Waste Management & Environmental Impact Assessment

Solid & Hazardous Waste Management

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Solid waste is defined as discarded solid fraction produced from domestic, commercial, trade, industrial, agricultural, institutional, mining activities and public services. The waste is a term that means useless, unwanted or discarded material.

Solid waste includes domestic waste, municipal waste, commercial waste, garbage (animal and vegetable waste), rubbish (inorganic excluding ashes), ashes and industrial waste, sludge from wastewater treatment plants etc. Actually, mainly the population living in the urban area produces much more solid waste than the rural one.

To handle the problem of solid waste in an efficient manner is known as the solid waste management. This management is a part of public health and sanitation and as per the Indian constitution it is the responsibility of states. In the states various local bodies like municipalities (in towns) or the municipal corporations (in cities) or the development authorities (in big cities) are to deal with solid waste management. Generally, the water supply and electricity are on the top priority of the state government and because of various reasons even they are in short supply. Then comes the collection conveyance treatment and disposal of wastewater. Unfortunately, the solid waste comes on the last priority.

It is estimated that the total solid waste generated by 300 million people in urban India is 38 million tons per year. Or in other words it is estimated that 1,00,000 ton of municipal solid waste is generated in India daily. Depending upon the status of the city the per capita generation of solid waste is from 0.2 to 0.6 kg per day. Higher is the status more amount of the waste is produced. In so called advanced countries this figure is much more, but there they observe strict rules and regulations. Even the dogs are not allowed to defecate on the roads where as in India it is a common practice for the human beings living in slums without a toilet.

DRAWBACKS IN PRESENT SWM SERVICES

No Storage of Waste at Source

There is no practice of storing the waste at source in a scientifically segregated way. Citizens have not been educated to keep domestic, trade, and institutional bins for storage of waste at source and stop littering on the streets.

No System of Primary Collection from the Doorstep

There is no public system of primary collection from the source of waste generation. The waste discharged here and there is later collected by municipal sanitation workers through street sweeping, drain cleaning, etc. Street sweeping has, thus become the principal method of primary collection.

Irregular Street Sweeping

Even street sweeping is not carried out on a day-to-day basis in most cities and towns in India. Generally commercial roads and important streets are prioritized and rest of the streets are swept occasionally or not swept at all. Generally, no sweeping is done on Sundays and public holidays and a back log is created on the next working day.

The tools used for street sweeping are generally inefficient and out-dated. For instance, the broom with a short handle is still in use forcing sweepers to bend for hours resulting in fatigue and loss of productivity. Traditional handcarts/tricycles are used for collection, which do not synchronize with the secondary storage systems. Waste is deposited on the ground necessitating multiple handling.

There are no uniform yardsticks adopted for street sweeping. Though, some states/cities have prescribed work-norms, these are not very scientific. Most of the cities allocate work to sanitation workers on ad hoc basis. The work distribution ranges between 200 metres to 1000 metres of street sweeping each day. Some sanitation workers are found under worked while some over burdened.

Waste Storage Depots

As waste is collected through traditional handcarts/tricycles that can carry only a small quantity of waste at a time, there is a practice to set up depots for temporary storage of waste to facilitate transportation through motorized vehicles. Generally, open sites or round cement concrete bins, masonry bins or concrete structures are used for temporary bulk storage, which necessitates multiple handling of waste. Waste often spills over which is both unsightly as well as unhygienic.

Transportation of Waste

Transportation of waste from the waste storage depots to the disposal site is done through a variety of vehicles such as bullock carts, three-wheelers, tractors, and trucks. A few cities use modern hydraulic vehicles as well. Most of the transport vehicles are old and open. They are usually loaded manually. The fleet is generally inadequate and utilization inoptimal. Inefficient workshop facilities do not do much to support this old and rumbling squad of squalid vehicles. The traditional transportation system does not synchronize with the system of primary collection and secondary waste storage facilities and multiple manual handling of waste results.

Processing of Waste

Generally no processing of municipal solid waste is done in the country. Only a few cities have been practising decentralized or centralized composting on a limited scale using aerobic or anaerobic systems of composting. In some towns un-segregated waste is put into the pits and allowed to decay for more than six months and the semi-decomposed material is sold out as compost. In some large cities aerobic compost plants of 100 MT to 700 MT capacities are set up but they are functioning much below installed capacity. A few towns are practising vermi-composting on a limited scale.

Disposal of Waste

Disposal of waste is the most neglected area of SWM services and the current practices are grossly unscientific. Almost all municipal authorities deposit solid waste at a dump-yard situated within or outside the city haphazardly and do not bother to spread and cover the waste with inert material. These sites emanate foul smell and become breeding grounds for flies, rodent, and pests. Liquid seeping through the rotting organic waste called leachate pollutes underground water and poses a serious threat to health and environment.

Landfill sites also release landfill gas with 50 to 60 per cent methane by volume. Methane is 21 times more potent than carbon dioxide aggravating problems related to global warming. It is estimated by TERI that in 1997 India released about 7 million tonnes of methane into the atmosphere. This could increase to 39 million tonnes by 2047 if no efforts are made to reduce the emission through composting, recycling, etc.

CLASSIFICATION OF SOLID WASTE

The solid waste can be classified as per the Manual on Municipal Solid Waste Management, Government of India publication as follows:

- **Domestic/Residential waste:** This type of waste is originated from single or multifamily household units. These wastes are generated from the household activities such as cooking (ashes) cleaning (dust) repairs (residues), hobbies (unusable), redecoration, empty containers, used packets, old clothes, books, papers, broken glass, plastic items, broken and useless furniture.
- **Municipal waste:** Municipal waste includes waste resulting from municipal activities and services such as street sweepings, dead animals, market waste and abandoned vehicles. Generally, this term 'Municipal Waste' is used in a wider sense to incorporate domestic wastes, institutional wastes and commercial wastes.
- **Commercial waste:** This category includes solid wastes that originate in offices, wholesale and retail markets, restaurants, hotels, warehouses (godowns) and other commercial establishments.
- **Institutional waste:** These are those wastes generated from institutions such as schools, colleges, universities, hospitals and research institutes. Some of these wastes (like hospitals) may be hazardous (more bad, offensive, strong, disease producing) waste.
- **Garbage:** Garbage is the term applied to animal and vegetable wastes generated from the handling, storage, sale, preparation, cooking and serving of food. Such wastes contain putrescible (easily and quickly biodegraded with bad smell) organic matter. This attracts rats, flies, mosquito and other vermin, that is why it requires immediate attention.
- **Rubbish:** It is a general term applied to solid wastes originating in households, commercial establishments and institutions excluding garbage and ashes.

- **Ashes**: These are the residues from the burning of wood, coal, charcoal, coke and other combustible matter for cooking and heating in houses institutions and small industries. When produced in large quantities in thermal power plants (fly ash) they are known as industrial wastes. Ashes consists of fine powdery residue, cinders and clinkers often mixed with small pieces of metal and glass.
- **Bulky waste:** Bulky wastes are large household wastes that cannot be accommodated in the normal storage containers of the household and thus they require special collection. Actually in India there is hardly any waste collected in this category as it is sold to the kabaries.
- **Street sweepings:** The waste collected from streets, walkways, parks etc. is known as street sweepings. In developing countries like our country manual street sweeping is done and it makes the largest portion of the municipal solid waste as we are in a habit of throwing everything on the streets. It includes mainly dust, dirt, plastic bags (thin), dry leaves, useless papers, cardboard, rags, tyres, vegetable matter etc. In our country most of the usable portion of the waste like rags, paper, thick plastic bags, plastic utensils, any form of metal is collected by the rag pickers. The organic matter including the paper and even plastic sheets is consumed by cows and other stray animals. Only in big cities or the developed countries they form the part of waste. That is why the calorific value of Indian solid waste is far less in comparison to the other countries.
- **Dead animals:** This term includes the dead animals that die naturally or by accidents on roads. It does not include the animal parts from slaughter houses which are regarded as industrial waste. There are two types of dead animals, large and small. The smaller ones like dogs cats rabbits, rats etc., are either consumed by the other animals or can be easily lifted and disposed. The large ones like cows, horses, camels etc. require special and immediate attention as traffic is affected and they emit foul smell.
- **Construction and demolition waste:** These are the wastes generated by the residue of the construction, refurnishment, repair and demolition of houses, commercial buildings and other structures. Generally, the demolition waste is used by the contractors in filling low lying areas and the plinth filling of new houses and nothing is left on the sites. Even then some small quantity of sand, stone or concrete may be left.
- **Industrial wastes:** The discarded solid material of manufacturing processes and industrial operations comes in this category. There is a vast range of substances that are unique for each industry so they are considered separately from municipal wastes.
- **Hazardous waste:** Hazardous waste is defined as wastes of industrial, intuitional or consumer origin that, because of their physical, chemical or biological characteristics are potentially dangerous to human beings and the environment. In some cases the active agents may be liquid or gaseous, they are classified as solid waste because they

are confined in solid containers. Typical examples are solvents, paints, and pesticides whose spent (empty) containers are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous waste can explode in the incinerators (controlled large kilns) and cause fires at land fill sites. Others such as pathological (disease producing) wastes from hospitals and radioactive waste, require special handling at all times. Proper management practice should ensure that hazardous wastes are collected, stored, transported and disposed off separately, preferably after treatment to make them harmless.

