DIECTORATE OF DISTANCE EDUCATION
AND
CONTINUING EDUCATION

Environmental Pollution

M.SC. ENVIRONMENT STUDIES

MANONMANIAM SUNDARANAR UNIVESITY
TIRUNELVELI

Environmental Pollution

Unit-I Concepts of atmosphere and Air Pollutants (Sources and classifications- indoor, vehicular,industrial and other sources). Meteorological aspects of Plume and stack dispersion,Chemical reactions of air pollution (Formation of fog and smog, acid rain). Ozonedepletion - Montreal protocol; Global warming - Kyoto protocol. Air quality standards,Monitoring of air pollution (Ambient air quality monitoring, Stack monitoring; PM 10 andPM 2.5) - Cleaner technologies (Settling chamber, Cyclones, Fabric filter, Electrostaticprecipitator, Wet scrubber, Control of gaseous pollutants absorption, adsorption andcombustion recovery system) - online monitoring of pollution.

Unit-II Properties of water; physiochemical and bacteriological properties of water, drinking waterquality standards; Water pollution- Classification (ground water, river, Marine) sources andsinks, Eutrophication. Control measures of water pollution (adsorption, flocculation, ionexchange and reverse osmosis). Preventive measures in industries to avoid water pollutions(End of pipe treatments and its alternatives, online monitoring and treatment ofindustrial effluents).

Unit-III Soil pollution; Definition; broad classification, Sources and broad classification ofpollution (e.g. urban areas, industrial areas, agriculture and livestock, landfills, sewagesludge, municipal solid waste dumps and hazardous waste), Soil quality and their impactson physio-chemical and biological properties of soil and plants, Sediment Pollution –Black carbon - Soil pollution control measures - On site (in situ) chemical, physical, soilvapour extraction, soil washing solidification/stabilization, electro-kinetic remediationthermical and biological methods. Off site (ex-situ, on-site and off-site): chemical methods,Physical solidification /stabilization/ immobilization, thermal, and biological(bioremediation and phytoremediation), Biostimulation, Bioaugmentation, Isolationcontainment of the affected area.

Unit-IV Concepts and types of municipal and Hazardous Solid Wastes (Hospital Wastes,Radioactive Wastes, industrial), Transport and waste minimization techniques (Disposal,leachate and landfill gas management Nuclear reactor safety). Legislation on managementand handling of municipal solid wastes and hazardous wastes Light pollution and controlmeasures; and Thermal pollution and control measures. Noise pollution – Sensing,Measurement, Abatement measures.

Unit-V Evaluation of Industrial Disasters and Pollution - Case Studies - Chemical Industries – Pesticide Industries, Bhopal Disaster, Chernobyl accident, Love canal Disaster, OilDisasters – Exxon, British Petroleum- Gulf of Mexico; e-wastes, Impact and RemedialMeasures. – Recent case studies in disasters.

Contents

1. Atmosphere and Air Pollution

Atmosphere

An atmosphere is a blanket of gases that surrounds the Earth. It is held near the surface of the planet by Earth's gravitational attraction. Argon, oxygen and nitrogen from the three main constituents of the atmosphere.

Definition

"Atmosphere is a protective layer of gases that shelters all life on Earth, keeping temperatures within a relatively small range and blocking out harmful rays of sunlight."

Features of the Atmosphere:

- Helps retain the sun's heat and prevents it from escaping back into space.
- Protects life from harmful radiation from the sun.
- Plays a major role in Earth's water cycle.
- Helps keep the climate on Earth moderate.

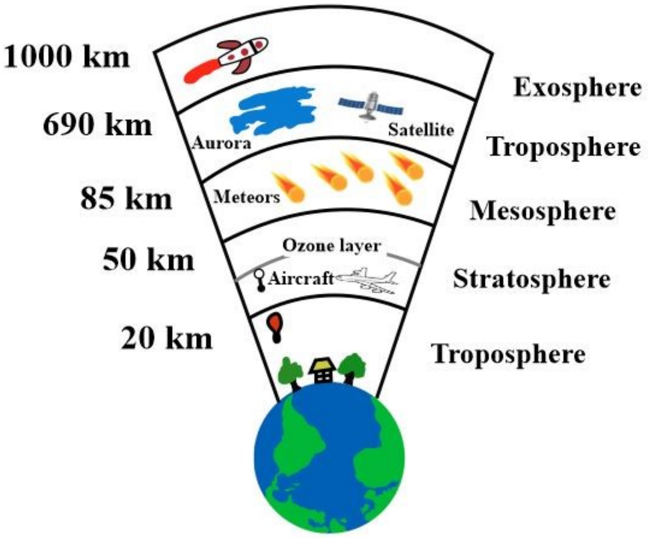
There is no boundary between the atmosphere and outer space. The atmosphere gets less dense and denser until it "blends" into outer space.

Layers of Atmosphere

The atmosphere has five distinct layers that are determined by the changes in temperature that happen with increasing altitude. Layers of Earth's atmosphere are divided into five different layers as:

- Exosphere
- Thermosphere
- Mesosphere

- Stratosphere
- Troposphere



various layers of the Earth's atmosphere

Troposphere

The troposphere is the lowest layer in the atmosphere. It extends upward to about 10 km above sea level starting from ground level. The lowest part of the troposphere is called the boundary layer and the topmost layer is called the tropopause. The troposphere contains 75% of all air in the atmosphere. Most clouds appear in this layer because 99% of the water vapour in the atmosphere is found here. Temperature and air pressure drop as you go higher in the troposphere. When a parcel of air moves upwards it expands. When air expands it cools. Due to this reason, the base of the troposphere is warmer than its base because the air in the surface of the Earth absorbs the sun's energy, gets heated up and moves upward as a result of which it cools down.

Stratosphere

Above the troposphere lies the stratosphere which extends from the top of the troposphere to about 50 km (31 miles) above the ground. The ozone layer lies within the stratosphere. Ozone molecules in this layer absorb high-energy ultraviolet (UV) light from the Sun and convert it into heat. Because of this, unlike the troposphere, the stratosphere gets warmer.

Mesosphere

Above the stratosphere is the mesosphere and it extends to a height of about 85 km (53 miles) from the ground. Here, the temperature grows colder as you rise up through the mesosphere. The coldest parts of our atmosphere are located in this layer and can reach –90°C.

Thermosphere

Thermosphere lies above the mesosphere and this is a region where the temperature increases as you go higher up. The temperature increase is caused due to the absorption of energetic ultraviolet and X-ray radiation from the sun. However, the air in this layer is so thin that it would feel freezing cold to us! Satellites orbit Earth within the thermosphere. Temperatures in the upper thermosphere can range from about 500° C to 2,000° C or higher. The aurora, the Northern Lights and Southern Lights, occur in the thermosphere.

Exosphere

Exosphere is the final frontier of the Earth's gaseous envelope. The air in the exosphere is constantly but gradually leaking out of the Earth's atmosphere into outer space. There is no clear-cut upper boundary where the exosphere finally fades away into space.

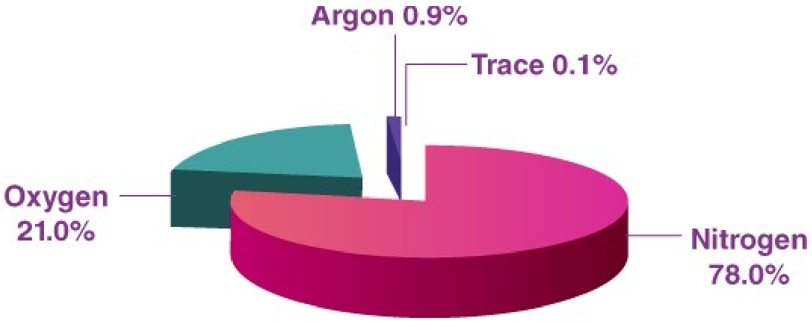
Ionosphere

The ionosphere isn't a distinct layer unlike other layers in the atmosphere. The ionosphere is a series of regions in parts of the mesosphere and thermosphere where high-energy radiation from the Sun has knocked electrons loose from their parent atoms and molecules.

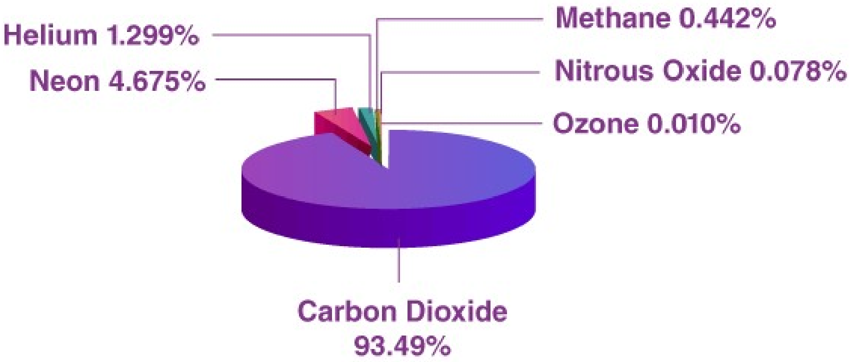
Characteristics of Layers of Atmosphere			
Region	**Altitude Range (km)**	**Temperature Range(0^oC)**	**Important Characteristics**
Troposphere	**0-11**	**15 to -56**	**Weather occurs here**
Stratosphere	**11-50**	**-56 to -2**	**The ozone layer is present here**
Mesosphere	**50-85**	**-2 to -92**	**Meteors burn in this layer**
Thermosphere	**85-800**	**-92 to 1200**	**Auroras occur here**

Composition of Atmosphere – Gases in the Atmosphere

The atmospheric composition of gas on Earth is largely conducted by the by-products of the life that it nurtures.



Dry air from earth's atmosphere contains 0.038% of carbon dioxide, 20.95% of oxygen, 78.08% of nitrogen and 0.93% of argon.



Traces of hydrogen, neon, helium, nitrous oxide, ozone and other "noble" gases, but generally a variable amount of water vapour is also present, on average about 1% at sea level.

Air Pollution

Introduction

Air pollution refers to the release of pollutants into the air that are detrimental to human health and the planet as a whole. The Clean Air Act authorizes the U.S. Environmental Protection Agency (EPA) to protect public health by regulating the emissions of these harmful air pollutants.

Air pollution is a change in the physical, chemical and biological characteristic of air that causes adverse effects on humans and other organisms. The ultimate result is a change in the natural environment and ecosystem. The substances that are responsible for causing air pollution are called air pollutants. These air pollutants can be either natural (e.g. wildfires) or synthetic (man-made); they may be in the form of gas, liquid or solid.

Types of Air Pollutants:

An air pollutant is known as a substance in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases.

Gaseous pollutants: they get mixed with the air and do not normally settle out eg. CO, NOx and SO2

Particulate pollutants: which comprises of finely divided solids or liquids and often exist in colloidal state as aerosols eg. Smoke, fumes, dust, mist, fog, smog and sprays.

In addition, they may be natural or man-made.

Natural air pollutants: Gases such as CO2, CO, H2S, SO2 and NOx as well particulate matter, such as sand, dust are continuously released into the atmosphere through natural activities such as forest fires. Volcanic eruptions, decay of vegetation, winds and sand or dust storms.

Man-made air pollutants:CO2, NOx, SO2, CO, hydrocarbons and particulates are released into atmosphere through automobile exhaust, population explosion and industrial activities.

Pollutants classified into organic pollutants, inorganic pollutants according to chemical composition.

Organic pollutants: eg. Hydrocarbons, aldehyde, ketones, amines and alcohols

Inorganic pollutants: 1. Carbon compounds: eg. CO and carbonates
2. nitrogen compounds: eg. NOx and NH_3
3. Sulphur compounds: eg. H_2S, SO_2, SO_3 and H_2SO_4
4. halogen compounds: eg. HF, HCl and metallic fluorides
5. oxidising agents eg. O_3

Pollutants can be classified as either primary or secondary according to origin. Usually, primary pollutants are substances directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories.

Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone is one of the many secondary pollutants that causes photochemical smog.

(1) Major primary pollutants produced by human activity

i. Sulphur oxides (SOx):

SO2 is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulphur compounds, their combustion generates sulphur dioxide. Further oxidation of SO2, usually in the presence of a catalyst such as NO2, forms H2SO4, and thus acid rain. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.

ii. Nitrogen oxides (NOx):

Especially nitrogen dioxide is emitted from high temperature combustion. Nitrogen dioxide is the chemical compound with the formula N02. It is responsible for photochemical smog, acid rain etc.

iii. Carbon monoxide:

It is a colourless, odourless, non-irritating but very poisonous gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.

iv. Carbon dioxide (CO2):

A greenhouse gas emitted from combustion but is also a gas vital to living organisms. It is a natural gas in the atmosphere.

v. **Volatile organic compounds:**

VOCs are an important outdoor air pollutant. In this field they are often divided into the separate categories of methane (CH4) and non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming.

Other hydrocarbon VOCs are also significant greenhouse gases via their role in creating ozone and in prolonging the life of methane in the atmosphere, although the effect varies depending on local air quality. Within the NMVOCs, the aromatic compounds benzene, toluene and xylene are suspected carcinogens and may lead to leukaemia through prolonged exposure. 1, 3-butadiene is another dangerous compound which is often associated with industrial uses.

vi. Particulate matter:

Particulates alternatively referred to as particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to particles and the gas together. Sources of particulate matter can be manmade or natural.

Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols.

Averaged over the globe, anthropogenic aerosols—those made by human activities—currently account for about 10 per cent of the total amount of aerosols in our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

vii. Persistent free radicals – connected to airborne fine particles could cause cardiopulmonary disease.

viii. Toxic metals – such as lead, cadmium and copper.

ix. Chlorofluorocarbons (CFCs) – harmful to the ozone layer emitted from products currently banned from use.

x. Ammonia (NH_3) – emitted from agricultural processes. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odour. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.

xi. Odours – such as from garbage, sewage, and industrial processes

xii. Radioactive pollutants – produced by nuclear explosions, war explosives, and natural processes such as the radioactive decay of radon.

Sources of Air Pollution

Sources of air pollution refer to the various locations, activities or factors which are responsible for the releasing of pollutants in the atmosphere. These sources can be classified into two major categories which are:

1.Anthropogenic sources (human activity)

It mostly related to burning different kinds of fuel:

i. “Stationary Sources” include smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices.

ii. “Mobile Sources” include motor vehicles, marine vessels, aircraft and the effect of sound etc.

iii. Chemicals, dust and controlled burn practices in agriculture and forestry management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.

iv. Fumes from paint, hair spray, varnish, aerosol sprays and other solvents.

v. Waste deposition in landfills, which generate methane. Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiate and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement.

v. Military, such as nuclear weapons, toxic gases, germ warfare and rocketry.

2.Natural sources:

i. Dust from natural sources, usually large areas of land with little or no vegetation.

ii. Methane, emitted by the digestion of food by animals, for example cattle.

iii. Radon gas from radioactive decay within the Earth's crust. Radon is a colourless, odourless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.

iv. Smoke and carbon monoxide from wildfires.

v. Volcanic activity, which produce sulphur, chlorine, and ash particulates.

Effects and fate of Air Pollutants:

There are Various Harmful Effects of the air Pollutants:

i. Carbon monoxide (source- Automobile exhaust, photochemical reactions in the atmosphere, biological oxidation by marine organisms, etc.)- Affects the respiratory activity as haemoglobin has more affinity for CO than for oxygen. Thus, CO combines with HB and thus reduces the oxygen-carrying capacity of blood. This results in blurred vision, headache, unconsciousness and death due to asphyxiation (lack of oxygen).

ii. Carbon di oxide (source- Carbon burning of fossil fuels, depletion of forests (that remove excess carbon dioxide and help in maintaining the oxygen-carbon dioxide ratio) – causes global warming.

iii. Sulphur dioxide (source- Industries, burning of fossil fuels, forest fires, electric generation plants, smelting plants, industrial boilers, petroleum refineries and volcanic eruptions)- Respiratory problems, severe headache, reduced productivity of plants, yellowing and reduced storage time for paper, yellowing and damage to limestone and marble, damage to leather, increased rate of corrosion of iron, steel, zinc and aluminium.

iv. Hydrocarbons Poly-nuclear Aromatic Compounds(PAC) and Poly-nuclear Aromatic Hydrocarbons(PAH) (source- Automobile exhaust and industries, leaking fuel tanks, leaching from toxic waste dumping sites and coal tar lining of some water supply pipes)- Carcinogenic (may cause leukaemia).

v. Chloro-fluoro carbons (CFCs) (source- Refrigerators, air conditioners, foam shaving cream, spray cans and cleaning solvents)- Destroy ozone layer which then permits harmful UV rays to enter the atmosphere. The ozone layer protects the earth from the ultraviolet rays sent down by the sun. If the ozone layer is depleted by human action, the effects on the planet could be catastrophic.

vi. Nitrogen Oxides (source- Automobile exhausts, burning of fossil fuels, forest fires, electric generation plants, smelting plants, industrial boilers, petroleum refineries and volcanic eruptions)- Forms photochemical smog, at higher concentrations causes leaf damage or affects the photosynthetic activities of plants and causes respiratory problems in mammals.

vii. Particulate matter Lead halides (lead pollution) (source- Combustion of leaded gasoline products) , Toxic effect in man.

viii. Asbestos particles (source- Mining activities) – Asbestosis – a cancerous disease of the lungs.

ix. Silicon dioxide (source- Stone cutting, pottery, glass manufacturing and cement industries) Silicosis, a cancerous disease.

x. Mercury (source- combustion of fossil fuel & plants)-brain & kidney damage.

Air pollutants affect plants by entering through stomata (leaf pores through which gases diffuse), destroy chlorophyll and affect photosynthesis. During the day time the stomata are wide open to facilitate photosynthesis. Air pollutants during day time affect plants by entering the leaf through these stomata more than night.

Pollutants also erode waxy coating of the leaves called cuticle. Cuticle prevents excessive water loss and damage from diseases, pests, drought and frost. Damage to leaf structure causes necrosis (dead areas of leaf), chlorosis (loss or reduction of chlorophyll causing yellowing of leaf) or epinasty (downward curling of leaf), and abscission (dropping of leaves).

Particulates deposited on leaves can form encrustations and plug the stomata and also reduce the availability of sunlight. The damage can result in death of the plant. S02 causes bleaching of leaves, chlorosis, injury and necrosis of leaves. N02 results in increased abscission and suppressed growth. O3 causes flecks on leaf surface, premature aging, necrosis and bleaching.

Peroxyacetyl nitrate (PAN) causes silvering of lower surface of leaf, damage to young and more sensitive leaves and suppressed growth. Fluorides cause necrosis of leaf-tip while ethylene results in epinasty, leaf abscission and dropping of flowers.

Meteorological aspects of Plume and stack dispersion:

Plume refers to the path and extent in the atmosphere of the gaseous effluents released from a source usually a stack (chimney). The behavior of a plume emitted from any stack depends on localized air stability. The Geometric forms of stack plumes are a function of the vertical temperature and wind profiles, vice versa, by looking at the plume one can state stability condition and dispersive capacity of atmosphere.

The behavior and dispersion of a plume entirely depend on the environmental lapse rate (ELR) influencing the flume behavior are the diurnal (seasonal) variations in the atmospheric stability and the long term variations which occur with change in seasons Effluents from town stacks are often injected to an effective height of several 100m aboveground because of the cumulative effects of buoyancy and velocity on plume rise other factors.

Plume behaviour

Six types of plume behavior are shown in the figure below; the spread of the plume is directly related to the vertical temperature gradient as shown in the figure.

1) Looping
2) Coning
3) Fanning
4) Lofting
5) Fumigation
6) Trapping

LOOPING:

It is a type of plume which has a wavy character. It occurs in a highly unstable atmosphere because of rapid mixing. The high degree of turbulence helps in dispersing the plume rapidly but high concentrations may occur close to the stack if the plume touches the ground.

CONING:

It is a type of plume which is shaped like a CONE. This takes place in a near neutral atmosphere, when the wind velocity is greater than 32 km/hr. However, the plume reaches the ground at greater distances than with loping.

FANNING:

It is a type of plume emitted under extreme inversion conditions. the plume under this condition will spread horizontally, but little if at all vertically. Therefore, the prediction of ground level concentration (SLC) is difficult here

LOFTING:

Lofting occurs when there is a strong lapse rate above a surface inversion. Under this condition, diffusion is rapid upwards, but downward diffusion does not penetrate the inversion layer under these conditions, emission will not reach surface.

FUMIGATION:

It is a phenomenon in which pollutants that are emitted into the atmosphere are brought rapidly to the ground level when the air destabilizes.

TRAPPING:

This refers to conditions where the plume is caught between inversions and can only diffuse within a limited vertical height. The lofting plume is most favorable air to minimizing air pollution. The fumigation and trapping plumes are very critical from the points of ground level pollutant concentrations

Stack dispersion models

There are five types of air pollution dispersion models, as well as some hybrids of the five types

- **Box model** — The box model is the simplest of the model types. It assumes the airshed (i.e., a given volume of atmospheric air in a geographical region) is in the shape of a box. It also assumes that the air pollutants inside the box are homogeneously distributed and uses that assumption to estimate the average pollutant concentrations anywhere within the airshed. Although useful, this model is very limited in its ability to accurately predict dispersion of air pollutants over an airshed because the assumption of homogeneous pollutant distribution is much too simple.
- **Gaussian model** — The Gaussian model is perhaps the oldest and perhaps the most commonly used model type. It assumes that the air pollutant dispersion has a Gaussian distribution, meaning that the pollutant distribution has a normal probability distribution. Gaussian models are most often used for predicting the dispersion of continuous, buoyant air pollution plumes originating from ground-level or elevated sources. Gaussian models may also be used for predicting the dispersion of non-continuous air pollution plumes (called puff models). The primary algorithm used in Gaussian modelling is the Generalized Dispersion Equation For a Continuous Point-Source Plume.
- **Lagrangian model** — a Lagrangian dispersion model mathematically follows pollution plume parcels (also called particles) as the parcels move in the atmosphere

and they model the motion of the parcels as a random walk process. The Lagrangian model then calculates the air pollution dispersion by computing the statistics of the trajectories of a large number of the pollution plume parcels. A Lagrangian model uses a moving frame of reference as the parcels move from their initial location. It is said that an observer of a Lagrangian model follows along with the plume.

- **Eulerian model** — a Eulerian dispersion model is similar to a Lagrangian model in that it also tracks the movement of a large number of pollution plume parcels as they move from their initial location. The most important difference between the two models is that the Eulerian model uses a fixed three-dimensional Cartesian grid as a frame of reference rather than a moving frame of reference. It is said that an observer of a Eulerian model watches the plume go by.
- **Dense gas model** — Dense gas models are models that simulate the dispersion of dense gas pollution plumes (i.e., pollution plumes that are heavier than air). The three most commonly used dense gas models are:
    - The DEGADIS model developed by Dr. Jerry Havens and Dr. Tom Spicer at the University of Arkansas under commission by the US Coast Guard and US EPA.
    - The SLAB model developed by the Lawrence Livermore National Laboratory funded by the US Department of Energy, the US Air Force and the American Petroleum Institute.
    - The HEGADAS model developed by Shell Oil's research division.

Meteorological factors affecting air pollution and its effects on air pollution

- Wind, speed and direction
- Temperature
- Atmospheric stability
- Mixing height
- Rainfall and precipitation
- Humidity
- Solar radiation
- Visibility

Wind, speed and direction

- It changes the concentration of pollutant near ground level.
- The pollutant gets diluted with high volume of atmospheric air.
- Gustiness determines the dilution of the pollutant with air.
- In plane area the wind speed decides the movement of pollutant.
- In hilly areas hills deflect the air flow.
- Wind speed can be measured by anemometer

Atmospheric Stability and inversion

- It is defined as the measure of atmospheric tendency to encourage the vertical motion.
- The degree of atmospheric stability is determined by temperature differences between the air parcel and the air surrounding in it.
- The rate at which the atmospheric temperature decreases with increase in altitude is known as lapse rate.
- When the negative lapse rate occurs, a dense cold air at the ground level is covered by warm air at higher level. This is inversion.
- Due to the temperature inversion the atmosphere is stable and mixing of air with pollutant takes place.

Mixing height

- It is the height above the earth surface to which pollutant will extend through the atmospheric turbulence.

Precipitation and Rainfall

- It exerts two-fold cleansing action on the pollutant.
- Rainfall accelerates the deposition of particulate matter on the ground.

Humidity

- The moisture content of the atmosphere affects the corrosive action of air pollutant and represents the potentiality for fog formation.

Solar Radiation

- It includes the chemical reaction between atmospheric air components and pollutants in air.
- The reaction depends upon the location.

Effects of meteorology on air pollution

- Solar radiation and temperature affect the quantity of pollutant by their influence on amount of space heating required.
- Sunshine is the reason for photochemical production of oxidant forming smog.
- The wind velocity, turbulence and stability affect the transport, dilution and dispersion of pollutant.
- The rainfall has a scavenging effect in washing out the particles in atmosphere.
- The humidity affects the pollutant concentration

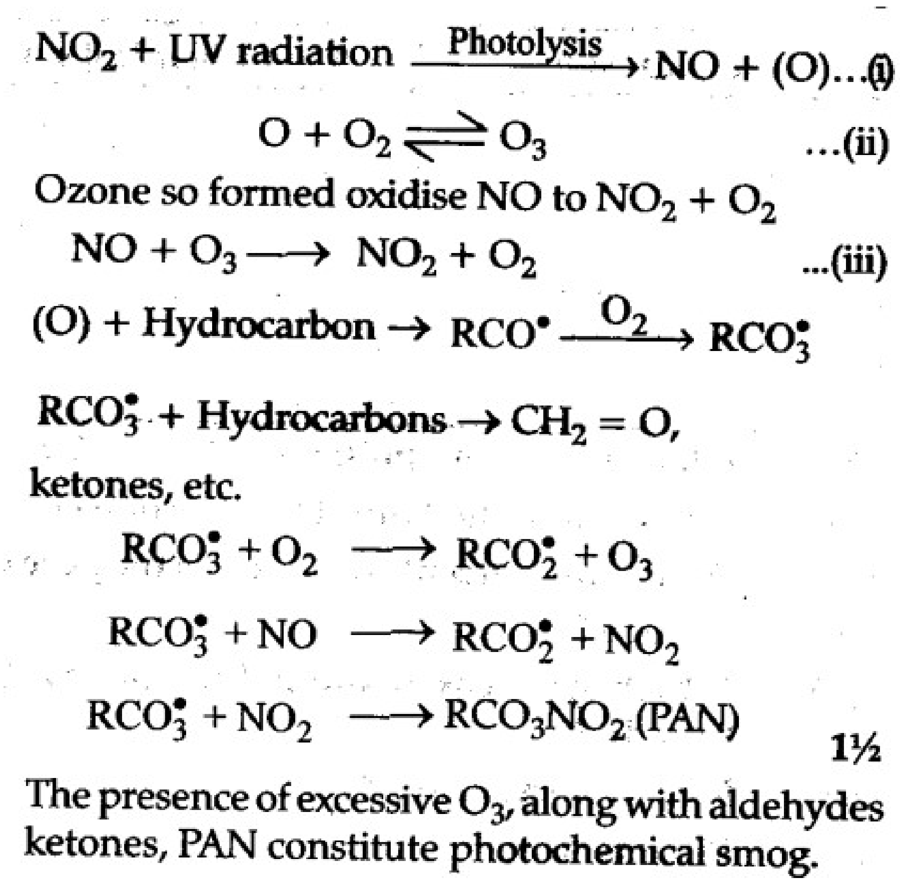
Chemical reactions of air pollution (Formation of fog and smog, acid rain):

Formation of smog

Photochemical smog is a type of air pollution that is formed when sunlight interacts with certain pollutants in the atmosphere. It is typically characterized by a hazy appearance in urban areas and can have harmful effects on human health and the environment. Photochemical smog is a complex mixture of pollutants, but its key components are ground-level ozone, nitrogen oxides, volatile organic compounds (VOCs), and other reactive organic gases.

Here is how photochemical smog is formed:

1. Emissions: The primary pollutants that contribute to the formation of photochemical smog are nitrogen oxides (NOx) and volatile organic compounds (VOCs). These pollutants are released into the atmosphere from sources such as vehicles, industrial processes, and the burning of fossil fuels.
2. Sunlight: When sunlight interacts with these primary pollutants, a series of complex chemical reactions occur in the atmosphere. Sunlight provides the energy needed to drive these reactions.
3. Formation of Ozone: One of the key components of photochemical smog is ozone (O3). Ozone is not directly emitted into the atmosphere but is formed as a result of reactions between NOx and VOCs in the presence of sunlight. These reactions can lead to the production of ozone at ground level, which is harmful to human health and the environment.
4. Secondary Pollutants: In addition to ozone, the reactions between NOx and VOCs can also produce other secondary pollutants such as peroxyacetyl nitrate (PAN) and aldehydes, which contribute to the overall composition of photochemical smog.
5. Health and Environmental Effects: Photochemical smog can have a range of harmful effects on human health, including respiratory problems, eye irritation, and aggravation of existing health conditions such as asthma. It can also have detrimental effects on crops, vegetation, and ecosystems.



NO_2 + UV radiation $\xrightarrow{\text{Photolysis}}$ NO + (O)...(i)

$$O + O_2 \rightleftharpoons O_3 \quad ...(ii)$$

Ozone so formed oxidise NO to $NO_2 + O_2$

$$NO + O_3 \longrightarrow NO_2 + O_2 \quad ...(iii)$$

$$(O) + \text{Hydrocarbon} \rightarrow RCO^{\bullet} \xrightarrow{O_2} RCO_3^{\bullet}$$

$RCO_3^{\bullet}$ + Hydrocarbons $\rightarrow CH_2 = O$,

ketones, etc.

$$RCO_3^{\bullet} + O_2 \longrightarrow RCO_2^{\bullet} + O_3$$

$$RCO_3^{\bullet} + NO \longrightarrow RCO_2^{\bullet} + NO_2$$

$$RCO_3^{\bullet} + NO_2 \longrightarrow RCO_3NO_2 \text{ (PAN)}$$

1½

The presence of excessive O_3, along with aldehydes ketones, PAN constitute photochemical smog.

Control:

(i) Efficient catalytic converters are being developed for fitting in the automobiles so that the emission of nitrogen oxides and hydrocarbons can be prevented.

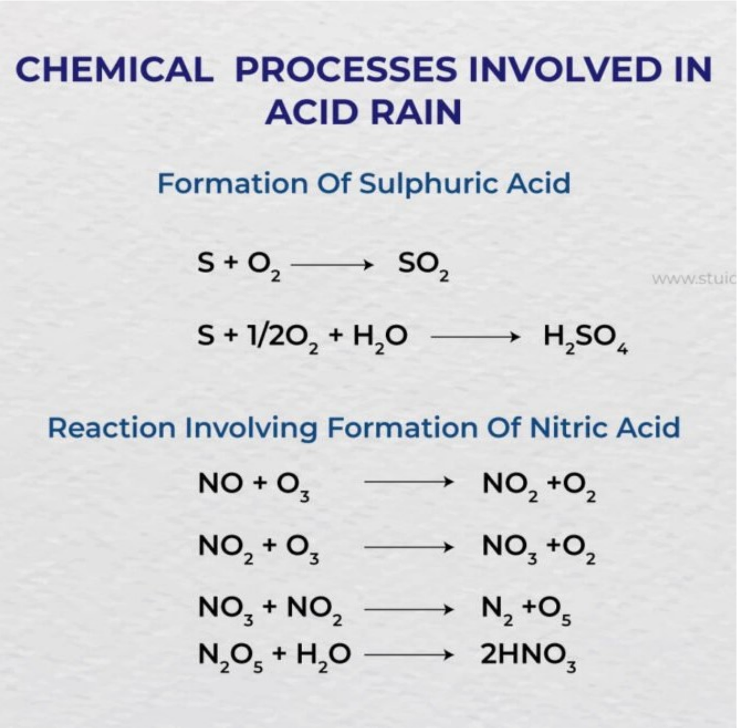
(ii) (ii) Certain chemical compounds are sprayed into atmosphere, which generate free radicals. These free radicals readily react with the free radicals responsible for the formation of photochemical smog and nullify their effect.

