

ENVIRONMENTAL STUDIES

(Diploma 3RD sem)



Education for a World State

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MODULE -1

AIR POLLUTION (CHAPTER-1)

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. The NRDC has been a leading authority on this law since it was established in 197. 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. In addition, they may be natural or man-made. Pollutants can be classified as either primary or secondary. 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

Sulphur oxides (SO_x):

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 (NO_x):

Especially nitrogen dioxide is emitted from high temperature combustion. Nitrogen dioxide is the chemical compound with the formula NO₂. 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 (NH₃) – emitted from agricultural processes. Ammonia is a compound with the formula NH₃. 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.

Secondary pollutants include:

- i. **Particulate matter** formed from gaseous primary pollutants and compounds in photochemical smog. Smog is a kind of air pollution; the word “smog” is a portmanteau of smoke and fog. Classic smog results from large amounts of coal burning in an area caused by a mixture of smoke and sulphur dioxide. Modern smog does not usually come from coal but from vehicular and industrial emissions that are acted on in the atmosphere by sunlight to form secondary pollutants that also combine with the primary emissions to form photochemical smog.
- ii. **Ground level ozone (O_3)** formed from NO_x and VOCs. Ozone (O_3) is a key constituent of the troposphere (it is also an important constituent of certain regions of the stratosphere commonly known as the Ozone layer). Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant, and a constituent of smog.
- iii. **Peroxyacetyl nitrate (PAN)** – similarly formed from NO_x and VOCs and is a dangerous air pollutant mostly affects our respiratory system and nervous system.

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. SO_2 causes bleaching of leaves, chlorosis, injury and necrosis of leaves. NO_2 results in increased abscission and suppressed growth. O_3 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.

4. Control of Air Pollution:

The following items are commonly used as pollution control devices by industry or transportation devices. They can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere.

i. Particulate Control:

Mechanical collectors (dust cyclones, multi-cyclones)- Cyclonic separation is a method of removing particulates from an air, gas or water stream, without the use of filters, through

vortex separation. Rotational effects and gravity are used to separate mixtures of solids and fluids.

A high speed rotating (air) flow is established within a cylindrical or conical container called a cyclone. Air flows in a spiral pattern, beginning at the top (wide end) of the cyclone and ending at the bottom (narrow) end before exiting the cyclone in a straight stream through the centre of the cyclone and out the top.

Larger (denser) particles in the rotating stream have too much inertia to follow the tight curve of the stream and strike the outside wall, falling then to the bottom of the cyclone where they can be removed.

In a conical system, as the rotating flow moves towards the narrow end of the cyclone the rotational radius of the stream is reduced, separating smaller and smaller particles. The cyclone geometry, together with flow rate, defines the cut point of the cyclone. This is the size of particle that will be removed from the stream with 50% efficiency. Particles larger than the cut point will be removed with a greater efficiency and smaller particles with a lower efficiency.

ii. Electrostatic Precipitators:

An electrostatic precipitator (ESP), or electrostatic air cleaner is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream.

In contrast to wet scrubbers which apply energy directly to the flowing fluid medium, an ESP applies energy only to the particulate matter being collected and therefore is very efficient in its consumption of energy (in the form of electricity).

iii. Particulate Scrubbers:

The term Wet scrubber describes a variety of devices that remove pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.

The design of wet scrubbers or any air pollution control device depends on the industrial process conditions and the nature of the air pollutants involved. Inlet gas characteristics and dust properties (if particles are present) are of primary importance.

Scrubbers can be designed to collect particulate matter and/or gaseous pollutants. Wet scrubbers remove dust particles by capturing them in liquid droplets. Wet scrubbers remove pollutant gases by dissolving or absorbing them into the liquid.

Any droplets that are in the scrubber inlet gas must be separated from the outlet gas stream by means of another device referred to as a mist eliminator or entrainment

separator (these terms are interchangeable). Also, the resultant scrubbing liquid must be treated prior to any ultimate discharge or being reused in the plant:

i. Vehicular pollution can be checked by regular tune-up of engines; replacement of more polluting old vehicles; installing catalytic converters; by engine modification to have fuel efficient (lean) mixtures to reduce CO and hydrocarbon emissions; and slow and cooler burning of fuels to reduce NO_x emission.

ii. Using low sulphur coal in industries.

iii. Minimise or modify activities which cause pollution e.g. transportation and energy production.

Global Warming and Greenhouse Effect

The history of the greenhouse effect and global warming. First of all, predicted by Svante Arrhenius was a Swedish scientist that was the first to claim in 1896 that fossil fuel combustion may eventually result in enhanced global warming. He proposed a relation between atmospheric carbon dioxide concentrations and temperature

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. In fact, water vapor is the most abundant greenhouse gas. However, human activities, such as burning of coal, exhaust fumes from vehicles, and burning of trees during deforestation activities, are contributing huge amounts of additional greenhouse gases into the atmosphere, where they enhance the greenhouse effect further and contribute to global warming.

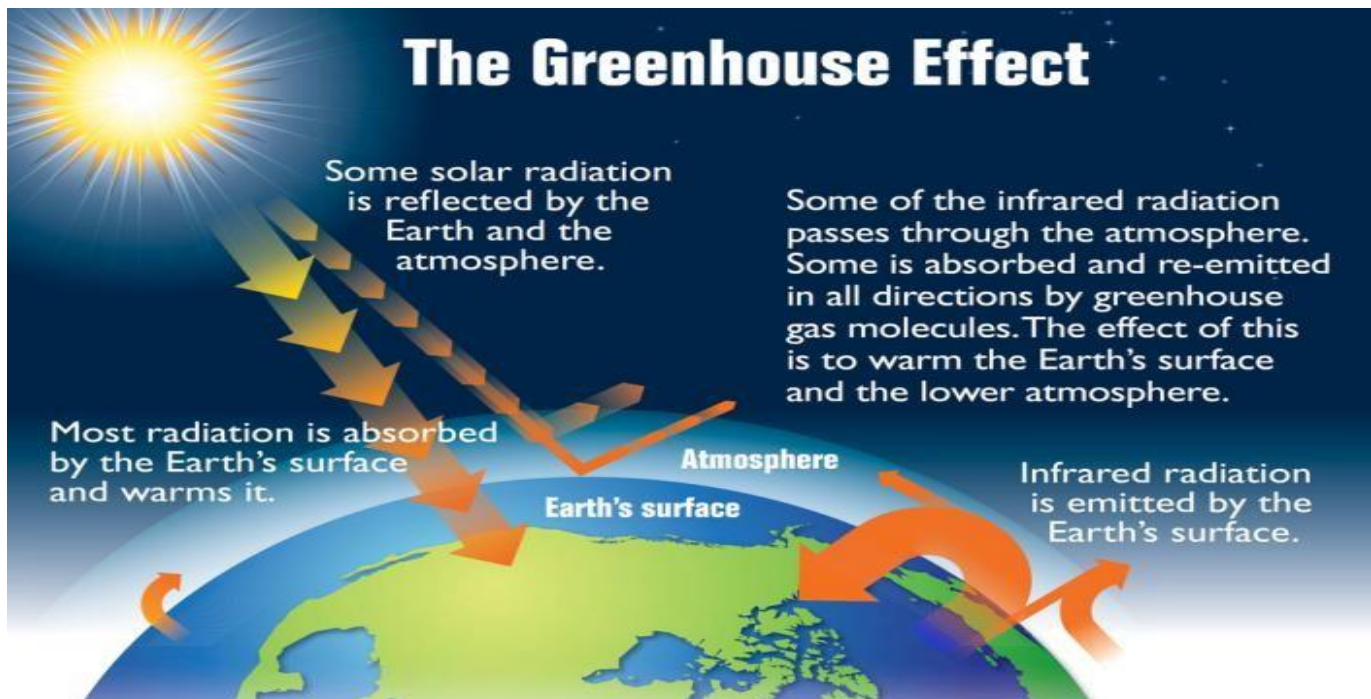
The Albedo Effect

Snowcapped mountains and ice sheets reflect radiation away from the Earth which is a phenomenon that is known as the albedo effect. This helps reduce the amount of heat absorbed by the Earth, and therefore plays a vital role in keeping the Earth cool.

When ice sheets melt, it exposes dark rock or vegetation that doesn't have the same reflective properties as ice, and thus tends to absorb rather than reflect heat.

Life sustains on Earth by depending on the energy coming from the sun. About 60 percent of the energy and light reaching the surface of the Earth passes through the air and clouds where the harmful gases get segregated and absorbed. These gases are radiated upwards in the form of infrared heat. About 89 percent of this heat is then taken by the greenhouse gases and radiated back to the surface. Due to depletion of the ozone

layer and global warming, the greenhouse effect has become the primary reason for which the Earth surface now radiates more heat than it usually should.



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 (H_2O)
2. Carbon dioxide (CO_2)
3. Methane (CH_4)
4. Nitrous oxide (N_2O)
5. Ozone (O_3)
6. Chlorofluorocarbons (CFCs)

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.

The principal forcing gases of the greenhouse effect are:

Carbon dioxide (CO₂)

- Methane (CH₄)
- Nitrous oxide (N₂O)
- Fluorinated gases

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.

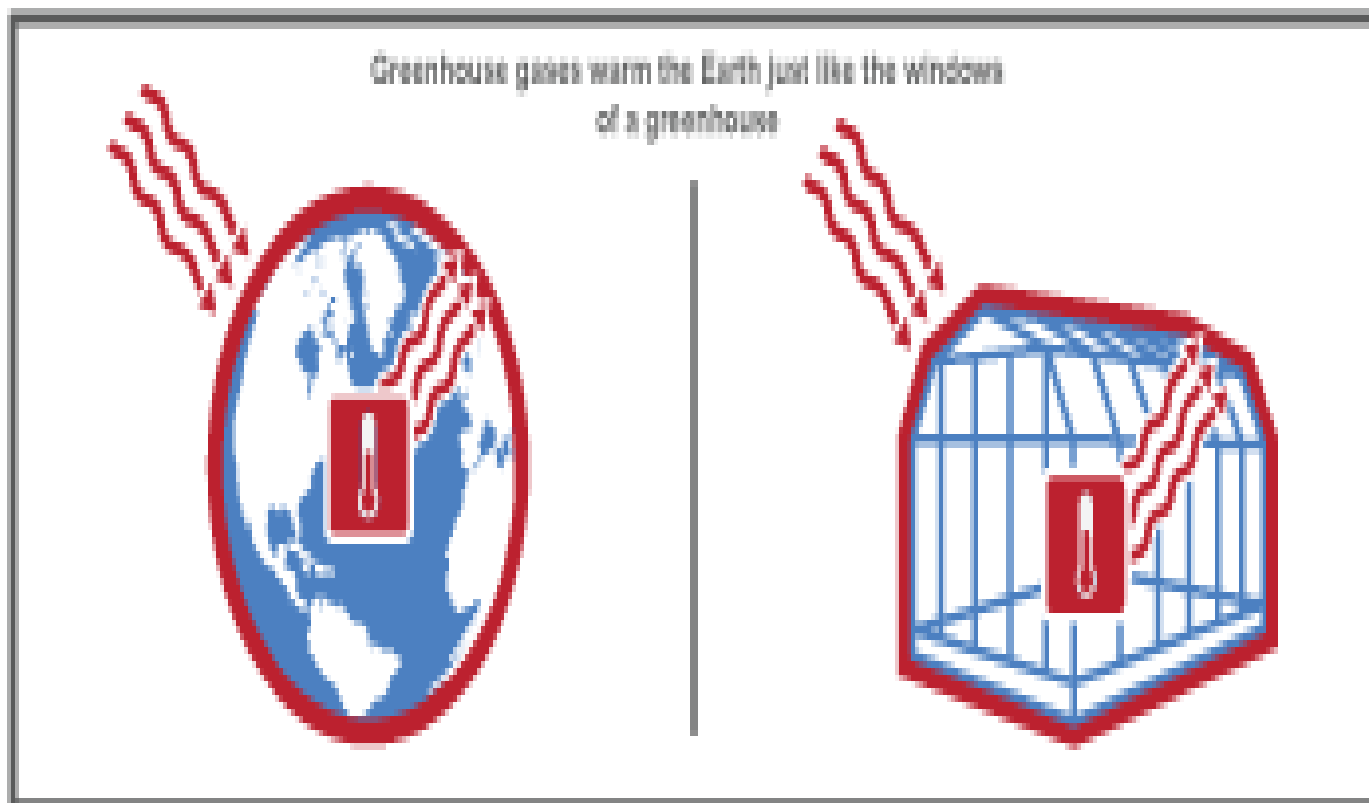
Carbon dioxide and the other non-condensing greenhouse gases are the key gases within the Earth's atmosphere that sustain the greenhouse effect and control its strength. Water vapor is a fast-acting feedback but its atmospheric concentration is controlled by the radiative forcing supplied by the non-condensing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

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

Working principle of Greenhouse effect

To understand exactly how the greenhouse effect works, imagine the following: a warm, sunny day where the sun shines bright on the Earth. This sunlight (shortwave radiation) passes into the planet's atmosphere and warms the Earth. Part of this energy is absorbed by the Earth's surface, transformed into heat (long wave radiation) and radiated back towards space. But as this heat goes up through the atmosphere, some of it is trapped by the different greenhouse gases and doesn't escape into space. This in turn warms up the Earth's atmosphere; just like the windows of a greenhouse that lets light in and keeps the heat within to warm the plants growing inside.



Since some of the heat can't escape into space, it continues to add up which then warms up the Earth. This is what we call the greenhouse effect. So the more greenhouse gases you have in the atmosphere, the more heat stays on Earth.

If the amount of energy from the sun and the amount of greenhouse gases in the atmosphere remain the same, then the average temperature on Earth will also be constant. But this is no longer the case. The amount of greenhouse gases in our atmosphere is the highest it has been in the last 3 million years.^{5 6} This is enhancing the greenhouse effect and making the Earth warmer than normal, which is affecting the planet's weather patterns, creating global warming and climate change.

Energy in and energy out

There's a delicate balancing act occurring every day all across the Earth, involving the radiation the planet receives from space and the radiation that's reflected back out to space.

Earth is constantly bombarded with enormous amounts of radiation, primarily from the sun. This solar radiation strikes the Earth's atmosphere in the form of visible light, plus ultraviolet (UV), infrared (IR) and other types of radiation that are invisible to the human eye.

UV radiation has a shorter wavelength and a higher energy level than visible light, while IR radiation has a longer wavelength and a weaker energy level. About 30 percent of the radiation striking Earth's atmosphere is immediately reflected back out to space by clouds, ice, snow, sand and other reflective surfaces, according to NASA. The remaining 70 percent of incoming solar radiation is absorbed by the oceans, the land and the atmosphere. As they heat up, the oceans, land and atmosphere release heat in the form of IR thermal radiation, which passes out of the atmosphere and into space.

It's this equilibrium of incoming and outgoing radiation that makes the Earth habitable, with an average temperature of about 59 degrees Fahrenheit (15 degrees Celsius), according to NASA. Without this atmospheric equilibrium, Earth would be as cold and lifeless as its moon, or as blazing hot as Venus. The moon, which has almost no atmosphere, is about minus 243 F (minus 153 °C) on its dark side. Venus, on the other hand, has a very dense atmosphere that traps solar radiation; the average temperature on Venus is about 864 F or 462° C.

Control of global Warming

We can't realistically stop the rise of CO₂ in the near term, but we can slow it and therefore reduce the consequences that will occur. 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.

ACID RAIN AND ITS EFFECT

About Acid Rain

Acid rain refers to a mixture of deposited material, both wet and dry, coming from the atmosphere containing more than normal amounts of nitric and sulfuric acids. Simply put, it means rain that is acidic in nature due to the presence of certain pollutants in the air due to cars and industrial processes. It is easily defined as rain, fog, sleet or snow that has been made acidic by pollutants in the air as a result of fossil fuel and industrial combustions that mostly emits Nitrogen Oxides (NO_x) and Sulfur Dioxide (SO₂). Acidity is determined on the basis of the pH level of the water droplets. Normal rain water is slightly acidic with a pH range of 5.3-6.0, because carbon dioxide and water present in the air react together to form carbonic acid, which is a weak acid. When the pH level of rain water falls below this range, it becomes acid rain.

When these gases react with water molecules and oxygen among other chemicals found in the atmosphere, mild acidic chemical compounds such as sulfuric and nitric acid are formed resulting to acid rain. Acid rain generally leads to weathering of buildings, corrosion of metals, and peeling of paints on surfaces. Erupting volcanoes contains some chemicals that can cause acid rain. Apart from this, burning of fossil fuels, running

of factories and automobiles due to human activities are few other reasons behind this activity.