- **Sewage waste:** The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and produced from the treatment of organic sludge from both the raw and treated sewage. The inorganic fraction of raw sewage such as grit is separated at the preliminary stage of treatment, but because it entrains putrescible organic matter that may contain disease producing bacteria (pathogens), must be buried or disposed off quickly.

IMPORTANCE OF CLASSIFICATION

Any one method of classification of solid waste is not sufficient because of the heterogeneous nature of solid wastes. Actually, the real knowledge of solid waste characteristics is very much essential to conceive the treatment and disposal. Sometimes the waste is disposed with extraction of energy out of it. For example electricity is generated or biogas is produced. In both these cases the waste must have a minimum value of calorific value or the organic matter respectively. It has happened in many cases like that of plant in Timarpur that did not work due to the different characteristics of the waste than those for which the plant was designed. Actually, the plant are generally imported and are based on higher calorific value solid waste whereas the average Indian solid waste has larger fraction of inorganic waste (dust, dirt, silt etc.), with lesser organic matter (vegetable, paper and other combustible matter), and hence has a very low calorific value (Kcal/Kg). So the knowledge of the characteristics and composition of the solid waste is utmost important. The classification of solid wastes as per the manual on SWM is given in a tabular form as follows:

Classification of Solid Waste in Tabular Form

Type of solid waste	Description	Sources
Food Waste (garbage)	Waste from preparation, cooking and serving of food market refuse. waste from handling, storage and sale of meat and vegetables	Households, institutions and commercial centers such as hotels. stores, restaurants, markets etc.
Rubbish	Combustible (primarily organic) paper, cardboards, cartons, wood boxes, plastics, rags, clothes, beddings, lather rubber grass, leaves yard trimmings. Non combustible (primarily inorganic) metals. tin	As above

	cans, metal foils, dirt, stones bricks, ceramics, crockery, glass bottles, other mineral refuse	
Ashes and residues	Residues from fires used for cooking and for heating buildings, cinders, clinkers, thermal power plants.	As above
Bulky waste	Large auto parts, tyres stoves, refrigerators, other large appliances. furniture, large crates, branches of trees etc.	As above
Street waste	Street sweepings, dirt, leaves, catch basin dirt animal droppings content of litter receptacles dead animals	Streets, sidewalks, alleys, vacant plots
Dead animals	Small animals: cats, dogs, poultry etc. Large animals: horses, cows etc.	Same as above
Construction and demolition waste	Plumber, roofing and sheathing scrap. rubble broken concrete plaster, conduit pipes, insulating wires etc.	Construction and demolition sites. remodeling, repairing sites
Industrial waste & sludges	Solid wastes resulting from industry processes and manufacturing operations, such as food processing wastes, boiler house cinders, wood plastic and metal scraps and shavings etc., sludge of sewage treatment plants and septic tanks, coarse screenings grit etc.	Factories, power plants, treatment plants etc.
Hazardous waste	Hazardous wastes: pathological waste, explosives, radioactive material toxic waste etc.	Households, hospitals, institutions. stores, industry etc.
Horticulture wastes	Tree trimmings, leaves, waste from parks and gardens etc.	Parks gardens roadside trees etc.

Industrial Solid Waste

The major generators of industrial solid wastes are the thermal power plants producing coal ash, the integrated Iron and Steel mills producing blast furnace slag and steel melting slag, non-ferrous industries like aluminium, zinc and copper producing red mud and tailings, sugar industries generating press mud, pulp and paper industries producing lime and fertilizer and allied industries producing gypsum.

Name	Source
Steel and Blast	Conversion of pig iron to

furnace	steel and manufacture of Iron
Brine mud	Caustic soda industry
Copper slag	By product from smelting of copper
Fly ash	Coal based thermal power plants
Kiln dust	Cement plants
Lime sludge	Sugar, paper, fertilizer tan-neries. soda ash. calcium carbide industries
Mica scraper waste	Mica mining areas
Phosphog\psum	Phosphoric acid plant. Ammonium phosphate
Red mud/ Bauxite	Mining and extraction of alumina from Bauxite
Coal washery dust	Coal mines
Iron tailing	Iron Ore
Lune stone wastes	Lune stone quarry

COMPOSITION AND CHARACTERISTICS OF SOLID WASTE

The composition and characteristics of municipal solid waste is not same throughout the world and even in the same country it changes from place to place and time to time. As explained earlier it depends upon the living standard, social customs, location of a place, climate and weather conditions etc. Higher is the standard of living, more is the waste produced. Alongwlth the total quantity of waste produced, the composition of waste is also different for different income groups.

The waste from poor communities contain more dust, dirt, inert material and the totally useless food remaining (rotten items). It has a lesser amount of paper waste as it is used in lower income groups again and again and ultimately for cooking and heating. The density of waste in poor community is more because of the above reasons. The moisture content of the waste of poor countries is high which renders it difficult for incineration (controlled burning at high temperatures).

Characteristics of Municipal Solid Waste in Indian Cities

The character of municipal solid waste is variable because of many reasons. It depends mainly upon the monetary level, but also the size of the city, its geographical conditions and the lifestyle. Simple conclusions cannot be drawn in each case and thus the solution to the problem of solid waste management should be site specific.

The content of paper waste normally increases for increasing population but the rubber etc., reduces as there are more chances of rubber recycling industries in bigger cities. Similarly, as the rag pickers are more active in big cities they pick up the light matter with more calorific value and thus the inert material is higher. Mostly the thin plastic bags form a major portion of the waste because in recycling the plastic has to be made firstly dirt free, means washing is a must. The thin sheets give lesser plastic material in comparison to the effort made in washing. So the rag pickers do not pick the thin plastic bags and that is why governments ban the thin plastic bags. The proportion of fine earth reduces with increase in population as the condition of roads improves in bigger cities.

The chemical characteristics indicate that as the inert matter increases with increase in population its calorific value decreases.

So there are many interrelated factors which make it difficult to predict the composition and characteristics of the solid waste of any city, it is better to take sufficient sample and analyze them for a long time before conceiving any treatment/disposal or energy extraction project.

PHYSICAL CHARACTERISTICS

Density

The knowledge of density is important for the design of all elements of the solid waste management systems like storage, transport and disposal. For example for a known volume of the solid waste its density gives us the idea about the requirement of the truck in tonnage. Every truck or similar vehicle has a permitted load capacity say 12 ton or so which it can carry according to law. In developed countries as their waste is light so compaction reduces the cartage charges substantially. The density varies significantly from source to the disposal site because of handling, change in moisture content, densification due to vibration of movement, disturbance by animals and birds (scavengers) etc.

Moisture Content

Moisture content of the solid waste is expressed as the weight of moisture per unit weight of wet material. Moisture content varies generally from 20 to 45% depending upon the climatic conditions and level of city (income group) etc. The increase of moisture content increases the weight and thus the cost of transportation and thus the storage section should take care of it.

Calorific Value

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kilo calorie per kilogram. The calorific value is determined in the laboratory by Bomb Calorimeter. If the energy is to be recovered or the waste is to be disposed, by incineration (controlled burning) the following points should be considered:

- Organic matter gives energy only in dry condition.
- The moisture content as free water reduces the dry organic matter per kilgram and hence requires a significant amount of energy for evaporation.