(iii) Toxic nature causes coughing, wheezing, bronchial constrictions and irritation to respiratory mucous system.

Formation of acid rain

Acid rain has an acidity of around 4, which is 1000 times more acidic than normal rain.

When humans burn fossil fuels, sulphur dioxide (SO2) and nitrogen oxides (NOx) are released into the atmosphere. Those air pollutants react with water, oxygen, and other substances to form airborne sulfuric and nitric acid.



CHEMICAL PROCESSES INVOLVED IN ACID RAIN

Formation Of Sulphuric Acid

$$S + O_2 \longrightarrow SO_2$$

$$S + 1/2O_2 + H_2O \longrightarrow H_2SO_4$$

Reaction Involving Formation Of Nitric Acid

$$NO + O_3 \longrightarrow NO_2 + O_2$$

$$NO_2 + O_3 \longrightarrow NO_3 + O_2$$

$$NO_3 + NO_2 \longrightarrow N_2 + O_5$$

$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

Effect on ecosystems

Acid rain adversely affects the life of aquatic organisms in environments such as streams, lakes, and marshes. At low pH, most of the fish eggs cannot hatch. At lower pH levels, some adult fish may die. Frogs have a critical pH of around 4. But the mayflies are much more sensitive and do not survive in a pH below 5.5.

Acid rain as it flows through the soil, can leach aluminum from clay particles and then flow into streams and lakes. This decreases the pH further and Al is harmful to both plants and animals. Acid rain also removes the necessary minerals and nutrients from the soil that is required for the trees to grow leaving them dead with brown leaves. It corrodes water pipes, making heavy metals to seep into drinking water.

Effect on human health

The emitted SO2 and NOX reacts in the atmosphere leading to minute sulfate and nitrate particles. Scientific studies have revealed that the inhalation of these particles adversely effects heart function, such as fatal heart attacks, increased heart diseases and increased lung infection involving breathing difficulties in people having asthma.

Effect on monuments and building

The Taj Mahal in Agra is one of the seven wonders in the world, a historical monument in pure white marble. The release of pollutants from the neighbouring Mathura Oil Refinery at

Agra and many other industries leads to acid rain and progressively corroded the Taj Mahal and leads in the discolouration of marble turning it yellowish.

Marble cancer is the term used for the deterioration of marble by acid rain.

The chemical reaction of acid rain with marble is:

$H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + H_2O + CO_2$

Ozone depletion - Montreal protocol;

Introduction

The earth's atmosphere is composed of many layers, each playing a significant role. The first layer stretching approximately 10 kilometers upwards from the earth's surface is known as the troposphere. A lot of human activities such as gas balloons, mountain climbing, and small aircraft flights take place within this region.

The stratosphere is the next layer above the troposphere stretching approximately 15 to 60 kilometers. The ozone layer sits in the lower region of the stratosphere from about 20-30 kilometers above the surface of the earth. The thickness of the ozone layer is about 3 to 5 mm, but it pretty much fluctuates depending on the season and geography.

Ozone layer is a deep layer in earth's atmosphere that contain ozone which is a naturally occurring molecule containing three oxygen atoms. These ozone molecules form a gaseous layer in the Earth's upper atmosphere called stratosphere. This lower region of stratosphere containing relatively higher concentration of ozone is called Ozonosphere. The Ozonosphere is found 15-35 km (9 to 22 miles) above the surface of the earth.

The concentration of ozone in the ozone layer is usually under 10 parts per million while the average concentration of ozone in the atmosphere is about 0.3 parts per million. The thickness of the ozone layer differs as per season and geography. The highest concentrations of ozone occur at altitudes from 26 to 28 km (16 to 17 miles) in the tropics and from 12 to 20 km (7 to 12 miles) towards the poles.

The ozone layer forms a thick layer in stratosphere, encircling the earth, that has large amount of ozone in it. The ozone layer protects life on earth from strong ultraviolet radiation that comes from the sun. Ultraviolet rays are harmful rays that can drive up the risk of deadly disorders like skin cancer, cataracts and damage the immune system. Ultraviolet rays are also capable of destroying single cell organism, terrestrial plant life, and aquatic ecosystems.

The ozone layer was discovered in 1913 by the French physicists Charles Fabry and Henri Buisson. The ozone layer has the capability to absorb almost 97-99% of the harmful ultraviolet radiations that sun emit and which can produce long term devastating effects on humans beings as well as plants and animals.

Composition of the Ozone Layer

It comes as a surprise that the same UV rays form the bulk of ozone layer. Ozone is an extraordinary kind of oxygen composed of 3 oxygen atoms instead of the normal 2 oxygen atoms. Ozone layer normally develops when a few kinds of electrical discharge or radiation splits the 2 atoms in an oxygen(O2) molecule, which then independently reunite with other types of molecules to form ozone. The ozone layer has been shielding life on planet earth for billions of years, but it's now being worn out by human activities.

People began to value the importance of the ozone layer when scientists released research finding suggesting that certain human-made chemicals known as chlorofluorocarbons managed to reach the stratosphere and depleted the ozone via a profound series of chemical reactions. The results of this research study prompted the signing of a global treaty known as the **Montreal Protocol in 1973**. This treaty helped in the reduction of the production of these harmful human-made chemicals.

Necessity of ozone layer

An essential property of ozone molecule is its ability to block solar radiations of wavelengths less than 290 nanometers from reaching Earth's surface. In this process, it also absorbs ultraviolet radiations that are dangerous for most living beings. UV radiation could injure or kill life on Earth. Though the absorption of UV radiations warms the stratosphere but it is important for life to flourish on planet Earth. Research scientists have anticipated disruption of susceptible terrestrial and aquatic ecosystems due to depletion of ozone layer.

Ultraviolet radiation could destroy the organic matter. Plants and plankton cannot thrive, both acts as food for land and sea animals, respectively. For humans, excessive exposure to ultraviolet radiation leads to higher risks of cancer (especially skin cancer) and cataracts. It is calculated that every 1 % decrease in ozone layer results in a 2-5 percent increase in the occurrence of skin cancer. Other ill-effects of the reduction of protective ozone layer include – increase in the incidence of cataracts, sunburns and suppression of the immune system.

Causes of Ozone Layer Depletion

Credible scientific studies have substantiated that the cause of ozone layer depletion is human activity, specifically, human-made chemicals that contain chlorine or bromine. These chemicals are widely known as ODS, an acronym for Ozone-Depleting Substances. The scientists have observed reduction in stratospheric ozone since early 1970's. It is found to be more prominent in Polar Regions.

Ozone-Depleting Substances have been proven to be eco-friendly, very stable and non-toxic in the atmosphere below. This is why they have gained popularity over the years. However, their stability comes at a price; they are able to float and remain static high up in the stratosphere. When up there, ODS are comfortably broken down by the strong UV light and the resultant chemical is chlorine and bromine. Chlorine and bromine are known to deplete the ozone layer at supersonic speeds. They do this by simply stripping off an atom from the ozone molecule. One chlorine molecule has the capability to break down thousands of ozone molecules.

Ozone-depleting substances have stayed and will continue to stay in the atmosphere for many years. This, essentially, implies that a lot of the ozone-depleting substances human have allowed to go into the atmosphere for the previous 90 years are still on their journey to the atmosphere, which is why they will contribute to ozone depletion.

The chief ozone-depleting substances include chlorofluorocarbons (CFCs), carbon tetrachloride, hydro chlorofluorocarbons (HCFCs) and methyl chloroform. Halons, sometimes known as brominated fluorocarbons, also contribute mightily to ozone depletion. However, their application is greatly restricted since they are utilized in specific fire extinguishers. The downside to halons is they are so potent that they are able to deplete the ozone layer 10 times more than ozone-depleting substances.

Scientists in this age are working around the clock to develop Hydro fluorocarbons (HFCs) to take the place of hydro chlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs) for use in vehicle air conditioning. Hydro chlorofluorocarbons are powerful greenhouse gases, but they are not able to deplete ozone. Chlorofluorocarbons, on the other hand, significantly contribute to climate change, which means Hydro fluorocarbons continue to be the better alternative until safer alternatives are available.

There are two regions in which the ozone layer has depleted.

- **In the mid-latitude**, for example, over Australia, ozone layer is thinned. This has led to an increase in the UV radiation reaching the earth. It is estimated that about 5-9% thickness of the ozone layer has decreased, increasing the risk of humans to over-exposure to UV radiation owing to outdoor lifestyle.
- **In atmospheric regions over Antarctica,** ozone layer is significantly thinned, especially in spring season. This has led to the formation of what is called ‘ozone hole’. Ozone holes refer to the regions of severely reduced ozone layers. Usually

ozone holes' form over the Poles during the onset of spring seasons. One of the largest such hole appears annually over Antarctica between September and November.

Natural causes of depletion of ozone layer:

Ozone layer has been found to be affected by certain natural phenomena such as Sun-spots and stratospheric winds. But this has been found to cause not more than 1-2% depletion of the ozone layer and the effects are also thought to be only temporary. It is also believed that the major volcanic eruptions

Man-made causes of depletion of ozone layer:

The main cause for the depletion of ozone is determined as excessive release of chlorine and bromine from man-made compounds such as chlorofluorocarbons (CFCs). CFCs (chlorofluorocarbons), halons, CH_3CCl_3 (Methyl chloroform), CCl_4 (Carbon tetrachloride), HCFCs (hydro-chlorofluorocarbons), hydrobromofluorocarbons and methyl bromide are found to have direct impact on the depletion of the ozone layer. These are categorized as ozone-depleting substances (ODS).

The problem with the Ozone-Depleting Substances (ODS) is that they are not washed back in the form of rain on the earth and in-fact remain in the atmosphere for quite a long time. With so much stability, they are transported into the stratosphere. The emission of ODS account for roughly 90% of total depletion of ozone layer in stratosphere. These gases are carried to the stratosphere layer of atmosphere where ultraviolet radiations from the sun break them to release chlorine (from CFCs) and bromine (from methyl bromide and halons).

The chlorine and bromine free radicals react with ozone molecule and destroy their molecular structure, thus depleting the ozone layer. One chlorine atom can break more than 1, 00,000 molecules of ozone. Bromine atom is believed to be 40 times more destructive than chlorine molecules.

Main Ozone Depleting Substances (ODS)

1. **Chlorofluorocarbons (CFCs)**

It's billed as the most extensively utilized ozone-depleting substance because it attributes to more than 80% of overall ozone depletion. It was utilized as a coolant in home appliances like freezers, refrigerators and air conditioners in both buildings and cars that were manufactured prior to 1995. This substance is usually contained in dry cleaning agents, hospital sterility, and industrial solvents. The substance is also utilized in foam products like mattresses and cushions and home insulation.

2. Hydrofluorocarbons (HCFCs)

Hydrofluorocarbons have over the years served in place of Chlorofluorocarbons. They are not as harmful as CFCs to ozone layer.

3. Halons

It's especially used in selected fire extinguishers in scenarios where the equipment or material could be devastated by water or extinguisher chemicals.

4. Carbon Tetrachloride

Used in selected fire extinguishers and solvents.

5. Methyl Chloroform

Commonly utilized in industries for cold cleaning, vapor degreasing, chemical processing, adhesives and some aerosols.

Solutions to ozone depletion or prevent to ozone depletion

1. Desist from using pesticides

Pesticides are great chemicals to rid your farm of pests and weeds, but they contribute enormously to ozone layer depletion. The surefire solution to get rid of pests and weeds is to apply natural methods. Just weed your farm manually and use alternative eco-friendly chemicals to alleviate pests.

2. Discourage driving of private vehicles

The easiest technique to minimize ozone depletion is to limit the number of vehicles on the road. These vehicles emit a lot of greenhouse gases that eventually form smog, a catalyst in the depletion of ozone layer.

3. Utilize environmentally friendly cleaning products

Most household cleaning products are loaded with harsh chemicals that find way to the atmosphere, eventually contributing to degradation of the ozone layer. Use natural and environmentally friendly cleaning products to arrest this situation.

4. Prohibit the use of harmful nitrous oxide

The Montreal Protocol formed in 1989 helped a lot in the limitation of Chlorofluorocarbons (CFCs). However, the protocol never covered nitrous oxide, which is a known harmful chemical that can destroy the ozone layer. Nitrous oxide is still in use today. Governments must take action now and outlaw nitrous oxide use to reduce the rate of ozone depletion.

Effect of ozone depletion

1. Effects on Human Health

Ozone layer depletion increases the amount of UVB that reaches the Earth's surface. Laboratory and epidemiological studies demonstrate that UVB causes non-melanoma skin cancer and plays a major role in malignant melanoma development. In addition, UVB has been linked to the development of cataracts, a clouding of the eye's lens.Because all sunlight contains some UVB, even with normal stratospheric ozone levels, it is always important to protect your skin and eyes from the sun. See a more detailed explanation of health effects linked to UVB exposure.

EPA uses the Atmospheric and Health Effects Framework model to estimate the health benefits of stronger ozone layer protection under the Montreal Protocol. Updated information on the benefits of EPA's efforts to address ozone layer depletion is available in a 2015 report, Updating Ozone Calculations and Emissions Profiles for Use in the Atmospheric and Health Effects Framework Model.

2. Effects on Plants

UVB radiation affects the physiological and developmental processes of plants. Despite mechanisms to reduce or repair these effects and an ability to adapt to increased levels of UVB, plant growth can be directly affected by UVB radiation.

Indirect changes caused by UVB (such as changes in plant form, how nutrients are distributed within the plant, timing of developmental phases and secondary metabolism) may be equally or sometimes more important than damaging effects of UVB. These changes can have important implications for plant competitive balance, herbivory, plant diseases, and biogeochemical cycles.

3. Effects on Marine Ecosystems

Phytoplankton form the foundation of aquatic food webs. Phytoplankton productivity is limited to the euphotic zone, the upper layer of the water column in which there is sufficient sunlight to support net productivity. Exposure to solar UVB radiation has been shown to affect both orientation and motility in phytoplankton, resulting in reduced survival rates for these organisms. Scientists have demonstrated a direct reduction in phytoplankton production due to ozone depletion-related increases in UVB.

UVB radiation has been found to cause damage to early developmental stages of fish, shrimp, crab, amphibians, and other marine animals. The most severe effects are decreased reproductive capacity and impaired larval development. Small increases in

UVB exposure could result in population reductions for small marine organisms with implications for the whole marine food chain.

4. Effects on Biogeochemical Cycles

Increases in UVB radiation could affect terrestrial and aquatic biogeochemical cycles, thus altering both sources and sinks of greenhouse and chemically important trace gases (e.g., carbon dioxide, carbon monoxide, carbonyl sulfide, ozone, and possibly other gases). These potential changes would contribute to biosphere-atmosphere feedbacks that mitigate or amplify the atmospheric concentrations of these gases.

5. Effects on Materials

Synthetic polymers, naturally occurring biopolymers, as well as some other materials of commercial interest are adversely affected by UVB radiation. Today's materials are somewhat protected from UVB by special additives. Yet, increases in UVB levels will accelerate their breakdown, limiting the length of time for which they are useful outdoors.

6. Climate effects

The depletion of the ozone hole has also caused an overall cooling trend on the Antarctic continent; this has masked to some extent the effects of warming temperatures, particularly on the larger part of East Antarctica and areas away from the peninsula region.

The loss of ozone has also led to increased winds and storms, both in frequency and strength. Winds in the Southern Ocean have been estimated to have increased by 15-20%. It has caused a low-pressure system to form in the Amundsen Sea again both with increased frequency and strength. This low pressure sucks cold air from the interior of Antarctic and across the Ross Sea leading to a great increase in the amount of sea-ice forming in this area in recent years.

Global warming - Kyoto protocol.

When we burn organic materials (i.e. carbon-containing) fuels, or organic matter decomposes, carbon dioxide is released into the air. It is transparent to incoming solar radiation, but opaque to some wavelengths of heat radiated from the warmed surface of the Earth, and so traps heat, leading eventually to a warming of the lower atmosphere” This is known as the greenhouse effect, as in principle, the atmosphere behaves in a similar manner to a garden greenhouse, it allows sunlight to penetrate, but heat is trapped within the atmosphere in the same way that it is trapped within the glass walls of a greenhouse. This trapped hot air is causing the earth to heat up, resulting in global warming, and ultimately climate change.

Greenhouse gases include naturally occurring gases, such as carbon dioxide, methane, and even water vapor.

Greenhouse Gases

Our planets contain many gases which surface a layer and prevent unwanted radiations to reach the surface. These gases are in certain proportions breaking which, the components get disturbed. The greenhouse gas absorbs and emits these radiations within the range which ultimately causes the greenhouse effect. The common greenhouse gases in Earth’s atmosphere are:

1. Water vapor (H2O)
2. Carbon dioxide (CO2)
3. Methane (CH4)
4. Nitrous oxide (N2O)
5. Ozone (O3)
6. Chlorofluorocarbons (CFCs)

Carbon dioxide, methane, nitrous oxide and the fluorinated gases are all well-mixed gases in the atmosphere that do not react to changes in temperature and air pressure, so the levels of these gases are not affected by condensation. Water vapor on the other hand, is a highly active component of the climate system that responds rapidly to changes in conditions by either condensing into rain or snow, or evaporating to return to the atmosphere.

Carbon dioxide and the other non-condensing greenhouse gases are the key gases within the Earth's atmosphere that sustain the greenhouse effect and control its strength. Water vapor is a fast-acting feedback but its atmospheric concentration is controlled by the radiative forcing supplied by the non-condensing greenhouse gases.

Causes of Global warming

With the coming of Industrial revolutions, the use of chemicals and fuel in the factories has increased to a dangerous amount. Along with it, deforestation due to industrial or economic purposes and the excess burning of fossil fuels like natural gas, oil, and coal, has increased the concentration of atmospheric carbon dioxide from 315 ppm (part per million by volume) to about 363 ppm since 1958. These are some of the primary reasons for which the heat gets trapped in the atmosphere thus causing global warming.

The greenhouse effect is caused by the interaction of the sun's energy with greenhouse gases such as carbon dioxide, methane, nitrous oxide and fluorinated gases in the Earth's atmosphere. The ability of these gases to trap heat is what causes the greenhouse effect.

Greenhouse gases are made of three or more atoms. This molecular structure makes it possible for these gases to trap heat in the atmosphere and then re-emit it towards the surface which further warms the Earth. This continuous cycle of trapping heat leads to an overall increase in global temperatures. This process, which is very similar to the way a greenhouse works, is why the gases that can produce this effect are collectively known as greenhouse gases.

Consequences of Global warming

- Warmer climate: On average, the Earth’s temperature will become warmer than earlier, while some places will get warm while others may not
- The rise of sea level: Due to global warming, the glaciers and ice sheets of Greenland and Atlantic will melt which will add water to the sea level, thus causing many disasters like Tsunami. A rise in sea level will also have an economic impact especially on the low-lying coastal areas and islands causing unavoidable soil erosion.
- Agricultural impact: According to multiple experiments, with the high concentration of CO2 in the atmosphere, the growth of crops is twice than the normal growth. At the same time, the shifting of the climatic pattern may change the areas where crops grow faster and better thus affecting the normal amount of agricultural production.
- Environmental effect; The greenhouse effect is a major factor in keeping the Earth warmer because it keeps some of the planet's heat that would otherwise escape from the atmosphere out to space. In fact, without the greenhouse effect the Earth's average global temperature would be much colder and life on Earth would not be possible.

Control of global Warming

- More fuel-efficient cars, less frivolous driving, more use of mass transit, improved insulation to decrease the fuel burned to heat and cool our homes, more efficient appliances, use of fluorescent rather than incandescent light bulbs, and careful monitoring of home electricity usage (turn off the lights and TV when not using them) can reduce our energy needs.

- Conversion to alternatives like wind and solar power which don't burn fossil fuels and emit CO2 into the atmosphere.
- Planting large areas with trees will consume CO2 as the trees grow, until the forests mature.
- Stopping deforestation in the tropical forests around the world, especially in the Amazon and Indonesian rain forests, will keep that carbon in the forest rather than sending it back into the atmosphere as the trees are burned or decay and are not replaced by more.
- Other techniques have also been proposed such as the chemical removal of CO2 from smokestacks and burial in deep underground reservoirs, though only certain areas can benefit from this, or disposal in the deep ocean where they will form a semi-stable compound under the cold temperatures and high pressures, though the CO2 could too easily come bubbling back up. These latter solutions are not well studied and wouldn't be especially cheap.
- Moreover, leaders, societies, communities, local planners, farmers, health organizations, need to recognize the changing climate and rising sea level as they make plans for the future. Our citizens need to be educated as to likely changes and how best to deal with the changing conditions.

Air quality standards:

The objectives of air quality standards are:

- To indicate the levels of air quality necessary with an adequate margin of safety to protect the public health, vegetation and property;
- To assist in establishing priorities for abatement and control of pollutant level;
- To provide uniform yardstick for assessing air quality at national level;
- To indicate the need and extent of monitoring programme.

In order to combat air pollution, it is required to identify the pollutants, its source of emission and investigate the effects of living and the environment. The Central Pollution Control Board has notified the revised National Ambient Air Quality Standards Gazette of India, Extra-ordinary Part-II Section 3, sub section (ii), dated Nov 18, 2009.

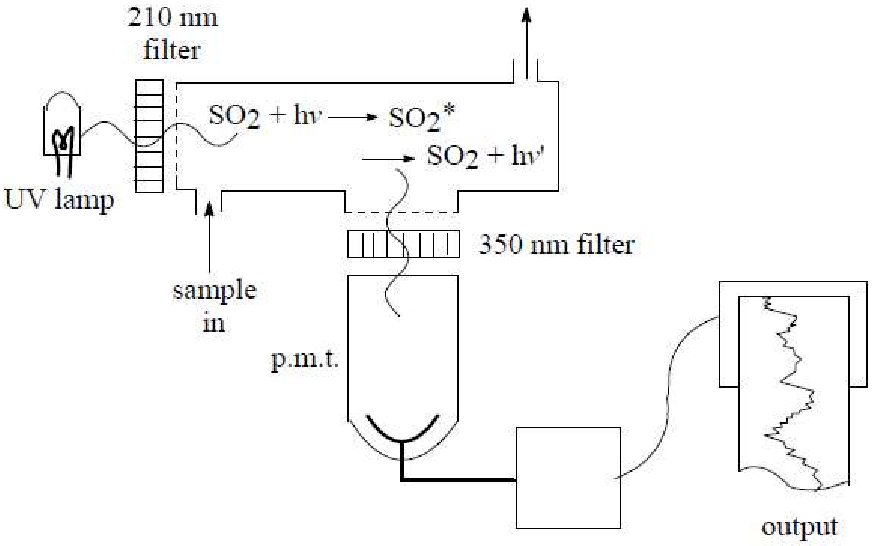
Pollutants	Time weighted average	Industrial, residential, rural and other areas	Ecologically sensitive area (notified by central government)	Methods of Measurement
Sulphur dioxide (SO_2), µg/m^3	Annual*	50	20	Improved West and Gaeke Method
	24 hours**	80	80	Ultraviolet Fluorescence
Nitrogen dioxide (NO_2), µg/m^3	Annual*	40	30	Jacob & Hochheiser modified (NaOH-$NaAsO_2$) method
	24 hours**	80	80	Gas Phase Chemiluminescence
Particulate matter (size less than 10 µm) or PM_{10}, µg/m^3	Annual*	60	60	Gravimetric
	24 hours**	100	100	TEOM
				Beta attenuation
Particulate matter (size less than 2.5 µm) or $PM_{2.5}$, µg/m^3	Annual*	40	40	Gravimetric
	24 hours**	60	60	TEOM
				Beta attenuation
Ozone (O^3) µg/m^3	8 hours*	100	100	UV Photometric
	1 hour**	180	180	Chemiluminescence
				Chemical Method
Lead (Pb) µg/m^3	Annual*	0.5	0.5	AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper
	24 hours**	1	1	ED-XRF using Teflon filter
Carbon Monoxide (CO) µg/m^3	8 hours**	2	2	Non dispersive Infrared (NDIR) Spectroscopy
	1 hour**	4	4	
Ammonia (NH3), µg/m^3	Annual*	100	100	Chemiluminescence
	24 hours**	400	400	Indophenol blue method
Benzene (C_6H_6), µg/m^3	Annual*	5	5	Gas chromatography (GC) based continuous analyser
				Adsorption and desorption followed by GC analysis
Benzo(a) Pyrene (BaP) particulate phase only, ng/m^3	Annual*	1	1	Solvent extraction followed by HPLC/GC analysis
Arsenic (As), ng/m^3	Annual*	6	6	AAS/ICP Method after sampling on EPM 2000 or equivalent paper
Nickel (Ni), ng/m^3	Annual*	20	20	AAS/ICP Method after sampling on EPM 2000 or equivalent paper

2. Monitoring of air pollution

Ultraviolet Fluorescence Analyzer for SO2 Measurement

SO2 concentration is measured by the ultraviolet fluorescence method, where the analysed sample is exposed to UV-lamp irradiation with energetic excitation of SO2 molecule. With the backward conversion of the molecule into the basic energetic level, energy as fluorescing radiation is released. This radiation is proportional to the sulfur dioxide concentration and is detected by a photomultiplier.

A typical layout of a fluorescence analyzer is given below; a UV lamp provides a source of radiation, either continuous or pulsed, which is filtered to admit a narrow band of light into the cell, centred at about 210 nm. The fluorescent radiation is measured at right angles to the incident beam, using a photomultiplier.

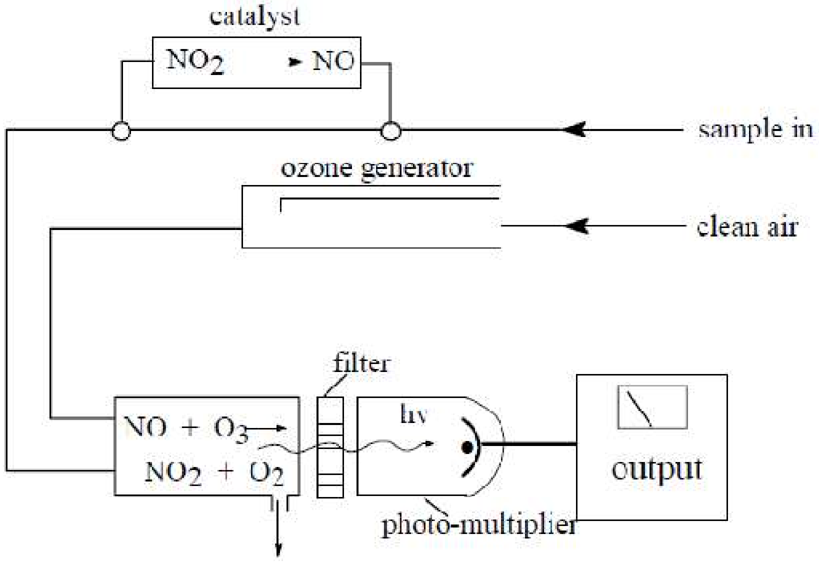


Chemiluminescence Analyzer for NOx Measurement

NOx concentration is measured by a chemiluminescence analyzer for the NO, NO2 and NOx concentration measurement. The principle of this method stands on the nitrogen molecule excitation by ozone. With the conversion of the molecule into the basic energetic level, liberation of radiation as chemiluminescence occurs. This radiation is detected by a photomultiplier. The analyzer design makes possible the acquirement of information on nitrogen monoxide (NO), nitrogen dioxide (NO2) and nitrogen oxides (NOx) concentrations. The reaction between NO and O3 is an example:

$NO + O_3 \rightarrow NO_2^* + O_2$

$NO_2^* \rightarrow NO_2 + h\nu$



A typical layout of a chemiluminescence analyser for NOx. Ozone is generated by the UV irradiation of clean air and mixed in a reaction chamber with the sample air. Light from the reaction passes through an optical filter and is detected with a photomultiplier tube. Clearly, NO2 in the sample will not be detected in this system. However, this can be reduced to NO by means of a heated catalyst, such as a stainless steel or molybdenum. If this is included in the system the instrument can respond to NO and NO2, i.e. NOx.

Suspended Particulate Monitoring (SPM) Methods

The term ’suspended particulate matter’ refers to particles which can remain suspended in air for significant periods of time, ranging from a few minutes for the larger particles through to several days for very fine material.

Air Sampler

Traditionally SPM is measured by sucking air through a filter and determining the weight of dust collected. The equipment used is known as a High-Volume Air Sampler (at high flow rates (typically 1.13 m3/min or 40 ft3 /min). Air is drawn into the sampler and through a glass fiber or quartz filter by means of a blower, so that particulate material collects on the filter surface. Without a size-selective inlet, particles of 100 µm size and less enter the sampling inlet and are collected on the downstream filter. The results are referred to as total suspended particulate (TSP). The collection efficiencies for particles larger than 20 µm decreases with increasing particle size, and it varies widely with the angle of the wind with respect to the roof ridge of the sampler shelter. When glass fiber filters are used, particles 100-0.1 µm or less in diameters are ordinarily collected. With a size-select inlet, PM10, PM2.5 or PM1 are collected on the quartz filter. The volume of air sampled is determined by a flow-rate indicator. The high-volume sampler is a compact unit consisting of a protective housing; an electric motor driven; a high-speed, high-volume blower; a filter holder; and a flow-controller for controlling the air-flow rate through the instrument. Air is drawn through a pre-weighed filter at a known rate, which collects any particles on the surface. The filter is weighed again to determine the mass of particles collected, and by dividing the mass by the total volume of air, we can calculate the concentration of the particles.

$$TSP = \frac{(W_f - W_i)\ \times\ 10^6}{V}$$

Where:

TSP = mass concentration of total suspended particulate matter in □g/m3,

Wi = initial weight of clean filter, in gram

Wf = final weight of exposed filter, in gram

V = air volume sampled, in m3, V = Qxt, Q = average sample flow rate at ambient temperature and pressure in m3/min, t = sampling time in minutes

10^6 = conversion of g to µg

For PM2.5 and PM10 concentration measurement the radiometric method is also used. It stands on beta-ray absorption in a sample captured on filtering material. The difference between the beta-ray absorption of the exposed and non-exposed filtering material, which is proportional to the mass of the captured suspended particle matter, gives the information on its concentration.

The suspended particulate matter continual monitoring is also carried out using the tapered element oscillating microbalance (TEOM). It measures the mass of the sample captured on a replaceable filter according to the oscillating tapered element frequency variation. The air sample passes through a filter where the dust particles are captured and runs through a hollow tapered element to a vacuum pump with an electronic flow control.

