MODULE 1

Pollution

Pollution is defined as the presence of impurities or pollutant substances in sufficient concentration levels, causing harmful effects on human beings, animals, plant life or material resources when exposed for a sufficient duration of time, thus reducing quality of life in the environment.

Environmental Pollution

Environmental Pollution is thus defined as "any undesirable change in the physical, chemical or biological characteristics of any component of the environment (air, water, soil) which can cause harmful effects in various forms of life or property."

Different types of pollution are as follows

1. Air Pollution

Air pollution may be defined as the presence of one or more contaminants in the air in large quantities and for long durations which may be or tend to be injurious to human, animal, plant life, or property, or which unreasonably interferes with the comfortable usage of air.

2. Water pollution

Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans and groundwater), very often by human activities. It occurs when pollutants (particles, chemicals or substances that make water contaminated) are discharged directly or indirectly into water bodies without enough treatment to get rid of harmful compounds.

3. Soil/Land Pollution

Soil contamination occurs when chemicals are released by spill or underground leakage. It can also occur by directly dumping and disposal of wastes. Among the most significant soil contaminants are hydrocarbons, heavy metals, herbicides, pesticides and chlorinated hydrocarbons.

4. Noise Pollution

Noise pollution is the disturbing or excessive noise that may harm the activity or balance of human or animal life. The source of most outdoor noise worldwide is mainly caused by

machines and transportation systems, motor vehicles, aircraft, and trains. Outdoor noise is summarized by the word environmental noise.

6. Radiation pollution

Radiation pollution can be defined as the release of radioactive substances or high-energy particles into the air, water, or earth as a result of human activity, either by accident or by design.

7. Thermal pollution

Thermal pollution is defined as sudden increase or decrease in temperature of a natural body of water which may be ocean, lake, river or pond by human influence. This normally occurs when a plant or facility takes in water from a natural resource and puts it back with an altered temperature.

8. Industrial pollution

Industrial pollution is generally referred to the undesirable outcome when factories (or other industrial plants) emits harmful by-products and waste into the environment such as emissions to air or water bodies (water pollution), deposition on landfills etc. (land pollution) or emission of toxic chemicals into the atmosphere (air pollution).

Types of Sources:

1. Point source

Single, identifiable source

E.g. smokestack, drainpipe etc.

2. Non-point source

Dispersed source,

E.g. runoff from pesticides, fertilizers

CARBON MONOXIDE (CO)

pollutant	sources	effects
Carbon monoxide. A gas that comes from the burning of fossil fuels, mostly in cars. It cannot be seen or smelled.	Carbon monoxide is released when engines burn fossil fuels. Emissions are higher when engines are not tuned properly, and when fuel is not completely burned. Cars emit a lot of the carbon monoxide found outdoors. Furnaces and heaters in the home can emit high concentrations of carbon monoxide, too, if they are not properly maintained.	Carbon monoxide makes it hard for body parts to get the oxygen they need to run correctly. Exposure to carbon monoxide makes people feel dizzy and tired and gives them headaches. In high concentrations it is fatal. Elderly people with heart disease are hospitalized more often when they are exposed to higher amounts of carbon monoxide.

NITROGEN DIOXIDE ($N0_2$)

pollutant	sources	effects
Nitrogen dioxide. A reddish-brown gas that comes from the burning of fossil fuels. It has a strong smell at high levels	Nitrogen dioxide mostly comes from power plants and cars. Nitrogen dioxide is formed in two ways—when nitrogen in the fuel is burned, or when nitrogen in the air reacts with oxygen at very high temperatures. Nitrogen dioxide can also react in the atmosphere to form ozone, acid rain, and particles	High levels of nitrogen dioxide exposure can give people coughs and can make them feel short of breath. People who are exposed to nitrogen dioxide for a long time have a higher chance of getting respiratory infections. Nitrogen dioxide reacts in the atmosphere to form acid rain, which can harm plants and animals.

SULPHUR DIOXIDE (SO_2)

pollutant	sources	effects
Sulfur dioxide. A corrosive gas that cannot be seen or smelled at low levels but can have a "rotten egg" smell at high levels.	Sulfur dioxide mostly comes from the burning of coal or oil in power plants. It also comes from factories that make chemicals, paper, or fuel. Like nitrogen dioxide, sulfur dioxide reacts in the atmosphere to form acid rain and particles.	Sulfur dioxide exposure can affect people who have asthma or emphysema by making it more difficult for them to breathe. It can also irritate people's eyes, noses, and throats. Sulfur dioxide can harm trees and crops, damage buildings, and make it harder for people to see long distances.

Ambient Air Quality Standards in India

From Arthapedia

Ambient air quality refers to the condition or quality of air surrounding us in the outdoors. National Ambient Air Quality Standards are the standards for ambient air quality set by the Central Pollution Control Board (http://cpcb.nic.in/) (CPCB) that is applicable nationwide. The CPCB has been conferred this power by the Air (Prevention and Control of Pollution) Act, 1981.

Ambient Air Quality Standards in India

The Air (Prevention and Control of Pollution) Act 1981 (http://www.envfor.nic.in/legis/air/air1.html) was enacted by the Central Government with the objective of arresting the deterioration of air quality. The Air (Prevention and Control of Pollution) Act 1981 describes the main functions of the Central Pollution Control Board (CPCB) as follows:

- To advise the Central Government on any matter concerning the improvement of the quality the air and the prevention, control and abatement of air pollution.
- To plan and cause to be executed a nation-wide programme for the prevention, control and abatement of air pollution.
- To provide technical assistance and guidance to the State Pollution Control Board.
- To carry out and sponsor investigations and research related to prevention, control and abatement of air pollution.
- To collect, compile and publish technical and statistical data related to air pollution; and
- To lay down and annul standards for the quality of air

The mandate provided to the CPCB under the Air (Prevention and Control of Pollution) Act empowers it to set standards for the quality of air.

The current National Ambient Air Quality Standards were notified on 18 November 2009 (http://www.cpcb.nic.in/upload/Latest/Latest_48_FINAL_AIR_STANDARD.pdf) by the Central Pollution Control Board.

Table 1: National Ambient Air Quality Standards

Pollutant	**Time Weighted Average**	**Concentration in Ambient Air**	
		Industrial, Residential, Rural and Other Areas	**Ecologically Sensitive Area (notified by Central Government)**
Sulphur Dioxide (SO_2), µg/m^3	Annual* 24 hours**	50 80	20 80
Nitrogen Dioxide (NO_2), µg/m^3	Annual* 24 hours**	40 80	30 80

Particulate Matter (size less than 10 µm) or PM_{10} µg/m^3	Annual* 24 hours**	60 100	60 100
Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$ µg/m^3	Annual* 24 hours**	40 60	40 60
Ozone (O_3) µg/m^3	8 hours* 1 hour**	100 180	100 180
Lead (Pb) µg/m^3	Annual* 24 hours**	0.50 1.0	0.50 1.0
Carbon Monoxide (CO) mg/m^3	8 hours* 1 hour**	02 04	02 04
Ammonia (NH_3) µg/m^3	Annual* 24 hours**	100 400	100 400
Benzene (C_6H_6) µg/m^3	Annual*	5	5
Benzo(a)Pyrene (BaP)-particulate phase only, ng/m^3	Annual*	1	1
Arsenic(As), ng/m^3	Annual*	6	60
Nickel (Ni), ng/m^3	Annual*	20	20

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.
** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time, they may exceed the limits but not on two consecutive days of monitoring.
Source: National Ambient Air Quality Standards, Central Pollution Control Board Notification in the Gazette of India, Extraordinary, New Delhi, 18th November, 2009

Prior to the November 2009 standards, India had set Air Quality standards on 11 April 1994, and this was later revised on 14 October 1998. The 2009 standards further lowered the maximum permissible limits for pollutants and made the standards uniform across the nation. Earlier, less stringent standards were prescribed for industrial zones as compared to residential areas.

Further, a new National Air Quality Index (AQI) (http://www.arthapedia.in /index.php?title=National_Air_Quality_Index) has been launched in October 2014 to disseminate information on air quality in an easily understandable form for the general public. The measurement of air quality is based on eight pollutants, namely, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb for which short-term (up to 24-hourly averaging period) National Ambient Air Quality Standards are prescribed and the worst reading in these pollutants represents the AQI for that city.

International Standards

The 2005 World Health Organization's "WHO Air quality guidelines" (http://whqlibdoc.who.int/hq/2006 /WHO_SDE_PHE_OEH_06.02_eng.pdf?ua=1) offer global guidance on thresholds and limits for 4 key air pollutants that pose health risks - particulate matter (PM), ozone (O3), nitrogen dioxide (NO2) and sulfur dioxide (SO2).

Guideline values prescribed by WHO are

$PM_{2.5}$

10 μg/m^3 annual mean

25 μg/m^3 24-hour mean

PM_{10}

20 μg/m^3 annual mean

50 μg/m^3 24-hour mean

O_3

100 μg/m^3 8-hour mean

NO_2

40 μg/m^3 annual mean

200 μg/m^3 1-hour mean

SO_2

20 μg/m^3 24-hour mean

500 μg/m^3 10-minute mean

The WHO Guidelines indicate that by reducing particulate matter (PM_{10}) pollution from 70 to 20 micrograms per cubic metre (μg/m), air pollution-related deaths can be cut by around 15%[1]. Indian Standards are slightly less stringent as compared to WHO guidelines. However, the world's average PM_{10} levels by region range from 26 to 208 μg/m^3, with a world's average of 71 μg/m^3 as per WHO estimates (http://www.who.int /phe/health_topics/outdoorair/databases/cities/en/) published in 2014.

Many countries have their own Ambient Air Quality Standards prescribed for their territories. The Clean Air Act in the US requires the Environment Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS). Two types of Ambient Air Quality Standards are identified in the Clean Air Act: *Primary standards* provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly and *Secondary standards* provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.[2] NAAQS has been set for six pollutants in the US, namely, carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution and sulphur dioxide. The values for these pollutants may be seen here (http://www.epa.gov/air/criteria.html) .

The European Union has also developed legislations on air quality standards. The pollutants for which the standards are specified are: $PM_{2.5}$, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), PM_{10}, lead (Pb), carbon monoxide (CO), Benzene, Ozone, Arsenic (As), Cadmium (Cd), Nickel (Ni), Polyclic Aromatic Hydrocarbons.[3] Details may be seen here (http://ec.europa.eu/environment/air/quality/standards.htm) .

1. Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide in 2012 according to WHO.

2. http://www.epa.gov/air/criteria.html

3. http://ec.europa.eu/environment/air/quality/standards.htm

Also See

- National Air Quality Index (http://www.arthapedia.in/index.php?title=National_Air_Quality_Index)

References

- National Ambient Air Quality Standards, Central Pollution Control Board Notification (http://www.cpcb.nic.in/upload/Latest/Latest_48_FINAL_AIR_STANDARD.pdf) in the Gazette of India, Extraordinary, New Delhi, 18th November, 2009
- Comparative study of European and US air quality standards (http://ec.europa.eu/environment/archives/cafe/activities/pdf/case_study2.pdf)
- WHO Factsheet on ambient air quality as updated in March 2014 (http://www.who.int/mediacentre/factsheets/fs313/en/)

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Types of Sources:

1. Point source

Single, identifiable source

E.g. smokestack, drainpipe etc.

2. Non-point source

Dispersed source,

E.g. runoff from pesticides, fertilizers

CLASSIFICATION OF POLLUTION

Pollution can be classified according to the environment in which it occurs or according to the type of pollutant by which pollution is caused.

Sometimes, pollution is made to classify into two broad categories:

1. Natural Pollution:

It originates from the natural process. Eg: Volcanic eruption, Fog, mist etc

2. Artificial Pollution:

It originates artificially by the interaction in between humanity and environment.

Eg: Vehicle emission, effluents from industries etc

Different types of pollutions are as follows:

1. Air pollution

2. Water pollution

3. Soil pollution

4. Noise pollution

5. Radiation pollution

6. Thermal pollution

7. Industrial pollution

POLLUTANTS

Any substance present in the environment in harmful concentration, which adversely alters the environment by damaging the growth rate of a species and by interfering with the food chains, is toxic and affects the health, comfort and property etc. is considered as a pollutant.

Classification of Pollutants:

The classification of pollutants is done from different points of view:

(i) Depending upon their existence in nature pollutants are of two types, namely quantitative and qualitative pollutants.

(a) Quantitative Pollutants:

These are those substances normally occurring in the environment, who acquire the status of a pollutant when their concentration gets increased due to the unmindful activities of man. For example, carbon dioxide, if present in the atmosphere in concentration greater than normal due to automobiles and industries, causes measurable effects on humans, animals, plants or property, then it is classified as a quantitative pollutant.

(b) Qualitative Pollutant:

These are those substances which do not normally occur in nature but are added by man, for example, insecticides.

(ii) Depending upon the form in which they persist after being released into the environment, the pollutants are categorized into two types, namely primary and secondary pollutants.

(a) Primary Pollutants:

These are those which are emitted directly from the source and persist in the form in which they were added to the environment. Typical examples of pollutants included under this category are ash, smoke, fumes, dust, nitric oxide, sulphur dioxide, hydrocarbons etc.

(b) Secondary Pollutants:

These are those which are formed from the primary pollutants by chemical interaction with some constituent present in the atmosphere. Examples are: Sulphur trioxide, nitrogen dioxide, aldehydes, ketones, ozone etc.

Nitrogen oxides and hydrocarbons are two primary pollutants released from automobiles but in the presence of sunlight, they react to form peroxyacyl nitrate (PAN) and ozone, two secondary pollutants which are far more toxic than the primary pollutants from which they are derived. This phenomenon of increased toxicity by chemical interaction among the pollutants is known as Synergism.

(iii) From the ecosystem point of view, i.e., according to their natural disposal, pollutants are of two types:

(a) Bio-degradable Pollutants:

These are the pollutants that are quickly degraded by natural means. Heat or thermal pollution, and domestic sewage are considered in this category as these can be rapidly decomposed by natural processes or by engineered systems such as municipal treatment, plants etc.

(b) Non-degradable Pollutants:

These are the substances that either do not degrade or degrade very slowly in the natural environment. These include mercury salts, long chain phenolic chemicals, DDT and Aluminium cans etc.

Such non-degradable pollutants accumulate and are biologically magnified as they move in the biogeochemical cycle and along food chains in the ecosystem. For example, DDT, when washed from the ground goes to the streams where it is absorbed by the phytoplankton's which are eaten by the fishes.

So, the initial dose of DDT which was harmless in the phytoplankton becomes very harmful as it accumulates in the fish day by day, with the result that large populations offish die or become sterile and same is the case with the birds feeding on such fishes. This phenomenon is known as bio-magnification or biological magnification.

AIR POLLUTION

Excessive discharge of foreign substances into the atmospheric air thereby adversely affecting the quality of air and causing damage to animals, plants and human beings is known as air pollution.

Air pollution can be defined as the ' presence of any substances in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment.

Gases such as CO, CO_2, H_2S, SO_2 and NO_2 as well as particulate matter, such as sand and dust, are continually released into the atmosphere through natural activities such as forest fires, volcanic eruptions, decay of vegetation, winds and sand or dust storms. Man-made pollutants e.g. CO_2, NO_2, SO_2, hydrocarbons, particulates etc. are also released into the atmosphere. The magnitude of the problem of air-pollution has increased alarmingly due to population explosion, industrialization, urbanization, automobiles and other human activities for greater comfort.

In general air pollution is the excessive concentration of foreign matter in air which adversely affect the well being of the individual or causes damage to property. As per World Health Organization (WHO) around 2.4 million people die annually from causes directly attributed to air pollution out of which 6.2 lakh peoples are Indians. Diseases such as bronchitis, lung cancer and heart disease may appear to people exposed to air pollution.

SOURCES OF AIR POLLUTION

- Sources of Air pollution are natural as well as anthropogenic sources. Some of them are
  - Motor vehicle exhaust
  - Power stations
  - Demolition of wastes
  - Industries
  - Road Construction
  - Volcanic eruption

- Forest fires

Classification of Sources of Air pollution

1) **Type of source –**
   - Natural source: Dust, Pollen grains, volcanic eruptions, forest fires, bacteria and other microorganisms
   - Anthropogenic source (Man-made): Industrial units, thermal power plants, automobile exhausts, fossil fuel burning, nuclear explosions

2) **Number and spatial distribution –**
   - Stationary sources: The sources which are stationary. It can be classified into –
     - ✓ Point source – A single identifiable large or small stationary source. Example are factories, power plants, chimney etc
     - ✓ Fugitive source – Sources which produce particulate matter which can be transferred by the action of wind. Examples are pollution by burning of agricultural waste, solid wastes etc
     - ✓ Area source – A large source based on a particular area such as industrial areas or urban areas. It can also be a source that pollutes a large area like agricultural waste runoff, fertilizer runoff, open burning etc

   - Mobile source – The sources which are moving in a definite path. Examples are automobiles, trains, aircrafts etc

CLASSIFICATION OF AIR-POLLUTANTS

The air pollutants may be classified in different ways as follows:

(a) According to origin:

i) Primary pollutants which are directly emitted into the atmosphere and found as such e.g. CO, NO_2, SO_2 and hydrocarbons.

ii) Secondary pollutants which are derived from the primary pollutants due to chemical or photo-chemical reactions in the atmosphere, e.g. Ozone, Peroxy-acyl nitrate (PAN), Photo-chemical smog, etc.

(b) According to chemical composition:

i) Organic pollutants, e.g. Hydrocarbons, aldehydes, ketones, amines and alcohols

ii) Inorganic pollutants

Carbon compounds (e.g. CO and carbonates)

Nitrogen compounds (e.g. NO_x and NH_3)

Sulphur compounds (e.g. H_2S, SO_3 and H_2SO_4)

Halogen compounds (e.g. HF, HCl and metallic fluorides)

Oxidising agents (e.g. O_3)

Inorganic particles (e.g. fly ash, silica, asbestos and dusts from transport, mining, metallurgical and other industrial activities).

(c) According to state of matter:

i) Gaseous pollutants which get mixed with the air and do not normally settle out, e.g., CO, NO_x and SO_2.

ii) Particulate pollutants which comprises of finely divided solids or liquids and often exist in colloidal state as aerosols, e.g., smoke, fumes, dust, mist, fog, smog and sprays.

Types of Air pollution

1) Natural air pollution and Anthropogenic air pollution

Natural air pollution is the air pollution caused due to natural sources. Examples are same as that of natural sources (Refer above)
Anthropogenic air pollution is the air pollution caused due to man-made sources. Examples are anthropogenic sources, stationary sources and mobile sources (Refer above)

2) Outdoor air pollution and indoor air pollution

Outdoor air pollution is mainly due to automobile exhaust and industrial emissions. The major outdoor pollutants are oxides of nitrogen, oxides of sulphur, ground level ozone, particulate matter, carbon monoxide, lead etc.

Indoor air pollution is due to the indoor air pollutants released by indoor activities such as smoking, cooking, paints, varnishes, nail polish removers etc.

3) **Primary air pollution and secondary air pollution**

Primary air pollution is mainly caused due to primary air pollutants that are emitted directly into the atmosphere from direct sources and exist in the same form (such as carbon monoxide, carbon dioxide, dust, smoke)

Secondary air pollution is caused due to the secondary air pollutants which are formed in the atmosphere by the interaction of two or more primary air pollutants or by the reaction of primary pollutant with other elements in the atmosphere in the presence or absence of sunlight. Examples of secondary air pollutants are photochemical smog, PAN (Peroxy Acetyl Nitrate), ozone etc

4) **Particulate matter pollution and Gaseous pollution**

Particulate matter pollution is due to particulate matter emission such as dust, smoke, fog, mist, aerosols, fumes etc. Particles larger than 10 mm gets trapped in the nose of human beings. Particles between 5 to 10 mm can be removed by physical processes in the throat. While particles of size less than 5 mm reach the bronchial tubes and cause serious health issues.

Gaseous air pollution is caused due to gaseous emissions such as sulphur dioxide, carbon monoxide, oxides of nitrogen, hydrocarbons etc.

EFFECTS OF AIR POLLUTION

Air pollution is a major environmental problem that affects all the living organisms in the environment.

Effects of Air pollution on Health –The effect of air pollution on human health general occur as a result of contact between pollutants and the body. The health depends on the concentration of contaminant present, time of exposure to the contaminant and the vulnerability of the person. Common health effects are:

1. Eye Nose and Throat irritation
2. Increase in mortality rate
3. Chronic pulmonary diseases like bronchitis and asthma
4. Carcinogenic agents cause cancer

5. CO readily combines with haemoglobin in blood replacing oxygen
6. Gastro intestinal damage, Liver and Kidney damage, abnormalities in fertility and pregnancy

Effects of Air Pollution on Plants & Animals

1. Suppressed growth & premature ageing in plants
2. Leaf bleaching
3. Acid deposition damages aquatic life
4. Respiratory problems in animals
5. Migration of seasonal birds

Effects of Air Pollution on Materials

1. Reduces visibility due to smog formation
2. Acid deposition corrodes metals, discolor buildings & clothes

CONTROL MEASURES TO REDUCE AIR POLLUTION

1. Use raw materials with less pollutants
2. Use better methods for removal of toxic & harmful pollutants
3. Implement effective legislation for controlling pollution from industry as well as vehicles
4. Ensure exhausts are in the same direction of the winds for easy dispersal
5. Afforestation programmes
6. Periodic air quality monitoring
7. Promotion of use of renewable energy sources
8. Determine priority air pollutants based on human health
9. Use of air pollution control equipments such as scrubbers, fabric filters, electrostatic precipitators etc. in industries.

CARBON MONOXIDE (CO)

pollutant	sources	effects
Carbon monoxide. A gas that comes from the burning of fossil fuels, mostly in cars. It cannot be seen or smelled.	Carbon monoxide is released when engines burn fossil fuels. Emissions are higher when engines are not tuned properly, and when fuel is not completely burned. Cars emit a lot of the carbon monoxide found outdoors. Furnaces and heaters in the home can emit high concentrations of carbon monoxide, too, if they are not properly maintained.	Carbon monoxide makes it hard for body parts to get the oxygen they need to run correctly. Exposure to carbon monoxide makes people feel dizzy and tired and gives them headaches. In high concentrations it is fatal. Elderly people with heart disease are hospitalized more often when they are exposed to higher amounts of carbon monoxide.

NITROGEN DIOXIDE (NO_2)

pollutant	sources	effects
Nitrogen dioxide. A reddish-brown gas that comes from the burning of fossil fuels. It has a strong smell at high levels	Nitrogen dioxide mostly comes from power plants and cars. Nitrogen dioxide is formed in two ways—when nitrogen in the fuel is burned, or when nitrogen in the air reacts with oxygen at very high temperatures. Nitrogen dioxide can also react in the atmosphere to form ozone, acid rain, and particles	High levels of nitrogen dioxide exposure can give people coughs and can make them feel short of breath. People who are exposed to nitrogen dioxide for a long time have a higher chance of getting respiratory infections. Nitrogen dioxide reacts in the atmosphere to form acid rain, which can harm plants and animals.

SULPHUR DIOXIDE (SO_2)

pollutant	sources	effects
Sulfur dioxide. A corrosive gas that cannot be seen or smelled at low levels but can have a "rotten egg" smell at high levels.	Sulfur dioxide mostly comes from the burning of coal or oil in power plants. It also comes from factories that make chemicals, paper, or fuel. Like nitrogen dioxide, sulfur dioxide reacts in the atmosphere to form acid rain and particles.	Sulfur dioxide exposure can affect people who have asthma or emphysema by making it more difficult for them to breathe. It can also irritate people's eyes, noses, and throats. Sulfur dioxide can harm trees and crops, damage buildings, and make it harder for people to see long distances.

WATER QUALITY INDICATORS

Water has three characteristics, i.e. **physical, chemical and biological characteristics**. Water quality indicators assess the quality of water so as to make decisions of reuse and methods of disposal. The raw treated water can be checked and analysed by studying and testing these characteristics as explained below:

Physical Characteristics of Water

1. Turbidity of Water

Turbidity refers to reduced visibility, haziness or clouding of water due to presence of large number of suspended particles which are normally visible to naked eye. The turbidity is measured by a turbidity rod or by a turbidity meter with optical observations and is expressed as the amount of suspended matter in mg/l or parts per million (ppm).

For water, ppm and mg/l are approximately equal. The standard unit is that which is produced by one milligram of finely divided silica (fuller's earth) in one litre of distilled water.

Turbidity Meters

Turbidity Rod:

The turbidity can be easily measured in the field with the help of a turbidity rod. It consists of an aluminium rod which is graduated as to give turbidity directly in silica units (mg/l)

Turbidimeter:

The turbidity can be easily measured in the laboratory with the help of a instruments called turbidity meter. In general, a turbidity meter works on the principle of measuring the interference caused by the water sample to the passage of light rays.

Jackson's candle Turbidimeter:

The height of water column will therefore be more for less turbid water and vice versa. Longer the light path lower the turbidity. Such a turbidimeter cannot measure turbidites lower than 25 JTU.

It can be used for natural sources only and cannot be used to measure the turbidity of treated water supplies, for which **Baylis turbidity meter** or **modern nephelometers** are used.

Baylis Turbidimeters

One of the two glass tubes is filled with water sample (whose turbidity I to be measured) and the other is filled with standard water solution of known turbidity. The electric bulb is lighted and the blue colour in both the tubes is observed from the top of the instrument.

Modern Nephelometer: for low turbidity less than 1 unit.

NTU – Nephelometric Turbidity Units

FTU – Formazin Turbidity Units

Ratio turbidimeter: River water has maximum amount of turbidity.

WHO prefers turbidity of drinking water to be not greater than 5 NTU and ideally less than 1 NTU .

2. Colour

The presence of colour in water is not objectionable from health point of view, but may spoil the colour of the clothes being washed. The standard unit of colour is that which is produced by one milligram of platinum cobalt dissolved in one litre of distilled water.

Colour determined by an instrument is known as **tintometer.**

For public supplies, the colour number on cobalt scale should not exceed 20 and should be preferably less than 10.

3. Taste and Odour

The extent of taste or odour present in a particular sample of water is measured by a term called **odour intensity**, which is related with the **threshold odour** or **threshold odour number.**

Water to be tested is therefore gradually diluted with odour free water, and the mixture at which the detection of odour by human observation is just lost, is determined. The number of times the sample is diluted represents the threshold odour number.

For public supplies, the water should generally free from odour, i.e. the threshold number should be 1 and should never exceed 3.

4. Temperature of Water

Aquatic animals and plants can survive only within a limited range of temperatures and hence it is important measurement of water quality. For potable water, temperature of about about 10° C is desirable. It should not be more than 25° C.

5. Salinity

Salinity refers to the saltiness or dissolved salt content in water. The total amount of dissolved salts present in water can be easily estimated by measuring the specific conductivity of water.

6. Total Solids, Suspended Solids and settleable solids

Total solids (suspended solids + dissolved solids) can be obtained by evaporating a sample of water and weighing the dry residue left and weighing the residue left on the filter paper.

The suspended solid can be found by filtering the water sample. Total permissible amount of solids in water is generally limited to 500 ppm.

Settleable solids refers to the quantity of solid impurities which will settle at the bottom, if the water sample is kept still.