- The ash content of the waste reduces the proportion of dry organic material per kilogram of waste. It also retains some heat.

So for economical recovery of energy the waste should contain minimum amount of moisture, ash and other inorganic matter.

Specific Weight (Density)

- Specific weight is defined as the weight of a material per unit volume (e.g. kg/m3, lb/ft3)
- Usually it refers to uncompacted waste.
- It varies with geographic location, season of the year, and length of time in storage.

Field capacity

- The total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity
- Field capacity is important in determining the formation of leachate in landfills

Permeability of Compacted Waste

The permeability (hydraulic conductivity) of compacted solid waste is an important physical property because it governs the movement of liquids & gases in a landfill. Permeability depends on; (i) pore size distribution (ii) surface area (iii) porosity

CHEMICAL CHARACTERISTICS

The chemical characteristics of solid waste are determined for assessing the treatment process. Mainly three chemical characteristics are determined, chemical, bio-chemical and toxicological.

- Chemical quantities of solid waste in Indian urban centres are pH, nitrogen, phosphorus, and potassium (N-P-K), total carbon, carbon/nitrogen ratio, calorific value.
- Bio-chemical characteristics include carbohydrate, proteins, natural fibre, and biodegradable factor.
- Toxic characteristics include heavy metals, pesticides, insecticides etc.

Consideration of lipids (fats, oils and grease) should also be done as they are of a very high calorific value (about 38000 Kcal/kg). These days synthetic organic materials like plastic have become a significant component of solid waste accounting for 5-7%. In India the plastic is non-biodegradable and thus poses a great problem. It chokes the drains and if burnt it produces poisonous gases. The thin plastic sheets and bags are not recycled as the cost of making it dirt & oil free makes the process uneconomical.

BIOLOGICAL PROPERTIES OF MSW

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
- 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

WASTE MANAGEMENT APPROACH

The solid waste management has a two fold approach. First is the minimization of waste at the source and other is the control on environmental pollution during its storage, conveyance and disposal.

Prevention is always better than cure. If the production of waste can be reduced at the source level it shall reduce the cost of conveyance treatment, disposal and shall save the environment. The waste minimization techniques are grouped in four major categories for hazardous as well as non hazardous waste, as follows:

Inventory Management and Improved Operation

- Inventorisation (making stock registers) and tracing of all raw materials.
- Purchasing of lesser toxic and more non-toxic production material.
- Implementation of employee's training and management feedback.
- Improving material receiving, storage and handling practices.

Modification of Equipment

- Installation of equipment that produce minimum waste.
- Modification of equipment to enhance recovery or recycling options.
- Redesigning of equipment or production lines to produce less waste.
- Improving operating efficiency of equipment.
- Observing strict preventive maintenance programme.

Modifications in Production Process

- Selection of non-hazardous raw material.
- Segregation of waste for recovery.
- Identification and elimination of leakages.
- Optimization of reactions and raw material use.

Recycling and Reuse

- Installation of closed-loop systems

- Recycling off site for another use
- Exchange of wastes

By adopting the above waste minimization techniques the waste is minimized at the source so that its handling and transportation charges are reduced and lesser efforts are to be done in disposal.

Utilization of Waste

After minimizing the waste at source one can think about the utilization of waste of one operation in the other operations as shown in the table below.

Waste	Areas of application
Flyash (fine coal ash generated by combustion of coal in power plants etc. One portion is the bottom ash another is the one collected in the separators from the flue gases.)	• As raw material in manufacturing of cement • As binding material with cement • As filler in mines • As plasticizer • As an aggregate in cellular concrete bricks and blocks • For stabilization of soil
Blast furnace slag	• Manufacturing slag cement, super sulphated cement • Making expansive cement coloured cement • and high early-strength cement • In refractory and ceramic industry • As a structural fill • As aggregate in concrete
Pulp and Paper	Lignin

SOLID WASTE MANAGEMENT

The solid waste management has the following components:

- Identification of waste and its minimization at the source
- Collection, segregation and storage at the site of collection
- Transportation
- Treatment
- Energy recovery

- Disposal

Identification of Waste and its Minimization at the Source

By the above described classification methods one can identify the waste easily. Identification helps in further processes of transportation, treatment and disposal, for example the hazardous waste is to be tackled in a different manner than the ordinary MSW.

The minimization of the waste production is the best strategy. For this, first of all the process should be such that there is a least production of waste.

Example: production of flyash as the waste in the thermal power plants. A huge quantity of flyash is produced where coal is burnt for making electricity. This flyash requires a large valuable land for disposal. As this flyash can be used for making of flyash bricks, making of cement and can be used with cement as binder etc; if sold or supplied free of cost from the site itself; shall reduce the burden of disposal.

Collection, Segregation and Storage at the Site of Collection

The main problem of solid waste management is the collection of solid waste. The household waste consists of all types of general waste. At present there is no scientific, clean, hygienic, efficient practice of waste collection in most of the cities of India including the metro cities. There is no practically imposed penalty on throwing of waste on the streets. Even defecating on open plots, sides of roads, railway lines; spitting on roads is a very common practice and nobody bothers about it. The ugly unhygienic scenes, and the bad smell (due to anaerobic digestion of organic matter) worsen the situation.

The best way would have been the *segregation* of waste at the generation point. Segregation means collecting it in different bins, or plastic bags. The domestic waste can be broadly separated as reusable (paper, plastic, metal etc.), and non reusable. The non reusable may have organic matter like kitchen waste or inorganic matter like dust, dirt etc. The organic matter is liable to decomposition (putrescible) and thus requires immediate attention. Fortunately in India the usable matter is rarely discarded as solid waste except which cannot be sold to kabaries. So even if only two containers or bags are used for separating organic and inorganic waste the problem is solved. This separated waste should be regularly collected by the worker directly from the houses at some well defined time. Then it should be transported in (covered vehicles)to some waste collection depots for utilization/transportation to different sites. The organic waste can be used for the production of biogas or for the extraction of energy, incineration (controlled burning or making organic compost, and vermi-composting. The storage in the intermediate collection sites should again be covered and out of the reach of the stray animals. Here it is proposed to make payment to the person collecting waste on the basis of the weight/volume of the waste collected by him/her and not on the daily basis. Here lies the actual problem. Because of the structure of the local municipal corporations and many other pressures this is generally not feasible. This is possible only if this work is given on contract basis and the work is done in a scientific professional way with the people's participation (segregation and proper handing over of the waste).

Transportation of Solid Waste

As stated earlier the waste is transported from the storage depots to the disposal sites in tractor trollies or ill designed open trucks. Though it has been instructed by the Hon'ble court that the transportation must be done in closed containers only. The industrial waste must be transported separately and must be disposed in a safe way after suitable treatment. Any type of the hazardous waste should be labelled and coded so that in case of an accident the emergency services know how to handle a spillage. Actually the work of transportation of solid waste must be done through the technically competent and well reputed contractors under the strict supervision of the experienced and honest municipal authorities and watchful citizens.

Treatment of Solid Waste

The waste has to be treated before disposal for the protection of environment. In the treatment the biodegradable waste can be processed by composting, vermi-composting, anaerobic digestion or any other appropriate biological processing for stabilization of waste. Actually every organic matter has a tendency to be converted into inorganic matter as the later is a stabilized form. If this conversion takes place in absence of oxygen (anaerobic digestion) which is a general case in solid waste processing, foul gases are evolved. During the anaerobic decomposition dirty, offensive dark coloured fluid is also generated that is known as the leachate.

Generally the solid waste contains both municipal and industrial waste. Small scale industries also generate huge quantity of solid waste and they are generally not in a position to treat their waste individually. It is therefore advisable that in a group of small scale industries the different wastes are characterized, identified, quantified and stored for treatment through a combination of recycling, recovery and reuse of resources such as, raw material, bio gas, steam and manure. The combined effluent treatment plants are to be operated by the local bodies where the cost of construction operation and maintenance is to be shared by the industry in proportion to the quality and quantity of their waste. However the assessment of the quality and quantity of waste is very difficult and requires appropriate testing facilities.

In any case the solid waste should be reduced in quantity at the source, segregated, then carefully transported and the economically treated before the final disposal.