Carbon monoxide Measurement

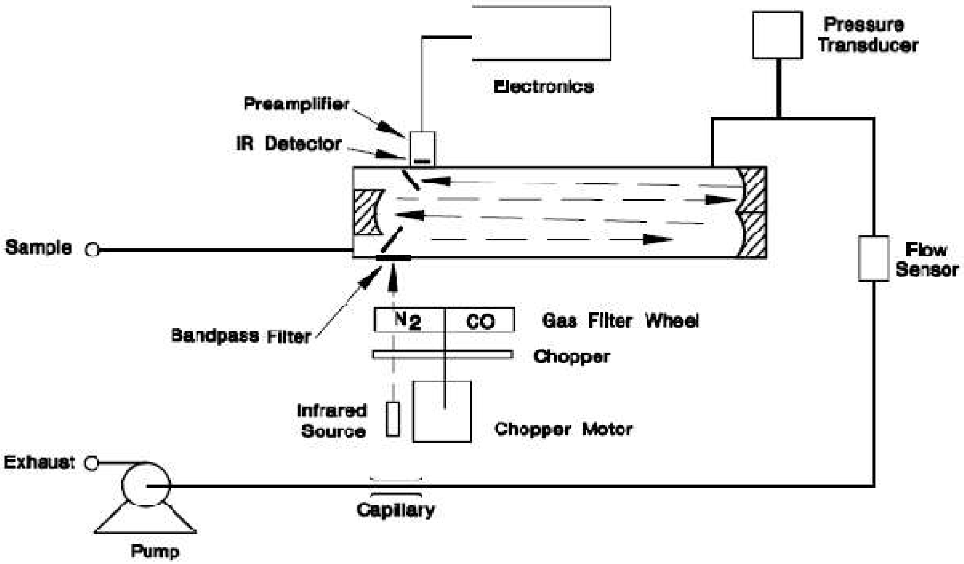
CO concentration is measured by the method of NDIR Gas-Filter Correlation (GFC) Spectroscopy or Gas Chromatography-Flame Ionization.

Gas-Filter Correlation (GFC) Spectroscopy

Carbon monoxide has a characteristic infrared absorption near 4.6 µm. The absorption of infrared radiation by the CO molecule therefore can be used to measure CO concentration in the presence of other gases. The NDIR method is based on this principle. Nondispersive infrared systems have several advantages. They are not sensitive to flow rate, they require no wet chemicals, they are reasonably independent of ambient air temperature changes, they are sensitive over wide concentration ranges, and they have short response times. Further, NDIR systems may be operated by nontechnical personnel.

Because infrared absorption is a non-linear measurement technique, it is necessary to transform the basic analyzer signal into a linear output. The sample is drawn into through the Sample bulkhead, as shown in Figure. The sample flows through the optical bench. Radiation from an infrared source is chopped and then passed through a gas filter alternating between CO and N2. The radiation then passes through a narrow bandpass interference filter and enters the optical bench where absorption by the sample gas occurs. The infrared radiation then exits the optical bench and falls on an infrared detector.

The CO gas filter acts to produce a reference beam that cannot be further attenuated by CO in the sample cell. The N2 side of the filter wheel is transparent to the infrared radiation and therefore produces a measure beam that can be absorbed by CO in the cell. The chopped detector signal is modulated by the alternation between the two gas filters with an amplitude related to the concentration of CO in the sample cell. Other gases do not cause modulation of the detector signal, since they absorb the reference and measure beams equally. Thus, the GFC system responds specifically to CO concentrations.



Stack monitoring PM 10 and PM 2.5:

Terms related to particulate matter:

Airborne particulate matter - this includes both organic and inorganic substances with diameters ranging from 0.001 to 100 µm.

Primary particulate matter - these are emitted directly to atmosphere. They tend not to change form once in the atmosphere. They can be from stack emissions but may also be from re-suspended soils and road dust.

Secondary particulate matter - these are formed in the atmosphere, usually as a result of chemical reactions, such as the oxidation of SO2 and NO2 in the presence of other pollutants.

Coarse particulate matter - particles between 2 to 100 µm in diameter.

Fine particulate matter - particles with a diameter of less than 2 µm. Fine particles below 1 µm travel deep into the alveoli region of the lung and may deposit on tissue or enter the bloodstream.

Ultra-fine particulate matter - particles with a diameter of less than 0.1 µm. In general, finer particles are considered to have a greater toxicity per unit mass than coarser particles, as such ultra-fines are of significant interest in terms of health effects.

PM10, PM2.5 - particles with a diameter of less than 10 and 2.5 µm. In stack emission measurements these are the particles which pass through a size-selective inlet with a 50% efficiency cut-off at 10 and 2.5 µm aerodynamic diameters respectively.

PM1 - particles with a diameter of less than 1µm.

Sources of PM10 and PM2.5

- the combustion of coal, oil, gasoline/petrol, diesel, wood, biomass;
- the atmospheric transformation products of SO2, NOx, ammonia and organiccompounds; including biogenic organic species such as terpines;
- high temperature industrial processes, such as smelters and steel mills;
- natural sources including spores, viruses and dust from naturally dry areas;
- re-entrainment of particulate matter through agricultural activities and from road dust.

Composition of PM:

The composition of particulate matter is highly variable and may include substances such assulphates, nitrates, hydrogen ions, ammonium, elemental carbon, silica, alumina, organiccompounds, trace elements, trace metals, particle bound water and biogenic organic species. The mixture will vary with source type, location and weather conditions, such as temperature and wind direction.

Cleaner technologies:

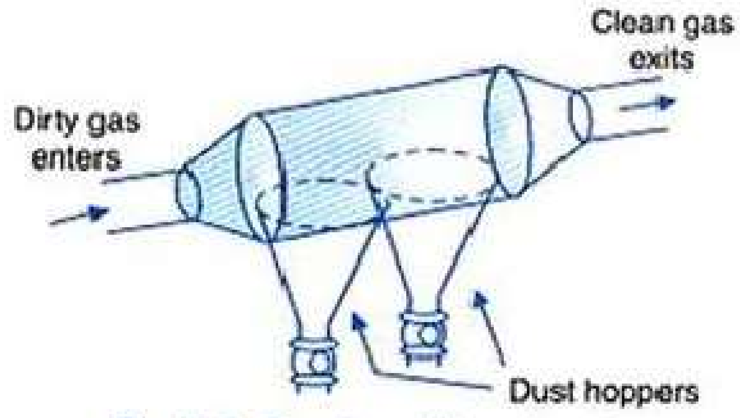
Control of particulate pollutants

Settling chamber:

- Oldest and simple method used for collection of solid particles
- Used to remove large abrasive particles from gas stream
- Collection efficiency for particles >50µm

Principle:

- As the air is passed through the chambers at a low velocity, the dust particles settle by gravity and the clear air comes out.
- PM collected at the bottom of the chamber (dust hopper)
- The usual velocity through settling chamber is between 0.5 2.5m/s



Advantages

- Low initial cost
- Simple construction
- Low maintenance cost
- Use any material for construction
- Pollutant collected in dry state

Disadvantages

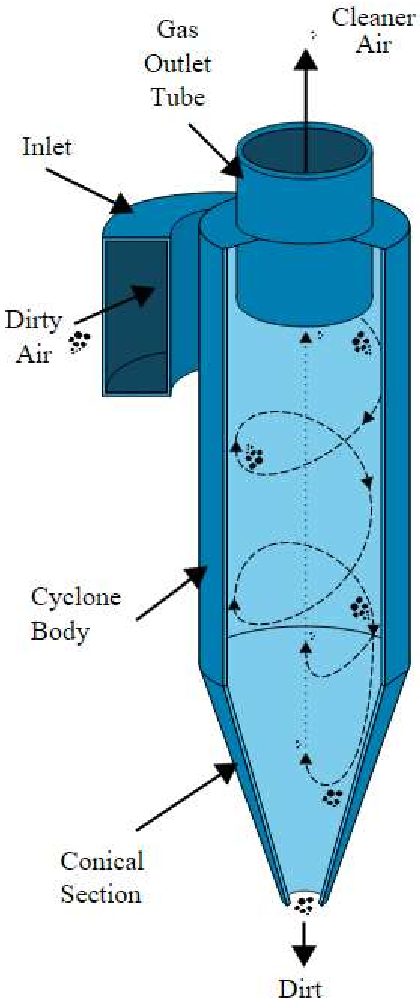
- Low collection efficiency
- Unable to handle sticky materials
- only comparatively large particles (greater than 50 micron) can be collected.
- Required large space

Cyclones separators:

- Cyclone use centrifugal forces for remove the fine particles
- It is also called centrifugal separators or inertial separators.
- Ideal for separation of dust particles with sizes 15 50µm.
- Cannot settle particles less than 10 µm size
- It is consisting of vertically placed cylinder with an inverted cone attached to its base

Principle of gravity settlement:

- As the air enters the cylinder, it takes a helical path downwards.
- Due to rapid spiralling movement of the air particles are thrown towards the walls by centrifugal force.
- The dust particles settle down in the hopper at the bottom, while the dust free air passes through a pipe and comes out.



The advantages of cyclones are:

i) low initial

ii) simple in construction and operation,

iii) low pressure drops,

iv) low maintenance requirements,

v) v) continuous disposal of solid particulate matter, and

vi) vi) use of any material in their construction that can withstand the temperature and pressure requirements.

The disadvantages of cyclones include:

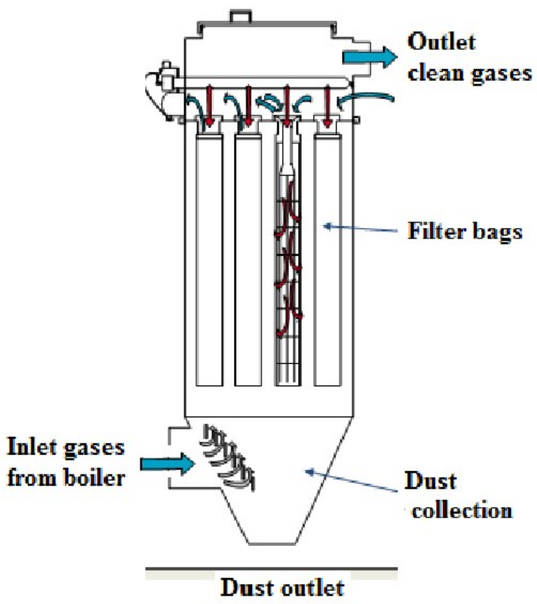
i) low collection efficiency for particles below 5 10 μm in diameter,

ii) severe abrasion problems can occur during the striking of particles on the walls of the cyclone, and

iii) a decrease in efficiency at low particulate concentration.

Fabric filter:

- Fabric filters are the most efficient and can separate particles with size less than 0.5 µ m in diameter.
- Fibrous medium like mats of wool cellulose as separator.
- As the air or gas is allowed to pass through a woven Fabric, the dust is trapped while the gas passes out, which filters outParticulate matter.
- Small particles are retained on the fabric.
- Collection of dust on the fabric filter results in formation ofdust layer (filter cake).
- Bag 120 400 mm in diameter, 2 4 m long.
- Hopper at the bottom to collect dust particles
- Remove particles up to 1 µm.
- Its efficiency up to 99%.



Advantages

- Higher collection efficiency for smaller than 10 µm particle size.
- Performance decrease becomes visible, giving prewarning
- Normal power consumption**.**

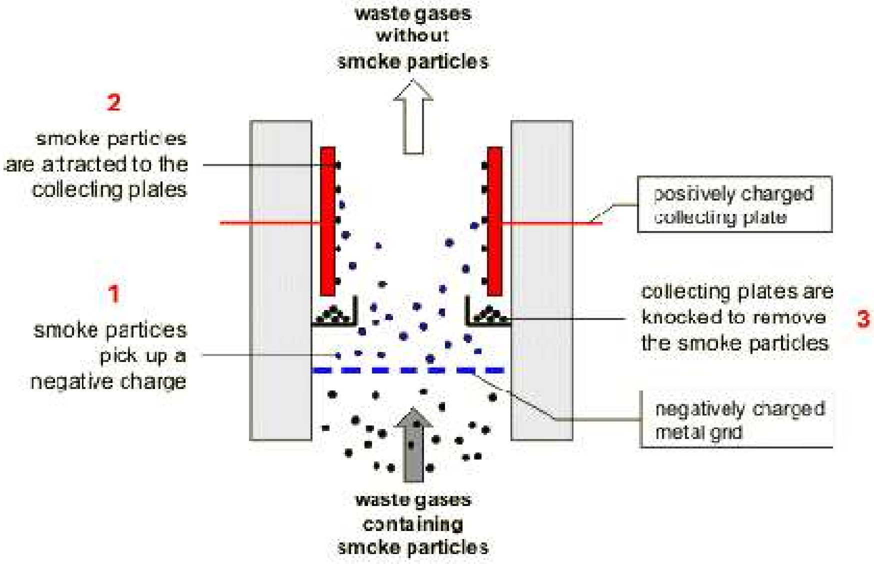
Disadvantages

- High temp. gases need to be cooled.
- High maintenance and fabric replacement cost.

- Large size equipment.
- Fabric is liable to chemical attack.

Electrostatic precipitator:

- Electrostatic precipitators are very efficient and versatile.
- The principle behind all electrostatic precipitators is to give electrostatic charge to particles in a given gas stream and then pass the particles through an electrostatic field that drives them to a collecting electrode.
- The electrostatic precipitators require maintenance of a high potential difference between the two electrodes, one is a discharging electrode and the other is a collecting electrode. Because of the high potential difference between the two electrodes, a powerful ionizing field is formed.
- The ionization creates an active glow zone (blue electric discharge) called the 'corona' or 'corona glow'. Gas ionization is the dissociation of gas molecules into free ions.
- As the particulate in the gas pass through the field, they get charged and migrate to the oppositely charged collecting electrode, lose their charge and are removed mechanically by rapping, vibration, or washing to a hopper below.
- 99% efficiency.
- Can remove particle size range of 0.1 µm to 1 µm



The advantages of using the ESP are:

i. High collection

ii. Particles as small as 0.1 micron can be removed.

iii. Low maintenance and operating cost.
iv. Low pressure drops (0.25 1.25 cm of water).
v. Satisfactory handling of a large volume of high temperature gas.
vi. Treatment time is negligible (0.1 10s).
vii. Cleaning is easy by removing the units of precipitator from operation.
viii. viii) There is no limit to solid, liquid or corrosive chemical usage.

The disadvantages of using the ESP are:

i. High initial
ii. Space requirement is more because of the large size of the equipment.
iii. Possible explosion hazards during collection of combustible gases or particulate.
iv. iv) Precautions are necessary to maintain safety during operation.
v. Proper gas flow distribution, particulate conductivity and corona spark over rate must be carefully maintained.
vi. The negatively charged electrodes during gas ionization produce the ozone.

Wet scrubber:

Wet collection devices are defined as the mechanical devices, which removes the dust particles from the gas by wetting the particles with a droplet diffusion or condensation or by impinging the wetted or unwetted particles on a collecting surface and cleaning them by a flush of fluid.

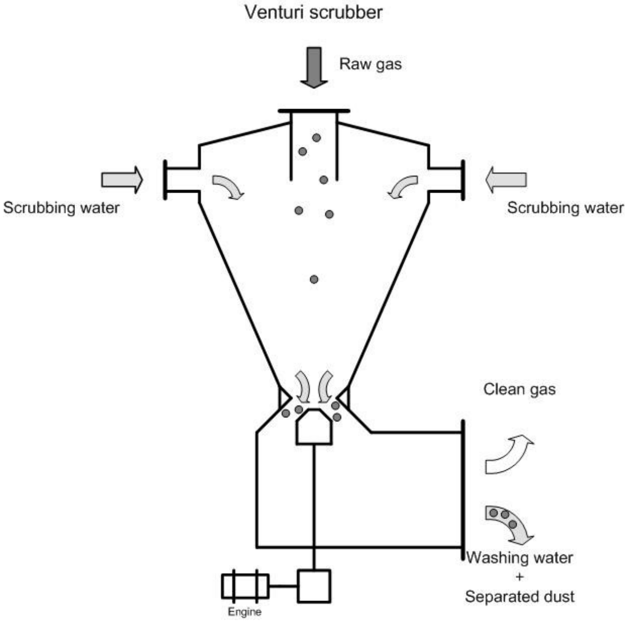
Scrubbing is the air pollution control technique, used to removed some particulate and/or gases from industrial air stream.

Wet scrubbing is defined as the air pollution control technique, used to clean air, fuel gas or other gases of various pollutants and dust particles with the scrubbing liquid (generally water).

The general wet collection devices are (a) cyclic scrubbers (b) spray chambers (c) venturi scrubbers (d) packed towers

Venturi-scrubbers

It can clean about 400 litres of gas per minute, generally mist can be removed by this device. It mainly consists of a venturi-throat, through which the gas pushes at a velocity of 3400 to 12600 m/min. generally the scrubbing liquid (water) is used and it is added in the direction of the flow of gas rate of 0.3 to 1.5 litres of gas per minute. The scrubbing liquid is introduced at the throat portion with nozzles. The efficiency of the venturi scrubbers varies with the input of power and it will be high up to 99% even for very small sized particles. Venturi scrubbers can work for abrasive, corrosive and high-temperature gases, if it is made up of good quality and the suitable materials.



Advantages

- Relatively low maintenance
- High removal yield
- Simple and compact construction
- No mechanical components
- Gaseous components are absorbed
- Able to deal with fluctuating gas flows
- No ventilator required

Disadvantages

Large pressure drops

Signs of erosion when scrubbing abrasive mediums

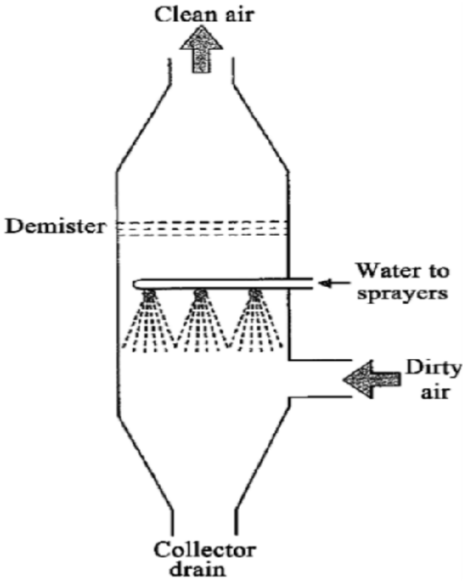
Control of gaseous pollutants

Absorption:

2. Absorption

This technique is widely used when the effluent gas contains hazardous pollutants like NOx, SOx, H2S, Fluorides, etc. The effluent gas is passed through a suitable liquid adsorbent like aq. NaOH, aq. HNO3, liquor NH3, NaOH+Phenol, Ethanolamine di Me Aniline, etc. One or more pollutants get absorbed / modified.

Equipments: Plate towers, packed towers,spray towers, bubble cap towers, scrubber towers, etc



Adsorption:

3. Adsorption

Conditions: This technique is used when the effluent gas contains pollutants like NOx, SOx, HF, Org. solvent vapors, Petroleum fractions, etc

Process: The effluent gas is passed through a porous solid adsorbent like Silicagel, Zeolite, Dolomite, Bauxite, Alumina, Limestone lumps, NaF pallets, Iron oxide, Activated Carbon, etc. Both the Organic & Inorganic pollutants are held over the interface of the solid adsorbent by

physical adsorption or chemo sorption.

Efficiency: - Depends upon the following factors

- Surface area per unit weight of adsorbent.
- Chemical nature of adsorbent.
- Nature & concentration of adsorbate pollutant
- Extent and time of contact of adsorbent & adsorbate

Advantages: -

- o Though installation cost of equipment is high, the operation & maintenance cost is quite low.
- o Sometime the value of recovered adsorbate material enhances economic feasibility.

Combustionrecovery system:

Combustion is an exothermic reaction, which develops the heat and light at a rapid rate. So temperature rises considerably. This is used when the pollutants in the gas stream are oxidizable to an inert gas. The pollutants like CO, hydrocarbons can be easily burned, oxidized and removed from the combustion equipment. The combustion process may be of three types:

1. Direct combustion
2. Thermal combustion
3. Catalytic combustion

Direct combustion

Direct combustor is a device in which air and all the combustible waste gases react at the burner. Complete combustion must occur intravenously since there is no residence chamber. the destruction efficiency is about 98%.

Thermal combustion

In this technique, the combustible waste gases pass over or around a burner flame, into a residence chamber where oxidation of the waste gas is completed. The destruction efficiency is about greater than 99%.

Catalytic combustion

In this method, a mixture of diluted organic gases and oxygen is exposed to a catalytic surface. Commonly used catalysts are platinum, vanadium, palladium and their oxides.

Catalysts are usually solids. That are neither reactants nor products of a reaction but yet alter the rate of chemical reaction.

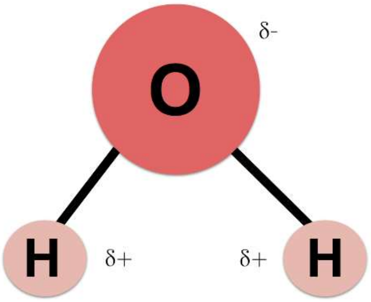
The effect of catalyst is to reduce the temperature required to oxidize the organic compounds, and hence the inlet gases need not be heated to ignition temperature.

It required less fuel, less contact time and low heat.

II. Water pollution

Properties of water

Water is the chemical substance with chemical formula H2O, one molecule of water has two hydrogen atoms covalently bonded to a single oxygen atom. Let us learn about the physical and chemical properties of water.



Physical properties of water

- Water is a colourless and tasteless liquid.
- The molecules of water have extensive hydrogen bonds resulting in unusual properties in the condensed form. This also leads to high melting and boiling points.
- As compared to other liquids, water has a higher specific heat, thermal conductivity, surface tension, dipole moment, etc. These properties form the reason for its significance in the biosphere.
- Water is an excellent solvent and therefore it helps in the transportation of ions and molecules required for metabolism.
- It has a high latent heat of vaporization which helps in the regulation of body temperature.

Chemical properties water

Water reacts with a lot of substances to form different compounds. Some significant reactions are as follows:

1. Amphoteric nature:

Water can act as both acid and base, which means that it is amphoteric in nature. Example:

Acidic Behaviour:

$$H_2O\,(l) + NH_3(aq) \leftrightarrow NH_4^+(aq) + OH^-\,(aq)$$

Basic Behavior:

$$H_2O\,(l) + H_2S\,(aq) \rightarrow H_3O^+(aq) + HS^-\,(aq)$$

2. Redox reactions:

Electropositive elements reduce water to hydrogen molecule. Thus, water is a great source of hydrogen. Let us see an example in this case:

$$H_2O\,(l) + 2Na(s) \rightarrow 2NaOH\,(aq) + H_2\,(g)$$

During the process of photosynthesis, water is oxidized to O2. As water can be oxidized and reduced, it is very useful in redox reactions.

3. Hydrolysis reaction

Water has a very strong hydrating tendency due to its dielectric constant. It dissolves many ionic compounds. Some covalent and ionic compounds can be hydrolyzed in water.

Drinkingwater quality standards

6.2.6 Water quality standards

Water is used for various purposes such as drinking, agriculture, industry and domestic use. Water quality standard develops the parameters which do not cause any hazard to human or impose limitations on use of water, according to the purpose of water usage. Accordingly, there are various water quality standards for different uses such as drinking, agriculture, industry and domestic use. In the setting of standards, agencies make political and scientific decisions about how the water will be used. Water quality standards are enforceable by law. The goals of water quality standards are to protect public health and the environment, and to maintain a standard of water quality consistent with its designated uses. It provides the 'teeth' for water quality legislation and also the yardstick by which performance may be evaluated.

Water quality standard in India

Central Pollution Control Board (CPCB) which comes under Ministry of Environment and Forest, Government of India, has categorized the surface water into five classes: A, B, C, D and E - depending upon its designated best use. The following classifications have been adopted in India–

Class A	Drinking water source without conventional treatment but after disinfection.
Class B	Outdoor bathing (organized).
Class C	Drinking water source after conventional treatment and disinfection.
Class D	Fish culture and wildlife propagation.
Class E	Irrigation, industrial cooling or controlled waste disposal.

The tolerance limits of parameters are specified as per classified use of water depending on various uses of water.

Surface water quality criteria for different uses

(Specified by CPCB, 1979 and the Bureau of Indian Standards, 1982)

Class A

Criteria

1. Total Coliforms Organism MPN/100 ml shall be 50 or less
   If MPN (most probable number) count is noticed to be more than fifty then regular Tests should be carried out. The criteria would be satisfied if during a period of time not more than 5% of the samples show greater than 200 MPN/100 *ml* and not more than 20% of samples show more than 50 MPN/100 ml.
2. pH: between 6.5 and 8.5
3. Dissolved Oxygen: 6 mg/*l* or more
4. Biochemical Oxygen Demand (5 days at 20°C): 2 mg/*l* or less
   Note: There shall be no visible discharge of domestic and industrial wastes into class A.

Class B

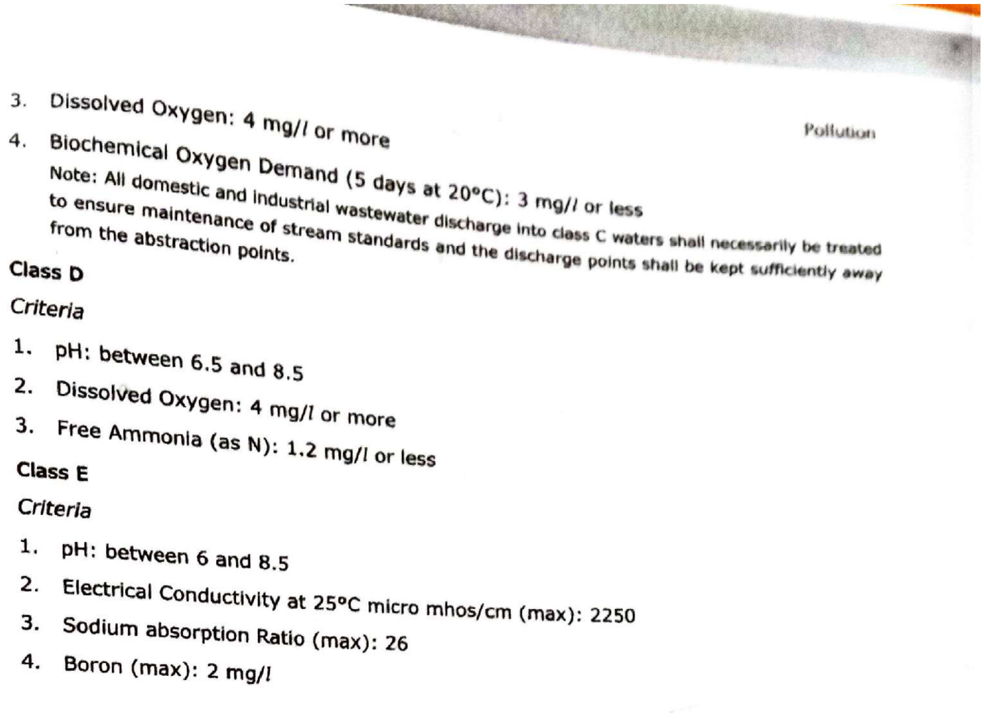
Criteria

1. Total Coliforms Organism MPN/100 *ml* shall be 500 or less
   If MPN count is noticed to be more than 500 MPN/100 *ml* then regular tests should be carried out. The criteria would be satisfied if during a period of time not more than 5% of the samples show greater than 2000 MPN/100 *ml* and not more than 20% of samples show greater than 500 MPN/100 ml.
2. pH: between 6.5 and 8.5
3. Dissolved Oxygen: 5 mg/*l* or more
4. Biochemical Oxygen Demand (5 days at 20°C): 3 mg/*l* or less
   Note: All domestic and industrial wastewater discharge upstream of bathing places shall be so regulated that the stream standards are maintained and that there is no visible floating matter including oils at the bathing places.

Class C

Criteria

1. Total Coliforms Organism MPN/100 *ml* shall be 5000 or less.
   If MPN count is noticed to be more than 5000 MPN/100 *ml* then regular tests should be carried out. The criteria would be satisfied if during a period of time not more than 5% of the samples show greater than 20,000 MPN/100 *ml* and not more than 20% of samples show greater than 5000 MPN/100 ml.
2. pH: between 6 and 9



3. Dissolved Oxygen: 4 mg/*l* or more
4. Biochemical Oxygen Demand (5 days at 20°C): 3 mg/*l* or less

Note: All domestic and industrial wastewater discharge into class C waters shall necessarily be treated to ensure maintenance of stream standards and the discharge points shall be kept sufficiently away from the abstraction points.

Class D

Criteria

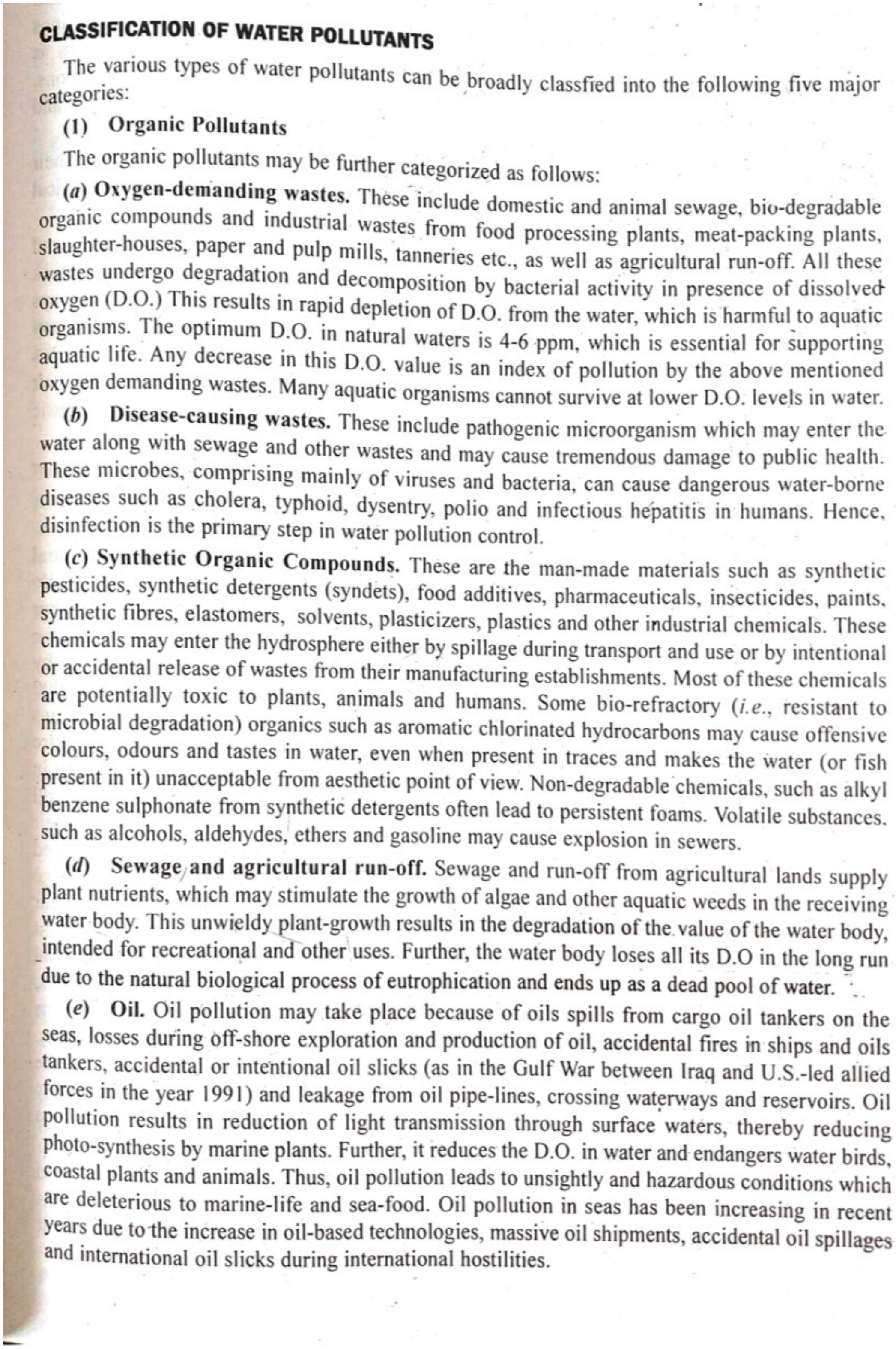
1. pH: between 6.5 and 8.5
2. Dissolved Oxygen: 4 mg/*l* or more
3. Free Ammonia (as N): 1.2 mg/*l* or less

Class E

Criteria

1. pH: between 6 and 8.5
2. Electrical Conductivity at 25°C micro mhos/cm (max): 2250
3. Sodium absorption Ratio (max): 26
4. Boron (max): 2 mg/*l*

3. Water pollution-sources and sinks



CLASSIFICATION OF WATER POLLUTANTS

The various types of water pollutants can be broadly classfied into the following five major categories:

(1) Organic Pollutants

The organic pollutants may be further categorized as follows:

(*a*) Oxygen-demanding wastes. These include domestic and animal sewage, bio-degradable organic compounds and industrial wastes from food processing plants, meat-packing plants, slaughter-houses, paper and pulp mills, tanneries etc., as well as agricultural run-off. All these wastes undergo degradation and decomposition by bacterial activity in presence of dissolved oxygen (D.O.) This results in rapid depletion of D.O. from the water, which is harmful to aquatic organisms. The optimum D.O. in natural waters is 4-6 ppm, which is essential for supporting aquatic life. Any decrease in this D.O. value is an index of pollution by the above mentioned oxygen demanding wastes. Many aquatic organisms cannot survive at lower D.O. levels in water.

