Principles of Environmental Engineering

Solid Waste Management

Solid Waste Management (SWM)

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.	As above

	Non combustible (primarily inorganic) metals. tin 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 &	Solid wastes resulting from industry	Factories, power plants, treatment
sludges	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.	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.

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.

EXPECTED QUANTITIES OF SOLID WASTE

For the assessment of collection, conveyance, treatment and disposal, the expected quantities of solid waste generated in a locality must be known. NEERI has done extensive work and has measured the quantities of waste generated in the Indian cities. The quantity of waste produced is lesser in Indian cities as compared to the developed countries, because of the poverty and the way of living. Ours is a more natural way of living and nature has its cycles to recycle the waste. In India the average solid waste produced per capita per day vary between 0.2-0.6 kg/capita/day, the higher value is for metropolitan cities. The total solid waste generated in urban area (towns with population more than 5000 and having other amenities) is estimated to be around 38 million tones per annum.

The actual forecast of waste quantity is as difficult as is estimation of the waste composition. The quantity also depends upon the living standard, size of the community, climate, particular days (like Diwali and other festivals), etc. Alongwith the quantity the density of the waste is also variable and it changes with the storage method, salvaging (sorting) activities, exposure

to weather, handling methods and decomposition. It can be noted as a general rule that the lower is the level of economic development, the greater is the change in the density of waste from generation and disposal. The waste in developing countries get compacted upto the disposal point in such a way that its volume reduces to half.

For the estimation of MSW generated in a proposed city (in future) following estimation can be done:

Expected residential waste: 0.3 to 0.6 kg/capita/day

Expected commercial refuse 0.1 to 0.2 kg/capita/day

Expected street sweepings: 0.05 to 0.2 kg/capita/day

Expected institutional refuse: 0.05 to 0.2 kg/capita/day.

If industrial solid waste is included in municipal waste for collection and disposal purposes, 0.1 to 1.0 Kg/capita/day may be added at the appropriate step. These generation rates are dependent upon the particular sites so they are to be supported by the held data.

Actually the solid waste quantity and quality both are very much variable and are dependent on many factors. It is very much difficult to anticipate in advance. So the waste generated should be carefully examined for quantity and quality and then only any activity should be planned.

Before going into further details of collection, conveyance, treatment and disposal of solid waste one should know the important physical and chemical characteristics of solid waste.

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.

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.

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.

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

The most common and easy way of disposal of solid waste is dumping it on land. 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.

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.

Vermi-composting

In the case of households or colonies vermi-composting which involves the stabilization of organic solid waste through special earthworm by conversion of the organic matter to worm casting is also done. Vermicomposting involves the culture of earthworms(vermiculture) for the stabilization of different variety of organic solid waste. Earthworms feed on any organic waste and consume two to five times of their body weight, excrete the mucus coated undigested matter as wormcasts. Wormcasts consists of organic matter that has undergone physical and chemical breakdown through the muscular activity that grinds the material to a particle size of 1 to 3 micron. The nutrient present in the wormcast are easily soluble in water and are thus readily available for the plant growth. Vermi-composting is a rich source of macro and micronutrients, vitamins, enzymes, antibiotics and hormones.

Anaerobic Digestion and Biomethanation

Biomethanation is a comparatively well-established technology for disinfections, deodorization and stabilization of sewage sludge, farmyard manures, animal slurries, and

industrial sludge. Its application to the organic fraction of MSW is more recent and less extensive. It leads to bio-gas/power generation in addition to production of compost (residual sludge). This method provides a value addition to the aerobic (composting) process and also offers certain other clear advantages over composting in terms of energy production/consumption, compost quality and net environmental gains.

Recently a 5 MW power plant based on biomethanation technology was constructed and operationalized at Lucknow but unfortunately it had to be closed down for various reasons, one among them being non-supply of appropriate quality of MSW to the plant. The organic content in the waste supplied to the plant is reported to have been as low as 15 per cent.

SANITARY LANDFILL

The term 'Landfill' means a unit operation for final disposal of municipal solid waste on land, that is designed and constructed with the objective of minimum impact on the environment. 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. Land filling is done for the mixed waste, that is not hazardous but not found suitable for waste processing, and recycling. Land fill is not suggested for bio waste as energy can be recovered out of it and its decomposition in the landfill shall produce leachates. Actually land filling should be used as the final disposal method and should be adopted for the waste from which the recycling is not possible and economic extraction of energy is also not possible. Sometimes it is useful for hazardous waste disposal, but then it has to be done very carefully.

BIO-MEDICAL WASTE

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.

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.

CHEMICAL TOILETS

A chemical toilet collects human excreta in a holding tank and uses chemicals to minimize odors. These toilets are usually, but not always, self-contained and movable. A chemical toilet is structured around a relatively small tank, which needs to be emptied frequently. It is not connected to a hole in the ground (like a pit latrine), nor to a septic tank, nor is it plumbed into a municipal system leading to a sewage treatment plant. When the tank is emptied, the contents are usually pumped into a sanitary sewer or directly to a treatment plant.

The portable toilets used on construction sites and at large gatherings such as music festivals are well-known types of chemical toilet. As they are usually used for short periods and because of their high prices, they are mostly rented rather than bought, often including servicing and cleaning.

Aircraft lavatories and passenger train toilets were in the past often designed as chemical toilets but are nowadays more likely to be vacuum toilets.

A simpler type of chemical toilet may be used in travel trailers (caravans) and on small boats.

Many chemical toilets use a blue dye in the bowl water. In the past, disinfection was generally carried out by mixing formaldehyde, bleach, or similar chemicals with the toilet water when flushed. Modern formulations are nitrate-based and work biologically.

ASSIGNMENT

Q.1. (AMIE S10, W12, 14, 15, 13, 6 marks): Describe about the sources and characteristics of solid wastes.

Q.2. (AMIE W10, 12, 7 marks): Explain the term "biomedical waste" and gisve its source.

Q.3. (AMIE S11, 5 marks): Briefly discuss the composition of municipal solid waste.

Q.4. (AMIE W11, 12 marks): Municipal solid wastes consist of diversity of objects from variety of sources. Name the wastes and identify the sources. Also, prepare a qualitative estimate of different wastes commonly generated in big urban centres in India.

Q.5. (AMIE W11, 8 marks): An urban community of about 1 lakh people has about 2.02 ha of landfill left that can be filled to about 9.15 m with refuse compacted to somewhere between 360 kg/m^3 and 480 kg/m^3. Estimate the life left with the landfill and also suggest any method to control leaching from the decomposed wastes.

[Hint: A family of four members fills up three garbage cans (capacity of each can 225 L) per week; density of uncompleted garbage = 120 kg/m^3].

Answer: 6.3 to 8.4 years.

Q.6. (AMIE W13, 14, 6 marks): The initial volume of a mass of solid waste is 15 m^3. After compaction, the volume is reduced to 3 m^3. Compute the percent volume reduction and compaction ratio.

Answer: 80%, 5

Hint: (i) Compaction ratio = initial volume/final volume (ii) % volume reduction = [(initial volume – final volume)/initial volume] x 100

Q.7. (AMIE W12, 5 marks): Write short note on chemical toilet.

Q.8. (AMIE W11, 6 marks): Name various types of exposure/risks caused on man by hazardous wastes in the environment.