Presently, large amounts of acid deposition is witnessed in the southeastern Canada, northeastern United States and most of Europe, including portions of Sweden, Norway, and Germany. In addition, some amount of acid deposition is found in parts of South Asia, South Africa, Sri Lanka, and Southern India.

Forms of Acid Rain

There are two forms in which acid deposition occurs – wet and dry. Both are discussed below:

- **Wet Deposition:** When the wind blows the acidic chemicals in the air to the areas where the weather is wet, the acids fall to the ground in the form of rain, sleet, fog, snow or mist. It removes acid from the atmosphere and deposits them on the earth's surface. When this acid flows through the ground, it affects large number of plants, animals and aquatic life. The water from drain flows into rivers and canals which is them mixed up with sea water, thereby affecting marine habitats.
- **Dry Deposition:** If the wind blows the acidic chemicals in the air to the areas where the weather is dry, the acidic pollutants slip into dust or smoke and fall to the ground as dry particles. These stick to the ground and other surfaces such as cars, houses, trees and buildings. Almost 50% of the acidic pollutants in the atmosphere fall back through dry deposition. These acidic pollutants can be washed away from earth surface by rainstorms.

Causes of Acid Rain

Both natural and man-made sources are known to play a role in the formation of acid rain. But, it is mainly caused by combustion of fossil fuels which results in emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x).

1. Natural Sources

The major natural causal agent for acid rain is volcanic emissions. Volcanoes emit acid producing gases to create higher than normal amounts of acid rain or any other form of precipitation such as fog and snow to an extent of affecting vegetation cover and health of residents within the surrounding. Decaying vegetation, wildfires and biological processes within the environment also generate the acid rain forming gases. Dimethyl sulfide is a typical example of a major biological contributor to sulfur containing elements into the atmosphere. Lightning strikes also naturally produces nitric oxides that react with water molecules via electrical activity to produce nitric acid, thereby forming acid rain.

2. Man-made sources

Human activities leading to chemical gas emissions such as sulfur and nitrogen are the primary contributors to acid rain. The activities include air pollution sources emitting sulfur and nitrogen gases like factories, power generations facilities, and automobiles. In particular, use of coal for electrical power generation is the biggest contributor to gaseous emissions leading to acid rain. Automobiles and factories also release high scores of gaseous emissions on daily basis into the air, especially in highly industrialized areas and urban regions with large numbers of car traffic. These gases react in the atmosphere with water, oxygen, and other chemicals to form various acidic compounds such as sulfuric

acid, ammonium nitrate, and nitric acid. As a result, these areas experience exceedingly high amounts of acid rain.

The existing winds blow these acidic compounds over large areas across borders and they fall back to the ground in the form of acid rain or other forms of precipitation. Upon reaching the earth, it flows across the surface, absorbs into the soil and enters into lakes and rivers and finally gets mixed up with sea water.

The gases i.e. sulfur dioxide (SO₂) and nitrogen oxides (NO_x) are primarily gases occurring from electric power generation by burning coal and responsible for acid rain.

Effects of Acid Rain

Acid rain has significant effects on the world environment and public health

- **Effect on Aquatic Environment:** Acid rain either falls directly on aquatic bodies or gets run off the forests, roads and fields to flow into streams, rivers and lakes. Over a period of time, acids get accumulated in the water and lower the overall pH of the water body. The aquatic plants and animals need a particular pH level of about 4.8 to survive. If the pH level falls below that the conditions become hostile for the survival of aquatic life. Acid rain tendency of altering pH and aluminum concentrations greatly affects pH concentration levels in surface water, thereby affecting fish as well as other aquatic life-forms. At pH levels below 5, most fish eggs cannot hatch. Lower pH can also kill adult fishes. Acid rain runoff from catchment areas into rivers and lakes has also reduced biodiversity as rivers and lakes become more acidic. Species including fish, plant and insect types in some lakes, rivers and brooks have been reduced and some even completely eliminated owing to excess acid rain flowing into the waters.
- **Effect on Forests:** It makes trees vulnerable to disease, extreme weather, and insects by destroying their leaves, damaging the bark and arresting their growth. Forest damage due to acid rain is most evident in Eastern Europe – especially Germany, Poland and Switzerland.
- **Effect on Soil:** Acid rain highly impacts on soil chemistry and biology. It means, soil microbes and biological activity as well as soil chemical compositions such as soil pH are damaged or reversed due to the effects of acid rain. The soil needs to maintain an optimum pH level for the continuity of biological activity. When acid rains seep into the soil, it means higher soil pH, which damages or reverses soil biological and chemical activities. Hence, sensitive soil microorganisms that cannot adapt to changes in pH are killed. High soil acidity also denatures enzymes for the soil microbes. On the same breadth, hydrogen ions of acid rain leach away vital minerals and nutrients such as calcium and magnesium.
- **Vegetation Cover and Plantations:** The damaging effects of acid rain on soil and high levels of dry depositions have endlessly damaged high altitude forests and vegetation cover since they are mostly encircled by acidic fogs and clouds. Besides, the widespread effects of acid rain on ecological harmony have led to stunted growth and even death of some forests and vegetation cover.
- **Effect on Architecture and Buildings:** Acid rain on buildings, especially those constructed with limestone, react with the minerals and corrode them away. This leaves the building weak and susceptible to decay. Modern buildings, cars, airplanes, steel bridges and pipes are all affected by acid rain. Irreplaceable damage can be caused to the old heritage buildings.

- **Effect on Public Health:** When in atmosphere, sulfur dioxide and nitrogen oxide gases and their particulate matter derivatives like sulfates and nitrates, degrades visibility and can cause accidents, leading to injuries and deaths. Human health is not directly affected by acid rain because acid rain water is too dilute to cause serious health problems. However, the dry depositions also known as gaseous particulates in the air which in this case are nitrogen oxides and sulfur dioxide can cause serious health problems when inhaled. Intensified levels of acid depositions in dry form in the air can cause lung and heart problems such as bronchitis and asthma.
- **Other Effects:** Acid rain leads to weathering of buildings, corrosion of metals, and peeling of paints on surfaces. Buildings and structures made of marble and limestone are the ones especially damaged by acid rain due to the reactivity of the acids in the rain and the calcium compounds in the structures. The effects are commonly seen on statues, old grave stones, historic monuments, and damaged buildings. Acid rain also corrodes metals like steel, bronze, copper, and iron.

Remedies to Acid Rain

1. Cleaning up Exhaust Pipes and Smokestacks

Most of the electric power supporting the modern-day energy requirements comes from combusting fossil fuels such as oil, natural gas, and coal that generate nitrogen oxides (NO_x) and sulfur dioxide (SO₂) as the chief contributors to acid rain. Burning coal largely accounts for SO₂ emissions while NO_x emissions are mostly from fossil fuel combustions.

Washing coal, use of coal comprised of low sulfur, and use of devices known as “scrubbers” can provide technical solution to SO₂ emissions. “Scrubbing” also called flue-gas desulfurization (FGD) typically work to chemically eliminate SO₂ from the gases leaving smokestacks. It can eliminate up to 95% of SO₂ gases. Power generation facilities can also shift to using fuels that emit much less SO₂ such as natural gas instead of burning coal. These methods are simply called emission reduction strategies.

Similarly, NO_x emissions from automobile fossil fuel combustions are mitigated upon by use of catalytic converters. Catalytic converters are fixed on the exhaust pipe system to reduce NO_x emission. Improvement of gasoline that combusts cleaner is also a strategy for reducing emission of NO_x gases.

2. Restoring Damaged Environments

Use of limestone or lime, a process called liming, is a practice that people can do to repair the damage caused by acid rain to lakes, rivers and brooks. Adding lime into acidic surface waters balances the acidity. It's a process that has extensively been used, for instance in Sweden, to keep the water pH at optimum. Even though, liming is an expensive method and has to be done repeatedly. Furthermore, it only offers a short-term solution at the expense of solving the broader challenges of SO₂ and NO_x emissions and risks to human health. Nevertheless, it helps to restore and allow the survival of aquatic life forms by improving chronically acidified surface waters.

3. Alternative Energy Sources

Besides fossil fuels, there is a wide range of alternative energy sources that can generate electrical power. These include wind energy, geothermal energy, solar energy, hydropower, and nuclear power. Harnessing these energy sources can offer effective electrical power alternatives instead of using fossil fuels. Fuel cells, natural gas, and batteries can also substitute use of fossil fuel as cleaner energy sources. As of today, all energy sources have environmental and economic costs as well as benefits. The only solution is using sustainable energy that can protect the future.

4. Individual, National/State, and International Actions

Millions of people directly and indirectly contribute to SO₂ and NO_x emissions. Mitigation of this challenge requires individuals to be more informed about energy conservation and ways of reducing emissions such as: turning off lights or electrical appliances when not using them; use public transport; use energy efficient electrical appliances; and use of hybrid vehicles or those with low NO_x emissions.

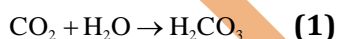
Measurement of Acid Rain

We use the pH scale to measure acid rain. The pH scale measures how acidic a substance is. It runs from 0 to 14; in which 0 is the most acidic, 7 is neutral, and 14 is the most basic. Although pure water is known to have a pH of 7, normal rainwater has a slightly more acidic pH of around 5.6. This pH level is due to the carbon dioxide oxides of Sulphur and Nitrogen in the atmosphere that dissolves into carbonic acid, sulphuric acid, nitric acid. Acid rain has an average pH of 4.2 to 4.4, which is almost ten times more acidic than normal rain.

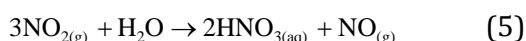
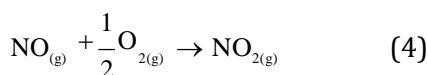
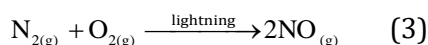
The level of acidity can be determined using high-tech devices or using litmus paper. When litmus paper is exposed to a substance, it changes color depending on the acidity: red for acidic, blue for basic, and a variety of colors for anything in Natural Acidity of Rainwater.

Pure water has a pH of 7.0 (neutral); however, natural, unpolluted rainwater actually has a pH of about 5.6 (acidic). [Recall from Experiment 1 that pH is a measure of the hydrogen ion (H⁺) concentration.] The acidity of rainwater comes from the natural presence of three substances (CO₂, NO, and SO₂) found in the troposphere (the lowest layer of the atmosphere). As is seen in Table I, carbon dioxide (CO₂) is present in the greatest concentration and therefore contributes the most to the natural acidity of rainwater.

Carbon dioxide reacts with water to form carbonic acid (Equation 1). Carbonic acid then dissociates to give the hydrogen ion (H⁺) and the hydrogen carbonate ion (HCO₃⁻) (Equation 2). The ability of H₂CO₃ to deliver H⁺ is what classifies this molecule as an acid, thus lowering the pH of a solution.



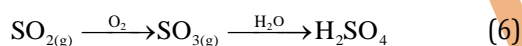
Nitric oxide (NO), which also contributes to the natural acidity of rainwater, is formed during lightning storms by the reaction of nitrogen and oxygen, two common atmospheric gases (Equation 3). In air, NO is oxidized to nitrogen dioxide (NO₂) (Equation 4), which in turn reacts with water to give nitric acid (HNO₃) (Equation 5). This acid dissociates in water to yield hydrogen ions and nitrate ions (NO₃⁻) in a reaction analogous to the dissociation of carbonic acid shown in Equation 2, again lowering the pH of the solution.



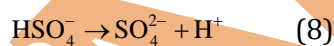
Acidity of Polluted Rainwater

Unfortunately, human industrial activity produces additional acid-forming compounds in far greater quantities than the natural sources of acidity described above. In some areas of the United States, the pH of rainwater can be 3.0 or lower, approximately 1000 times more acidic than normal rainwater. In 1982, the pH of a fog on the West Coast of the United States was measured at 1.8 when rainwater is too acidic, it can cause problems ranging from killing freshwater fish and damaging crops, to eroding buildings and monuments. About one-fourth of the acidity of rain is accounted for by nitric acid (HNO_3). In addition to the natural processes that form small amounts of nitric acid in rainwater, high-temperature air combustion, such as occurs in car engines and power plants, produces large amounts of NO gas. This gas then forms nitric acid via Equations 4 and 5. Thus, a process that occurs naturally at levels tolerable by the environment can harm the environment when human activity causes the process (*e.g.*, formation of nitric acid) to occur to a much greater extent.

What about the other 75% of the acidity of rain? Most is accounted for by the presence of sulfuric acid (H_2SO_4) in rainwater. Although sulfuric acid may be produced naturally in small quantities from biological decay and volcanic activity, it is produced almost entirely by human activity, especially the combustion of sulfur-containing fossil fuels in power plants. When these fossil fuels are burned, the sulfur contained in them reacts with oxygen from the air to form sulfur dioxide (SO_2). Combustion of fossil fuels accounts for approximately 80% of the total atmospheric SO_2 in the United States. The effects of burning fossil fuels can be dramatic: in contrast to the unpolluted atmospheric SO_2 concentration of 0 to 0.01 ppm, polluted urban air can contain 0.1 to 2 ppm SO_2 , or up to 200 times more SO_2 like the oxides of carbon and nitrogen, reacts with water to form sulfuric acid (Equation 6).



Sulfuric acid is a strong acid, so it readily dissociates in water, to give an H^+ ion and an HSO_4^- ion (Equation 7). The HSO_4^- ion may further dissociate to give H^+ and SO_4^{2-} (Equation 8). Thus, the presence of H_2SO_4 causes the concentration of H^+ ions to increase dramatically, and so the pH of the rainwater drops to harmful levels.



Ocean Acidification

Ocean Acidification

A pH unit is a measure of acidity ranging from 0-14. The lower the value, the more acidic the environment. Becoming more acidic is a relative shift in pH to a lower value.

Chemistry behind Acid rain.

When carbon dioxide (CO_2) is absorbed by seawater, chemical reactions occur that reduce seawater pH, carbonate ion concentration, and saturation states of biologically important calcium carbonate minerals. These chemical reactions are termed "ocean acidification" or "OA". Calcium carbonate minerals are the building blocks for the skeletons and shells of many marine organisms. In areas where most life now congregates in the ocean, the

seawater is supersaturated with respect to calcium carbonate minerals. This means there are abundant building blocks for calcifying organisms to build their skeletons and shells. However, continued ocean acidification is causing many parts of the ocean to become under saturated with these minerals, which is likely to affect the ability of some organisms to produce and maintain their shells.

Since the beginning of the Industrial Revolution, the pH of surface ocean waters has fallen by 0.1 pH units. Since the pH scale, like the Richter scale, is logarithmic, **this change represents approximately a 30 percent increase in acidity**. Future predictions indicate that the oceans will continue to absorb carbon dioxide and become even more acidic. Estimates of future carbon dioxide levels, based on business as usual emission scenarios, indicate that by the end of this century the surface waters of the ocean could be nearly 150 percent more acidic, resulting in a pH that the oceans haven't experienced for more than 20 million years.

The Biological Impacts

Ocean acidification is expected to impact ocean species to varying degrees. Photosynthetic algae and sea grasses may benefit from higher CO₂ conditions in the ocean, as they require CO₂ to live just like plants on land. On the other hand, studies have shown that a more acidic environment has a dramatic effect on some calcifying species, including oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton. When shelled organisms are at risk, the entire food web may also be at risk. Today, more than a billion people worldwide rely on food from the ocean as their primary source of protein. Many jobs and economies in the U.S. and around the world depend on the fish and shellfish in our ocean.

Pteropods

The pteropod, or "sea butterfly", is a tiny sea creature about the size of a small pea. Pteropods are eaten by organisms ranging in size from tiny krill to whales and are a major food source for North Pacific juvenile salmon. The photos below show what happens to a pteropod's shell when placed in sea water with pH and carbonate levels projected for the year 2100. The shell slowly dissolves after 45 days it is destroyed

Shellfish



In recent years, there have been near total failures of developing oysters in both aquaculture facilities and natural ecosystems on the West Coast. These larval oyster failures appear to be correlated with naturally occurring upwelling events that bring low pH waters under saturated in aragonite as well as other water quality changes to near shore environments. Lower pH values occur naturally on the West Coast during upwelling events, but a recent observations indicate that anthropogenic CO₂ is contributing to seasonal under saturation. Low pH may be a factor in the current oyster reproductive failure; however, more research is needed to disentangle potential acidification effects from other risk factors, such as episodic freshwater inflow, pathogen increases, or low dissolved oxygen. It is premature to conclude that acidification is responsible for the recent oyster failures, but acidification is a potential factor in the current crisis to this \$100 million a year industry, prompting **new collaborations** and accelerated research on ocean acidification and potential biological impacts.