(*b*) Disease-causing wastes. These include pathogenic microorganism which may enter the water along with sewage and other wastes and may cause tremendous damage to public health. These microbes, comprising mainly of viruses and bacteria, can cause dangerous water-borne diseases such as cholera, typhoid, dysentry, polio and infectious hepatitis in humans. Hence, disinfection is the primary step in water pollution control.

(*c*) Synthetic Organic Compounds. These are the man-made materials such as synthetic pesticides, synthetic detergents (syndets), food additives, pharmaceuticals, insecticides, paints, synthetic fibres, elastomers, solvents, plasticizers, plastics and other industrial chemicals. These chemicals may enter the hydrosphere either by spillage during transport and use or by intentional or accidental release of wastes from their manufacturing establishments. Most of these chemicals are potentially toxic to plants, animals and humans. Some bio-refractory (*i.e.*, resistant to microbial degradation) organics such as aromatic chlorinated hydrocarbons may cause offensive colours, odours and tastes in water, even when present in traces and makes the water (or fish present in it) unacceptable from aesthetic point of view. Non-degradable chemicals, such as alkyl benzene sulphonate from synthetic detergents often lead to persistent foams. Volatile substances. such as alcohols, aldehydes, ethers and gasoline may cause explosion in sewers.

(*d*) Sewage and agricultural run-off. Sewage and run-off from agricultural lands supply plant nutrients, which may stimulate the growth of algae and other aquatic weeds in the receiving water body. This unwieldy plant-growth results in the degradation of the value of the water body, intended for recreational and other uses. Further, the water body loses all its D.O in the long run due to the natural biological process of eutrophication and ends up as a dead pool of water.

(*e*) Oil. Oil pollution may take place because of oils spills from cargo oil tankers on the seas, losses during off-shore exploration and production of oil, accidental fires in ships and oils tankers, accidental or intentional oil slicks (as in the Gulf War between Iraq and U.S.-led allied forces in the year 1991) and leakage from oil pipe-lines, crossing waterways and reservoirs. Oil pollution results in reduction of light transmission through surface waters, thereby reducing photo-synthesis by marine plants. Further, it reduces the D.O. in water and endangers water birds, coastal plants and animals. Thus, oil pollution leads to unsightly and hazardous conditions which are deleterious to marine-life and sea-food. Oil pollution in seas has been increasing in recent years due to the increase in oil-based technologies, massive oil shipments, accidental oil spillages and international oil slicks during international hostilities.

(2) Inorganic Pollutants

Inorganic pollutants comprise of mineral acids, inorganic salts, finely divided metal or metal compounds, trace elements, cyanides, sulphates, nitrates, organometallic compounds and complexes of metals with organics present in natural waters. The metal-organic interactions involve natural organic species, such as fulvic acids and synthetic organic species, such as EDTA. These interactions are influenced by or influence redox equilibria, acid-base reactions, colloid formation and reactions involving micro-organisms in water. Algal growths in water and metal toxicity in aquatic ecosystems are also influenced by these interactions.

Various metals and metallic compounds released from anthropogenic activities add up to their natural background levels in water. Some of these trace metals play essential roles in biological processes, but at higher concentrations, they may be toxic to biota:

The most toxic among the trace elements are the heavy metals, such as Hg, Cd and Pb and metalloids, such as As, Sb and Se. The heavy metals have a great affinity for sulphur and attack the -SH bonds in enzymes, thereby immobilizing the latter. Protein carboxylic acid groups ($-COOH$) and amino-groups ($-NH_2$) may also be attacked by the heavy metal ions. The heavy metals that may be bound to the cell membranes interfere with the transport phenomena across the cell wall. Heavy metals also tend to precipitate phosphate biocompounds or catalyse their decomposition. Water pollution by heavy metals occurs mostly due to street dust, domestic sewage and industrial effluents.

Polyphosphates from detergents serve as algal nutrients and thus are significant as water pollutants.

(3) Suspended solids and sediments

Sediments are mostly contributed by soil erosion by natural processes, agricultural development, strip mining and construction activities. Suspended solids in water mainly comprise of silt, sand and minerals eroded from the land. Soil erosion by water, wind and other natural forces are very significant for tropical countries like India. It is estimated that out of the total land area of 328 million hectares, 175 million hectares are susceptible to degradation by soil erosion. It is also estimated that the continents are losing 5.8 cm of surface soil every 1000 years. About 6000 metric tonnes of soil are washed away into the sea every year, which means that about 5.37 million tonnes of NPK (nitrogen, phosphorous and potassium) fertilizers are washed away into the sea. The erosion leads to qualitative and quantitative degradation of soil in land area. Thus, soil may be getting removed from agricultural land to areas where it is not at all required, such as water reservoirs. Soil particles eroded by running water ultimately find their way into water reservoirs and such a process is called 'siltation'. Reservoirs and dams are filled with soil particles and other solid materials, because of siltation. This reduces the water storage capacity of the dams and reservoirs and thus shortens their life. Such problems are faced with our reservoirs such as Ram Ganga, Hirakud, Nizamsagar, Bhakra and Maithan, and the resultant reduction in live storage capacity of the reservoirs may lead to severe loss of irrigation potential of our country by the end of this century. apart from the filling up of the reservoirs and harbours, the suspended solids present in water bodies may block the sunlight required for photosynthesis by the bottom vegetation. This may also smother sell fish, corals and other bottom life forms. Deposition of solids in quiescent stretches of streams impairs the normal aquatic life in the steams. Further, sludge blankets containing organic solids decompose, leading to anaerobic conditions and formation of obnoxious gases. The tremendous problem of soil erosion can be controlled by proper cultivation practices and efficient soil and forest management techniques.

The organic matter content in sediments is generally higher than that in soils. Sediments and suspended particles exchange cations with the surrounding aquatic medium and act as repositories for trace metals such as Cu, Co, Ni, Mn, Cr and Mo. Suspended solids such as silt and coal may injure the gills of the fish and cause asphyxiation.

Dr. M. Vanaja

(4) Radioactive Materials

The radioactive water pollutants may originate from the following anthropogenic activities:

(*a*) Mining and processing of ores, e.g., Uranium tailings.

(*b*) Increasing use of radioactive isotopes in research, agricultral, industrial and medical (diagnostic as well as therapeutic) applications, e.g., I^{131}, P^{32}, CO^{60}, Ca^{45}, S^{35}, C^{14}, Rb^{86}, Ir^{132} and Cs^{137}

(*c*) Radioactive materials from nuclear power plants and nuclear reactors, e.g., Sr^{90}, Cs^{137}, Pu^{248}, Am^{241}.

(*d*) Radioactive materials from testing and use of nuclear weaponry, e.g., Sr^{90}, Cs^{137}

The radioactive isotopes found in water include Sr^{90}, I^{131}, Cs^{137}, Cs^{141}, Co^{60}, Mn^{54}, Fe^{55}, Pu^{239}, Ba^{140}, K^{40}, Ra^{226}.

These radioactive isotopes are toxic to life-forms. For instance, Sr^{90}, which emanates from testing of nuclear weapons, accumulates in bones and teeth and causes serious disorders in human beings. The maximum permissible level of Sr^{90} in water is 10 pico curies per liter (1 pico curie = 10^{-12} curie).

(5) Heat

Waste heat is produced in all processes in which heat is converted into mechanical work. Thus, considerable thermal pollution results from thermal power plants, particularly the nuclear-power-based electricity generating plants. In such industries, where the water in used as a coolant, the waste hot water is returned to the original water bodies. Hence the temperature of the water body increases. This rise in temperature decreases the DO content of water, which adversely affects the aquatic life. Moreover, any rise in temperature may increase the susceptibility of aquatic biota to the toxic effects of some chemicals, such as methyl mercury and some polycyclic aromotic hydrocarbons. Reduction of DO in water may alter the spectrum of organisms that can adopt to live the that temperature and that DO levels. Suspended solids in water may also cause bad odours and tastes and also may promote conditions favourable for growth of pathogenic becteria.

If the pollutant concentration in the receiving waters is not within the acceptable limits, adequate steps must be taken to minimize or remove them by suitable treatment technique e.g., sedimentation, filtration, biological oxidation, chemical precipitation of adsorption by activated carbon.

CHARACTERISATION OF WASTE WATERS

Waste waters are characterised on the basic of various physical, chemical and biological characteristics apart from flow data detail:

(1) Physical Characteristic. Colour, Odour, Dissolved Oxygen (D.O.), Insoluble Substances (settleable solids, suspended solids), Corrosive properties, Radio-activity, Temperature range, Foamability, etc.

(2) Chemical Characteristic. Chemical oxygen demand (C.O.D.), pH, Acidity of Alkalinity, Hardness, Total Carbon, Total dissolved solids, chlorine demand, known organic and inorganic components such as Cl^-, S^2, SO_4^{4-}, N, P, Pb, Cd, Hg, Cr, As, surfactants, phenols hydrocarbons oils and greases.

(3) Biochemical characteristics. Biochemical oxygen demand (B.O.D), presence of pathogenic bactreria etc., and toxicity to man, aquatic organisms, plants and other life forms.

The actual methods used for the treatment of a waste depend upon the characteristics of the particular waste.

Suspended solids. The suspeded solids are determined by filtering and aliquot of the sample through a previously weighed sintered crucible or a tared Gooch crucible and drying the crucible at 103°C to 105°C to constant weight. The difference in weight indicated as mg/l gives the suspended solids content of the sample.

Settleable solids. The settleable solids content of a sample is obtained by allowing 1 litre of the sample to settle for about 1 hour at 20°C in an Imhoff cone, which is a tapered conical tube. The volume of settleable matter in the cone is recorded as ml/l. The settleable solids may also be expressed in mg/l which can be calculated by the difference between mg/l suspended solids minus mg/l non-settleable matter determined by the procedure described as above.

Total Solids. The total solids content of a sample is determined by evaporating a know volume of the sewage of waste water sample, and drying the residue for 24 hours at 103°C to 105°C, followed by weighing. This gives the total solids content of the sample, which includes the dissolved as well as suspended solids.

Dissolved oxygen (DO). The measurement of DO gives a ready assessment of purity of water. The determination of dissolved oxygen is the basis of BOD (Biochemical Oxygen Demand) test, which is commonly used to evaluate the pollution strength of waste waters. The determination of DO content is also essential for maintaining aerobic conditions in the receiving waters and also in the aerobic treatment of sewage and industrial waste waters.

The DO content of a water sample is determined iodometrically by the modified Winkler's method. The principle involved in this method is that when manganous sulphate is added to the water sample containing alkaline potassium iodide, manganese hydroxide is formed. This is oxidised to basic manganic oxide by the DO present in the water sample. When sulphuric acid is added, the basic manganic oxide liberates iodine, which is equivalent to the DO originally present in the water sample. The liberated iodine is titrated with a standard hypo solution, using starch as indicator.

Interference due to nitrite can be eliminated by adding sodium azide to the alkaline potassium iodide solution used above.

$$MnSO_4 + 2\,KOH \longrightarrow Mn(OH)_2 + K_2SO_4$$

$$2Mn(OH)_2 + O_2\ (\text{from DO}) \longrightarrow \underset{\text{Basic manganic oxide}}{2\,MnO(OH)_2}$$

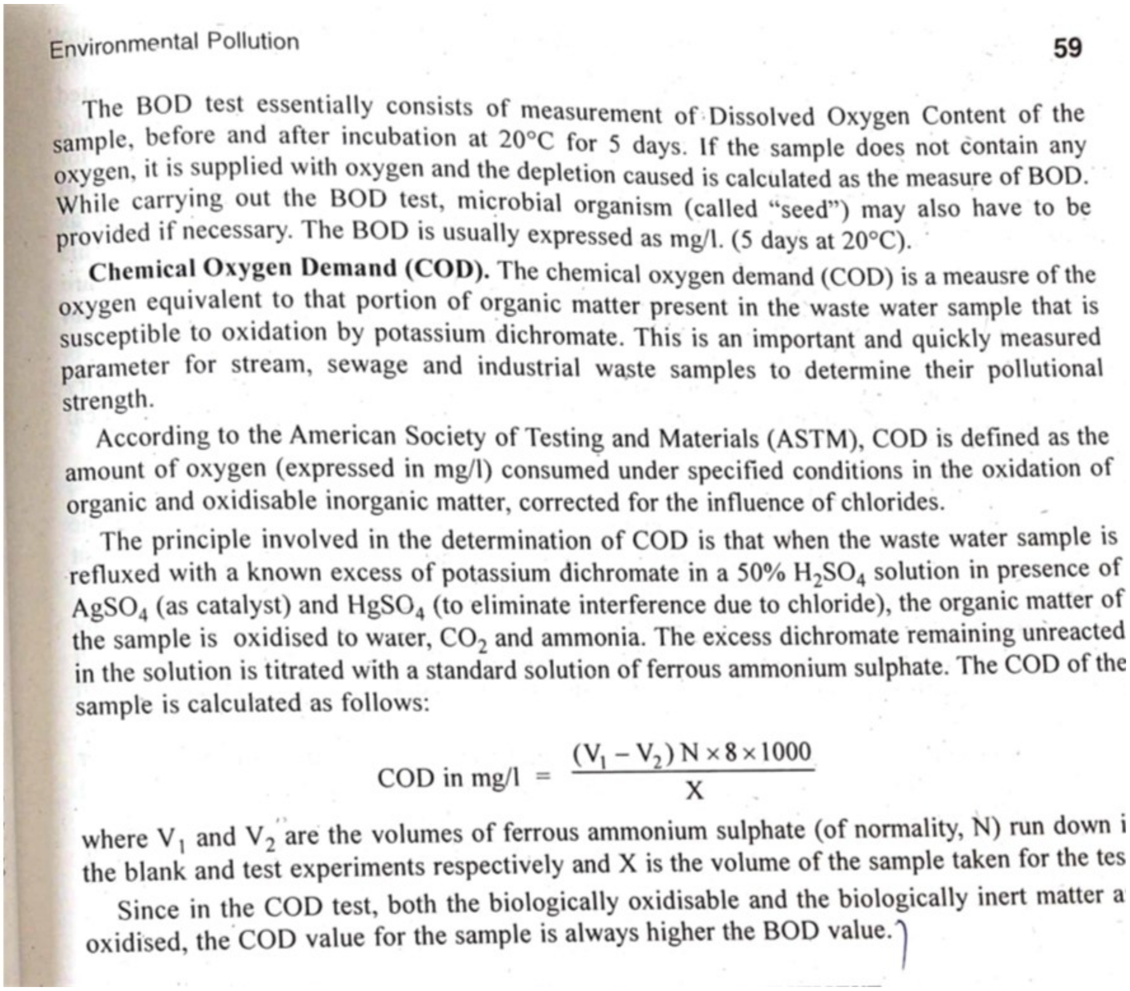
$$MnO(OH)_2 + 2H_2SO_4 \longrightarrow \underset{\text{Manganic sulphate}}{Mn(SO_4)_2} + 3H_2O$$

$$Mn(SO_4)_2 + 2KI \longrightarrow MnSO_4 + K_2SO_4 + I_2$$

$$\underset{\text{Sodium thiosulphate}}{2Na_2S_2O_3} + I_2 \longrightarrow \underset{\text{Sodium tetrathionate}}{Na_2S_4O_6} + 2NaI$$

The DO is usually expressed as Mg/l (or ppm)

Biochemial Oxygen Demand (BOD). Biochemical oxygen demand represents the quantity of oxygen required by bacteria and other microorganisms during the biochemical degradation and transformation of organic matter present in wastewater under aerobic conditions. BOD test is a very valuable test in the analysis of sewage, industrial effluents and grossly polluted waters. In spite of the inherent limitations, the BOD test is still valued as the best test for assessing the organic pollution. BOD is considered as the major characteristic used in stream pollution control. It gives very valuable information regarding the purification capacity of streams and serves as a guide-line for the Regulatory Authorities to check the quality of effluents discharged into such water bodies.



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The BOD test essentially consists of measurement of Dissolved Oxygen Content of the sample, before and after incubation at 20°C for 5 days. If the sample does not contain any oxygen, it is supplied with oxygen and the depletion caused is calculated as the measure of BOD. While carrying out the BOD test, microbial organism (called "seed") may also have to be provided if necessary. The BOD is usually expressed as mg/l. (5 days at 20°C).

Chemical Oxygen Demand (COD). The chemical oxygen demand (COD) is a meausre of the oxygen equivalent to that portion of organic matter present in the waste water sample that is susceptible to oxidation by potassium dichromate. This is an important and quickly measured parameter for stream, sewage and industrial waste samples to determine their pollutional strength.

According to the American Society of Testing and Materials (ASTM), COD is defined as the amount of oxygen (expressed in mg/l) consumed under specified conditions in the oxidation of organic and oxidisable inorganic matter, corrected for the influence of chlorides.

The principle involved in the determination of COD is that when the waste water sample is refluxed with a known excess of potassium dichromate in a 50% H_2SO_4 solution in presence of $AgSO_4$ (as catalyst) and $HgSO_4$ (to eliminate interference due to chloride), the organic matter of the sample is oxidised to waıer, CO_2 and ammonia. The excess dichromate remaining unreacted in the solution is titrated with a standard solution of ferrous ammonium sulphate. The COD of the sample is calculated as follows:

$$\text{COD in mg/l} = \frac{(V_1 - V_2)\, N \times 8 \times 1000}{X}$$

where V_1 and V_2 are the volumes of ferrous ammonium sulphate (of normality, N) run down i the blank and test experiments respectively and X is the volume of the sample taken for the tes

Since in the COD test, both the biologically oxidisable and the biologically inert matter a oxidised, the COD value for the sample is always higher the BOD value.

Eutrophication:

Eutrophication, defined as the addition of 'excess' nutrients to a water body, is a widespread environmental problem facing the world's aquatic habitats.

Eutrophication is the process in which a water body becomes overly enriched with nutrients, leading to the plentiful growth of simple plant life. The excessive growth (or bloom) of algae and plankton in a water body are indicators of this process. Eutrophication is considered to be a serious environmental concern since it often results in the deterioration of water quality and the depletion of dissolved oxygen in water bodies. Eutrophic waters can eventually become "dead zones" that are incapable of supporting life.

Causes of Eutrophication

The availability of nutrients such as nitrogen and phosphorus limits the growth of plant life in an ecosystem. When water bodies are overly enriched with these nutrients, the growth of algae, plankton, and other simple plant life is favoured over the growth of more complex plant life.

Phosphorus is considered one of the primary limiting factors for the growth of plant life in freshwater ecosystems. Several sources also claim that the availability of nitrogen is an important limiting factor for the growth of algae.

Phosphates tend to stick to the soil and are transported along with it. Therefore, soil erosion is a major contributor to the phosphorus enrichment of water bodies. Some other phosphorus-rich sources that enrich water bodies with the nutrient include:

Fertilizers
Untreated sewage
Detergents containing phosphorus
Industrial discharge of waste.

Among these sources, the primary contributors to eutrophication include agricultureand industrial wastes.

Effects of Eutrophication

Primarily, the adverse effects of eutrophication on aquatic bodies include a decrease in biodiversity, an increase in toxicity of the water body, and a change in species dominance. Some other important effects of this process are listed below.

- Phytoplanktons grow much faster in such situations. These phytoplankton species are toxic and are inedible.
- Gelatinous zooplankton blooms fast in these waters.
- Increased biomass of epiphytic and benthic algae can be observed in eutrophic waters.
- Significant changes arise in the species composition of macrophytes and the biomass.
- The water loses its transparency and develops a bad smell and colour. The treatment of this water becomes difficult.
- Depletion of dissolved oxygen in the water body.
- Frequent fish kill incidents occur and many desirable fish species are removed from the water body.
- The populations of shellfish and harvestable fish are lowered.
- The aesthetic value of the water body diminishes significantly.

Ecological Effects of Eutrophication

Decrease in Biodiversity

Increase in Water Toxicity

Invasion of New Species

Control measures of water pollution

Adsorption:

Adsorption with active carbon is frequently used as tertiary purification for the removal of organic micropollutants and COD from wastewater, as well as metals in organic complexes to a lesser extent. The adsorption factor is determined by various groups and compounds in the substances to be removed.

Adsorption is a wastewater purification technique used to remove a variety of compounds from industrial wastewater. Adsorption is most commonly used to remove non-degradable organic compounds from groundwater, drinking water preparation, process water, or as a tertiary cleansing step after biological water purification.

Adsorption occurs when molecules in a liquid bind to the surface of a solid substance.

Adsorbents have a large internal surface area that allows for adsorption.

Active carbon is by far the most commonly used adsorbent, and it is especially well-suited to the removal of a polar compounds.

Other adsorbents are employed in specific applications:

1. **Zeolites, whether natural or synthetic (alumina-silicate-polymers)**

   Possess a very homogeneous pore distribution as well as polar bonding sites. Zeolites are far more selective than active carbon

2. **Naturally occurring clay minerals**

   Used to adsorb very polar organic and inorganic matter (ions);

3. **Silica gel and aluminum that has been activated**

   Adsorbents with a high affinity for water that are typically used to remove water from a polar medium.

4. **Silicic acid**

   Wood, charcoal, and coconut can all be used to produce active carbon. Each type has a distinct surface, grain size, and pore diameter. Active carbon is available in powder, granular, and impregnated forms.

5. Active carbon in powder form is added to aerobic and anaerobic wastewater purification systems, as well as physico-chemical wastewater purification processes.

In this case, the added active carbon is removed and treated alongside the resulting sludge.

6. **Various other applications**

In open or closed filters, active carbon in the form of grains or pellets is commonly used. In most industrial applications, closed filters are used. They are constructed in such a way that the to-be-treated liquid is pumped under pressure through the filter and over the active carbon. Open filters are most commonly used in drinking water applications, where water flows through active carbon beds using gravity.

Filtration with active carbon

Adsorption with active carbon is frequently used as tertiary purification for the removal of organic micropollutants and COD from wastewater, as well as metals in organic complexes to a lesser extent.

The adsorption factor is determined by various groups and compounds in the substances to be removed.

Other types of adsorbents

Other adsorbents are used at low concentrations or when selectivity is required. For example, zeolites can be used to remove iron, ammonium, nitrate, manganese, or heavy metals.

Coagulation and Flocculation

Suspended solids

Suspended solids in water include sand, soil, organic materials, bacteria, viruses and other. Typical size variations of particulates found in surface water are list in Table (5.1). A suspension of particles that will not be settled is known as a stable suspension. The particles that make up these suspensions are known as colloids.

The colloidal suspension may contain:

- organic materials
- metal oxides
- insoluble toxic compounds
- stable emulsions
- material producing turbidity

Colloids are commonly classified as:

· Hydrophilic: Hydrophilic colloids are typically formed by large organic molecules that become hydrated (solvated) when they are in the presence of water (e.g., proteins)

· Hydrophobic: Hydrophobic colloids are made of small colloidal particles having little or no affinity for water (the solvent) (e.g., clays, metal oxides).

Flocculation is the process of gentle and continuous stirring of coagulated water for the purpose of forming flocs through the aggregation of the minute particles present in the water. It is thus the conditioning of water to form flocs that can be readily removed by settling, dissolved air flotation or filtration, fig (5.8). The efficiency of the flocculation process is largely determined by the number of collisions between the minute coagulated particles per unit of time.

Ionexchange

Ion exchange is the process used for the removal of undesirable anions and cations from the waste water. It allows the separation of dissolved ionic species through their transfer from the liquid phase to a solid exchange material, where they replace other ions of the same charge that, in turn, pass to the liquid phase. In this reversible process, chemical transformations do not take place in the ionic species involved or in the exchanger material, enabling their recovery after the ion exchange. The soils and sands were the first known ion exchangers used and as the universality of ion exchangers grew from the last few years many synthetic exchangers have been evolved. Earlier ion exchangers used were natural zeolites, but now there are synthetic zeolites and polymeric ion exchangers are used. The interest for the applications of the ion exchange lies precisely in the possibility of reusing the exchanger material again and again. In order to do so, the material must previously undergo a regeneration process before recovering its initial conditions.

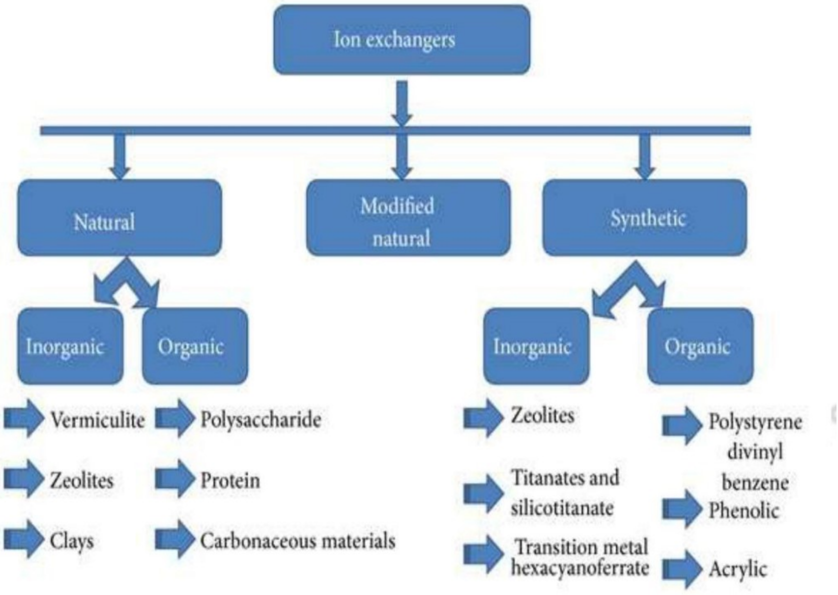
Ion exchange resins are typically presented in the form of spherical particles and consist of an organic or inorganic network structure with attached functional groups that contains soluble and mobile exchangeable ions. Most of the ion exchange resins are synthetic and made up by the polymerization of organic compounds into a three-dimensional structure and the degree of crosslinking between organic chains determines the pore size. In aqueous solution and depending on their selectivity towards the ions contained in the solution, resin functional groups carry out the exchange process by replacing their counter ions with the ions of interest to be removed from the solution. The exchange process between the resin and the aqueous solution comprises phases of diffusion, adsorption, electrostatic attraction and acid-base balance. The process is entirely reversible and under the appropriate acid or base conditions, the equilibrium can be moved in opposite direction, resulting in the original chemical form of the resin. Thisproperty allows ion exchange resins to be used through many load and regeneration cycles. The cost effectiveness of treatment processes based on ion exchange is due precisely to the number of regeneration cycles that can be obtained with a specific resin under certain operating conditions and constitutes a major design factor.

When the resin comes in contact with water, swelling of the resin results into the decrease of cross-linking density and the functional groups are exposed. The exchangeable ion dissociates from the resin and becomes mobile, thus exchange of ions in the aqueous phase by the exchanger takes place and overall charge neutrality is maintained, otherwise the resin will attract or repel ions to maintain the charge balance.

Cations, such as calcium, magnesium, barium, strontium and radium, can be separated from an aqueous solution by using a cation-exchange resin and anions like fluoride, nitrate, arsenate, selenate, chromate, as well as humic and fulvic acids can be separated by means of an anion-exchange resin. Cations are exchanged for hydrogen or sodium and anions for hydroxyl ions. Exchange capacity is determined by the number of functional groups per unit mass of the resin.

All ion exchange resins will establish ion selectivity based on the type of resin and resin structure, removing either cations or anions. Some resins have been traced to target removal of specific chemicals and some are designed to perform in particular conditions.

Types of ion exchangers:



Reverse osmosis

Reverse osmosis is a water filtration process and it uses pressure to force water molecules through a semipermeable membrane. Contaminants are removed from the water during this process, leaving behind clean freshwater.

Reverse osmosis is an effective way to remove many types of contaminants. It includes sediment, bacteria, viruses, chlorine, fluoride, lead, and other heavy metals.

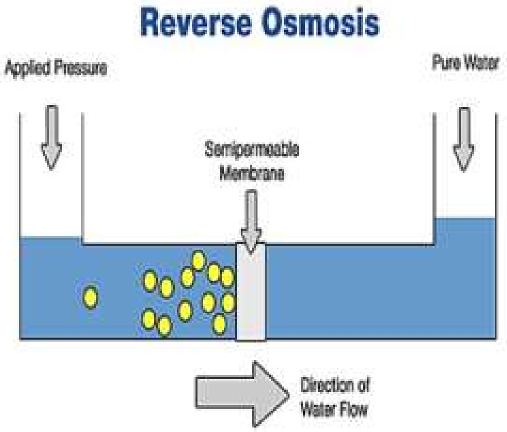
Reverse osmosis can be used to purify both municipal tap water and well water. It is often used to desalinate saltwater, making it safe for drinking and other uses.

Reverse osmosis is a water purification technique that pushes water through a membrane(s) with high-pressure pumps. It’s an excellent method for removing pollutants from drinking water. And the amount of pressure required varies based on the total quantity of contaminants in the water supply.

The liquid that has been filtered of its dissolved solids is known as permeate or product water. The residue of pollutants in the brine, which remains after the concentrated stream of contaminants has been removed, is released as reject water.

The reverse osmosis membranes filter out all undesirable salts and minerals from the feed water as it goes through the system. Water with up to 99 percent dissolved solid levels can be filtered by top-brands membranes (Dupont Filmtec, Hydranautics). However, the rejected stream is recycled through the reverse osmosis system for water conservation.

The reverse osmosis process is more similar to a cross-flow filtration technique. Cross-flow filtering is far more efficient since it has two outlets for the solution to enter to handle higher pollutants levels. Because the permeate and concentrated water flow in opposing directions, the membrane surface stays clean, and build-up is reduced.