Chemical Characteristics of Water

1. pH value of Water

pH is the measure of hydrogen ion concentration in the water. It indicates the acidity or alkalinity of water. If the pH of water is more than 7, it will be alkaline and if it is less than 7, it will be acidic.

The alkalinity is caused by the presence of bicarbonate of calcium and magnesium or by the carbonates of hydroxides of sodium, potassium, calcium and magnesium.

Some, but not all of the compounds that cause alkalinity also cause hardness.

pH Measurement:

The pH value of water can be measured quickly and automatically with the help of a **Potentiometer.**

Permissible pH value for public supplies may range between 6.6 to 8.4.

The lower value of pH may cause incrustation, sediment deposits, difficulty in chlorination.

2. Hardness of Water

Hard waters are undesirable because they may lead to greater soap consumption, scaling of boilers, causing corrosion and incrustation of pipes, making food tasteless etc. Underground waters are generally harder than surface waters.

Temporary Hardness: If bicarbonates and carbonates of calcium and magnesium are present in water, the water is render hard temporarily as this hardness can be removed to some extent by simple boiling or to full extent by adding lime to water. Such a hardness is known as temporary hardness or carbonate hardness.

Permanent Hardness: If sulphates, chlorides and nitrates of calcium or magnesium are present in water, they cannot be removed at al by simple boiling and therefore, such water require special treatment for softening. Such a hardness is known as permanent hardness or non-carbonate hardness.

It is caused by sulphates, chlorides, nitrates of Ca and Mg.

Water with hardness upto 75 ppm are considered soft and above 200 ppm are considered hard and in between is considered as moderately hard. The prescribed hardness limit for public supplies range between 75 to 115 ppm.

3. Chloride Content

The chloride content of water can be measured by titrating the water with standard silver nitrate solution using potassium chromate as indicator.

The chloride content of treated water to be supplied to the public should not exceed a value of about 250 ppm.

(5) Nitrogen Content

The presence of nitrogen in water may occur in one or more of the following reasons:

1. **Albuminous or Organic Matter:** It indicates the quantity of nitrogen present in water before the decomposition of organic molten has started. It should not exceed 0.3mg/l
2. **Free ammonia:** It indicates very first stage of decomposition of organic matter. It should not exceed 0.15mg/l
3. **Nitrites:** Not fully oxidized organic matter in water. Nitrites is highly dangerous and therefore the permissible amount of nitrites in water should be nil.

4. **Nitrates:** It indicates fully oxidized organic matter in water. Nitrates in water is not harmful. However the presence of too much of nitrates in water may adversely affect the health of infants causing a disease called **methemoglobinemia** commonly called **blue baby disease.** The nitrate concentration in domestic water supplies is limited to 45 mg/l.

5. Metal and other chemical substances in water:

Iron – 0.3ppm, excess of these cause discolouration of clothes.

Manganese – 0.05ppm

Copper – 1.3ppm

Sulphate – 250 ppm

Fluoride – 1.5 ppm, excess of this effects human lungs and other respiratory organs.

Fluoride concentration of less than 0.8 – 1.0 ppm cause dental cavity (tooth decay). If fluoride concentration is greater than 1.5ppm, causing spotting and discolouration of teeth (a disease called fluorosis).

6. Dissolved gases

Dissolved Oxygen (DO)

Oxygen gas is generally absorbed by water from the atmosphere but it being consumed by unstable organic matter for their oxidation. Hence, if the oxygen present in water is found to be less than its saturation level, it indicates presence of organic matter and consequently making the waters suspicious.

Biological Oxygen Demand (BOD):

The extent of organic matter present in water sample can be estimated by supplying oxygen to this sample and finding the oxygen consumed by the organic matter present in water. This oxygen demand is known as Biological oxygen demand (BOD).

It is not practically possible to determine ultimate oxygen demand. Hence, BOD of water during the first five days at 20°C is generally taken as the standard demand.

$BOD_5 = BOD$ of 5 days = Loss of oxygen in mg/l x dilution factor.

The BOD of safe drinking water must be nil.

Bacterial Characteristics of Water

Biological assessment may be required to access the sustainability of water.

Five types of parasitic organisms (i.e. bacteria, protozoa, viruses, worms and fungi) are generally known to be infective to main and are found in water.

1. Bacteria

A virus is a small infectious agent that replicates only inside the living cells of an organism. Viruses can infect all types of life forms, from animals and plants to microorganisms, including bacteria.

4. Worms

These are the larva of flies.

5. Fungi

These are those plants which grow without sunlight and live on other plants or animals, dead or alive.

Coliform index:

Coliform sometimes called bacteria coli (B-coli) or Escherichia (E-coli) are disease-causing bacteria. E. coli can cause an infection even if you ingest only small amounts. Coliform index may be defined as the reciprocal of the smallest quantity of a sample which would give a positive portion. It measures the count of live E-coli bacteria in water.

If not more than 1 coliform is present per 100ml of water, then water is said to be safe for drinking.

WATER BORNE DISEASES

Disease and Transmission	Microbial Agent	Sources of Agent in Water Supply	General Symptoms
Cholera	Spread by the bacterium *Vibrio cholerae*	Drinking water contaminated with the bacterium	In severe forms it is known to be one of the most rapidly fatal illnesses known. Symptoms include very watery diarrhea, nausea, cramps, nosebleed, rapid pulse, vomiting, and hypovolemic shock (in severe cases), at which point death can occur in 12–18 hours.
Hepatitis A	Hepatitis A virus (HAV)	Can manifest itself in water (and food)	Symptoms are only acute (no chronic stage to the virus) and include Fatigue, fever, abdominal pain, nausea, diarrhea, weight loss, itching, jaundice and depression.
Hepatitis E	Hepatitis E virus (HEV)	Enters water through the feces of infected individuals (fecal-oral)	Symptoms of acute hepatitis (liver disease), including fever, fatigue, loss of appetite, nausea, vomiting, abdominal pain, jaundice, dark urine, clay-colored stool, and joint pain
Leptospirosis	Caused by bacterium of genus *Leptospira*	Water contaminated by the animal urine carrying the bacteria	Begins with flu-like symptoms then resolves. The second phase then occurs involving meningitis, liver damage (causes jaundice), and renal failure
Typhoid fever	Salmonella typhi (Bacteria)	Ingestion of water contaminated with feces	Characterized by sustained fever up to 40 °C (104 °F), profuse sweating; diarrhea may occur. Symptoms progress to delirium, and the spleen and liver enlarge if untreated. In

		of an infected person	this case it can last up to four weeks and cause death. Some people with typhoid fever develop a rash called "rose spots", small red spots on the abdomen and chest.
Dysentery	Caused by a number of species in the genera *Shigella* and *Salmonella (Bacteria)*	Water contaminated with the bacterium	Frequent passage of feces with blood and/or mucus and in some cases vomiting of blood.
Poliomyelitis (Polio)	Poliovirus	Enters water through the feces of infected individuals	90-95% of patients show no symptoms, 4-8% have minor symptoms (comparatively) with delirium, headache, fever, and occasional seizures, and spastic paralysis, 1% have symptoms of non-paralytic aseptic meningitis. The rest have serious symptoms resulting in paralysis or death
Amoebiasis	Protozoan (*Entamoeba histolytica*) (Cyst-like appearance)	Sewage, non-treated drinking water, flies in water supply, saliva transfer(if the other person has the disease) (hand-to-mouth)	Abdominal discomfort, fatigue, weight loss, diarrhoea, bloating, fever

E-coli infection	Certain strains of *Escherichia coli* (comm only *E. coli*) (Bacteria)	Water contaminate d with the bacteria	Mostly diarrhoea. Can cause death in immuno compromised individuals, the very young, and the elderly due to dehydration from prolonged illness.
Desmodesmus infection	Desmodesm us armatus (algae)	Naturally occurs in water. Can enter open wounds	Similar to fungal infection (darkening of skin, peeling, rashes etc)
Dracunculiasis [Guinea worm disease]	Dracunculia sis medinensis (worm)	Female worm emerges from host skin and releases larvae in water. Ingestion of contaminate d water.	Slightfever,itchy rash, nausea, vomiting, dia rrhea, dizziness, followed by formation of painful blister (typically on lower body parts)

MODULE 3

SOLID WASTE: Classification and sources of Solid Waste, Characteristics of Solid Waste, e- waste, Radioactive wastes

LAND/SOIL POLLUTION: Effects of urbanization on land degradation, Impact of Modern Agriculture on Soil, pesticide pollution, Effect on Environment

What is solid waste?

Any material that we can discard, that is not liquid or gas, is a solid waste.

Solid wastes are the organic and inorganic waste materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen refuse, paper, appliances, paint cans, batteries, etc., produced in a society, which do not generally carry any value to the first user(s).

CLASSIFICATION OF SOLID WASTES

Solid wastes, thus, encompass both a heterogeneous mass of wastes from the urban community as well as a more homogeneous accumulation of agricultural, industrial and mineral wastes. While wastes have little or no value in one setting or to the one who wants to dispose them, the discharged wastes may gain significant value in another setting. Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated/ disposed is, therefore, essential for the design and operation of the functional elements associated with the management of solid wastes.

Solid wastes are classified on the basis of source of generation and type.

Source-based classification

Historically, the sources of solid wastes have been consistent, dependent on sectors and activities (Tchobanoglous, et al., 1977), and these include the following:

(i) **Residential:** This refers to wastes from dwellings, apartments, etc., and consists of leftover food, vegetable peels, plastic, clothes, ashes, etc.

(ii) **Commercial:** This refers to wastes consisting of leftover food, glasses, metals, ashes, etc., generated from stores, restaurants, markets, hotels, motels, auto-repair shops, medical facilities, etc.

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

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

cleaning, landscaping, etc. (Note, however, in India *municipal* can typically subsume items at (i) to (iii) above).

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

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

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

It is important to define the various types of solid wastes that are generated from various sources.

Type-based classification

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

(i) **Garbage:** This refers to animal and vegetable wastes resulting from the handling, sale, storage, preparation, cooking and serving of food. Garbage comprising these wastes contains putrescible (rotting) organic matter, which produces an obnoxious odour and attracts rats and other vermin. It, therefore, requires special attention in storage, handling and disposal.

(ii) **Ashes and residues:** These are substances remaining from the burning of wood, coal, charcoal, coke and other combustible materials for cooking and heating in houses, institutions and small industrial establishments. When produced in large quantities, as in power-generation plants and factories, these are classified as industrial wastes. Ashes consist of fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass. Since ashes and residues are almost entirely inorganic, they are valuable in landfills.

(iii) **Combustible and non-combustible wastes:** These consist of wastes generated from households, institutions, commercial activities, etc., excluding food wastes and other highly putrescible material. Typically, while *combustible material* consists of paper, cardboard, textile, rubber, garden trimmings, etc., *non-combustible material* consists of such items as glass, crockery, tin and aluminium cans, ferrous and non-ferrous material and dirt.

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

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

(vi) **Biodegradable and non-biodegradable wastes:** *Biodegradable wastes* mainly refer to substances consisting of organic matter such as leftover food, vegetable and fruit peels, paper, textile, wood, etc., generated from various household and industrial activities. Because of the action of micro-organisms, these wastes are degraded from complex to simpler compounds. *Non-biodegradable* wastes consist of inorganic and recyclable materials such as plastic, glass, cans, metals, etc. Table 1.1 below shows a comparison of biodegradable and non-biodegradable wastes with their degeneration time, i.e., the time required to break from a complex to a simple biological form:

Table 1.1 Biodegradable and Non-Biodegradable Wastes: Degeneration Time

CATEGORTY	TYPE OF WASTE	APPROXIMATE TIME TAKEN TO DEGENERATE
Biodegradable	Organic waste such as vegetables and fruit peels, leftover food stuffs etc	A week or two
	Paper	10-30 days
	Cotton cloth	2-5 months
	Woollen item	1 year
	Wood	10-15 years
Non-biodegradable	Tin, aluminium and other metals such as cans	100-500 yrs
	Plastic bags	One million yrs
	Glass bottles	Undetermined

From Table 1.1, we can easily deduce the environmental consequences associated with non-biodegradable wastes such as plastics, glass, etc.

(vii) **Dead animals:** With regard to municipal wastes, dead animals are those that die naturally or are accidentally killed on the road. Note that this category does not include carcasses and animal parts from slaughter-houses, which are regarded as industrial wastes. Dead animals are divided into two groups – large and small. Among the large animals are horses, cows, goats, sheep, pigs, etc., and among the small ones are dogs, cats, rabbits, rats, etc. The reason for this differentiation is that large animals require special equipment for lifting and handling when they are removed. If not collected promptly, dead animals pose a threat to public health since they attract flies and other vermin as they decay. Their presence in public places is particularly offensive from the aesthetic point of view as well.

(viii) **Abandoned vehicles:** This category includes automobiles, trucks and trailers that are abandoned on streets and other public places. However, abandoned vehicles have significant scrap value for their metal, and their value to collectors is highly variable.

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

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

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

(xii) **Sewage wastes:** The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derived from the treatment of organic sludge separated from both raw and treated sewages. The inorganic fraction of raw sewage such as grit and eggshells is separated at the preliminary stage of treatment, as it may entrain putrescible organic matter with pathogens and must be buried without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but is invariably uneconomical. Solid sludge, therefore, enters the stream of municipal wastes, unless special arrangements are made for its disposal.

Table 1.2 : Classification of Solid Wastes

	Type	Description	Sources
Solid Wastes	Garbage	Food waste: wastes from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meat.	Households, institutions and commercial concerns such as hotels, stores, restaurants, markets, etc.
	Combustible and non–combustible	Combustible (primary organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings, etc.	
		Non-combustible (primary inorganic) metals, tin, cans, glass bottles, crockery, stones, etc.	
	Ashes	Residue from fires used for cooking and for heating building cinders	
	Bulky wastes	Large auto parts, tyres, stoves, refrigerators other large appliances, furniture, large crates, trees, branches, stumps, etc.	Streets, sidewalks, alleys, vacant lots, etc.
	Street wastes	Street sweepings, dirt, leaves, etc.	
	Dead animals	Dogs, cats, rats, donkeys, etc.	
	Abandoned vehicles	Automobiles and spare parts	
	Construction and demolition wastes	Roofing, and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc.	Construction and demolition sites.
	Industrial wastes	Solid wastes resulting from industry processes and manufacturing operations, such as, food processing wastes, boiler house cinders, wood, plastic and metal scraps, shavings, etc	Factories, power plants, etc.
	Hazardous wastes	Pathological wastes, explosives, radioactive materials, etc.	Households, hospitals, institutions, stores, industry, etc.
	Animal and agricultural wastes	Manure, crop residues, etc.	Livestock, farms, feedlots and agriculture
	Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

SOLID WASTE MANAGEMENT (SWM)

Solid waste management (SWM) is associated with the control of waste generation, its storage, collection, transfer and transport, processing and disposal in a manner that is in accordance with the best principles of public health, economics, engineering, conservation, aesthetics, public attitude and other environmental considerations. Put differently, the SWM processes differ depending on factors such as economic status (e.g., the ratio of wealth created by the production of primary products to that derived from manufactured goods, per capita income, etc.), degree of industrialisation, social development (e.g., education, literacy, healthcare, etc.) and quality of life of a location. In addition, regional, seasonal and economic differences influence the SWM processes. This, therefore, warrants management strategies that are economically viable, technically feasible and socially acceptable to carry out such of the functions as are listed below:

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

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

SWM system

A SWM system refers to a combination of various functional elements associated with the management of solid wastes. The system, when put in place, facilitates the collection and disposal of solid wastes in the community at minimal costs, while preserving public health and ensuring little or minimal adverse impact on the environment. The functional elements that constitute the system are:

(i) **Waste generation:** Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted into goods for consumption. For example, wastes are generated from households, commercial areas, industries, institutions, street cleaning and other municipal services. The most important aspect of this part of the SWM system is the identification of waste.

(ii) **Waste storage:** Storage is a key functional element because collection of wastes never takes place at the source or at the time of their generation. The heterogeneous wastes generated in residential areas must be removed within 8 days due to shortage of storage space and presence of biodegradable material. Onsite storage is of primary importance due to aesthetic consideration, public health and economics involved. Some of the options for storage are plastic containers, conventional dustbins (of households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc. Obviously, these vary greatly in size, form and material.

(iii) **Waste collection:** This includes gathering of wastes and hauling them to the location, where the collection vehicle is emptied, which may be a transfer station (i.e., intermediate station where wastes from smaller vehicles are transferred to larger ones and also segregated), a processing plant or a disposal site. Collection depends on the number of containers, frequency of collection, types of collection services and routes. Typically, collection is provided under various management arrangements, ranging from municipal services to franchised services, and under various forms of contracts.

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

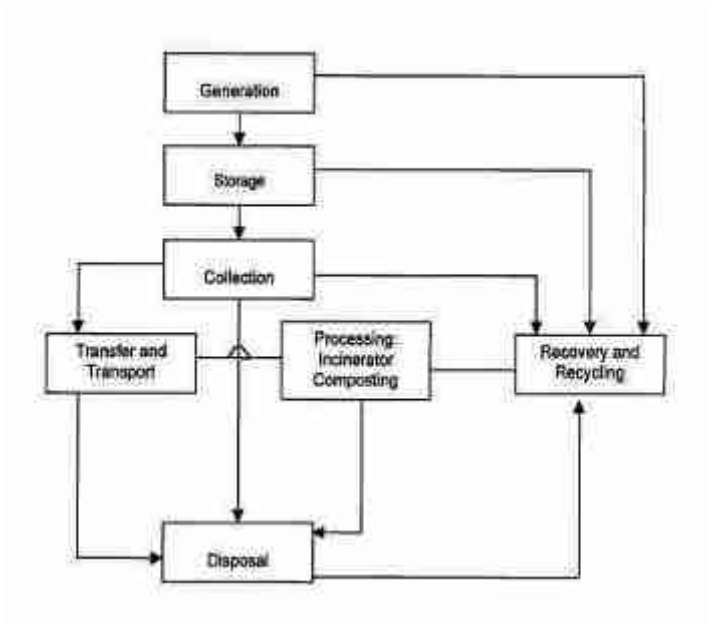
(iv) **Transfer and transport:** This functional element involves: the transfer of wastes from smaller collection vehicles, where necessary to overcome the problem of narrow access lanes, to larger ones at transfer stations; the subsequent transport of the wastes, usually over long distances, to disposal sites. The factors that contribute to the designing of a transfer station include the type of transfer operation, capacity, equipment, accessories and environmental requirements.

(v) **Processing:** Processing is required to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling. The important processing techniques

include compaction, thermal volume reduction, manual separation of waste components, incineration and composting.

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

(vii) **Waste disposal:** Disposal is the ultimate fate of all solid wastes, be they residential wastes, semi-solid wastes from municipal and industrial treatment plants, incinerator residues, composts or other substances that have no further use to the society. Thus, land use planning becomes a primary determinant in the selection, design and operation of landfill operations. A modern sanitary landfill is a method of disposing solid waste without creating a nuisance and hazard to public health. Generally, engineering principles are followed to confine the wastes to the smallest possible area, reduce them to the lowest particle volume by compaction at the site and cover them after each day's operation to reduce exposure to vermin. One of the most important functional elements of SWM, therefore, relates to the final use of the reclaimed land. In Figure 1.1 below, we show you a typical SWM system with its functional elements and linkages:



Factors affecting SWM system

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

(i) **Quantities and characteristics of wastes:** The quantities of wastes generated generally depend on the income level of a family, as higher income category tends to generate larger quantity of wastes, compared to low-income category. The quantity ranges from about 0.25 to about 2.3 kg per person per day, indicating a strong correlation between waste production and per capita income. One of the measures of waste composition (and characteristics) is density, which ranges from 150 kg/m3 to 600 kg/m3. Proportion of paper and packaging materials in the waste largely account for the differences. When this proportion is high, the density is low and vice versa. The wastes of high density reflect a relatively high proportion of organic matter and moisture and lower levels of recycling.

(ii) **Climate and seasonal variations:** There are regions in extreme north (> 70 N Latitude) and south (> 60 S Latitude), where temperatures are very low for much of the year. In cold climates, drifting snow and frozen ground interfere with landfill operations, and therefore, trenches must be dug in summer and cover material stockpiled for winter use. Tropical climates, on the other hand, are subject to sharp seasonal variations from wet to dry season, which cause significant changes in the moisture content of solid waste, varying from less than 50% in dry season to greater than 65% in wet months. Collection and disposal of wastes in the wet months are often problematic.

High temperatures and humidity cause solid wastes to decompose far more rapidly than they do in colder climates. The frequency of waste collection in high temperature and humid climates should, therefore, be higher than that in cold climates. In sub-tropical or desert climate, there is no significant variation in moisture content of wastes (due to low rainfall) and low production of leachate from sanitary landfill. High winds and wind blown sand and dust, however, cause special problems at landfill sites. While temperature inversions can cause airborne pollutants to be trapped near ground level, landfill sites can affect groundwater by altering the thermal properties of the soil.

(iii) **Physical characteristics of an urban area:** In urban areas (i.e., towns and cities), where the layout of streets and houses is such that access by vehicles is possible and door-to-door collection of solid wastes is the accepted norm either by large compaction vehicle or smaller

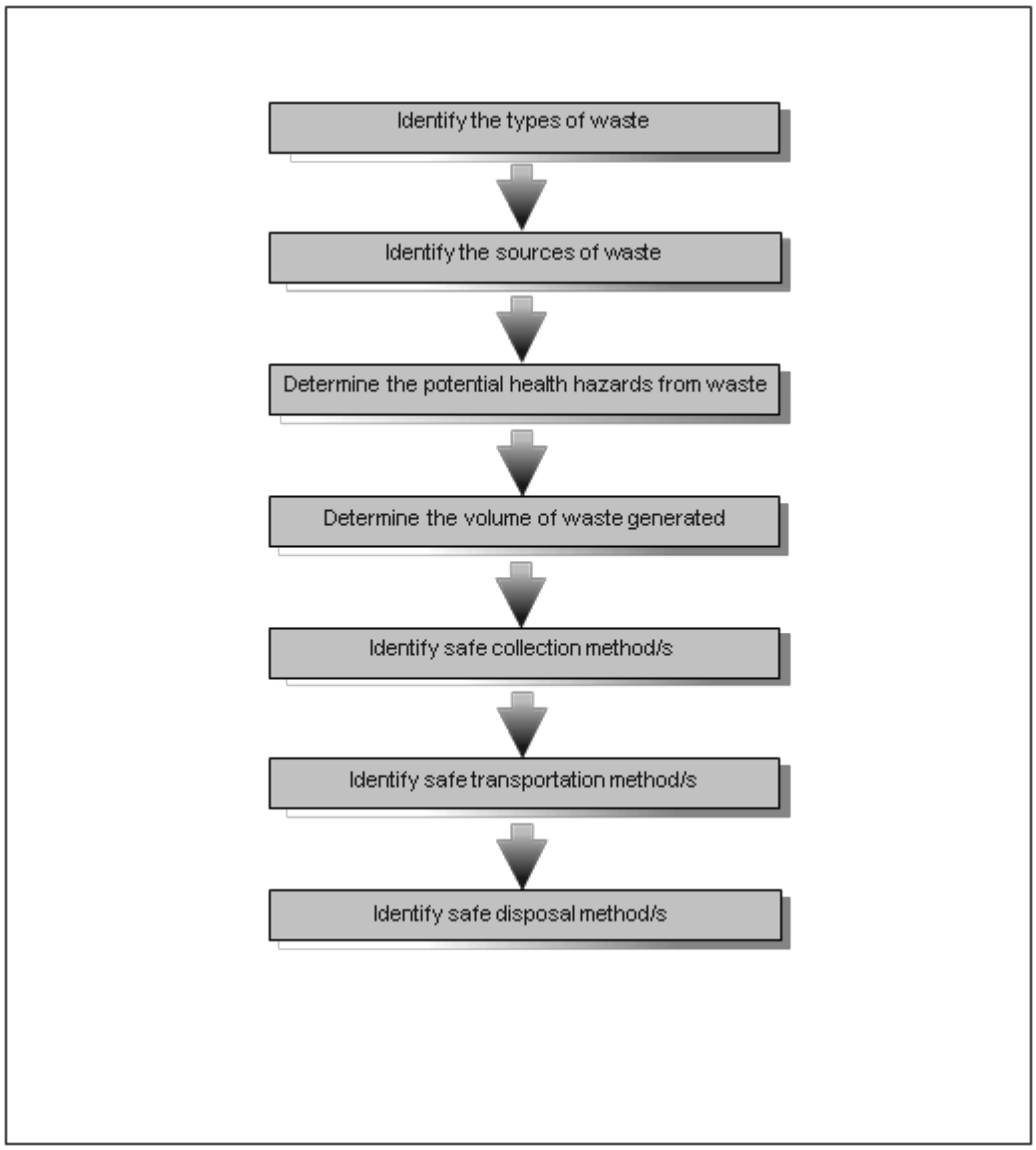
vehicle. The picture is, however, quite different in the inner and older city areas where narrow lanes make service by vehicles difficult and often impossible. Added to this is the problem of urban sprawl in the outskirts (of the cities) where population is growing at an alarming rate. Access ways are narrow, unpaved and tortuous, and therefore, not accessible to collection vehicles. Problems of solid waste storage and collection are most acute in such areas.

(iv) **Financial and foreign exchange constraints:** Solid waste management accounts for sizeable proportions of the budgets of municipal corporations. This is allocated for capital resources, which go towards the purchase of equipments, vehicles, and fuel and labour costs. Typically, 10% to 40% of the revenues of municipalities are allocated to solid waste management. In regions where wage rates are low, the aim is to optimise vehicle productivity. The unfavourable financial situation of some countries hinders purchase of equipment and vehicles, and this situation is further worsened by the acute shortage of foreign exchange. This means that the balance between the degree of mechanisation and the size of the labour force becomes a critical issue in arriving at the most cost-effective solution.

(v) **Cultural constraints:** In some regions, long-standing traditions preclude the intrusion of waste collection on the precincts of households, and therefore, influence the collection system. In others, where the tradition of caste persists, recruits to the labour force for street cleaning and handling of waste must be drawn from certain sections of the population, while others will not consent to placing storage bins in their immediate vicinity. Social norms of a community more often than not over-ride what many may consider rational solutions. Waste management should, therefore, be sensitive to such local patterns of living and consider these factors in planning, design and operation.

(vi) **Management and technical resources:** Solid waste management, to be successful, requires a wide spectrum of workforce in keeping with the demands of the system. The best system for a region is one which makes full use of indigenous crafts and professional skills and/or ensures that training programmes are in place to provide a self-sustaining supply of trained workforce.

In order to establish effective solid waste management in the affected area the following process should be used:



Key components of solid waste management

Solid waste management can be divided into five key components:

- Generation
- Storage
- Collection
- Transportation
- Disposal

Generation

Generation of solid waste is the stage at which materials become valueless to the owner and

since they have no use for them and require them no longer, they wish to get rid of them. Items which may be valueless to one individual may not necessarily be valueless to another. For example, waste items such as tins and cans may be highly sought after by young children.