Coral

Many marine organisms that produce calcium carbonate shells or skeletons are negatively impacted by increasing CO₂ levels and decreasing pH in seawater. For example, increasing ocean acidification has been shown to significantly reduce the ability of reef-building corals to produce their skeletons. In a **recent paper**, coral biologists reported that ocean acidification could compromise the successful fertilization, larval settlement and survivorship of Elkhorn coral, an endangered species. These research results suggest that ocean acidification could severely impact the ability of coral reefs to recover from disturbance. Other research indicates that, by the end of this century, coral reefs may erode faster than they can be rebuilt. This could compromise the long-term viability of these ecosystems and perhaps impact the estimated one million species that depend on coral reef habitat

Oysters, Mussels, Urchins and Starfish



(Ochre seastars (*Pisaster ochraceus*) feed on mussels off the coast of Oregon.)

Generally, shelled animals—including mussels, clams, urchins and starfish—are going to **have trouble building their shells** in more acidic water, just like the corals. Mussels and oysters are expected to grow less shell by 25 percent and 10 percent respectively by

the end of the century. Urchins and starfish aren't as well studied, but they **build their shell-like parts from high-magnesium calcite**, a type of calcium carbonate that dissolves even more quickly than the aragonite form of calcium carbonate that corals use. This means a weaker shell for these organisms, increasing the chance of being crushed or eaten.

Some of the major impacts on these organisms go beyond adult shell-building, however. Mussels' byssal threads, with which they famously cling to rocks in the pounding surf, **can't hold on as well** in acidic water. Meanwhile, oyster larvae fail to even begin growing their shells. In their first 48 hours of life, oyster larvae **undergo a massive growth spurt**, building their shells quickly so they can start feeding. But the more acidic seawater eats away at their shells before they can form; this has **already caused massive oyster die-offs** in the U.S. Pacific Northwest.

This massive failure isn't universal, however: studies have found that crustaceans (such as lobsters, crabs, and shrimp) **grow even stronger shells** under higher acidity. This may be because their shells are constructed differently. Additionally, some species may have already adapted to higher acidity or have the ability to do so, **such as purple sea urchins**. (Although a new study found that **larval urchins have trouble digesting** their food under raised acidity.)

Of course, the loss of these organisms would have much larger effects in the food chain, as they are food and habitat for many other animals.

Zooplankton

There are two major types of zooplankton (tiny drifting animals) that build shells made of calcium carbonate: **foraminifera** and **pteropods**. They may be small, but they are big players in the food webs of the ocean, as almost all larger life eats zooplankton or other animals that eat zooplankton. They are also critical to the **carbon cycle**—how carbon (as carbon dioxide and calcium carbonate) moves between air, land and sea. Oceans contain the greatest amount of actively cycled carbon in the world and are also very important in storing carbon. When shelled zooplankton (as well as shelled phytoplankton) die and sink to the seafloor, they carry their calcium carbonate shells with them, which are deposited as rock or sediment and stored for the foreseeable future. This is an important way that carbon dioxide is removed from the atmosphere, slowing the rise in temperature caused by the **greenhouse effect**.

These tiny organisms reproduce so quickly that they may be able to adapt to acidity better than large, slow-reproducing animals. However, experiments in the lab and at carbon dioxide seeps (where pH is naturally low) have found that foraminifera do not handle higher acidity very well, as their shells dissolve rapidly. One study even predicts that foraminifera from tropical areas **will be extinct by the end of the century**.

The shells of pteropods are **already dissolving in the Southern Ocean**, where more acidic water from the deep sea rises to the surface, hastening the effects of acidification caused by human-derived carbon dioxide. Like corals, these sea snails are particularly susceptible because their shells are made of aragonite, a delicate form of calcium carbonate that is 50 percent more soluble in seawater.

One big unknown is whether acidification will affect **jellyfish** populations. In this case, the fear is that they will survive unharmed. Jellyfish compete with fish and other predators for food, mainly smaller zooplankton—and they also eat young fish

themselves. If jellyfish thrive under warm and more acidic conditions while most other organisms suffer, it's possible that **jellies will dominate some ecosystems** (a problem already seen in parts of the ocean).

Plants and Algae



Neptune grass (*Posidonia oceanica*) is a slow-growing and long-lived seagrass native to the Mediterranean.

Plants and many algae may thrive under acidic conditions. These organisms make their energy from combining sunlight and carbon dioxide—so more carbon dioxide in the water doesn't hurt them, but helps.

Sea grasses form shallow-water ecosystems along coasts that serve as nurseries for many larger fish, and can be home to thousands of different organisms. Under more acidic lab conditions, they were able to reproduce better, grow taller, and grow deeper roots—all good things. However, they are in decline for a number of other reasons, especially pollution flowing into coastal seawater and it's unlikely that this boost from acidification will compensate entirely for losses caused by these other stresses.

Some species of algae grow better under more acidic conditions with the boost in carbon dioxide. But coralline algae, which build calcium carbonate skeletons and help cement coral reefs, do not fare so well. Most coralline algae species build shells from the high-magnesium calcite form of calcium carbonate, which is more soluble than the aragonite or regular calcite forms. One study found that, in acidifying conditions, coralline algae covered 92 percent less area, making space for other types of non-calcifying algae, which can smother and damage coral reefs. This is doubly bad because many coral larvae prefer to settle onto coralline algae when they are ready to leave the plankton stage and start life on a coral reef.

One major group of phytoplankton (single celled algae that float and grow in surface waters), the coccolithophores, grows shells. Early studies found that, like other shelled animals, their shells weakened, making them susceptible to damage. But a longer-term study let a common coccolithophore (*Emiliania huxleyi*) reproduce for 700 generations, taking about 12 full months, in the warmer and more acidic conditions expected to become reality in 100 years. The population was able to adapt, growing strong shells. It could be that they just needed more time to adapt, or that adaptation varies species by species or even population by population.

Fish



Two bright orange anemonefish poke their heads between anemone tentacles.

While fish don't have shells, they will still feel the effects of acidification. Because the surrounding water has a lower pH, a fish's cells often come into balance with the seawater by taking in carbonic acid. This changes the pH of the fish's blood, a condition called acidosis.

Although the fish is then in harmony with its environment, many of the chemical reactions that take place in its body can be altered. Just a small change in pH can make a huge difference in survival. In humans, for instance, a drop in blood pH of 0.2-0.3 can cause seizures, comas, and even death. Likewise, a fish is also sensitive to pH and has to put its body into overdrive to bring its chemistry back to normal. To do so, it will burn extra energy to excrete the excess acid out of its blood through its gills, kidneys and intestines. It might not seem like this would use a lot of energy, but even a slight increase reduces the energy a fish has to take care of other tasks, such as digesting food, swimming rapidly to escape predators or catch food, and reproducing. It can also slow fish's growth.

Even slightly more acidic water may also affect fishes' minds. While clownfish can normally hear and avoid noisy predators, in more acidic water, they do not flee threatening noise. Clownfish also stray farther from home and have trouble "smelling" their way back. This may happen because acidification, which changes the pH of a fish's body and brain, could alter how the brain processes information. Additionally, cobia (a kind of popular game fish) grow larger otoliths—small ear bones that affect hearing and balance in more acidic water, which could affect their ability to navigate and avoid prey. While there is still a lot to learn, these findings suggest that we may see unpredictable changes in animal behavior under acidification.

The ability to adapt to higher acidity will vary from fish species to fish species, and what qualities will help or hurt a given fish species is unknown. A shift in dominant fish species could have major impacts on the food web and on human fisheries.

OZONE LAYER AND ITS DEPLETION

Introduction

To understand ozone layer, it would be helpful to know the different layers of the atmosphere. 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(O_2) 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 a 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.

These targeted efforts have seen the ozone layer recovering over the past years. The thickness of the ozone layer varies immensely on any day and location. Due to relentless

vertical atmospheric air circulation in both the stratosphere and troposphere, the amount of ozone layer shielding humans from strong UV rays can be lesser or greater. In addition, those residing in higher elevations are at risk of UV radiation than those at lower elevations.

The Stratospheric ozone plays a big role in protecting humans from the harshness of the sun. However, there is also a kind of ozone developed just above the ground as a result of sun rays coming into contact with pollution in the atmosphere, which is hazardous to human health. In some individuals, it can lead to complications in breathing and often takes place during summer when pollution is rampant in cities where the air is static.

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)

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.

Hydrofluorocarbons (HCFCs)

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

Halons

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

Carbon Tetrachloride

Used in selected fire extinguishers and solvents.

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

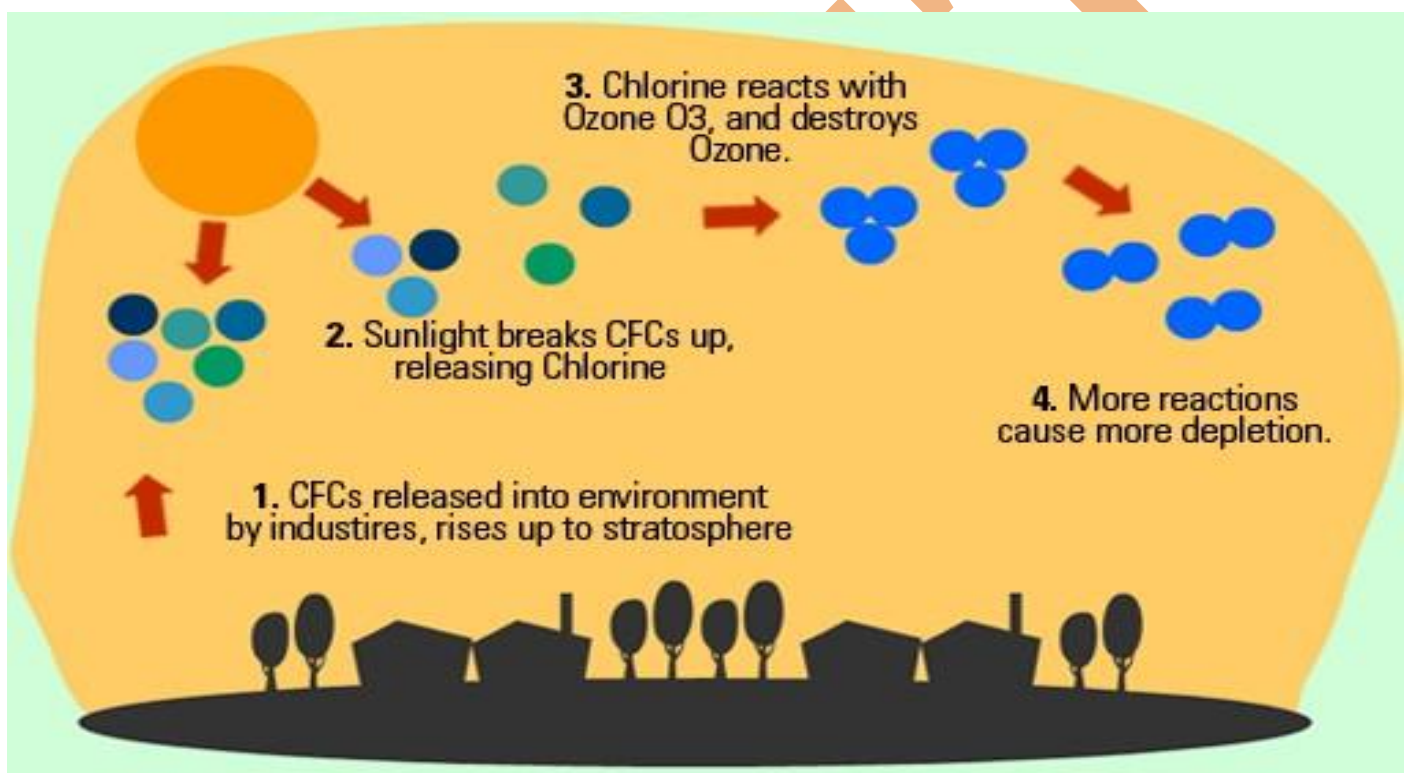
The Montreal Protocol formed in 1989 helped a lot in the limitation of Chlorofluorocarbons (CFCs). However, the protocol never covered nitrous oxide, which is a known harmful chemical that can destroy the ozone layer. Nitrous oxide is still in use today. Governments must take action now and outlaw nitrous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



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.

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.

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.

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.

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.

Air quality standards

In order to protect our health, vegetation and ecosystems, EU directives set down air quality standards in Ireland and the other member states for a wide variety of pollutants. These rules include how we should monitor, assess and manage ambient air quality.

The European Commission set down the principles to this approach in 1996 with its Air Quality Framework Directive. Four "daughter" directives lay down limits for specific pollutants:

- 1st Daughter Directive: Sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead
- 2nd Daughter Directive: Carbon monoxide and benzene

- 3rd Daughter Directive: Ozone
- 4th Daughter Directive: Polyaromatic hydrocarbons, arsenic, nickel, cadmium and mercury in ambient air

The **Ambient Air Quality and Cleaner Air for Europe (CAFE) Directive** (2008/50/EC) was published in May 2008. It replaced the Framework Directive and the first, second and third Daughter Directives. The **fourth Daughter Directive** (2004/107/EC) will be included in CAFE at a later stage. The limit and target values for both Directives are outlined below.

The CAFE Directive was transposed into Irish legislation by the **Air Quality Standards Regulations 2011** (S.I. No. 180 of 2011). It replaces the Air Quality Standards Regulations 2002 (S.I. No. 271 of 2002), the Ozone in Ambient Air Regulations 2004 (S.I. No. 53 of 2004) and S.I. No. 33 of 1999.

The fourth Daughter Directive was transposed into Irish legislation by the **Arsenic, Cadmium, Mercury, Nickel and Polycyclic Aromatic Hydrocarbons in Ambient Air Regulations 2009** (S.I. No. 58 of 2009).

- Directive on ambient air quality and cleaner air for Europe (CAFE) - replaces the air framework directive and the first three daughter directives - 2008/50/EC
- Air quality standards regulations 2011 - SI 180 of 2011 transposed the CAFE Directive into Irish law.
- Fourth 'daughter' directive - relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons - 2004/107/EC
- The arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air Regulations 2009 - SI 58 of 2009 transposed the 4th Daughter Directive into Irish law.

Directives set targets for air quality

The following tables show the limit or target values specified by the five published directives that set down limits for specific air pollutants. The directives cover:

- Sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM10 and PM2.5) and lead
- Carbon monoxide and benzene
- Ozone
- Arsenic, Cadmium, Nickel and Benzene, phenol

Check the bottom of this article for explanations of the abbreviations used.

Limit values of CAFE Directive 2008/50/EC

Pollutant	Limit Value Objective	Averaging Period	Limit Value ug/m3	Limit Value ppb	Basis of Application of the Limit Value	Limit Value of Attainment Date
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SO2	Protection of human health	1 hour	350	132	Not to be exceeded more than 24 times in a calendar year	1 Jan 2005
SO2	Protection of human health	24 hours	125	47	Not to be exceeded more than 3 times in a calendar year	1 Jan 2005
SO2	Protection of vegetation	calendar year	20	7.5	Annual mean	19 July 2001
SO2	Protection of vegetation	1 Oct to 31 Mar	20	7.5	Winter mean	19 July 2001
NO2	Protection of human health	1 hour	200	105	Not to be exceeded more than 18 times in a calendar year	1 Jan 2010
NO2	Protection of human health	calendar year	40	21	Annual mean	1 Jan 2010
NO + NO ₂	Protection of ecosystems	calendar year	30	16	Annual mean	19 July 2001
PM10	Protection of human health	24 hours	50		Not to be exceeded more than 35 times in a calendar year	1 Jan 2005
PM10	Protection of human health	calendar year	40		Annual mean	1 Jan 2005
PM2.5 - Stage 1	Protection of human health	calendar year	25		Annual mean	1 Jan 2015
PM2.5 - Stage 2	Protection of human health	calendar year	20		Annual mean	1 Jan 2020

Lead	Protection of human health	calendar year	0.5		Annual mean	1 Jan 2005
Carbon Monoxide	Protection of human health	8 hours	10,000	8620	Not to be exceeded	1 Jan 2005
Benzene	Protection of human health	calendar year	5	1.5	Annual mean	1 Jan 2010

Alert thresholds

The public must be informed if the following thresholds are exceeded for three consecutive hours.

