatment plants and valuable materials recycled. In other cases, the volume of the waste is reduced by pulverization (33 per cent) or by incineration.

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For sanitary landfill, the following principles should be followed:

1. Solid wastes should be deposited in a regulated manner, preferably in gravel pit
2. Solid wastes should be spread in thin layers with ground cover of at least 15 cm
3. All factors likely to contribute to water pollution should be eliminated
4. The wastes should not be burnt openly

In the man-made gravel pit, fine-grained soil is useful in containing undesirable gas and water movements outside the landfill area. With increase in urbanization and expansion of cities beyond the periphery, land suitable for landfill becomes more and more scarce. In such cases, planned sanitary landfill, backed by modern solid waste management, can provide the community with better environmental management.

Composting and Municipal Waste Composting Projects

This is the biological process where fresh organic wastes are allowed to be decomposed into humus-like substances. The process is conducted by a complete automatic system which consists of several steps: (1) The crude refuse is dumped into a container or to a belt conveyor. (2) Iron or metallic particles are removed by a magnetic separator. (3) The material is then transferred in a wet condition to a rotatory cylinder, analogous to a rotatory drier. The cylinder rotates slowly on large tyres and the wastes move from one end to the other. They are thoroughly mixed and pulverized by abrasion. Air is introduced at low pressure throughout the length of the cylinder. Here aerobic micro-organisms ensure rapid decomposition of the wastes under aerobic conditions.

In several parts of India, compost plants are in operation *e.g.*, in Ahmedabad, Kolkata, Mumbai, Chennai, Delhi, Pune, and Hyderabad. The minimum plant capacity is 100 tonnes per day. The Government encourages feeding of compost plants by municipal wastes as *raw materials*. Compost has been used by Indian Agricultural Research Institute (IARI) to produce blue-green algae-coated granulated compost.

Vermicomposting

Vermiculture or use of earthworms in biotechnology, where the earthworms feed on and degrade a variety of organic waste, eliminates noxious elements and converts the waste into vermicompost, which is a high-grade, nutrient-rich compost and a very significant biofertilizer and soil conditioner. Vermicompost enhances soil productivity and increases crop yield. Over 3000 species of earthworm have been identified from different parts of the world out of which 385 species have been found in India. The useful species found in India are *Lampito mauritii, Dichogaster bolaui, Drawida willsi I etc.*

Incineration

This is the preferred technique for waste management, particularly in the developed countries. It reduces the waste volume by 90 per cent at 900–1000°C. Incineration offers environment-friendly technique—free from corrosion, emission of offensive odours and also free from bacteria and wet organic matter which gives off foul odours and gases. The waste heat from incineration can be utilized for supplementing electricity generation for domestic heating, etc. The only drawback is that the technique is costly at present requiring expensive equipment.

Two types of incinerators are used for unsorted wastes. The batch type plant is manually stoked and has a relatively small-rated capacity. The operation is intermittent and lacks uniform

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burning temperature. This leads to incomplete combustion and yields an unstable residue. These units are not suitable for large cities. The continuous feed plant has larger storage bins, automatic feed hoppers and a variety of moving gates and ash-removal systems. The unit maintains a uniform combustion range, can be fitted with pollution control devices and yields stable residue.

Biomedical Waste (BMW)

Biomedical Wastes (BMW) are generated by hospitals, nursing homes, clinics, dispensaries, veterinary houses, pathological laboratories and blood banks. BMW harms people and environment as they are highly infectious. Considering the seriousness of this solid waste problem, Government of India, has passed Biomedical Waste (Management and Handling) Act in 1998. The act emphasizes on the safe-disposal methods to be strictly followed by the hospitals and other health-care units, producing BMW.

About 80% of BMW are benign and comparable to domestic waste. The remaining 20% is hazardous—it may be infectious and toxic. BMW is reservoir of pathogenic micro-organisms, which can cause contamination and give rise to infection. Improper disposal of biomedical waste may also cause pollution of air, water and soil. Run off from untreated or improperly treated BMW dumped on the land can contaminate surface and ground water supplies—exposing the entire population to the risk of diseases and parasites.

