UNIT 13 HAZARDOUS WASTE CHEMICALS

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13.1 INTRODUCTION

You know that living beings require food. They use food for their growth and development and for producing energy. In this process they also generate wastes. Industries also use raw materials, process them to yield useful products and are left with wastes which may sometimes exceed 50 per cent of the raw materials used. This is quite inevitable, as industry increases in size and complexity. We have learnt in Unit 6, that unlike natural ecosystems which can cope with the demand for food as well as the disposal of the wastes, in the case of industries, the waste can go on accumulating unless properly disposed off. Some of this waste is hazardous in nature, and may need special care with regard to diposal.

Although hazardous waste chemicals make up to 15 per cent of the total industrial wastes, their extremely dangerous nature requires that they be properly and carefully disposed off. If this waste is not judiciously disposed off, the natural resources can be seriously contaminated, posing a serious threat to the quality of environment in general and human health in particular. Various methods of hazardous waste disposal have been described in this unit.

International concensus on a universally acceptable, comprehensive definition and system of classification of hazardous wastes has not been reached. One of the reasons for this disagreement is that suitable parameters of definition are difficult to identify. In this unit, you will learn how to define the term hazardous wastes and distinguish it from toxic chemicals.

Waste is often a complex mixture that makes the analysis of its composition difficult and often a very costly exercise. Even if adequate analytical data are available, the significance of a particular waste component is seldom appreciated. You will learn in this unit about the concept of hazardous waste management, i.e., what treatment a waste should undergo before disposal, and what are the after-effects of improperly disposed wastes in the long run. A special mention will be made about waste management in India.

Objectives

After studying this unit you will be able to:

- define and classify the hazardous waste chemicals and distinguish them from toxic chemicals
- explain the pre-requisites of hazardous waste management
- compare and contrast various methods for disposal of hazardous wastes
- describe how hazardous waste is being disposed off presently in our country
- appreciate the impact or improper management of hazardous waste chemicals.

13.2 CHARACTERISATION OF HAZARDOUS WASTES

Hazardous wastes are chemical by-products of an industry, a factory or a chemical plant. They may result from household activities or even from a hospital or a research laboratory. Armed conflicts, where nuclear or chemical weapons are used, also release enormous amounts of hazardous wastes. A chemical produced by any of the above sources which may endanger human health, pollute the environment or carry hidden risk to life if managed or disposed off improperly is called **'hazardous'**. A waste is considered as hazardous if it has any one of the following characteristics:

- Ignitability—catches fire easily,
- Corrosiveness—wears away other materials,
- Reactivity—reacts strongly with water or explodes on reaction with other chemicals,
- Radioactivity—releases ionizing radiations, and
- Toxicity—produces symptoms of metabolic disorders, poisoning, disease, mutations, cancer or malformations.

13.2.1 Toxic Versus Hazardous

A compound, microorganism or an agent which causes symptoms of ailments such as vomitting, giddiness, diarrhoea or the like, is said to be pathogenic. If it induces genetic changes on consumption, it is said to be mutagenic. If it causes formation of galls or morphological abnormalities, it is known as teratogenic. And if it causes cancer, it is said to be carcinogenic.

Generally, the terms **"toxic"** and **"hazardous"** are used interchangeably as if they were synonymous. But this is not true. The former refers to **intrinsic** characteristics whereas the latter includes **extrinsic** characteristics also. **"Toxic"**—defines the capacity of a substance to produce injury after entering the metabolic processes of the consumer, an animal, a plant or a human being. The changes caused may either be pathogenic, mutagenic, teratogenic or carcinogenic.

The term 'hazardous' denotes the potential of a substance to pose threat to life or material through any one of properties mentioned above, namely, toxicity, ignitibility, corrosiveness, reactivity, explosiveness or radioactivity. The term "hazardous" is thus broader and includes "toxic" wastes in its spectrum.

You can see that some substances may be hazardous on more than one account. For example, benzene is toxic as well as ignitable; strong acids and alkalis from corrosive mixtures which sometimes explode if improperly handled.

13.2.2 Defining Hazardous Wastes

Recognising the fact that the term "hazardous" implies both intrinsic and extrinsic properties, a complete definition of hazardous wastes should answer the following five questions :

i) Hazardous to what?

ii) Hazardous to what degree?

iii) Hazardous for what reason?

iv) Hazardous at what time?

v) Hazardous under what conditions?

Definition of Hazardous Waste

Answering the above questions, a complete definition of hazardous waste can be only as follows :

Hazardous waste means a waste, which because of its quantity, concentration or physical, chemical or biological characteristcis may :

a) cause or significantly contribute to an increase in mortality or an increase in serious, irreversible or incapacitating reversible illness, or

b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

Try the following SAQ to test whether you have understood the characteristics of hazardous wastes.

SAQ 1

Fill in the blanks using appropriate words and compare your answers with those given at the end of this unit:

i) A compound which induces genetic changes on consumption is said to be..... . If it causes formation of galls or morphological abnormalities it is known as..... . And if it causes cancer, it is said to be.....

ii) A waste is proposed as hazardous if it has any one of the following characteristics:

a) ....., i.e., catches fire easily

b) ....., i.e., wears away other materials

c) ....., i.e., reacts strongly with water

d) ....., i.e., releases ionising radiations

e) ....., i.e., produces symptoms of poisoning

iii) A complete definition of "hazardous waste" includes the physical, chemical or biological properties of a waste which because of its quantity or concentration may—

a) cause or significantly contribute to an increase in..... or an increase in serious.....or incapacitating.....illness, or

b) pose a substantial present or.....hazard to human health or the environment when improperly....., ..., transported or.....off, or otherwise managed.

13.2.3 Waste Classification

For effective management and disposal of hazardous waste, waste classification is an essential pre-requisite. Generally, the following approaches have been followed internationally to classify the hazardous wastes :

- Listing by source approach
- Listing by pure component approach
- Criteria approach
- Exclusive list approach

Listing by Source Approach

There are certain activities which lead to the generation of hazardous wastes. In this system of classifiction, the wastes have been identified on the basis of their source of generation. Table 13.1 indicates the sources and the activities which generate hazardous wastes.

Table 13.1 : Sources and Their Activities Generating Hazardous Wastes

S.No.	Source	Activity
1.	Coal Industry	Production of coal and coal products
2.	Petroleum Industry	Extraction of petroleum and natural gas, petroleum refining
3.	Metallurgical industry	Mining and beneficiation of ores, extraction of metals from ores
4.	Electroplating Industry	Metal finishing operations, manufacture of mirrors
5.	Chemical Industry	Production of primary organic and inorganic chemicals, pesticides, drugs, detergents etc.
6.	Paints and Related Industries	Production of inks, varnish, paints, glues photographic products, rubber, plastic perfumes, explosives and other secondary chemicals
7.	Leather Industry	Tanning of leather dyes and dye intermediates
8.	Textile Industry	Laundering, bleaching, and cloth dyeing
9.	Automobile Industry	Servicing and repairs of automobile engines
10.	Hospitals	Medical services, aid to outdoor patients, sterilisation of instruments, radio-therapy
11.	Laboratories	Research and analysis of old chemicals/materials, discovery of new chemicals/materials
12.	Fuel Regeneration Industries	Regeneration and recovery of radioactive wastes
13.	Household Activities	Household activities, bathing, cooking, laundering
14.	Pollution Control Facilities	Residues from pollution control operations

Listing by Pure Component Approach

As per this method, the wastes have been classified as hazardous based on the toxic and hazardous constituents present in the waste. A list of hazardous wastes which contain toxic and hazardous constituents is given in Appendix I. There are 35 generic types of wastes based on the toxic and hazardous constituents present in the waste.