Energy Recovery and Disposal

The most common methods of energy recovery and disposal for non hazardous solid waste are incineration, composting and landfill. The final disposal of waste should be done in such a way that it remains a waste in actual sense, i.e. nothing can be recovered out of it and it could not be used any where. So before putting it on land for land-filling if it has a substantial portion of biodegradable fraction then compost (organic manure) should be made out of it. This shall reduce the final volume of the waste to be disposed on land and shall give us money in terms of the manure. The organic manure is environment friendly and also provides

us micronutrients that increase the fertility of the soil. If this work is done more effectively by some special worms this is known as vermi-composting.

COMPOSTING

The organic matter (consisting of carbon, hydrogen, nitrogen, oxygen, and sulfur) has a tendency of being converted into inorganic matter as the later is a stable form. The food, excreta and other organic waste gets decomposed (changed into inorganic form) and produce gases like biogas (mainly methane) and solids of decomposition like sulphates, nitrates, phosphates etc. These solid (nutrient) are extracted by the roots of plants and trees in dissolved form and they again produce the organic matter in the form of their products. Those products come in the food chain and again the organic waste is produced. This way the different natural cycles keep on proceeding.

Composting is an organized method of producing compost manure (decomposed organic matter) through this natural phenomenon. Compost is more useful as it contains the nutrients like N, P, K as well as the micronutrients. Micronutrients like iron are very much useful for good health and immunity. As the organic matter can be decomposed in two ways i.e. in the presence of oxygen or in the absence of oxygen, composting can be done aerobically or anaerobically.

During aerobic composting aerobic micro-organisms oxidize the organic compounds to carbon dioxide, nitrite and nitrates. The reaction is exothermic and the temperature rises. The nitrates, sulphates etc. are used by the plants and carbon is synthesized in the photosynthesis by the plants.

In the anaerobic process the anaerobic bacteria, while metabolizing the nutrients, break down the organic compounds through a process of reduction. The gases evolved are mainly CH_4 and CO_2 (bio-gas). If collected properly as in a biogas plant the gas can be used for heating or even for driving engines.

The composting can be done to the collected organic waste at some site or at the individual house hold.

INCINERATION

Incineration *means* burning of solid waste in controlled conditions. The most usual practice of disposal of solid waste is burning in open fields. This slow burning at low temperature produces many hazardous gases. Generally the waste is collected in the streets or roads and the heap of this waste is left there itself for drying or collection of more waste on it. Then this waste is either transported to some distant site or burnt there itself. This waste contains inorganic matter also and because of this burning in heaps there is no control of supply of oxygen or rather there is no oxygen supply except that present in the voids. This incomplete combustion at a low temperature produces hazardous gases and these gases pollute the environment very close to us. Particularly the gases produced by the burning of plastic, rubber and other such materials produce very much harmful gases.

Incinerator. Incinerator means any enclosed device using controlled flame combustion. Incineration uses heat to convert complex toxic organic compounds into mostly carbon dioxide and water. At temperatures ranging from 400 to 1600°C complex organic molecules break down into basic atoms. The incineration is a good method of disposal and recovery of energy (in the form of heat produced by burning) only if it works properly. The combustion temperatures of conventional incinerators are about 760° C in the furnace and more than 870° C in the secondary combustion chamber. These high temperature are required to avoid odour from incomplete combustion but are not sufficient to burn or even melt the glass. Some modern incinerators use supplementary fuel to produce high temperatures upto 1650° C to convert even metal and glass to ashes. These incinerators reduce waste volume significantly i.e. upto 97%.

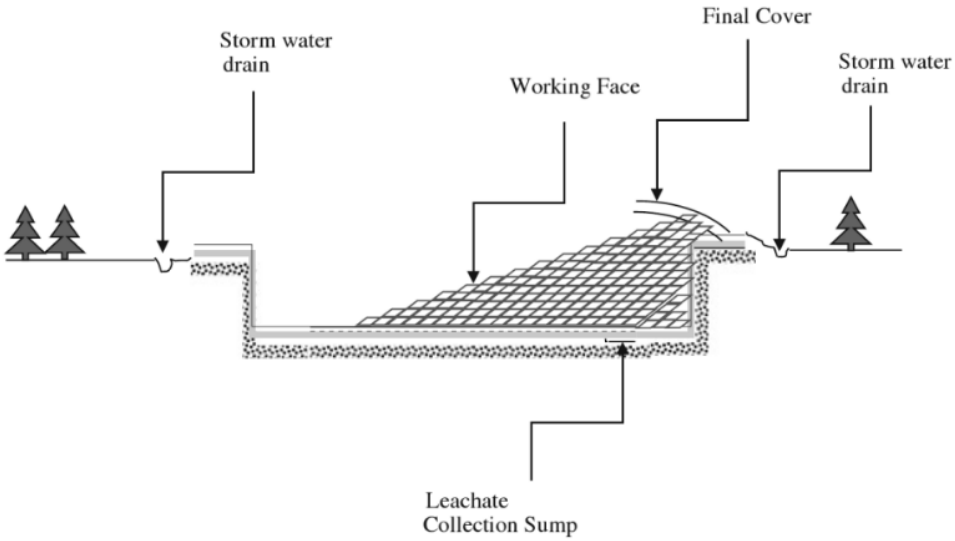
Actually, the incineration is best way of disposing hazardous waste, like hospital and other wastes. The incineration is definitely better than open burning but as stated earlier if it is not properly working, with all controls, then it can prove to be more dangerous, as it gasifies the pollutants and sends them to the atmosphere.

In general incinerators comprise of a storage pit, fuel tanks, a furnace, a heat recovery boiler, effluent gas purification unit, an induced draft fan and a stack (chimney).

An incinerator capable of generating 3.75 MW power from 300 TPD MSW was installed at Timarpur, Delhi in the year 1987. It could not operate successfully due to low net calorific value of MSW. The plant is lying idle and the investment is wasted.

LANDFILL (SANITARY LANDFILL OR SECURED LANDFILL)

The most common and easy way of disposal of solid waste is dumping it on land. The term **sanitary landfill** is used for a landfill with the provision of liner (protective layer) and leachate collection system to prevent ground water contamination. A landfill diagram is shown below.



The inorganic waste like construction and demolition waste can be easily used for filling of low lying areas or plinth filling of buildings or the earthwork of roads. When the combined waste (inorganic and organic) is disposed on the land then the decomposition of the organic matter takes place in due course of time. This decomposition produces gases (like methane) and dark coloured dirty offensive water known as *leachate*. If the ground on which the waste is disposed is pervious then this leachate percolates and mixes with the ground water and badly pollutes it. If the waste is hazardous means that contains harmful chemicals and heavy metals, or pathogens then the situation becomes more aggravated. The mixing of these pollutant through leachate makes the water polluted and contaminated.

Secondly in open landfills the rain water increases the volume of leachate and mixes it with the ground or surface water source more easily. So the landfill should be so designed that it contains an impermeable barrier to stop the mixing of leachate with the water. It should have a diversion for the rain water and proper arrangement of the collection treatment and disposal of leachate. Such type of landfill is known as the sanitary landfill and are the most desirable ones. They may appear costly, but for long lifetime of such works and comparing the end results the cost/ton of waste disposed might be less than any other method of disposal.

An engineered landfill or sanitary landfill facility is an integrated waste management disposal system. Disposal in an engineered waste landfill facility is the final stage in the waste management process, providing long-term confinement of waste materials. An appropriate treatment may be needed to process the waste for final disposal. Some of the processing may include minimizing or eliminating hazardous properties, stabilizing the waste, and/or reducing its volume.

Sanitary landfill facilities are generally located in areas where the potential for degradation of the quality of air, land, and water is minimal. Similarly, a sanitary landfill should be located away from an airport to avoid air accidents between birds and aeroplanes. The location should preferably be outside 100-year flood plain and should not be located in the close proximity of wild life sanctuaries, monuments and other important places which is ecologically important. Location of sanitary land fill should also consider seismic sensitivity of the area to avoid environmental damage during earthquake.

A typical landfill will undergo the following activities during its life time:

- planning,
- site selection,
- site preparation,
- landfill bed construction,
- leachate and gas collection system incorporation,
- land filling,
- monitoring,
- closure of landfill, and

- post closure monitoring.