Storage

Storage is a system for keeping materials after they have been discarded and prior to collection and final disposal. Where on-site disposal systems are implemented, such as where people discard items directly into family pits, storage may not be necessary. In emergency situations, especially in the early stages, it is likely that the affected population will discard domestic waste in poorly defined heaps close to dwelling areas. If this is the case, improved disposal or storage facilities should be provided fairly quickly and these should be located where people are able to use them easily. Improved storage facilities include:

- Small containers: household containers, plastic bins, etc.
- Large containers: communal bins, oil drums, etc.
- Shallow pits
- Communal depots: walled or fenced-in areas

In determining the size, quantity and distribution of storage facilities the number of users, type of waste and maximum walking distance must be considered. The frequency of emptying must also be determined, and it should be ensured that all facilities are reasonably safe from theft or vandalism.

Collection

Collection simply refers to how waste is collected for transportation to the final disposal site. Any collection system should be carefully planned to ensure that storage facilities do not become overloaded. Collection intervals and volumes of collected waste must be estimated carefully.

Transportation

This is the stage when solid waste is transported to the final disposal site (see 7.6 for more details). There are various modes of transport which may be adopted and the chosen method depends upon local availability and the volume of waste to be transported. Types of transportation can be divided into three categories:

- Human-powered: open hand-cart, hand-cart with bins, wheelbarrow, tricycle
- Animal-powered: donkey-drawn cart
- Motorised: tractor and trailer, standard truck, tipper-truck

Disposal

The final stage of solid waste management is safe disposal where associated risks are minimised. There are four main methods for the disposal of solid waste:

- Land application: burial or landfilling
- Composting
- Burning or incineration
- Recycling (resource recovery)

On-site disposal options

The technology choices outlined below are general guidelines for disposal and storage of waste on-site, these may be adapted for the particular site and situation in question.

Communal pit disposal

Perhaps the simplest solid waste management system is where consumers dispose of waste directly into a communal pit. The size of this pit will depend on the number of people it serves. The long-term recommended objective is six cubic metres per fifty people. The pit should be fenced off to prevent small children falling in and should generally not be more than 100m from the dwellings to be served. Ideally, waste should be covered at least weekly with a thin layer of soil to minimise flies and other pests. Figure 7.2 illustrates a simple communal pit.

Advantages: It is rapid to implement; and requires little operation and maintenance.

Constraints: The distance to communal pit may cause indiscriminate disposal; and waste workers required to manage pits.

Family pit disposal

Family pits may provide a better long-term option where there is adequate space. These should be fairly shallow (up to 1m deep) and families should be encouraged to regularly cover waste with soil from sweeping or ash from fires used for cooking. This method is best suited where families have large plots and where organic food wastes are the main compo- nent of domestic refuse.

Advantages: Families are responsible for managing their own waste; no external waste workers are required; and community mobilisation can be incorporated into hygiene promo- tion programme.

Constraints: Involves considerable community mobilisation for construction, operation and maintenance of pits; and considerable space is needed.

Communal bins

Communal bins or containers are designed to collect waste where it will not be dispersed by wind or animals, and where it can easily be removed for transportation and disposal. Plastic containers are generally inappropriate since these may be blown over by the wind, can easily be removed and may be desirable for alternative uses. A popular solution is to provide oil drums cut in half. The bases of these should be perforated to allow liquid to pass out and to prevent their use for other purposes. A lid and handles can be provided if necessary.

In general, a single 100-litre bin should be provided for every fifty people in domestic areas, every one hundred people at feeding centres and every ten market stalls. In general, bins should be emptied daily.

Advantages: Bins are potentially a highly hygienic and sanitary management method; and final disposal of waste well away from dwelling areas.

Constraints: Significant collection, transportation and human resources are required; sys- tem takes time to implement; and efficient management is essential.

Family bins

Family bins are rarely used in emergency situations since they require an intensive collection and transportation system and the number of containers or bins required is likely to be huge.

In the later stages of an emergency, however, community members can be encouraged to make their own refuse baskets or pots and to take responsibility to empty these at communal pits or depots.

Advantages: Families are responsible for maintaining collection containers; and potentially a highly sanitary management method.

Constraints: In general, the number of bins required is too large; significant collection, transportation and human resources are required; takes time to implement; and efficient management essential.

Communal disposal without bins

For some public institutions, such as markets or distribution centres, solid waste manage- ment systems without bins can be implemented, whereby users dispose of waste directly onto the ground. This can only work if cleaners are employed to regularly sweep around market stalls, gather waste together and transport it to a designated off-site disposal site. This is likely to be

appropriate for vegetable waste but slaughterhouse waste should be disposed of in liquid-tight containers and buried separately.

Advantages: System rapid to implement; there is minimal reliance on actions of users; and it may be in line with traditional/usual practice.

Constraints: Requires efficient and effective management; and full-time waste workers must be employed.

Transportation options

Where bins or collection containers require emptying, transportation to the final disposal point is required. As described, waste transportation methods may be human-powered, animal-powered or motorised.

Human-powered

Wheelbarrows are ideal for the transportation of waste around small sites such as markets but are rarely appropriate where waste must be transported considerable distances off-site. Handcarts provide a better solution for longer distances since these can carry significantly more waste and can be pushed by more than one person. Carts may be open or can be fitted with several containers or bins.

Animal-powered

Animal-powered transportation means such as a horse or donkey with cart are likely to be appropriate where they are commonly used locally. This may be ideal for transportation to middle distance sites

Motorised

Where the distance to the final disposal site is great, or where the volume of waste to be transported is high, the use of a motorised vehicle may be the only appropriate option. Options include tractor and trailer, a standard truck, or a tipper-truck, the final choice depending largely on availability and speed of procurement.

For large volumes of waste it may sometimes be appropriate to have a two-stage transportation system requiring a transfer station. For example, waste is transported by handcart to a transfer station where it is loaded into a truck to be taken to an off-site disposal site several kilometres away.

Off-site disposal options

The technology choices outlined below are general options for the final disposal of waste off-site.

Landfilling

Once solid waste is transported off-site it is normally taken to a landfill site. Here the waste is placed in a large excavation (pit or trench) in the ground, which is back-filled with excavated soil each day waste is tipped. Ideally, about 0.5m of soil should cover the deposited refuse at the end of each day to prevent animals from digging up the waste and flies from breeding.

The location of landfill sites should be decided upon through consultation with the local authorities and the affected population. Sites should preferably be fenced, and at least one kilometre downwind of the nearest dwellings.

Advantages: A sanitary disposal method if managed effectively.

Constraints: A reasonably large area is required.

Incineration

Although burning or incineration is often used for the disposal of combustible waste, this should generally only take place off-site or a considerable distance downwind of dwellings. Burning refuse within dwelling areas may create a significant smoke or fire hazard, espe- cially if several fires are lit simultaneously. Burning may be used to reduce the volume of waste and may be appropriate where there is limited space for burial or landfill. Waste should be ignited within pits and covered with soil once incinerated, in the same manner as landfilling. The same constraints for siting landfill sites should be applied here also.

Advantages: Burning reduces volume of combustible waste considerably; and it is appropri- ate in off-site pits to reduce scavenging.

Constraints: There can be smoke or fire hazards.

Composting

Simple composting of vegetables and other organic waste can be applied in many situations. Where people have their own gardens or vegetable plots, organic waste can be dug into the soil to add humus and fibre. This makes the waste perfectly safe and also assists the growing

process. This should be encouraged wherever possible, particularly in the later stages of an emergency programme.

Properly managed composting requires careful monitoring of decomposing waste to control moisture and chemical levels and promote microbial activity. This is designed to produce compost which is safe to handle and which acts as a good fertiliser. Such systems require considerable knowledge and experience and are best managed centrally. In general, they are unlikely to be appropriate in emergencies.

Advantages: Composting is environmentally friendly; and beneficial for crops.

Constraints: Intensive management and experienced personnel are required for large-scale operations.

Recycling

Complex recycling systems are unlikely to be appropriate but the recycling of some waste items may be possible on occasions. Plastic bags, containers, tins and glass will often be automatically recycled since they are likely to be scarce commodities in many situations. In most developing country contexts there exists a strong tradition of recycling leading to lower volumes of waste than in many more developed societies.

Advantages: Recycling is environmentally friendly.

Constraints: There is limited potential in most emergency situations; and it is expensive to set up.

WASTE CHARACTERISTICS

In order to identify the exact characteristics of municipal wastes, it is necessary that we analyse them using physical, chemical and biological characteristics.

Physical characteristics

Information and data on the physical characteristics of solid wastes are important for the selection and operation of equipment and for the analysis and design of disposal facilities. The required information and data include the following:

(i) **Density:** Density of waste, i.e., its mass per unit volume (kg/m^3), is a critical factor in the design of a SWM system, e.g., the design of sanitary landfills, storage, types of collection and transport vehicles, etc. To explain, an efficient operation of a landfill demands compaction of wastes to optimum density. Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density of 100 kg/m^3 to 400 kg/m^3. In other words, a waste collection vehicle can haul four times the weight of waste in its compacted state than when it is uncompacted. A high initial density of waste precludes the achievement of a high compaction ratio and the compaction ratio achieved is no greater than 1.5:1. Significant changes in density occur spontaneously as the waste moves from source to disposal, due to scavenging, handling, wetting and drying by the weather, vibration in the collection vehicle and decomposition. Note that:

- the effect of increasing the moisture content of the waste is detrimental in the sense that dry density decreases at higher moisture levels;
- soil-cover plays an important role in containing the waste;
- there is an upper limit to the density, and the conservative estimate of in-place density for waste in a sanitary landfill is about 600 kg/m^3.

(ii) **Moisture content:** Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total weight of the wet waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour. In the main, wastes should be insulated from rainfall or other extraneous water. We can calculate the moisture percentage, using the formula given below: A typical range of moisture

content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are not uncommon.

$$\text{Moisture content (\%)} = = \frac{\textit{wet weight} - \textit{dry weight}}{\textit{wet weight}} \times 100$$

(iii) **Size:** Measurement of size distribution of particles in waste stream is important because of its significance in the design of mechanical separators and shredders. Generally, the results of size distribution analysis are expressed in the manner used for soil particle analysis. That is to say, they are expressed as a plot of particle size (mm) against percentage, less than a given value.

- $S_c = l$
- $S_c = \frac{l+w}{2}$
- $S_c = \frac{l+w+h}{3}$
- $S_c = \sqrt{l \times w}$
- $S_c = \sqrt[3]{l \times w \times h}$

Where, $S\_(c)$ = size of component in mm w = width in mm

h = height in mm l = length in mm

The physical properties that are essential to analyse wastes disposed at landfills are:

I. Field capacity: The field capacity of MSW is the total amount of moisture which can be retained in a waste sample subject to gravitational pull. It is a critical measure because water in excess of field capacity will form leachate, and leachate can be a major problem in landfills. Field capacity varies with the degree of applied pressure and the state of decomposition of the wastes.

II. Permeability of compacted wastes: The hydraulic conductivity of compacted wastes is an important physical property because it governs the movement of liquids and gases in a landfill. Permeability depends on the other properties of the solid material include pore size distribution, surface area and porosity.

Porosity: It represents the amount of voids per unit overall volume of material. The porosity of MSW varies typically from 0.40 to 0.67 depending on the compaction and composition of the waste. Porosity of solid waste n= e/ (1+e) Where e is void ratio of solid waste

III. Compressibility of MSW: Degree of physical changes of the suspended solids or filter cake when subjected to pressure.

$\Delta HT = \Delta Hi + \Delta Hc + \Delta H\alpha$

[ΔHT= total settlement; ΔHi=immediate settlement; ΔHc = consolidation settlement; $\Delta H\alpha$ = secondary compression or creep.]

$C'\alpha = \Delta H / [H0 \times (\text{Log}(t2/t1))] = C\alpha / (1+e0)$

[*Cα, C'α* = Secondary compression index and Modified secondary Compression index; and

t1, t2= Starting and ending time of secondary settlement respectively.]

Chemical characteristics

Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behaviour of waste, as it moves through the waste management system. The products of decomposition and heating values are two examples of chemical characteristics. If solid wastes are to be used as fuel, or are used for any other purpose, we must know their chemical characteristics, including the following:

(i) **Lipids:** This class of compounds includes fats, oils and grease, and the principal sources of lipids are garbage, cooking oils and fats. Lipids have high heating values, about 38,000 kJ/kg (kilojoules per kilogram), which makes waste with high lipid content suitable for energy recovery. Since lipids become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. Though they are biodegradable, the rate of biodegradation is relatively slow because lipids have a low solubility in water.

(ii) **Carbohydrates:** These are found primarily in food and yard wastes, which encompass sugar and polymer of sugars (e.g., starch, cellulose, etc.) with general formula $(CH_2O)x$. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates attract flies and rats, and therefore, should not be left exposed for long duration.

(iii) **Proteins:** These are compounds containing carbon, hydrogen, oxygen and nitrogen, and consist of an organic acid with a substituted amine group (NH_2). They are mainly found in food and garden wastes. The partial decomposition of these compounds can result in the production of amines that have unpleasant odours.

(iv) **Natural fibres:** These are found in paper products, food and yard wastes and include the natural compounds, cellulose and lignin, that are resistant to biodegradation. (Note that paper is almost 100% cellulose, cotton over 95% and wood products over 40%.) Because they are a highly combustible solid waste, having a high proportion of paper and wood products, they are suitable for incineration. Calorific values of oven-dried paper products are in the range of 12,000 -18,000 kJ/kg and of wood about 20,000 kJ/kg, i.e., about half that for fuel oil, which is 44,200 kJ/kg.

(v) **Synthetic organic material (Plastics):** Accounting for 1 – 10%, plastics have become a significant component of solid waste in recent years. They are highly resistant to biodegradation and, therefore, are objectionable and of special concern in SWM. Hence the increasing attention being paid to the recycling of plastics to reduce the proportion of this waste component at disposal sites. Plastics have a high heating value, about 32,000 kJ/kg, which makes them very suitable for incineration. But, you must note that polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas. The latter increases corrosion in the combustion system and is responsible for acid rain.

(vi) **Non-combustibles:** This class includes glass, ceramics, metals, dust and ashes, and accounts for 12 – 25% of dry solids.

(vii) **Heating value:** An evaluation of the potential of waste material for use as fuel for incineration requires a determination of its heating value, expressed as kilojoules per kilogram (kJ/kg). The heating value is determined experimentally using the *Bomb calorimeter test*, in which the heat generated, at a constant temperature of 25^0C from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water (100^0C), the combustion water remains in the liquid state. However, during combustion, the temperature of the combustion gases reaches above 100C, and the resultant water is in the vapour form. Table 2.3 shows the typical inert residue and heating values for the components of municipal solid waste.

Table 2.3 Typical Heating and Inert Residue Values

Component	Inert Residue %		Heating Value (kJ/kg)	
	Range	Typical	Range	Typical
Food wastes	2-8	5	3500-7000	4500
Paper	4-8	6	11500-18500	16500
Cardboard	3-6	5	14000-17500	16000
Plastics	2-20	10	28000-37000	32500
Textiles	2-4	2.5	15000-20000	17500

Component	Inert Residue %		Heating Value (kJ/kg)	
	Range	Typical	Range	Typical
Rubber	8-20	10	21000-28000	18500
Leather	8-20	10	15000-20000	17500
Garden trimmings	2-6	4.5	2300-18500	6500
Wood	0.6-2	1.5	17500-20000	18500
Glass	96-99	98	120-240	140
Tin cans	96-99	96	-	-
Nonferrous metals	90-99	96	240-1200	700
Ferrous metals	94-99	98	240-1200	700
Dirt, ash, bricks, etc.	60-80	70	2300-11500	7000
Municipal solid waste	-	-	9500-13000	10500

Note that while evaluating incineration as a means of disposal or energy recovery, we need to consider the heating values of respective constituents.

- Organic material yields energy only when dry.
- The moisture content in the waste reduces the dry organic material per kilogram of waste and requires a significant amount of energy for drying.
- The ash content of the waste reduces the proportion of dry organic material per kilogram of waste and retains some heat when removed from the furnace.

(viii) **Ultimate analysis:** This refers to an analysis of waste to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur, and the analysis is done to make mass balance calculation for a chemical or thermal process. Besides, it is necessary to determine ash fraction because of its potentially harmful environmental effects, brought about by the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc. Note that other metals (e.g., iron, magnesium, etc.) may also be present but they are non-toxic. Table 2.4 shows the result of ultimate analysis of a typical municipal solid waste:

Table 2.4 Municipal Solid Waste: A Typical Ultimate Analysis

Element	**Range (%dry weight)**
Carbon	25-30
Hydrogen	2.5-6.0
Oxygen	15-30
Nitrogen	0.25-1.2
Sulphur	0.02-0.12
Ash	12-30

(ix) **Proximate analysis:** This is important in evaluating the combustion properties of wastes or a waste or refuse derived fuel. The fractions of interest are:

- moisture content, which adds weight to the waste without increasing its heating value, and the evaporation of water reduces the heat released from the fuel;
- ash, which adds weight without generating any heat during combustion;
- volatile matter, i.e., that portion of the waste that is converted to gases before and during combustion;
- fixed carbon, which represents the carbon remaining on the surface grates as charcoal. A waste or fuel with a high proportion of fixed carbon requires a longer retention time

on the furnace grates to achieve complete combustion than a waste or fuel with a low proportion of fixed carbon.

Table 2.5 Municipal Solid Waste: A Typical Proximate Analysis

Components		**Value, percent**
	Range	**Typical**
Moisture	15-40	20
Volatile matter	40-60	53
Fixed carbon	5-12	7
Glass, metal, ash	15-30	20

To evaluate alternative processing and recovery options (e.g., incineration process), we need information on the chemical characteristics of wastes, and wastes can typically be a combination of combustible and non-combustible materials.

Biological Characteristics

- Biodegradability of waste
- Odours
- Breeding of flies

The most important biological characteristic of the organic fraction of MSW is that almost all of the organic components can be converted biologically to gases and relatively inert organic and inorganic solids. The production of odours and the generation of flies are also related to the putrescible nature of the organic materials found in MSW (e.g., food wastes).

Excluding plastic, rubber and leather components, the organic fraction of most MSW can be classified as follows:

- Water-soluble constituents such as sugars, starches, amino acids, and various organic acids.
- Hemicelluloses, a condensation product of five- and six-carbon sugars
- Cellulose, a condensation product of the six-carbon sugar glucose
- Fats, oils, and waxes which are esters of alcohols and long-chain fatty Acids
- Lignin, a polymeric material containing aromatic rings with methoxyl groups
- Lignocelluloses, a combination of lignin and cellulose

• Proteins, which are composed of chains of amino acids

Biodegradability of Organic Waste Components:

- Volatile solids (VS) content, determined by ignition at 550^0 C, is often used as a measure of the biodegradability of the organic fraction of MSW.
- Estimate the biodegradable fraction, using the following relationship:

  BF = 0.83 – 0.028 LC

  Where,

  BF= biodegradable fraction expressed on a volatile solids (VS) basis

  0.83 = empirical constant

  0.028 = empirical constant

  LC = lignin content of VS expressed as a percent of dry weight
- Wastes with high lignin contents, such as newsprint, are significantly less biodegradable than the other organic wastes found in MSW.

E- WASTES

Electronic waste or e-waste may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets, and refrigerators. This includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal as well as re-usables (working and repairable electronics) and secondary scraps (copper, steel, plastic, etc.). The term "waste" is reserved for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations, because of loads of surplus electronics (good, recyclable, and non-recyclable).

Several public policy advocates apply the term "e-waste" and "e-scrap" broadly to all surplus electronics. Electronic waste or e-waste describes discarded electrical or electronic devices. Used electronics which are destined for reuse, resale, salvage, recycling, or disposal are also considered e-waste. Informal processing of e-waste in developing countries can lead to adverse human health effects and environmental pollution. Electronic scrap components, such as CPUs, contain potentially harmful materials such as lead, cadmium and beryllium. Recycling and disposal of e-waste may involve significant risk to health of workers and communities in developed countries and great care must be taken to avoid unsafe exposure in recycling operations and leaking of materials such as heavy metals from landfills and incinerator ashes.

E-waste or electronic waste is created when an electronic product is discarded after the end of its useful life. The rapid expansion of technology means that a very large amount of e-waste is created every minute.

Electronic waste or e-waste may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets, and refrigerators. This includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal as well as re-usables (working and repairable electronics) and secondary scraps (copper, steel, plastic, etc.). The term "waste" is reserved for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations, because loads of surplus electronics are frequently commingled (good, recyclable, and non-recyclable). Several public policy advocates apply the term "e-waste" and "e-scrap" broadly to all surplus electronics. Cathode ray tubes(CRTs) are considered one of the hardest types to recycle.

CRTs have a relatively high concentration of lead and phosphors (not to be confused with phosphorus), both of which are necessary for the display. The United States Environmental Protection Agency (EPA) includes discarded CRT monitors in its category of "hazardous household waste" but considers CRTs that have been set aside for testing to be commodities if they are not discarded, speculatively accumulated, or left unprotected from weather and other damage. These CRT devices are often confused between the DLP Rear Projection TV, both of which have a different recycling process due to the materials of which they are composed.

Environmental impact of E waste

The processes of dismantling and disposing of electronic waste in developing countries led to a number of environmental impacts. Liquid and atmospheric releases end up in bodies of water, groundwater, soil, and air and therefore in land and sea animals – both domesticated and wild, in crops eaten by both animals and human, and in drinking water.

One study of environmental effects, found the following:

- Airborne dioxins
- Carcinogens
- Heavy metals

The environmental impact of the processing of different electronic waste components

E-Waste Component	Process Used	Potential Environmental Hazard
Cathode ray tubes (used in TVs, computer monitors, ATM, video cameras, and more)	Breaking and removal of yoke, then dumping	Lead, barium and other heavy metals leaching into the ground water and release of toxic phosphor
Printed circuit board (image behind table – a thin plate on which chips and other electronic components are placed)	De-soldering and removal of computer chips; open burning and acid baths to remove metals after chips are removed.	Air emissions and discharge into rivers of glass dust, tin, lead, brominated dioxin, beryllium cadmium, and mercury
Chips and other gold plated components	Chemical stripping using nitric and	PAHs, heavy metals, brominated flame retardants discharged directly into

	hydrochloric acid and burning of chips	rivers acidifying fish and flora. Tin and lead contamination of surface and groundwater. Air emissions of brominated dioxins, heavy metals, and PAHs
Plastics from printers, keyboards, monitors, etc.	Shredding and low temp melting to be reused	Emissions of brominated dioxins, heavy metals, and hydrocarbons
Computer wires	Open burning and stripping to remove copper	PAHs released into air, water, and soil.

Recycling of - waste

Computer monitors are typically packed into low stacks on wooden pallets for recycling and then shrink-wrapped.

Recycling is an essential element of e-waste management. Properly carried out, it should greatly reduce the leakage of toxic materials into the environment and mitigate against the exhaustion of natural resources. However, it does need to be encouraged by local authorities and through community education.

One of the major challenges is recycling the printed circuit boards from the electronic wastes. The circuit boards contain such precious metals as gold, silver, platinum, etc. and such base metals as copper, iron, aluminum, etc. One way e-waste is processed is by melting circuit boards, burning cable sheathing to recover copper wire and open- pit acid leaching for separating metals of value. Conventional method employed is mechanical shredding and separation but the recycling efficiency is low. Alternative methods such as cryogenic decomposition have been studied for printed circuit board recycling, and some other methods are still under investigation. Properly disposing of or reusing electronics can help prevent health problems, reduce greenhouse-gas emissions, and create jobs. Reuse and refurbishing offer a more environmentally friendly and socially conscious alternative to downcycling processes.

In many developed countries, electronic waste processing usually first involves dismantling the equipment into various parts (metal frames, power supplies, circuit boards, plastics), often by hand, but increasingly by automated shredding equipment.

In an alternative bulk system, a hopper conveys material for shredding into an unsophisticated mechanical separator, with screening and granulating machines to separate constituent metal and plastic fractions, which are sold to smelters or plastics recyclers. Such recycling machinery is enclosed and employs a dust collection system. Some of the emissions are caught by scrubbers and screens. Magnets, eddy currents, and Trommel screens are employed to separate glass, plastic, and ferrous and nonferrous metals, which can then be further separated at a smelter.

Leaded glass from CRTs is reused in car batteries, ammunition, and lead wheel weights, or sold to foundries as a fluxing agent in processing raw lead ore. Copper, gold, palladium, silver and tin are valuable metals sold to smelters for recycling. Hazardous smoke and gases are captured, contained and treated to mitigate environmental threat. These methods allow for safe reclamation of all valuable computer construction materials.

An ideal electronic waste recycling plant combines dismantling for component recovery with increased cost-effective processing of bulk electronic waste. Reuse is an alternative option to recycling because it extends the lifespan of a device. Devices still need eventual recycling, but by allowing others to purchase used electronics, recycling can be postponed and value gained from device use.

Benefits of recycling

Recycling raw materials from end-of-life electronics is the most effective solution to the growing e-waste problem. Most electronic devices contain a variety of materials, including metals that can be recovered for future uses. By dismantling and providing reuse possibilities, intact natural resources are conserved and air and water pollution caused by hazardous disposal is avoided. Additionally, recycling reduces the amount of greenhouse gas emissions caused by the manufacturing of new products.Another benefit of recycling e-waste is that many of the materials can be recycled and re-used again. Materials that can be recycled include "ferrous (iron-based) and non-ferrous metals, glass, and various types of plastic." “Non-ferrous metals, mainly aluminum and copper can all be re-smelted and re-manufactured. Ferrous metals such as steel and iron can be also be re-used."Due to the recent surge in popularity in 3D printing, certain 3D printers have been designed (FDM variety) to produce waste that can be easily recycled which decreases the amount of harmful pollutants in the atmosphere.The excess plastic from these printers that comes out as a byproduct can also be reused to create new 3D printed creations.

Benefits of recycling are extended when responsible recycling methods are used. In the U.S., responsible recycling aims to minimize the dangers to human health and the environment that

disposed and dismantled electronics can create. Responsible recycling ensures best management practices of the electronics being recycled, worker health and safety, and consideration for the environment locally and abroad. In Europe, metals that are recycled are returned to companies of origin at a reduced cost. Through a committed recycling system, manufacturers in Japan have been pushed to make their products more sustainable. Since many companies were responsible for the recycling of their own products, this imposed responsibility on manufacturers requiring many to redesign their infrastructure. As a result, manufacturers in Japan have the added option to sell the recycled metals.

Repair

One of the factors which exacerbate the e-waste problem is the diminishing lifetime of many electrical and electronic goods. There are two drivers (in particular) for this trend. On the one hand, consumer demand for low cost products mitigates against product quality and results in short product lifetimes. On the other, manufacturers in some sectors encourage a regular upgrade cycle, and may even enforce it though restricted availability of spare parts, service manuals and software updates, or through planned obsolescence.

Consumer dissatisfaction with this state of affairs has led to a growing repair movement. Often, this is at a community level such as through repair cafès or the "restart parties" promoted by the Restart Project.