Pollutant	Averaging Period	Limit Value
Sulphur Dioxide	1 hour	500 ug/m ³
Nitrogen Dioxide	1 hour	400 ug/m ³

Target values and long-term objectives of CAFE Directive 2008/50/EC

Target values for ozone from 2010

Objective	Parameter	Value
Protection of human health	Maximum daily 8 hour mean	120 ug/m³ not to be exceeded more than 25 days per calendar year averaged over 3 years
Protection of vegetation	AOT40, calculated from 1 hour values from May to July	18000 ug/m ³ -h averaged over 5 years

Long-term objectives for ozone from 2020

Objective	Parameter	Value
Protection of human health	Maximum daily 8 hour mean	120 ug/m³
Protection of vegetation	AOT40, calculated from 1 hour values from May to	6000 ug/m ³ -h

	July	
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The public must be informed if ozone levels exceed the following thresholds

	Parameter	Threshold
Information Threshold	1 hour average	180 ug/m3
Alert Threshold	1 hour average	240 ug/m3

Target Values of Directive 2004/107/EC

Pollutant	Limit Value Objective	Averaging Period	Target Value ng/m3	Limit Value Attainment Date
Arsenic	Protection of human health	calendar year	6	31 Dec 2012
Cadmium	Protection of human health	calendar year	5	31 Dec 2012
Nickel	Protection of human health	calendar year	20	31 Dec 2012
Benzo(a)pyrene	Protection of human health	calendar year	1	31 Dec 2012

Nitrogen dioxide 1 ppb = 1.91 ug/m3
 Sulphur dioxide 1 ppb = 2.66 ug/m3
 Ozone 1 ppb = 2.0 ug/m3
 Carbon monoxide 1 ppb = 1.16 ug/m3
 Benzene 1 ppb = 3.24 ug/m3

Photochemical smog

Photochemical smog is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne particles and ground-level ozone. This noxious mixture of air pollutants may include the following: Aldehydes.

- Photochemical smog is composed of primary and secondary pollutants.
- Primary pollutants, which include nitrogen oxides and volatile organic compounds, are introduced into the atmosphere via vehicular emissions and industrial processes.
- Secondary pollutants, like ozone, result from the reaction of primary pollutants with ultraviolet light.
- Photochemical smog is most common in sunny and dry cities, like Los Angeles.

- Smog has a variety of negative health impacts.

Terms

- volatile evaporating or vaporizing readily under normal conditions; having a low boiling point
- monatomic substance consisting of a single atom (not molecules of the element); examples include the noble gases and many metals
- Photochemical smog type of air pollution formed through solar radiation reacting with airborne pollutants, like nitrogen oxides and volatile organic compounds
- Photochemical smog is composed of primary and secondary pollutants.
- Primary pollutants, which include nitrogen oxides and volatile organic compounds, are introduced into the atmosphere via vehicular emissions and industrial processes.
- Secondary pollutants, like ozone, result from the reaction of primary pollutants with ultraviolet light.
- Photochemical smog is most common in sunny and dry cities, like Los Angeles.
- Smog has a variety of negative health impacts.

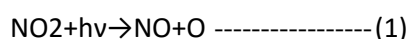
Causes Photochemical Smog

The components of photochemical smog were established during the 1950s. This type of air pollution is formed through the reaction of solar radiation with airborne pollutants like nitrogen oxides and volatile organic compounds. These compounds, which are called primary pollutants, are often introduced into the atmosphere through automobile emissions and industrial processes. Ultraviolet light can split nitrogen dioxide into nitric oxide and monatomic oxygen; this monatomic oxygen can then react with oxygen gas to form ozone. Products like ozone, aldehydes, and peroxyacetyl nitrates are called secondary pollutants. The mixture of these primary and secondary pollutants forms photochemical smog.

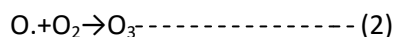
Both the primary and secondary pollutants in photochemical smog are highly reactive. These oxidizing compounds have been linked to a variety of negative health outcomes; ozone, for example, is known to irritate the lungs. Smog is a particular health danger in some of the world's sunniest and most populated cities, such as Los Angeles; Los Angeles is typically sunny, and the sun reacts with the chemicals produced by cars and other industrial processes. Smog can also affect areas of the country that are sunny less frequently, such as New York City. In fact, most major cities have problems with smog and air pollution.

The following substances are identified in photochemical smog:

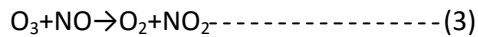
1. Nitrogen Dioxide (NO_2) from vehicle exhaust, is photolyzed by ultraviolet (UV) radiation ($h\nu$) from the sun and decomposes into Nitrogen Oxide (NO) and an oxygen radical:



2. The oxygen radical then reacts with an atmospheric oxygen molecule to create ozone, O_3 :

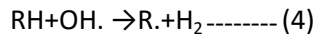


3. Under normal conditions, O₃ reacts with NO, to produce NO₂ and an oxygen molecule:

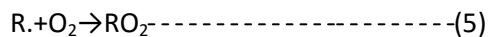


This is a continual cycle that leads only to a temporary increase in net ozone production. To create photochemical smog on the scale observed in Los Angeles, the process must include Volatile organic compounds (VOC's).

4. VOC's react with hydroxide in the atmosphere to create water and a reactive VOC molecule:



5. The reactive VOC can then bind with an oxygen molecule to create an oxidized VOC:



6. The oxidized VOC can now bond with the nitrogen oxide produced in the earlier set of equations to form nitrogen dioxide and a reactive VOC molecule:



In the second set of equations, it is apparent that nitrogen oxide, produced in equation 1, is oxidized in equation 6 without the destruction of any ozone. This means that in the presence of VOCs, equation 3 is essentially eliminated, leading to a large and rapid build-up in the photochemical smog in the lower atmosphere.

Control of Photochemical Smog

Every new vehicle sold in the United States must include a catalytic converter to reduce photochemical emissions. Catalytic converters force CO and incompletely combusted hydrocarbons to react with a metal catalyst, typically platinum, to produce CO₂ and H₂O. Additionally, catalytic converters reduce nitrogen oxides from exhaust gases into O₂ and N₂, eliminating the cycle of ozone formation. Many scientists have suggested that pumping gas at night could reduce photochemical ozone formation by limiting the amount of exposure VOCs have with sunlight.

Effects of photochemical smog

1. Effects on Human Health

Smog is composed of a mixture of air pollutants which can endanger human health.

Various human health problems such as emphysema, asthma, chronic bronchitis, lung infections, and cancers are caused or exacerbated by the effects of smog. The effects include:

- **Coughing and irritation of the eyes, chest, nose and throat:** High ozone levels can irritate the respiratory system leading to coughing and wheezing. These effects generally last for only a few days after exposure, but the particles in the smog can continue to damage the lungs even after the irritations disappear.
- **Aggravation of asthma:** Asthma conditions are severely worsened by smog and can trigger asthma attacks.
- **Breathing difficulties and lung damage:** Bronchitis, pneumonia, and emphysema are some of the lung conditions linked to the effects of smog as it damages the lining of the lungs. Smog also makes it difficult for people to breathe properly.
- **Premature deaths because of respiratory and cancer diseases:** A 2013 WHO report indicated that cumulative exposure to smog heightens the chances of premature death

from cancers and respiratory diseases. Thousands of premature deaths in the United States, Europe, and Asian countries are linked to inhalation of smog particles. Such chemical particles include benzene, formaldehyde, and butadiene which are all comprised of cancer-causing carcinogens.

- **Birth defects and low birth weights:** Smog is highly linked to birth defects and low birth weight. Pregnant women who have been exposed to smog have had babies with birth defects. Spina bifida – a condition depicting malformations of the spinal column, and anencephaly – underdevelopment or absence, or only part of the brain, are birth defects associated with smog exposure. Furthermore, studies suggest that even as low as 5 μg exposure to smog particulate matter can result in risks of very low birth weights at delivery.
- **The risk of developing rickets:** Heavy smog that lasts for prolonged periods blocks UV rays from reaching the earth surface. This results in low production of Vitamin D leading to rickets due to impaired metabolism of calcium and phosphorus in the bone marrow.
- **Risks of road accidents or even plane crash:** Smog interferes with natural visibility and irritates the eyes. On this basis, it may prevent the driver or flight controller from reading important signs or signals thereby increasing the probability of road accidents or even plane crash.

2. Implications for Plants and Animals

Smog inhibits the growth of plants and can lead to extensive damage to crops, trees, and vegetation. When crops and vegetables such as wheat, soybeans, tomatoes, peanuts, cotton and kales are exposed to smog, it interferes with their ability to fight infections thus increasing susceptibility to diseases.

The smog's impact of altering the natural environment makes it difficult for animals to adapt or survive in such toxic conditions, which can kill countless animal species or make them susceptible to illness. Photochemical smog caused when nitrogen oxides react in the presence of sunlight, is established to destroy plant life and irritate sensitive tissues of both plants and animals.

WATER POLLUTION (CHAPTER-2)

Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater). This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds.

What is water pollution?

Water pollution can be defined in many ways. Usually, it means one or more substances are added in water to such an extent that they cause problems for animals or people. Oceans, lakes, rivers, and other inland waters can naturally clean up a certain amount of pollution by dispersing it harmlessly. If you poured a cup of black ink into a river, the ink would quickly disappear into the river's much larger volume of clean water. The ink would still be there in the river, but in such a low concentration that you would not be able to see it. At such low levels, the chemicals in the ink probably would not present any real problem. However, if you poured gallons of ink into a river every few seconds through a pipe, the river would quickly turn black. The chemicals in the ink could very quickly have an

effect on the quality of the water. This, in turn, could affect the health of all the plants, animals, and humans whose lives depend on the river.

Thus, water pollution is all about *quantities*: how much of a polluting substance is released and how big a volume of water it is released into. A small quantity of a toxic chemical may have little impact if it is spilled into the ocean from a ship. But the same amount of the same chemical can have a much bigger impact pumped into a lake or river, where there is less clean water to disperse it.

Water pollution almost always means that some damage has been done to an ocean, river, lake, or other water source. A 1969 United Nations report defined ocean pollution as:

"The introduction by man, directly or indirectly of toxic substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality for use of sea water and reduction of amenities."

Fortunately, Earth is forgiving and damage from water pollution is often reversible.

Major types of water pollution

When we think of Earth's water resources, we think of huge oceans, lakes, and rivers. Water resources like these are called surface waters. The most obvious type of water pollution affects surface waters. For example, a spill from an oil tanker creates an oil slick that can affect a vast area of the ocean.

Not all of Earth's water sits on its surface, however. A great deal of water is held in underground rock structures known as aquifers, which we cannot see and seldom think about. Water stored underground in aquifers is known as groundwater. Aquifers feed our rivers and supply much of our drinking water. They too can become polluted, for example, when weed killers used in people's gardens drain into the ground. Groundwater pollution is much less obvious than surface-water pollution, but is no less of a problem. In 1996, a study in Iowa in the United States found that over half the state's groundwater wells were contaminated with weed killers.

Surface water and groundwater are the two types of water resources that pollution affects. There are also two different ways in which pollution can occur. If pollution comes from a single location, such as a discharge pipe attached to a factory, it is known as point-source pollution. Other examples of point source pollution include an oil spill from a tanker, a discharge from a smoke stack (factory chimney), or someone pouring oil from their car down a drain. A great deal of water pollution happens not from one single source but from many different scattered sources. This is called nonpoint-source pollution.

When point-source pollution enters the environment, the place most affected is usually the area immediately around the source. For example, when a tanker accident occurs, the oil slick is concentrated around the tanker itself and, in the right ocean conditions, the pollution disperses the further away from the tanker you go. This is less likely to happen with nonpoint source pollution which, by definition, enters the environment from many different places at once.

Sometimes pollution that enters the environment in one place has an effect hundreds or even thousands of miles away. This is known as trans boundary pollution. One example is the way radioactive waste travels through the oceans from nuclear reprocessing plants in England and France to nearby countries such as Ireland and Norway.

There are two main ways of measuring the quality of water. One is to take samples of the water and measure the concentrations of different chemicals that it contains. If the chemicals are dangerous or the concentrations are too great, we can regard the water as polluted. Measurements like this are known as chemical indicators of water quality. Another way to measure water quality involves examining the fish, insects, and other invertebrates that the water will support. If many different types of creatures can live in a river, the quality is likely to be very good; if the river supports no fish life at all, the quality is obviously much poorer. Measurements like this are called biological indicators of water quality.

Causes of water pollution.

Most water pollution doesn't begin in the water itself. Let us take the oceans: around 80 percent of ocean pollution enters our seas from the land. Virtually any human activity can have an effect on the quality of our water environment. When farmers fertilize the fields, the chemicals they use are gradually washed by rain into the groundwater or surface waters nearby. Sometimes the causes of water pollution are quite surprising. Chemicals released by smokestacks (chimneys) can enter the atmosphere and then fall back to earth as rain, entering seas, rivers, and lakes and causing water pollution. That's called atmospheric deposition. Water pollution has many different causes and this is one of the reasons why it is such a difficult problem to solve.

Sewage Water

With billions of people on the planet, disposing of sewage waste is a major problem. According to 2015 and 2016 figures from the World Health Organization, some 663 million people (9 percent of the world's population) don't have access to safe drinking water, while 2.4 billion (40 percent of the world's population) don't have proper sanitation (hygienic toilet facilities); although there have been great improvements in securing access to clean water, relatively little progress has been made on improving global sanitation in the last decade. Sewage disposal affects people's immediate environments and leads to water-related illnesses such as diarrhea that kills 525,000 children under five each year In

developed countries, most people have flush toilets that take sewage waste quickly and hygienically away from their homes.

Yet the problem of sewage disposal does not end there. When you flush the toilet, the waste has to go somewhere and, even after it leaves the sewage treatment works, there is still waste to dispose of. Sometimes sewage waste is pumped untreated into the sea. Until the early 1990s, around 5 million tons of sewage was dumped by barge from New York City each year. According to 2002 figures from the UK government's Department for the Environment, Food, and Rural Affairs (DEFRA), the sewers of Britain collect around 11 billion liters of waste water every day, some of it still pumped untreated into the sea through long pipes. The New River that crosses the border from Mexico into California once carried with it 20–25 million gallons (76–95 million liters) of raw sewage each day; a new waste water plant on the US-Mexico border, completed in 2007, substantially solved that problem.

sewage is considered as a completely natural substance that should be broken down harmlessly in the environment: 90 percent of sewage is water. In practice, sewage contains all kinds of other chemicals, from the pharmaceutical drugs people take to the paper, plastic, and other wastes they flush down their toilets. When people are sick with viruses, the sewage they produce carries those viruses into the environment. It is possible to catch illnesses such as hepatitis, typhoid, and cholera from river and sea water.

Nutrients

Suitably treated and used in moderate quantities, sewage can be a fertilizer: it returns important nutrients to the environment, such as nitrogen and phosphorus, which plants and animals need for growth. The trouble is, sewage is often released in much greater quantities than the natural environment can cope with. Chemical fertilizers used by farmers also add nutrients to the soil, which drain into rivers and seas and add to the fertilizing effect of the sewage. Together, sewage and fertilizers can cause a massive increase in the growth of algae or plankton that overwhelms huge areas of oceans, lakes, or rivers. This is known as a harmful algal bloom (also known as an HAB or red tide, because it can turn the water red). It is harmful because it removes oxygen from the water that kills other forms of life, leading to what is known as a dead zone. The Gulf of Mexico has one of the world's most spectacular dead zones. Each summer, according to studies by the NOAA, it grows to an area of around 5500–6000 square miles (14,000–15,500 square kilometers), which is about the same size as the state of Connecticut.

Waste water

A few statistics illustrate the scale of the problem that waste water (chemicals washed down drains and discharged from factories) can cause. Around half of all ocean pollution is caused by sewage and waste water. Each year, the world generates perhaps 5–10 billion tons of industrial waste, much of which is pumped untreated into rivers, oceans, and other waterways. In the United States alone,

around 400,000 factories take clean water from rivers, and many pump polluted waters back in their place. However, there have been major improvements in waste water treatment recently. Since 1970, in the United States, the Environmental Protection Agency (EPA) has invested about \$70 billion in improving water treatment plants that, as of 2015, serve around 88 percent of the US population (compared to just 69 percent in 1972). However, another \$271 billion is still needed to update and upgrade the system.

Factories are point sources of water pollution, but quite a lot of water is polluted by ordinary people from nonpoint sources; this is how ordinary water becomes waste water in the first place. Virtually everyone pours chemicals of one sort or another down their drains or toilets. Even detergents used in washing machines and dishwashers eventually end up in our rivers and oceans. So do the pesticides we use on our gardens. A lot of toxic pollution also enters waste water from highway runoff. Highways are typically covered with a cocktail of toxic chemicals—everything from spilled fuel and brake fluids to bits of worn tires (themselves made from chemical additives) and exhaust emissions. When it rains, these chemicals wash into drains and rivers. It is not unusual for heavy summer rainstorms to wash toxic chemicals into rivers in such concentrations that they kill large numbers of fish overnight. It has been estimated that, in one year, the highway runoff from a single large city leaks as much oil into our water environment as a typical tanker spill. Some highway runoff runs away into drains; others can pollute groundwater or accumulate in the land next to a road, making it increasingly toxic as the years go by.