4. Soil pollution

Definition

Soil pollution is defined as the presence of toxic chemicals (pollutants or contaminants) in soil, in high enough concentrations to pose a risk to human health and/or the ecosystem. In the case of contaminants which occur naturally in soil, even when their levels are not high enough to pose a risk, soil pollution is still said to occur if the levels of the contaminants in soil exceed the levels that should naturally be present

The main reason why the soil becomes contaminated is due to the presence of manmade waste. The waste produced from nature itself such as dead plants, carcasses of animals and rotten fruits and vegetables only adds to the fertility of the soil. However, our waste products are full of chemicals that are not originally found in nature and lead to soil pollution

Main Causes of Soil Pollution

1. **Industrial Activity:** Industrial activity has been the biggest contributor to the problem in the last century, especially since the amount of mining and manufacturing has increased. Most industries are dependent on extracting minerals from the Earth. Whether it is iron ore or coal, the by products are contaminated and they are not disposed off in a manner that can be considered safe. As a result, the industrial waste lingers in the soil surface for a long time and makes it unsuitable for use.

2. **Agricultural Activities:** Chemical utilization has gone up tremendously since technology provided us with modern pesticides and fertilizers. They are full of chemicals that are not produced in nature and cannot be broken down by it. As a result, they seep into the ground after they mix with water and slowly reduce the fertility of the soil. Other chemicals damage the composition of the soil and make it easier to erode by water and air. Plants absorb many of these pesticides and when they decompose, they cause soil pollution since they become a part of the land.

3. **Waste Disposal:** Finally, a growing cause for concern is how we dispose of our waste. While industrial waste is sure to cause contamination, there is another way in which we are adding to the pollution. Every human produces a certain amount of personal waste products by way or urine and feces.

While much of it moves into the sewer the system, there is also a large amount that is dumped directly into landfills in the form of diapers. Even the sewer system ends at the landfill, where the biological waste pollutes the soil and water. This is because our bodies are full of toxins and chemicals which are now seeping into the land and causing pollution of soil.

4. Accidental Oil Spills: Oil leaks can happen during storage and transport of chemicals. This can be seen at most of the fuel stations. The chemicals present 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.

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

Effects of Soil Pollution

Effect on Health of Humans:

Considering how soil is the reason we are able to sustain ourselves, the contamination of it has major consequences on our health. Crops and plants grown on polluted soil absorb much of the pollution and then pass these on to us. This could explain the sudden surge in small and terminal illnesses.

Long term exposure to such soil can affect the genetic make-up of the body, causing congenital illnesses and chronic health problems that cannot be cured easily. In fact, it can sicken the livestock to a considerable extent and cause food poisoning over a long period of time. The soil pollution can even lead to widespread famines if the plants are unable to grow in it.

Effect on Growth of Plants:

The ecological balance of any system gets affected due to the widespread contamination of the soil. Most plants are unable to adapt when the chemistry of the soil changes so radically in a short period of time. Fungi and bacteria found in the soil that bind it together begin to decline, which creates an additional problem of soil erosion.

The fertility slowly diminishes, making land unsuitable for agriculture and any local vegetation to survive. The soil pollution causes large tracts of land to become hazardous to health. Unlike deserts, which are suitable for its native vegetation, such land cannot support most forms of life.

Decreased Soil Fertility:

The toxic chemicals present in the soil can decrease soil fertility and therefore decrease in the soil yield. The contaminated soil is then used to produce fruits and vegetables which lacks quality nutrients and may contain some poisonous substance to cause serious health problems in people consuming them.

Toxic Dust:

The emission of toxic and foul gases from landfills pollutes the environment and causes serious effects on health of some people. The unpleasant smell causes inconvenience to other people.

Changes in Soil Structure:

The death of many soil organisms (e.g. earthworms) in the soil can lead to alteration in soil structure. Apart from that, it could also force other predators to move to other places in search of food.

A number of ways have been suggested to curb the current rate of pollution. Such attempts at cleaning up the environment require plenty of time and resources to be

Physical, chemical and biological properties of soil

Soil is the upper weathered layer of the Earth's crust affected by plants and animals. A vertical section through this zone constitutes a soil profile; in each soil profile, there are usually several distinguishable layers or horizons, which enable different types of soil to be recognized.

Soil contains matter in all three states: solid, liquid, and gaseous. The solid portion is partly organic and partly inorganic. The **inorganic, or mineral, part of the soil is made up of particles derived from the parent material, the rocks which weather to form the soil.** The **organic portion consists of living and decayed plant and animal materials such as roots and worms.** The **end-product of decay is humus,** black amorphous organic matter. Soil water is a dilute but complex chemical solution derived from direct precipitation and from run-off, seepage, and groundwater. The soil atmosphere fills the pore spaces of the soil when these are not occupied by water.

The **texture of soil refers to the sizes of the solid particles composing the soil.** The **sizes range from gravel to clay.** The proportions of the different sizes present vary from soil to soil and from layer to layer. **Texture largely determines the water-retention properties of the soil.** In **sandy soil, pore spaces are large and water drains rapidly:** in **clay soil, the individual pore spaces are too small for adequate drainage**. Generally speaking, **loam textures are best for plant growth**.

Soil acidity is a property related to the proportion of exchangeable hydrogen ion present in the soil in relation to other elements. The **degree of acidity is measured on the logarithmic pH scale** which **ranges from 0 (extreme acidity) to 14 (extreme**

alkalinity). Few soils reach these limits; a **pH value of about 6.5 is normally regarded as the most favorable for the growth of cereal crops.**

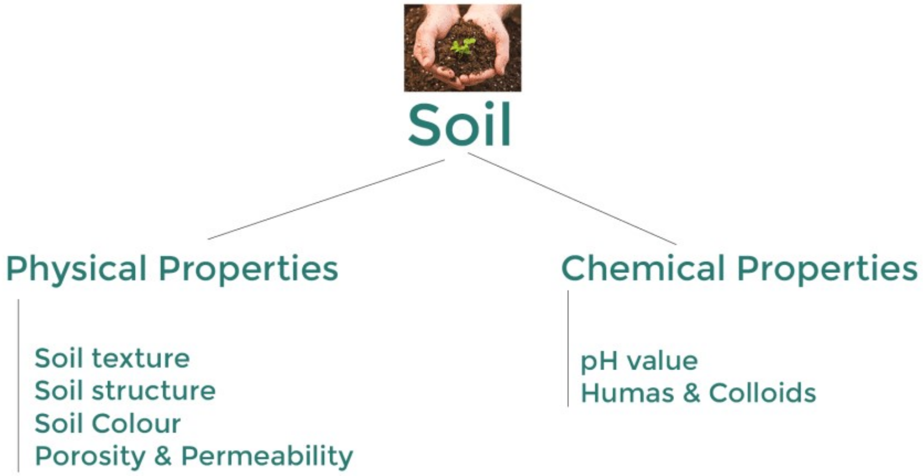
Colour varies considerably in soils and can tell us much about how a soil is formed and what it is made up of. In recently formed soils, the **colour will largely reflect that of the parent material,** but in many other cases, the colour is different from the underlying rock. **Soils can range from white to black**, **usually depending on the amount of humus.**

In cool humid areas, most soils contain relatively high humus content and are generally black or dark brown, whereas in **desert or semi-desert areas, little humus is present and soils are light brown or grey. Reddish colors in soils are associated with the presence of ferric compounds, particularly the oxides and hydroxides**, and usually indicate that the soil is well-drained, although locally the colour may be derived from a red-coloured parent material.

Properties of Soil

All soils contain mineral particles, organic matter, water, and air. The combinations of these determine the soil's properties – its texture, structure, porosity, chemistry, and colour.

Knowing a soil's water, mineral, and organic components and their proportions can help us determine its productivity and what the best use for that soil may be. Several soil properties that can be readily tested or examined are used to describe and differentiate soil types.



Physical Properties of soil

It **depends upon the amount, size, shape, arrangement, and mineral composition** of soil particles. It also depends on the organic matter content and pore spaces.

Soil Texture:

Soil texture defines the proportion in which the soil separates to make the mineral component of the soil. These separates can be classified as **sand, clay, and silt.** Sand and silt are of no importance to the soil as they don't contribute to the soil's ability to restore water or nutrients. **Clay is an active part of soil texture as clay has a small size and it has a large amount of surface area per unit mass and it helps in storing ions and water.**

The **soil texture refers to the coarseness/fineness of the mineral matter in the soil. It is determined by the proportion of the sand, silt, and clay particles**. **The equal proportion of all three of them is known as loam**. Soil texture affects the water holding capacity, nutrient retention, nutrient fixation, drainage, compressibility, and aeration of the soil.

- **Clay**: Particle Size – diameters **less than 0.002** millimeter
- **Silt**: Particle Size – diameters between 0.002 millimeters to 0.05 millimeters.
- **Sand**: Particle Size – diameters between 0.05 and 2 millimeters.

Rocks larger than 2 millimeters are regarded as pebbles, gravel, or rock fragments *and technically are not soil particles.*

Loamy Soil: Loamy soil is the one in which none of the three (sand/silt/clay) dominates the other two. In particular, **loamy soil has about 40% sand, 40%silt, and 20% clay**.

Soil Structure:

It is the **arrangement of soil particles into certain patterns** like- plate like structure, block like structure, prism-like structure, etc.

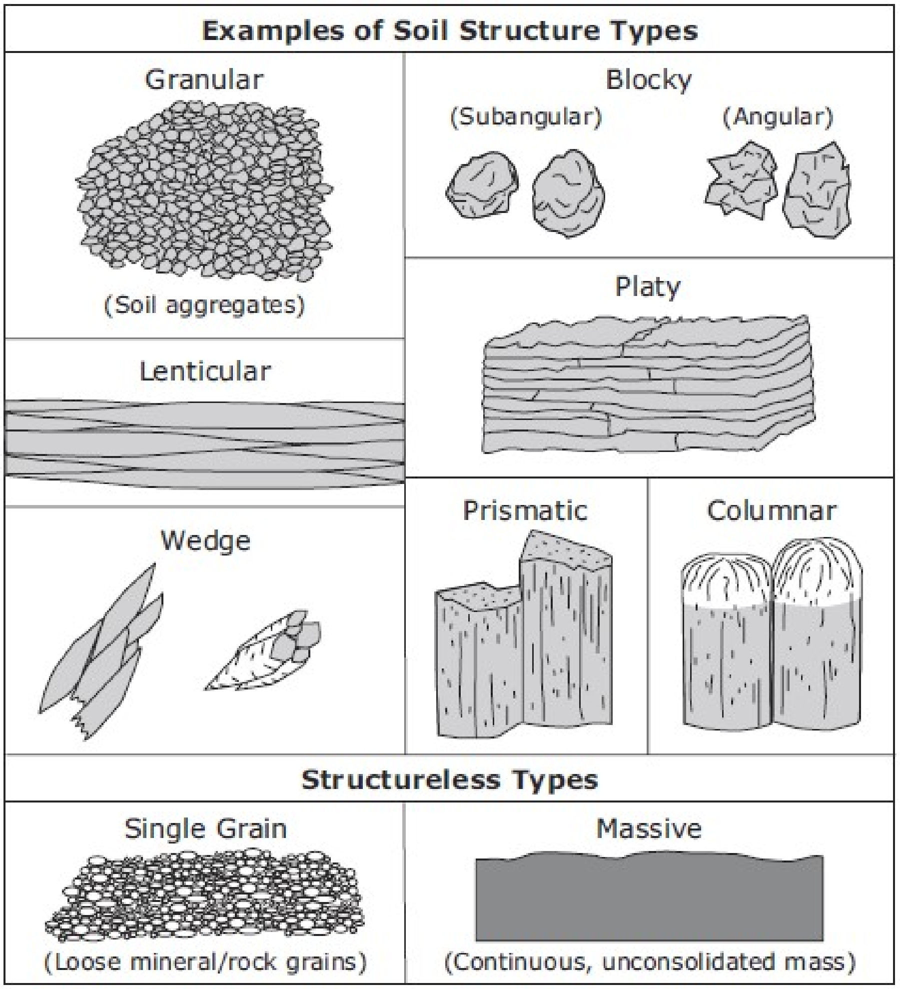
Soil structure describes the way the sand, silt, and clay particles are clumped together. Organic matter (decaying plants and animals) and soil organisms like earthworms and bacteria influence soil structure.

Clays, organic matter, and materials excreted by soil organisms bind the soil particles together to form aggregates. **Soil structure is important for plant growth, regulating the movement of air and water, influencing root development, and affecting nutrient availability.**

Good quality soils are friable (crumbly) and have fine aggregates so the soil breaks up easily if you squeeze it. Poor soil structure has coarse, very firm clods or no structure at all.

Some structural characteristics of soil:

- **Permeability** – The ease with which liquids/gases can pass through rocks or a layer of soil is called permeability. It depends on the size, shape, and packing of particles. It is usually greatest in sandy soils and poor in clayey soils.
- **Porosity** – The volume of water which can be held within the soil is called its porosity. It is expressed as a ratio of the volume of voids (pores) to the total volume of the material.

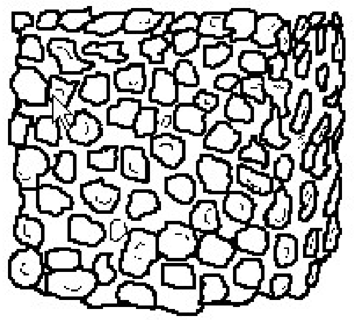
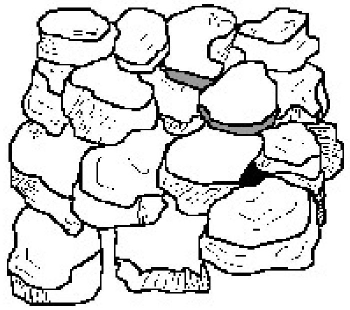
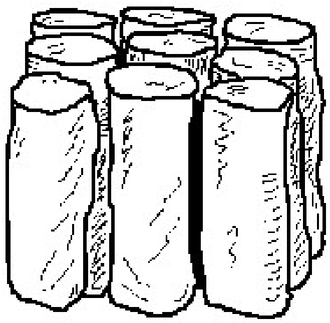
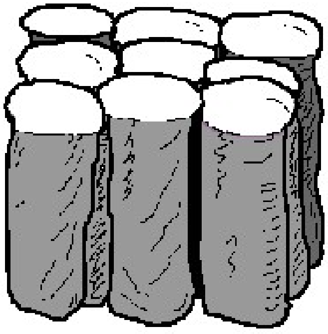
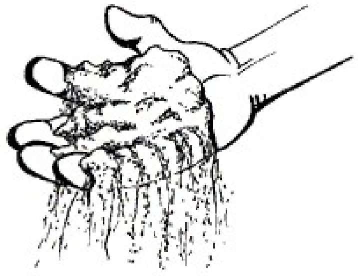


There are 5 basic types of structural units:

1. **Platy**: Plate-like aggregates that form parallel to the horizons like pages in a book.
    - This type of structure may reduce air, water, and root movement.
    - a common structure in an E horizon and usually not seen in other horizons.
2. **Blocky**: Two types–angular blocky and subangular blocky
    - These types of structures are commonly seen in the B horizon.

- Angular is cube-like with sharp corners while subangular blocky has rounded corners.

3. **Prismatic**: Vertical axis is longer than the horizontal axis. If the top is flat, it is referred to as prismatic.If the top is rounded, it is called columnar.
4. **Granular**: Peds are round and porous, spheroidal. This is usually the structure of A horizons.
5. **Structureless**: No observable aggregation or structural units.
   - Single grain-sand
   - Massive-solid mass without aggregates

		
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.	**Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.	**Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
		
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.	**Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.	**Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

Soil Colour:

Basically soil color (brown, yellow, red) depends on oxidized or **ferric iron** compounds. **Darker the color of the soil, the more organic content it contains.** The higher the organic content, the higher soil temperature as they absorb more heat due to the darker color.

Soils rich in humus tend to be dark because decomposed organic matter is black or brown. Soils with **high humus content are usually very fertile**, so dark brown or black soils are often referred to as 'rich'.

Red or yellow soils typically indicate the presence of iron.

Soil colour is described by the parameters called hue, value and chroma. Hue represents the dominant wave length or colour of the light; value refers to the lightness of the colour; chroma, relative purity or strength of the colour.

The colour of the soil in terms of the above parameters could be quickly determined by comparison of the sample with a standard set of colour chips mounted in **a note-book called MUNSELL SOIL COLOUR CHARTS**.

In these charts, the right-hand top corner represents the Hue; the vertical axis, the value; and the horizontal axis, the chroma.

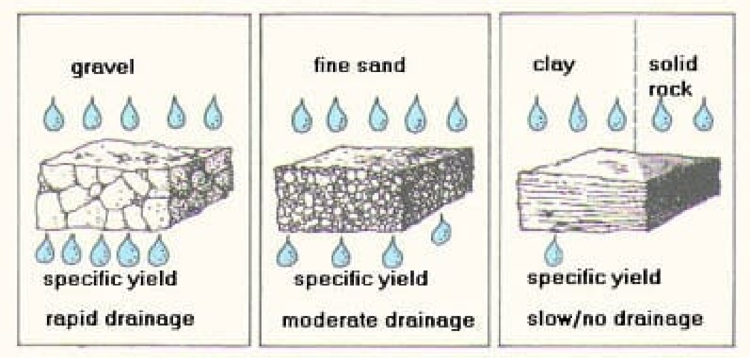
Soil permeability:

Soil permeability is a broad term used to define the ability of the soil for transmitting water. It is important to understand the water dynamics and the water balance of the soil and it must be known for accurate management of irrigation. It is determined partly by texture, with sandy soils having high permeability as compared to clay soils and it can be altered by soil management.

- **Most porous rocks are permeable with the exception of clay in which pore spaces are so small that they are often sealed with groundwater held by surface**

tension. Another exception – **granite is non-porous but permeable**. It is a crystalline rock and hence non-porous. Its individual crystals absorb little or no water but the rock may have numerous joints/ cracks through which the water can pass rendering it permeable.

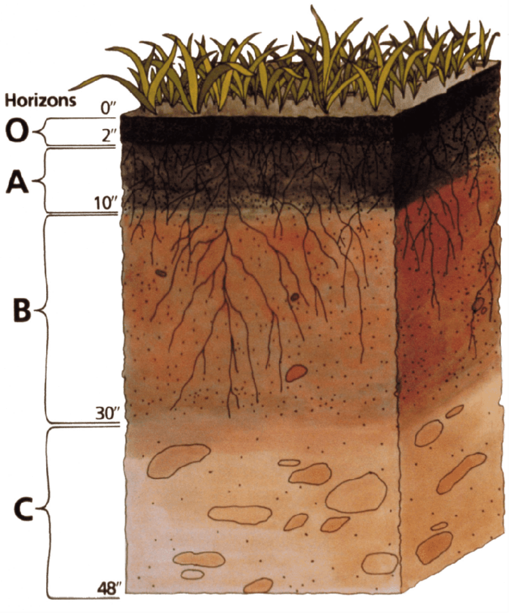
- **A soil with high organic content also tends to have high porosity.**



Soil Horizon:

1. The soil is divided vertically into different horizons from top to bottom namely:

- **A-Horizon:** This is the **uppermost layer of soil and also called topsoil.** This layer is rich in humus and minerals and holds most of the water as compared to other layers. This layer consists of sand, silt, and clay. It is also home to many living organisms like snakes, earthworms, etc.
- **B-Horizon**: This is the **second layer from the top and is a little rich in humus and it supports moisture**. This layer consists of silt, clay, weathered rocks, and some nutrients. Minerals are more in this layer as compared to the top layer.
- **C-Horizon**: **This layer consists of small pieces of rocks broken down due to weathering.**
- **BedRock: This layer is the last layer and consists of layers of solid unweathered rock.**



Chemical properties of soil

Chemical properties of soils depend on the following factors:

- **Inorganic matter present in the Soil:** The mineral content of the soil is the major factor that differentiates various types of soil. It is so because of its abundance in the soil.
- **Organic matter present in Soil:** Though these matters present in very small quantities but they play important role in deciding the fertility of the soil.
- **Colloidal properties of Soil**: Colloids are mainly of two types:
  - Clay Colloids: they are important for the adsorption of a large quantity of water.
  - Organic Colloids: these help in increasing the moisture and nutrient retention capacity of the soil.
- **the pH of Soil:** The measure of the chemical reaction which a soil shows is expressed by its pH value. The pH value of soil determines its acidic or basic nature.

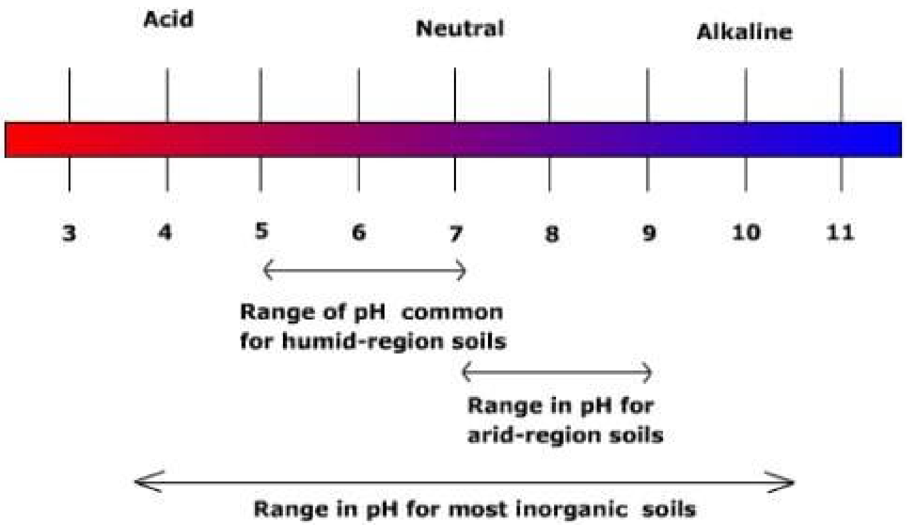
Acidity & Alkalinity:

An important aspect of soil chemistry is acidity, alkalinity (baseness), or neutrality.

Low pH values indicate acidic soil, and a **high pH indicates alkaline** conditions. **Most complex plants grow only in the soils with levels between pH 4 and pH 10** but optimum pH varies with the plant species.

- In **arid and semi-arid regions, soils tend to be alkaline** and **soils in humid regions tend to be acidic.**

- **To correct soil alkalinity and to make the soil more productive, the soil can be flushed with irrigation water.**
- Strongly acidic soils are also detrimental to plant growth, but soil acidity can generally be corrected by adding lime to the soil.

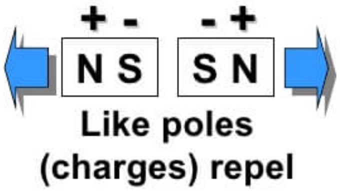


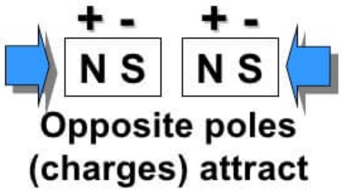
The most important **effect of pH in the soil is on ion solubility,** which in turn affects microbial and plant growth. A **pH range of 6.0 to 6.8 is ideal for most crops because it coincides with optimum solubility of the most important plant nutrients.** Some minor elements (e.g., iron) and most heavy metals are more soluble at lower pH. This makes pH management important in controlling the movement of heavy metals (and potential groundwater contamination) in soil.

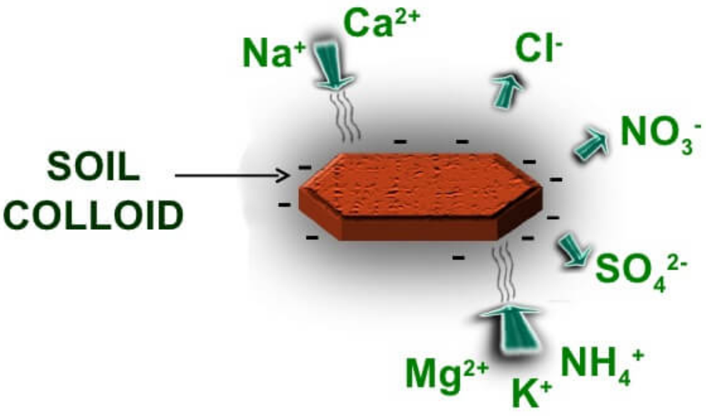
Lime requirement, or the amount of liming material needed to raise the soil pH to a certain level, increases with **CEC(cation exchange capacity)**. **To decrease the soil pH, sulfur can be added,** which produces sulfuric acid.

Soil Colloids:

Soil colloids are the most active constituent of the soil and they are important because their surfaces **attract soil nutrients dissolved in soil, water as positively charged mineral ions, or cations.**

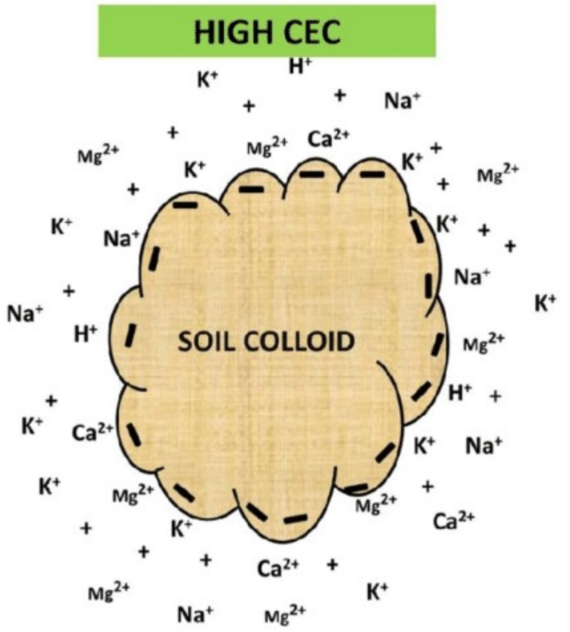


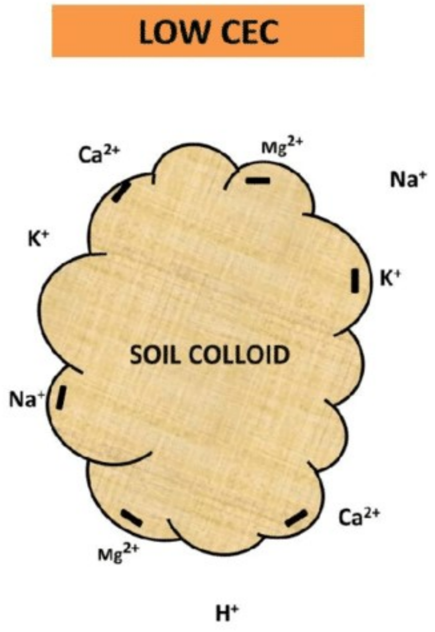




Some cations are needed for plant growth, including calcium (Ca++), Magnesium (Mg ++), Potassium (K+), and sodium (Na+). They need to be dissolved in a soil-water solution to be available to plants when they are in close contact with root membranes.

The **fertility of the soil-water solution for plants is based on the capability of the soil to hold and exchange cations; this is referred to as the cation-exchange capacity**. Without soil colloids, most vital nutrients would be leached out of the soil by percolating water and carried away in streams.



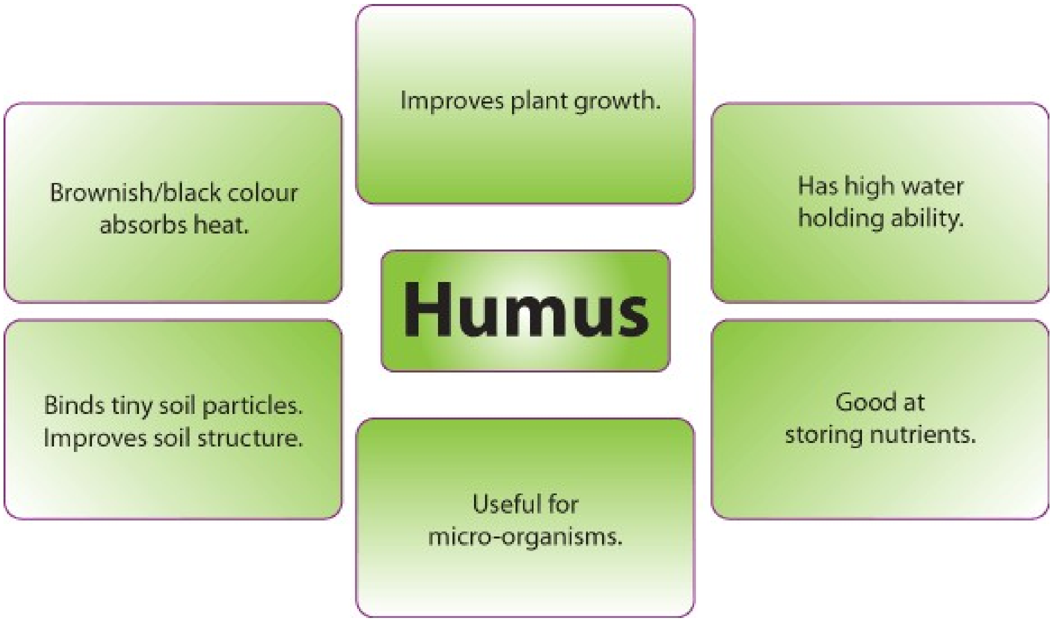


Biological Properties of Soil

Organic matter in the soil improves soil structure and increasing the nutrient and water holding capacity of the soil. Organic matter also provides a food supply for soil biology. Soils with low organic matter can have a ‘poor’ structure, hold little water, and erode or leach nutrients easily. The exception is cracking clay soils where clay minerals have the main effect on the structure. **Soils with high organic matter levels have a ‘good’ structure, good water-holding capacity, and reduced erosion and nutrient leaching.**

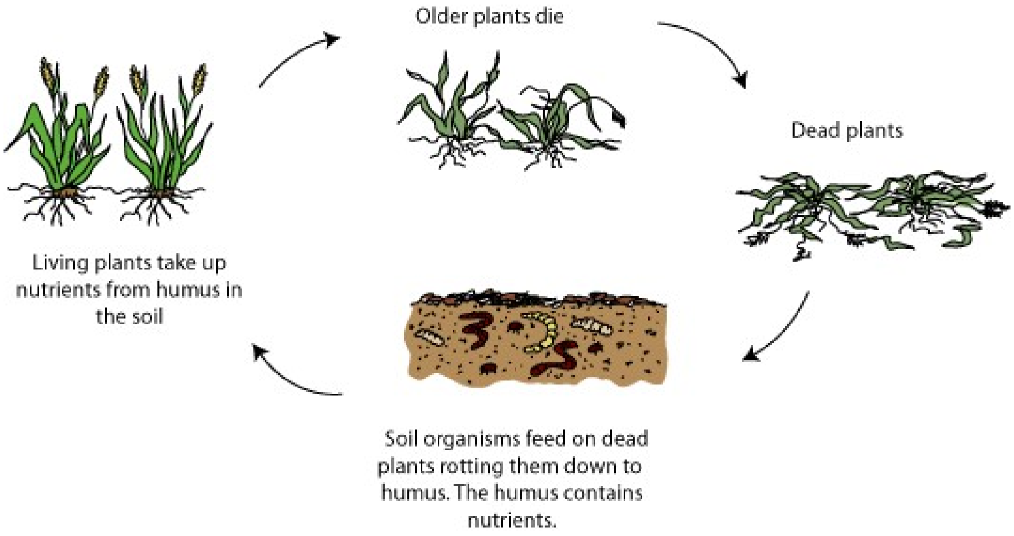
Biological properties include:

- organic matter
- soil organisms
- the presence of disease-causing organisms.



The total role of biologic processes in soil formation includes the presence and activities of living plants and animals as well as their non-living organic products. **Living plants contribute to soil formation in two basic ways.**

(i) Biomass i.e. the production of organic matter the biomass both above the soil as stems and leaves and within the soil as roots. It provides the raw material of organic matter in the **O horizon** and in lower horizons. The decomposer organisms process this raw material, reducing it to humus and ultimately to its initial components carbon dioxide and water.