Criteria Approach

Normally, a chemical or a compound does not exist in pure form in the waste. A waste is generally a complex mixture of different chemicals and/or compounds which exhibit certain properties. In this system of waste classification, the wastes exhibiting the following characteristics have been classified as hazardous wastes :

- Ignitability, e.g., hydrocarbons
- Reactivity, e.g., nitrates, chromates and permanganates
- Corrosivity, e.g., acids and alkalis
- Toxicity, e.g., pesticides, lead, arsenic or cadmium compounds
- EP-Toxicity, e.g., radioactive wastes.

Most of the countries follow a combination of these approaches in classifying and identifying their hazardous wastes. For example, United States of America, United Kingdom, West Germany etc., have adopted a combination of Listing by Source and Criteria approaches. Norway has adopted the Listing by Pure Component approach.

Recently, Government of India has passed rules for the Management of Toxic and Hazardous Wastes. In our country, the combination of Listing by Pure Component and Source has been adopted in identifying the hazardous wastes. The list of hazardous wastes, identified by the Government of India is given in Appendix II.

Exclusive List Approach

In listing by exclusion approach, the chemical wastes which cause no harm to human health, environmental quality and life, in general are listed by intuition. The waste chemicals which **do not** fall under this category have been designated as hazardous. This method of classifying the wastes is arbitrary because it results from the subjective opinion of the person classifying the wastes. Thus, it is not a good method of classification.

We will discuss the management of hazardous waste in the next section. Before taking that up, you may try the following SAQ:

SAQ 2

1) Fill in the blanks using appropriate words :

i) For effective planning, its management and disposal of hazardous waste,..... ..... is an essential requisite.

ii) There are.....kinds of waste generating activities when wastes are classified based on their source.

iii) In the listing by pure component approach, 35 generic types of wastes have been identified based on the.....and.....constituents present in the waste.

iv) Government of India has adopted a combination of approach and listing by..... .....approach for classifying the hazardous wastes. The list identifies.....,.....categories of wastes.

2) Match the industries given in Column A with their respective activities in Column B.

	Column A		Column B
a)	Chemical Industry	a)	Metal finishing operation, manufacture of mirrors.
b)	Leather Industry	b)	Mining and beneficiation of ores, extraction of metals from ores
c)	Paint and Related Industry	c)	Production of primary organic and inorganic chemicals, pesticides, drugs, detergents etc.
d)	Electroplating Industry	d)	Production of inks, varnish, paints glues, photographic products, rubber, plastics, Perfumes, explosives and other secondary chemicals.
e)	Metallurgical Industry	e)	Tanning of leather, dyes and dye intermediates.

13.3 CONCEPT OF WASTE MANAGEMENT

Hazardous wastes have become an important environmental and public health issue which concerns many countries in the world. In the modern framework of hazardous waste management, a four pronged strategy has been adopted:

i) Minimising the quantity of waste
ii) Recycling of industrial waste
iii) Treatment of the waste
iv) Collection, transport and disposal of waste in an environmentally sound manner

All four of these approaches are important and are not exclusive of each other. When dealing with a given hazardous waste problem, often there is a need to utilise a combination of the four general approaches outlined above. We will discuss, in brief, each of these four approaches.

11.3.1 Waste Minimisation

The first priority in hazardous waste management is to reduce the quantity of waste to minimum. Three major waste reduction schemes which are often used can be summarised as below:

i) **Process Modification :** Often the industrial process can be altered in such a way that the use of raw materials is optimised and the amount of hazardous waste is reduced to barest minimum. For example, in zinc electroplating, the sulphate salt is substituted by the chloride compound with slight modification of the process; this can eliminate the cyanide problem.

ii) **Waste Concentration :** The waste can be concentrated using evaporation, precipitation or decantation techniques which means that the volume of waste can be considerably reduced using these methods. Incineration, viz., oxidation of inflammable waste is often practised in order to reduce the volume of waste to be handled. It is an excellent method of waste disposal, but the cost of operation usually exceeds the net gains. You will read more about incineration in Section 13.4.2.

iii) **Waste Segregation :** Segregating the hazardous waste streams from non-hazardous streams decreases the volume of hazardous wastes, thus, making it easier to treat.

13.3.2 Recycling Industrial Wastes

Many substances in refuse wastes have value. They include glass, wood fibre from paper products, and metal. Scientists have developed ways of recycling many wastes so they can be used again. Almost all materials are recyclable. However, in some more energy will be expended in recovery than the recovered value warrants.

The two broad ways of processing hazardous waste are waste reuse and waste recycling. We shall briefly deal with them.

i) Waste Reuse : In some cases waste material can be used as a raw material with very little processing. Transfer of the waste "as is" without reprocessing, to another facility is known as waste reuse or waste exchange. Unwanted materials of commerce such as outdated chemicals or untested materials not meeting the high quality control requirements of purchasing industry, can be reused without processing. Process wastes such as cardboard for making paper pulp, copper or other metal salt solutions for metal recovery, oils that can be used as fuels. This includes a variety of other materials that can be reused as industrial feed stocks.

ii) **Waste Recycling :** Recycling differs from reuse in that the waste must first be treated before it can be used in a manufacturing process. When a transfer of waste "as is" is not possible, reprocessing the waste for material recovery is known as recycling. For example, baghouse dust from scrap steel processors, containing upto 25 per cent zinc oxide, can be combined with waste sulphuric acid to make galvaniser's pickle acid. The spent pickle liquor containing 8-10 per cent zinc sulphate and some iron salts is then usable as fertiliser in agricultural fields. Use of waste organic solvents is the best example of recycling waste.

SAQ 3

1) Fill in the blanks using appropriate words :

i) Hazardous waste must undergo the following four steps before it can be disposed in an environmentally sound manner.
   a) .....of the quantity of waste
   b) .....of industrial waste
   c) .....of the waste
   d) .....and disposal of waste

ii) Minimisation of the volume of waste is achieved through the following three ways :
   a) ..... modification
   b) ..... of waste and
   c) ..... segmentation.

iii) Transfer of waste "as is" without reprocessing, to another facility is known as waste ..... When a transfer "as is" is not possible, and it needs reprocessing for material recovery before it can be used in factory, then it is known as waste .....