Electronic waste substances

E-Waste Component	**Electric Appliances in which they are found**	**Adverse Health Effects**
Americium	The radioactive source in smoke alarms.	It is known to be carcinogenic.
Lead	Solder, CRT monitor glass, lead-acid batteries, some formulations of PVC. A typical 15-inch cathode ray tube may contain 1.5 pounds of lead, but other CRTs have been estimated as having up to 8 pounds of lead.	Adverse effects of lead exposure include impaired cognitive function, behavioral disturbances, attention deficits, hyperactivity, conduct problems, and lower IQ. These effects are most damaging to children

		whose developing nervous systems are very susceptible to damage caused by lead, cadmium, and mercury.
Mercury	Found in fluorescent tubes (numerous applications), tilt switches (mechanical doorbells, thermostats), and ccfl backlights in flat screen monitors.	Health effects include sensory impairment, dermatitis, memory loss, and muscle weakness. Exposure in-utero causes fetal deficits in motor function, attention, and verbal domains.Environmental effects in animals include death, reduced fertility, and slower growth and development.
Cadmium	Found in light-sensitive resistors, corrosion-resistant alloys for marine and aviation environments, and nickel-cadmium batteries. The most common form of cadmium is found in Nickel-cadmium rechargeable batteries. These batteries tend to contain between 6 and 18% cadmium. The sale of Nickel-Cadmium batteries has been banned in the European Union except for medical use. When not properly recycled it can leach into the soil, harming microorganisms and disrupting the soil ecosystem. Exposure is caused by proximity to hazardous waste sites and factories and workers in the metal refining industry.	The inhalation of cadmium can cause severe damage to the lungs and is also known to cause kidney damage.Cadmium is also associated with deficits in cognition, learning, behavior, and neuromotor skills in children.

Hexavalent chromium	Used in metal coatings to protect from corrosion.	A known carcinogen after occupational inhalation exposure. There is also evidence of cytotoxic and genotoxic effects of some chemicals, which have been shown to inhibit cell proliferation, cause cell membrane lesion, cause DNA single-strand breaks, and elevate Reactive Oxygen Species (ROS) levels.
Sulphur	Found in lead-acid batteries.	Health effects include liver damage, kidney damage, heart damage, eye and throat irritation. When released into the environment, it can create sulphuric acid through sulphur dioxide.
Brominated Flame Retardants (BFRs)	Used as flame retardants in plastics in most electronics. Includes PBBs, PBDE, DecaBDE, Oct aBDE, PentaBDE.	Health effects include impaired development of the nervous system, thyroid problems, liver problems.Environmental effects: similar effects as in animals as humans. PBBs were banned from 1973 to 1977 on. PCBs were banned during the 1980s.
Perfluorooctan oic acid (PFOA)	Used as an antistatic additive in industrial applications and found in electronics, also found in non-stick cookware (PTFE). PFOAs are formed	Studies in mice have found the following health effects: Hepatotoxicity, developmental toxicity, immunotoxicity, hormonal effects and

	synthetically through environmental degradation.	carcinogenic effects. Studies have found increased maternal PFOA levels to be associated with an increased risk of spontaneous abortion (miscarriage) and stillbirth. Increased maternal levels of PFOA are also associated with decreases in mean gestational age (preterm birth), mean birth weight (low birth weight), mean birth length (small for gestational age), and mean APGAR score.
Beryllium oxide	Filler in some thermal interface materials such as thermal grease used on heat sinks for CPUs and power transistors, magnetrons, X-ray-transparent ceramic windows, heat transfer fins in vacuum tubes, and gas lasers.	Occupational exposures associated with lung cancer, other common adverse health effects are beryllium sensitization, chronic beryllium disease, and acute beryllium disease.
Polyvinyl chloride(PVC)	Commonly found in electronics and is typically used as insulation for electrical cables.	In the manufacturing phase, toxic and hazardous raw material, including dioxins are released. PVC such as chlorine tend to bioaccumulate. Over time, the compounds that contain chlorine can become pollutants in the air, water, and soil. This poses a problem as human and animals can ingest them. Additionally, exposure to toxins can result in

		reproductive and developmental health effects.

Generally non-hazardous

E-Waste Component	Process Used
Aluminium	nearly all electronic goods using more than a few watts of power (heatsinks), electrolytic capacitors.
Copper	copper wire, printed circuit board tracks, component leads.
Germanium	1950s–1960s transistorized electronics (bipolar junction transistors).
Gold	connector plating, primarily in computer equipment.
Lithium	lithium-ion batteries.
Nickel	nickel-cadmium batteries.
Silicon	glass, transistors, ICs, printed circuit boards.
Tin	solder, coatings on component leads.
Zinc	plating for steel parts.

RADIOACTIVE WASTE

Radioactive (or nuclear) waste is a byproduct from nuclear reactors, fuel processing plants, hospitals and research facilities. Radioactive waste is also generated while decommissioning and dismantling nuclear reactors and other nuclear facilities. There are two broad classifications: high-level or low-level waste. High-level waste is primarily spent fuel removed from reactors after producing electricity. Low-level waste comes from reactor operations and from medical, academic, industrial, and other commercial uses of radioactive materials.

High-Level Waste

High-level radioactive waste primarily is uranium fuel that has been used in a nuclear power reactor and is "spent," or no longer efficient in producing electricity. Spent fuel is thermally hot as well as highly radioactive and requires remote handling and shielding. Nuclear reactor fuel contains ceramic pellets of uranium 235 inside of metal rods. Before these fuel rods are used, they are only slightly radioactive and may be handled without special shielding.

During the fission process, two things happen to the uranium in the fuel. First, uranium atoms split, creating energy that is used to produce electricity. The fission creates radioactive isotopes of lighter elements such as cesium-137 and strontium-90. These isotopes, called "fission products," account for most of the heat and penetrating radiation in high-level waste. Second, some uranium atoms capture neutrons produced during fission. These atoms form heavier elements such as plutonium. These heavier-than-uranium, or "transuranic," elements do not produce nearly the amount of heat or penetrating radiation that fission products do, but they take much longer to decay. Transuranic wastes, sometimes called TRU, account for most of the radioactive hazard remaining in high-level waste after 1,000 years.

Radioactive isotopes eventually decay, or disintegrate, to harmless materials. Some isotopes decay in hours or even minutes, but others decay very slowly. Strontium-90 and cesium-137 have half-lives of about 30 years (half the radioactivity will decay in 30 years). Plutonium-239 has a half-life of 24,000 years.

High-level wastes are hazardous because they produce fatal radiation doses during short periods of direct exposure. For example, 10 years after removal from a reactor, the surface dose rate for a typical spent fuel assembly exceeds 10,000 rem/hour – far greater than the fatal whole-body dose for humans of about 500 rem received all at once. If isotopes from these high-level wastes get into groundwater or rivers, they may enter food chains. The dose produced

through this indirect exposure would be much smaller than a direct-exposure dose, but a much larger population could be exposed. Reprocessing separates residual uranium and plutonium from the fission products. The uranium and plutonium can be used again as fuel.

Storage and Disposal

Nuclear power plants store spent nuclear fuel in "spent fuel pools." These pools are made of reinforced concrete several feet thick, with steel liners. The water is typically about 40 feet deep and serves both to shield the radiation and cool the rods. As the pools near capacity, utilities move some of the older spent fuel into "dry cask" storage. These casks are stainless steel canisters surrounded by concrete. Fuel is typically cooled at least five years in the pool before transfer to cask. NRC has authorized transfer as early as three years; the industry norm is about 10 years. The NRC certifies cask designs and licenses dry cask storage facilities for up to 40 years. The certifications and licenses can be renewed.

The NRC believes spent fuel pools and dry casks both provide adequate protection for public health and safety and the environment. Therefore there is no pressing safety or security reason to mandate earlier transfer of fuel from pool to cask.

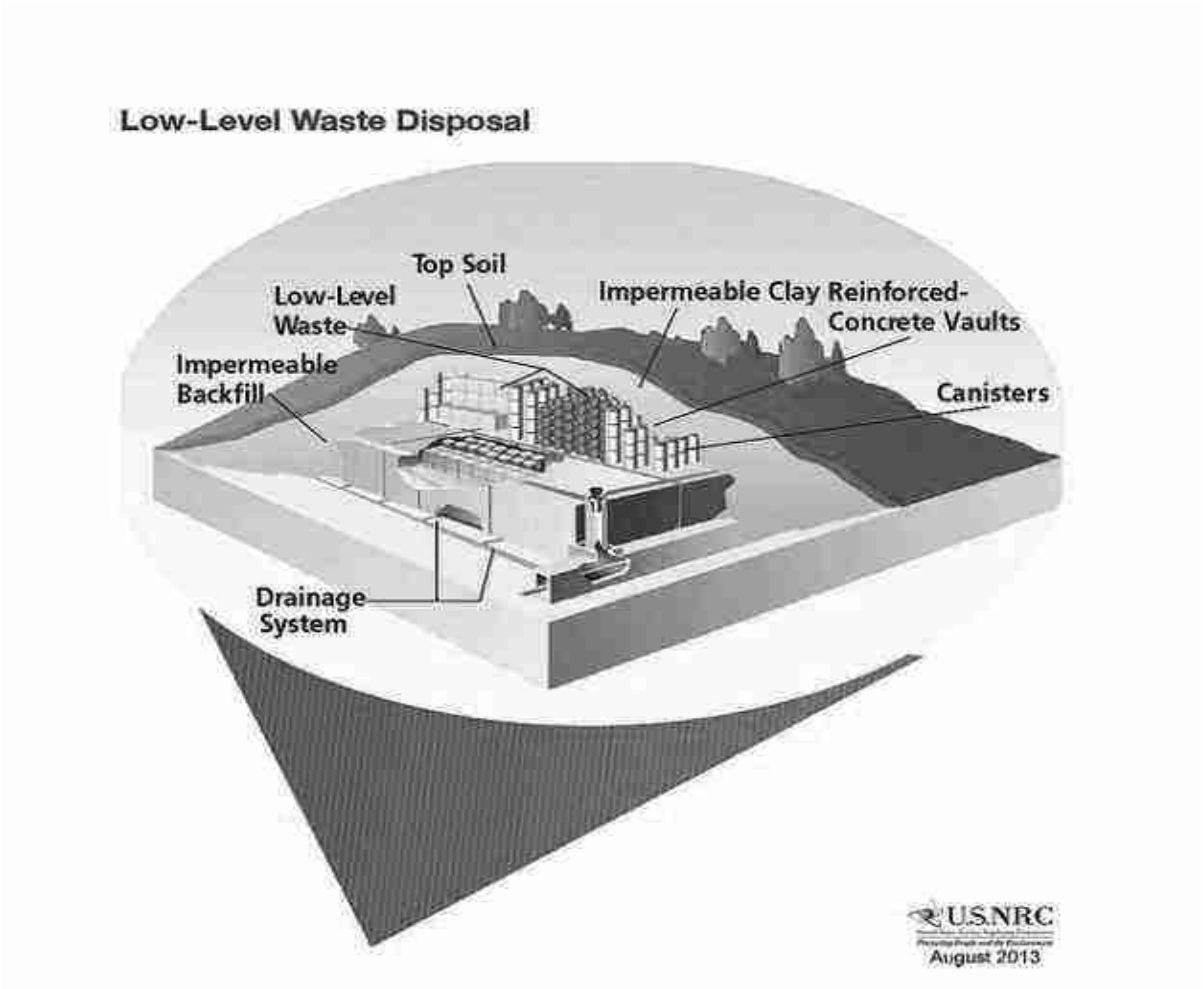
Dry Cask Storage of Spent Fuel

Spent fuel storage at power plant sites is considered temporary, with the ultimate goal being permanent disposal. However, at this time there are no facilities for permanent disposal of high-level waste.

Low-Level Waste

Low-level wastes, generally defined as radioactive wastes other than high-level and wastes from uranium recovery operations, are commonly disposed of in near-surface facilities rather than in a geologic repository. There is no intent to recover the wastes once they are disposed of.

Low-level waste includes items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. This waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipment and tools, luminous dials, medical tubes, swabs, injection needles, syringes, and laboratory animal carcasses and tissues. The radioactivity can range from just above background levels found in nature to much higher levels in certain cases such as parts from inside the reactor vessel in a nuclear power plant. Low-level waste is typically stored on-site by licensees, either until it has decayed away and can be disposed of as ordinary trash, or until amounts are large enough for shipment to a low-level waste disposal site in approved containers.



LAND DEGRADATION

- Land degradation is the most important environmental problem currently challenging sustainable development in many parts of the world.
- The change in the characteristic and quality of soil which adversely affect its fertility is called as Degradation.
- The problem is most acute where the environment is intrinsically vulnerable and where the population is losing control of its own resources.
- Land Degradation means

1. Loss of natural fertility of soil because of loss of nutrients.
2. Less vegetation cover
3. Changes in the characteristic of soil.
4. Pollution of water resources from the contamination of soil through which water sweeps into ground or runoff to the water bodies.
5. Changes in climatic conditions because of unbalance created in the environment.

Causes of Land Pollution

1) Deforestation and Soil erosion:

Deforestation carried out to create dry lands is one of the major concerns. Land that is once converted into a dry or barren land, can never be made fertile again. Exposed land and loosened soil may lead to soil erosion. Land conversion is another major cause, meaning the alteration or modification of the original properties of the land to make it use worthy for a specific purpose.

2) Agricultural activities:

With growing human population, demand for food has increased considerably. Farmers often use highly toxic fertilizers and pesticides to get rid off insects, fungi and bacteria from their crops. With the over use of these chemicals, they result in contamination and poisoning of soil.

3) Industrialization:

Due to increase in demand for food, shelter and house, more goods are produced. This resulted in creation of more waste that needs to be disposed of. To meet the demand of the growing population, more industries were developed which led to deforestation.

4) Construction activities:

Due to urbanization, large amount of construction activities are taking place which has resulted in large waste articles like wood, metal, bricks, plastic etc

5) Nuclear waste:

Nuclear plants can produce huge amount of energy through nuclear fission and fusion. The left over radioactive material contains harmful and toxic chemicals that can affect human health. They are dumped beneath the earth to avoid any casualty.

6) Sewage treatment:

Large amount of solid waste is leftover once the sewage has been treated. The left over material is sent to landfill site which end up in polluting the environment.

7) Acid rain:

Acid rain is caused when pollutants present in the air mixes up with the rain and fall back on the ground. This polluted water could dissolve away some of the important nutrients found in soil and change the structure of the soil.

8) Accidental oil spills:

Chemicals in the fuel deteriorates the quality of soil and make them unsuitable for cultivation. These chemicals can enter into the groundwater through soil and make the water undrinkable.

9) Mining activities:

A source of land pollution. Huge holes are dug for mining and these holes can pose a hazard as they form deep mining pools. Metals like cadmium and lead will be deposited, which are toxic contaminating the soil. This will leave the mining

land barren and unable to use again.

10) Shifting Cultivation

Forest is burnt to use the land for cultivation,until the soil loses it's fertility. Once the land becomes inadequate for crop production, it is left barren and hance leads to soil erosion.

EFFECTS OF URBANIZATION ON LAND POLLUTION

Urbanization is the increased number of inhabitants in the urban areas. The trend of urbanization has been in its greatest boom since 1980's. Presently more and more people flock towards cities for better living conditions and facilities.

This immediate drift towards urbanization has created various environmental issues. Some of the major effects include

1. **Soil erosion:** Conversion of agricultural land and forest, as well as reclaiming of wetlands, for urban uses and infrastructure, are associated with widespread removal of vegetation to support urban ecosystem which in turn led to soil erosion. The conversion of Earth's land surface to urban uses is one of the most irreversible human impacts on the global biosphere. It drives the loss of farmland, affects local climate, fragments habitats, and threatens biodiversity.
2. **Landslides:** The stability of slopes (both natural and artificial) determines the vulnerability of landslides or slope failures Encroachment of urban land into nearby forested or vegetated areas, and the expansion of built up areas and transportation networks into steeper terrain destabilizing slopes lead to slope failures
3. **Effect on Climate:** The conversion of Earth's land surface to urban uses leads to loss in the forest cover of Earth which in turn going to affect the amount of rain.
4. **Improper waste disposal:** Urban activities generate large quantities of city wastes including several biodegradable materials (like vegetables, animal wastes, papers, wooden pieces, carcasses, plant twigs, leaves, cloth wastes as well as sweepings) and many non-biodegradable materials (such as plastic bags, plastic bottles, plastic wastes, glass bottles, glass pieces, stone / cement pieces). Uncollected and improperly handled solid waste can have serious health consequences.

- Clogging of drains Causing serious drainage problems including the burst / leakage of drainage lines leading to health problems.
- Barrier to movement of water -Solid wastes have seriously damaged the normal movement of water thus creating problem of inundation, damage to foundation of buildings as well as public health hazards.
- Foul smell - generated by dumping the wastes at a place.
- Increased microbial activities Microbial decomposition of organic wastes generate large quantities of methane besides many chemicals to pollute the soil and water flowing on its surface hospital waste.
- Create many health problems - as they may have dangerous pathogen within them besides dangerous medicines, injections.
- Pollution of underground soil.
- Chemicals released by industrial wastes, Decomposed and partially decomposed materials of sanitary wastes.

5. **Decrease in food production:** As the world population and land degradation increase, world food security decrease.

IMPACT OF MODERN AGRICULTURE ON LAND DEGRADATION

Agriculture is an art, science and industry of managing the growth of plants and animals for human use. Agriculture includes preparation of soil for cultivation of crops, harvesting crops, breeding and raising livestock, dairying and forestry.

The two major types of agriculture are:

- Traditional agriculture and
- Modern or Industrialized agriculture

Modern Agriculture

Modern agriculture makes use of hybrid seeds of single crop variety, technologically advanced equipment, fertilizers, pesticides and water to produce large amounts of single crop. As agriculture has become more intensive, farmers have become capable of producing higher yields using less labor and less land. But environmental impacts have increased, including potential degradation of the soil and water resources vital to both farm productivity and human health.

1. **Deforestation and Soil erosion**

- In agriculture, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage.
- Soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinisation and soil acidity problems are the conditions that can accelerate the soil erosion process.
- Erosion affects productivity because it removes the surface soils, containing most of the organic matter, plant nutrients, and fine soil particles, which help to retain water and nutrients in the root zone where they are available to plants.
- The subsoil that remains then tend to be less fertile, less absorbent, and less able to retain pesticides, fertilizers, and other plant nutrients.

2. **Damages**

- Caused by agricultural machinery in soil
- The use of tractors combined with harvesters increased with suitable machinery has made easy to work on difficult soils and has brought such lands under plough.
- This result in soil compaction and is characterized by increased density of the soil, reduced air volume and a reduced ability to drain off surplus water.

3) Wrong soil tillage

- Wrong soil tillage with regards of without any concern field location, soil structure and climate conditions cause soil erosion and results in inefficient soils.

4) Loss of Soil Fertility

- The introduction of intensive cultivation to get the maximum production and the variety of crops through multiple cropping, crop rotations, changing crop combination from the same unit of land has resulted in the decline of the productivity and total production due to critical limit of the soil.

5) Water logging

- If water stands on land for most of the year, it is called water logging. In water logged conditions, pore-voids in the soil get filled with water and soil-air gets depleted. In such a condition the roots of plants do not get enough air for respiration. Water logging also leads to low mechanical strength of soil and low crop yield.

6) Excessive use of Fertlizers

- Micronutrient imbalance: Chemical fertilizers used in modern agriculture contain Nitrogen, Phosphorus and Potassium (N, P, K) which are macronutrients. Excess use of fertilizers in fields causes micronutrient imbalance
- Nitrate pollution: Excess Nitrogenous fertilizers applied in fields leach deep into the soil contaminating the groundwater. If the concentration of nitrate in drinking water exceeds 25 mg/L it leads to a fatal condition in new-born babies. This condition is termed "Blue Baby Syndrome"
- Eutrophication: The application of excess fertilizers in fields leads to wash off of the nutrient loaded water into nearby lakes causing over- nourishment. This is called "Eutrophication.

7) Use of Pesticides

- Death of non-target organisms: Several insecticides kill not only the target species but also several beneficial not target organisms in the soil. Pesticide resistance: Some pests that survive the pesticide generate highly resistant generations that are immune to all kinds of pesticides. These pests are called "superpests“ Bio-magnification: Most pesticides are non-biodegradable and accumulate in the food chain. This is called bio-accumulation or bio-magnification. These pesticides in a bio-magnified form are harmful to human beings. Risk of cancer: Pesticide enhances the risk of cancer in two ways (i) It acts as a carcinogen and (ii) It indirectly suppresses the immune system

8) Increase in Soil Salinity

- The increase in soil salinity, salinization, is an effect of salt accumulation in the soil. Irrigation and agricultural processes that discharge nitrate and phosphate deposits in the soil are the primary contributors to increasing salt levels in the soil. Increased soil salinity makes it difficult for plants to absorb soil moisture and reduces groundwater quality. Crops and plants grown in these regions combined with other soil pollutant effects are highly poisonous and can cause severe health disorders when consumed.

PESTICIDE POLLUTION

A pesticide is a substance or a mixture of substance intended for preventing, destroying or repelling or lessening the damage caused by the pest.

Classification of pesticide

1. Herbicide
2. Insecticide
3. Rodenticide
4. Nematicide
5. Molluscicide

6. Fungicide
7. Algaecides
8. Bactericide
9. Piscicide

Pathways of pesticide movement

- Absorbed by crops
- Vapourises to atmosphere
- Degraded by UV light (Photo degradation)
- Deposited by rainfall
- Surface runoff to lakes and rivers
- Leaching and breakdown in soil.
- Leaching and degradation by microbes

Hazards of Pesticides

1) Adverse environmental Impact

- Pesticides causes pollution of soil, water and air.
- The pesticidal residue washed along with rain water, is added to the nearby water resources making it unfit for drinking.
- Decreases the soil fertility.
- Pesticides are persistant organic pollutants and cause soil pollution.

They enter the food chain and cause problem of biomagnifications.

- Several pesticides kill not only the target species but also several beneficial not target organisms in the soil.

- They are non-biodegradable and affects the balance of the ecosystem.

2) Health issues.

- Health issues such as cancer, birth defects, neurological disorders etc which results from long term exposure to pesticides as well as from food cycle.

3) Development of pest resistance

- Due to overuse of these harmful chemicals, pests have developed resistance to them. The species that have survived can reproduce a large number of pesticide resistant offspring within a short span of time. These highly resistant pests are called "superpests“

CONTROL OF PESTICIDE POLLUTION

- **Mechanical methods**
- **Biological methods**
- **Environmental methods**
- **Chemical methods**

1) Mechanical methods:

- **Hand picking:** Method of choice when pests are slowly crawling and are not able to fly e.g caterpillars
- **Trapping:** Is used for flying pests which cant be picked by hand or burned.
- **Burning:** Is used for flying pests which cant be picked by hand and can cause damage. Pests are burned and waste is removed frequently

2) Biological control:

Unlike chemical method, biological methods will not leave any toxic material in the soil. In biological pest control method, some natural predators, parasites, viruses and bacteria are introduced in soil. These control the population of pests that are harmful to us.

3) Environmental methods:

The surrounding of the pest is changed in such a way it becomes unfavorable for its growth It can be achieved by removing food stuff needed for the growth of the pest 4)Chemical methods. In this method, certain chemicals are used for controlling pests.
E.g. Rodenticides, Insecticides, Herbicides, fungicides

EFFECT OF POLLUTION ON ENVIRONMENT AND LIFE SUSTENANCE

- The contamination or degradation of soils impacts heavily on the health of plants.
- Humans are also affected in numerous ways either directly or indirectly.
- Polluted soil can harm humans by making contact with the soil or consuming vegetation produced from contaminated soils.

Some of the effects are detailed as follows.

1.Endangering Human Health

- More than 70% of the soil pollutants are carcinogenic in nature, intensifying the chances of developing cancer in the humans exposed to the polluted soils.
- Long term exposure to benzene and polychlorinated biphenyls (PCBs), resuts in the development of leukemia and liver cancer respectively.
- Soil pollutants can also cause skin diseases, muscular blockage, and central nervous system disorders.
- Humans can be affected indirectly due to bioaccumulation or food poisoning. It happens when people consume crops that are grown in the polluted soils or when they consume animal products that feed on plants from polluted soils.
- As a result, humans suffer from acute illnesses and may experience premature death.

2. Economic lossess

- The crops grown in the soils and the nearby lands are often poisoned with heavy metals and chemicals are, discarded after harvesting because of high toxicity levels.

- It is considered unfit for human consumption. Consequently, it leads to enormous economic losses.

3. Air and Water Contamination

- Polluted soil by natural means contributes to air contamination by discharging volatile compounds into the atmosphere.
- Soil pollution can also lead to water pollution if the toxic chemicals and materials like dangerous heavy metals leach into groundwater or contaminate storm water runoff, which reaches lakes, rivers, streams, or oceans.

4. Effects on Plant life

- When soils are repeatedly contaminated and accumulate large amounts of poisonous materials and chemicals, the soil reaches a point where it cannot support plant life.
- Soil pollutants interfere with soil chemistry, biology, and structure.
- When these changes occur, beneficial soil bacteria, soil microorganisms, soil nutrients, and soil chemical processes begin to deteriorate to an extent where they diminish soil fertility.
- The soil becomes unsuitable for crop survival or any other form of vegetation.
- The plants die and animals dependent on the plants will also die.
- This leads to migration of the larger animals and predators to other regions to find food supply, gradually leading to a reduction in wildlife and extinction.

5. Acidification

- Acid rain reduces soil chemistry and nutrients, which would further contribute to ecological balance disturbance and soil erosion.

6. Diminished soil fertility

- The most evident and crucial element of the soil is its fertility.
- The harmful chemicals and heavy metals in the soil decrease soil microbial and chemical activity.

- Once the soil is contaminated with chemicals and heavy metals or degraded due to human activities such as mining, its fertility depreciates and might even be lost entirely.

7. Increase in soil salinity

- The increase in soil salinity, salinization, is an effect of salt accumulation in the soil. Irrigation and agricultural processes that discharge nitrate and phosphate deposits in the soil are the primary contributors to increasing salt levels in the soil. Increased soil salinity makes it difficult for plants to absorb soil moisture and reduces groundwater quality. Crops and plants grown in these regions combined with other soil pollutant effects are highly poisonous and can cause severe health disorders when consumed.

MODULE IV

Noise Pollution: Sources and Effects, measurement of noise, Equivalent sound pressure level, control measures

Definition:

Sound, a normal feature of our life, is the means of communication and entertainment in most animals, including human beings. It is also a very effective alarm system. A low sound is pleasant whereas a loud sound is unpleasant and is commonly referred to as 'noise'. Noise can be defined as an unpleasant and unwanted sound.

Whether a given sound is as pleasant as music or as unpleasant as noise depends on its loudness, duration, rhythm and the mood of the person. But loudness is definitely the most significant criterion which converts sound into noise. Exposure to loud noise is indeed annoying and harmful too.

Noise is a physical form of pollution and is not directly harmful to the life supporting systems namely air, soil and water. Its effects are more directly on the receiver i.e. man. Noise pollution is the result of modern industrialized urban life and congestion due to over population.

Even though noise pollution is not fatal to human life, yet its importance cannot be overlooked because repeated exposure to noise reduces the sleeping hours and productivity or efficiency of a human being. It affects the peace of mind and invades the privacy of a human being. The importance of noise pollution as environmental problem is being recognised as the ill effects of noise on human health and environment are becoming evident with each passing day.