Advantages of sanitary landfills

- As compared to an ordinary dump, sanitary fill has the advantage of minimizing odor and fire nuisances and of eliminating such health hazards as insect and rodent breeding.
- Over such other disposal methods as incineration, reduction, and hog feeding, it has the advantages of cheapness and simplicity, since no separation of refuse is required.
- The only manpower requirement at many landfills is a machine operator.
- Landfill operations are usually elastic enough to care for usual quantities of refuse caused by expanding populations.
- Properly operated fills can be located in such a way that collection trucks have convenient access.
- Finally, the expended filled land can often be reclaimed for profitable resale.

Disadvantages

- The main disadvantage is that unless careful and continuous supervision is given, the fill may deteriorate into an ordinary dump. A sanitary fill of any size should preferably be under the supervision of a sanitary engineer.
- Property devoted to landfilling is no longer available as productive farmland or as a taxable property.
- The most serious problem by far is groundwater contamination. As water seeps through any material, various chemicals in the material may dissolve in water and get carried along in a process called leaching. The water with various pollutants in it is called leachate. As water seep through solid wastes, a harmful leachate is generated.
- Solid wastes is about two-thirds organic material that is why it is exposed to decay. However, buried wastes do not have access to oxygen. Therefore their decomposition is anaerobic, and a major by-product of the process is biogas, which is a mixture of carbon dioxide and methane, a highly combustible substance. Produced deep in a landfill, biogas may seep horizontally through the soil and rock, enter basements, and even cause explosions if it accumulates and is ignited. Also gases seeping to the surface kill vegetation by poisoning the roots.
- Incomplete Decomposition The commonly used plastics in solid wastes are resistant to natural decomposition because of their molecular structure.

Types of Sanitary Landfill

Mechanized Sanitary Landfill

The mechanized sanitary landfill is designed for large cities and populations that produce more than 40 tons of waste daily. To operate this type of sanitary landfill, a solid waste

compactor is required, as well as specialized earth-moving equipment: track-type tractor, backhoe, loader, dump truck, etc.

Semi-mechanized Sanitary Landfill

When a town needs to dispose of 16 - 40 tons daily of solid wastes in the sanitary landfill, it is advisable to use heavy machinery to support the manual labour, to ensure that the garbage will be thoroughly compacted, and the fill banks properly stabilized, thereby prolonging the useful life of the landfill. A farm tractor adapted with bulldozer or blade and with a scraper or roller for compacting could be suitable for operating this "semi-mechanized" landfill.

Manual Sanitary Landfill

This is an adaptation of the sanitary landfill project for small communities which, in view of the quantity and type of waste produced which is less than 15 tons/day, and their unstable economic situation, where they cannot afford to buy heavy equipment because of its high operating and maintenance costs. The term "manual" refers to the fact that the task of compacting and confining the waste can be carried out by a team of labourers using hand tools.

Example (AMIE S16, 12 marks)

What is meant by sanitary landfill? Estimate the area required for a sanitary site under the following conditions:

Design life of the site: 30 years

MSW generation rate: 25 N per person per day

MSW compact unit weight: 5 kN/m^3

Average fill depth: 5 m

Solution

Total municipal waste

Total MSW generated in 30 years = population x MSW generation rate (per day) x 365 x 30

= 100,000 x 365 x 30 x 25

Capacity of landfill

Capacity of landfill

$$= \frac{Total\ MSW\ generated}{MSW\ compacted\ unit\ wt.} = \frac{100,000\,x\,30\,x\,365\,x\,25}{5\,x10^3\ N/m^3} = 5475,000\,m^3$$

Landfill area

Area of landfill required

$$= \frac{Capacity\ of\ landfill}{Average\ fill\ depth} = \frac{5475000}{5} = 1095000\,m^2 = 109.5\,ha$$

Example (AMIE W15, 8 marks)

A medium sized urban community (100,000 population) has about 2 ha of land that can be filled up to a depth of about 7 m with refuse compacted somewhere between 335 kg/m^3 and 175 kg/m^3. Determine the working life of the site (information available: a family of four produce 3 can (225 L) of garbage per week; uncompacted garbage weighs 115 kg/m^3).

Solution

Given data

Area of land available = 2 ha = 20,000 m^2

Land filling depth = 7m

Population = 100,000

Family members = 3

Garbage per week by one family = 3 cans each of 225 L

Density of compacted refuse = 355 kg/m^3 and 475 kg/m^3

Volume

Volume available for garbage/refuse

= 20,000 x 7 = 140,000 m^3

Average density

Average density will be

$$= \frac{355+475}{2} = 415\,kg/m^3$$

Volume for filling

Assuming 25% of space for covering with soil, then the space available for filling of compacted refuse will be

$$= 140,000\left(1-\frac{25}{100}\right) = 105,000\,m^3$$

Disposable garbage

The amount of garbage which can be disposed off will be

= 105,000 m^3 x 415 kg/m^3

= 43,575,000 kg

Volume of garbage per week

Volume of garbage produced per week (7 days) will be

= garbage per person per week x population

$$= \left(\frac{3x225}{4}\right)x100,000$$

= 16875000 L

= 16875 kg

Mass of garbage per week

Mass of garbage produced per week

= 16875 m^3 x 115 kg/m^3

= 1940625 kg

Life of site

It will be

= total capacity/refuse disposal rate

= 43575000 kg/1940625 kg/week

= 22.45 week

Problem

A community with one lakh people has about 2 ha of land left that can be filled to a depth of about 9 m with the refuse compacted to somewhere 355 kg/m^3 and 475 kg/m^3. Determine the remaining life of the site. (Assume garbage can size is 225 L used to dispose the garbage; compacted garbage (e.g. 117 kg/m^3) is roughly one-fourth of the volume of the uncompacted garbage.

Answer: 82 to 83 weeks

BIO-MEDICAL WASTE (WASTE FROM HOSPITALS)

Bio-medical waste means any solid and/or liquid waste including its container and any intermediate product, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research pertaining there to or in the production or testing thereof.

The physico-chemical and biological nature of these components, their toxicity and potential hazard are different, necessitating different methods/options for their treatment/disposal in schedule I of the bio-medical waste (management and handling) Rules, 1998 the waste originating from different kinds of such establishment, has been categorized in different categories as below:

Components of bio-medical waste

- Human anatomical waste (tissues, organs, body parts etc.)
- Animal waste (as above from veterinary hospitals etc.)
- Microbiology and biotechnology waste, such as laboratory cultures, microorganisms, human and animal cell cultures, toxins etc.
- Waste sharps, such as hypodermic needles, syringes, scalpels, broken glass etc.
- Discarded medicines and cyto-toxic drugs.
- Soiled waste such as dressings, bandages, plaster casts, material contaminated with blood etc.
- Solid waste (disposable items like tubes, catheters etc. excluding sharps).
- Liquid waste generated from any of the infected areas.
- Incineration ash.
- Chemical waste.

If the above mentioned bio-medical wastes are not handled properly they shall create many hazards. Following are the main environmental concerns with respect to improper disposal of bio-medical waste management:

- Spread of infection and disease through vectors (fly, mosquito, insects etc.) which affect the in-house as well as surrounding population.
- Spread of infection through unauthorized recycling of disposable items such as hypodermic needles, tubes, blades, bottles etc.
- Reaction due to use of discarded medicines.
- Toxic emissions from defective/inefficient incineration.
- Indiscriminate disposal of incinerator ash/residues.

For safe handling of the biomedical waste it is recommended that proper labelling and colour coding is done. It is desirable to use colour coding means use of specific coloured container with liner/sealed container (for sharps) for particular wastes. The untreated waste should not be stored for a period of more than 48 hours. For this purpose a simple notice in English, Hindi and local language describing clearly about the storage of a particular category of waste in a particularly labelled and coloured container is a must. The container should be sturdy enough, without any puncture and leakage. The container should be covered and preferably operated by foot. In case of plastic bags they should be fitted securely in a container. The sharps must be stored in a puncture proof container and before putting them in the containers they must be mutilated by a needle cutter. The containers should be wheeled and placed in a permanent position tightly. They should be carried for further transportation preferably from the separate corridors and should not cross the regular path of patients and visitors.

Different methods of treatment and disposal are useful for the different category of the bio-medical waste. Depending upon the quantity of waste generated small installations may adopt local (in house) disinfections, mutilation/shredding and autoclaving and off-site incineration at a common facility followed by a sanitary and secured landfill.