2) State whether the following statements are true or false.

a) The first priority in hazardous waste management is to reduce the quantity of waste to minimum.

b) Incineration is an excellent method of waste disposal but its cost of operation is high.

c) There is no way for effective, cheap and environmentally safe disposal of hazardous wastes.

d) When a waste requires treatment before use it is known as **waste reuse.**

13.3.3 Treatment of Hazardous Wastes

After material recovery, the waste water containing hazardous waste chemicals should be detoxified and neutralised through treatment. There are many technologies available for treating hazardous wastes before they are ultimately disposed of. Their aim is to modify the physical and/or chemical properties of the wastes so that they are rendered harmless. Selection of a treatment process depends on many factors such as the nature of the waste, the desired characteristics of the output stream, and economic and energy considerations. The treatment technologies can be divided into the following groups, namely:

- physical treatment
- chemical treatment
- biological treatment
- solidification, and
- incineration

Physical treatment : is conducted using various methods such as phase separation. Phase separation includes three steps, namely: lagooning, prolonged storage in tanks and sludge drying in beds. Lagooning and tank storage are collectively used to separate particulate impurities. We suggest you to go through "sedimentation" under treatment of sewage discussed in Unit 11 to refresh your memory.

Chemical treatment : is used to facilitate complete breakdown of hazardous wastes and more usually to modify the chemical properties of the wastes, e.g., to reduce water solubility or to neutralise acidity or alkalinity. The techniques involve oxidation, chemical reduction, neutralisation, heavy metal precipitation, oil/water separation and solvents/fuels recovery.

Biological treatment : The gross impurities obtained from treatment of sewage are collectively known as sludge, which is given biological treatment, before disposal. This is known as sludge processing which has become important since improvements in industrial waste water treatment. The typical technologies for sludge processing include conditioning, digestion, composting, thickening or dewatering and solidification.

i) **Conditioning :** In this step the sludge is exposed to atmosphere for a stipulated period until a desired consistency is reached.

ii) **Digestion :** In this process the sludge is treated with bacteria which break down the long chain compounds into simpler ones

iii) **Composting :** In this step the organic matter in the waste sludge is converted into a usable stable material.

Soldification : processes convert the liquid waste into insoluble, rock-hard material and are used as pre-treatment prior to landfill disposal. This is usually done by mixing the waste with various reactants to produce a solid mass. The basic aim of solidification process is to immobilise the hazardous constituents of the waste, so that these do not leach out at the landfill disposal site.

Incineration : Apart from the above mentioned methods incineration is also a method of detoxification, in which oxidation of waste detoxifies the waste from its toxic proportion, about which you will read in section 13.4.2. Incineration, we have already learnt, is a good method of waste minimisation. It is also a method of waste disposal.

13.3.4 Collection, Transport and Disposal

Waste disposal is a multiphase activity, the different stages of which, i.e. collection, interim storage, transport, treatment and disposal are highly interdependent, both technically and organisationally. Safe collection and transport of hazardous waste form a critical link in the chain between its point of generation and its place of treatment and disposal. In many respects, the same precautions apply to hazardous waste in transit as apply to the carriage of dangerous goods; however, additional problems arise from the hazardous nature of certain wastes because:

i) waste in general has no perceptible economic value to the generator;

ii) the chemical and physical properties of a waste may not be precisely known because it is frequently a complex mixture from which all economically useful components have been extracted:

iii) mixing of non-compatible wastes for convenience in transit could create an acute hazard, either immediately or on treatment and disposal (for example, a mixture of ether waste containing a sodium residue with an aqueous ether waste will explode).

Therefore, for a safe and secure disposal of hazardous waste, there should be a proper collection, transport and storage system. The non-compatible wastes should be segregated and transported separately.

SAQ 4

1) Fill in the blanks using appropriate words:

1) i) After material recovery, the waste should be.....and.....through treatment, which means to modify the physical and/or chemical properties of the wastes in such a way that the wastes are rendered.....

ii) Selection of a treatment process depends on many factors such as nature of the wastes, desired characteristics of the..... and economic and ..... considerations.

iii) Physical treatment is conducted using various methods such as phase separation, which includes three steps, namely....., ... in beds and prolonged..... in tanks.

iv) Sludge processing includes,....., ..., ..., ... or dewatering and solidification.

v) Incineration, which is..... of wastes, is another method of detoxification of inflammable wastes. This method minimises the.....of waste to be handled as well.

13.4 DISPOSAL OF HAZARDOUS WASTE

The final disposal of the hazardous wastes also needs to be carefully planned. There are four different ways in which hazardous wastes can be finally disposed.

Landfill disposal.
Incineration.
Dumping at sea
Underground disposal

We shall now discuss each of the above method of disposal of hazardous wastes.

13.4.1 Landfill Disposal

The disposal of hazardous waste by landfilling is an important method of disposal in many countries. Landfilling means storing harmful substances under the ground. This involves hauling the refuse to an area allocated for this purpose. In India such areas range from unsanitary **open dumps** to properly operated **sanitary landfills. Open dumps** are a poor method of waste disposal because they cause environmental problems. For example, they can ruin the appearance of an area and provide a home

for rats and other rodents who spread disease. If garbage is exposed, it rots and smells foul. Most dumps allow some burning, which fills the surroundings with smoke. In addition, rain water can drain through refuse and carry harmful substances to streams.

Properly operated **sanitary landfills** cause little damage to the environment. The area to be filled with waste must be lined with a nonporous substance such as clay, or high density polyethylene (HDPE)—plastic membrane to prevent the wastes from leaking to the surrounding areas. The wastes are packed and dumped at the site and covered with earth each day. They cover of earth prevents insects and rodents from getting into refuse. Operators of these sites forbid burning. In time, sanitary landfill sites become filled up, many communities then cover the site for a final time and use the area for recreational purpose.

A typical landfill site consists of an artificial double liner at the bottom and a cover at the top. The cross section of a conceptual design of a double lined hazardous landfill is shown in Fig. 13.1.

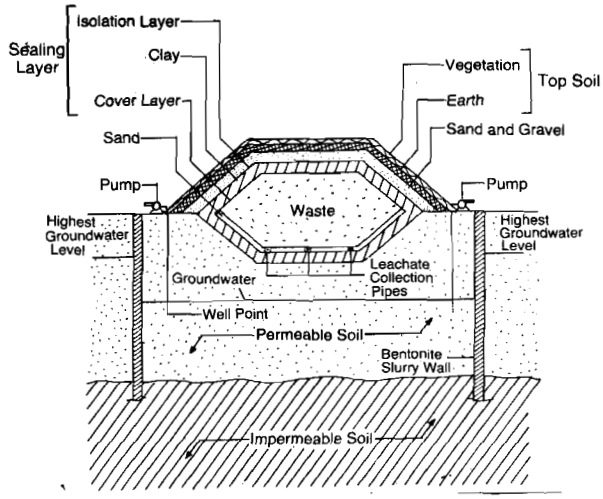


Fig. 13.1 : The outline of a typical landfill site

The above design of landfill site does not have any provision for monitoring and repair of the site. In the recent past, a new concept has developed in which the landfill site is constructed on a structure consisting of concrete cells. The cell is a space for plant personnel to visit and observe any fault and repair the same. The design of such a landfill known as highly secure landfill, is shown in Fig. 13.2