Sources of Noise Pollution:

Major causes / sources of noise pollution are:

(i) Industrial Sources:

Progress in technology (industrialization) has resulted in creating noise pollution. Textile mills, printing presses, engineering establishments and metal works etc. contribute heavily towards noise pollution. In industrial cities like Kolkata, Ludhiana, Kanpur etc., often the industrial zones are not separated from the residential zones of the city especially in the case of small scale industries.

These operate from workshops located on the ground floors of the residential areas and cause annoyance, discomfort and irritation to the residents exposed to the noise that is inevitably produced. The situation is much better in modern planned cities like Chandigarh where the industrial area is kept away from the residential areas and both are separated from each other by a sufficiently wide green belt.

(ii) Transport Vehicles:

Automobile revolution in urban centres has proved to be a big source of noise pollution. Increasing traffic has given rise to traffic jams in congested areas where the repeated hooting of horns by impatient drivers pierce the ears of all road users. Noise from airplanes constitutes an increasing serious problem in big cities like Delhi & Mumbai. Airport situated in the vicinity of population centres and the air planes pass over residential areas. Heavy trucks, buses trains, jet-planes, motor-cycles, scooters, mopeds, jeeps—the list of vehicles is endless but the outcome is same — noise pollution.

(iii) Household:

The household is an industry in itself and is a source of many indoor noises such as the banging of doors, noise of playing children, crying of infants, moving of furniture, loud conversation of the inhabitants etc. Besides these are the entertainment equipment in the house, namely the radio, record-players and television sets. Domestic gadgets like the mixer-grinders, pressure cookers, desert coolers, air- conditioners, exhaust fans, vacuum cleaners, sewing and washing machines are all indoor sources of noise pollution.

(iv) Public Address System:

In India people need only the slightest of an excuse for using loud speakers. The reason may be a religious function, birth, death, marriage, elections, demonstration, or just commercial advertising. Public system, therefore, contributes in its own way towards noise pollution.

(v) Agricultural Machines:

Tractors, thrashers, harvesters, tube wells, powered tillers etc. have all made agriculture highly mechanical but at the same time highly noisy. Noise level 90 dB to 98 dB due to running of farm machines have been recorded in the state of Punjab.

(vi) Defence Equipment:

A lot of noise pollution is added to the atmosphere by artillery, tanks, launching of rockets, explosions, exercising of military airplanes and shooting practices. Screams of jet engines and sonic booms have a deafening impact on the ears and in extreme cases have been known to shatter the window panes and old dilapidated buildings.

(vii) Miscellaneous Sources:

The automobile repair shops, construction-works, blasting, bulldozing, stone crushing etc. are other sources of noise pollution.

Effects of Noise:

Noise is generally harmful and a serious health hazard. It has far-reaching consequences and has many physical, physiological as well as psychological effects on human beings.

(i) Physical Effects:

The physical manifestation of noise pollution is the effect on hearing ability. Repeated exposure to noise may result in temporary or permanent shifting of the hearing threshold of a person depending upon the level and duration of exposure. The immediate and acute effect of noise pollution is impairment of hearing (i.e. total deafness.) Human ears have sensory cells for hearing. If these cells are subjected to repeated sounds of high intensity before they have an opportunity to recover fully, they can become permanently damaged leading to impairment of hearing. Besides the sensory cells, the delicate tympanic membrane or the ear drum can also be permanently damaged by a sudden loud noise such as an explosion.

(ii) Physiological Effects:

The physiological manifestations of noise pollution are several as mentioned below:

(a) Headache by dilating blood vessels of the brain.

(b) Increase in the rate of heart-beat.

(c) Narrowing of arteries.

(d) Fluctuations in the arterial blood pressure by increasing the level of cholesterol in the blood.

(e) Decrease in heart output.

(f) Pain in the heart.

(g) Digestive spasms through anxiety and dilation of the pupil of the eye, thereby causing eye-strain.

(h) Impairment of night vision.

(i) Decrease in the rate of colour perception.

(j) Lowering of concentration and effect on memory,

(k) Muscular strain and nervous breakdown.

(iii) Psychological Effect:

The psychological manifestations of noise pollution are:

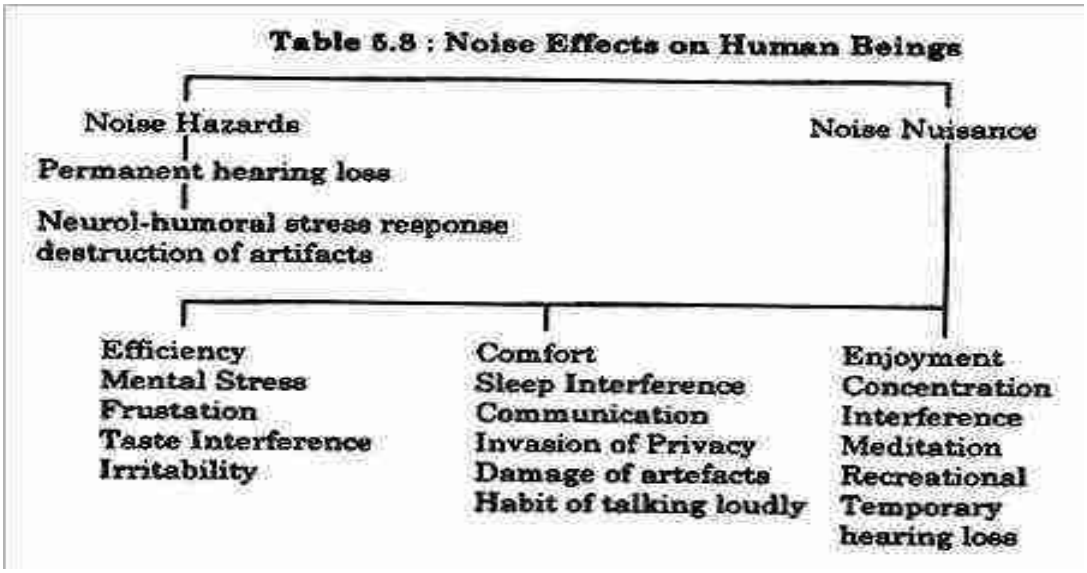
(a) Depression and fatigue which considerably reduces the efficiency of a person.

(b) Insomnia as a result of lack of undisturbed and refreshing sleep

(c) Straining of senses and annoyance as a result of slow but persistent noise from motorcycles, alarm clocks, call bells, telephone rings etc.

(d) Affecting of psychomotor performance of a person by a sudden loud sound

(e) Emotional disturbance



Noise Pollution Level and its Harmful Effects:

Level (in db)	Effects
up to 23	No disturbance
30—60	Stress, tension, psychological (illness, heart attack) effects especially at upper range.
60—90	Damage to health, psychological and vegetative (disturbance in stomach-gall function, pains in muscles, high blood pressure, disturbance in sleeping)
60—120	Damages to health and ontological (ear diseases) effects
Above 120	Painful effects in long run.

Measurement of Noise:

Noise measurement provides us assessment of adverse impacts of noise and adopting suitable control techniques for noise reduction.

Sound Level Meter

Sound level meter is used in laboratories to measure noise pollution. Noise Level in Decibel is measured with an instrument called sound level meter.

- Sound level meters (SLMs) measure sound pressure level and are commonly used in noise pollution studies.
- Positioned in desired location with no obstruction from source and sound is taken.
- Basic parts include microphone, amplifiers, weighting networks and display reading in dB.

Working Operation of Sound Level Meter

- First, When a sound wave hits the microphone, it causes a diaphragm to vibrate and the microphone convert the energy in the sound into an electrical signal

- When these signals reaches the electronic network, this network modifies the signal and then provide meaningful results.

- These results are transmitted through a visual display for communication

Weighing Network in Sound Level Meter

SLM consists of 3 internationally accepted weighing network

The weighing networks are electronic filter circuits build into the meter to weaken certain frequency.

There are 3 weighing scales

- A weighing scale- Severely filters the frequency. A for human intensity to low intensity sound.

- B weighing scale- Moderately filters the frequency. B for medium intensity sound

- C weighing Scale- Hardly filters frequency. C for human response to high intensity sound.

Table 4 : Equipment used in the measurement of noise levels

S.No.	Equipments	Specification/Area of usage
1.	Sound level meter	Type-0 : Laboratory reference standard Type-1 : Lab use and field use in specified controlled environment. Type-2 : General field use (Commonly used) Type-3 : Noise survey
2.	Impulse meters	For measurement of impulse noise levels e.g. hammer blows, punch press strokes etc.
3.	Frequency analysers	For detailed design and engineering purpose using a set of filters.
4.	Graphic recorders	Attached to sound level meter. Plots the SPL as a function of time on a moving paper chart.
5.	Noise dasimeters	Used to find out the noise levels in a working environment. Attached to the worker.
6.	Calibrators	For checking the accuracy of sound level meters.

Laboratory Guidelines:

- The Minister of Environment and Forest (MEF) have declared Indian standards for ambient noise level which are given in table 5.

- MEF classified 6 a.m. – 9 p.m. as day hours and 9 p.m. – 6 a.m. as night hours.
- The workers facing noise level > 90 dB in factories are prescribed for protection against noise by State Pollution Control Board.

Table 5 : Indian Standards for ambient noise levels

Area	Noise Limits, Leq, dB (A)	
	Day Time	Night Time
Silence zone	50	45
Residential area	55	45
Commercial area	65	55
Industrial area	75	65

Silence Zone:

- Up to 100 meter around hospitals, educational institutions and courts.
- The zones are to be declared by competent authority.
- Use of vehicle horns, loud speakers and bursting of crackers shall be banned in these zones.

Table 8 : Acceptable noise limits for working areas.

Area Classification	Acceptable Noise Limits dB (A)
General Offices	50
Private offices and small conference rooms	45
Offices and conference rooms where a high standard is required	35
Workshop and machinery buildings where communication is necessary	70
Workshop offices, plant offices and control rooms, and other areas where easy communication is necessary	60

NOISE CONTROL MEASURES

Some of the ways to control noise pollution are as follows:

(1) Control at Receiver's End

(2) Suppression of Noise at Source

(3) Acoustic Zoning

(4) Sound Insulation at Construction Stages

(5) Planting of Trees

(6) Legislative Measures.

Noise pollution can be effectively controlled by taking the following measures:

(1) Control at Receiver's End:

For people working in noisy installations, ear-protection aids like ear-plugs, ear-muffs, noise helmets, headphones etc. must be provided to reduce occupational exposure.

(2) Suppression of Noise at Source:

This is possible if working methods are improved by:

(a) Designing, fabricating and using quieter machines to replace the noisy ones.

(b) Proper lubrication and better maintenance of machines.

(c) Installing noisy machines in sound proof chambers.

(d) Covering noise-producing machine parts with sound-absorbing materials to check noise production.

(e) Reducing the noise produced from a vibrating machine by vibration damping i.e. making a layer of damping material (rubber, neoprene, cork or plastic) beneath the machine.

(f) Using silencers to control noise from automobiles, ducts, exhausts etc. and convey systems with ends opening into the atmosphere.

(g) Using glass wool or mineral wool covered with a sheet of perforated metal for the purpose of mechanical protection.

(3) Acoustic Zoning:

Increased distance between source and receiver by zoning of noisy industrial areas, bus terminals and railway stations, aerodromes etc. away from the residential areas would go a long way in minimising noise pollution. There should be silence zones near the residential areas, educational institutions and above all, near hospitals.

(4) Sound Insulation at Construction Stages:

(a) Sound travels through the cracks that get left between the door and the wall. For reducing noise, this space (jamb frame gap) should be packed with sound absorbing material.

(b) Sound insulation can be done by constructing windows with double or triple panes of glass and filling the gaps with sound absorbing materials.

(c) Acoustical tiles, hair felt, perforated plywood etc. can be fixed on walls, ceilings, floors etc. to reduce noise (especially for sound proof recording rooms etc.)

(5) Planting of Trees:

Planting green trees and shrubs along roads, hospitals, educational institutions etc. help in noise reduction to a considerable extent.

(6) Legislative Measures:

Strict legislative measures need to be enforced to curb the menace of noise pollution. Some of these measures could be:

(a) Minimum use of loudspeakers and amplifiers especially near silence zones.

(b) Banning pressure horns in automobiles.

(c) Framing a separate Noise Pollution Act.

20.3. Characteristics of Sound and its Measurement

By our knowledge of physics, we are aware that sound is produced in the environment by alternating pressure changes in the air, and is caused by the vibrations of solid objects or separation of fluids, as they pass over, around, or through holes in solid objects. These vibrations cause the surrounding air to undergo compression, then rarefaction, again compression, then rarefaction, and so on. *Such alternating compression and rarefaction of the surrounding air produces sound waves which propagate in the form of sinusoidal path, as shown in Fig. 20.1 (a) and (b).*

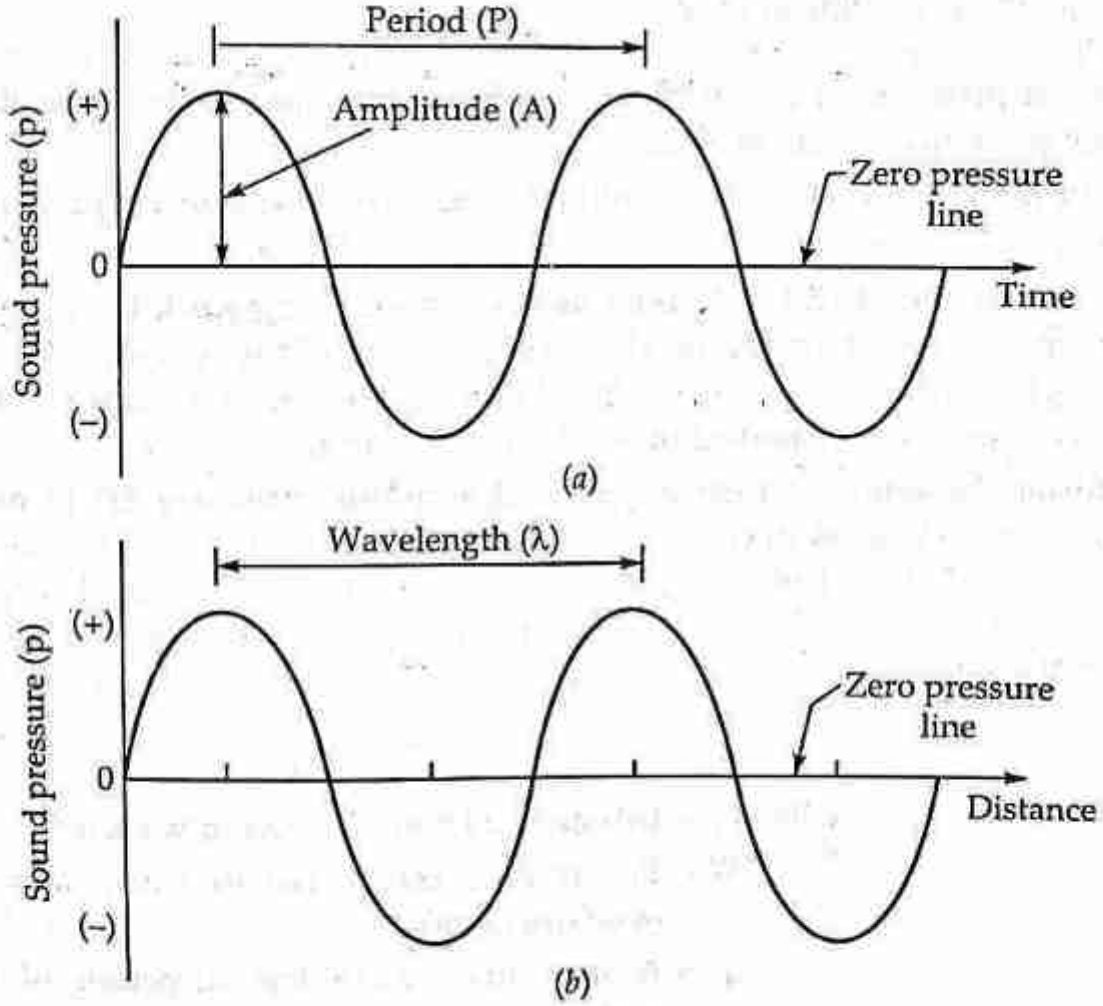


Fig. 20.1. Typical sinusoidal sound waves produced by alternating compression and rarefaction of air molecules.

As indicated in Fig. 20.1 (*a*), the time between the successive peaks or troughs of oscillation is called **the period** (*P*), and its inverse, which represents the number of times a peak arrives in one second, is called the **frequency** (*f*). Hence

$$P = \frac{1}{f} \qquad ...(20.1)$$

Moreover, as shown in Fig. 20.1 (*b*), the distance between successive peaks or troughs is called the **wavelength** (λ), which is related to frequency (*f*) by the relation

$$\lambda = C \cdot \frac{1}{f} \qquad ...(20.2)$$

where C = the velocity of sound wave.

The amplitude (*A*) of the wave is the height of the peak sound pressure measured above or below the zero pressure line. The equivalent pressure of such a sine wave is represented by root mean square pressure (p_{rms}) as

$$p_{rms} = \sqrt{p_{(t)}^2} = \sqrt{\frac{1}{T} \cdot \int_0^T p_{(t)}^2 \, dt} \qquad ...(20.3)$$

where $p_{(t)}$ = Pressure at any time t.

The r.m.s. sound pressure is, thus, obtained by adding the squares of amplitude values at small time intervals, and dividing the total by the averaging time, and finally taking the square root of the total. This works out equal to $\frac{A}{\sqrt{2}}$ for a regular sine wave.

The sound pressure (p_{rms}) is further related to atmospheric pressure and barometric pressure by the equation

Sound pressure = Total atmospheric pressure – barometric pressure ...(20.4)

The **power of sound** (*W*) is defined as the rate of doing work by a travelling sound wave in the direction of the propagation of the wave. *The energy transmitted by a sound wave in the direction of its propagation is thus, defined as its power,* and is represented in watts in S.I. units.

In addition to *sound pressure* (p_{rms}), the **sound intensity** (*I*) is another important term which is used to measure sound. It is defined as the sound power averaged* over the time, per unit area normal to the direction of propagation of the sound wave. Intensity and power of a sound wave are related by the equation

$$I = \frac{W}{a} \qquad ...(20.5)$$

where I = Intensity of sound wave in watt/m^2

W = Power of sound wave in watts (averaged over the time)

a = A unit area ⊥ to the direction of wave motion.

*Weighted average.

Sound intensity (I) is further related to r.m.s. sound pressure by the equation

$$I = \frac{p_{rms}^2}{\rho . C} \quad ...(20.6)$$

where p_{rms} = r.m.s. sound pressure in pascals (Pa)

ρ = Density of air or medium in which sound wave is travelling in kg/m^3

C = Velocity of sound wave in m/s.

The density of air (ρ) and the speed of sound (C) used in the above equation can be known if the temperature of air is known. In other words, given the temperature and pressure of air, the density of air can be determined from the standard tables ; and the speed of sound in air at 101.325 kPa* may be determined by the equation

$$C = 20.05 \sqrt{T} \quad ...(20.7)$$

where T is the absolute temperature in kelvin (K)

C is in m/s.

20.4. Levels of Noise

The sound pressure of the faintest sound that can be heard by a normal healthy individual is about 20 micro-pascal (μ-Pa). On the other hand, the loudest sound produced by a Saturn rocket at the lift off stage is about 200 Pa. This astronomical variation in sound pressure (varying from 20 μ-Pa to 200 Pa) is usually avoided by expressing sound pressure on a scale based on the log of the ratio of the measured sound pressure and a reference standard pressure. Measurements on this scale are called **levels**. The **sound level** (L) is, thus, represented as

$$L = \log_{10} \frac{Q}{Q_o} \text{ (bels)} \quad ...(20.8)$$

where Q = Measured quantity of *sound pressure*, or sound intensity

Q_0 = Reference standard quantity of sound pressure, or sound intensity, as the case may be

L = Sound level in bels (B).

The unit of sound level obtained in Eq. (20.8) is bels (B), and since it turns out to be a rather large unit, a smaller unit of **decibels** (dB)** is generally used.

Hence, when sound level is expressed in decibels, the Eq. (20.8) reduces to

$$\boxed{L \text{ in dB} = 10 \,.\, \log_{10} \frac{Q}{Q_o}} \quad ...(20.9)$$

(*i*) The reference standard quantity Q_0 in the above equation is taken to be equal to 20 μPa, when *sound pressure* is measured. In that eventuality, Eq. (20.9) reduces to

*1 Atmospheric Pressure = 760 mm of Hg. = 101.325 kPa

**1 dB = $\frac{1}{10}$ B.

Sound pressure level (L_p) in dB

$$= L_p = 10 \cdot \log_{10} \left(\frac{p_{rms}}{20\ \mu Pa} \right)^{2*} \quad \text{where } p_{rms} \text{ is in } \mu Pa$$

or

$$\boxed{L_p \text{ in dB} = 20 \log_{10} \left(\frac{p_{rms}}{20\ \mu Pa} \right)} \quad ...(20.10)$$

The sound pressure levels so measured are reported as dB *re* : 20 μPa.

(*ii*) Similarly, the reference standard quantity Q_0 in Eq. (20.9) is taken to be equal to 10^{-12} W/m², when *sound intensity* level is measured. The sound intensity level is thus given as :

Sound intensity level (L_i) in dB

$$L_i \text{ in dB} = 10 \log_{10} \left(\frac{I}{10^{-12}} \right) \quad ...(20.11)$$

where I is in W/m².

Out of these two terms, *i.e. sound pressure* and *sound intensity*, **sound pressure level** on reference scale of 20 μPa, is usually adopted to express sound levels in decibels.

Note 1. It can thus, be seen that sound intensity varies as square of the sound pressure (rms of course)

Note 2. An increase of 20 dB in sound pressure level will correspond to the sound pressure (p_{rms}) or loudness of sound, increasing by 10 times.

Note 3. One dB is the faintest sound which can be perceived by human ear, and the maximum sound which can be tolerated by human ear is about 180 dB.

The co-relation of the two scales of sound measurement are shown in table 20.1.

A scale showing some common sound pressure levels is shown in Fig. 20.2.

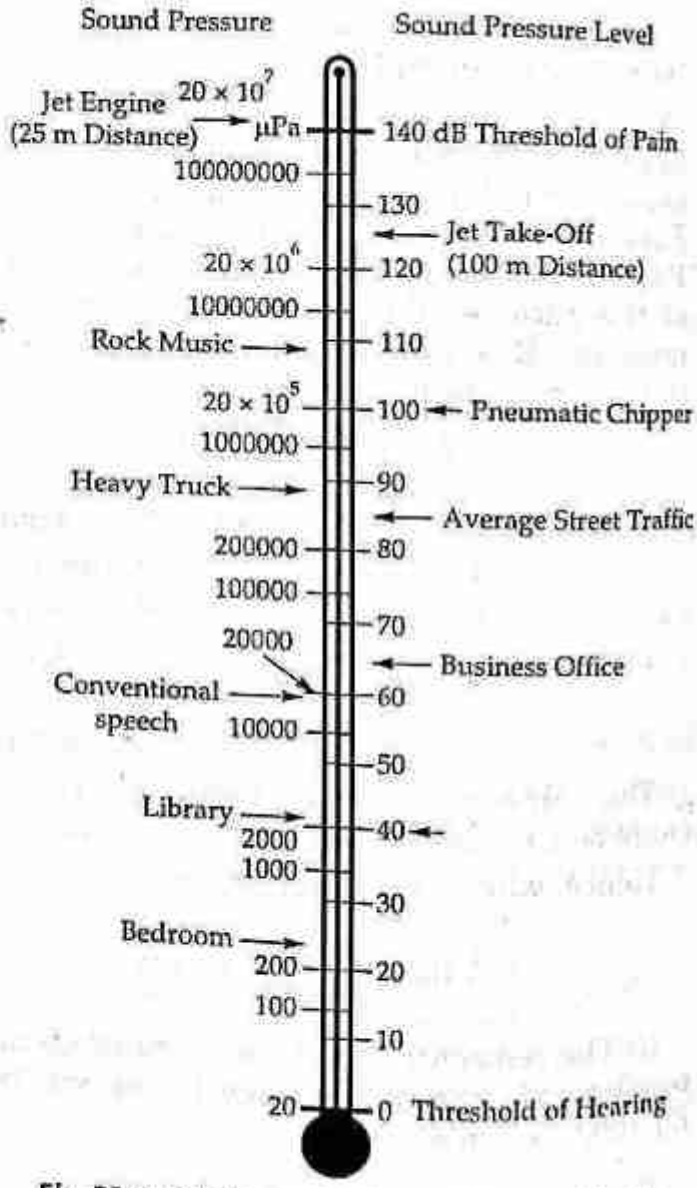


Fig. 20.2. Relative scale of sound pressure levels

*Since sound measuring instruments measure the r.m.s. pressure, the sound pressure is computed by squaring their r.m.s. values.

16.5 METHODS OF NOISE CONTROL

There are different methods used to control the objectionable noise and the choice of one over the other depends on economical justification. The different methods commonly used to reduce noise level are discussed below.

1. Resonance. This is one of the main causes of amplification of noise dependent on how it was originally produced. Basically the energy is stored up and released at a higher intensity due to the effect of resonance. It can be reduced by one of the following methods.

(*a*) **Damping.** It is achieved by bonding damping compounds to the surface of sheet metal that is resonant. Resonance can be reduced in ducts and flues by filling the cavities with mineral wool.

(*b*) **Isolation.** It involves the use of vibrator isolators or flexible connections. This is very effective way of reducing resonance.

(*c*) **De-Tuning.** This treatment is necessary if the resonant frequency of the structure is the same as that of the exchange force. Hence by a change in frequency of the exciting force or the resonant frequency of the structure, the effect may be reduced considerably.

2. Radiation. A fan bolted rigidly to a roof will use the roof to radiate energy to the surroudings. For this reason, in heating and ventilating applications, fans are usually mounted on anti-vibration mounts with flexible connection connecting the fan to ducting. A good method of reducing noise radiated from ducts or panels is to lag them with rockwool and further put some kind of impervious surface over the rockwool.

The most common source of noise in heating and ventilating and engine exhaust are noise transmitted in air flows. This is reduced by using silencers. The silencers are lined with 10 cm thick rockwool which absorbs the sound. With such silencers, sound absorption is very poor at low frequency and improves as the frequency increases until the point where the wavelength of the sound is twice the duct width where the attenuation effect begins to reduce as the frequency is raised.

3. Impending Noise Transfer. When the noise cannot be reduced sufficiently by any of the methods so far discussed, the source of noise must be enclosed in some way. This will stop the noise getting to the surrounding area. An important point is that an enclosure ability to attenuate sound is a function of its mass and doubling the surface density increases the attenuation by 5 to 6 dB.

The above mentioned methods to reduce noise can be used at the source, along the part of noise travel or protecting the receiver from getting noise. These are discussed below.

4. Control of Noise at Source. It is universally accepted fact that the best way to control noise is to avoid making it. The previous table shows that lower speeds, lower B.P., lower pressures and lower velocities offer significant opportunities.

Lower speed fans moving air at lower velocities through duct, may involve the use of a little more sheet metal and a slightly larger fan wheel and housing, but they enormously simplify the problems of noise and vibration control. Further, it is usually cheaper in totoal to provide a lower speed system than to add the ancillary noise and vibration control equipments for high speed system.