E-WASTE IN INDIA

Electronic waste is emerging as a serious public health and environmental issue in India. India is the "*fifth largest electronic waste producer in the world*"; approximately 2 million tons of e-waste are generated annually and an undisclosed amount of e-waste is imported from other countries around the world.

Annually, computer devices account for nearly 70% of e-waste, 12% comes from the telecom sector, 8% from medical equipment and 7% from electric equipment. The government, public sector companies, and private sector companies generate nearly 75% of electronic waste, with the contribution of individual household being only 16%.

E-waste is a popular, informal name for electronic products nearing the end of their "*useful life*." Computers, televisions, VCRs, stereos, copiers, and fax machines are common electronic products. Many of these products can be reused, refurbished, or recycled. There is an upgradation done to this E-waste garbage list which includes gadgets like smartphone, tablets, laptops, video game consoles, cameras and many more.

While e-waste recycling is a source of income for many people in India, it also poses numerous health and environmental risks. More than 95% of India's e-waste is illegally recycled by informal waste pickers called kabadiwalas or raddiwalas. These workers operate independently, outside of any formal organization which makes enforcing e-waste regulations difficult-to-impossible. Recyclers often rely on rudimentary recycling techniques that can release toxic pollutants into the surrounding area. The release of toxic pollutants associated with crude e-waste recycling can have far reaching, irreversible consequences.

Health Impacts

Electronic equipments contain many hazardous metallic contaminants such as lead, cadmium, and beryllium and brominated flame-retardants. The fraction including iron, copper, aluminium, gold, and other metals in e-waste is over 60%, while plastics account for about 30% and the hazardous pollutants comprise only about 2.70%.

Of many toxic heavy metals, lead is the most widely used in electronic devices for various purposes, resulting in a variety of health hazards due to environmental contamination. Lead enters biological systems via food, water, air, and soil. Children are particularly vulnerable to lead poisoning – more so than adults because they absorb more lead from their environment and their nervous system and blood get affected.

E-Waste Management

For the recycling of e-waste, India heavily depends on the unorganized sector as only a handful of organized e-waste recycling facilities are available. Over 95% of the e-waste is

treated and processed in the majority of urban slums of the country, where untrained workers carry out the dangerous procedures without personal protective equipment, which are detrimental not only to their health but also to the environment.

Recycling and treatment facilities require a high initial investment, particularly those fitted with technologically advanced equipments and processes. For the dismantling of one computer piece, these workers only get Rs. 5 or 10. For such a small amount, workers ruin their lives. Such "*backyard recyclers*" do not have wastewater treatment facilities, exhaust-waste gas treatment, and personal health protection equipment.

In Environmental (Protection) Act 1986, the "polluter pays principle" is enacted to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment.

CPCB India is finalizing the set of rules and most recently issued a formal set of guidelines for proper and eco-friendly handling and disposal of the electronic waste. The Ministry of Environment and Forests is now processing the rules framed by electronics equipment manufacturers with the help of NGOs.

As an effort to make the users aware of the recycling of e-waste, many electronic companies such as Apple, Dell, and HP have started various recycling schemes. Nokia India announced its "recycling campaign" for the Indian region. The program encouraged mobile phone users to dispose of their used handsets and accessories, irrespective of the brand, at any of the 1,300 green recycling bins put up across the priority dealers and care centres. Nokia is also planning to launch an electronic waste management program.

PLASTIC WASTE

Plastic pollution is the accumulation of plastic objects and particles (e.g. plastic bottles, bags etc.) in the Earth's environment that adversely affects wildlife, wildlife habitat, and humans.

Plastics are inexpensive and durable, and as a result levels of plastic production by humans are high. However, the chemical structure of most plastics renders them resistant to many natural processes of degradation and as a result they are slow to degrade. Together, these two factors have led to a high prominence of plastic pollution in the environment.

Plastic pollution can afflict land, waterways and oceans.

Effects of plastic pollution

- **Animals**. Plastic wastes have been mistaken for food by numerous animals, mainly marine wildlife. Large quantities of plastics have been found in the stomachs of many dead animals. When the plastics are ingested, they upset or fill up the digestive systems of the animals thus contributing to their death due to blockage or starvation. Marine animals can also be trapped in plastic waste where they are exposed to predators or starve to death.
- **Human Health**. Plastics are made up of a variety of toxic chemicals. As such, its uses and exposure are associated with a number of human health concerns. Chemicals

leached from the plastics contain toxic compounds. These chemicals have been established to upset the thyroid hormones and can be very destructive to women of reproductive age and young children.

- **Land Pollution**. Plastics wastes have resulted in the destruction and decline in quality of the earth's land surfaces in term of use, landscape and ability to support life forms. Mainly, it's because plastics leach hazardous chemicals on land, forms breeding grounds for diseases, and litters available space thereby reducing the productive land areas. The bulk of plastics also end up in the landfills and since they take years to breakdown they heap up causing significant health implications to plants, people, and animals within the surrounding.
- **Air Pollution**. Often, plastics are burned in the open air. This leads to air pollution because poisonous chemicals are released into the atmosphere during combustion. Plus, when animals or humans inhale the polluted air it can affect their general well-being and cause respiratory disorders.
- **Groundwater Pollution**. Whenever plastics are dumped in landfills, the hazardous chemicals present in them seep underground when it rains. The leaching chemicals and toxic elements infiltrate into the aquifers and water table, indirectly affecting groundwater quality. Eventually, it thwarts the efforts of water conservation around the world since it endangers the sustainability of the waters.
- **Water Pollution**. Many lakes and oceans have reported alarming cases of plastic debris floating on water surfaces, affecting a great number of aquatic creatures. It leads to dreadful consequences to marine creatures that swallow the toxic chemicals. Besides, the hazardous plastic chemicals contaminate water and reduce its quality.
- **Economic Losses and Tourist Distraction**. Scattered plastics at the beaches or on dumpsites/towers/traffic lights/poles within cities usually portray a very bad picture of the respective regions and depict environmental insensitivity. Winds may also carry the plastics to other areas, increasing plastic littering. As a result, tourism to such areas is affected leading to loss of tourism revenue.

Plastic waste disposal

- **Landfilling**. All plastics can be disposed in landfills. However, landfilling is considered highly wasteful as it requires a vast amount of space and the chemical constituents and energy contained in plastic is lost (wasted) in this disposal route. In countries where landfills are poorly managed, plastic wastes can be easily blown into waterways or carried out to sea by flood water. In addition, when plastics decompose in landfills, they may leak pollutants into the soil and surrounding environment.
- **Incineration**. Plastics are derived from petroleum or natural gas, giving them a stored energy value higher than any other material commonly found in the waste stream. Incineration return some of the energy from plastic production. However,

plastic incineration tends to cause negative environment and health effects as hazardous substances may be released into the atmosphere in the process.

- **Recycling**. Many plastics can be recycled. and the materials recovered can be given a second-life. However, this method is not fully utilized, due to difficulties with the collection and sorting of plastic waste. Many developing (and even some developed countries) have poor waste management facilities which often result in plastics (and other waste) being recklessly disposed into rivers and water bodies. Even though recycling is the most effective way to deal with plastic waste, its effectiveness is highly depended on public awareness, economic viability, and the implementation of public infrastructures to make recycling more efficient.
- **Biodegradable Plastics**. Biodegradable plastics are plastics that decompose by the action of living organisms. Biodegradable plastics have the potential to solve a number of waste-management issues, especially for disposable packaging that cannot be easily separated from organic waste.

Hazardous Waste Management

It is difficult to define the hazardous waste exactly as it is a very general and wide term. However, it may be defined *as any waste in solid, liquid or gaseous form which because of its quantity and concentration or its physical, chemical, radiological, or infectious characteristics, may cause ill effect on the human health or the environment if not properly stored, transported and disposed.* The designation of a material to be hazardous is done through the standard tests for the following criteria:

- **Radioactivity**: If the level of radioactivity exceeds the permissible concentration limits the waste is termed as hazardous.
- **Bio-concentration**: This criteria is used for chemicals such as chlorinated hydrocarbon pesticides.
- **Flammability**: The ease with which certain substance catches fire and sustains combustion.
- **Reactivity**: Chemicals like sodium are extremely reactive with water.
- **Toxicity**: The capacity of causing damage to the human health and the environment, like the poisonous effect is the measure of toxicity.
- **Genetic and carcinogenic potential:** The potential of causing cancer etc.