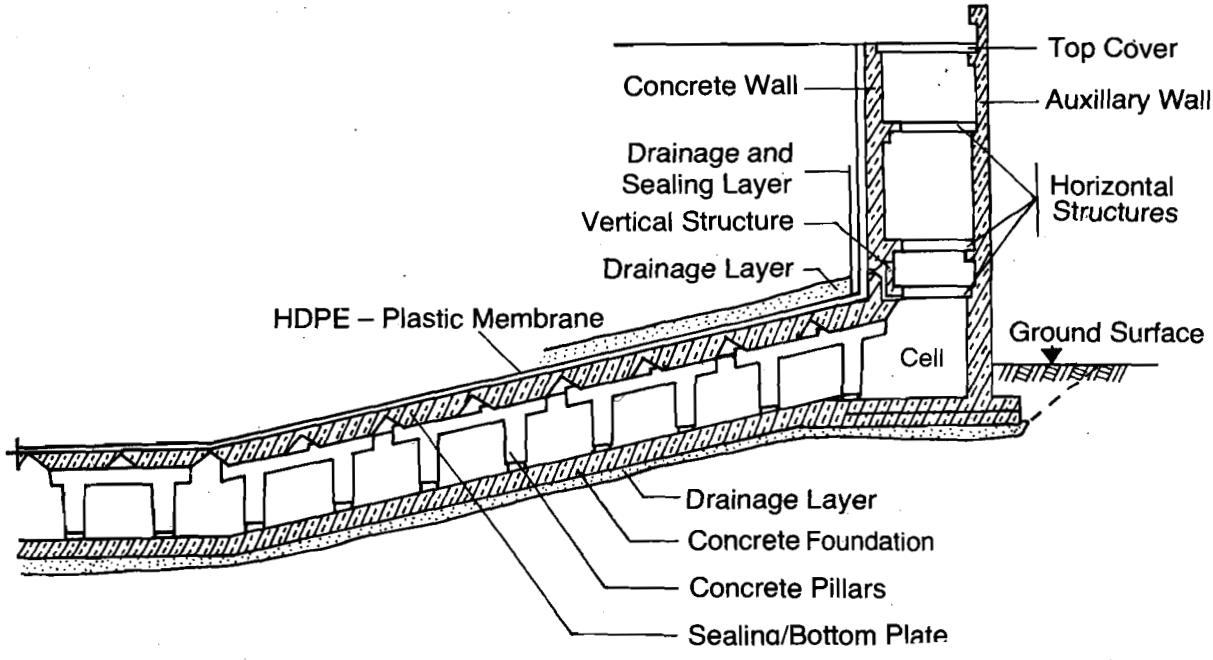


Fig. 13.2 The design of a highly secure modern landfill site

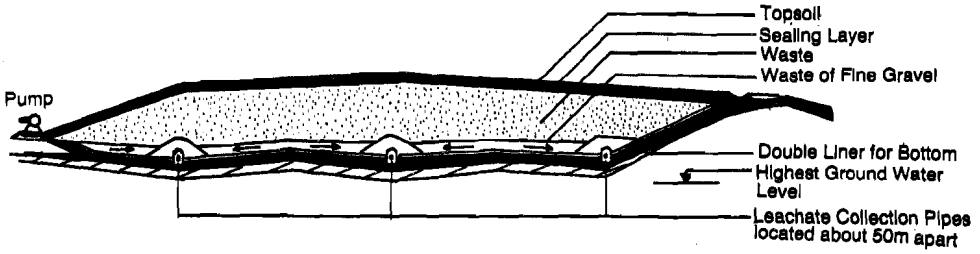


Fig. 13.3 The final shape of a site after years of landfilling

After years of landfilling the final shape of the land looks something like in Fig. 13.3.

13.4.2 Incineration

Incineration burns waste products. This is another method many industries and large cities use if they do not have enough vacant areas for disposal sites nearby. Most hazardous wastes are detoxified in this process. This is also an excellent method of waste minimisation, waste detoxification and disposal, but its cost of operation is very high, if the heat content of waste is not reutilised.

The selection of incineration depends on the type and characteristics of the waste. A typical incinerator consists of a combustion chamber, burner chamber, precooler, scrubber, exhaust fan and stack to let out the gases Fig 13.4.

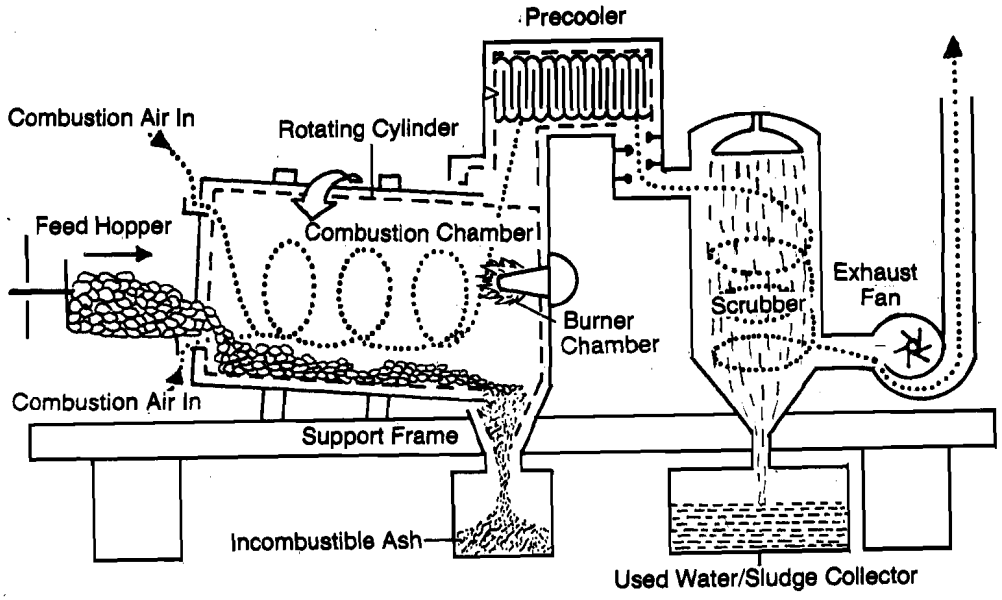


Fig. 13.4 A typical hazardous waste incineration unit

Advantages

Incineration is a process for the high-temperature oxidation of gaseous, liquid or solid wastes, converting them into gases and an incombustible residue. The flue gases are released to the atmosphere with or without recovery of heat and with or without cleaning; and any slag or ash produced is deposited in a landfill. In general, incineration may be considered as an alternative method of detoxifying some non-recoverable highly toxic wastes. It is an excellent method of reducing waste volume, and in addition offers the possibility for recovering the heat content of the waste. In some communities heat from municipal waste incineration is used to produce steam. This steam drives turbines that produce electric power. Recyling of heat thus reduces the cost of operation of incinerators.

Waste Input

Generally, the wastes having inflammable characteristics are incinerated. The following types of wastes are commonly treated in hazardous waste incinerators:

- Solvent waste and sludges
- Waste mineral oils
- Varnish and paint wastes and sludges
- Plastics, rubber and latex waste sludges and emulsions
- Oils, emulsions and oil/water mixtures
- Phenolic wastes
- Mineral oil sludges
- Resin waste
- Grease and wax wastes
- Pesticide wastes
- Acid tar and spent clay
- Organic wastes containing halogen, sulphur or phosphorus compounds.