Chemical waste

Detergents are relatively mild substances. At the opposite end of the spectrum are highly toxic chemicals such as polychlorinated biphenyls (PCBs). They were once widely used to manufacture electronic circuit boards, but their harmful effects have now been recognized and their use is highly restricted in many countries. Nevertheless, an estimated half million tons of PCBs were discharged into the environment during the 20th century. In a classic example of transboundary pollution, traces of PCBs have even been found in birds and fish in the Arctic. They were carried there through the oceans, thousands of miles from where they originally entered the environment. Although PCBs are widely banned, their effects will be felt for many decades because they last a long time in the environment without breaking down.

Another kind of toxic pollution comes from heavy metals, such as lead, cadmium, and mercury. Lead was once commonly used in gasoline (petrol), though its use is now restricted in some countries. Mercury and cadmium are still used in batteries (though some brands now use other metals instead). Until recently, a highly toxic chemical called tributyltin (TBT) was used in paints to protect boats from the ravaging effects of the oceans. Ironically, however, TBT was gradually recognized as a pollutant: boats painted with it were doing as much damage to the oceans as the oceans were doing to the boats.

The best known example of heavy metal pollution in the oceans took place in 1938 when a Japanese factory discharged a significant amount of mercury metal into Minamata Bay, contaminating the fish stocks there. It took a decade for the problem to come to light. By that time, many local people had eaten the fish and around 2000 were poisoned. Hundreds of people were left dead or disabled

Radioactive waste

People view radioactive waste with great alarm and for good reason. At high enough concentrations it can kill; in lower concentrations it can cause cancers and other illnesses. The biggest sources of radioactive pollution in Europe are two factories that reprocess waste fuel from nuclear power plants: Sellafield on the north-west coast of Britain and Cap La Hague on the north coast of France. Both discharge radioactive waste water into the sea, which ocean currents then carry around the world. Countries such as Norway, which lie downstream from Britain, receive significant doses of radioactive pollution from Sellafield. The Norwegian government has repeatedly complained that Sellafield has increased radiation levels along its coast by 6–10 times. Both the Irish and Norwegian governments continue to press for the plant's closure.

Oil Pollution

When we think of ocean pollution, huge black oil slicks often spring to mind, yet these spectacular accidents represent only a tiny fraction of all the pollution entering our oceans. Even considering oil by itself, tanker spills are not as significant as they might seem: only 12 percent of the oil that enters the oceans comes from tanker accidents; over 70 percent of oil pollution at sea comes from routine shipping and from the oil people pour down drains on land. However, what makes tanker spills so destructive is the sheer quantity of oil they release *at once* in other words, the concentration of oil they produce in one very localized part of the marine environment. The biggest oil spill in recent years (and the biggest ever spill in US waters) occurred when the tanker *Exxon Valdez* broke up in Prince William Sound in Alaska in 1989. Around 12 million gallons (44 million liters) of oil were released into the pristine wilderness—enough to fill your living room 800 times over! Estimates of the marine animals killed in the spill vary from approximately 1000 sea otters and 34,000 birds to as many as 2800 sea otters and 250,000 sea birds. Several billion salmon and herring eggs are also believed to have been destroyed.

Plastics

If you've ever taken part in a community beach clean, you'll know that plastic is far and away the most common substance that washes up with the waves. There are three reasons for this: plastic is one of the most common materials, used for making virtually every kind of manufactured object from clothing to automobile parts; plastic is light and floats easily so it can travel enormous distances across the oceans; most plastics are not biodegradable (they do not break down naturally in the environment), which means that things like plastic bottle tops can survive

in the marine environment for a long time. (A plastic bottle can survive an estimated 450 years in the ocean and plastic fishing line can last up to 600 years.)

While plastics are not toxic in quite the same way as poisonous chemicals, they nevertheless present a major hazard to seabirds, fish, and other marine creatures. For example, plastic fishing lines and other debris can strangle or choke fish. (This is sometimes called ghost fishing.) About half of all the world's seabird species are known to have eaten plastic residues. In one study of 450 shearwaters in the North Pacific, over 80 percent of the birds were found to contain plastic residues in their stomachs. In the early 1990s, marine scientist Tim Benton collected debris from a 2km (1.5 mile) length of beach in the remote Pitcairn islands in the South Pacific. His study recorded approximately a thousand pieces of garbage including 268 pieces of plastic, 71 plastic bottles, and two dolls heads.

Alien species

Most people's idea of water pollution involves things like sewage, toxic metals, or oil slicks, but pollution can be biological as well as chemical. In some parts of the world, alien species are a major problem. Alien species (sometimes known as invasive species) are animals or plants from one region that have been introduced into a different ecosystem where they do not belong. Outside their normal environment, they have no natural predators, so they rapidly run wild, crowding out the usual animals or plants that thrive there. Common examples of alien species include zebra mussels in the Great Lakes of the USA, which were carried there from Europe by ballast water (waste water flushed from ships). The Mediterranean Sea has been invaded by a kind of alien algae called *Caulerpa taxifolia*. In the Black Sea, an alien jellyfish called *Mnemiopsis leidyi* reduced fish stocks by 90 percent after arriving in ballast water. In San Francisco Bay, Asian clams called *Potamocorbula amurensis*, also introduced by ballast water, have dramatically altered the ecosystem.

Other forms of pollution

These are the most common forms of pollution—but by no means the only ones. Heat or thermal pollution from factories and power plants also causes problems in rivers. By raising the temperature, it reduces the amount of oxygen dissolved in the water, thus also reducing the level of aquatic life that the river can support.

Another type of pollution involves the disruption of sediments (fine-grained powders) that flow from rivers into the sea. Dams built for hydroelectric power or water reservoirs can reduce the sediment flow. This reduces the formation of beaches, increases coastal erosion (the natural destruction of cliffs by the sea), and reduces the flow of nutrients from rivers into seas (potentially reducing coastal fish stocks). Increased sediments can also present a problem. During construction work, soil, rock, and other fine powders sometimes enters nearby rivers in large quantities, causing it to become turbid (muddy or silted). The extra sediment can block the gills of fish, effectively suffocating them. Construction firms often now take precautions to prevent this kind of pollution from happening.

Effects of water pollution.

Some people believe pollution is an inescapable result of human activity: they argue that if we want to have factories, cities, ships, cars, oil, and coastal resorts, some degree of pollution is almost certain to result. In other words, pollution is a necessary evil that people must put up with if they want to make progress. Fortunately, not everyone agrees with this view. One reason people have woken up to the problem of pollution is that it brings costs of its own that undermine any economic benefits that come about by polluting.

For example, take oil spills. They can happen if tankers are too poorly built to survive accidents at sea. But the economic benefit of compromising on tanker quality brings an economic cost when an oil spill occurs. The oil can wash up on nearby beaches, devastate the ecosystem, and severely affect tourism. The main problem is that the people who bear the cost of the spill (typically a small coastal community) are not the people who caused the problem in the first place (the people who operate the tanker). Yet, arguably, everyone who puts gasoline (petrol) into their car or uses almost any kind of petroleum-fueled transport contributes to the problem in some way. So oil spills are a problem for everyone, not just people who live by the coast and tanker operates.

Sewage is another good example of how pollution can affect us all. Sewage discharged into coastal waters can wash up on beaches and cause a health hazard. People who bathe or surf in the water can fall ill if they swallow polluted water—yet sewage can have other harmful effects too: it can poison shellfish (such as cockles and mussels) that grow near the shore. People who eat poisoned shellfish risk suffering from an acute and sometimes fatal illness called paralytic shellfish poisoning. Shellfish is no longer caught along many shores because it is simply too polluted with sewage or toxic chemical wastes that have discharged from the land nearby.

Pollution matters because it harms the environment on which people depend. The environment is not something distant and separate from our lives. It's not pretty shoreline hundreds of miles from our homes or a wilderness landscape that we see only on TV. The environment is everything that surrounds us that gives us life and health. Destroying the environment ultimately reduces the quality of our own lives—and that, most selfishly, is why pollution should matter to all of us.

Control of water pollution

Education

Making people aware of the problem is the first step to solving it. In the early 1990s, when surfers in Britain grew tired of catching illnesses from water polluted with sewage, they formed a group called Surfers Against Sewage to force governments and water companies to clean up their act. People who've grown tired of walking the world's polluted beaches often band together to organize community beach-cleaning sessions. Anglers who no longer catch so many fish

have campaigned for tougher penalties against factories that pour pollution into our rivers. Greater public awareness can make a positive difference.

Laws

One of the biggest problems with water pollution is its transboundary nature. Many rivers cross countries, while seas span whole continents. Pollution discharged by factories in one country with poor environmental standards can cause problems in neighboring nations, even when they have tougher laws and higher standards. Environmental laws can make it tougher for people to pollute, but to be really effective they have to operate across national and international borders. This is why we have international laws governing the oceans, such as the 1982 UN Convention on the Law of the Sea (signed by over 120 nations), the 1972 London (Dumping) Convention, the 1978 MARPOL International Convention for the Prevention of Pollution from Ships, and the 1998 OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic. The European Union has water-protection laws (known as directives) that apply to all of its member states. They include the 1976 Bathing Water Directive, which seeks to ensure the quality of the waters that people use for recreation. Most countries also have their own water pollution laws. In the United States, for example, there is the 1972 Clean Water Act and the 1974 Safe Drinking Water Act.

Economics

Most environmental experts agree that the best way to tackle pollution is through something called the polluter pays principle. This means that whoever causes pollution should have to pay to clean it up, one way or another. Polluter pays can operate in all kinds of ways. It could mean that tanker owners should have to take out insurance that covers the cost of oil spill cleanups, for example. It could also mean that shoppers should have to pay for their plastic grocery bags, as is now common in Ireland, to encourage recycling and minimize waste. Or it could mean that factories that use rivers must have their water inlet pipes downstream of their effluent outflow pipes, so if they cause pollution they themselves are the first people to suffer. Ultimately, the polluter pays principle is designed to deter people from polluting by making it less expensive for them to behave in an environmentally responsible way.

The water quality standards regulation requires that States and authorized Indian Tribes specify appropriate water uses to be achieved and protected. Appropriate uses are identified by taking into consideration the use and value of the water body for public water supply, for protection of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes.

In designating uses for a water body, States and Tribes examine the suitability of a water body for the uses based on the physical, chemical, and biological characteristics of the water body, its geographical setting and scenic qualities, and economic considerations. Each water body does not necessarily require a unique

set of uses. Instead, the characteristics necessary to support a use can be identified so that water bodies having those characteristics can be grouped together as supporting particular uses.

STANDARDS OF WATER QUALITY

There are many sources of water quality criteria and standards - they may originate in the Member States of the European Union, or may be adopted by the Council or Parliament of the EU, or by individual countries, or they may be issued by international bodies.

Further, these various levels specified will take cognisance of the differing uses for which water quality must be maintained. The requirements, as regards suitability, of water for industrial use, for drinking, for boilers and so on, may differ widely and each may be quite demanding. The ultimate objective of the imposition of standards (which may necessitate extensive treatment prior to use) is the protection of the end uses, be these by humans, animals, agriculture or industry. In the present context, however, the main considerations are in regard to safeguarding public health and the protection of the whole aquatic environment. Both have very high quality requirements which complement each other to a great extent. For example, in general terms, if a river or lake water meets the most stringent fishery requirements it will meet all or virtually all other environmental quality objectives [EQOs). In fact, the EU Framework Directive in the field of Water Policy¹ defines a single EQO - achieving and maintaining "good ecological status." ² In Ireland the origins of the vast majority of water quality standards imposed to date are the various EU Directives which since 1975 have specified the quality required of waters for different uses. Under the most important Directives, however, the actual standards which are in legal force are enshrined in the corresponding Ministerial Regulations. These give effect in Irish law to the quality and other requirements of the Directives. It is important to bear in mind that the Minister for the Environment and Local Government has (and exercises) the power to require that national standards may be stricter than the levels laid down in the Directives. It should also be understood that, in cases where Regulations have been made in connection with a Directive, it is the Regulations which must be adhered to. Both Directives and Regulations are aimed primarily at the safeguarding of human health by protecting both waters and fish (as part of the food chain), as well, of course, as the aquatic environment at large. Because of the importance of these Directives and Regulations and their complexity (including the interrelationship between different Directives) their main provisions are for convenience summarised below insofar as they deal with quality standards. However, sampling and analytical aspects of the Directives are not covered here. The adoption of the Framework Directive will mean that the standards enshrined in the individual water Directives will (over a period of time) be subsumed into the former and that the latter enactments will be repealed

WATER QUALITY STANDARDS AS PER INDIAN STANDARD

Colour, Hazen Units	
IS 10500-1991	Desirable : 5 Hz. , Permissible : 25 Hz.

Risks or effects	Visible tint, acceptance decreases
Sources	Tannins, Iron, Copper, Manganese Natural deposits
Treatment	Filtration, Distillation, Reverse osmosis, Ozonisation

Odour	
IS 10500-1991	Unobjectionable
Risks or effects	Rotten egg, Musty, Chemical
Sources	Chlorine, Hydrogen sulfide, Organic matter, Septic contamination, Methane gas
Treatment	Activated carbon, Air stripping, oxidation, Filtration

pH	
IS 10500-1991	Desirable :6.5 – 8.5, Permissible :No relaxation
Risks or effects	Low pH - corrosion, metallic taste High pH – bitter/soda taste, deposits
Sources	Natural
Treatment	Increase pH by soda ash Decrease pH with white vinegar / citric acid

Total Dissolved Solids (TDS)	
IS 10500-1991	Desirable : 500 mg/l , Permissible : 2000 mg/l
Risks or effects	Hardness, scaly deposits, sediment, cloudy colored water, staining, salty or bitter taste, corrosion of pipes and fittings
Sources	Livestock waste, septic system Landfills, nature of soil Hazardous waste landfills Dissolved minerals, iron and manganese
Treatment	Reverse Osmosis, Distillation, deionization by ion exchange

Hardness	
IS 10500-1991	Desirable :300 mg/l , Permissible : 600 mg/l
Risks or effects	Scale in utensils and hot water system, soap scums
Sources	Dissolved calcium and magnesium from soil and aquifer minerals containing limestone or dolomite
Treatment	Water Softener Ion Exchanger , Reverse Osmosis

Alkalinity	
IS 10500-1991	Desirable : 200 mg/l , Permissible : 600 mg/lit
Risks or effects	Low Alkalinity (i.e. high acidity) causes deterioration of plumbing and increases the chance for many heavy metals in water are present in pipes, solder or plumbing fixtures.
Sources	Pipes, landfills Hazardous waste landfills
Treatment	Neutralizing agent

Iron, Fe	
IS 10500-1991	Desirable : 0.3 mg/l , Permissible : 1.0 mg/l
Risks or effects	Brackish color, rusty sediment, bitter or metallic taste, browngreen stains, iron bacteria, discolored beverages
Sources	Leaching of cast iron pipes in water distribution systems Natural
Treatment	Oxidizing Filter , Green-sand Mechanical Filter

Manganese, Mn	
IS 10500-1991	Desirable : 0.1 mg/l , Permissible : 0.3 mg/l
Risks or effects	Brownish color, black stains on laundry and fixtures at .2 mg/l, bitter taste, altered taste of water-mixed beverages
Sources	Landfills Deposits in rock and soil
Treatment	Ion Exchange , Chlorination, Oxidizing Filter , Green-sand Mechanical Filter

Sulphate, SO₄	
IS 10500-1991	Desirable : 200 mg/l, Permissible : 400 mg/l
Risks or effects	Bitter, medicinal taste, scaly deposits, corrosion, laxative effects, "rotten-egg" odor from hydrogen sulfide gas formation
Sources	Animal sewage, septic system, sewage By-product of coal mining, industrial waste Natural deposits or salt
Sulphate Treatment	Ion Exchange , Distillation , Reverse Osmosis

Nitrate, NO₃-

IS 10500-1991	Desirable : 45 mg/l, Permissible : 100 mg/lit
Risks or effects	Methemoglobinemia or blue baby disease in infants
Sources	Livestock facilities, septic systems, manure lagoons, fertilizers Household waste water, fertilizers Fertilizers Natural Deposits
Treatment	Ion Exchange, Distillation, Reverse Osmosis