(ii) Nutrient Recycling: It involves the cycling of nutrients from the soil in dead plant tissues. Nutrient recycling is a mechanism by which nutrients are prevented from escaping through the leaching action of surplus soil water moving downward through the soil.

Animals living in the soil play an important role in biologic processes of soil. e.g. earthworms rework the soil not only by burrowing but also bypassing the soil through their intestinal tracts.

Some of the **important factors which decide the biological behavior of soi**l are:

- **Respiration rate:** CO2 evolution under standard laboratory conditions or at the field.
- **Potential N/C mineralization:** Increase in mineral Nitrogen or Carbon content under standard laboratory conditions.
- **Earthworms:** Density of earthworms.
- **Bacterial biomass:** Total bacterial biomass for a given soil mass.
- **Bacterial diversity:** It can be determined by functional groups, or describing genetic diversity.
- **Presence of pathogens:** By different pathology techniques, from cultures to DNA profiling.

5. Sediment Pollution

Clay, silt, sand gravel can be suspended and carried in water. When a river flows into a lake or ocean, its flow velocity decreases, and the sediments often settle out. Overtime, as sediments accumulate, new land is formed. A river delta is flat, low-lying plain created from deposited sediments. River deltas, with their abundant wildlife and waterways for the trade routes, have always been important settlement sites for people. Sediments are also deposited on land when a river overflows its banks during a flood. Sediments are not necessarily pollutants; they are important, for example, in regenerating soils in agricultural areas and providing essential nutrients to wetland areas. Sediment pollution occurs when excessive amounts of suspended soil particles eventually settle out and accumulate on the bottom of the body of water. Sediment pollution comes from erosion of agricultural lands, forest soils exposed by logging, degraded stream banks, overgrazed rangelands, strip mines and construction. Control of soil erosion reduces sediment pollution in waterways.

Effects of sediment pollution

- Sediment pollution reduces light penetration, covers aquatic organisms brings insoluble toxic pollutants into the water, they make the water turbid, which turn decreases the distance that light penetrates. Because the base of the food web in an aquatic ecosystem consists of photosynthetic algae and plants that require for photosynthesis, turbid water lessens the ability of producers to photosynthesis.

- Extreme turbidity reduces the number of photosynthesizing organisms. Which in turn causes a decrease in the number of aquatic organisms that feed on the primary producers.
- Sediments adversely affect water quality by carrying toxic chemicals, both inorganic and organic into the water.
- The sediment particles provide surface area to which some insoluble toxic chemicals adhere, so that when sediments get into water, the toxic chemicals get in as well.
- Disease causing agents are also transported into water via sediments
- When sediments settle out of solution, they fill in waterways. This problem is particularly serious in lakes and channels through which ships must pass. Thus, sediment pollution adversely affects the shipping industry.

6. Black carbon

Black Carbon (BC) is a **short-lived pollutant that is the second-largest contributor** to warming the planet behind **carbon dioxide (CO_2).**

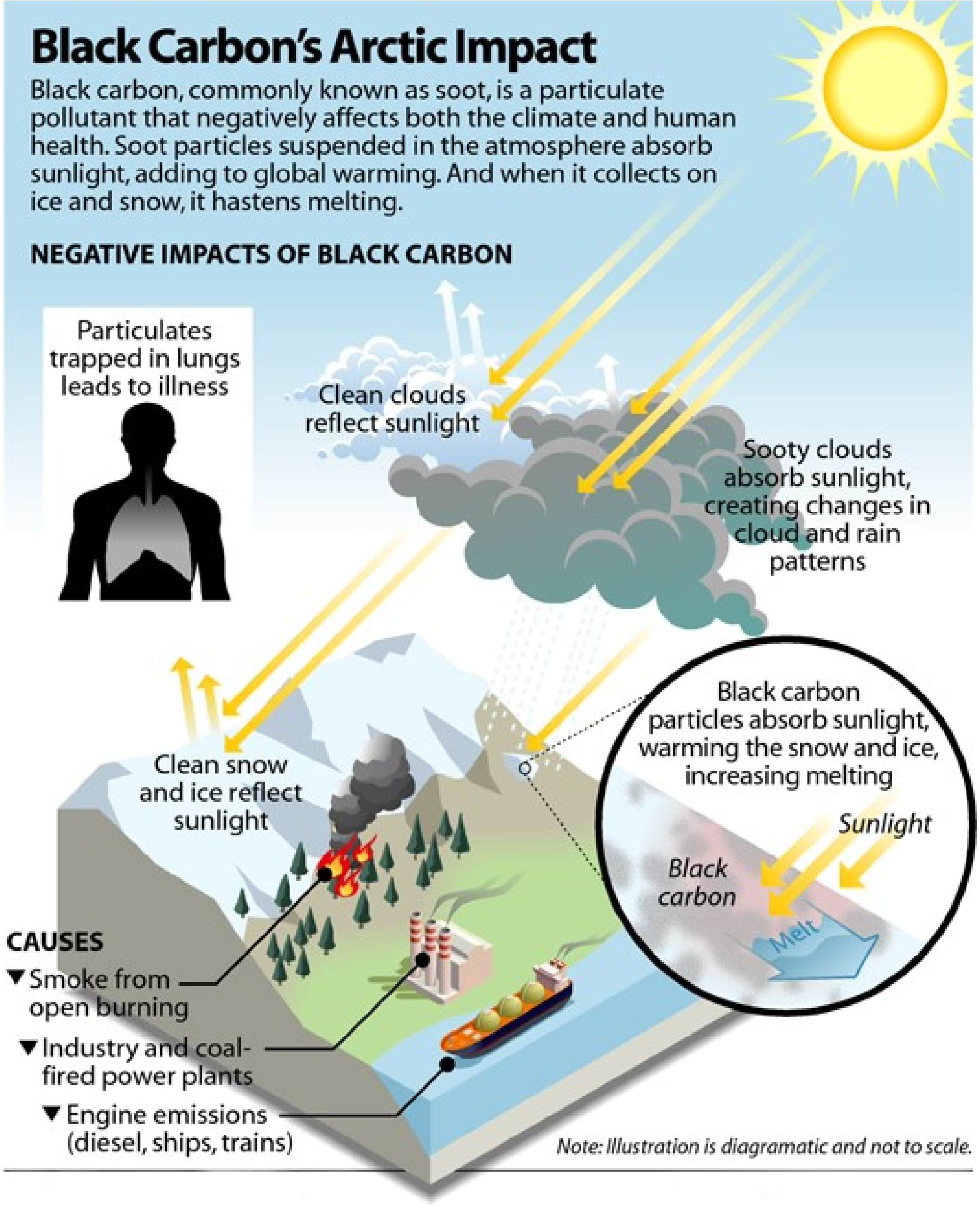
Unlike other **greenhouse gas emissions,** BC is quickly washed out and can be eliminated from the atmosphere if emissions stop.

Unlike historical carbon emissions it is also a localised source with greater local impact.

Black carbon is a kind of an aerosol.

General Impacts

- Among aerosols (such as brown carbon, sulphates), Black Carbon has been recognized as the **second most important anthropogenic agent for climate change** and the **primary marker to understand the adverse effects caused by air pollution.**
- Black carbon absorbs solar energy, it warms the atmosphere. When it falls to earth with precipitation, it darkens the surface of snow and ice, reducing their albedo (the reflecting power of a surface), warming the snow, and hastening melting.
- **Emission**: It gets **emitted from gas and diesel engines, coal-fired power plants,** and other sources that burn **fossil fuel.** It comprises a significant portion of particulate matter or PM, which is an air pollutant.



Control measures

Pradhan Mantri Ujjwala Yojana:

Under this initiative, the government is promoting use of **cleaner household cooking fuels.**

BS VI Emission Norms:

Leapfrogging from BS-IV to **BS-VI norms** for fuel and vehicles from 1st April, 2020.

Introducing Cleaner Fuels:

Introduction of cleaner / alternate fuels like gaseous fuel (**CNG, LPG** etc.), **ethanol blending.**

SATAT Scheme

A new initiative, **"Sustainable Alternative Towards Affordable Transportation (SATAT),** has been launched to set up 5000 **Compressed Bio-Gas (CBG)** production plants and make CBG available in the market for use.

Managing Crop Residue:

Agricultural machines and equipment for in-situ crop residue management in Punjab, Haryana, Uttar Pradesh and NCT of Delhi are promoted under the Central Sector Scheme on **Promoting Agricultural Mechanization** for in-situ Crop Residue Management with 50% subsidy to individual farmers and 80% subsidy to the establishment of Custom Hiring Centres.

National Clean Air Programme:

The Central Government is implementing the **National Clean Air Programme** as a long-term, time-bound, national-level strategy to tackle the air pollution problem across the country in a comprehensive manner.

The Centre has set a new target of a **40% reduction in particulate matter concentration in cities covered under the scheme by 2026**, updating the earlier goal of 20 to 30% reduction by 2024.

City specific Clean Air Action Plans:

The **Central Pollution Control Board (CPCB)** has identified 131 cities based on ambient air quality levels exceeding national ambient air quality standards, and cities with a million plus population.

City specific Clean Air Action Plans **have been prepared and rolled out for implementation in these cities.**

These plans define time bound targets to control city specific air polluting sources (soil & road dust, vehicles, domestic fuel, municipal solid waste burning, construction material and industries, etc.).

FAME Scheme

Faster Adoption and Manufacturing of Electric Vehicles (FAME) phase-2 scheme has been rolled out.

7. Soil pollution control measure

Reducing use of chemical fertilizer and pesticides

Applying bio-fertilizers and manures can reduce chemical fertilizer and pesticide use and thereby minimize soil pollution. For instance, in gardens, make use of organic fertilizers and pesticides, because firstly they are usually made of natural substances, secondly are bio-degradable and thirdly do-little harm to the natural balance in the soil. Aware and insist people on buying natural and organic food, because chemical pesticides and fertilizers are not used in their growing process. Not only are organic foods healthier for the environment, they are also healthier for you and your family. Examples of some common organic pesticides include Cayenne pepper spray, Soap spray, Tobacco powder, Pyrethrin, Neem, Sabadilla etc.

Reusing, recycling and recovery of materials

Materials such as glass containers, plastic bags, paper, cloth etc. can be reused at domestic levels rather than being disposed, reducing solid waste pollution. This decreases the volume of refuse and helps in the conservation of natural resources. For example, the recovery of one tone of paper cans save17 trees.

Reforestation

Deforestation or the cutting down of trees are the main cause of erosion of the soil due to which the loss of fertility of the soil occurs which leads to soil pollution. Reforestation is an effective method of preventing soil pollution. Another can be cut down the usage of paper or use recycled paper. This will lead fewer trees to be cut down and therefore reduced deforestation.

Restoring forest and grass cover to check wastelands, soil erosion and floods can be attempted to control land loss and soil erosion. On the other hand, crop rotation or mixed cropping can improve the fertility of the land.

Waste minimization

The 3 R’s principle: Reduce, Reuse, and Recycle help in help in minimization of waste production.Reduce the quantity and toxicity of refuse and trash that you discard. Reuse containers and try to repair things that are broken.Recycle products wherever possible, which includes buying recycled products i.e., recycled paper books, paper bags etc.

Some of the major types of solid waste which are major cause of soil pollution are as follows:

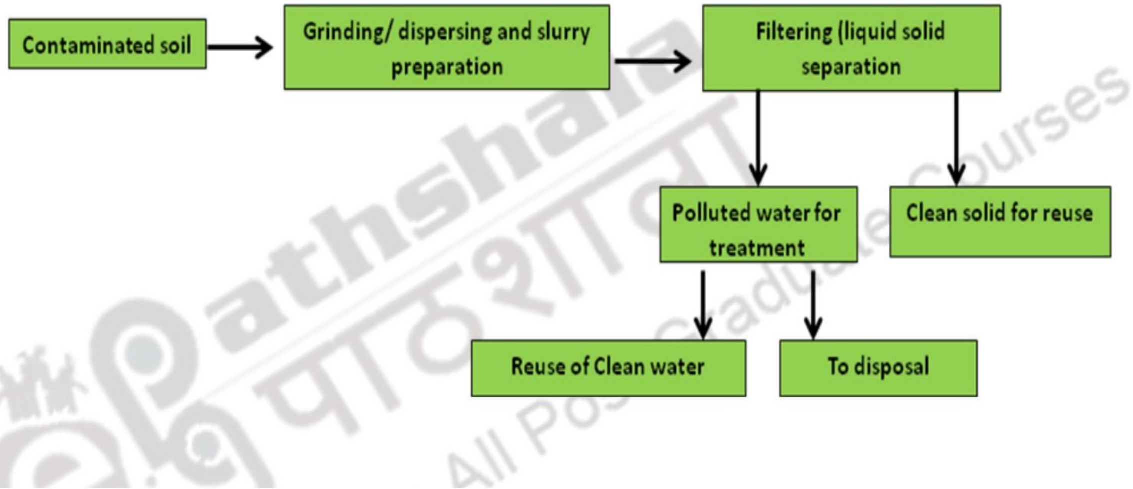
Municipal Solid Waste (MSW) Hazardous Wastes, Industrial Wastes, Agricultural Wastes Bio-medical Wastes Management of solid waste disposal can be done by adopting proper methods such as industrial wastes can be rendered less hazardous by treating physically, chemically and biologically. The insoluble biodegradable material should be permitted to degrade under controlled conditions; acidic and alkaline wastes should be first neutralized before being disposed. New areas for storage of hazardous waste should be regularly investigated such as deep well injection and more secure landfills to protect our soil from damaging effect cause otherwise.

Further soil pollution can be restricted by

- Strong regulatory programs to reduce soil contamination need to be implemented.
- Reduce consumption and reduce your trash is the best way as the less rubbish we create the less chance of the waste that it will end up in our soil.
- Use of plastic bags which are a major cause of pollution must be ban.
- Most appropriate and secure disposal of waste including nuclear wastes.
- Encouraging social and agro forestry programs.
- Undertaking many pollution awareness programs.
- There is a need to educate the public about the harms done when they litter.

Soil pollution control techniques:

Removing the contaminated soil and replacing it with clean soil is one of the simplest physical methods for remediation. This process including dig, dump and replace, only be possible if extent and depth of the contaminated region is small. The contaminated soil excavated from the site can be either disposed of in an engineered landfill or subjected to simple washing as shown in figure



Soil washing for granular soils contaminated with inorganic pollutant

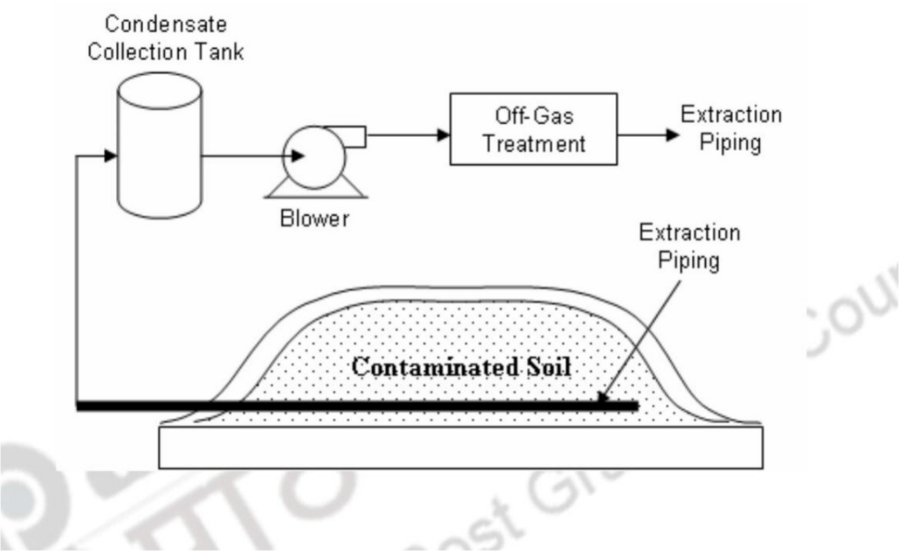
a) Electroremediation

The technique is used to remove heavy metals or polar compounds as pollutant migrate in an electric field. Migrating particles have a permanent electric charge or they are polarized. Under the influence of an electromagnetic field contaminants migrate through the soil towards the cathode or anode area, where contaminants are removed by any of the methods: chemical precipitation, adhesion to the electrodes surfaces and removing and processing the contamination away from the remediated site.

b) *Ex-situ* soil vapor extraction (SVE)

Volatile and some semi-volatile contaminants are removed in this *ex situ* soil vapor extraction (SVE) technology. Volatilization of organics is encouraged by placing excavated soil over a network of aboveground piping to which a vacuum is applied (Hyman and Dupont, 2001).

Directional drilling, pneumatic and hydraulic fracturing, and thermal enhancement (e.g. hot air or steam injection) helps in improving the potency of SVE technique. Gas flow through the subsurface is generally boosted by directional drilling and fracturing enhancements peculiarly in lower permeability zones and the latter such as hot air or steam injection helps in boosting of subsurface soil temperature and thus improvement of volatility of contamination.



***Ex-situ* soil vapor extraction (SVE) system**

c) Extraction and separation techniques

In solvent extraction, an extracting agent in general (an aqueous solution but preferably an organic solvent) along with the contaminated & oil is mixed. Potential applications include the removal of metals using a mineral solution, zinc lead, organo-metallic compounds and some cyanides using sodium hydroxide solution. Hydrocarbons and halogenated hydrocarbons can also be removed. Usually, Contaminants are present in the finer or coarser fraction of the soil or the organic components, which can be removed in some cases using a process which separates the soil into fractions by any of the process like specific gravity or particle size or settling velocity.

d) Thermal methods

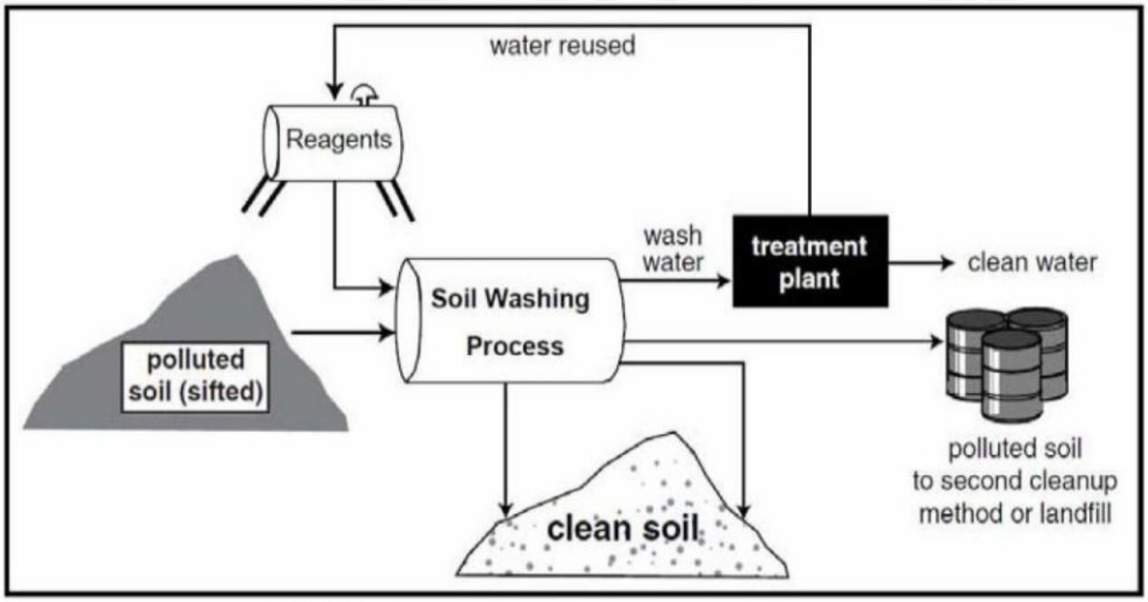
Destruction of the contaminants directly or indirectly at an appropriate temperature can be done by any of the two ways of heat treatment methods; removal of contaminants by evaporation either by direct heat transfer from heated air or an open flame or by indirect heat transfer. The gas so leaving the heating device must be treated to destroy or remove any contaminants or unwanted products of combustion. Stream stripping is another process in which steam is injected into soil which leads to evaporation of volatile contaminants which may be water soluble or insoluble.

e) **Chemical methods**:

Chemical methods are developed on the basis of different chemical processes, which include oxidation and reduction, extraction, precipitation of sparingly soluble chemical compounds, pH stabilization. During the process detoxification is completed only when intimate contact between soil and chemical is there regularly.

f) **Soil washing**:

The method uses a wide spectrum of leaching solutions from water to strong inorganic acids. There are two types of washing firstly separation of fine particles with adsorbed contaminants in a stream of dissolvent (water or solutions of inorganic salts Ca or Mg) and finally extraction of contaminants. It is a fast and efficient method for cleaning up of contaminated soil but high cost, generation of additional chemical waste and invasive in nature results in low level of community acceptance of this technique.



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Schematic diagram of soil washing Source: Dadrasnia et al., 2013

g) Chemical and photochemical reduction

In this method, the total mineralization (by chemical reactions) of organic contaminants and the effective transformation of organic and inorganic contaminants into non-toxic, less toxic or chemically inert forms takes place. Theoretically, this method could be applied both *ex situ* and *in situ*; however, in practice, because of its high invasivity, only *ex-situ* techniques are used. The method is suitable for the removal of organic compounds (oil compounds, organic solvents, pesticides) and inorganic ones (ions or heavy metals, oxyanions). The reagents used in this method are: ozone, hydrogen peroxide, chlorates, chlorine monoxides and other oxidation or reduction reagents. In the case of the photochemical process, an additional factor is ultraviolet radiation.

h) *In- situ* immobilization of contaminants:

This method is used for the immobilization of inorganic contaminants such as heavy metals (it is rarely applied to organic contaminants). The method is based on the introduction into the soil of different substances (cement, poly epoxide resin, zeolites) which bond strongly with the contaminants or create scarcely soluble chemical associations (carbonates or phosphates). The effects of remediation technique are also the modification of the soil chemical properties and hence causing the immobilization of heavy metals or their chemical transformation into less mobile forms by pH changes. This method is often used in emergency cases to prevent the contaminated area from spreading, often in connection with fit stabilization as a supporting technique. This method is applied to medium or low contaminated areas.

Biological treatment methods

In biological treatment, there is involvement of the use of microorganisms or vegetation or phytoremediation. Microorganisms like bacteria, fungi can mutate harmful chemicals to such substances which are less harmful than original one. Microbial bioremediation occurs under both aerobic and anaerobic conditions and at contaminated sites as either intrinsic or enhanced biodegradation. Bioremediation technologies can be largely classified as *ex-situ* or *in- situ*. *Ex-situ* treatment involves physical removal of contaminated area to another area within the site. Various *ex-situ* treatments processes like bioreactors, land farming, anaerobic digestion, composting, biosorption can be used in practice. In contrast to *ex-situ* techniques, *in- situ* techniques comprised of treatment of the contaminated material in place like bioventing which involves treatment of the contaminated soil and biostimulation of indigenous aquifer microorganisms. In bioventing, gas is injected into the subsurface to increase the biodegradation process of the contaminant. To expedite degradation of microbes, low amounts of oxygen is outfitted to contaminated unsaturated soils. With the help of oxygen, the microbes gain energy and carbon for their growth by oxidizing the contaminants and this oxygen is supplied by air injection wells that push air into the subsurface. Hydrocarbons and some chlorinated compounds are depraved by aerobic venting. Whole range of organic contaminants including phenol, polychlorinated hydrocarbons, oil and oil products, dioxins, etc can be treated by applying microbial treatment methods which appear to be more promising and the problem can be solve by any of the two methods.

1. Microbes already presented on the site may be collected and cultured in the laboratory.
2. In the laboratory strains of microbes can be developed that is capable of metabolizing particular chemicals.

For creating optimum conditions excavation of the soil prior to treatment offers the greatest scope. Using standard earth moving techniques excavated soil can be placed on thin layers to various depths and then microbes and nutrients applied using standard agricultural techniques such as fertilizing, ploughing etc. For example, oil zapper used for treatment of oil contaminated soils

Bioreactors: Bioreactors treated the contaminated soil either in solid or slurry phase. Because of more manageable, controllable and predictable conditions in a bioreactor system the rate and extent of biodegradation are greater than in situ or in solid-phase systems. Before being placed in a bioreactor soil requires pre-treatment (e.g., excavation) or the pollutant can be removed from the soil via soil washing or physical extraction process (e.g., vacuum extraction). Mixing in a closed container confirms the pollutants, water, air, nutrients and microorganisms are in permanent contact. The pH can be maintained by adding acid or alkalinity. A slurry bioreactor is a containment vessel and apparatus used to devise a three-phase (solid, liquid, and gas) mixing condition. To make possible the bioremediation rate of water-soluble pollutants and soil bound contaminants mixed to form water slurry and biomass capable of degrading target contaminants.

Phytoremediation

In this technique plants are used to extract, immobilize or degrade the contaminants in soil, groundwater and other contaminated media. Large areas of shallow contamination can be best treated by this process. However phytoremediation has its limitation of possible bioconcentration of contaminants up the food chain. The contaminated vegetation and root zone may impact plant-eating animals and soil organisms. The applicability of phytoremediation is limited by several factors. First, it is important that the polluted site of significance is able to sustain plant growth. This requires proper climate, soil characteristics such as pH and texture, and sufficient water and nutrients. Second, Phytoremediation is practical only in situations where contamination is shallow because plant roots go deep. Third, for situations requiring rapid treatment, it is not suitable since the time requirements for phytoremediation are sometimes long relative to some conventional technologies such as land filling and incineration. The process of phytoremediation takes place through several mechanisms:

1. Direct uptake, and absorption into plant biomass of contaminants
2. In the subsurface Immobilization or Phytostabilization of contaminants
3. Discharge of plant enzymes into the rhizosphere that proceed directly on the contaminants
4. In the rhizosphere stimulation of microbial mediated degradation

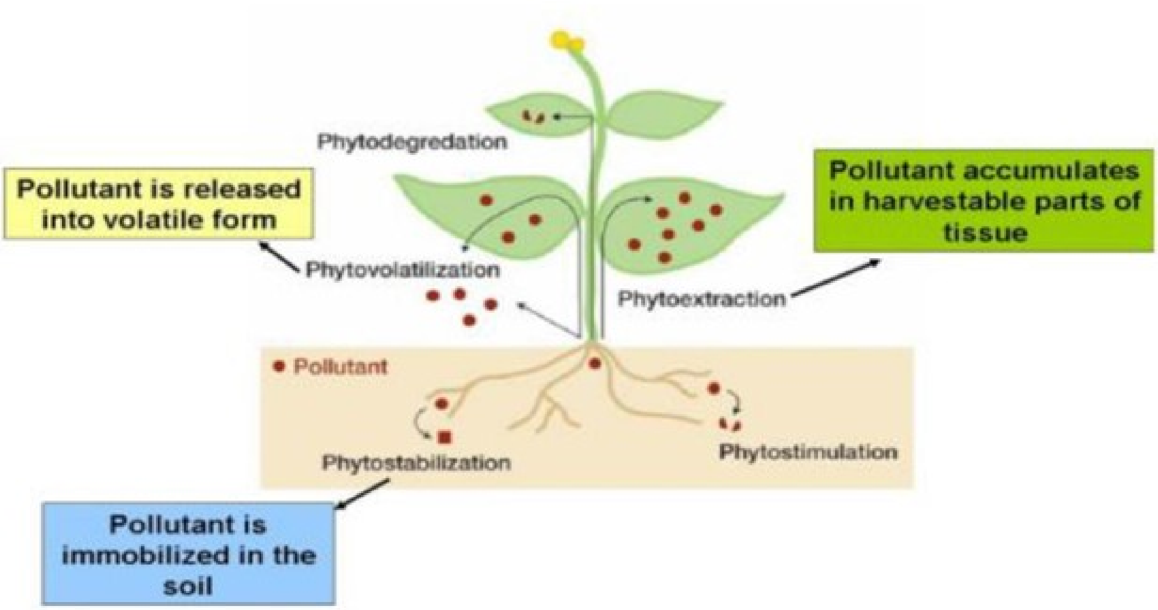


Fig. 31.5 Mechanisms of Bioremediation by plants

Source: Pilon Smits, 2005 Annual Reviews in plant Biol

Biostimulation and Bioaugmentation

Bioaugmentation and biostimulation are two practices that utilize microorganisms that are capable of degrading contaminants to purify contaminated areas.

Bioaugmentation

Bioaugmentation is the addition of specific cultured microorganisms, especially archaea and bacteria into contaminated soil or groundwater for the purpose of biodegradation of contaminants. Cultured microorganisms are added to the contaminated environment. These microbes are specific microorganisms identified as microorganisms that are capable of degrading specific target contaminants. They increase the rate of degradation of contaminants. Therefore, bioaugmentation is used in many processes: to accelerate the reductive dechlorination process, achieve remediation targets, and realize cost savings. Due to adding of cultured microorganisms, the microbial population at the site increases. Moreover, it improves the clean-up process and reduces the time and cost of the degradation process. Bioaugmentation is commonly practised in the municipal wastewater treatment plants. Microbes are added to activated sludge bioreactors in order to enhance the breakdown of contaminants. Bioaugmentation is important in clearing fuel contaminations, especially petroleum spills in soil and water. Since cultured microorganisms are introduced into an environment that is new to them, their establishment is problematic and the success of the biodegradation process is also doubtful.

Biostimulation

Biostimulation is the stimulation of existing microorganisms through modification of the environment by adding nutrients (phosphorus and nitrogen), electron donors and electron acceptors, to promote the biodegradation process.Theenvironment is modified in order to stimulate native microorganisms especially bacteria those are capable of biodegradation. Existing microorganisms are stimulated to promote degradation. Biodegradation is a natural process that is done by microorganisms. Biostimulation can be enhanced by the bioaugmentation or the addition of exogenous microorganisms in order to increase the microbial population in the site. However, the biostimulation process needs prior knowledge of the microbes that are present and their in situ activities.