Wastes having high chlorine, sulphur, nitrogen and phosphorus contents, polychlorinated biphenyls (PCB) and those containing heavy metals and carcinogenic substances need special incineration technologies and precautions. A large number of municipal incinerators lack adequate air pollution control devices. Burning in many of these devices may release gases and solid particles that may harm human health, damage property and kill plants. The flue gases from ordinary incinerators can be dangerous in the absence of pollution control devices. Furthermore, as you have read earlier, incineration sometimes becomes a costly affair.

13.4.3 Dumping at Sea

Another method of disposal of hazardous wastes involves dumping wastes at deep sea, designed to prevent contamination of groundwater.

Disposal at sea, of waste generated on land, is based on the misconceived notion that the enoromous volume of water available for dilution, enables the seas to be used as a dump without permanent damage. However, this is an erroneous conviction. The decision to choose this method of disposal is generally based on financial considerations. The site of disposal is determined by the geographical location of the waste producer.

Disposal of waste at sea is controlled by international legislation and by the national legislation required for the ratification of the international legislation. To prevent pollution of the seas by the direct discharge of waste, the international legislation bans the dumping of extraordinarily hazardous wastes such as organic silicon compounds, halogenated organics, mercury and its compounds, cadmium, carcinogenic waste and plastics into the sea. The last of these can seriously disturb fishing and navigation. You have already read in Unit 11 about the eruption of "minamata" disease among Japanese Fishermen resulting from disposal of industrial wastes at sea.

13.4.4 Underground Disposal

It may be excessively expensive to dispose off certain hazardous wastes, such as radioactive nuclear wastes, in an environmentally acceptable manner at landfill still sites or incinerate them at thermal treatment plants. These wastes are generated in all operations associated with the use of nuclear energy for national defence or peaceful purposes such as mining of radioactive ore, production of nuclear fuel, laboratory experiments and medical treatment. Underground disposal may provide an environmentally and economically viable option in case of radioactive wastes. The underground disposal of hazardous waste is acceptable only in inactive or partially active mines that meet specific geological and technical criteria. Worldwide, only one deep-mine disposal facility is currently in operation: a worked-out halite/potash salt mine at Herfa Neurode in the Federal Republic of Germany (now united Germany).

Salt mines are often used for **radioactive waste disposal** because the excellent properties of salt deposits prevent the interaction of wastes with other geological formations. The very existence of a salt deposit is a proof that the underground site has been unaffected by water for millions of years. Salt is impermeable to liquids and gases. Due to its hygroscopic nature, salt is capable of absorbing water entering the formation from outside and of repairing minor fractures by recrystallisation, thus maintaining the original impermeability. This feature is frequently supplemented by impermeable upper strata consisting of wastes, usually rock, from mines or other industries. The atmosphere in salt mines is extremely dry, so metal equipment and

containers do not rust. There is no risk of methane explosions as in coal mines. Bursting of carbon dioxide gas inclusions in the salt mines may be observed during excavation of rocks but this does not pose a risk, particularly after mining operations have ceased. Thermal conductivity of salt is good. Salt is strong, permitting the excavation of spacious, stable galleries. In addition, salt has a certain plasticity under pressure, allowing the dispersion of strain and increasing the overall stability.

Thus, in principle you have learnt that there are four methods of waste disposal.

i) Landfilling of solid wastes
ii) Incineration of inflammable organic wastes
iii) Dumping of wastes at sea, and
iv) Underground disposal usually of radioactive wastes.

You will see in the coming sub-sections as to how these methods are actually practiced under field condition.

SAQ 5

1) Fill in the blanks using appropriate words:
   i) Problems of hazardous waste disposal arise from the fact that (a) waste in general has no perceptible.....value to the generator; (b) the chemical and physical.....,.. may not be known; and (c) mixing of ..... wastes for convenience could create an acute hazard.
   ii) Insanitary open dumps are a poor method of waste disposal because they provide home for.....; garbage rots and smells.....; burning of garbage fills the surroundings with.....; and rain water may carry..... substances to streams.
   iii) Properly operated sanitary.....cause no damage to the environment. The area to be filled with waste must be lined with.....substance such as clay or HDPE—polyethylene membrane, to prevent the waste from.....to the surrounding areas.
   iv) Salt mines are often used for radioactive waste disposal because salt is.....to water and is hygroscopic and is able to.....minor fractures by recrystallisation. The atmosphere inside salt caverns is dry, so metal containers do not..... In addition, salt has a certain .....allowing overall stability of disposal site.

13.5 HAZARDOUS WASTE MANAGEMENT IN INDIA

We would now briefly discuss generation and disposal of hazardous waste in India.

13.5.1 Sources of Waste Generation

In general, hazardous waste generation can be broadly grouped into two categories, viz., Process-oriented and Pollution Control-oriented. The process-oriented waste is generated during the processing of raw materials to get the finished products; while pollution control-oriented waste originates from the treatment of gaseous and liquid effluents.

The magnitude and characteristics of industrial hazardous waste is dependent on various factors—for example, size of the unit, production technologies, process efficiency and raw materials processed. In India, there are industries generating large quantities of solid waste with relatively less concentration of hazardous constituents, (e.g., metallurgical industry like iron and steel, fertilisers, thermal power stations, etc.). On the other hand, there are other groups of industries dealing with pesticides, electroplating, metal finishing, chlor-alkali, photographic chemicals, etc. which generate comparatively less quantity of solid waste but with high concentration of toxic and hazardous constituents. The later type of wastes require special handling, storage, treatment and disposal techniques.

Nearly 15 per cent of the total solid waste generated by the industries, comes under the hazardous waste category. Though hazardous wastes account for a small

proportion of all wastes, their impact can be disastrous as they not only seriously affect the environment but also endanger the human health through inclusion in the food chain.

13.5.2 Prevalent Methods of Disposal

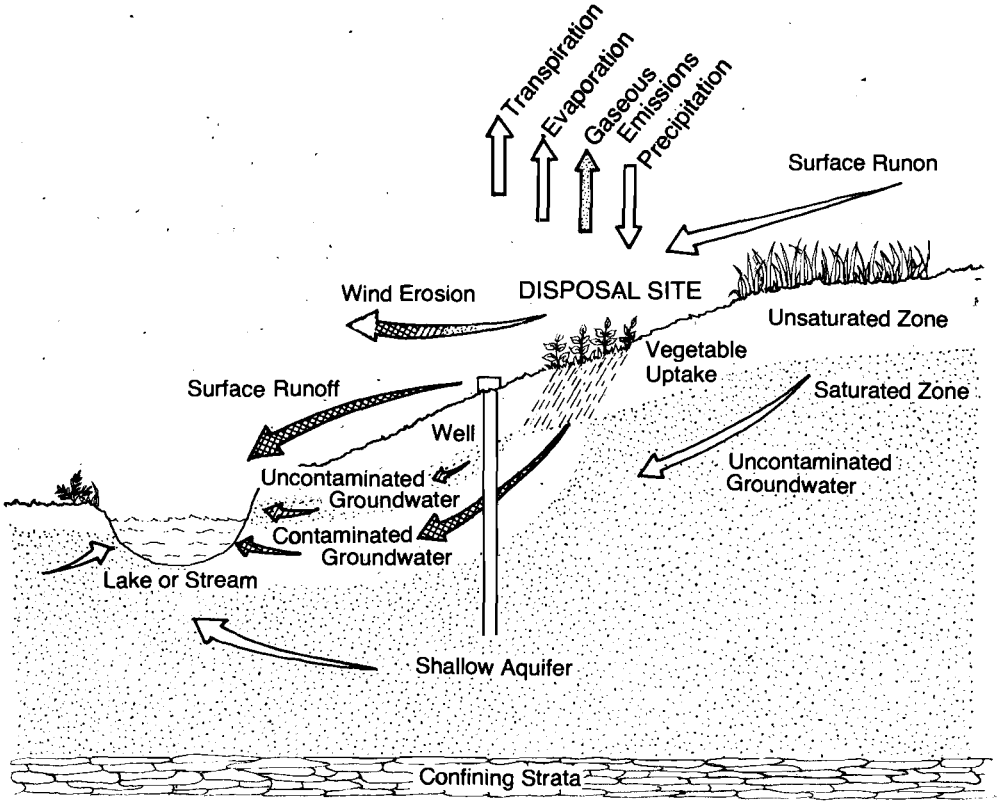
In the absence of proper regulatory control over handling, treatment and disposal, the hazardous wastes are mostly disposed wherever the space is easily available and accessible to the waste generators. Presently, the following methods of disposal of hazardous industrial wastes are followed in our country:

- Disposal along with city refuse
- Disposal on river beds and banks
- Open-pit burning
- Disposal in low lying areas, estuaries and seas
- Burning in self-designed incinerators.

Most of the heavy metal bearing and highly toxic wastes containing as pesticides, solvent distillates, phenolics, cyanide waste, etc. are being disposed off using above mentioned methods. From the standpoint of impact what is significant is the method of disposal and the compatibility and complex interaction of these wastes with the receiving environment, a proper evaluation of which is not available in India. Let us see what are the harmful effects of disposal of wastes in an improper way.

13.6 EFFECTS OF IMPROPER WASTE DISPOSAL

Improper disposal of hazardous waste causes adverse effects on human health and the environment. The normal practices of waste disposal such as insanitary open dump, landfilling, discharge in water courses, or open-pit burning will need modification when dealing with hazardous wastes. The principle hazard of improper waste disposal is contamination of soil and groundwater. This arises largely from the waste containing hazardous substances deposited in landfills or on the ground. Fig. 13.5 illustrates in a simplified manner the mechanisms through which hazardous substances can enter the human environment after being "disposed of" in a landfill.



With regard to hazardous waste disposal sites, atleast five different routes of human exposure are possible:

i) direct ingestion through drinking

ii) inhalation of contaminants that volatilise from heated water

ii) absorption through the skin during washing and bathing

iv) ingestion through consumption of goods derived from plants or animals exposed to polluted groundwater, and

v) absorption through the skin when handling contaminated soil.

A worldwide awareness has been created amongst the public against the improper and uncontrolled dumping of hazardous wastes. Such practices have brought about the death of livestock and ill-health in humans. Some of the examples of improper disposal of hazardous wastes are given below.

During the seventies more than 250 houses were built in the Netherlands in the municipality named Lekkerkerk on a belt where hazardous and toxic waste had been dumped. After nearly ten years, the ill effects of dumped hazardous waste were noticed by the residents of that area and about 150,000 tonnes of the polluted soil had to be dug out and disposed of. The total cost of the remedial action was about 200 million Dutch guilders.

In Japan, zinc mining industry at Kamioka discharged effluents containing toxic material without treatment into the Zintsu River. Water from the river was, and continues to be, used for drinking and irrigation. In 1919, a thirty-five year old patient is said to have exhibited symptoms similar to those of Itai-Itai disease, which is now known to be caused by **cadmium** poisoning. In 1955, Itai-Itai disease was reported to the Society of Medicine, yet only in 1963 did the Ministry of Public Health and Welfare organise a survey committee on this pollution associated disease. It took another ten years before the Japanese Government announced official findings on Itai-Itai disease, linking it to health damage caused by **cadmium**

In another case, in Hamburg city of West Germany, during 1935 to 1971, about 150,000 m^3 of waste oil as liquid chemical waste and 50,000 drums of solid chemical waste was dumped alongwith the city refuse in Georgswerder landfill site. The total area of the site is about 42 hectares and it is 40 m high. In 1983, **dioxine** was identified in the oily leachate from the landfill site. The cleaning up cost of this site would be more than 100 million Deustche Mark.

One of the most alarming case came into limelight in 1988 when village Bichhri of Udaipur district suffered a heavy toll because of water pollutants released from Silver Chemicals Factory. The water has become red all over from the dye stuff waste released by the factory. Drinking this water causes vomitting. It is worthless for all irrigation purposes. Grass can't grow near the pools containing this water. Today, in December 1990, the water continues to be contaminated, as the amount of pollutants is virtually 1.5 lakh times the standards of safety prescribed by an Aligarh Muslim University study. According to the Observer, the authorities have sued the culprits but procedures of court are too long to provide instant respite to residents of Bichhri village.

Cyanide is one of the raw materials used for electroplating and heat treatment operations of metals. The waste generated as sludge from these operations contains high concentration of cyanide.

A considerable number of large and small scale units, using cyanide as raw material, are located near Madras. Since at present, there is no control over the disposal of hazardous wastes, they are being disposed off indiscriminately. Recently, on 21 August 1989, an incident of cyanide dumping has come to light in Madras with the death of a number of buffaloes. Based on the police reports, the Tamil Nadu Pollution Control Board served a show cause notice to M/s. T. I. Cycles in Madras. After investigations, it was traced that the unit in question had dumped their cyanide bearing waste near Ezhilnagar canal. This resulted in pollution of canal water and subsequently the death of buffaloes confirmed that the death was due to cyanide contamination. The unit has, however, admitted that they had handed over vast

quantities of cyanide waste to the contractor for dumping into the sea at a specified distance of 7 kilometer from the sea shore. The contractor dumped the waste on Ezhilnagar canal bank. An analysis of canal water showed that the cyanide content was as high as 210 milligrams per litre. Since the canal passes through a low income group colony, the pollution of canal water could have resulted in loss of human life, had it gone undetected.

SAQ 6

1) Fill in the blanks using appropriate words:

i) Presently, the principle methods of industrial waste disposal in our country are:
   a) Disposal along with.....
   b) Disposal in..... areas
   c) Disposal in river beds and.....
   d) Disposal into..... and sea
   e) ..... burning
   f) Burning in self-designed.....

ii) The principle hazard of improper waste disposal is the contamination of..... and .....

iii) Some wastes pollute rivers or lakes and others contaminate..... and poison people.

iv) Certain harmful wastes may pollute the..... or create a..... hazard.

13.7 SUMMARY

In this unit we have learnt that:

- As a basic principle, hazardous wastes should be so managed that adverse effects to the welfare of the community are minimised.
- Wastes can be reused or recycled, in order to minimise the volume of waste to be disposed. Toxic waste must be treated before disposal. This can be done using chemical, physical or biological means. After detoxification, the waste should be carefully transported avoiding mixing of non-compatible chemicals.
- This follows disposal of waste into a properly operated sanitary landfill. The waste can also be incinerated or dumped in underground salt mines.
- We have also learnt about the harmful effects of improper disposal of wastes in India as well as in other countries.