Chloride, Cl	
IS 10500-1991	Desirable : 250 mg/l , Permissible : 1000 mg/l
Risks or effects	High blood pressure, salty taste, corroded pipes, fixtures and appliances, blackening and pitting of stainless steel
Sources	Fertilizers Industrial wastes Minerals, seawater
Treatment	Reverse Osmosis , Distillation, Activated Carbon

Fluoride, F	
IS 10500-1991	Desirable : 1.0 mg/l, Permissible : 1.5 mg/l
Risks or effects	Brownish discoloration of teeth, bone damage
Sources	Industrial waste Geological
Treatment	Activated Alumina, Distillation, Reverse Osmosis, Ion Exchange

Arsenic, As	
IS:10500-1991	Desirable: 0.05 mg/l Permissible: No relaxation
Risks or effects	Weight loss; Depression; Lack of energy; Skin and nervous system toxicity
Sources	Previously used in pesticides (orchards) Improper waste disposal or product storage of glass or electronics, Mining Rocks
Treatment	Activated Alumina Filtration, Reverse Osmosis, Distillation, Chemical

	Precipitation, Ion exchange, lime softening
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Chromium, Cr	
IS 10500-1991	Desirable : 0.05 mg/l, Permissible : No relaxation
Risks or effects	Skin irritation, skin and nasal ulcers, lung tumors, gastrointestinal effects, damage to the nervous system and circulatory system, accumulates in the spleen, bones, kidney and liver
Sources	Septic systems Industrial discharge, mining sites Geological
Treatment	Ion Exchange, Reverse Osmosis, Distillation

Copper, Cu	
IS 10500-1991	Desirable : 0.05 mg/l, Permissible : 1.5 mg/l
Risks or effects	Anemia, digestive disturbances, liver and kidney damage, gastrointestinal irritations, bitter or metallic taste; Blue-green stains on plumbing fixtures
Sources	Leaching from copper water pipes and tubing, algae treatment Industrial and mining waste, wood preservatives Natural deposits
Treatment	Ion Exchange, Reverse Osmosis, Distillation

Cyanide	
IS 10500-1991	Desirable : 0.05 mg/l, Permissible : No relaxation
Risks or effects	Thyroid, nervous system damage
Sources	Fertilizer Electronics, steel, plastics mining

Treatment	Ion Exchange, Reverse Osmosis, Chlorination
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Lead, Pb	
IS 10500-1991	Desirable : 0.05 mg/l, Permissible : No relaxation
Risks or effects	Reduces mental capacity (mental retardation), interference with kidney and neurological functions, hearing loss, blood disorders, hypertension, death at high levels
Sources	Paint, diesel fuel combustion Pipes and solder, discarded batteries, paint, leaded gasoline Natural deposits
Treatment	Ion Exchange, Activated Carbon , Reverse Osmosis, Distillation

Mercury, Hg	
IS 10500-1991	Desirable : 0.001 mg/l, Permissible : No relaxation
Risks or effects	Loss of vision and hearing, intellectual deterioration, kidney and nervous system disorders, death at high levels
Sources	Fungicides Batteries, fungicides Mining, electrical equipment, plant, paper and vinyl chloride Natural deposits
Treatment	Reverse Osmosis, Distillation

Zinc, Zn	
IS 10500-1991	Desirable :5 mg/l, Permissible : 15 mg/l
Risks or effects	Metallic taste
Sources	Leaching of galvanized pipes and fittings, paints, dyes Natural deposits
Treatment	Ion Exchange Water Softeners, Reverse Osmosis, Distillation

Total Coliform Bacteria	
IS 10500-1991	95% of samples should not contain coliform in 100 ml 10 coliform / 100ml
Risks or effects	Gastrointestinal illness

Sources	Livestock facilities, septic systems, manure lagoons Household waste water Naturally occurring
Treatment	Chlorination , Ultraviolet, Distillation, Iodination

E.coliform Bacteria	
IS 10500-1991	Nil / 100ml
Risks or effects	Gastrointestinal illness
Sources	Livestock facilities, septic systems, manure lagoons Household waste water Naturally occurring
Treatment	Chlorination , Ultraviolet, Distillation, Iodination

EUTROFICATION

Algae grow in the sea feeding on nutrients in the water. Algae grow better when more nutrients (nitrates and phosphates) are present in the water column. A small increase in algal biomass has no adverse effects on the ecosystem and can even lead to an increase of certain fish populations. An overgrowth however can lead to an algal bloom which may disturb the water. The algae may keep out the light and when they eventually die, they are decomposed by bacteria which consume oxygen in this process so that the water may become temporarily anoxic (hypoxia) which may be toxic to aquatic life. An enrichment by or excess of nutrients to the water is called eutrophication and may result in an explosive growth of algae. Depending on the environment (quiet bay or rough seas) and the type of algae (microscopic or macroscopic), a 'bloom' can be observed in different forms: foam or a green tide on the beach.

Definition-Eutrophication is an enrichment of water by nutrient salts that causes structural changes to the ecosystem such as: increased production of algae and aquatic plants, depletion of fish species, general deterioration of water quality and other effects that reduce and preclude use

Il water bodies are subject to a natural and slow eutrophication process, which in recent decades has undergone a very rapid progression due to the presence of man and his activities (so called cultural eutrophication).

The cultural eutrophication process consists of a continuous increase in the contribution of nutrients, mainly nitrogen and phosphorus (organic load) until it exceeds the capacity of the water body (i.e. the capacity of a lake, river or sea to purify itself) , triggering structural changes in the waters.

These structural changes mainly depend on 3 factors:

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These structural changes mainly depend on 3 factors:

- Use of fertilisers: Agricultural practices and the use of fertilisers in the soil contribute to the accumulation of nutrients. When these nutrients reach high concentration levels and the ground is no longer able to assimilate them, they are carried by rain into rivers and groundwater that flow into lakes or seas.
- Discharge of waste water into water bodies: In various parts of the world, and particularly in developing countries, waste water is discharged directly into water bodies such as rivers, lakes and seas. The result of this is the release of a high quantity of nutrients which stimulates the disproportionate growth of algae. In industrialised countries, on the other hand, waste water can be illegally discharged directly into water bodies. When instead water is treated by means of water treatment plants before discharge into the environment, the treatments applied are not always such as to reduce the organic load, with the consequent accumulation of nutrients in the ecosystem
- Reduction of self-purification capacity: Over the years, lakes accumulate large quantities of solid material transported by the water (sediments). These sediments are such as to be able to absorb large amounts of nutrients and pollutants. Consequently, the accumulation of sediments starts to fill the basin and, increasing the interactions between water and sediment, the resuspension of nutrients present at the bottom of the basin is facilitated. This phenomenon could in fact lead to a further deterioration of water quality, accentuating the processes connected with eutrophication

Formation mechanism

Eutrophication is characterised by a significant increase of algae (microscopic organisms similar to plants) due to the greater availability of one or more growth factors necessary for photosynthesis, such as sunlight, carbon dioxide and nutrients (nitrogen and phosphorus). When algae start to grow in an uncontrolled manner, an increasingly large biomass is formed which is destined to degrade. In deep water, a large amount of organic substance accumulates, represented by the algae having reached the end of their life cycle. To destroy all the dead algae, an excessive consumption of oxygen is required, in some cases almost total, by microorganisms. An anoxic (oxygen-free) environment is thus created on the lake bottom, with the growth of organisms capable of living in the absence of oxygen (anaerobic), responsible for the degradation of the biomass. The microorganisms, decomposing the organic substance in the absence of oxygen, free compounds that are toxic, such as ammonia and hydrogen sulphide. The absence of oxygen reduces biodiversity causing, in certain cases, even the death of animal and plant species. All this happens when the rate of degradation of the algae by microorganisms is greater than that of oxygen regeneration, which in summer is already present in low concentrations.

Effects of eutrophication

The disturbance of aquatic equilibria may be more or less evident according to the enrichment of water by nutrients (phosphorus and nitrogen). An aquatic environment with a limited availability of phosphorus and nitrogen is described as “oligotrophic” while one with high availability of these elements is called “eutrophic”; a lake with intermediate availability is called “mesotrophic”. When the eutrophication phenomenon becomes particularly intense, undesirable effects and environmental imbalances are generated. The two most acute phenomena of eutrophication are hypoxia in the deep part of the lake (or lack of oxygen) and algal blooms that produce harmful toxins, processes that can destroy aquatic life in the affected areas

Cause of Eutrofication

The main effects caused by eutrophication can be summarised as follows

- abundance of particulate substances (phytoplankton, zooplankton, bacteria, fungi and debris) that determine the turbidity and colouration of the water;
- abundance of inorganic chemicals such ammonia, nitrites, hydrogen sulphide etc. that in the drinking water treatment plants induce the formation of harmful substances such as nitrosamines suspected of mutagenicity;
- abundance of organic substances that give the water disagreeable odours or tastes, barely masked by chlorination in the case of drinking water. These substances, moreover, form complex chemical compounds that prevent normal purification processes and are deposited on the walls of the water purifier inlet tubes, accelerating corrosion and limiting the flow rate;
- the water acquires disagreeable odours or tastes (of earth, of rotten fish, of cloves, of watermelon, etc.) due to the presence of particular algae;
- disappearance or significant reduction of quality fish with very negative effects on fishing (instead of quality species such as trout undesirable ones such as carp become established);
- possible affirmation of toxic algae with potential damage to the population and animals drinking the affected water;
- prohibition of touristic use of the lake and bathing, due to both the foul odour on the shores caused by the presence of certain algae, as well as the turbidity and anything but clean and attractive appearance of the water; bathing is dangerous because certain algae cause skin irritation;
- reduction of oxygen concentration, especially in the deeper layers of the lake at the end of summer and in autumn.
- In the light of these significant repercussions and serious consequent economic and naturalistic damage, there is a clear need to curb the progress of eutrophication, avoiding the collapse of the affected ecosystems.

Control of Eutrofication

In the past, the traditional eutrophication reduction strategies, including the alteration of excess nutrients, physical mixing of the water, application of powerful herbicides and algacides, have proven ineffective, expensive and impractical for large ecosystems (Michael F. Chislock, 2013). Today, the main control mechanism of the eutrophic process is based on prevention techniques, namely removal of the nutrients that are introduced into water bodies from the water. It would be sufficient to reduce the concentrations of one of the two main nutrients (nitrogen and phosphorus), in particular phosphorus which

is considered to be the limiting factor for the growth of algae, acting on localised loads (loads associated with waste water) and widespread loads (phosphorus loads determined by diffuse sources such as land and rain). The load is the quantity (milligrams, kilograms, tons, etc.) of nutrients introduced into the environment due to human activity.

The possible activities to be undertaken to prevent the introduction of nutrients and to limit phosphorus loads can be summarised as follows

- abundance of organic substances that give the water disagreeable odours or tastes, barely masked by chlorination in the case of drinking water. These substances, moreover, form complex chemical compounds that prevent normal purification processes and are deposited on the walls of the water purifier inlet tubes, accelerating corrosion and limiting the flow rate;
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The possible activities to be undertaken to prevent the introduction of nutrients and to limit phosphorus loads can be summarised as follows

- improvement of the purifying performance of waste water treatment plants, installing tertiary treatment systems to reduce nutrient concentrations;
- implementation of effective filter ecosystems to remove nitrogen and phosphorus present in the run-off water (such as phyto-purification plants);

- reduction of phosphorous in detergents;
- rationalisation of agricultural techniques through proper planning of fertilisation and use of slow release fertilisers;
- use of alternative practices in animal husbandry to limit the production of waste water.
- removal and treatment of hypolimnetic water (deep water in contact with the sediments) rich in nutrients since in direct contact with the release source;
- drainage of the first 10-20 cm of sediment subject to biological reactions and with high phosphorus concentrations;
- oxygenation of water for restore the ecological conditions, reducing the negative effects of the eutrophic process, such as scarcity of oxygen and formation of toxic compounds deriving from the anaerobic metabolism;
- chemical precipitation of phosphorous by the addition of iron or aluminium salts or calcium carbonate to the water, which give rise to the precipitation of the respective iron, aluminium or calcium orthophosphates, thereby reducing the negative effects related to the excessive presence of phosphorus in the sediments.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD, also called Biological Oxygen Demand) is the amount of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period.

Biochemical oxygen demand (BOD), the amount of dissolved oxygen used by microorganisms in the biological process of metabolizing organic matter in water. The more organic matter there is (e.g., in sewage and polluted bodies of water), the greater the BOD; and the greater the BOD, the lower the amount of dissolved oxygen available for higher animals such as fishes. The BOD is therefore a reliable gauge of the organic pollution of a body of water. One of the main reasons for treating wastewater prior to its discharge into a water resource is to lower its BOD i.e., reduce its need of oxygen and thereby lessen its demand from the streams, lakes, rivers, or estuaries into which it is released.

CALCULATIONS

To determine the value of the BOD in mg/L, use the following formula:

$$\text{BOD, mg/L} = [(\text{Initial DO} - \text{Final DO}) \times 300] / \text{mL sample}$$

For example:

Initial DO = 8.2 mg/L

Final DO = 4.4 mg/L

Sample size = 5 mL

$$\text{BOD mg/L} = [(8.2 - 4.4) \times 300] / 5 = (3.8 \times 300) / 5 = 1140 / 5 = 228 \text{ mg/L}$$

Whenever a sample is dechlorinated, it must be seeded. If the sample is seeded, a correction factor must be calculated to determine the effects that the seed material has on the DO depletion. A number of BOD's must be run on the seed material to determine the seed correction factor.

Chemical Oxygen Demand (COD)

The COD (Chemical Oxygen Demand) test represents the amount of chemically digestible organics (food). COD measures all organics that were biochemically digestible as well as all the organics that can be digested by heat and sulphuric acid. It is used in the same applications as BOD. COD has the advantage over BOD in that the analysis can be completed within a few hours whereas BOD requires 5 days. The major drawback of the COD test is the presence of hazardous chemicals and toxic waste disposal. COD Theory Like the BOD test, oxygen is used to oxidize the organics to carbon dioxide and water. However, instead of free dissolved oxygen, chemically bound oxygen in potassium dichromate $K_2Cr_2O_7$ is used to oxidize the organics. As the potassium dichromate is used up the Cr^{+3} ion is produced. The amount of dichromate used is proportional to the amount of organics present. Likewise, the amount of Cr^{+3} ion present is proportional to the amount of organics digested. Organics + $K_2Cr_2O_7 \rightarrow Cr^{+3}$ (Orange) (Green) Most labs use the Hach Method to measure COD. This method uses test tubes with premeasured amounts of potassium dichromate, sulphuric acid, and catalyst. For the digestion to occur, the reaction needs acid, heat, and a catalyst. The acid is sulphuric acid and is already in the tube. The sample will get very hot when the sample is added to the acid and mixed. Be sure the cap is on tight before mixing and mix just prior to placing in the digestion reactor

Determination of COD

his procedure covers the determination of chemical oxygen demand (COD) and the calculation for the analysis of waste-water in different stages of Effluent Treatment Plant (ETP) in the lab. chemical oxygen demand is a measure of the oxygen required to oxidize all compounds, both organic and inorganic in water.

Reagents preparation for chemical oxygen demand:

1. Standard potassium dichromate solution (0.25N): weigh 12.259gm of previously dried potassium dichromate at $103^{\circ}C$ to $105^{\circ}C$ for 2 hrs and dissolve in distilled water and makeup to 1000 ml in a volumetric flask.
2. Ferro indicator solution: Weigh 1.485 gm of 1,10-Phenanthroline monohydrate and 695 mg ferrous sulphate dissolved in distilled water and dilute to 100 ml in a volumetric flask.
3. 0.1N Ferrous Ammonium Sulphate (FAS): Weigh 39.212gm of FAS and dissolve in distilled water. Add 20 ml concentrated sulphuric acid, cool and dilute to 1000 ml in a volumetric flask.
4. Mercuric Sulphate (powder)
5. Sulphuric acid reagent:
6. Prepare sulphuric acid reagent by dissolving 22 gm of silver sulphate in 2.5 litres of conc. sulphuric acid.
7. Potassium Hydrogen Phthalate standard:
8. Dissolve 0.425 gm of KHP, previously dried at $120^{\circ}C$ for 2 hrs, in 1 litre distilled water. KHP has theoretical COD of $1.176 O_2/mg$ and this solution has theoretical COD of 500 micrograms of O_2/ml of 500ppm.
9. 0.1N Potassium Dichromate Solution:
10. Dissolve 0.5gm of Potassium dichromate in 100ml of water

Standardization of FAS:

- Take an iodine flask containing 90 ml of water.