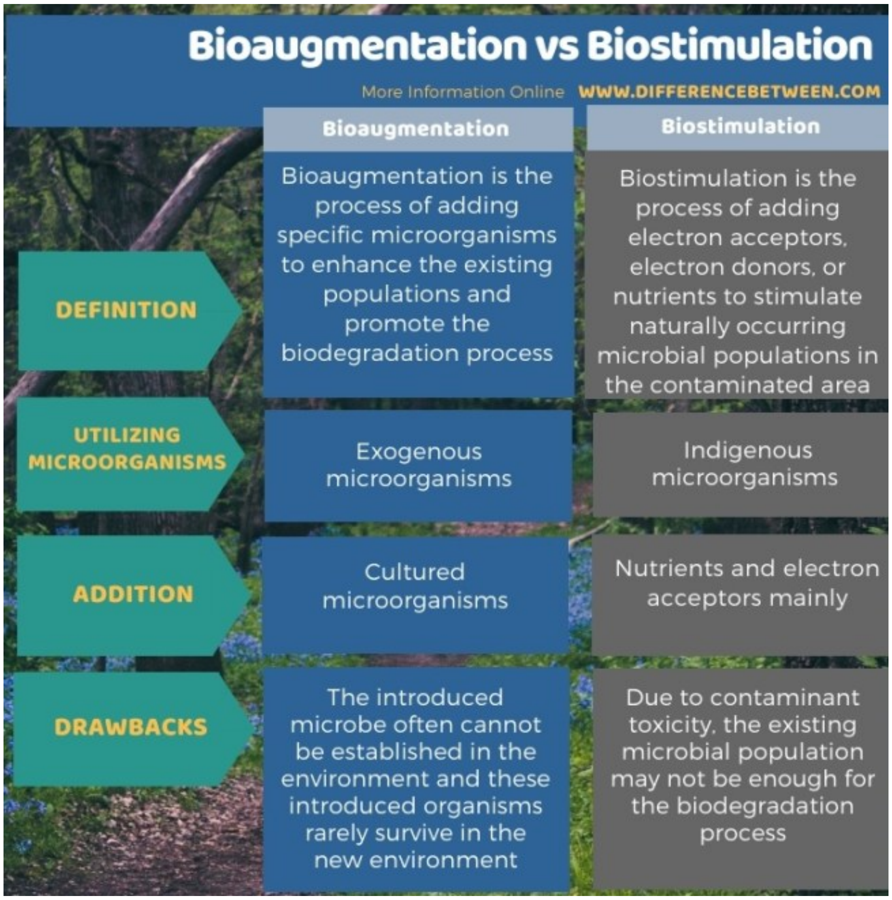
Similarities between Bioaugmentation and Biostimulation

- Bioaugmentation and biostimulation are two sustainable treatment methods to clean polluted areas.
- Biostimulation can be enhanced by bioaugmentation.
- In both processes, microorganisms are utilized.
- Both methods are biological methods.
- These methods do not result in toxic by-products and are not harmful, unlike chemical methods.
- Both methods have received much attention nowadays due to their potential and sustainability.
- They are promising and long-term solutions for the degradation of contaminated soil and water.
- They are cost-effective methods, unlike chemical methods

Difference between Bioaugmentation and Biostimulation

Bioaugmentation is the process of adding specific microorganisms to enhance the existing populations and promote biodegradation process while biostimulation is the process of adding electron acceptors, electron donors, or nutrients to stimulate naturally occurring microbial populations in the contaminated area. So, this is the difference between bioaugmentation and biostimulation.

In bioaugmentation, exogenous microorganisms are mainly used, while in biostimulation, indigenous microorganisms are used. Therefore, this is another difference between bioaugmentation and biostimulation.



Bioaugmentation vs Biostimulation

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	Bioaugmentation	Biostimulation
DEFINITION	Bioaugmentation is the process of adding specific microorganisms to enhance the existing populations and promote the biodegradation process	Biostimulation is the process of adding electron acceptors, electron donors, or nutrients to stimulate naturally occurring microbial populations in the contaminated area
UTILIZING MICROORGANISMS	Exogenous microorganisms	Indigenous microorganisms
ADDITION	Cultured microorganisms	Nutrients and electron acceptors mainly
DRAWBACKS	The introduced microbe often cannot be established in the environment and these introduced organisms rarely survive in the new environment	Due to contaminant toxicity, the existing microbial population may not be enough for the biodegradation process

8. Municipal and Hazardous Solid Wastes

Waste is defined as any unwanted or unusable substance that is discarded after primary use. Wastes are normally generated as a result of human and animal activities. Urbanization and rapid advancements in industrialization has led to an increase in the production and consumption processes resulting in the generation of wastes from various sectors that include agricultural, commercial, domestic, industrial, institutional, social and from community activities. Over time, these wastes accumulate and can have real impacts on the health and the environment. Waste management is intended to reduce adverse effects of waste on health, the environment or aesthetics. So to carry out efficient management of wastes, knowledge about the source of wastes, its types and classification must be known. Hence, this module gives us an overview about wastes and its classification. Classification of wastes Wastes are commonly classified based on the physical state as solid wastes, liquid wastes and gaseous wastes. Solid wastes are any discarded or abandoned materials that can be solid, liquid, semi-solid or containerized gaseous material discarded by the human society. These include urban wastes, agricultural wastes, biomedical wastes and radioactive wastes. The term refuse is also used for solid wastes. Examples of solid wastes include waste tires, septage, scrap metal, latex paints, furniture and toys, garbage, appliances and vehicles, oil and anti-freeze, empty aerosol cans, paint cans and compressed gas cylinders, construction and demolition debris, asbestos, plastics, styrofoam containers, bottles etc. Liquid wastes : Liquid wastes can be defined as liquids/fluids that are generated from washing, flushing or manufacturing processes of the industries. They are also called as sewage. The most common practice of disposing liquid waste is to discharge it in ground or rivers and other water bodies without treatment.

Examples: domestic washings, chemicals, oils, waste water from ponds, Wastewater from manufacturing industries, manure, waste oil, fats, oils or grease (FOG), used oil, and hazardous household liquids.

Classification of solid wastes

It is mandatory to classify solid wastes into groups that pose similar risks to the environment and human health for safe disposal. According to the modern systems of waste management, solid wastes are classified based on their source, type, properties and its effect on human health and environment. Source based classification Wastes are produced from different sources and are categorized as follows.

Municipal solid waste (MSW)

Municipal solid waste commonly referred to as trash, garbage or refuse comprises of street wastes, dead animals, market wastes, abandoned vehicles, household garbage, rubbish, construction and demolition debris, sanitation residue, packaging materials, trade refuges etc. They are collected from residential houses, markets, streets and other places mostly from urban areas and disposed of by municipal bodies. The proportion of different constituents of municipal wastes vary from place to place and season to season depending on the food habits, life style, standard of living and extent of commercial and industrial activities in the area. Municipal wastes their contents and source are illustrated in table given below. Municipal solid wastes are further categorized based on their physical, chemical and biological properties Industrial wastes Wastes generated during industrial activities such as manufacturing and processing involved in chemical plants, paint industry, cement factories, metallurgical plants, thermal power plants, petroleum, coal, gas, sanitary, textile, food processing and paper industry are referred to as industrial wastes. Some examples of industrial wastes are chemical solvents, paints, sandpaper, paper products, industrial by-products, metals, and radioactive wastes. Industrial solid wastes are further classified as hazardous and nonhazardous wastes. Institutional/ Commercial wastes Solid wastes originating from administrative, educational and public buildings such as offices, schools, colleges, hospitals, government centres, prisons and other commercial establishments like wholesale and retail stores, restaurants, hotels, markets, warehouses. Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes are the examples of industrial and commercial wastes.

Agricultural wastes Agriculture wastes includes both natural (organic) and non-natural wastes generated through farming activities. These activities include but are not limited to dairy farming, horticulture, seed growing, livestock breeding, grazing land, market gardens, nursery plots, and even woodlands. Some of agricultural wastes include spoiled food grains, vegetables, animal and plant wastes, litter, pesticides,fertilizers etc. Other agricultural wastes are produced from agricultural products processing industries like sugarcane factories, tobacco processing units, slaughter houses, livestock, poultry etc. Agricultural wastes are mostly biodegradable but few wastes like pesticide and fertilizers are toxic. When discharged to the environment, agricultural wastes can be both beneficial and detrimental to living matter.

Hazardous wastes

Hazardous waste is defined as chemical material that can no longer be used for its intended purpose and is known to be harmful or potentially harmful to plants, animals and human health or to the environment. Hazardous wastes may be in the form of solids, liquids, sludge’s or gases. In some cases, although the active agents may be liquid or gaseous, they are classified as solid waste because they are confined in solid containers. They are generated primarily by chemical production, manufacturing and other industrial activities. The hazardous waste materials may be toxic, reactive, ignitable, explosive, corrosive, infectious or radioactive. If improperly handled, they can cause substantial harm to human health and to the environment. So good management practice should ensure that hazardous wastes are collected, stored, transported and disposed off separately, to render them innocuous. Some of the important hazardous wastes are lead, mercury, cadmium, chromium, many drugs, leather, pesticides, dye, rubber, solvents, paints and effluents from different industries.

Waste minimization

Certain concepts are fundamental to waste management policy universally. These include waste minimization or prevention, waste hierarchy, life-cycle of a product, resource efficiency and environmentally sound management. Waste minimization refers to strategies that aim to prevent waste at source through upstream interventions (UNEP, 2013). Waste minimization involves redesigning products and/or changing societal patterns, concerning consumption and production, of waste generation, to prevent the creation of waste and minimize the toxicity of waste that is produced (USEPA, 1995). The most effective way to reduce waste is by not creating it in the first place. Some examples of waste reduction include using reusable plates and coffee mugs instead of disposable ones, buying durable products that can be repaired rather than replaced, etc.

The need for waste minimization

Waste is not only an environmental problem but also an economic loss as these are resources that are not being used. The amount of waste generated is steadily increasing across the world. This can be attributed to a number of factors like change in consumptive patterns of people, economic growth and globalisation etc. The increasing quantity of waste is in turn putting high demand on land as landfill is one of the commonest techniques for tackling waste. However, globally the available land for this purpose is decreasing due to growing population and demand for land for other purposes. Thus, the shrinking land resource is one of the major drivers for waste minimization.

Secondly, the dumpsites or landfill sites have been identified as a major contributor of green house gases thus confirming their positive role in climate change. This in turn is drawing attention to better waste management practices thatemphasize on waste reduction. Thirdly, the cost of waste management is going high. In order to overcome this it becomes essential to target the reduction in waste production, which can be achieved by better production processes. Therefore it can be concluded that the increasing quantity of waste, decreasing availability of landfill site, role of waste in climate change and the high cost of waste management are some of the important drivers for minimizing the quantity of waste.

Approaches to waste minimization

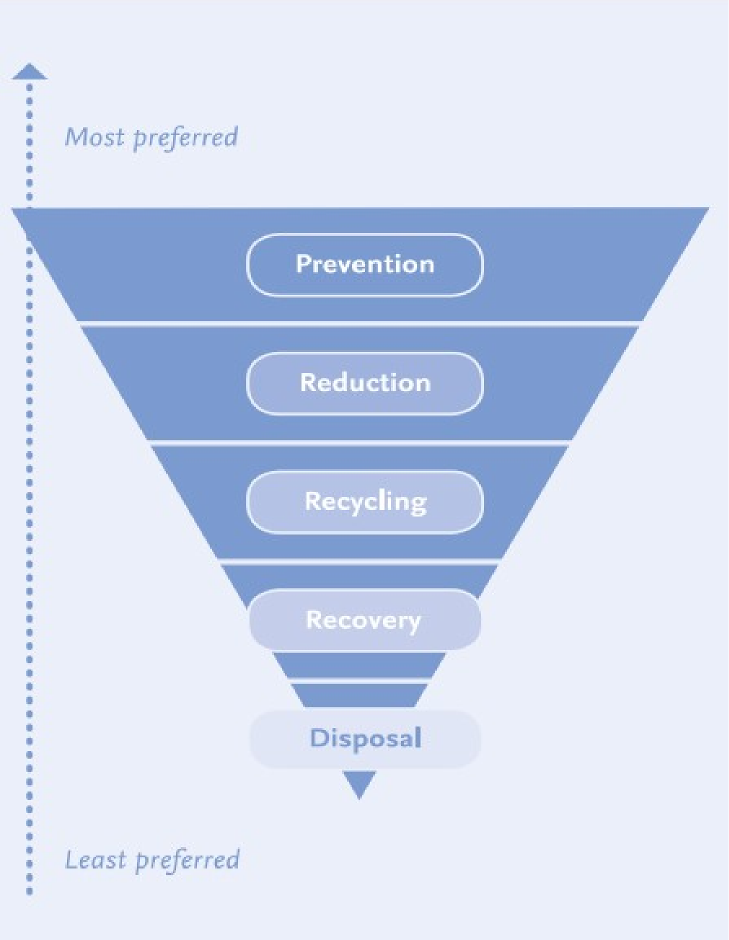
Having realized the need for minimizing waste the next step would be to explore the ways to achieve this. Waste generation has two sides namely the production side and the consumption side and it is important to work on both the aspects in order to achieve this. At the production side actions must be taken at industrial level, which should include

i. Effective processes for manufacturing products with enhanced materials
ii. Cleaner and safer production
iii. Improved design for reuse, recycle and durability
iv. Resource maximization
v. Reducing the volume of toxic materials
vi. Reduction of production waste
vii. Facilitate recycling

At consumptive level actions must be taken at individual level which should include

i. Increased awareness on impact of waste and role of individuals to tackle the same
ii. Change in consumption behavior and lifestyles
iii. Participation in waste management programs

Hierarchy of waste management The waste management hierarchy indicates an order of preference for action to reduce and manage waste (UNEP, 2013). It is usually represented as an inverted pyramid.



The top of the pyramid is the flat base here (as it is inverted) and it emphasizes foremost on prevention of waste generation. Prevention can be done by using less material during manufacture. Avoiding hazardous material is also a means of prevention. Prevention is also known as reduce This is the first ‘R’ of waste management. The next preferred action is to reduce waste generation through re-use. Reuse refers to materials that can be used again in their original form. This is the second ‘R’ of waste management. Reuse can be done through repair, refurbishing the whole item or its spare parts. Recycling, including composting or anaerobic digestion, is the next preferred action. Recycling is the process of collecting and processing materials that would otherwise be disposed of as waste and turning them into new products. This is the third ‘R’ of waste management. After exhausting these three R’s the waste management looks at materials recovery and waste-to-energy processes. Energy is recovered from processes such as combustion and pyrolysis. The final action, which is represented by the pointed top of the pyramid, is disposal, which is the least preferred option. Landfill and incineration without energy recovery are the disposal options in waste hierarchy.

- Prevention: o Use less packing material o Reuse the packaging material. o Minimize printing and print on both sides. Reduce paper use by using email o Use one side printed paper as notepads The environmental benefits of prevention will reduce green house gas emissions, energy consumption and resource reuse.

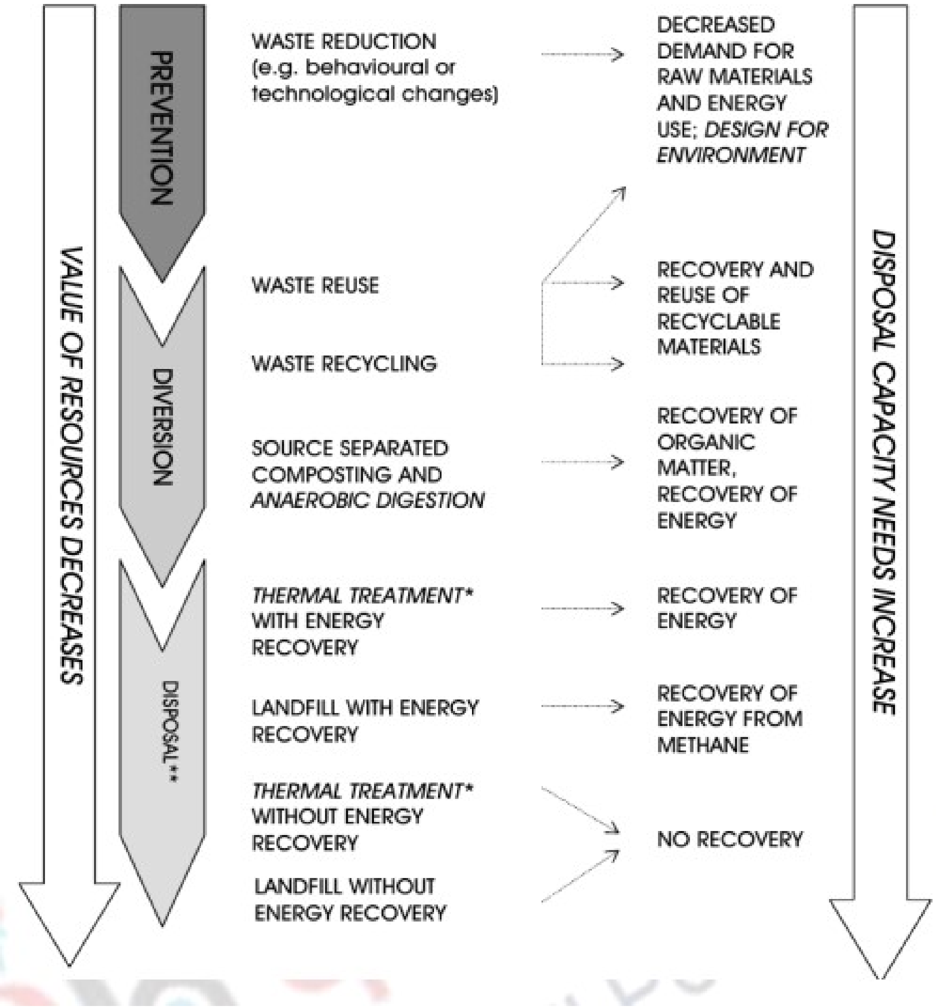
- Reuse: Segregate and shred paper and sell it. Use one side printed paper as notepads. Reuse reduces the environmental impacts

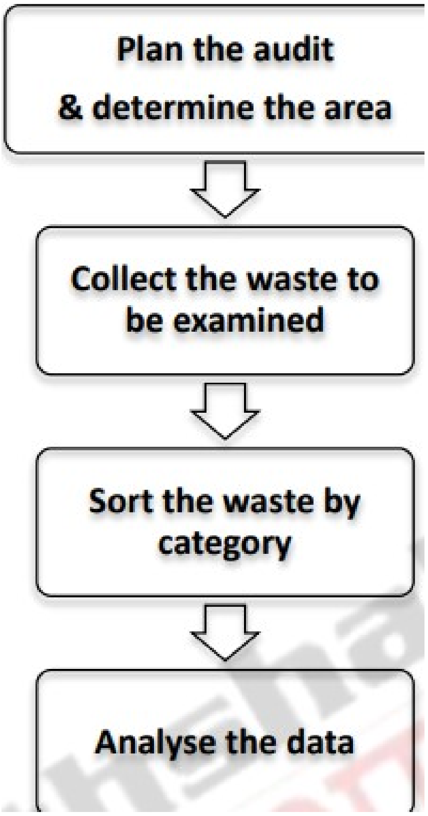
- Recycling: segregate paper from waste, sort by grade and recycle in paper industry. At certain times, energy is also recovered from paper. Recycling saves the energy and minimizes the fossil fuel consumption. Typically twice the amount of energy is saved.

- Disposal: If any of the above options does not work properly then the waste paper is compacted or baled to reduce its volume. By doing so the space in the landfill is reduced and the frequency of collection can be minimized. Paper should be avoided in landfills as it emits methane.

Waste Audit

For any waste management program to be effective it is essential that accurate information on the quantity and composition of the waste stream be known. A ‘waste audit’ is the first step towards it.


VALUE OF RESOURCES DECREASES
PREVENTION
DIVERSION
DISPOSAL**
WASTE REDUCTION (e.g. behavioural or technological changes)
DECREASED DEMAND FOR RAW MATERIALS AND ENERGY USE; *DESIGN FOR ENVIRONMENT*
WASTE REUSE
WASTE RECYCLING
RECOVERY AND REUSE OF RECYCLABLE MATERIALS
SOURCE SEPARATED COMPOSTING AND *ANAEROBIC DIGESTION*
RECOVERY OF ORGANIC MATTER, RECOVERY OF ENERGY
*THERMAL TREATMENT** WITH ENERGY RECOVERY
RECOVERY OF ENERGY
LANDFILL WITH ENERGY RECOVERY
RECOVERY OF ENERGY FROM METHANE
*THERMAL TREATMENT** WITHOUT ENERGY RECOVERY
LANDFILL WITHOUT ENERGY RECOVERY
NO RECOVERY
DISPOSAL CAPACITY NEEDS INCREASE



The first step in waste audit is planning and determining the study area. In case of institutional waste a team with the knowledge of waste together with its source of generation within the organization should be put together. This team can include one or two motivated and responsible people (depending on the size of the organization) from each of the business area like maintenance, cleaning, purchasing, production line etc. The objective of waste audit should be clear to all the members of the team for it to be successful. The team should then walk through the facility to get to know about the types of wastes generated and their location. This will then enable the team members to identify the study area. The second step should be to collect the waste from designated study area. There should be clear instruction regarding the type of waste to be collected for the audit. Protect gear should be worn by the team members for this purpose. After the collection comes the third step, which is sorting. Sorting will enable in analyzing the types and quantity of waste generated by the organization. The quantification of different components in the waste stream can either be done indirectly based on purchase records (i.e., material wasted = material purchased - (material used in product + material unused) or directly by weighing the waste sorted and collected.

The last step is to analyze the data thus collected so as to identify the waste trends and habits of the organization. This can be done using an excel spreadsheet analysis. This is crucial to draw a waste management plan and monitor its implementation. Thus waste audit is a crucial procedure for waste management.

What are the Initiatives Related to Waste Management?

- Solid Waste Management Rules 2016:
    - These rules replaced the Municipal Solid Wastes (Management and Handling) Rules, 2000 and focus on segregation of waste at source, responsibility on the manufacturer to dispose of sanitary and packaging wastes, user fees for collection, disposal and processing from the bulk generator.
- Waste to Wealth Portal:
    - It aims to identify, develop, and deploy technologies to treat waste to generate energy, recycle materials, and extract resources of value.
- Waste to Energy:
    - A waste-to-energy or energy-from-waste plant converts municipal and industrial solid waste into electricity and/or heat for industrial processing.
- Plastic Waste Management (PWM) Rules, 2016:
    - It mandates the generators of plastic waste to take steps to minimize generation of plastic waste, prevent littering of plastic waste, and ensure segregated storage of waste at source among other measures.
    - In Feb 2022, Plastic Waste Management (Amendment) Rules, 2022 were notified.
- Project REPLAN:
    - It aims to make carry bags by mixing processed and treated plastic waste with cotton fibre rags in the ratio 20:80.
- Plastic Waste Management (Amendment) Rules, 2022:

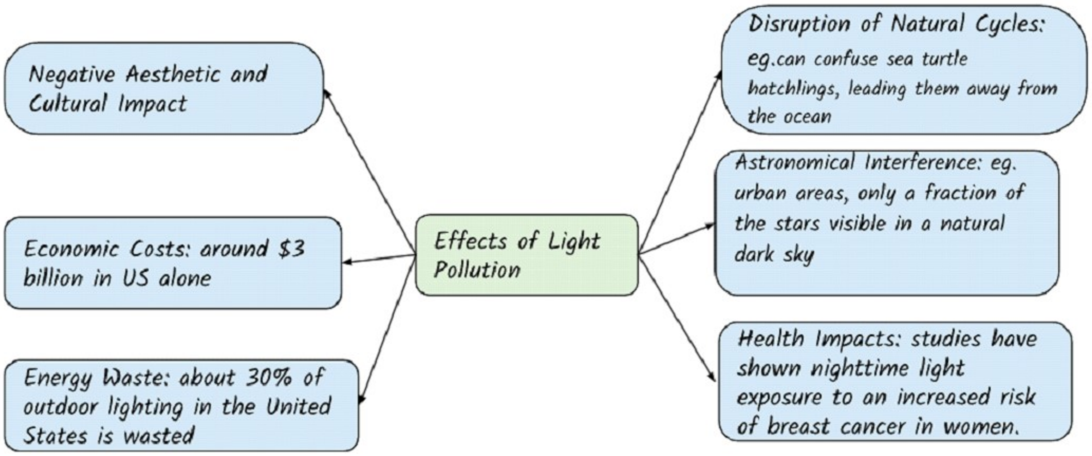
  - The rules specify the responsibilities of various stakeholders such as manufacturers, importers, retailers, and consumers. All these stakeholders have a role to play in ensuring that plastic waste is managed properly and does not end up polluting the environment.

9. Light pollution

Light pollution is the presence of excessive or misdirected artificial lighting in the environment, which disrupts the natural darkness of the night sky; examples include bright streetlights, billboard lights, and illuminated buildings.

Causes

- **Outdoor Lighting:** Unshielded streetlights and floodlights that emit light in all directions, contributing to sky glow and glare. (Example: Las Vegas Strip)
- **Urbanization:** Increased artificial lighting due to the rapid growth of cities. (Example: Tokyo, New York City)
- **Industrialization:** Intense lighting in industrial facilities.
- **Advertising and Signage:** Brightly lit billboards and neon signs.
- **Inefficient Lighting Practices:** Outdated lighting technologies emit excessive light.
- **Security Lighting:** Poorly designed or overly bright security lighting.
- **Sports Facilities and Stadiums:** Intense lighting for night events. (Example: Olympic stadiums)



Measures to control light pollution

- Energy-efficient and downward-directed lighting with motion sensors to reduce unnecessary illumination.
- **Dark Sky Parks and Reserves:** Establish designated areas with strict regulations to minimize light pollution and protect natural darkness for stargazing and wildlife.
- **Light-Optimized Urban Design**
- **Lighting Regulations and Policies:** Implement and enforce lighting ordinances that control the intensity, direction, and timing of outdoor lighting.
- **Innovative Lighting Technologies:** Encourage adoption of low-intensity, energy-efficient lighting solutions like LEDs and smart lighting systems.

Initiatives taken

- **International Dark-Sky Association (IDA):** Global organization protecting the night sky and reducing light pollution through guidelines and dark sky preserves.
- **Globe at Night:** Citizen science campaign reporting light pollution levels to raise awareness and support reduction efforts.
- **International Year of Light (IYL):** UN initiative promoting sustainable lighting practices and addressing light pollution.

- **The Dark Sky Scotland Project:** Promotes dark skies in Scotland through collaboration and implementation of effective lighting solutions.

10. THERMAL POLLUTION

Thermal pollution is defined as a human-caused change in the temperature of a natural body of water, such as an ocean, lake, river, or pond. When a plant or facility takes water from a natural resource and returns it at a different temperature, this is what happens. Typically, these facilities use it to cool their machinery or to aid in the production of their products.

- The term "thermal pollution" refers to an increase in the optimum water temperature caused by industrial processes (steel factories, electric power plants, and atomic power plants).
- Many industries generate their electricity and cool their generators with water.
- This hot water is released back into the system from which it was drawn, causing surface water to warm.
- If the system is not properly flushed, the temperature may rise permanently. If the water is released into the well-flushed system, however, there is no permanent increase in temperature.

CAUSES OF THERMAL POLLUTION

1. Water as a Coolant in Power, Manufacturing, and Industrial Facilities:

- The largest source of thermal pollution is manufacturing and production plants.
- These plants draw water from a nearby source to keep machines cool, then release it at a higher temperature back to the source.
- The water temperature rises dramatically when heated water returns to the river or ocean.
- When oxygen levels in the water are altered, it can affect the quality and longevity of life in underwater wildlife. This process can also obliterate streamside vegetation, which is reliant on constant oxygen and temperature levels.

- Industries are essentially lowering the quality of life for these marine-based life forms by altering natural environments, and if their practices are not controlled and careful, they can eventually destroy habitats.

2. Soil Erosion:

- Another major cause of thermal pollution is soil erosion.
- Water bodies rise as a result of constant soil erosion, exposing them to more sunlight.
- The high temperature may cause anaerobic conditions in aquatic biomes, which could be fatal.

3. Deforestation:

- Trees and plants block sunlight from reaching lakes, ponds, and rivers directly.
- When forests are cut down, these water bodies are exposed to direct sunlight, absorbing more heat and raising their temperature.
- Deforestation is also a major contributor to higher levels of greenhouse gases in the atmosphere, resulting in global warming.

4. Runoff from Paved Surfaces:

- Urban runoff from paved surfaces such as roads and parking lots can heat surface waters.
- During the summer, the pavement becomes quite hot, resulting in warm runoff that enters sewer systems and water bodies.

5. Natural Causes:

- Volcanoes and geothermal activity beneath the oceans and seas can cause warm lava to rise in temperature, raising the temperature of water bodies.
- Lightning can also cause massive amounts of heat to be released into the oceans. This means that the water source's overall temperature will rise, having significant environmental consequences.

EFFECTS OF THERMAL POLLUTION

- When it comes to the effects of thermal pollution, there are generally two schools of thought among recognized scientists and scholars.
- Some argue about the negative effects of pollution on marine ecosystems and how it undermines good environmental practices.
- However, some argue that if these industries did not function as they do, some of the most basic aspects of human life would be rendered obsolete.
- We wouldn't be able to properly maintain wastewater, we wouldn't have any industries capable of producing the goods we require, and so on.
- However, the negative effects of thermal pollution on ecosystems far outweigh the benefits that industries gain from participating in the practice.

1. Reduced levels of DO (Dissolved Oxygen): The amount of DO (Dissolved Oxygen) in water decreases as the temperature rises. Warm water has a lower oxygen content than cold water. Reduced oxygen levels can cause suffocation in plants and animals such as fish, amphibians, and copepods, resulting in anaerobic conditions. Warmer water encourages algae growth on the water's surface, which can reduce oxygen levels in the water over time.

2. Increase in Toxins: Due to the constant flow of high-temperature discharge from industries, toxins are being regurgitated into natural bodies of water at an alarming rate. These toxins could contain chemicals or radiation that hurt the local ecology and make people more susceptible to disease.

3. Biodiversity Loss: A decrease in biological activity in the water could result in a significant loss of biodiversity. Changes in the environment may cause certain species of organisms to relocate, while a large number of species may migrate in due to warmer waters. Organisms that can easily adapt to warmer temperatures may have an advantage over organisms that aren't used to them.

4. Ecological Impact:A sudden temperature change can kill a lot of fish, insects, plants, and amphibians. Hotter water may be beneficial to some species, but it could be fatal to others. The level of activity increases as the water temperature drops, and the level of activity decreases as the water temperature rises. Small temperature changes, such as one degree

Celsius, can cause significant changes in organism metabolism and other detrimental cellular biology effects in many aquatic species.

5. Affects Reproductive Systems: Increasing temperatures can cause a significant halt in the reproduction of marine wildlife (although reproduction can still occur between fish – the likelihood of defects in newborns is significantly higher) because reproduction can only occur within a certain temperature range. Excessive heat can cause immature eggs to be released or prevent certain eggs from developing normally.

6. Increases Metabolic Rate: Thermal pollution causes an increase in enzyme activity in organisms, causing them to consume more food than they would normally require if their environment remained unchanged. It disrupts the food chain's stability and changes the composition of species.

7. Migration: Warm water can cause certain species of organisms to migrate to a more suitable environment that meets their survival needs. As a result, those species that rely on them for their daily food may suffer as their food chain is disrupted.

CONTROLLING THERMAL POLLUTION

Thermal pollution must be controlled because its negative effects on aquatic ecosystems maybe detrimental in the future.

The following are viable solutions to chronic thermal discharge into water bodies:

1. **Cooling Ponds:**
    - The most basic method of controlling thermal discharges is to use cooling ponds or reservoirs.
    - In cooling ponds, heated effluents on the surface of the water maximize heat dissipation to the atmosphere while reducing water area and volume.
    - This is the simplest and most affordable method for cooling water to a very low temperature. However, in terms of air-water contact, the technique alone is less desirable and inefficient
2. **Cooling Towers:**

- The cooling process is defined as the use of water from water sources for cooling purposes, with the water being returned to the water body after passing through the condenser.
- Cooling towers are designed to control the temperature of water to improve the cooling process. Cooling towers are used to dissipate the recovered waste heat, thereby preventing thermal pollution.

3. Artificial Lake:

- Artificial lakes are man-made bodies of water that can be used as a cooling alternative to natural lakes.
- At one end, heated effluents can be discharged into the lake, while water for cooling can be withdrawn from the other. Through evaporation, the heat is eventually dissipated.
- These lakes must be replenished regularly. Several methods for converting thermal effluents from power plants into useful heat resources have been proposed and developed to maximize the benefits.

11. NOISE POLLUTION

- As per the Central Pollution Control Board's mandate for noise pollution, noise is defined as unwanted sound.
- Noise pollution is generally defined as regular exposure to elevated sound levels that may lead to adverse effects in humans or other living organisms.
- According to WHO, sound intensities which are less than 70 dB are not damaging for living organisms, regardless of how long or consistent the exposure is. Exposure for more that 8 hours to constant noise 85dB may be hazardous.