13.8 TERMINAL QUESTIONS

1 What is the difference between Toxic and Hazardous Wastes?

2 State if the following statements are True or False.
   i) Toxic refers to an extrinsic property.
   ii) Exclusive list system of waste classification has been followed in most of the countries.
   iii) Oily sludge has to be landfilled.
   iv) Hospital waste has to be incinerated.
   v) Pollution control facilities do not generate hazardous waste.

3 Explain exclusive list system of waste classification.

4 What strategy should be adopted for hazardous waste management?

5 State the kind of chemical wastes which need special kinds of technologies if they are to be incinerated.

6 Give one example each of waste reuse and waste recycle.

7 Name seven sources and list their activities generating wastes.

13.9 ANSWERS

Self Assessment Questions

1) i) mutagenic, teratogenic, carcinogenic
   ii) a) ignitability, b) corrossiveness, c) reactivity, d) radioactivity, e) toxicity
   iii) a) Mortality, irreversible, reversible
   b) potential, treated, stored, disposed

2
a) i) Waste classification
   ii) fourteen
   iii) toxic, hazardous
   iv) pure component, eighteen

b) i) c)
   ii) e)
   iii) d)
   iv) a)
   v) b)

3
a) i) minimisation, recycling, treatment, collection, transport
   ii) process, concentration, waste
   iii) reuse, recycling

b) i) True
   ii) True
   iii) False
   iv) False

4 i) detoxified, neutralised, harmless
   ii) output stream, energy
   iii) lagooning, sludge drying, storage
   iv) conditioning, digestion, composting, thickening
   v) oxidation, volume

5 i) economic, properties, non-compatible
   ii) home, foul, smoke, harmful
   iii) landfills, non-porous, leaking
   iv) impermeable, repair, rust, plasticity

6 i) city refuse, low-lying, banks, estuaries, open-pit, incinerators
   ii) soil, groundwater
   iii) food
   iv) air, fire

Terminal Questions

1) **Toxic** refers to the capacity of a substance to produce injury, kill or impair an organism while **hazardous** refers to the probability that injury will result from the use of the substance.

2) i) False
   ii) True
   iii) False
   iv) True
   v) False
   vi) False

3) In exclusive list system of waste classification, only groups of non-hazardous wastes have been listed by intuition. The wastes which do not fall under this category have been designated as hazardous wastes.

4) For an effective hazardous waste management system, the following strategy has to be adopted.

i) Minimisation of hazardous waste generation by using low-waste or non-polluting technologies.
ii) The possibility of reusing the generated waste, either as raw material or for recovery of valuable products should be investigated before its ultimate disposal is considered.
iii) The waste should be detoxified or neutralised through physical, chemical, biological treatment or sludge processing and solidification.
iv) The unavoidable hazardous waste should be segregated from the non-hazardous ones and collected and stored separately. Finally, the hazardous wastes should be disposed off properly in a secured landfill site.

5) Wastes having chlorine, sulphur, nitrogen and phosphorus contents, polychlorinated biphenyls and those containing heavy metals and carcinogenic substances need special incineration technologies with due precautions.

6) Process wastes such as waste card board can be **reused** in paper industry for making paper pulp. An example of waste **recycle** is as follows. Baghouse dust from scrap steel process can be chemically reacted with waste sulphuric acid to make a useful fertiliser which is technically known as spent pickle liquor.

Appendix I : Generic Types of Wastes

S. No.	Wastes which consist of
1.	Anatomical substances; hospital and clinical wastes
2.	Pharmaceuticals, drugs, medicines and veterinary compounds
3.	Wood preservatives
4.	Biocides and phyto-pharmaceutical substances
5.	Residues from substances employed as solvents
6.	Halogenated organic substances not employed as solvents
7.	Tempering salts containing cyanides
8.	Mineral oils and oily substances i.e., cutting sludges
9.	Oil/water emulsions, hydrocarbon/water mixtures
10.	Substances containing PCBs and/or PCTs, e.g.,dielectrics
11.	Tarry materials arising from refining, distillation and any pyrolytic treatment, e.g. still bottoms
12.	Inks, dyes, pigments, paints, lacquers, varnish
13.	Resins, latex, plasticisers, glues/adhesives
14.	Chemical substances arising from research and development or teaching activities which are not identified and/or are new and the effects of which on man and/or the environment are not known, e.g., laboratory residues
15.	Pyrotechnics and other explosive materials
16.	Photographic chemicals and processing materials
17.	Any material contaminated with polychlorinated dibenzofuran
18.	Any material contaminated with any congener of polychlorinated dibenzofuran
19.	Animal or vegetable soaps, fats, waxes
20.	Non-halogenated organic substances not employed as solvents
21.	Inorganic substances without metals
22.	Ashes and/or cinders
23.	Soil, sand, clay including dredging spoils
24.	Non-cyanidic tempering salts
25.	Metallic dust, powder
26.	Spent catalyst materials
27.	Liquids or sludges containing metals
28.	Residue from pollution control operations
29.	Decarbonisation residues

30. Ion-exchange residues
31. Residue from cleaning of tanks and/or equipment
32. Contaminated containers containing hazardous and toxic chemicals
33. Batteries and other electrical cells
34. Vegetable oils, household wastes
35. Materials which have been segregated from household wastes and which exhibit any of the hazardous characteristic such as radioactivity, non degradability.

Appendix II : Categories of Hazardous Wastes Recognised by Government of India

Waste Categories	Types of Wastes	Regulatory Hazardous Quantities
Waste Category No. 1	Cyanide wastes	1 kg./yr. calculated as cyanide
Waste Category No. 2	Metal finishing wastes	10 kg/yr. the sum of the specified substance calculated as pure metal
Waste Category No. 3	Waste containing water soluble chemical compounds of lead, copper, zinc, chromium, nickel, selenium, barium and antimony	10 kg/yr. the sum of the specified substance calculated as a pure metal
Waste Category No. 4	Mercury, arsenic, thallium and cadmium bearing wastes	5 kg/yr. the sum of the specified substance calculated as pure metal
Waste Category No. 5	Non-halogenated hydrocarbons including solvents	200kg/yr. calculated as non-halogenated hydrocarbons
Waste Category No. 6	Halogenated hydrocarbons including solvents	50kg/yr. calculated as halogenated hydrocarbons
Waste Category No. 7	Wastes from paints, pigments, glue, varnish and printing ink	250kg/yr. calculated as oil or oil emulsions
Waste Category No. 8	Wastes from dyes and dye intermediates containing inorganic chemical compounds	200kg/yr. calculated as inorganic chemicals
Waste Category No. 9	Wastes from dyes and dye intermediates containing organic chemical compounds	50 kg/yr calculated as organic chemicals
Waste Category No. 10	Waste oil and oil emulsions	1000 kg/yr calculated as oil and oil emulsions
Waste Category No. 11	Tarry wastes from refining and tar residues from distillation of pyrolytic treatment	200 kg/yr calculated as tar
Waste Category No. 12	Sludges arising from treatment of waste water containing heavy metals, toxic organic, oils, emulsions and spent chemicals including incineration ash	Irrespective of any quantity
Waste Category No. 13	Phenols	5 kg/yr calculated as phenols
Waste Category No. 14	Asbestos	200 kg/yr calculated as asbestos
Waste Category No. 15	Waste from manufacturing of pesticides and herbicides and residues from pesticide and herbicide formulation units	5 kg/yr calculated as pesticides and their intermediate products
Waste Category No. 16	Acid/alkaline/slurry wastes	200 kg/yr calculated as acids/alkalies
Waste Category No. 17	Off-specification and discarded products	Irrespective of any quantity
Waste Category No. 18	Discarded containers and container liners or hazardous and toxic chemical radioactive wastes	Irrespective of any quantitiy

GLOSSARY

Abattoir : Slaughterhouse waste

Albedo : The proportion of solar light which is reflected from the atmosphere and surface of a planet back into space.