- Take 10 ml of 0.1N Potassium dichromate solution (prepare 0.1N Potassium dichromate solution by dissolving about 0.5 gm potassium dichromate in 100 ml of water).
- Add 12 ml of conc. sulphuric acid. Cool the content in the flask to laboratory temperature.
- Add 3 to 5 drops of ferroin indicator solution.
- Titrate against 0.1N ferrous ammonium sulphate solution until the colour changes from blue to red.
- Note down the initial burette reading (I) and note down the final burette reading.

Calculate the normality of FAS as follows.
 Normality of FAS = $W / (TV \times 0.04904 \times 10)$.

Where TV= (F-I) volume of ferrous ammonium sulphate solution consumed in the titration

W= weight of potassium dichromate taken.

Determination of chemical oxygen demand, COD:

1. Pipette 20 ml of sample in 250 ml of refluxing flask.
2. Add approximately 400 mg (a pinch) of mercuric sulphate.
3. Add 10 ml of potassium dichromate by pipette.
4. 30 ml of the conc. sulphuric acid reagent by measuring cylinder. Acid should be added in a controlled manner with the mixing of the sample.
5. If the sample colour changes to green, dilute the sample and repeat the procedure for the diluted sample.
6. Connect the reflux flask through the condenser and reflux for a minimum period of 2hrs at 150°C.
7. Add 80 ml distilled water through condenser cool it to room temp and titrated with standard sulphate using 2 to 4 drops of ferroin indicator.
8. The endpoint is the sharp colour change from blue-green to brick red, even though blue-green reappear within minutes. Let the titrate value be 'V' ml
9. Reflux in the same manner a blank with distilled water 20ml and follow the procedure from previously. Let the titrate value be 'B' ml.
10. Calculate the COD (mg/l) as follows

COD= ((B-V)×N(FAS)×8000)/vol. of sample(ml).

Application of chemical oxygen demand for the treatment of effluent generated in vegetable oil refinery:

We have evidence that chemical oxygen demand represents the amount organic matter content in effluents. It is used as measuring variable to develop the kinetic data of biological process units. For example, estimation of reaction rate constants of Fenton type reagents is done using chemical oxygen demand as measuring variable. The order of the reaction is determined by the analysing the kinetic data to design the process equipment that conducts advanced oxidation processes.

Most biological treatments designs cannot eliminate organic matter even the effluents undergo pre-treatment as separation of oil and alum flotation treatment. The need of oxidizing reagents like Fenton reagent (possess hydroxyl radicals) is required to recalcitrant organic compounds and chemical oxygen demand is only possible specification to know the performance of the reagents.

MODULE-II (WATER TREATMENT)

The following steps are adopted for purification of drinking water

1. Coagulation and flocculation

Coagulation and flocculation are used to remove colour, turbidity, algae and other microorganisms from surface waters. The addition of a chemical coagulant to the water causes the formation of a precipitate, or floc, which entraps these impurities. Iron and aluminium can also be removed under suitable conditions. The floc is separated from the treated water by sedimentation and/or filtration, although flotation processes may be used in place of sedimentation. The most commonly used coagulants are aluminium sulphate and ferric sulphate, although other coagulants are available. Coagulants are dosed in solution at a rate determined by raw water quality near the inlet of a mixing tank or flocculator. The coagulant is rapidly and thoroughly dispersed on dosing by adding it at a point of high turbulence. The water is allowed to flocculate and then passes into the sedimentation tank (sometimes known as a clarifier) to allow aggregation of the flocs, which settle out to form sludge. This sludge will need to be periodically removed. The advantages of coagulation are that it reduces the time required to settle out suspended solids and is very effective in removing fine particles that are otherwise very difficult to remove. Coagulation can also be effective in removing many protozoa, bacteria and viruses. The principal disadvantages of using coagulants for treatment of small supplies are the cost and the need for accurate dosing, thorough mixing and frequent monitoring. Coagulants need accurate dosing equipment to function efficiently and the dose required depends on raw water quality that can vary rapidly. The efficiency of the coagulation process depends on the raw water properties, the coagulant used and operational factors including mixing conditions, temperature, coagulant dose rate and pH value. The choice of coagulant and determination of optimum operating conditions for a specific raw water are normally determined by bench scale coagulation tests. Thus, while coagulation and flocculation are the most effective treatment for removal of colour and turbidity they may not be suitable for small water supplies because of the level of control required and the need to dispose of significant volumes of sludge.

Sedimentation

Simple sedimentation (i.e. unassisted by coagulation) may be used to reduce turbidity and solids in suspension. Sedimentation tanks are designed to reduce the velocity of flow of water so as to permit suspended solids to settle under gravity. There are many different designs of tanks and selection is based on simple settlement tests or by experience of existing tanks treating similar waters. Without the aid of coagulation, these will only remove large or heavy particles, and due to the length of time this process will take, the system will usually require storage tanks to balance peaks and troughs in demand. Sedimentation tanks are usually rectangular with length to width ratios between 2:1 and 5:1. The depth of the tank is usually between 1.5 and 2.0m. The inlet and outlet must be at opposite ends of the tank. The inlet should be designed to distribute the incoming flow as evenly as possible across the tank width and to avoid

streaming which would otherwise reduce sedimentation efficiency. Baffles may be installed to prevent short circuiting. The outlet should be designed to collect the clarified water over the entire tank width. The tank should be covered to prevent contamination and ingress. Sedimentation tanks require cleaning when performance deteriorates. This will not normally be more frequent than once per year. 5.5 Filtration Turbidity and algae are removed from raw waters by screens, gravel filters, slow sand, rapid gravity filters or cartridge filters. The difference between slow and rapid sand filtration is not a simple matter of the speed of filtration, but in the underlying concept of the treatment process. Slow sand filtration is essentially a biological process whereas rapid sand filtration is a physical treatment process. Many small private water supplies will rely on cartridge filters consisting of a woven or spun filter within a standard housing.

Screenings and Filtration

Screens are effective for the removal of particulate material and debris from raw water and are used on many surface water intakes. Coarse screens will remove weeds and debris while band screens or micro strainers will remove smaller particles including fish and may be effective in removing large algae. Micro strainers are used as a pre-treatment to reduce solids loading before coagulation or subsequent filtration. A micro strainer may consist of a rotating drum fitted with very fine mesh panels, or may be a fixed mesh that the water flows through. The mesh will ensure that suspended solids, including algae, are retained. The extent of solids removal will be determined by the mesh size and the nature of the raw water. Water will need subsequent treatment downstream and screens should only be considered as a preliminary treatment stage.

Gravel filters

Gravel filters may be used to remove turbidity and algae. A simple gravel filter for the protection of a stream or river inlet. A larger gravel filter may consist of a rectangular channel or tank divided into several sections and filled with graded gravel (size range 4 to 30mm). The raw water enters through an inlet distribution chamber and flows horizontally through the tank, encountering first the coarse and then the finer gravel. The filtered water is collected in an outlet chamber. Solids removed from the raw water accumulate on the floor of the filter. Gravel filters can operate for several years before cleaning becomes necessary. The size of a gravel filter will depend on water quality, flow rate and size of gravel. A filter can be up to 12m long, 2 to 5m wide and 1 to 1.5m deep. The filter should normally be sized for a flow rate of between 0.5 to 1.0 cubic metres per square metre of filter surface area per hour ($\text{m}^3 / \text{m}^2 \cdot \text{h}$). A gravel filter will need subsequent treatment downstream, and should only be considered as a preliminary treatment stage.

Slow sand filters

Slow sand filters, sometimes preceded by micro strainers or coarse filtration, are used to remove turbidity, algae and microorganisms. Slow sand filtration is a simple and reliable process and is therefore often suitable for the treatment of small supplies provided that

sufficient land is available. Slow sand filters usually consist of tanks containing sharp sand (size range 0.15-0.30mm) to a depth of between 0.5 to 1.5m. For small supplies, modular units of 1.25m diameter are available – a tandem installation would occupy a concrete apron of about 8 to 10 m². The raw water flows downwards and turbidity and microorganisms are removed by filtration in the top few centimetres of the sand. A biological layer of sludge, known as the schmutzdecke, develops on the surface of the filter that can be effective in removing microorganisms. Treated water is collected in underdrains or pipework at the bottom of the filter. The top few centimetres of sand containing the accumulated solids are removed and replaced periodically. Filter runs of between 2 and 10 weeks are possible, depending on raw water quality and flow rate. Slow sand filters are often operated in tandem; one in service whilst the other is cleaned and time allowed for the schmutzdecke to re-establish. A variant of the slow sand filter, the “Inverness filter”, has been widely used in Scotland. It uses the same grade of sand and operates at the same flow rate as the traditional slow sand filter but the water flows upwards. Filtration is achieved throughout the filter bed and a true schmutzdecke does not develop. The sand is “washed” by opening a valve at the bottom of the filter and allowing the filter bed to drain rapidly. Slow sand filters should be sized for a water flow rate of between 0.1 and 0.3 m³ /m² .h. The flow rate should be controlled and the filter designed with a treated water reservoir of sufficient capacity to accommodate fluctuations in demand, and thus permit operation of filters at a steady and continuous rate.

Rapid gravity filters

Rapid gravity filters are most commonly used to remove floc from coagulated waters. They may also be used to remove turbidity, algae and iron and manganese from raw waters. Granular activated carbon media may be used to remove organic compounds. Rapid gravity sand filters usually consist of rectangular tanks containing silica sand and/or anthracite media (size range 0.5 to 1.0 mm) to a depth of between 0.6 and 1.0m. The water flows downwards and solids become concentrated in the upper layers of the bed. Treated water is collected via nozzles in the floor of the filter. The accumulated solids are removed periodically by backwashing with treated water, usually preceded by scouring of the media with air. Frequency of backwashing depends on loading rate and raw water quality and is typically every 24 hours. Backwashing can be initiated automatically after a predetermined headloss has been reached or may be carried out manually. Backwash flowrates will be stipulated by the manufacturer. It is important to achieve the required bed expansion in order to ensure filters are washing properly, but care must be taken to prevent loss of media with too high a flowrate. A dilute sludge that requires disposal is produced which may be discharged to sewer, soak away, or after treatment, to a watercourse provided that any required discharge consent is obtained.

Pressure filters

Pressure filters are sometimes used where it is necessary to maintain hydraulic head in order to eliminate the need for additional pumping. The filter bed is enclosed in a cylindrical shell. Small pressure filters capable of treating up to approximately 15m³/h can be manufactured in glass reinforced plastics. Larger pressure filters are manufactured in specially coated steel. Operation and performance are generally as described for the rapid gravity filter and similar facilities are required for backwashing and disposal of the dilute sludge. A similar range of contaminants can be removed depending on the filter medium.

Aeration

Air stripping is used for removal of volatile organics (e.g. solvents), carbon dioxide, disinfection by-products, some taste and odour causing compounds, and radon. It is a fairly specialist technique, and not commonly found as a treatment process on private water supplies, although aeration can sometimes be found in the oxidation stage of the treatment process for the removal of iron and manganese. Aeration processes are designed to achieve efficient mass transfer of oxygen into water and removal of gases and volatile compounds by air stripping. Oxygen transfer can usually be achieved using a simple cascade or diffusion of air into water, without the need for elaborate equipment. Stripping of gases or volatile compounds, however, may require specialised plant that provides a high degree of mass transfer. For oxygen transfer, cascade or step aerators are designed so that water flows in a thin film to achieve efficient mass transfer. Cascade aeration may introduce a significant headloss; design requirements are between 1.0 and 3.0m to provide a loading of 10 to 30m³ /m² .h. If such headloss is unacceptable the alternative is to use compressed air diffused through a system of submerged perforated pipes. These types of aerator are used for oxidation and precipitation of iron and manganese. To achieve air stripping various techniques can be used including counter current cascade aeration in packed towers, diffused aeration in basins and spray aeration. Packed tower aerators are most commonly used because of their high energy efficiency and compact design.

Chemical treatment Control of pH The pH value of water may need to be adjusted during treatment and before distribution for several reasons, including:

- to ensure that the pH value meets the water quality standards
- to control corrosion in the distribution system and consumers' installations or to reduce plumb solvency
- to improve the effectiveness and efficiency of disinfection
- to facilitate the removal of iron and manganese
- to facilitate the removal of colour and turbidity by chemical coagulation
- For removal of hardness
- For removal of other contaminants including some metals Many raw surface waters are slightly acidic and coagulation processes further increase acidity. Increase of pH can be achieved by:
 - dosing with sodium hydroxide, calcium hydroxide or sodium carbonate
 - passage of the water through a bed of alkaline medium
- removal of excess carbon dioxide by aeration Where necessary, reduction of pH can be achieved by dosing with a suitable acid such as sulphuric acid, hydrochloric acid, sodium hydrogen sulphate or carbon dioxide.

Iron and manganese Removal

Iron and manganese removal in groundwater, iron is usually present as dissolved ferrous compounds. To remove iron in this form, it is necessary to oxidise ferrous iron, usually by aeration, to the insoluble ferric hydroxide and to remove the precipitated material in a subsequent filtration stage. It is important to ensure that oxidation does not give rise to colloidal species which may pass through the filters. If the iron is present as an organic complex, a strong oxidant such as chlorine or potassium permanganate must be used. Manganese is usually present as dissolved manganese compounds. Removal is achieved by oxidation to insoluble manganese dioxide using catalytic filters or potassium permanganate followed by filtration, or by coagulation at high pH followed by filtration. In surface waters, iron and manganese are usually present in their oxidised forms and are associated with the suspended solids, which can be removed by filtration. Where coagulation is practised for the removal of colour and turbidity, iron removal may be achieved simultaneously. Iron and manganese may be combined with organic matter in very stable forms. The usual treatment in this case is coagulation followed by oxidation with chlorine or potassium permanganate and filtration. There are a number of proprietary systems on the market which will oxidise and filter iron and manganese within a single unit with automated control systems.

Taste and odour removal

Taste and odour can be removed by several methods, including aeration, zonation and adsorption on activated carbon. The method used will depend on the source of the taste and odour. Adsorption on activated carbon is generally the most effective methods for the removal of earthy or mouldy taste and odour. Powdered activated carbon can be dosed directly to the water before coagulation and then subsequently removed by sedimentation. Powdered activated carbon is generally used as a one off treatment. Where regular treatment is required, granular activated carbon (GAC) is the preferred solution and this may be used as a filter medium replacing sand in existing filters or alternatively in a post-filtration adsorption stage. In this arrangement, GAC will need to be periodically removed and regenerated, often by the manufacturer and typically once every 12-24 months. When returned and reinstalled it will require washing and running to waste before being returned to supply. This is to allow any contaminants and impurities to be washed out. In this type of installation, it is customary to have a system with several GAC beds so that one can be taken out of service without impacting on overall water quality. In private water supplies, the usual method is to use a replaceable GAC cartridge located within a standard cartridge filter housing. This cartridge will be replaced at regular intervals.

Nitrate removal

Nitrate removal is usually achieved by ion-exchange. Water is passed through a column of synthetic resin beads that remove anions including nitrate and exchange them for equivalent amounts of chloride. When the capacity for exchange is exhausted, the resin is regenerated by backwashing with a concentrated solution of sodium chloride. This restores the resin to its initial chloride form. The bed is then rinsed with clean water and returned to service. The waste solution and rinse waters, containing high concentrations of sodium chloride, as well as nitrate, are collected for disposal. Conventional anion exchange resins have a higher affinity for sulphate than for nitrate. This means that they preferentially remove sulphate and reduce the capacity for nitrate, leading in turn to higher running costs (for regenerate) and greater volumes of waste for disposal. As a result, nitrate selective resins, which give better uptake of nitrate in the presence of

sulphate and reduce process costs, are preferred. Nitrate-selective resins preferentially remove nitrate and also add less chloride to the treated water because of the lower sulphate removal. This is desirable since high chloride concentrations and chloride to bicarbonate ratios are associated with increased corrosion of certain metals. A sodium bicarbonate rinse can be used after regeneration with sodium chloride to convert the resin in the lower part of the bed to the bicarbonate form and reduce the chloride to bicarbonate ratio during the early part of the run. An ion-exchange plant consists of two or more reactors operated in parallel. Run lengths of up to 24 hours can be achieved before regeneration is necessary. Regeneration consumes up to 2 percent of the volume of treated water and takes about two hours. Performance is affected by the choice of resin, the concentrations of nitrate and sulphate in the raw water, and the volume and concentration of sodium chloride solution used for regeneration. Operation of an ion-exchange plant is normally fully automatic. Surface waters may require pre-treatment by coagulation to remove organic colour and suspended solids, which would foul the resin. Nitrate can also be removed by some membrane processes and by biological denitrification. Resins are available for removal of many anions and cations and have been successfully used at a small scale for removal of colour.