As a result of the reusage of unsterilized syringes, 8 to 16 million Hepatitis B, 2.3 to 4.7 million Hepatitis C and 80,000 to 1,60,000 HIV infections are estimated to occur annually. These could be avoided if syringes are disposed properly and safely.

Incineration is commonly employed for the treatment of BMW. The solid waste is burnt at a high temperature (900°C) in presence of oxygen. If the incineration works at a lower temperature, the incineration is incomplete, the pathogens can survive. Due to insufficient temperature in the process chamber, it may also produce toxic compounds like furans and dioxins. Therefore, temperature is very important for the process.

Industrial Solid Waste (ISW)

Different types of industries produce large quantities of solid wastes. These wastes are normally managed by the concerned industries. For example, coal-based power plants produce large quantities of coal flyash. In India, about 100 million tonnes of coal flyash are produced annually. Coal flyash is considered as a hazardous pollutant as it causes respiratory diseases (Sec. 9.1.6).

Land and Ocean Disposal

Radioactive wastes from nuclear power stations are generally fused in glass containers and lowered to the ocean floor. In USA, such wastes are sealed in metal drums and buried underground at great depths. But they may leak or be damaged by earthquake and release the wastes into ground water.

Hazardous wastes dumped into soil/ditch have chances of leaking to the ground. A typical case history is that of the *Love Canal* in *Niagara Falls*, New York, USA. In 1930–53, the canal ditch was the dumpsite for hazardous chemical wastes and municipal wastes. In 1953, the ditch was filled up; it was covered with clay and was sold to the City Board of Education, which built an elementary school over there. Some houses were also built. Soon the residents of these houses (300 families) and the school authorities complained of foul odour and illnesses. In 1978, it was found that some 25 toxic organic compounds known *as carcinogens*, leaked into the basements in the area and dispersed

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into air. As a result of these findings, the State of New York declared emergency in the area and transferred all the families and the school from the site (Fig. 13.2).

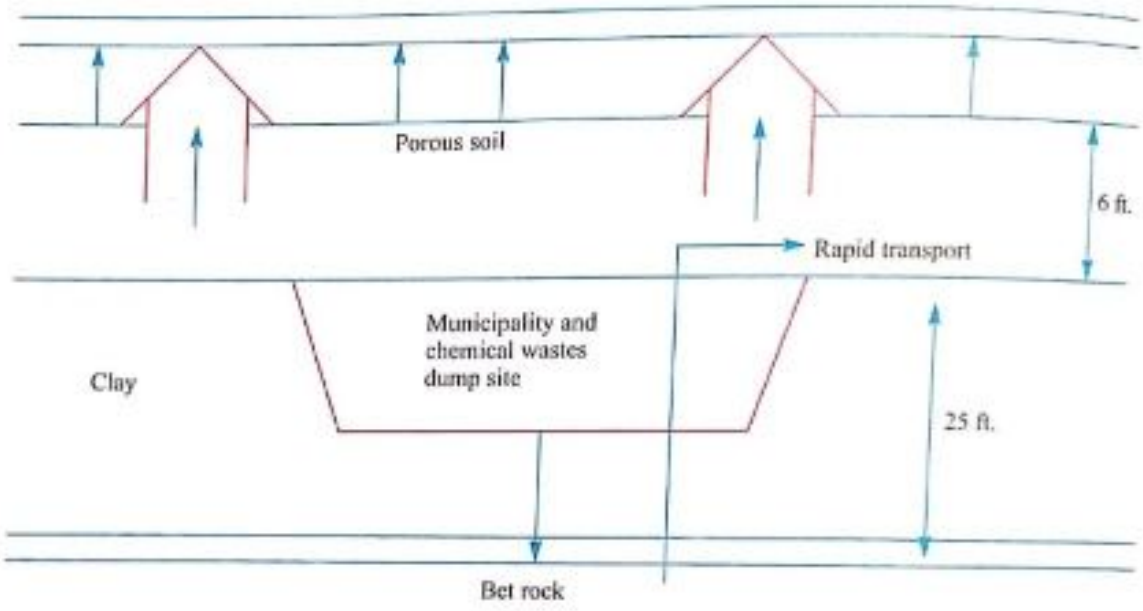

Fig. 13.2 Transport of toxic normal chemicals from Love Canal dumpsite into adjoining areas

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