When the fan motor B.P. exceeds 100 and pressure exceeds 15 cm of water, the noise and vibration generated are reduced by mounting the entire assembly (housing, fan and motor) on a slab that floats on resilient pads. The whole assembly becomes a floating room so that rumbles and vibrations are not transmitted at the building structure.

5. Path Control of Noise. When the noise generating system has been made as quiet as possible, further efforts to control the noise must be directed at the transmission paths from the source.

The surfaces and panels attached to the source, the structure on which it is supported, the earth on which the entire assembly rests, the pipes, ducts, conducts, cables, wires and belts attached to it and even the fluid flowing to, through and from it, all provide potential energy transmission paths. Obviously, they cannot be disconnected so some means of minimising transmission and radiation of acoustic energy by means of these paths is necessary.

Transmission of acoustic energy from the source to any connected object depends on the efficiency of the connection and the radiation of acoustic energy from a connected object, depends on its radiation efficiency. Rigid attachment of a sound source to a large thin metal plate provides a very efficient energy radiation mechanism. The source drives the plate, the plate drives the air touching its surfaces and we have familiar *Loud Speaker*. An increase in radiating surface area amplifies the original signal of a small mechanical device (pump,

motor). Of course, no new energy has been created but a more efficient means of coupling the vibratory energy of the source to the surrounding air has been provided.

Since noise generation of a system is related to the efficiency of the connections between source and radiating surfaces and to the rate of energy flow between them, what is needed is a means of minimizing the energy flow — an *Impedance Mismatch* between the source and structure.

The acoustic impedance of a material (A_i) is given by $A_i = \rho C_s$ where ρ is the density of the material in kg/cm³ and C_s is the velocity of sound in that material in cm/sec. This gives the unit of acoustic impedance as (kg-cm/cm³-sec).

A high impedance material is efficient energy coupler betwee the source and attached material and a low impedance material is an inefficient couple or an isolator which is desirable for reducing the noise level.

Table 16.2 lists the acoustic impedance of coomon materials used in many industries. Steel, for exaple, has an impedance of 4250 while that of rubber is only 7.25. Therefore, a block of rubber between two blocks of steel would provide good noise insulation. So, instead of bolting down a noisy machine, it is better to float it on low impedance mountings.

In pipe and duct systems, resilient conections of lines to the noise generator (pump, fan) is useful in two ways. they provide the desired impedance mismatch and also an energy storage mechanism to accept the pulsating flow and return it the downstream line in a smoother flow—somewhat analogous to changing AC to DC. Even an elastometer expansion joint in a large pipeline may remove as much as 10 to 15 dB of energy from the line.

Table 16.2 Acoustic Impedance of Various Materials

Material	*Acoustic Impedance*		*Material*	*Acoustic Impedance*	
	kg-cm/cm³-sec	*db-in/in³-sec*		*kg-cm/cm³-sec*	*db-in/in³-sec*
Soft rubber	7.25	100	Glass	1450	20000
Cork	12.00	165	Lead	1490	20500
Pine	138.00	1900	Cast Iron	2840	39000
Water	145.00	2000	Copper	3270	45000
Concrete	1020.00	1400	Steel	4250	58500

16.5.1 Sound Absorption

After the source has been made as quite as possible and transmission path as efficient as possible, other noise control methods may be considered.

Absorbents work as transducers. They convert to heat only the energy that reaches them and they cannot reach down the source and suck up the sound. Therefore, their purpose is to prevent reflection of sound from the surfaces to which they are applied. They do not affect the production of sound.

The operator of a machine, in its near field, will receive little benefit from absorption applied to the building surface. If the absorbents are placed on the interior surfaces of an enclosure surrounding a machine, they can provide considerable attenuation.

Sound Absorption Materials. Glass wools, Fibre glass, mineral wools and polyurethane foam are commonly used as sound absorption materials. They are more effective in absorbing relatively high frequency noises, although these materials become loaded with contamination rather quickly. The sound absorption coefficients of fibrous glass with respect to frequency are listed below:

Table 16.3 Absorption Coefficients of Fibrous Glass

Frequency	125	250	500	1000	2000	4000
Absorption coefficient of Fibrous glass	0.23	0.50	0.73	0.88	0.91	0.97

16.5.2 Sound Barriers

Sound barriers sometimes can be used to re-distribute the sound field of a noisy machine. If a noise source is enclosed or surrounded by an effective sound barrier, the energy would not escape to the surroundings. However, a barrier must be relatively massive and air tight.

Simply wrapping a noisy machine in an absorptive blanket is quite furtile. There may be reduction of a few dB at higher frequency, but almost no attenuation at lower frequencies. Surrounding a machine with a good enclosure can provide up to 50 dB attenuation depending on the weight of the enclosure panels, and the air-tightness of the construction. The greater the mass of the panel, the better is its shielding and higher the frequency of the sound, the better is the performance of the barrier.

The material must cause a loss of 24 dB and be absorptive enough to prevent the sound from being reflected back to the source. A barrier such as glass fibre with minimum thickness of 5 cm and weighing more than 7.5 kg/m^2 is sufficient. However barriers with heavier density may be needed to control low frequency noises.

A complete enclosure is rarely feasible, because it is usually necessary to provide openings for various purposes such as getting materials to and from the machine. Unfortunately, any opening appreciably degrades the effectiveness of an enclosure. For example, opening of 1 cm^2 area transmits as much sound as does 10 m^2 of a 2.5 cm concrete block wall. The barrier must cut-off line of sight between the listener and source and it must be sufficient massive (10 kg/m^3) to prevent easy transmission through it.

16.5.3 Protecting the Receiver

After enerything feasible has been done to reduce the noise at the source and to minimise the transmission of noise and if any of these steps is impracticable, it may be beneficial to protect the listener exposed to the noise. Regulatory agencies generally stress over that noise control must be accompanied by engineering methods discussed earlier and only after such methods remain inoperative, protection will be considered acceptable. In reality, they are the last resorts for very few situations where engineering methods are not feasible or adequate.

In highly automated installation, such as large central heating cooling plants, only a few workers are usually required to attend operations. In such instances, it may be wise to enclose the workers rather than noisy equipments or processes.

16.5.4 Acoustical Baffles

Properly selected and installed acoustical baffles can effectively control noise and reverberation time in big plants. But knowledge of noise regulations, acoustic criteria and the way baffles function is necessary for its successful application.

Baffles are manufactured in various sizes and shapes including flat panels, cylinders etc. Individual units usually consist of 2 to 5 cm thick of acoustically absorbent mineral and glass fibres, polyurethane foam in a decorative or protective wrapper. Some baffles are sealed in a plastic film envelope that provides resistance to moisture and permits cleaning by water or steam.

Installing baffles is relatively simple. Units can be suspended by tabs, wires, cables or chains from overhead bar joints, beams or roof decks. They may be hung in parallel rows, in cross rows or in various geometric patterns. Baffles normally do not affect work flow or do not require any alternation in work patterns. They reduce reverberation but do not effectively lower near field noise—such as that received by a worker directly from his mahcine. The maximum noise reduction achieved by baffles is about 10 dB.

Sound absorbing materials when used into an acoustically reflective room reduce the noise level in those portions of the space in which reverbent field noise predominates over free field noise. Baffles cannot effectively reduce free field noise, so the other effective methods should be used. Reverberant field conditions must exist if noise reduction is to be obtained with acoutical baffles.

The effectiveness of different noise controlling methods varies according to the type of source and its operating parameters. Expereinces to date indicates that reduction of less than 20 dB are required in almost 90% of the cases and such reductions can be accomplished economically by the number of methods discussed earlier. In 10% unusual cases, extra steps are often required and extra costs are usually incurred. Occassionally, major modifications in plant or process are required. In other instances, reduced hours in such environments are the only feasible approaches.

16.5.5 Control of Stubborn Rumble

Curing distribution system noise is usually more expensive and difficult than fan noise.

Noise criteria (NC) curves give the maximum permissible sound pressures for eight octave bands in various space uses as shown in Fig 16.7.

Common duct generated noise is characterised by a low frequency rumble whic generally shows up in the first 3 to 4 octave bands. In general, low frequency rumble, characteristic of distribution system noise, is intermittent. This is partly because random turbulence frequncies are exciting and then cancelling the few major low frequency resonances of the pipe. This intermittent noise apparently has a high irritation value which is not properly accounted for in the NC curve system as important frequency range is below the NC curve scale.

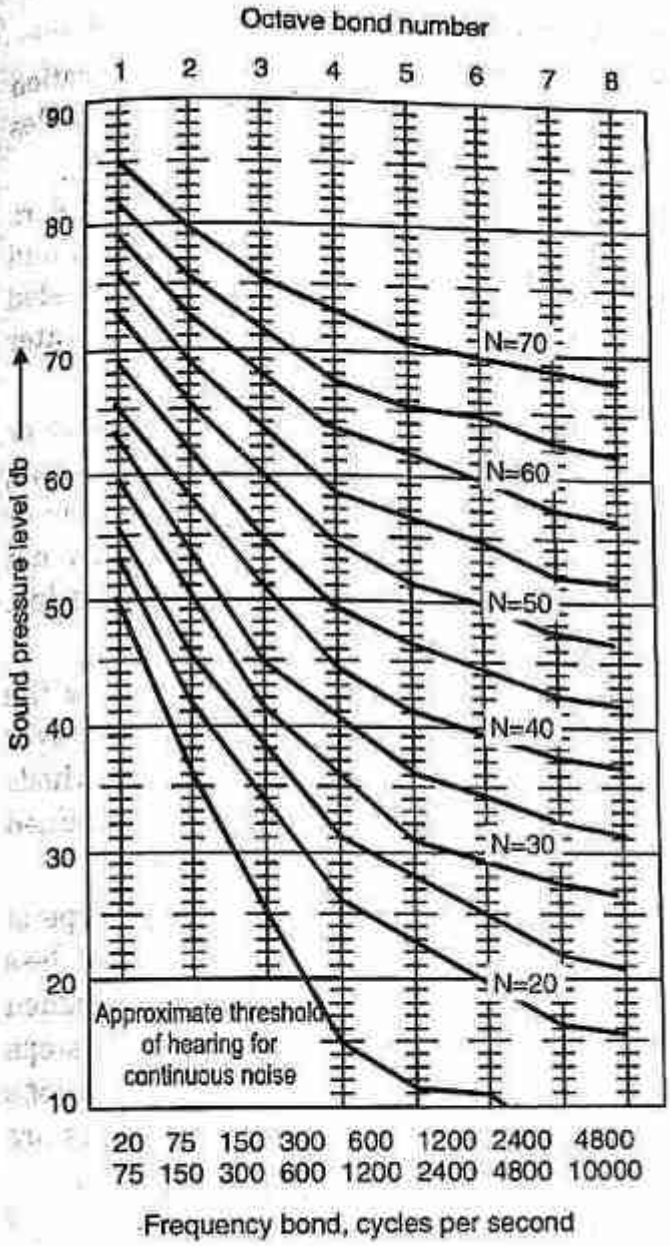


Fig. 16.7 Noise criteria curves

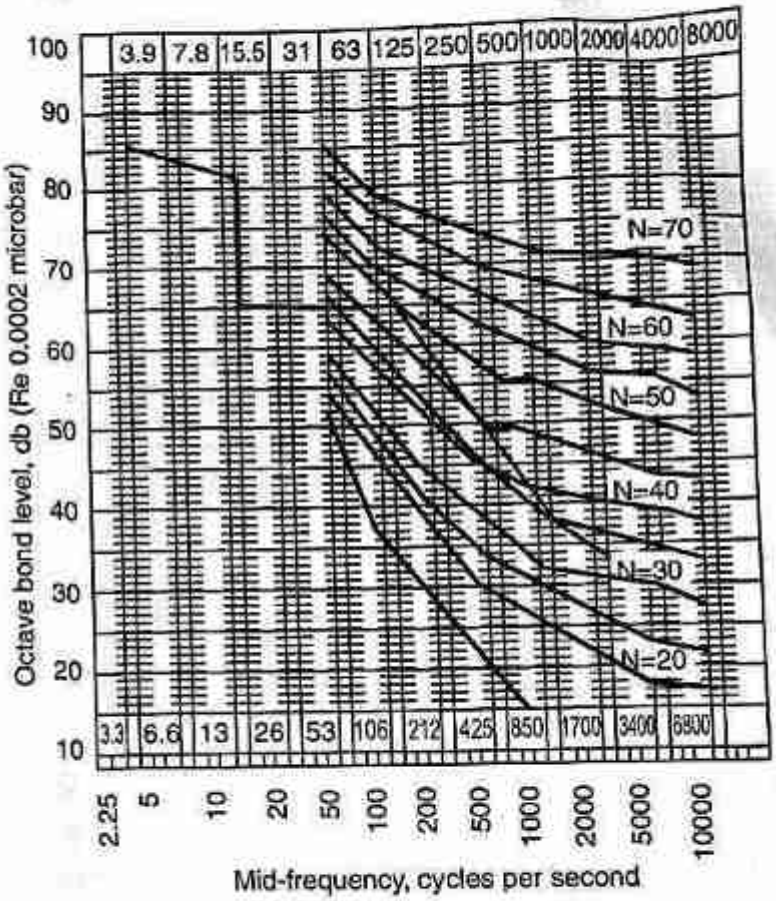


Fig. 16.8 Actually curves of an air distribution system noise of low frequency type

Figure 16.8 shows a curve of actual sound readings made in space suffering from low frequency rumble noise. One rarely solves this type of problem with sound traps, additional acoustical lining or duct wall damping compounds. Sound barrier ceilings or constructions around duct work provides noticeable reductions primarily in the higher frequency octave bands, the net result is that low frequency noise becomes more noticeable in the absence of the high frequencies. Acoustical duct lining and sound traps are virtually ineffective in attenuating noise ranging from below first band through second band noise.

16.5.6 Control of Exterior Noise

Like interior sound, exterior sound travels by pressure waves in either structure borne or air borne community complaints but structure borne noise can also be equally annoying.

The machine sound is conducted from the plant through the ground which is an excellent transmitter of vibrations. Structure borne noise can be controlled at the source. the recommended method is to place vibration isolators (such as spring mounts) under the offending equipment.

Sound transmission to surrounding areas can be reduced further by treating plant buildings as noise equipment enclosures. Walls should be constructed with materials having a high Sound transmission Loss (STL), such as heavy masonry, insulated double sections or pre-engineered building components with glass fiber insulation.

There is little acoustical data available for roof system. In general, the heavier the roof system and greater its thermal resistance, the lower its sound transmission ability. A metal or gypsum roof deck with an adequate layer of thermal insulation controls noise satisfactorily in most instances.

Windows or other building openings are potential noise escape points and should be kept to a minimum. Fig. 16.9 shows the effect of openings on sound transmission. Entrances and exits should have tight fitting doors. If possible, barriers and baffles should be erected in front of all doors and windows.

Air-intake and discharge vents should be equipped with silencers.

Whenever possible, it is advisable that building radiating the most noise be located as far as possible from residences.

Barriers such as earthen mounds or concrete walls with glass fiber insulation on the side that faces the noise source can isolate or block noise from adjacent residence. Such walls are particularly effective where high STL values are needed at the low frequencies or for noise sources that are not too high off the ground (as electrical transformers).

What is noise?

It's important to understand the distinction between noise and sound. Noise is a type of sound and is defined as unwanted, annoying, unpleasant or loud.

Our ears are excellent at telling us what noise is. Most commonly, noise is an annoying tone that causes mild to major discomfort or irritation. These tones pierce through the background noise that accompanies our lives.

When it comes to measuring the different types of noise, we want to replicate the how the human ear interprets noise in order to get an accurate representation of its impact.

That's why we use something called the A-weighted frequency, which is much more sensitive between the 500 Hz and 6 kHz range.

The Four types of noise

1. Continuous noise

Continuous noise is exactly what it says on the tin: it's noise that is produced continuously, for example, by machinery that keeps running without interruption. This could come from factory equipment, engine noise, or heating and ventilation systems.

You can measure continuous noise for just a few minutes with a sound level meter to get a sufficient representation of the noise level.

2. Intermittent noise

Intermittent noise is a noise level that increases and decreases rapidly. This might be caused by a train passing by, factory equipment that operates in cycles, or aircraft flying above your house.

We measure intermittent noise in a similar way to continuous noise, with a sound level meter. However, you also need to know the duration of each occurrence and the time between each one. To gain a more reliable estimate of the noise level, you should measure over multiple occurrences to calculate an average.

3. Impulsive noise

Impulsive noise is most commonly associated with the construction and demolition industry. These sudden bursts of noise can startle you by their fast and surprising nature. Impulsive noises are commonly created by explosions or construction equipment, such as pile drivers

To measure impulsive noise, you will need a sound level meter or a personal noise dosimeter that can calculate Peak values.

4. Low-frequency noise

Low-frequency noise makes up part of the fabric of our daily soundscape. Whether it's the low background hum of a nearby power station or the roaring of large diesel engines, we're exposed to low-frequency noise constantly. It also happens to be the hardest type of noise to reduce at source, so it can easily spread for miles around.

For low-frequency noise, you should be using a sound level meter with third octave band analysis, so you can analyse the low frequencies that make up the noise.

MODULE V

Impacts of pollutants, types, scale of impact- Global, local pollutants. Climate change, Ozone layer depletion, Deforestation, land degradation, Environmental impact assessment, Need for EIA

IMPACT OF POLLUTANTS

- Impacts due to Air pollution
- Impacts due to water pollution
- Impacts due to soil pollution
- Impacts due to noise pollution

Already discussed in previous modules

Impact of Pollutants on Human Health

- Adverse air quality can kill many organisms including humans.
- Ozone pollution can cause respiratory disease, cardiovascular disease, throat inflammation, chest pain, and congestion.
- Water pollution causes approximately 14,000 deaths per day, mostly due to contamination of drinking water by untreated sewage in developing countries.
- An estimated 500 million Indians have no access to a proper toilet, Over ten million people in India fell ill with waterborne illnesses in 2013, and 1,535 people died, most of them children.
- The WHO estimated in 2007 that air pollution causes half a million deaths per year in India.
- Oil spills can cause skin irritations and rashes.
- Noise pollution induces hearing loss, high blood pressure, stress, and sleep disturbance.
- Mercury has been linked to developmental deficits in children and neurologic symptoms.
- Older people are majorly exposed to diseases induced by air pollution.
- Those with heart or lung disorders are at additional risk.
- Children and infants are also at serious risk.
- Lead and other heavy metals have been shown to cause neurological problems.
- Chemical and radioactive substances can cause cancer and as well as birth defects.

Impact of Pollutants on Environment

There are a number of effects on environment:

- Bio magnification describes situations where toxins (such as heavy metals) may pass through trophic levels, becoming exponentially more concentrated in the process.
- Carbon dioxide emissions cause ocean acidification, the ongoing decrease in the pH of the Earth's oceans as CO_2 becomes dissolved.
- The emission of greenhouse gases leads to global warming which affects ecosystems in many ways.
- Invasive species can out compete native species and reduce biodiversity. Invasive plants can contribute debris and biomolecules that can alter soil and chemical compositions of an environment, often reducing native species competitiveness.
- Nitrogen oxides are removed from the air by rain and fertilise land which can change the species composition of ecosystems.
- Smog and haze can reduce the amount of sunlight received by plants to carry out photosynthesis and leads to the production of tropospheric ozone which damages plants.
- Soil can become infertile and unsuitable for plants. This will affect other organisms in the food web.
- Sulphur dioxide and nitrogen oxides can cause acid rain which lowers the pH value of soil.
- Organic pollution of watercourses can deplete oxygen levels and reduce species diversity.

IMPACT OF POLLUTANTS GASEOUS POLLUTANTS

Pollutants like carbon dioxide (CO2), carbon monoxide (CO), sulphur dioxide (SO2), nitrous oxide (NO) and nitrogen dioxide (NO2) are collectively called as Inorganic gaseous pollutants. These are the major contributors to the indoor air pollution.

1. SULPHUR DIOXIDE (SO2):

It is a colourless gas with a sharp pungent smell produced by volcanoes and in various industrial processes. The primary threat of SO2 to urban atmosphere may arises not from SO2 itself but from the changes it undergoes in the atmosphere, such as the formation of H2SO4 and sulphate aerosols. Effects on:

i) Environment and property

- Causes acid rain
- Corrosion to metals
- Damage to agriculture

ii) Human health

- It causes cardiac disease
- Respiratory disease like Asthma
- Eye irritation
- Throat trouble

2. NITROGEN OXIDES (NOX)

NOx are emitted as nitrogen oxide which is rapidly oxidized to more toxic nitrogen dioxide (NO2). NO2 is colourless, odourless gas present in atmosphere.

Effects on:

i) Environment and property

- Precursor of ozone formed in the troposphere

ii) Human health

- Irritation to nose and throat
- It leads to irritation of eyes and even lung blocking
- Respiratory illness among children has been reported in areas containing high NO2.

3. OZONE (O3)

Ozone is a pale blue gas, soluble in water and non-polar solvent with specific sharp odor. Effects on:

i) Environment and property

- Ozone causes crack in car tires

- Ozone present in upper troposphere acts as greenhouse gas

ii) Human health

- Aggravation of asthma
- Inflammation and damage to lungs

4. CARBON MONOXIDE (CO)

It is also called as carbonous oxide, it is a colorless, odorless and tasteless gas which is slightly lighter then air.

Effect on:

i) Environment and property

- Causes global warming

ii) Human health

- It causes headache, visual difficulty, paralysis and even death in human beings.
- Persons with heart disease are sensitive to CO poisoning and may experience chest pain.
- CO enters the bloodstream through lungs and combines with hemoglobin forms carboxyhemoglobin. This condition is known as anoxemia, which inhibits blood's oxygen carrying capacity to organs and tissues.

5. HYDROCARBONS (HC)

Aromatic hydrocarbons are more reactive then aliphatic ones and causes eye irritation. Aliphatic hydrocarbons produce undesirable effects at concentration 102 to103 times higher than those usually found in the atmosphere. Hydrocarbons undergoes chemical reaction in presence of sunlight and nitrogen oxide Effects on:

i) Environment and property

- Cracking of rubber Extensive damage to plant life
- Causes damage to buildings, sculpture and paints

ii) Human health

- photochemical smog which results in reduced visibility, irritation to eyes and lungs
- Decreases lung function
- Chronic bronchitis
- Premature death in people with heart or lung disease

6. PARTICULATE MATTER

Air born particles smaller than 2.5 µm called fine particles. Composed mainly of carbonaceous materials, inorganic compounds and trace metal compounds.

Effects on:

i) Environment and property

- Fly ash reduces pH balance and portability of water
- Particulates accelerate corrosion of metals
- Causes damage to buildings, sculpture and paints

ii) Human health

- Decreases lung function
- Chronic bronchitis
- Premature death in people with heart or lung disease

7. OTHERS: LEAD, NICKEL, CADMIUM, MERCURY, ASBESTOS.

Pollutant	**Level (ppm) and exposure**	**Effects**
SO_2	0.3 to 0.5 for several days	Bleached spots, chronic injury to spinach and other leafy vegetables
NO_2	0.5 for 10-12 days	Suppressed growth of tomatoes
Ozone	0.03 for 8 hours	Fleck on upper surface of leaves
Peroxyacetyl nitrate	0.01 to 0.05 for few hours	Glazing or bronzing of underside of leaf, damage to sensitive plants

GLOBAL AND LOCAL POLLUTANTS

In turning to global pollutants, the problems inherent in local pollutants will become worse. With local pollutants, we were dealing with problems of externalities within a country or state. We now have to consider externalities crossing national boundaries. In the case of global pollutants, we have even more trouble understanding the consequences of our actions and the potential solutions than local pollutants.

1. Transfer coefficients are hard to determine. Especially true for trace gases, i.e., gases that are a minor component in the atmosphere.

2. In the short term, trends are difficult to determine.

3. Cannot force other nations to abate their emissions as in the domestic case

Major issue:

- Ozone depletion and global warming.
- Concentration levels of GHGs and ODCs have been increasing

Some examples of scale of impact due to global and local pollutants are given below:

1. Deterioration of Taj Mahal

- Mathura Oil Refinery – 40kms away from Taj Mahal
- Emits 25-30 tonnes of S02 daily
- Air pollution studies estimate that any increase in S02 conc. above present level of 1.25kg/m3 will result in acidic precipitation.
- This will covert S02 to sulphuric acid – "Stone cancer"
- This sulphuric acid will react with calcium carbonate in the marble to form calcium sulphate – pitting in Taj Mahal
- Discolouration of the white marble surface ie, appearance of a yellowish layer and yellow grey deposits or brown rust like stains on the white marble – chipping and breaking of edges of marble slabs and formation of cracks in the marbles are some of the examples of deterioration of Taj Mahal
- Many steps are being taken to save Taj from the deteriorating effects of environmental pollution

2. Ganga Pollution

- Ganga is the ninth largest river in the world with a length of 2525kms
- It is a popular belief that river Ganga is the purifier of all and its water is considered sacred
- Ganga is a perennial river serving as a source of irrigation and water supply in the fertile gangatic basin
- Twenty five towns on the river bank discharge 1340 million litres of sewage everyday into the Ganga
- Around 260 million litres of chemical effluents join the river in a day
- Hundreds of tanneries and dozens of paper mills, sugar and chemical industries discharge their wastes directly into river without treatment
- Around 35,000 dead bodies are dumped every year, 27 types of pathogens are detected in the water.
- We now led to the situation that action has to be taken to prevent pollution of river Ganga

3. The London Smog

- The London Smog incident took place in December (5th -9th) in 1952 in England
- A high pressure air mass created a temperature inversion formed a white fog over vast areas of London
- The fog became a thick black fog as the conc. of sulphur oxide and particulate pollutants increased owing to extensive combustion of fuel by automobiles and fossil fuel powered industries
- Increased conc. of pollutants caused nearly 4000 deaths due to suffocation
- Similar fog conditions occurred in London in January 1956 as well as in Los Angeles in 15th – 16th December 1966 resulting more death due to respiratory and heart diseases
- A harmonious relationship of man and nature can be achieved by modifying the current pattern od development which is responsible for the large scale environmental damages

EFFECTS OF POLLUTANT

1. Environment Degradation: Environment is the first casualty for increase in pollution weather in air or water. The increase in the amount of CO2 in the atmosphere leads to smog which can restrict sunlight from reaching the earth. Thus, preventing plants in the process of photosynthesis. Gases like Sulfur dioxide and nitrogen oxide can cause acid rain. Water pollution in terms of Oil spill may lead to death of several wildlife species.

2. Global Warming: The emission of greenhouse gases particularly CO2 is leading to global warming. Every other day new industries are being set up, new vehicles come on roads and trees are cut to make way for new homes. All of them, in direct or indirect way lead to increase in CO2 in the environment. The increase in CO2 leads to melting of polar ice caps which increases the sea level and pose danger for the people living near coastal areas.

3. Ozone Layer Depletion: Ozone layer is the thin shield high up in the sky that stops ultra violet rays from reaching the earth. As a result of human activities, chemicals, such as chlorofluorocarbons (CFCs), were released it to the atmosphere which contributed to the depletion of ozone layer.