By the above criteria the hazardous waste can be identified but the actual impact is based upon the quantity. It can be suggested that the most suitable method of dealing with hazardous waste is converting it into non-hazardous form, but that is not possible always, and may not be economical and technically possible also. The most commonly used method of disposing of hazardous waste is the hazardous waste landfill. The specially designed landfills are used to provide complete protection for the surface and subsurface waters from the

hazardous waste. As they have to carefully deal with, such type of landfills are equipped with clay liners, monitoring wells and ground water barriers. The strategy is strict segregation from the environment and complete care in storage and transportation.

The Central Government has made the Hazardous Waste (Management & Handling) Rules, 1989 and has amended them on January 6, 2000. According to them, the occupier generating hazardous waste is bound to take all necessary steps to ensure that such wastes are properly handled and disposed off without any adverse effect. The occupier shall also be responsible for the collection, conveyance, storage, treatment and disposal of these wastes in consultation with the pollution control boards. The manual on MSWM has a list of the categories of Hazardous Waste as specified in the schedule I to the rules amended on January 2000 by the government. The list includes for example petrochemical processes, natural gas production, production and use of zinc, lead, cadmium, arsenic etc., production of pharmaceuticals, preservatives, cosmetics, photo-chemicals etc.

The waste generated from medical activities can also be hazardous, toxic and even lethal because of their high potential of disease transmission. The hazardous and toxic part of waste from hospitals comprising infectious, bio-medical and radioactive materials as well as sharps (needles, knives etc.) creates a great risk if not handled properly. Actually a major part of biomedical waste is non-hazardous, but if proper segregation is not there it makes the whole waste as hazardous. Apart from a part of hazardous waste the biomedical waste should be studied separately.

CHARACTERISTICS OF HAZARDOUS WASTES

- **Instability**. A waste is an ignitable hazardous waste, if it has a flash point of less than 60 °C; readily catches fire and burns so vigorously as to create a hazard; or is an ignitable compressed gas or an oxidiser.
- **Corrosivity**. A liquid waste which has a pH of less than or equal to 2 or greater than or equal to 12.5 is considered to be a corrosive hazardous waste. Sodium hydroxide, a caustic solution with a high pH, is often used by many industries to clean or degrease metal parts. Hydrochloric acid, a solution with a low pH, is used by many industries to clean metal parts prior to painting. When these caustic or acid solutions are disposed off, the waste is a corrosive hazardous waste.
- **Reactivity**. A material is considered a reactive hazardous waste, if it is unstable, reacts violently with water, generates toxic gases when exposed to water or corrosive materials, or if it is capable of detonation or explosion when exposed to heat or a flame. Examples of reactive wastes would be waste gunpowder, sodium metal or wastes containing cyanides or sulphides.
- **Toxicity**. To determine if a waste is a toxic hazardous waste, a representative sample of the material must be subjected to a test conducted in a certified laboratory. The toxic characteristic identifies wastes that are likely to leach dangerous concentrations of toxic chemicals into ground water.

CLASSIFICATION OF HAZARDOUS WASTE

- **Radioactive substance**. Substances that emit ionising radiation are radioactive. Such substances are hazardous because prolonged exposure to radiation often results in damage to living organisms. Radioactive substances are of special concern because they persist for a long period. The management of radioactive wastes is highly controlled by national and state regulatory agencies. Disposal sites that are used for the long-term storage of radioactive wastes are not used for the disposal of any other solid waste.
- **Chemicals**. Most hazardous chemical wastes can be classified into four groups: synthetic organics, inorganic metals, salts, acids and bases, and flammables and explosives. Some of the chemicals are hazardous because they are highly toxic to most life forms. When such hazardous compounds are present in a waste stream at levels equal to, or greater than, their threshold levels, the entire waste stream is identified as hazardous.
- **Biomedical wastes**. The principal sources of hazardous biological wastes are hospitals and biological research facilities. The ability to infect other living organisms and the ability to produce toxins are the most significant characteristics of hazardous biological wastes. This group mainly includes malignant tissues discarded during surgical procedures and contaminated materials, such as hypodermic needles, bandages and outdated drugs. This waste can also be generated as a by-product of industrial biological conversion processes.
- **Flammable wastes**. Most flammable wastes are also identified as hazardous chemical wastes. This dual grouping is necessary because of the high potential hazard in storing, collecting and disposing off flammable wastes. These wastes may be liquid, gaseous or solid, but most often they are liquids. Typical examples include organic solvents, oils, plasticisers and organic sludges.
- **Explosives**. Explosive hazardous wastes are mainly ordnance (artillery) materials, i.e., the wastes resulting from ordnance manufacturing and some industrial gases. Similar to flammables, these wastes also have a high potential for hazard in storage, collection and disposal, and therefore, they should be considered separately in addition to being listed as hazardous chemicals. These wastes may exist in solid, liquid or gaseous form.

HAZARDOUS WASTE TREATMENT

Physical Treatment

- **Clarification**. Suspended solid particles less than 100 ppm (pans per million) concentration are removed from an aqueous stream. This is usually accomplished by depth filtration and cross-flow filtration and the primary aim is to produce a clear aqueous effluent, which can either be discharged directly, or further processed. The suspended solids are concentrated in a reject stream.

- **Dewatering of slurries of typically 1% to 30 % solids by weight**. Here, the aim is to concentrate the solids into a phase or solid form for disposal or further treatment. This is usually accomplished by cake filtration. The filtration treatment, for example, can be used for neutralisation of strong acid with lime or limestone, or precipitation of dissolved heavy metals as carbonates or sulphides followed by settling and thickening of the resulting precipitated solids as slurry. The slurry can be dewatered by cake filtration and the effluent from the settling step can be filtered by depth filtration prior to discharge.

Chemical Treatment

- **Chemical precipitation**. This is a process by which the soluble substance is converted to an insoluble form either by a chemical reaction or by change in the composition of the solvent to diminish the solubility of the substance in it. Settling and/or filtration can then remove the precipitated solids. In the treatment of hazardous waste, the process has a wide applicability in the removal of toxic metal from aqueous wastes by converting them to an insoluble form. This includes wastes containing arsenic, barium, cadmium. chromium, copper, lead, mercury, nickel, selenium, silver, thallium and zinc. The sources of wastes containing metals are metal plating and polishing, inorganic pigment, mining and the electronic industries. Hazardous wastes containing metals are also generated from cleanup of uncontrolled hazardous waste sites, e.g.. leachate or contaminated ground water.

- **Chemical oxidation and reduction (redox).** In these reactions, the oxidation state of one reactant is raised, while that of the other reactant is lowered. When electrons are removed from an ion, atom, or molecule, the substance is oxidised and when electrons are added to a substance, it is reduced. Such reactions are used in treatment of metal-bearing wastes, sulphides, cyanides and chromium and in the treatment of many organic wastes such as phenols, pesticides and sulphur containing compounds. Since these treatment processes involve chemical reactions, both reactants are generally in solution. However, in some cases, a solution reacts with a slightly soluble solid or gas.

- **Solidification**. This refers to a process in which materials are added to the waste to produce a solid. It may or may not involve a chemical bonding between the toxic contaminant and the additive.

- **Stabilisation**. This refers to a process by which a waste is converted to a more chemically stable form. Subsuming solidification, stabilisation represents the use of a chemical reaction to transform the toxic component to a new, nontoxic compound or substance.

- **Chemical fixation.** This implies the transformation of toxic contaminants to a new non-toxic compound. The term has been misused to describe processes, which do not involve chemical bonding of the contaminant to the binder.

- **Encapsulation**: This is a process involving the complete coating or enclosure of a toxic particle or waste agglomerate with a new substance.