Causes of noise pollution

Industrialization:

- The growing industries in urban areas are a major cause of noise pollution these days which use various machines that are capable of generating a large amount of noise.

Improper Planning of Urban Areas:

- Improper and poor urban planning plays a major role in creating noise pollution, mostly in developing countries due to congested houses, small space, poor parking facilities and frequent fights over basic amenities which disrupts the environment of society.

Social Events:

- In several social events, songs are often played on full volume by the people which makes the living condition pretty worse thus creating noise pollution. Weddings, public gatherings involve loudspeakers to play music resulting in the production of unwanted noise in the neighbourhood.

Vehicles and transportation:

- Increased number of vehicles on the roads is one of the reasons for noise pollution.
- For example, traffic jams, underground trains, aircraft, etc produces heavy noise which may lead to a situation of hearing disability.

Construction Sites:

- Various construction activities which include mining, construction of bridges, dams, buildings, etc contributes greatly to creating noise pollution.

Agriculture:

- Agricultural machines such as tractors, trolleys, harvesters creates louder noises >> and most of farmers are unaware of its adverse health consequences

Effects of noise pollution

1. Health Issues

Hypertension:

- Longer exposure to loud noise result in elevated blood levels which can cause hypertension in humans.

Hearing Disability:

- Constant exposure to loud noise which is beyond the range of normal sound intensity can damage the eardrums, thus resulting in hearing disability.

Sleeping disorders:

- Noise pollution can also affect the sleep cycle of an individual which may lead to sleeping disorder, low energy level and fatigue.

Cardiovascular issues:

- Loud noises also results in an increase in normal blood pressure level and causes several cardiovascular diseases in a normal person.

Mental disorders

- Higher prevalence of mental disorders have been observed in people living in crowded areas and areas that are prone to a high level of noise pollution

Socio-economic issues:

- Since noise pollution leads to sleep disturbance and health issues >> it affects the individual's work performance during the day >> it leads to poor labour productivity.
- It also negatively affects school performance in children.

Communication troubles:

- High decibel noise can put trouble and may not allow two people to communicate freely. Constant sharp noise can give you a severe headache and disturb emotional balance.

Damages buildings:

- Noise has harmful effects on non-living materials too.
- Numerous examples can be cited where old buildings and even new constructions have developed cracks under the stress of explosive sounds.

Child development:

- Children appear to be more sensitive to noise pollution, and a number of noise-pollution-related diseases and dysfunctions are known to affect children, from hearing impairment to psychological and physical effects.

Effects on Wildlife and Marine Life

- Our oceans are no longer quiet. Thousands of oil drills, sonars, seismic survey devices, coastal recreational watercraft and shipping vessels are now populating our waters, and that is a serious cause of noise pollution for marine life.
- Whales are among the most affected, as their hearing helps them orient themselves, feed and communicate.
- Noise pollution thus interferes with cetaceans' (whales and dolphins) feeding habits, reproductive patterns and migration routes, and can even cause hemorrhage and death.
- Other than marine life, land animals are also affected by noise pollution in the form of traffic, firecrackers etc., and birds are especially affected by the increased air traffic.

Initiatives:

Central Pollution Control Board (CPCB):

- The CPCB is mandated to track noise levels, set standards as well as ensure, via their State units, that sources of excessive noise are controlled.
- The agency has a manual monitoring system where sensors are installed in major cities and few cities have the facility to track noise levels in real time.

Air (Prevention and Control of Pollution) Act, 1981

- Section 2 (a) of the Air (Prevention and Control of Pollution) Act, 1981 includes noise in the definition of 'air pollution'.
- Noise emanating from industry is regulated by State Pollution Control Boards / Pollution Control Committees (SPCBs / PCCs) for states / Union territories under the Air (Prevention and Control of Pollution) Act, 1981.

Noise Pollution (Regulation and Control) Rules, 2000

- Noise pollution and its sources are regulated under The Noise Pollution (Regulation and Control) Rules, 2000 under The Environment (Protection) Act, 1986.
- The Act has defined ambient acceptable noise levels, silence zones, restrictions on the use of loudspeakers, horns, sound-emitting construction equipment, and bursting of crackers.
- It has also laid down the responsibility for enforcement. *ƒ*
- At present, violation of noise pollution rules is a criminal offence punishable under Environment (Protection) Act, 1986

Environment (Protection) Rules, 1986

- Noise standards for motor vehicles, air-conditioners, refrigerators, diesel generators and certain types of construction equipment are prescribed under the Environment (Protection) Rules, 1986.

National Ambient Noise Monitoring Network (NANMN)

- 70 noise monitoring stations under the NANMN was established in 2011, across seven cities.

Silence zones:

- These are declared by the state governments >> around hospitals, educational institutions and courts.

Judicial initiatives:

- Revising fines for violations of noise pollution norms:
- The National Green Tribunal in 2019, while hearing a case related to noise pollution, had asked the Central Pollution Control Board to look at revising fines for violations of noise pollution norms.
- Ban on loudspeakers during night time at public places:
- The Supreme Court in 2005 banned the use of loudspeakers and music systems between 10 pm to 6 am (except in the cases of public

emergencies) at public places citing serious effects of noise pollution on health of the people living in such areas.

- Use of loudspeaker – not a fundamental right:
- In 2016, the Bombay High Court ruled that the use of loudspeaker was not a fundamental right.
- The Bombay High Court observed that no religion or sect could claim that the right to use a loudspeaker or a public address system was a fundamental right conferred by Article 25 of the Constitution of India.

Suggestions:

Worker's safety:

- To provide protective devices like ear muffs or cotton plugs to the workers who work in various industries and construction sites.

Zoning:

- To enforce acoustic zoning by distancing human settlements from industrial areas, aerodromes and railway stations.

Traffic management:

- Highway traffics should be diverted through bye-passes and over-bridges and should not be allowed to pass through the towns and cities.

Awareness building:

- Decibel metres should be installed along highways and in factories to check and control the intensity of noise pollution.

Sound proofing machines in industrial units:

- Sound-proof chambers should be installed for the machines generating loudnoise.

Creation of 'green belt' to check noise pollution

- It has been seen that plants are efficient absorbers of noise, especially noise of higher frequency.
- In metropolitan areas a green belt of vegetation and open spaces in general may have a great value in noise control as in air purification

Silence zones:

- Silence zones should be created for educational institutes, hospitals and important offices.

12. Evaluation of Industrial Disasters and Pollution - Case Studies

Evaluation of Industrial Disasters and Pollution

Industrial pollution is a major cause of degradation of the environment which in turn is a key factor in turning extreme weather events into natural disasters. Degradation of the environment not only intensifies disasters but also increases the potential for secondary disasters. From the point of view of response to disruptive events the society looks to stakeholders, institutions and the government. One such stakeholder interface in a semi-urban/rural setting is that between the local community and the neighbourhood industrial units.

The community forms a part of the industrial unit's work force and the industry in turn relies on this workforce during crisis for the success of its business continuity plans. The community-industry interface comprises of a human resource sensitised to the risk assessment of the industries, extent of its polluting activities and more importantly to safety techniques and actions to be taken during an emergency. This community-industry interface can be leveraged to reduce the vulnerability of the community. This paper examines how this can be achieved through the formation of positive community pressure on the polluting local industrial units created by the provision of suitable information in the public domain being interpreted for community consumption by the elements of this interface. Secondly by using the knowledge and expertise of this interface with regards to industrial safety and risk management to spur pre-disaster actions at the community level.

Bhopal disaster

Bhopal disaster, chemical leak in 1984 in the city of Bhopal, Madhya Pradesh state, India. At the time, it was called the worst industrial accident in history.

On December 3, 1984, about 45 tons of the dangerous gas methyl isocyanate escaped from an insecticide plant that was owned by the Indian subsidiary of the American firm Union Carbide Corporation. The gas drifted over the densely populated neighbourhoods around the plant, killing thousands of people immediately and creating a panic as tens of thousands of others attempted to flee Bhopal. The final death toll was estimated to be between 15,000 and 20,000. Some half a million survivors suffered respiratory problems, eye irritation or blindness, and other maladies resulting from exposure to the toxic gas; many were awarded compensation of a few hundred dollars. Investigations later established that substandard operating and safety procedures at the understaffed plant had led to the disaster. In 1998 the former factory site was turned over to the state of Madhya Pradesh.

The contemporary city

Bhopal is known as the "city of lakes"; its name is a derivation of Bhoj Tal ("Bhoj's Lake"), a lake constructed by Bhoj, a Hindu raja, in the 11th century. Today that lake is the Upper Bhopal Lake (Bada Talab), which is connected to the Lower Bhopal Lake (Chhota Talab) by an aqueduct. The lakes supply drinking water and are used for recreation. Around the lakes are several palaces and a fort dating from about 1728. Bhopal has several mosques, including the 19th-century Taj-ul-Masjid, the largest mosque in India. A three-day religious pilgrimage is held at the mosque annually, which attracts Muslim pilgrims from all parts of India. Other significant attractions in and around Bhopal include Fatehgarh Fort; Lakshminarayan Temple; Bharat Bhawan, a multipurpose arts centre; the Museum of Man, an open-air exhibit of replicas of different Indian tribal dwellings; and Van Vihar National Park, a zoological park.

Bhopal has several hospitals and a musical academy and is the seat of Bhopal University (founded 1970), which has several affiliated colleges in the city. Industries in the city include cotton and flour milling, cloth weaving and painting, and the manufacture of transformers, switch gears, traction motors, and other heavy electrical equipment, as well as matches, sealing wax, and sporting goods.

Background

- Post-midnight on December 3, 1984, Methyl Isocyanate (MIC) (Chemical formula- CH_3NCO or C_2H_3NO) leaked from the pesticide plant of Union Carbide (now Dow Chemicals), an MNC, in Madhya Pradesh capital Bhopal. It is estimated that about 40 tonnes of gas and other chemicals leaked from the Union Carbide factory.
- Methyl isocyanate is extremely toxic gas and if its concentration in the air touches 21ppm (parts per million), it can cause death within minutes of inhaling the gas.
- It is one of the worst chemical disasters globally and still continues to have its ill effects on the people of the affected areas.
- After the tragedy, the government of India enacted a Public Liability Insurance Act (1991), making it mandatory for industries to get insurance the premium for this insurance would contribute to an Environment Relief Fund to provide compensation to victims of a Bhopal-like disaster.

The Chernobyl disaster

- The Chornobyl disaster began on 26 April 1986 with the explosion of the No. 4 reactor of the Chornobyl Nuclear Power Plant, near the city of Pripyat in the north of the Ukrainian SSR, close to the border with the Byelorussian SSR, in the Soviet Union.

Causes of Chornobyl accident

- On April 26, 1986, the Number Four RBMK reactor at the nuclear power plant at Chernobyl, Ukraine, went out of control during a test at low power, leading to an explosion and fire that demolished the reactor building and released large amounts of radiation into the atmosphere.
- Safety measures were ignored, and the uranium fuel in the reactor overheated and melted through the protective barriers.
- RBMK reactors do not have what is known as a containment structure, a concrete and steel dome over the reactor itself designed to keep radiation inside the plant in the event of such an accident.

- Consequently, radioactive elements including plutonium, iodine, strontium, and cesium were scattered over a wide area.
- In addition, the graphite blocks used as a moderating material in the RBMK caught fire at high temperatures as air entered the reactor core, which contributed to the emission of radioactive materials into the environment.

Fatalities from disaster:

- According to the International Atomic Energy Agency, the initial explosion killed two workers, with 28 firemen and emergency clean-up workers dying within three months from Acute Radiation Sickness.
- In 2005, the UN predicted that around 4,000 people may eventually die due to radiation exposure.
- A 2006 World Health Organization study predicted 9,000 cancer-related fatalities in Ukraine, Belarus, and Russia as a result of the Chernobyl disaster.
- An area of roughly 2,600 sq km remains (permanently) out of bounds for human habitation, due to the radio-active contamination.
- The Chornobyl disaster is said to have released 400 times more radiation than the atomic bomb dropped on Hiroshima, Japan by the United States.

Who is to be blamed for the disaster?

- There is no consensus on who or what was to blame for the Chornobyl disaster.
- Lawyers and the chief designer of the reactor, N A Dollezhal, blamed the operators for failing to meet "production discipline."
- The Soviet Union emphasized human error as the cause of the disaster, rather than design or manufacturing flaws.
- Operators of the reactor did not agree with this version and believed their actions were by regulations.
- Some experts argued that inadequate human-machine interaction and design faults of the core and control system were the main causes of the accident.

- Most of the experts agree on one fact the explosion resulted from reckless decision-making and failure to follow proper guidelines by the reactor operators. Operators believed they always had access to a kill switch to stop reactor operation, but its design contributed to the explosion.

The Love Canal Disaster

One of the most famous and important examples of groundwater pollution in the U.S. is the Love Canal tragedy in Niagara Falls, New York. It is important because the pollution disaster at Love Canal, along with similar pollution calamities at that time (Times Beach, Missouri and Valley of Drums, Kentucky), helped to create Superfund, a federal program instituted in 1980 and designed to identify and clean up the worst of the hazardous chemical waste sites in the U.S.

Love Canal is a neighborhood in Niagara Falls named after a large ditch (approximately 15 m wide, 3–12 m deep, and 1600 m long) that was dug in the 1890s for hydroelectric power. The ditch was abandoned before it actually generated any power and went mostly unused for decades, except for swimming by local residents. In the 1920s Niagara Falls began dumping urban waste into Love Canal, and in the 1940s the U.S. Army dumped waste from World War II there, including waste from the frantic effort to build a nuclear bomb. Hooker Chemical purchased the land in 1942 and lined it with clay. Then, the company put into Love Canal an estimated 21,000 tons of hazardous chemical waste, including the carcinogens benzene, dioxin, and PCBs in large metal barrels and covered them with more clay. In 1953, Hooker sold the land to the Niagara Falls school board for $1, and included a clause in the sales contract that both described the land use (filled with chemical waste) and absolved them from any future damage claims from the buried waste. The school board promptly built a public school on the site and sold the surrounding land for a housing project that built 200 or so homes along the canal banks and another 1,000 in the neighborhood (Figure 1). During construction, the canal's clay cap and walls were breached, damaging some of the metal barrels.

Eventually, the chemical waste seeped into people's basements, and the metal barrels worked their way to the surface. Trees and gardens began to die; bicycle tires and the rubber soles of children's shoes disintegrated in noxious puddles. From the 1950s to the late 1970s, residents repeatedly complained of strange odors and substances that surfaced in their yards. City officials investigated the area, but did not act to solve the problem.

Local residents allegedly experienced major health problems including high rates of miscarriages, birth defects, and chromosome damage, but studies by the New York State Health Department disputed that. Finally, in 1978 President Carter declared a state of emergency at Love Canal, making it the first human-caused environmental problem to be designated that way. The Love Canal incident became a symbol of improperly stored chemical waste. Clean up of Love Canal, which was funded by Superfund and completely finished in 2004, involved removing contaminated soil, installing drainage pipes to capture contaminated groundwater for treatment, and covering it with clay and plastic. In 1995, Occidental Chemical (the modern name for Hooker Chemical) paid $102 million to Superfund for cleanup and $27 million to Federal Emergency Management Association for the relocation of more than 1,000 families. New York State paid $98 million to EPA and the US government paid $8 million for pollution by the Army. The total clean-up cost was estimated to be $275 million.

The Love Canal tragedy helped to create Superfund, which has analyzed tens of thousands of hazardous waste sites in the U.S. and cleaned up hundreds of the worst ones. Nevertheless, over 1,000 major hazardous waste sites with a significant risk to human health or the environment are still in the process of being cleaned.

Oil spills

Oil spills occur when petroleum oil is released into the ocean following accidents, such as vessels crashing or damage and problems with oil platforms and drilling. They can have devastating effects on the environment, affecting marine and coastal ecologies, and are not easy to remove. The ocean tide, currents and weather affect the movement of oil spills, making them unpredictable.

Radar data is typically used to detect oil spills with satellites, but it can be very difficult to locate oil spills as looking for relatively small patches of oil in vast oceans is a challenge. Identifying oil is also difficult, as a dark patch on the ocean may be from the event in question, or a natural release of oil or different substance altogether. Once a particular oil spill that needs to be monitored is identified, however, satellites can play a useful role in noting the source, mapping the extent and tracking the direction the spill may take.

Oil disaster – Exxon

On March 24, 1989 the oil tanker Exxon Valdez ran aground in Prince William Sound, Alaska, spilling 11 million gallons of oil. The ecologically sensitive location, season of the year, and large scale of this spill resulted in one of the largest environmental disasters in U.S. history.

Exxon settled in 1991 with funds disbursed in three discrete parts: criminal plea agreement ($25 million), criminal restitution ($100 million), and civil settlement ($900 million).

Impacts

The spill affected more than 1,300 miles of shoreline, with immense impacts for fish and wildlife and their habitats, as well as for local industries and communities.

The oil killed:

- An estimated 250,000 seabirds
- 2,800 sea otters
- 300 harbor seals
- 250 bald eagles
- As many as 22 killer whales
- Billions of salmon and herring eggs
- More than 25 years since the spill, the following species remain in a "Not Recovering" or "Unknown" status:
- Killer whales (family group known as pod AT1)
- Kittlitz's murrelets
- Marbled murrelets
- Pigeon guillemots

What's Happening Now?

Settlement funds have been used to fund multiple restoration and protection projects throughout Prince William Sound, the Gulf of Alaska, and for habitats outside of the state that are important for migratory species. More than 600,000 acres of land have been protected using settlement funds and matching funds from numerous restoration, research, and monitoring programs.

Current restoration activities are focused on:

- Long-term herring research and monitoring
- Long-term monitoring of marine conditions and injured resources
- Shorter-term harbor protection and restoration projects
- Lingering oil
- Habitat protection
- Long-term monitoring of marine conditions and restoration effectiveness is ongoing.

Ultimately, the Exxon Valdez spill resulted in a close examination of the status of oil spill prevention, response, and cleanup in the United States. One result was the passage of the Oil Pollution Act of 1990, which led to the establishment of NOAA's DARRP program.

British Petroleum Oil spill

On April 20, 2010, BP's Deepwater Horizon oil rig exploded, killing 11 men and dumping nearly 5 million barrels of oil—the equivalent of over 200 million gallons—into the Gulf of Mexico. The five Gulf states suffered hundreds of miles of oiled coastline, with Louisiana's coast and wildlife receiving the greatest percentage of direct ecological damage.

In April 2016, a federal judge approved the settlement between the U.S. Department of Justice and BP for natural resource injuries stemming from the spill. This settlement included the largest civil settlement ever awarded. Under this agreement, BP will pay $20.8 billion for restoration to address injuries to the Gulf ecosystem.

ENVIRONMENTAL EFFECTS

Even more than six years after the incident, the disaster's long-term effects are still unfolding. Damage done to animals and plants will have a rippling effect through the food web for years to come. Hydrocarbons from the crude oil remain in the Gulf of Mexico habitats and waters and will linger in some places for many years. The catastrophe further damaged ecosystems that were already compromised and collapsing, especially in the Mississippi River Delta and across coastal Louisiana.

Additional ecosystem and wildlife impacts include:BP-Oil-Disaster_2

A 2016 NOAA study found a large number of dead dolphins in heavily oiled places, including Barataria Bay, La.

A 2014 study found evidence of a 1,250-square-mile area of oil contamination on the ocean floor around the Macondo wellhead in deep Gulf sediments.

Studies estimate 800,000 birds died as a result of being exposed to BP oil.

Modeling for a recent stock assessment projected that between 20,000 and 60,000 Kemp's ridley sea turtles died in 2010 as a result of the spill.

A 2014 study found concentrations of PAH (polycyclic aromatic hydrocarbon) – which can cause harmful effects in many birds, fish and wildlife – in Barataria and Terrebonne marshes, which may persist for decades.

A 2012 study found that oiled marshes in Barataria Bay eroded at double the rate of non-oiled marshes.

A 2015 survey found that 70 percent of Americans believed BP should pay maximum fines under the Clean Water Act for its role in the 2010 Gulf oil spill.

Ongoing Response and Recovery

Restoring the Gulf Coast means making it better than it was before the spill. Different mechanisms are in place to ensure that happens, and that a significant portion of the fines BP and other responsible parties must pay will be invested in restoration of the areas damaged by the spill.

Natural Resource Damage Assessment (NRDA)

In the NRDA process, Trustees (government officials acting on behalf of the public) evaluate recreational opportunities lost as a result of the spill and injuries to natural resources like fish, birds, sea turtles, marine mammals and nearshore ecosystems. The Trustees assessed the type and amount of restoration needed in order to return the Gulf to its original condition and to compensate the public for the natural resource services that were injured or lost. The Gulf oil disaster NRDA was the largest one ever done.

One year after the spill, in 2011, BP agreed to provide up to $1 billion for early restoration projects under NRDA. Public meetings and thousands of comments from Gulf citizens helped form the early restoration phase and allowed Gulf restoration to begin sooner.

In October 2015, the Trustees released an ecosystem restoration plan to address impacts from the spill. The draft plan allocated up to $8.8 billion for restoration from a proposed settlement with BP. Learn more about NRDA funding for Gulf restoration.

The RESTORE Act

The bipartisan Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act (RESTORE Act) dedicates 80 percent of the civil penalties paid by BP and others responsible for the 2010 oil disaster toward Gulf restoration. The RESTORE Act established the Gulf Coast Ecosystem Restoration Council and designated that the penalty money be deposited into a Gulf Coast Restoration Trust Fund, which will be allocated according to the following framework:

35 percent equally divided among the five Gulf states for ecological restoration, economic development and tourism promotion;

30 percent plus interest managed by the RESTORE Council for ecosystem restoration under the Comprehensive Plan;

30 percent divided among the Gulf states according to a formula to implement state expenditure plans, which require approval of the Council;

2.5 percent plus interest for the Gulf Coast Ecosystem Restoration Science, Observation, Monitoring and Technology Program within the Department of Commerce’s National Oceanic and Atmospheric Administration (NOAA); and

2.5 percent plus interest allocated to the States for Centers of Excellence Research grants, which will each focus on science, technology and monitoring related to gulf restoration.

E-waste

E-waste or Electronic waste is any electrical or electronic equipment that’s been discarded. This includes working and broken items that are thrown in the garbage or donated to a charity reseller, their components, consumables, parts, and spares.

E-waste is particularly dangerous due to toxic chemicals that naturally leach from the metals inside when buried.

Harmful effects of e-waste:

Electronics contain toxic substances – therefore they must be handled with care when no longer wanted or needed.

The consequences of improper e-waste disposal in landfills or other non-dumping sites pose serious threats to current public health and can pollute ecosystems for generations to come. When electronics are improperly disposed of and end up in landfills, toxic chemicals are released, impacting the earth’s air, soil, water, and ultimately, human health.

Effects on Air quality:

Contamination in the air occurs when e-waste is informally disposed of by dismantling, shredding, or melting the materials, releasing dust particles or toxins, such as dioxins, into the environment that cause air pollution and damage respiratory health.

Chronic diseases and cancers are at a higher risk to occur when burning e-waste because it also releases fine particles, which can travel thousands of miles, creating numerous negative health risks to humans and animals.

The negative effects on air from informal e-waste recycling are most dangerous for those who handle this waste, but the pollution can extend thousands of miles away from recycling sites

The air pollution caused by e-waste impacts some animal species more than others, which may be endangering these species and the biodiversity of certain regions that are chronically polluted. Over time, air pollution can hurt water quality, soil, and plant species, creating irreversible damage to ecosystems.

Effects on Soil

When the improper disposal of e-waste in regular landfills or in places where it is dumped illegally, both heavy metals and flame retardants can seep directly from the e-waste into the soil, causing contamination of underlying groundwater or contamination of crops that may be planted nearby or in the area in the future. When the soil is contaminated by heavy metals, the crops become vulnerable to absorbing these toxins, which can cause many illnesses and doesn’t allow the farmland to be as productive as possible.

Effects on Water

After soil contamination, heavy metals from e-waste, such as mercury, lithium, lead, and barium, then leak through the earth even further to reach groundwater.

When these heavy metals reach groundwater, they eventually make their way into ponds, streams, rivers, and lakes. Through these pathways, acidification and toxicity are created in the water, which is unsafe for animals, plants, and communities even if they are miles away from a recycling site. Clean drinking water becomes problematic to find.

Acidification can kill marine and freshwater organisms, disturb biodiversity, and harm ecosystems. If acidification is present in water supplies, it can damage ecosystems.

Effects on Humans

Electronic waste contains toxic components that are dangerous to human health, such as mercury, lead, cadmium, polybrominated flame retardants, barium, and lithium.

The negative health effects of these toxins on humans include brain, heart, liver, kidney, and skeletal system damage. It can also considerably affect the nervous and reproductive systems of the human body, leading to disease and birth defects.

Improper disposal of e-waste is unbelievably dangerous to the global environment, which is why it is so important to spread awareness on this growing problem and the threatening aftermath.

To avoid these toxic effects of e-waste, it is crucial to properly re-cycle, so that items can be recycled, refurbished, resold, or reused.

Important international agreements related to e-waste:

International Convention for Prevention of Pollution from Ships (MARPOL)

MARPOL addresses pollution from ships by oil; by noxious liquid substances carried in bulk; harmful substances carried by sea in packaged form; sewage, garbage; and the prevention of air pollution from ships.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989)

The Basel Convention aims to protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements, and disposal of hazardous and other wastes. Among key provisions of the Basel Convention are environmentally sound management, transboundary movement, waste minimization, and waste disposal practices aimed at mitigating adverse effects on human health and the environment.

The Nairobi Declaration and decision IX/6 was adopted by the 9th meeting of the conference of the parties to the Basel Convention in 2006 and gave a mandate to the secretariat of the Basel Convention to implement a work plan for the environment sound management of e-waste.

Montreal Protocol on Ozone Depleting substances (1989)

The Montreal Protocol is an international treaty that aims to protect the ozone layer by phasing out the production and use of ozone-depleting substances (ODS). ODS, chlorofluorocarbons (CFCs), and hydrochlorofluorocarbon (HCFCs) as refrigerants are still used in some refrigerators and air conditioners. Waste refrigerators and air conditioners will also likely contain CFCs or HCFCs.

United Nations Framework on Convention on Climate Change (UNFCCC)

Although not directly involved in e-waste, UNFCCC has been active as part of the e-waste from toxic to the green initiative. Through the initiative, waste pickers in India have been trained to collect electronic waste, such as computers and mobile phones, for safe disposal and recycling.

Rotterdam Convention on Prior Informed Consent Procedure for certain hazardous chemicals and pesticides in international trade (1998)

The Rotterdam Convention promotes shared responsibilities in relation to the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm. It also calls on exporters of hazardous chemicals to use proper labeling, to include directions on safe handling, and to inform purchasers of any known restrictions or bans.

The Durban Declaration, 2008

The declaration called for an African regional platform/forum on e-waste alongside international bodies. The requirements of the declaration are as follows: countries must review existing legislation, improve their compliance with legislation and amend existing legislation regarding e-waste management.

E-waste generation in India

According to the Central Pollution Control Board (CPCB), India generated more than 10 lakh tonnes of e-waste in 2019-20, an increase from 7 lakh tonnes in 2017-18.

But the e-waste dismantling capacity has not been increased from 7.82 lakh tonnes since 2017-18.

In 2018, the Ministry of Environment had told the tribunal that 95% of e-waste in India is recycled by the informal sector and scrap dealers unscientifically dispose of it by burning or dissolving it in acids.

E-Waste Management Rules, 2016

The Ministry of Environment, Forest and Climate Change (MoEFCC) notified the E-Waste Management Rules, 2016 by replacing the E-waste (Management & Handling) Rules, 2011.

- Over 21 products (Schedule-I) were included under the purview of the rule. It included Compact Fluorescent Lamp (CFL) and other mercury-containing lamps, as well as other such equipment.
- For the first time, the rules brought the producers under Extended Producer Responsibility (EPR), along with targets. Producers have been made responsible for the collection of E-waste and its exchange.

- Various producers can have a separate Producer Responsibility Organisation(PRO) and ensure collection of E-waste, as well as its disposal in an environmentally sound manner.
- The Deposit Refund Scheme has been introduced as an additional economic instrument wherein the producer charges an additional amount as a deposit at the time of sale of the electrical and electronic equipment and returns it to the consumer along with interest when the end-of-life electrical and electronic equipment is returned.
- The role of State Governments has been also introduced to ensure the safety, health, and skill development of the workers involved in dismantling and recycling operations.
- A provision of penalty for violation of rules has also been introduced.
- Urban Local Bodies(Municipal Committee/Council/Corporation) has been assigned the duty to collect and channel the orphan products to authorized dismantlers or recyclers.
- Allocation of proper space to existing and upcoming industrial units for e-waste dismantling and recycling.

Way forward:

E-waste management is a great challenge for governments of many developing countries such as India. This is becoming a huge public health issue and is exponentially increasing by the day.

To separately collect, effectively treat, and dispose of e-waste, as well as divert it from conventional landfills and open burning, it is essential to integrate the informal sector with the formal sector.

The competent authorities in developing countries need to establish mechanisms for handling and treatment of e-waste safely and sustainably.

Increasing information campaigns, capacity building, and awareness are critical to promoting environment-friendly e-waste management programs.

More efforts are required on the improvement of the current practices such as collection schemes and management practices to reduce the illegal trade of e-waste.

Reducing the number of hazardous substances in e-products will also have a positive effect in dealing with the specific e-waste streams since it will support the prevention process.

Oil Disasters – Gulf of Mexico

What is the source of the spill?

- The source of the miles-long oil spill was believed to be in the Bay Marchand area of the Gulf of Mexico.
- It appears to be coming from a source underwater at an offshore drilling site
- Damaged pipelines in the Bay are possible reasons for the spill.

Gulf of Mexico

- The Gulf of Mexico is an ocean basin and a marginal sea of the Atlantic Ocean, largely surrounded by the North American continent.

What is an oil spill?

- An oil spill refers to any uncontrolled release of crude oil, gasoline, fuels, or other oil by-products into the environment.
- **Harmful effects of oil spill**
    - Oil spills can pollute land, air, or water.
    - It prevents sufficient amounts of sunlight from penetrating the surface.
    - It also reduces the level of dissolved oxygen.
    - Oil-coated birds and marine mammals may die from hypothermia
    - Ingested oil can be toxic to affected animals, and damage their habitat and reproductive rate.

Cleanup of Oil Spill:

- **Containment Booms**: Floating barriers, called booms are used to restrict the spread of oil and to allow for its recovery, removal, or dispersal.
- **Skimmers**: They are devices used for physically separating spilled oil from the water's surface.

- **Sorbents**: Various sorbents (e.g., straw, volcanic ash, and shavings of polyester-derived plastic) that absorb the oil from the water are used.
- **Dispersing agents:** These are chemicals that contain surfactants, or compounds that act to break liquid substances such as oil into small droplets.
- **Biological agents**: Nutrients, enzymes, or microorganisms such as Alcanivorax bacteria or Methylocella silvestris that increase the rate at which natural biodegradation of oil occurs are added

Oil Disaster-Exxon

What Happened?

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Prepared by

Dr.G.Annadurai M.Sc.,Ph.D.,
Professor
Sri Paramakalyani Centre for Excellence in Environmental Sciences
MANONMANIAM SUNDARANAR UNIVERSITY
Alwarkurichi – 627412, Tamilnadu, INDIA