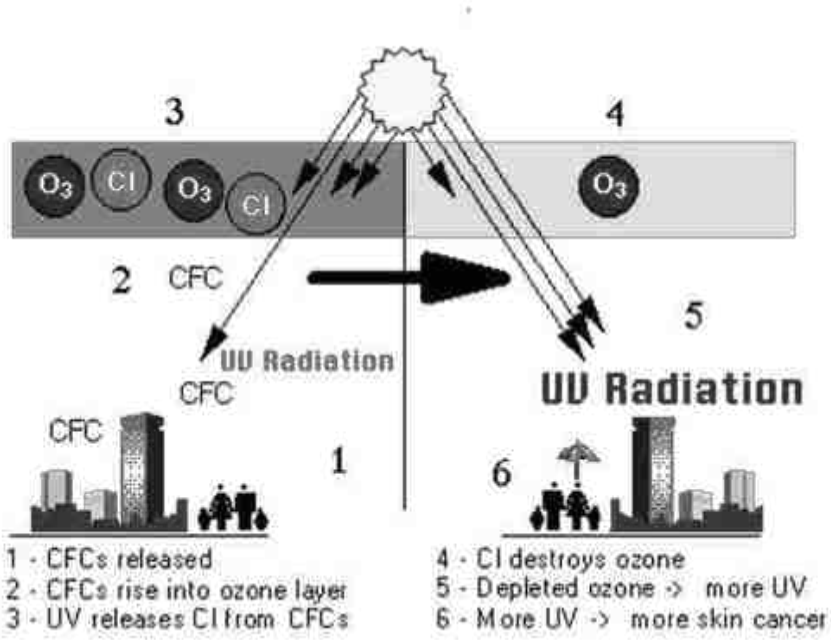
GLOBAL CLIMATIC CHANGE

Climate change occurs when changes in Earth's climate system result in new weather patterns that last for at least a few decades, and maybe for millions of years. The climate system is comprised of five interacting parts, the atmosphere, hydrosphere, cryosphere, biosphere, and lithosphere. As the climate warms, it changes the nature of global rainfall, evaporation, snow, stream flow and other factors that affect water supply and quality. Specific impacts include: Warmer water temperatures affect water quality and accelerate water pollution. Global warming refers to surface temperature increases while climate change includes global warming and everything else that increasing greenhouse gas levels affect. Global warming is projected to have a number of effects on the oceans. Ongoing effects include rising sea levels due to thermal expansion and melting of glaciers and ice sheets, and warming of the ocean surface, leading to increased temperature stratification. Global warming is a long-term rise in the average temperature of the Earth's climate system, an aspect of climate change shown by temperature measurements and by multiple effects of the warming.

OZONE LAYER DEPLETION

Chlorofluorocarbons (CFCs) and other halogenated ozone depleting substances (ODS) are mainly responsible for man-made chemical ozone depletion. The total amount of effective halogens (chlorine and bromine) in the stratosphere can be calculated and are known as the equivalent effective stratospheric chlorine (EESC).

- Ozone destruction by UV rays-UV radiation from the sun releases the radicals Cl and ClO .Ozone is a highly unstable molecule so it readily donates its extra oxygen molecule to free radical species such as hydrogen, bromine, and chlorine. These compound species act as catalysts in the breakdown of ozone molecules.



- The ozone layer present in the stratosphere acts as a protective shield. It saves the earth from the harmful ultraviolet rays of the sun. The compounds containing CFCs (chlorofluorocarbons) are mainly responsible for ozone layer depletion as these compounds react with ozone in the presence of ultraviolet rays to form oxygen molecule and thus, destroying ozone. Scientists have already found an ozone hole over the South Pole. Once the ozone layer is depleted, ultraviolet rays will pass through the troposphere and eventually to earth. These rays cause aging of the skin, skin cancer, cataract and sunburn to humans as well as animals. Phytoplankton dies in the presence of ultraviolet rays which results in a decrease in fish productivity.

Causes & Effects of Ozone Layer Depletion

- The evaporation of surface water through the stomata of leaves increases, which results in decreased moisture content of the soil.
- The proteins cells in plants undergo harmful mutations, all due to ultraviolet radiations.
- Paints and fibers are also damaged by the increased levels of ultraviolet rays, causing them to fade faster.
- Chlorofluorocarbons and other halocarbons are held responsible for ozone layer depletion, but if we explore more about them we will find that these are major greenhouse gases.
- These gases absorb heat in the atmosphere and increase the earth's temperature, resulting in global warming.
- Increase in earth's temperature causes melting up of ice caps.
- This raises the water level of the oceans and seas.
- Coastal areas get flooded and area under land cover reduces.

The Ozone Hole

In the year 1980 scientists reported the depletion of ozone layer in the region of Antarctica which is commonly known as the ozone hole. Ozone layer depletion occurs due to unique sets of climatic conditions. In the summertime, nitrogen dioxide and methane react with chlorine monoxide and chlorine atoms which result in a shrinkage of chlorine and hence prevents ozone layer depletion.

$ClO\ (g) + NO_2\ (g) \rightarrow ClONO_2\ (g)$

$Cl\ (g) + CH_4\ (g) \rightarrow CH_3\ (g) + HCl\ (g)$

During winter, special types of clouds are formed over the Antarctic region. These clouds provide the surface for the hydrolysis of chlorine nitrate to form hypochlorous acid. Chlorine nitrate also reacts with hydrogen chloride thereby producing molecular chlorine.

$ClONO_2\ (g) + H_2O\ (g) \rightarrow HOCl\ (g) + HNO_3\ (g)$ $ClONO_2\ (g) + HCl\ (g) \rightarrow Cl_2\ (g) + HNO_3(g)$

During spring, sunlight enters Antarctica and breaks up the clouds. Photolysis of HOCl and Cl_2 occurs which forms chlorine radicals and this reaction initiates the ozone layer depletion.

Prevention and Measures

•**Private vehicle driving should be limited** – Vehicular emission results into smog, which harms the ozone layer. Carpooling, using public modes of transportation, walking, cycling etc should be promoted.

•**Avoid using pesticides** – Pesticides are used for getting rid of weeds but are very harmful to the ozone layer. Natural remedies should be used instead of pesticides.

•**Using eco-friendly products** – We can use eco-friendly cleaning products for domestic purposes and save the ozone from further deterioration.

•**Replacing CFC's used in air conditioners and refrigerators**- Hydro fluorocarbons (HFCs) have been identified as potential replacements for CFCs (which is the major cause of Ozone Layer Depletion) as they have an Ozone Depletion Potential of 0. Use of HFCs in place of CFCs will go a long way in protecting our Ozone layer from getting depleted.

•**Proper Waste disposal techniques**- Avoid burning waste materials like plastic and other materials. Give non-decomposable products for recycling or try and reuse them for other purposes.

DEFORESTATION

Deforestation, the clearing or thinning of forests by humans. Deforestation represents one of the largest issues in global land use. Estimates of deforestation traditionally are based on the area of forest cleared for human use, including removal of the trees for wood products and for croplands and grazing lands. In the practice of clear-cutting, all the trees are removed from the land, which completely destroys the forest. In some cases, however, even partial logging and accidental fires thin out the trees enough to change the forest structure dramatically.

What is Deforestation?

• Deforestation, clearance or clearing is the removal of a forest.

• Examples of deforestation include conversion of forestland to farms, ranches, or urban use.

Causes of Deforestation

(i) Shifting cultivation

- Most of the clearing of forest is done for agricultural purposes.

- Poor farmers cut down trees or burn it and start agriculture. Intensive or modern agriculture destroy the forest on a large scale.
- It is principal cause of deforestation in some countries like America(35%), Asia(50%),Africa(70%).

(ii) Commercial logging

- It involves cutting trees for sale as timber or pulp.
- It employs heavy machinery to remove cut trees and build roads.
- Logging roads enable people to access the interiors of the forest, which in results in deforestation .
- In Africa, 75% of land being cleared by poor farmers is land that has been previously logged.

(iii)Mining and dams

- Mining, industrial development and hydroelectric power plant projects are also causes of deforestation.
- Dams open the previously inaccessible forest and damage ecosystems.
- In Brazil, the grand carajas project occupies 90,000 km^2.
- It also affect 23 tribal groups and also cause the high soil, water and air pollution.

(iv) Other reasons

- Deforestation also occurs due to overgrazing and conversion of forest to pasture for domestic animals.
- Expansion of agribusiness that grows oil palm, rubber, fruit trees and ornamental plants has also resulted in deforestation.
- Governmental sponsored programs that resettle landless farmers on forested sites have contributed to deforestation all around the world.
- Other reasons includes fire, pest, etc.

Effects of Deforestation

1) **Soil Erosion**:- The soil gets washed away with rain water on sloppy area in the absence of trees leading to soil erosion.

2) **Expansion of Deserts**:- Due to action of strong wind mass of land gradually gets covered to sand deserts.

3) **Decrease in Rainfall**:- In the absence of forest, rainfall decreases considerably because forests bring rains and maintains high humidity in atmosphere.

4) **Loss of Fertile Land**:- Less rainfall results into the loss of fertile land owing to less natural vegetation growth.

5) **Effect on Climate**:- Deforestation includes regional and global climate change. Climate has become warmer due to the lack of humidity in deforestation regions and also patterns of rainfall has changed. Droughts have become common.

6) **Economic Losses**:- Deforestation will cause loss of industrial timber and non-timber products and loss of long term productivity on the site.

7) **Loss of Bio-diversity**:- Deforestation cause the biodiversity leading to disturbances in ecological balance world wild.

8) **Loss of medical Plants**:- There are many species of plants, which have been used in India for centuries as insecticide, fungicide, in medicine and in bio-fertilizers. Deforestation may lead to the extinction of these valuable plants.

9) **Environmental Changes**:- It will lead to increase in carbon dioxide concentration and other air pollutants. This would result in Global Warming.

10) **Change in living Habits**:- This may force indigenous people to live a new life which they are not prepared. Disturbance in forest eco-system may result in other eco-systems that may be separated by great distances.

Forest Degradation in India

• Depletion of forestry cover less than 90% is considered as forest degradation and more than 90% is considered as deforestation, according to Food and Agriculture Organisation (FAO) of the UN.

• Logging is considered as a forest degradation and not as a deforestation.

• In India timber is used for preparing plywood, veneer, boards, doors, windows and other furniture.

• Wood is also used for cooking and heating.

• Population, rapid development and men's dependency on forest are mainly responsible for Forest Degradation.

• India has lost 3.4 million hectares of forest cover from the period of 1951-1970.

• Nearly 1% of land is turning barren per year due to deforestation.

Control Measures of Deforestation

• **Reforestation:-**

Many countries in the world have started reforestation and forestry, and East Asian nations are leading in this regard. Many East Asian countries, including China, have successfully managed to reverse deforestation.

• **Legislation :-**

By making suitable changes in the law, so that cutting trees in a forest will not only lead to deforestation being controlled in a major way, but its flow may also be reversed.

• **Wildlife Sanctuaries :-**

Sanctuaries are very important, not only to save wildlife, but to save trees as well. Sanctuaries go a long way in protecting all wildlife.

• **Commercial Forest Plantations :-**

There can be special forest plantations for all the wood that is needed for the industry. This way the wood can be cut in a controlled and regulated environment.

• **Cities :-**

All cities, let alone new cities, have to be managed properly. Their expansion has to be curtailed or at least done in a systematic manner, so that there is enough green cover, and new trees are planted where ever possible.

•**Incentive to Corporate :-**

Tax cuts should be granted to corporations, to get them actively interested in reforestation.

•**Water Management :-**

Improper water management affects deforestation in a big way. If the wildlife doesn't have water, then the entire ecosystem will falter. The construction of new dams should be planned properly, so that any one area isn't deprived of water, while another area has abundance of it.

LAND DEGRADATION

- Land degradation is the most important environmental problem currently challenging sustainable development in many parts of the world.
- The change in the characteristic and quality of soil which adversely affect its fertility is called as Degradation.
- The problem is most acute where the environment is intrinsically vulnerable and where the population is losing control of its own resources.

- **Land Degradation means**

1. Loss of natural fertility of soil because of loss of nutrients.
2. Less vegetation cover
3. Changes in the characteristic of soil.
4. Pollution of water resources from the contamination of soil through which water sweeps into ground or runoff to the water bodies.
5. Changes in climatic conditions because of unbalance created in the environment.

Causes of Land Degradation

1) Deforestation and Soil erosion:

Deforestation carried out to create dry lands is one of the major concerns. Land that is once converted into a dry or barren land, can never be made fertile again. Exposed land and loosened soil may lead to soil erosion. Land conversion is another major cause, meaning the alteration or modification of the original properties of the land to make it use worthy for a specific purpose.

2) Agricultural activities:

With growing human population, demand for food has increased considerably. Farmers often use highly toxic fertilizers and pesticides to get rid off insects, fungi and bacteria from their crops. With the over use of these chemicals, they result in contamination and poisoning of soil.

3) Industrialization:

Due to increase in demand for food, shelter and house, more goods are produced. This resulted in creation of more waste that needs to be disposed of. To meet the demand of the growing population, more industries were developed which led to deforestation.

4) Construction activities:

Due to urbanization, large amount of construction activities are taking place which has resulted in large waste articles like wood, metal, bricks, plastic etc

5) Nuclear waste:

Nuclear plants can produce huge amount of energy through nuclear fission and fusion. The left

over radioactive material contains harmful and toxic chemicals that can affect human health. They are dumped beneath the earth to avoid any casualty.

6) Sewage treatment:

Large amount of solid waste is leftover once the sewage has been treated. The left over material is sent to landfill site which end up in polluting the environment.

7) Acid rain:

Acid rain is caused when pollutants present in the air mixes up with the rain and fall back on the ground. This polluted water could dissolve away some of the important nutrients found in soil and change the structure of the soil.

8) Accidental oil spills:

Chemicals in the fuel deteriorates the quality of soil and make them unsuitable for cultivation. These chemicals can enter into the groundwater through soil and make the water undrinkable.

9) Mining activities:

A source of land pollution. Huge holes are dug for mining and these holes can pose a hazard as they form deep mining pools. Metals like cadmium and lead will be deposited, which are toxic contaminating the soil. This will leave the mining land barren and unable to use again.

10) Shifting Cultivation

Forest is burnt to use the land for cultivation, until the soil loses it's fertility. Once the land becomes inadequate for crop production, it is left barren and hence leads to soil erosion.

Effects or Impacts:

1. Decline in the chemical, physical and/or biological properties of soil.

2. Reduced availability of potable water.

3. Lessened volumes of surface water.

4. Impacts on livestock and agriculture e.g. loss of animals due to dehydration, reduced yields.

5. Decline in productivity.

6. Water and food insecurity.

7. Biodiversity loss.

Prevention and Control Measures for Land Degradation:

Following are some practises for controlling land degradation:

1. Strip farming:

It is & practice in which cultivated crops are sown in alternative strips to prevent water movement.

2. Crop Rotation:

It is one of the agricultural practice in which different crops are grown in same area following a rotation system which helps in replenishment of the soil.

3. Ridge and Furrow Formation:

Soil erosion is one of the factors responsible for lad degradation. It can be prevented by formation of ridge and furrow during irrigation which lessens run off.

4. Construction of Dams:

This usually checks or reduces the velocity of run off so that soil support vegetation.

5. Contour Farming:

This type of farming is usually practiced across the hill side and is useful in collecting and diverting the run off to avoid erosion.

ENVIRONMENTAL IMPACT ASSESSMENT

Environmental assessment (**EA**) is the assessment of the environmental consequences (positive and negative) of a plan, policy, program, or actual projects prior to the decision to move forward with the proposed action. The term "**environmental impact assessment**" (**EIA**) is usually used when applied to actual projects by individuals or companies and the term "strategic environmental assessment" (SEA) applies to policies, plans and programmes most often proposed by organs of state. Environmental assessments may be governed by rules of administrative procedure regarding public participation and documentation of decision making, and may be subject to judicial review.

The purpose of the assessment is to ensure that decision makers consider the environmental impacts when deciding whether or not to proceed with a project. The International Association for Impact Assessment (IAIA) defines an environmental impact assessment as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made". EIAs are unique in that they do not require adherence to a predetermined environmental outcome, but rather they require decision makers to account for environmental values in their decisions and to justify those decisions in light of detailed environmental studies and public comments on the potential environmental impacts.

Definitions of EIA:

Environmental Impact Assessment is defined as an activity designed to identify the impact on the bio geophysical environment, on man and well-being of legislative proposals, projects, policies, operational procedures and to interpret and communicate information. EIA is a systematic process of identifying future consequences of a current or proposed action.

Objective of EIA:

The objective of EIA is

- To identify, predict and evaluate the economic, environmental and social impact of development activities
- To provide information on the environmental consequences for decision making and
- To promote environmentally sound and sustainable development through the identification of appropriate alternatives and mitigation measures.

EIA is widely accepted as a tool to ensure sustained development with minimum environmental degradation.

EIA has main three functions:

- To predict the environmental problems
- To find ways to avoid them
- To enhance positive effects

Why EIA?

EIA is intended to prevent or minimize potentially adverse environmental impacts and enhance the overall quality of a project. The main benefits and advantages of EIA are:

- ✓ Lower project costs in the long-term
- ✓ Increased project acceptance
- ✓ Improved project design
- ✓ Informed decision making
- ✓ Environmentally sensitive decisions
- ✓ Increased accountability and transparency
- ✓ Reduced environmental damage
- ✓ Improved integration of projects into their environmental and social settings

Which type of projects under go EIA?

- ✓ Agriculture
- ✓ Construction (Road networks, Malls, Townships, Dam etc)
- ✓ Industries
- ✓ Electrical projects
- ✓ Waste disposal
- ✓ Any developmental projects around Protected Areas / Nature Preserves
- ✓ Clean Development Mechanism CDM projects

Need of EIA

Environment is composed of Biotic & Abiotic components. There is a dynamic equilibrium between these components. When a project is undertaken it tends to disturb these components. To maintain the quality of environment the perspective impacts of the project on natural environment are studied on time and remedial measures must be taken so as to promote sustainable and holistic development of the project. This is done through EIA.

For Example, a forest ecosystem is a complete ecosystem which provides food, shelter to a wide variety of species. It provides firewood, resins, timber, medicinal herbs, etc. to us. Therefore forests are our lifeline. Whenever a project is undertaken which demands clearing of the forest like construction of road or a dam, then EIA helps us to access the impact of that activity on this life line. It also suggests alternate project sites and alternate process technologies.

Purpose of EIA

- To conserve the resources
- To minimise the waste
- To recover the by product
- To utilize the equipment efficiently

Importance of EIA:

- ✓ EIA is potentially a useful component of good environmental management.
- ✓ It is the Government policy that any industrial project has to obtain EIA clearance from the Ministry of Environment before approval by the planning commission.

Benefits of EIA

- Facilitates informed decision making by providing clear, well-structured dispassionate analysis of the effect and consequences of proposed projects.
- Pre-emption or early withdrawal of unsound proposals.
- Assists in the selection of alternatives, including the selection of the best practicable and most environmentally friendly option.
- Results in best practice prediction and mitigation of adverse effects of projects.
- Influences both project selection and design by screening out environmentally unsound projects, as well as modifying feasible projects - Mitigation of negative environmental and social impacts.
- Guides formal approval, including the establishment of terms and conditions of project implementation and follow- up.
- Mitigation of negative environmental and social impacts.

- Serves as an adaptive, organizational learning process, in which the lessons of experience are feedback into policy, institutional and project design - Enhancement of positive aspects

Limitations of EIA

EIA suffers from following limitations

- EIA should be undertaken at the policy and planning level rather than at the project level.
- Range of Possible alternatives in the project EIA is often small.
- There is no criteria to decide what type of project are to undergo EIA. A lot of unnecessary expense and delay in project clearance could be avoided as there are many projects that do not require an in-depth EIA.
- Lack of comprehensive environment information base, limitation of time, manpower and financial resources make EIA very complicated and time consuming.
- More research and development of improved methodologies is required to overcome limitations relating to the uncertainties in data.
- EIA, reports are too academic, bureaucratic and lengthy containing too many tables of collected data without any data analysis, interpretation and environmental implications.
- In actual practice EIA ends immediately after project clearance, no follow up action is taken.
- It does not incorporate the strategies of preventing environmental intervention. The issue of resource conservation, waste minimization, by product recovery and improvement in efficiency of equipment, need to be pursued as the explicit goal in EIA.

EIA Clearance required

Total EIA clearance is required for 32 categories of developmental works broadly categorized into following industrial sectors:

- ✓ Mining
- ✓ Thermal power plant
- ✓ River valley
- ✓ Infrastructure (Road, highway, ports, harbour, airports,
- ✓ Industries including very small electroplating or foundry units

TYPES OF ENVIRONMENTAL IMPACTS

Some of the environmental impacts are :

1. Direct Impact,

2. Indirect Impact,

3.Cumulative impacts and

4.Induced Impact

Direct Impacts:

Direct impacts occur through direct interaction of an activity with an environmental, social, or economic component.

For example, a discharge of any industry or an effluent from the Effluent Treatment Plant (ETP) from the industrial estates into a river may lead to a decline in water quality in terms of high biological oxygen demand (BOD) or dissolved oxygen (DO) or rise of water toxins.

Indirect Impacts:

Indirect impacts on the environment are these which are not a direct result of the project, often produced away from or as a result of a complex impact pathway. The indirect impacts are also known as secondary or even third level impacts.

For example, ambient air SO_2 rise due to stack emissions may deposit on land as SO_4 and cause acidic soils. Another example of indirect impact is the decline in water quality due to rise in temperature of water bodies receiving cooling water discharge from the nearby industry.

This may, in turn, lead to a secondary indirect impact on aquatic flora in that water body and may further cause reduction in fish population. Reduction in fishing harvests, affecting the income of fishermen is a third level impact. Such impacts are characterized as socioeconomic (third level) impacts.

The indirect impacts may also include growth- inducing impacts and other effects related to induced changes to the pattern of land use or additional road network, population density or growth rate (e.g. around a power project). In the process, air, water and other natural systems including the ecosystem may also be affected.

Cumulative Impacts:

Cumulative impact consists of an impact that is created as a result of the combination of the project evaluated in the EIA together with other projects causing related impacts. These impacts occur when the incremental impact of the project is combined with the cumulative effects of other past, present and reasonably foreseeable future projects.

Induced Impacts:

The cumulative impacts can be, due to induced actions of projects and activities that may occur if the action under assessment is implemented such as growth inducing impacts and other effects related to induced changes to the pattern of future land use or additional road network, population density or growth rate. Induced actions may not be officially announced or be part of any official plan. Increase in workforce and nearby communities contributes to this effect.

They usually have no direct relationship with the action under assessment and represent the growth- inducing potential of an action. New roads leading from those constructed for a project, increased recreational activities, and construction of new service facilities are examples of induce actions.

However, the cumulative impacts due to induced development or third level or even secondary indirect impacts are difficult to be quantified. Because of higher levels' of uncertainties, these' impacts cannot be normally assessed over a long time horizon. An EIA practitioner usually can only guess as to what such induced impacts may be and the possible extent of their implications on the environmental factors.

MODULE VI

EIA Procedure-Screening, Scoping, EIA procedure in India, Impact analysis- checklists, matrix methods, overlay analysis, Case studies of EIA

INTRODUCTION

An environmental impact assessment (EIA) is an assessment of the possible positive or negative impact that a proposed project may have on the environment, considering natural, social and economic aspects.

EIA Methodology:

Whenever a new development project is planned which is likely to affect environmental quality, it is necessary to carry out EIA.

1. The first step in EIA method is to determine whether the project under consideration follows the jurisdiction of the relevant acts and regulations and if so, whether it is likely to create a significant environmental disruption.
2. If so, an EIA is undertaken and the environmental impact statement (EIS) is prepared.
3. In many countries, EIS is open to public scrutiny and is reviewed at public hearings.
4. Finally, a political decision is taken.

The development project may be

(i) accepted or

(ii) accepted with amendments or

(iii) an alternative proposal is accepted or

(iv) rejected.

Environment Impact Assessment Process:

In EIA system, there are sequence of activities implemented in a project in logical manner termed as EIA process.

Guiding Principles:

The entire process of EIA is governed by eight guiding principles**.**

1. Participation:

An appropriate and timely access to the process for all interested parties.

2. Transparency:

All assessment decisions and their basis should be open and accessible.

3. Certainty:

The process and timing of the assessment should be agreed by all participants in advance.

4. Accountability:

The decision makers of all parties are responsible for their action and decisions under the assessment process.

5. Credibility:

Assessment is undertaken with professionalism and objectivity.

6. Cost effectiveness:

The assessment process and its outcomes will ensure environmental protection at the least cost to the society.

7. Flexibility:

The assessment process should be able to deal efficiently with any proposal and decision making situation.

8. Practicality:

The information and outputs provided by the assessment process are readily usable in decision making and planning.

Participants in EIA Process:

1. Proponent:

Government or Private Agency which initiates the project.

2. Decision maker:

Designated individual or group.

3. Assessor:

Agency responsible for the preparation of EIS.

4. Reviewer:

Individual/Agency/Board.

5. Expert advisers, Media and Public, Environmental organisations etc.

GENERAL STEPS INVOLVED IN EIA

The main steps in EIAs process:-

- Screening
- Scoping
- Prediction and Mitigation
- Management and Monitoring
- Audit

- **Screening** often results in a categorization of the project and from this a decision is made on whether or not a full EIA is to be carried out.
- **Scoping** is the process of determining which are the most critical issues to study and will involve community participation to some degree. It is at this early stage that EIA can most strongly influence the outline proposal.
- Detailed **prediction and mitigation** studies follow scoping and are carried out in parallel with feasibility studies.
- The main output report is called an ***Environmental Impact Statement*****,** and contains a detailed plan for managing and monitoring environmental impacts both during and after implementation.
- Finally, an **audit** of the EIA process is carried out some time after implementation. The audit serves a useful feedback and learning function.

EIA Process in Sequence of Application:

1. Stakeholder's Involvement:

Stakeholders' involvement occurs in various stages of EIA to ensure quality, efficiency and effectiveness.

2. Project Screening and Scoping:

(i) Determine necessity for EIA requirement.

(ii) Describe various screening criteria.

(iii) Scoping determines coverage or scope of EIA.

3. Project Design and Construction:

(i) Type of project under consideration.

(ii) Physical dimensions of the area being considered.

(iii) Whether the resources will be used optically?

(iv) Whether there is an irretrievable commitment of land?

(v) Whether the project is a critical phase of a larger development?

(vi) Whether there will be serious environmental disruptions during construction?

(vii) What are the long-term plans of the proponent?

4. Project Operation:

(i) What provisions have been made to check the safety equipment regularly?

(ii) How will the hazardous waste products be handled?

(iii) What are the contingency plans developed to cope up with the possible accidents?

(iv) What provisions have been made for training the employees for environmental protection?

(v) What plans have been made for environmental monitoring?

5. Site Characteristics:

(i) Whether the site is susceptible to floods, earth quakes and other natural disasters?

(ii) Whether the terrain is creating problems in predicting ground water characteristics and air pollution etc.?

(iii) Whether the local environment is conductive for the success of the project?

(iv) How many people are likely to be displaced because of the project?

(v) What are the main attributes (e.g., protein content, calorie content, weed or pest status, carnivorousness, rarity of species, etc.) of the local fauna and flora?