Aleveoli (sing. alveolus) : Small, thin-walled membranous sacs covered with a network of capillaries, found in the lungs.

Antiknock agent : Substances added to gasoline in small (below 1%) amounts to prevent explosive combustion (knocking). The most familiar of these is tetraethylead, $Pb(C_2H_5)_4$, TEL.

Automobile exhaust : A stream of used-up fluid from an engine.

Bay : A partially enclosed inlet of the ocean.

Biological control : Reduction or control of a pest by introducing a suitable predator into its habitat, e.g. the control of the greenhouse white fly *Thriaeurodes* by the minute chalcid chalcid wasp *Encarsia*. The use of a predator to control the population of pathogen another animal which is a pest.

Biological magnification : Increase in concentration of chemicals in the bodies of animals with increasing trophic level.

Bronchitis : Inflammation of bronchii, the branches of trachae, the wind pipe.

Coli count : The number of *E.coli* bacteria in a unit volume of water, used as an indicator of fecal pollution of water.

Composting : Biological oxidation of organic waste sewage, to render the waste harmless.

Conditioning : Exposure of industrial waste, sludge for a stipulated time until the desired consistency is reached.

Contour : (1) An imaginary line on the surface of the earth connecting points of same elevation. (2) A line drawn on a map to show the location of points of the same elevation. A series of contour lines on the map shows the topography of the land.

Cover crops : Those crops which are grown primarily to cover the soil and to reduce the loss of moisture due to leaching and erosion by wind and water. Many a times such crops are not harvested.

Denudation : Refers to the sum total of the processes which cause general lowering of the land surface. It involves the process of weathering, transportation and erosion.

DOM : Abbreviation for dissolved organic matter.

Electroplating : A group of methods employed for the deposition of a protective metal layer on metal articles using electrolysis of an aqueous solution of metal salt.

Emulsion : A liquid with microscopic particles of another liquid suspended in it. For example, milk is a suspension of fat particles in water. Emulsions play an important role in manufacture of soap, in the food industry (butter, margarine) in the processing of natural rubber, in the manufacture of various lubricants, in medicine, in painting, etc.

Equilibrium : A system is said to be in equilibrium if a number of forces acting on it produce no change in its functional state.

Estuaries : A partially enclosed coastal embayment where fresh water and seawater meet and mix.

E.coli : *Eschaerichia coli,* a bacterium inhabiting the mammalian colon.

Eutrophic : Containing abundant nutrient material.

Exploitative interaction : Struggle among different species or members of the same species for a necessary resource that is in short supply.

Fault : Fracture in rock along which the adjacent rock surface have been differentially placed.

Galvanisation : A method of depositing a protective layer on metal articles using molten metal.

Lagoon : Large outdoor basin for holding industrial waste sludge.

Lagooning : Storage of untreated industrial waste water in lagoons.

Land capability : Suitability of land for use without damage.

Larynx : The part of the throat containing the vocal chords.

Leaching : Dissolution of soluble constituents of a soil mass by liquid water.

Melanoma : Skin disease

Mobility of Metals : Refers to extraction of soluble metals or salts from a soil mass by percolating water.

Mutagen : Any chemical substance or physical agent (e.g. atomic radiations) capable of inducing inheritable genetic change.

Octane number : A number indicating the degree of knocking of light motor fuels (petrol) used in internal combustion engines, measured with reference to standard mixtures of iso octane (octane number 100) and n-heptane (octane number 0) taken in ratios from 100:0.

Pathogen : (Adjective Pathogenic)—a microbe that causes disease. It is impracticable to test water for all possible pathogens and most of them are less likely to survive outside the body than *Escherichia coli,* consequently its absence is taken to show that pathogens are also absent.

Pathogenic : Capable of causing disease.

Percolation : Downward movement of water through the soil. Percolation occurs predominantly in downward direction.

Pickling of metals : A method of dipping the metal ware in mild acid to prepare it for cleaning its surface.

Plasticisers : A non-volatile organic solvent forming gels with materials to which it is added. Used to decrease the temperature of softening (vitrification) of polymer materials, increase their elasticity and resistence to breakage. They are mainly used in manufacture of plastics, rubbers, synthetic leather, laquers and dyes. The most familiar plasticisers are esters of phthalic acid, esters of phosphoric acid, various oils.

Pneumatic drill : A drill operated by force of movement of air.

Preservative : Substance which prevents bacterial action, mold growth, fermentation or decomposition.

Pyrolysis (pyr, a fire) : Splitting of complex organic molecules into similar ones at high temperatures. Pyrolysis includes thermal decomposition, but it may also include condensation, isomerisation and like processes. The term is usually referred to cooking of petroleum at about 700c in the absence of air and often in the presence of catalysts; pyrolysis also occurs in destructive distillation of wood, peat and bituminous coal (coking).

Pyrotechnics : Techniques involving pyrolysis of matter.

Rivetting : Construction of concrete walls to avoid soil erosion.

Smouldering : To burn slowly without flame.

Soil profile : The strata of a seasoned soil, which have been climate controlled and fully developed so as to be inequilibrium with the weathering regime. Succession of horizons as viewed in the exposed anatomy of the soil body. Vertical section of the soil from the surface through all its horizons into the spray.

Species diversity : In ecology, a numerical measure counting the number of species in an area with their relative abundance.

Strip cropping : Growing of a soil exposing and erosion permitting crop in strips of suitable widths across slopes on the level or contour, alternating with strips of soil protecting and erosion resisting crops.

Succession : the process of community change through time.

Tar : A liquid product obtained by the destructive distillation of coal, lignite, wood and shale.

Tempering : Process of annealing in which the hardened metal is heated a second time, to a temperature below the critical and then cooled. In metal casting technique, the addition of water to molding sand mixtures.

Terracing : Terrace consists of a series of platforms along contours, cut into hill slope in a step like formation. These platforms are separated at regular intervals by vertical drops or by steep sides and protected by vegetation and sometimes by packed stone retaining walls.

Turbidity : Condition of reduced visibility in water due to presence of suspended particles.

Weathering : The term used for wearing down of a land mass by wind, precipitation, living agents and chemical action, an important feature of the process is that it affects land mass *in situ,* and no transportation takes place. This factor distinguishes it clearly from erosion.

Further Readings

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