Thermal Treatment

The two main thermal treatments used with regard to hazardous wastes are:

- **Incineration**. Incineration can be regarded as either a pre-treatment of hazardous waste, prior to final disposal or as a means of valorising waste by recovering energy. It includes both the burning of mixed solid waste or burning of selected parts of the waste stream as a fuel. The concept of treating hazardous waste is similar to that of municipal solid waste (already discussed).
- **Pyrolysis**. This is defined as the chemical decomposition or change brought about by heating in the absence of oxygen. This is a thermal process for transformation of solid and liquid carbonaceous materials into gaseous components and the solid residue containing fixed carbon and ash. The application of pyrolysis to hazardous waste treatment leads to a two-step process for disposal. In the first step, wastes are heated separating the volatile contents (e.g.. combustible gases, water vapour, etc.) from non-volatile char and ash. In the second step volatile components are burned under proper conditions to assure incineration of all hazardous components.

Biological Treatment

- **Land treatment**. This is a waste treatment and disposal process, where a waste is mixed with or incorporated into the surface soil and is degraded, transformed or immobilised through proper management. The other terminologies used commonly include land cultivation, land farming, land application and sludge spreading. Compared to other land disposal options (e.g.. landfill and surface impoundments), land treatment has lower long-term monitoring, maintenance and potential clean up liabilities and because of this, it has received considerable attention as an ultimate disposal method.
- **Enzymatic systems.** Enzymes are complex proteins ubiquitous in nature. These proteins, composed of amino acids, are linked together via peptide bonds. Enzymes capable of transforming hazardous waste chemicals to nontoxic products can be harvested from microorganisms grown in mass culture.
- **Composting**. The principles involved in composting organic hazardous wastes are the same as those in the composting of all organic materials, though with moderate modifications. The microbiology of hazardous wastes differs from that of composting in the use of inoculums. The reaction is that certain types of hazardous waste molecules can be degraded by only one or a very few microbial species, which may not be widely distributed or abundant in nature. The factors important in composting of hazardous wastes are those that govern all biological reactions.

- **Aerobic and anaerobic treatment**. Hazardous materials are present in low to high concentration in wastewaters, leachate and soil. These wastes are characterised by high organic content (e.g., up to 40.000 mg/1 total organic carbon), low and high pH (2 to 12). elevated salt levels (sometimes, over 5%), and presence of heavy metals and hazardous organics. Hazardous wastes can be treated using either aerobic or anaerobic treatment methods. (i) In aerobic treatment, under proper conditions, microorganisms grow. They need a carbon and energy source, which many hazardous wastes satisfy, nutrients such as nitrogen, phosphorus and trace metals and a source of oxygen. (ii) Anaerobic treatment is a sequential biologically destructive process in which hydrocarbons are converted, in the absence of free oxygen, from complex to simpler molecules, and ultimately to carbon dioxide and methane.

RADIOACTIVE WASTE

Radioactive waste is a type of hazardous waste that contains radioactive material. Radioactive waste is usually a by-product of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine. Radioactive waste is regulated by government agencies in order to protect human health and the environment. Radioactivity naturally decreases over time, so radioactive waste has to be isolated and confined in appropriate disposal facilities for a sufficient period until it no longer poses a threat.

The time radioactive waste must be stored for depends on the type of waste and radioactive isotopes. Current approaches to managing radioactive waste have been segregation and storage for short-lived waste, near-surface disposal for low and some intermediate-level waste, and burial in a deep geological repository or transmutation for the high-level waste.

Management of radiation wastes

Overall philosophy for safe management of radioactive wastes in India, is based on the concept of

- Delay and Delay
- Dilute and Disperse
- Concentrate and Contain.

Effective management involves segregation, characterization, handling, treatment, conditioning and monitoring prior to final disposal.

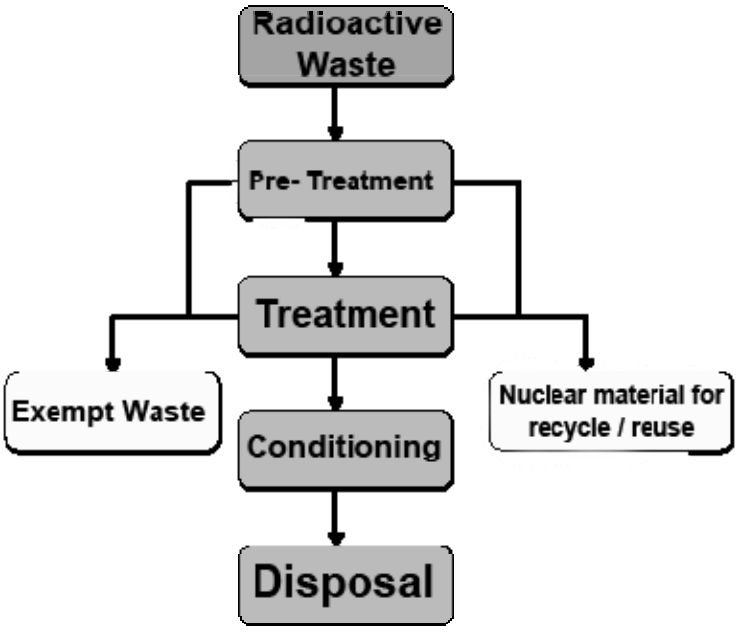
Proper disposal is essential to ensure protection of the health and safety of the public and quality of the environment including air. soil, and water supplies.

Radiological hazards associated with short lived wastes <30 years half life get significantly reduced over a few hundred years by radioactive decay. The high level wastes contain large concentration of both short and long lived radionuclide s, warranting high degree of isolation from the biosphere and usually calls for final disposal into geological formation (repository)

A key idea was that long-term disposal would be best carried out by identifying suitable sites at which the waste could be buried, a process called deep geological disposal

Low level waste is comparatively easy to dispose of. The level of radioactivity and the half life of the radioactive isotopes in low level waste are relatively small. Storing the waste for a period of 10 to 50 years will allow most of the radioactive isotopes in low level waste to decay, at which point the waste can be disposed of as normal refuse.

A brief summary of the various radioactive waste management practices followed in India has been presented below:



ASSIGNMENT

Q.1. (AMIE S15, 8 marks): Explain how the volume of solid wastes could be reduced in an educational institute in India.

Q.2. (AMIE W16, 10 marks): Describe the solid wastes generated from some big industries and how they are effectively handled.

Q.3. (AMIE W15, 12 marks): Name the types of municipal wastes (e.g. solids) with their sources and also name the methods of management of these to keep the urban environment free from litters and garbage.

Q.4. (AMIE W16, 10 marks): Describe various methods of minimization and reduction of solid wastes produced by various industries.

Q.5. (AMIE S19, 7 marks): Enumerate and describe the physical, chemical and biological characteristics of solid waste.

Q.6. (AMIE W17, 12 marks): Besides traditional wastes (e.g. excepting the radioactive wastes) two new type of wastes, namely: e-wastes and plastics, etc, have posed very serious threats on the environment - name the various problems caused by them and suggest appropriate methods and strategies of management of those problems.

Q.7. (AMIE W17, 8 marks): Sanitary land fill although the most oldest and widely used method to dispose municipal solid wastes has various shortcomings - discuss in short.

Q.8. (AMIE W17, 12 marks): It is required to estimate the land area needed to dispose the solid wastes generated by small community of 100,000 inhabitants under the following conditions, namely: design life of the site 30 years, average fill depth 4 (m), solid wastes generated per person per day 25 (N), weight of the compacted solid wastes 5 (kN) per cubic metre.

Q.9. (AMIE S19, 10 marks): Define hazardous waste as per environment Protection Act 1986. What are the main characteristics of hazardous waste. Discuss its impact on human health.

Q.10. (AMIE S15, 12 marks): What are the hazardous wastes? Discuss various sources of hazardous wastes.

Q.11. (AMIE W16, 10 marks): How hazardous wastes are classified? Describe the control measures and management of hazardous wastes.

Q.12. (AMIE W15, 12 marks): Hazardous wastes (excluding radioactive wastes) pose multiple health and safety risks-defining the hazardous, name the various risks and briefly state the methods of safe disposal of these wastes.

Q.13. (AMIE W17, 20 marks): Very little is known and understood of the long term effects (e.g. toxicity etc.) of bio-accumulation with chemicals and hazardous wastes on soils and living species of flora and fauna - elaborate in brief.

Q.14. (AMIE W18, 10 marks): Describe with the help of neat sketches about the hazardous solid waste disposal by secured landfill method.

Q.15. (AMIE S19, 10 marks): Illustrate the treatment of solid and liquid radioactive waste. Also draw the flowchart for the same.