(vi) Whether the project will interfere with the movements of fish population and important migratory animals?

(vii) Whether historic sites are likely to be endangered because of the project?

6. Possible Environmental Impacts:

(i) What are the possible short-term and long-term environmental impacts from the projects during construction and after construction?

(ii) Who would be effected because of these impacts?

7. Mitigation Measures:

(i) Design system to avoid, reduce and minimize adverse impacts.

(ii) Enhance beneficial outcomes.

8. Monitoring and auditing measures:

(i) Identify impacts that require monitoring and auditing.

9. Socio-Economic Factors:

(i) Who are the expected gainers and losers by the projects?

(ii) Where are the expected trade-offs?

(iii) Will the project interfere (blend, increase or reduce) with the existing inequalities between occupational, ethnic and age groups?

(iv) Will it affect the patterns of local/regional/national culture?

10. Availability of Information and Resources:

(i) Whether local and outside experts are available to consult specific impacts of the project?

(ii) Whether the relevant guidelines, technical information and other publications are available to identify the possible impacts of similar projects?

(iii) Whether relevant environmental standards, by-laws etc. are considered?

(iv) Whether the sources of relevant environmental data are identified and whether they are accessible?

(v) Whether the views of the specialist groups and general public regarding the project have been considered?

(vi) Whether the competent technical manpower is available to handle the project?

11. EIA Report and Review:

Complete information in report including non-technical summary, methodologies used, results, interpretation and conclusions. Review assesses adequacy of issues and facilitate decision making process.

12. Decision Making:

The project may be accepted, accepted with alterations or rejected. The structure of an EIA process is dictated primarily by the need to accommodate each of the key issues discussed above. Although there may be variations in the detailed procedures, adopted within a particular country, most systems in essence conform to the pattern shown as a broad outline of an EIA system).

ENVIRONMENTAL IMPACT ASSESSMENT IN INDIA

Introduction to Environmental Impact Assessment:

The environmental impact assessment in India was started in 1976-77, when the planning commission asked the Department of Science and Technology to examine the river valley projects from environmental angel. This was subsequently extended to cover those projects, which required approval of the Public Investment Board.

Then the Govt. of India enacted the Environment (Protection) Act on 23rd May 1986 to achieve the objective the decision that were taken is to make environmental impact assessment statutory. After following the legal procedure, a notification was issued on 27th Jan 94. 10thApril, 1997 and 27th Jan 2000. Making environmental impact assessment statutory for 30 development projects (Schedule I), the mandatory EIA clearance procedure started.

The EIA process in India is made up of the following phases: (EIA PROCEDURE)

1. Project description
2. Screening
3. Scoping and consideration of alternatives
4. Baseline data collection
5. Impact prediction
6. Assessment of alternatives, delineation of mitigation measures and environmental impact statement (EIS)

7. Public hearing
8. Environment Management Plan (EMP)
9. Decision making
10. Monitoring the clearance conditions
11. Post Monitoring (EIA audit)

Project description

It is the condensed description of all aspects of the project showing boundary, site layout, location map etc. it is based on the project feasibility study. The project proposal shall also include all relevant information available including a land use map in order for it to move to next stage which is screening. The submission of project proposal signifies the the commencement of the EIA process.

Screening:

First stage of EIA, screening is the scrutiny of application, which determines whether the proposed project requires an EIA and if it does, then the level of assessment required. Screening is done to see whether a project requires environmental clearance as per the statutory notifications.

Screening Criteria are based upon:

(i) Scales of investment;

(ii) Type of development; and,

(iii) Location of development.

A Project requires statutory environmental clearance only if the provisions of EIA notification and/or one or more statutory notification is mentioned.

Scoping:

Scoping is a process of detailing the terms of reference of EIA. It has to be done by the consultant in consultation with the project proponent and guidance, if need be, from Impact Assessment Agency. The Ministry of Environment and Forests has published guidelines for different sectors, which outline the significant issues to be addressed in the EIA studies Quantifiable impacts are to be assessed on the basis of magnitude, prevalence, frequency and

duration and non-quantifiable impacts (such as aesthetic or recreational value), significance is commonly determined through the socio-economic criteria.

After the areas, where the project could have significant impact, are identified, the baseline status of these should be monitored and then the likely changes in these on account of the construction and operation of the proposed project should be predicted. Recent years, scoping was determined by **"Term of reference"** clearance by MoEF.

Baseline Data:

Baseline data describes the existing environmental status of the identified study area. The site-specific primary data should be monitored for the identified parameters and supplemented by secondary data if available.

Impact Prediction:

Impact prediction is a way of 'mapping' the environmental consequences of the significant aspects of the project and its alternatives. Environmental impact can never be predicted with absolute certainty and this is all the more reason to consider all possible factors and take all possible precautions for reducing the degree of uncertainty.

The Following Impacts of the Project should be assessed:

Air:

Changes in ambient levels and ground level concentrations due to total emissions from point, line and area sources effects on soils, materials, vegetation, and human health.

Noise:

Changes in ambient levels due to noise generated from equipment and movement of vehicles effect fauna and human health.

Water:

(i) Availability to competing users

(ii) Changes in quality

(iii) Sediment transport

(iv) Ingress of saline water

Land:

(i) Changes in land use and drainage pattern

(ii) Changes in land quality including

(iii) Effects of waste disposal

(iv) Changes in shoreline/river-bank and their stability-

Biological:

(i) Deforestation/tree-cutting and shrinkage of animal habitat

(ii) Impact on fauna and flora (including aquatic species if any) due to contaminants/pollutants

(iii) Impact on rare and endangered species, endemic species, and migratory path/route of animals

(iv) Impact on breeding and nesting grounds

Socio-Economic:

(i) Impact on the local community including demographic changes

(ii) Impact on economic status

(iii) Impact on human health

(iv) Impact of increased traffic

Assessment of Alternatives, Delineation of Mitigation Measure and Environmental Impact Assessment Report (EIS):

For every project, possible alternatives should be identified and environmental attributes compared. Alternatives should cover both project location and process technologies. Alternatives mould considers 'no project' option also. Alternatives should then be ranked for selection of the best environmental option for optimum economic benefits to the community at large.

Once alternatives have been reviewed, a mitigation plan should be drawn up for the selected option and is supplemented with an Environmental Management Plan (EMP) to guide the

proponent towards environmental improvements. The EMP is a crucial input to monitoring the clearance conditions and therefore details of monitoring should be included in the EMP.

An EIA report should provide clear information to the decision-maker on the different environmental scenarios without the project, with the project and with project alternatives. Uncertainties should be clearly reflected in the EIA report.

Public Hearing:

Law requires that the public must be informed and consulted on a proposed development after the completion of EIA report. Any one likely to be affected by the proposed project is entitled to have access to the Executive Summary of the EIA.

The affected persons may include:

(i) Bonafide local residents

(ii) Local associations,

(iii) Environmental groups: active in the area

(iv) Any other person located at the project site/ sites of displacement

They are to be given an opportunity to make oral/written suggestions to the State Pollution Control Board as per Schedule IV of Annex I.

Environment Management Plan:

It is a plan or program that seeks to achieve a required end state and describes how activities, which have or could, have an adverse impact on the environment, will be mitigated, controlled, and monitored during the commissioning, mobilization, construction, operation, maintenance and decommissioning of a project; and that the positive benefits of the projects are enhanced.

Decision Making:

Decision making process involve consultation between the project proponent (assisted by a consultant) and the impact assessment authority (assisted by an expert group if necessary). The decision on environmental clearance is arrived at through a number of steps including evaluation of EIA and Environmental management plan.

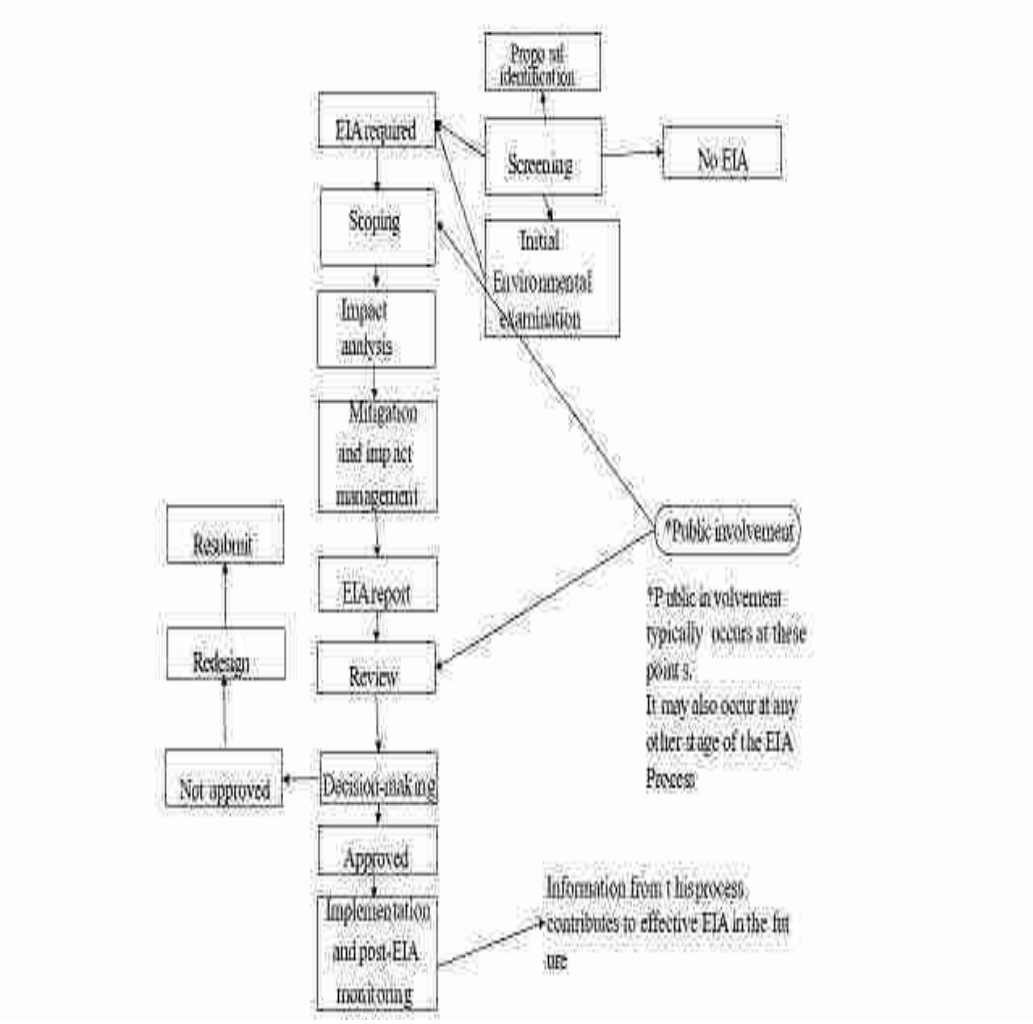
Monitoring the Clearance Conditions:

Monitoring should be done during both construction and operation phases of a project. This is not only to ensure that the commitments made are compiled with but also to observe where the predictions made in the EIA reports were correct or not.

Where the impacts exceed the predicted levels, corrective action should be taken. Monitoring will enable the regulatory agency to review the validity of predictions and the conditions of implementation of the Environmental Management Plan (EMP).

Post Monitoring (EIA Audit):

This stage comes to play once the project is commissioned. It checks to ensure that the impacts of the project do not exceed the legal standards and implementation of the mitigation measures are in the manner as described in the EIA report.



Generalized EIA process flow chart

ENVIRONMENTAL IMPACT STATEMENT (EIS)

EIS should contain the following information's/data:

1. Description of proposed action (construction, operation and shut down phase) and selection of alternatives to the proposed action.

2. Nature and magnitude of the likely environmental effects.

3. Possibility of earthquakes and cyclones.

4. Possible effects on surface and ground water quality, soil and air quality.

5. Effects on vegetation, wild life and endangered species.

6. Economic and demographic factors.

7. Identification of relevant human concerns.

8. Noise pollution. Efficient use of inputs.

9. Recycling and reduction of waste.

10. Risk analysis and disaster management.

The EIA Directive

The EIA Directive requires projects likely to have significant effects on the Environment by virtue of their nature, size or location to undergo an environmental assessment before the competent authority in question grants consent. The EIA Directive defines a project as the execution of construction works or of other installations or schemes, other interventions in the natural surroundings and landscape including those involving the extraction of mineral resources. The EIA should **identify**, **describe** and **assess** the **direct** and **indirect** effects of a project on the following factors:

- ✓ Human beings
- ✓ Fauna and flora
- ✓ Soil, Water & Air
- ✓ Climate and the landscape
- ✓ Material Assets
- ✓ Cultural Heritage

- ✓ Interaction between all above factors

EIA therefore should have a very strong social dimensions

ENVIRONMENTAL MANAGEMENT PLAN (EMP)

It is a plan or program that seeks to achieve a required end state and describes how activities, which have or could, have an adverse impact on the environment, will be mitigated, controlled, and monitored during the commissioning, mobilization, construction, operation, maintenance and decommissioning of a project; and that the positive benefits of the projects are enhanced.

EPA, 2005 states that EMP is the action an organization is taking to determine how it affects the environment, complies with regulations, keeps track of environmental management activities, and meets environmental goals and targets. It also documents key elements of environmental management including the environmental policy, responsibilities, applicable standard operating procedures and Best Management Practices (BMP), record keeping, reports, communication, training, monitoring, and corrective action.

- The EMP features the "Plan, Do, Check, Act" model (EPA, 2005) for ongoing improvement:
- Plan - Planning, including identifying environmental impacts and establishing environmental goals.
- Do - Implementing, including employee training and establishing operational controls.
- Check - Checking, including auditing, monitoring and taking corrective action.
- Act - Reviewing, including progress reviews and taking action to make needed changes.

Environmental management is easier if you have an EMP, because it will help you better track your environmental management activities and implement them in a more organized and streamlined manner. An EMP gives you a framework (EPA, 2005) in which to:

- Comply - Assist you in assessing compliance with environmental regulations
- Improve - Allow you to identify opportunities for improvement and cost savings
- Know - Decrease costly confusion for your employees by spelling out exactly what is expected of them.

Purpose of the EMP:

- Encourage good management practices through planning and commitment to environmental issues concerning any project;
- It tells how the management of the environment is reported and performance evaluated periodically;
- To provide rational and practical environmental guidelines that will assist in minimizing the potential environmental impact of activities;
- Helps in minimizing disturbance to the environment (physical, biological and ecological, socioeconomic, cultural, and archaeological,) ;
- Combat all forms of pollution through monitoring air, noise, land, water, waste, and energy and natural resources;
- Protection of sensitive and endangered flora and fauna;
- Prevent land degradation;
- Comply and adhere to all applicable laws, regulations, standards and guidelines for the protection of the environment;
- Adopt best practicable waste management for all types of waste (liquid and solid) with objective on prevention, minimization, recycling, treatment or disposal of wastes;
- Describe all monitoring procedures required to identify impacts on the environment;
- Train and bring awareness to employees and contractors with regard to environmental obligations and compliance.
- Reduce environmental risk and provide better Health, Safety and Environment (HS&E)
- Increase efficiency through minimum consumption and conservation of energy depleteable resources
- An EMP also provides with a plan answering - what, where, when, how and who?
- Establishing the reporting system to be undertaken during the construction.
- The EMP also serves to highlight specific requirements that will be monitored during the development and should the environmental impacts not have been satisfactorily prevented or mitigated, corrective action will have to be taken

TERMS OF REFERENCE (ToR) in EIA

TOR or Terms of Reference is a document produced by the authority conducting the EIA study. It is formed during Scoping-the second stage in the EIA process. All the stakeholders are invited to submit their concerns regarding the project during a public hearing organized by the EIA committee, which is followed by discussions and deliberations. The finalized list of this stage of EIA is submitted to the Ministry in the form of TOR.

TOR is an important document in the process of EIA because it sets the guidelines for the study. A TOR is drawn up with the following questions in mind.

1. The purpose of the study/project.

2. The extent of the study.

3. The stakeholders' requirements; each stakeholder looks at different aspects of the project differently. Complex information needs to be explained appropriately.

Content of TOR

TOR highlights the points *that need to be covered* (the TOR itself does not elaborate on these points unless required) during the EIA study, which include-

1. A description of the project, it's purposes and extent.

2. All the agencies responsible in the developmental project and the EIA study.

3. A description of the existing environmental conditions in the project site and surrounding areas.

4. The stakeholders that will be benefited and harmed by the fulfillment of the project.

5. The environmental aspects the project is likely to affect.

6. The impacts, both positive and negative, the project will have on the area and the locals.

7. The impact the environment could have on the project.

8. A list/description of the species endemic to the area, which are likely to be effected.

9. How in-depth does the EIA study need to be; whether baseline data is available or whether the study be sourced from secondary data.

10. Possible alternatives for the project in terms of design, site, technology, implementation, etc.

11. The legal requirements of the project and future legislation that need to be drafted.

12. If the project site comes under special categories, and the legislation regarding the same.

13. Recommended mitigation strategies.

14. The expertise required for the EIA study.

15. The expected time limit for the entire EIA study.

16. Natural Resource Valuation (NRV), if possible.

17. The budget of the study, also called cost-benefit analysis.

It is important that the TOR be drawn up exhaustively to ensure that the EIA study carried out is effective in warding off as much environmental damage as possible. TORs take about 45 days to prepare in today's EIA studies.

Under the Ministry of Environment, Forests and Climate Change guidelines, reference TORs for the most common developmental projects have been drawn up in the ministry website. This reference document lists out the most important aspects and impacts of large, common developmental projects. This eases the burden on the EIA committees working to conduct EIA of large projects. They take most of the information to be mentioned in the TOR from this reference. All that is included from their side are site specific issues that arise for each individual project; for example, the presence of a unique ecosystem in the area (mangroves etc), presence of protected areas in the project vicinity, etc.

EIA - IMPACT ANALYSIS

This stage of EIA identifies and predicts the likely Environmental and social impact of the proposed project and evaluates the significance

Methods for impact analysis include:

- Impact Identification
- Impact Prediction
- Impact Evaluation

Impact Identification

- Impact Identification attempts to answer the question, "what will happen when a project enters its operational stage?"
- A List of important impacts such as changes in ambient air quality, changes in water and soil qualities, noise levels, wildlife habitats, species diversity, social and cultural systems, employment levels etc. may be prepared.
- The important sources of impact like smoke emission, consumption of water, discharge of effluents etc. are identified.

Methods of impact identification/impact analysis/impact assessment methodologies:

- Checklists
- Matrices
- Overlays

1. Checklists:

- Checklist means a listing of potential Environmental Impacts.
- A comprehensive and user friendly checklist is an invaluable aid for several activities of EIA, particularly scoping and defining baseline studies
- The checklist has been prepared for non-specialists and enables much time consuming work to be carried out in advance of expert data
- It includes extensive data collection sheets
- The collected data can then be used to answer a series of questions to identify major impacts and to identify shortages of data.
- This method is done to assess the nature of the impacts i.e. its type such as adverse /beneficial, short term or long term, no effect or significant impact, reversible or irreversible etc.

- These methodologies present a specific list of environmental parameters to be investigated for possible impacts, or a list of agency activities known to have caused environmental concern.
- They may have considerable value when many repetitive actions are carried out under similar circumstances.
- They do not, themselves, establish a direct cause- effect link, but merely suggest lines of examination.

Types of checklists:

- **Simple Checklists.**

  Simple checklists are a list of parameters without guidelines regarding either interpretation or measurement of environmental parameters or specific data needs or impact prediction and assessment.
- **Descriptive Checklists.**

  Descriptive checklists include list of environmental factors along with information on measurement, impact prediction and assessment.
- **Scaling and weighting Checklists.**

  Scaling and weighting checklists facilitate decision making. Such checklists are strong in impact identification. While including the function of impact identification, they include a certain degree of interpretation and evaluation.
- **Questionnaire Checklists**

  It based on a set of questions to be answered. Some of the questions may concern indirect impacts and possible mitigation measures. They may also provide a scale for classifying estimated impacts from highly adverse to highly beneficial

Advantages	Disadvantages
Simple to understand and use	Do not distinguish between direct and indirect impacts
Good for site selection and priority setting	Do not link action and impact
	Sometime it is a cumbersome task

Eg: Simple checklist for a bridge construction

	Yes	No
Proposed activities		
Dredging	√	
Blasting	√	
Pier construction	√	
Traffic diversion		√
Affected physical components		
Water quality	√	
Water quantity		√
Soil quality	√	
Soil quantity		√
Air quality	√	
Affected biological components		
Fish populations	√	
Spawning of fish	√	
Bird habitat		√
Wildlife habitat		√
Affected socio-economic components		
Employment		√
Noise	√	
Health	√	

2. Matrices:

- It was pioneer by Leopold et al (1971).
- Matrix indicates causes and effect by posting activities on the rows and environmental parameters on the column
- In this way, the impacts of individual components of projects as well as major alternatives can be compared
- Matrix and its variants provide us a framework of interaction of different actions /activities of a project with potential environmental impact (EI) caused by them.
- The matrix methodologies incorporates both a list of project activities and a checklist of potentially impacted environmental characteristics.
- It is a simple interaction matrix is formed where project actions are listed along one axis i.e. vertically and EI are listed along the other side i.e. horizontally.
- The two lists are then related in a matrix which identifies cause and effect relationships between specific activities and impacts.
- It lists about 100 project actions and about 88 environmental characteristic and condition.
- In a way, the matrix presents both alternatives from the checklist approach (i.e., both attributes and activities) to be considered simultaneously.
- Matrix methodologies may either specify which actions impact which environmental characteristics or may simply list the range of possible actions and characteristics in an open matrix to be completed by the analyst.

Advantages	Disadvantages
Link action to impact	Difficult to distinguish direct and indirect impacts
Good method for displaying EIA results	Significant potential for double-counting of impacts
	Qualitative

ENVIRONMENTAL FACTORS		PHYSICAL MEDIUM							SOCIO-ECONOMIC MEDIUM				
		E1 AIR	E2 LAND AND SOIL	E3 WATER	E4 FLORA	E5 FAUNA	E6 LANDSCAPE	E7 NOISE AND VIBRATION	E8 LAND USE	E9 CULTURAL FACTORS	E10 INFRASTRUCTURE	E11 HUMAN FACTORS	E12 POPULATION AND ECONOMY
PROJECT ACTIONS HAVING THE POTENTIAL TO CAUSE AN IMPACT													
A1	Modification of industrial site		X					X	X	X			X
A2	Modification of industrial buildings		X				X	X					
A3	Modification of property limits		X						X				
A4	Demolition of buildings	X	X				X	X	X			X	
A5	Construction of new buildings	X	X				X	X	X			X	
A6	Landfills and earth movements	X	X				X	X				X	
A7	Silting and drainage		X	X									
A8	Recycling of wastes		X										X
A9	Transport of materials	X					X				X	X	
A10	Handling of hazardous radioactive or toxic materials											X	
A11	Emission of liquid and gaseous effluents	X	X	X	X	X						X	
A12	Use of rubble tips or solid inert waste tips		X	X	X	X	X	X	X			X	
A13	Storage of solid radioactive wastes		X	X	X	X	X		X			X	
A14	Fires	X					X					X	
A15	Releases or leakage of contaminating liquids or gases	X	X	X	X	X			X			X	
A16	Operating failures											X	
A17	Personnel accidents											X	
A18	Structural failures due to external events	X	X	X	X	X		X	X			X	X
A19	Monitoring and control operations											X	

3. Overlays:

- Overlays provide a technique for illustrating the geographical extent of different environmental impacts.
- Each overlay is a map of single impact
- These methodologies rely upon a set of maps of project area's environmental characteristics (physical, social, ecological, aesthetic).
- These maps are overlaid to produce a composite characterisation of the regional environment.
- Separate mapping of critical environmental features at the same scale as project's site plan.
- Impacts are identified by noting the congruence of inherently antagonistic environmental characteristics within the project boundaries.
- E.g. wetlands, steep slopes, soils, floodplains, bedrock outcrops, wildlife habitats, vegetative communities, and cultural resources.
- Older Technique: environmental features are mapped on transparent plastic in different colours, which is cumbersome.
- Newer Technique: **Geographic Information Systems (GIS)**, can make this technique particularly suitable for comparing options, pinpointing sensitive zones and proposing different areas or methods of land management.

Advantages	Disadvantages
Easy to understand and use	Address only direct impacts
Good display method	Do not address impact duration or probability
Good for site selection setting	

6.8 CASE STUDY OF EIA

The **Environment Impact Assessment** (EIA) reported on the **Narmada Sagar Project (NSP)** one of the largest dams in the Narmada Valley development project to be located in the Khandwa district of Madhya Pradesh, claimed that the project will wipe out many species of flora (plants) and fauna (animals).

The EIA reported that 31 species with considerable ethnobotonical value will face **extinction** because of habitat changes in the submergence zone and also in the adjacent residential forests. The report also pointed out that many of the species which face submergence cannot be compensated in the residual forest areas either in terms of quantity (or) quality.

The report claimed that high quality wildlife habitat of 420 sq.km will be lost due to the NSP dam and related constructions like hydroelectric generation units and canals. In some areas, animals like chital, sambar and nilgai will be further threatened by near absence of corridors between submergence zone and refuge areas in peripheral forests. Among aquatic lines, otters and turtles will be lost because of unsuitable refuge habitat and their inability to migrate.

There will be a great loss to bird species. The fish varieties will also decline due to inundation of natural water bodies.

The EIA report also pointed out that there will be inadequate rehabilitation of the villagers and it is impossible to compensate for the natural resources lost. The report has also recommended the following three protected areas in the residual forests.

1. The Naramada National Park
2. The Surmanya Sanctuary
3. Omkareshwar Sanctuary

The above three protected area covers 759 sq km of compact and rich wildlife habitat with low human pressure.

EIA of Silent Valley Hydel project

The silent valley hydroelectric project was proposed by Kerala government to utilize the water of Kunthipuzha to generate power. The Kerala State Electricity board justified that successful completion of the project would stabilize the voltage fluctuation in the region and cause for the development of this backward area. Also, the water could be used in the downstream areas for irrigation purpose.

But EIA has given the following reports.

1. Silent Valley is the habitat of many endangered species of plants and animals.
2. If a portion of forest is destroyed by submersion, then all the threatened plant and animal species are likely to be affected.
3. After jungle clearance and deforestation, the top soil will be washed away in a single monsoon resulting in the land degradation -ie making land unfit for future productive exploitation.
4. In the silent valley, the natural vegetation provides habitat for many wild life species. But, when this area is submerged due to this project, it would lead to the destruction of nesting sites of the various species of birds and destruction of spawning grounds of important fish species. This makes the wild animals to come out of forests into the fringes to raid the crops and cattle-lifting in the villages around the forests.

Many environmentalists noted that the alternate path ways available immediately for providing power, irrigation and jobs at no ecological risks will help to achieve the desired goals more speedily and economically.

The EIA had given a report that the project was **neither essential nor unavoidable**. It also stated that no safeguards could possibly protect the ecological balance of the Silent Valley Ecosystem. It is better to implement such projects in ecologically less valuable areas. The EIA has helped to achieve harmony between the 'present needs' and 'future generations' needs to achieve sustainable development. It has avoided the destruction of biological wealth of inestimatable value.