DISINFECTION PROCESS OF DRINKING WATER:

Water disinfection means the removal, deactivation or killing of pathogenic microorganisms. Microorganisms are destroyed or deactivated, resulting in termination of growth and reproduction. When microorganisms are not removed from drinking water, drinking water usage will cause people to fall ill.

Disinfectants used for water purification:

For chemical disinfection of water, the following disinfectants can be used:

- Chlorine (Cl_2)
- Chlorine dioxide (ClO_2)
- Hypo chlorite (OCl^-)
- Ozone (O_3)
- Halogens: bromine (Br_2), iodine (I)
- Bromine chloride (BrCl)

For physical disinfection of water, the following disinfectants can be used:

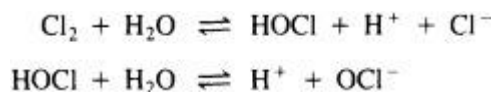
- Ultraviolet light (UV)
- Electronic radiation
- Gamma rays

- Heat

Chlorination:

Chlorination has been the predominant method of drinking water disinfection in the United States for more than 70 years. When concerns about the formation of trihalomethanes and other halogenated hydrocarbon by-products began to stimulate the reexamination of chlorination practices in the early 1970s, chlorine was being used to disinfect about 95% of the potable water supplied in the United States (Morris, 1971).

Chlorine, a strong oxidizing and disinfecting agent, is an effective microbiocide against most waterborne pathogens. It is inexpensive and relatively convenient to produce, store, transport, and use. Nonetheless, because it is a gas at room temperature it can present safety problems, especially during transportation and storage. Its high solubility in water makes it easy to apply in controlled amounts either as chlorine gas, which readily dissolves in water at room temperature, or as a salt of hypochlorite, which is formed by the reaction of chlorine and water as follows:



During chlorination, the relative concentrations of the hypochlorous acid (HOCl) and hypochlorite ions (OCl⁻), together termed "free chlorine," are determined mainly by measurement of pH. HOCl, a more effective biocide than OCl⁻, dissociates into OCl⁻ between a pH of 7.0 and 8.0, the range in which most potable water undergoes treatment

Ozone

Ozone (O₃) is a strong oxidizing gas that reacts rapidly with most organic (and many inorganic) molecules. Its short half-life in water, approximately 10 to 30 minutes in practical treatment applications, requires ozone to be generated on-site for use as a disinfectant. Ozone does not produce a disinfecting residual, so a second disinfectant must usually be added to the treated water to furnish the necessary protection in the distribution system.

Ozone is used as the primary disinfectant in many drinking water treatment plants, mostly in Europe and Canada. Small-scale applications have been limited in the past owing to maintenance and repair requirements for a reliable power source; but the large-scale technology is well established, and both the reliability and efficiency of ozone technology are improving rapidly. A typical ozone disinfection system consists of modular solid-state generators, air pre-drying equipment (necessary to produce ozone efficiently), and contactors designed to produce good mixing with the water being treated.

Chlorine Dioxide

Chlorine dioxide (ClO₂) is used mainly as an industrial bleaching agent for wood pulp, textiles, flour, fats, oils, and waxes, but it has been widely used at drinking water treatment plants for taste, odour, and algal control; iron and manganese removal; and (mainly in Europe) disinfection. Since ClO₂ is unstable; sensitive to temperature, pressure, and light; and explosive in air at concentrations of about 4% or more, it is usually generated and used on-site to avoid problems of bulk storage and distribution.

Chloramination

Although chloramines are less effective than free chlorine as biocides they are more persistent and do not react to form trihalo methanes. Concerns about halogenated by-products of chlorination, and the maximum contaminant level (MCL) of 0.10 mg of total trihalomethanes per liter set by the Environmental Protection Agency under the Safe Drinking Water Act (EPA 1979, 1980), have caused treatment facilities in several states to increase or switch to chloramination (Hack, 1985).

Kansas now requires the use of ammonia to convert all the free-chlorine residual to chloramines following 30 minutes of chlorination. The Metropolitan Water District of Southern California has changed from chlorination to chloramination for distribution system disinfection. In contrast, several states continue to prohibit chloramination, as Kansas formerly did.

Phosphorous removal processes from water:

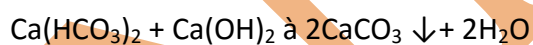
The removal of phosphorous from wastewater involves the incorporation of phosphate into TSS and the subsequent removal from these solids. Phosphorous can be incorporated into either biological solids (e.g. microorganisms) or chemical precipitates.

Phosphate precipitation

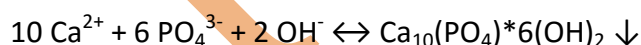
Chemical precipitation is used to remove the inorganic forms of phosphate by the addition of a coagulant and a mixing of wastewater and coagulant. The multivalent metal ions most commonly used are calcium, aluminium and iron.

Calcium:

it is usually added in the form of lime $\text{Ca}(\text{OH})_2$. It reacts with the natural alkalinity in the wastewater to produce calcium carbonate, which is primarily responsible for enhancing SS removal.



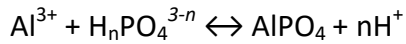
As the pH value of the wastewater increases beyond about 10, excess calcium ions will then react with the phosphate, to precipitate in hydroxylapatite:



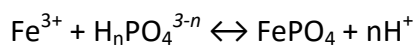
Because the reaction is between the lime and the alkalinity of the wastewater, the quantity required will be, in general, independent of the amount of phosphate present. It will depend primarily on the alkalinity of the wastewater. The lime dose required can be approximated at 1.5 times the alkalinity as CaCO_3 . Neutralisation may be required to reduce pH before subsequent treatment or disposal. Recarbonation with carbon dioxide (CO_2) is used to lower the pH value.

Aluminium and Iron:

Alum or hydrated aluminium sulphate is widely used precipitating phosphates and aluminium phosphates (AlPO_4). The basic reaction is:



This reaction is deceptively simple and must be considered in light of the many competing reactions and their associated equilibrium constants and the effects of alkalinity, pH, trace elements found in wastewater. The dosage rate required is a function of the phosphorous removal required. The efficiency of coagulation falls as the concentration of phosphorous decreases. In practice, an 80-90% removal rate is achieved at coagulant dosage rates between 50 and 200 mg/l. Dosages are generally established on the basis of bench-scale tests and occasionally by full-scale tests, especially if polymers are used. Aluminium coagulants can adversely affect the microbial population in activated sludge, especially protozoa and rotifers, at dosage rates higher than 150 mg/l. However, this does not affect much either BOD or TSS removal, as the clarification function of protozoa and rotifers is largely compensated by the enhanced removal of SS by chemical precipitation. Ferric chloride or sulphate and ferrous sulphate are widely used for phosphorous removal, although the actual reactions are not fully understood. The basic reaction is:

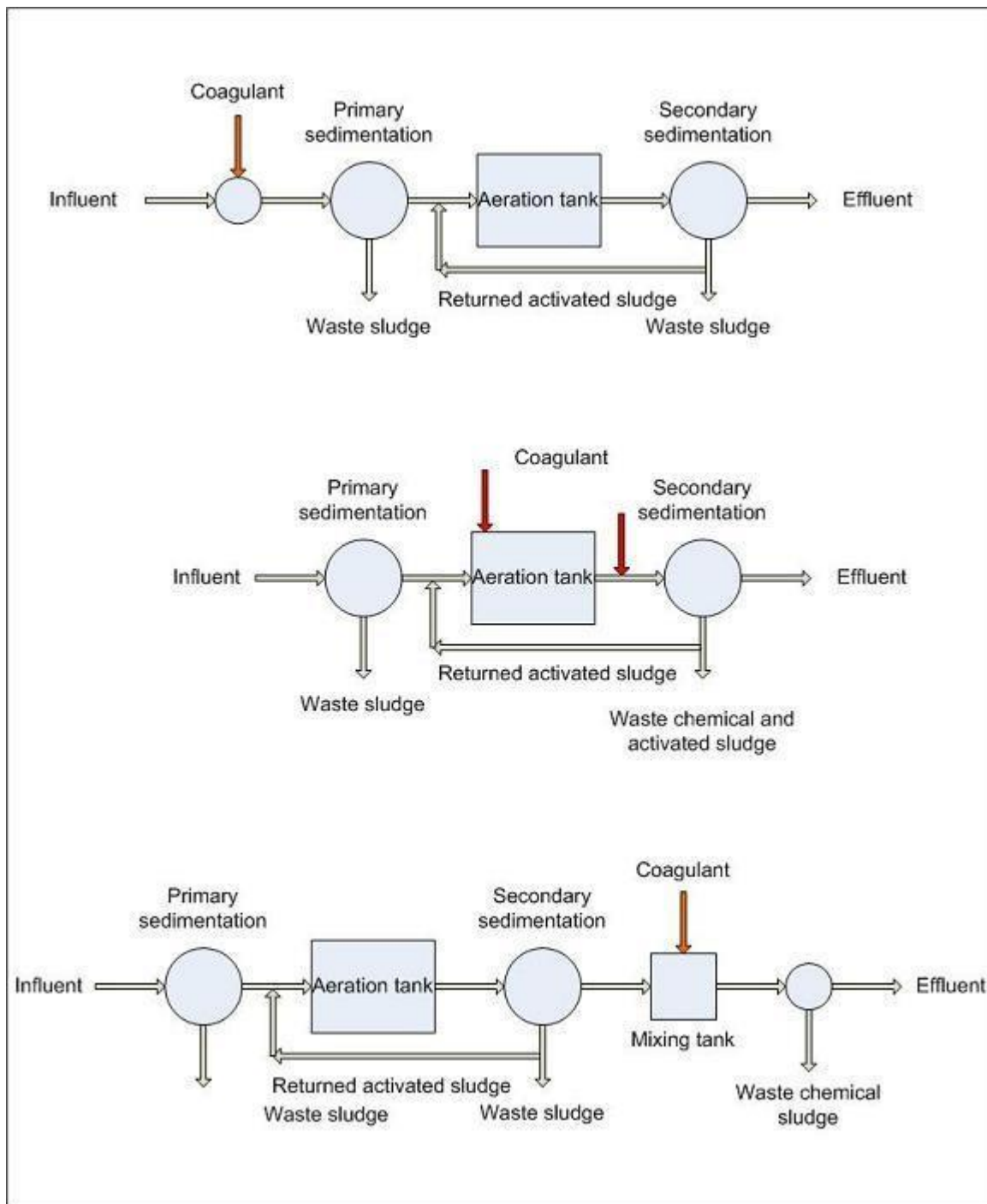


Ferric ions combine to form ferric phosphate. They react slowly with the natural alkalinity and so a coagulant aid, such as lime, is normally added to raise the pH in order to enhance the coagulation.

Strategies

The main phosphate removal processes are as follows:

1. Treatment of raw/primary wastewater
2. Treatment of final effluent of biological plants (post precipitation)
3. Treatment contemporary to the secondary biologic reaction (co-precipitation).



The first process is included in the general category of chemical precipitation processes. Phosphorous is removed with 90% efficiency and the final P concentration is lower than 0.5 mg/l. The chemical dosage for P removal is the same as the dosage needed for BOD and SS removal, which uses the main part of these chemicals. As mentioned above lime consumption is dependent on the alkalinity of the wastewater: only 10% of the lime fed is used in the phosphorous removal reaction. The remaining amount reacts with water alkalinity, with softening. To determine the lime quantity needed it is possible to use diagrams: i.e. the lime used to reach pH 11 is 2-2.5 times water alkalinity.

The post precipitation is a standard treatment of a secondary effluent, usually using only metallic reagents. It is the process that gives the highest efficiency in phosphorous removal. Efficiency can reach 95%, and P concentration in the effluent can be lower than 0.5 mg/l. Post precipitation gives also a good removal of the SS that escape the final sedimentation of the secondary process. Its advantage is also to guarantee purification efficiency at a certain extent even if the biological process is not efficient for some reason. The chemical action is stronger, since the previous biologic treatment transforms part of the organic phosphates in orthophosphates. Disadvantages are high costs for the treatment plant (big ponds and mixing devices) and sometimes a too dilute effluent. Using ferric salts there is also the risk of having some iron in the effluent, with residual coloration. The metallic ions dosage is about 1.5-2.5 ions for every phosphorus ion (on average about 10-30 g/mc of water).

The precipitation process is particularly suitable for active sludge plants, where the chemicals are fed directly in the aeration tank or before it. The continuous sludge recirculation, together with the coagulation-flocculation and adsorption process due to active sludge, allows a reduction in chemical consumption. Moreover, the costs for the plant are lower, since there is no need for big post precipitation ponds. In this process the chemical added are only iron and aluminium, lime is added only for pH correction. Lower costs and more simplicity are contrasted by a phosphorous removal efficiency lower than with post precipitation (below 85%). The phosphorous concentration in the final effluent is about 1 mg/l. Another disadvantage is that biological and chemical sludge are mixed, so they cannot be used separately in next stages. Mixed sledges need bigger sedimentation tanks than activated sludge.

Biological processes

Over the past 20 years, several biological suspended growth process configurations have been used to accomplish biological phosphorous removal. The most important are shown in the following picture. The principal advantages of biological phosphorous removal are reduced chemical costs and less sludge production as compared to chemical precipitation.

In the biological removal of phosphorous, the phosphorous in the influent wastewater is incorporated into cell biomass, which is subsequently removed from the process as a result of sludge wasting. The reactor configuration provides the P accumulating organisms (PAO) with a competitive advantage over other bacteria. So PAO are encouraged to grow and consume phosphorous. The reactor configuration is comprised of an anaerobic tank and an activated sludge activated tank. The retention time in the anaerobic tank is about 0.50 to 1.00 hours and its contents are mixed to provide contact with the return activated sludge and influent wastewater.

In the anaerobic zone: Under anaerobic conditions, PAO assimilate fermentation products (i.e. volatile fatty acids) into storage products within the cells with the concomitant release of phosphorous from stored polyphosphates. Acetate is produced by fermentation of bsCOD, which is dissolved degradable organic material that can be easily

assimilated by the biomass. Using energy available from stored polyphosphates, the PAO assimilate acetate and produce intracellular polyhydroxybutyrate (PHB) storage products. Concurrent with the acetate uptake is the release of orthophosphates, as well as magnesium, potassium, calcium cations. The PHB content in the PAO increases as the polyphosphate decreases.

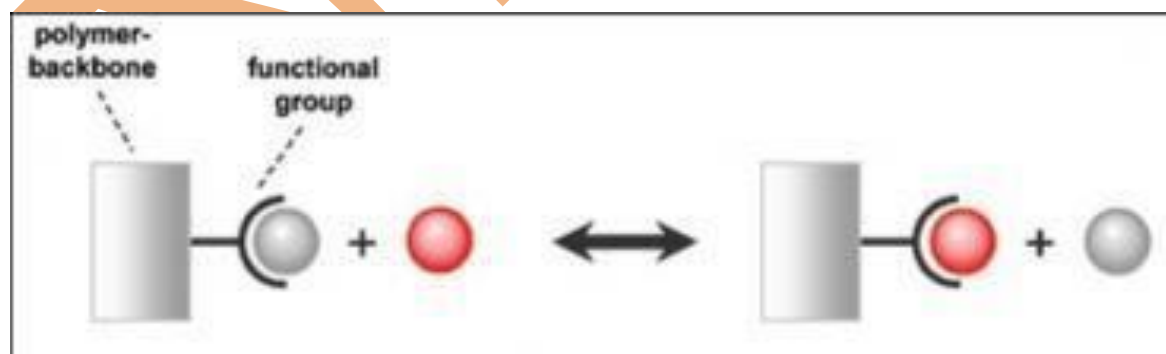
In the aerobic zone: energy is produced by the oxidation of storage products and polyphosphate storage within the cell increases. Stored PHB is metabolized, providing energy from oxidation and carbon for new cell growth. Some glycogen is produced from PHB metabolism. The energy released from PHB oxidation is used to form polyphosphate bonds in cell storage. The soluble orthophosphate is removed from solution and incorporated into polyphosphates within the bacterial cell. PHB utilisation also enhances cell growth and this new biomass with high polyphosphate storage accounts for phosphorous removal. As a portion of the biomass is wasted, the stored phosphorous is removed from the bio- treatment reactor for ultimate disposal with the waste sludge.

The amount of phosphorous removed by biological storage can be estimated from the amount of COD that is available in the wastewater influent. Better performance for BPR systems is achieved when COD acetate is available at a steady rate.

Ion exchange Process for water treatment:

Ion exchange (IE) is a water treatment method where one or more undesirable contaminants are removed from water by exchange with another non-objectionable, or less objectionable substance. Both the contaminant and the exchanged substance must be dissolved and have the same type (+, -) of electrical charge.

Ion exchange resins : Synthetic and industrially produced ion exchange resins consist of small, microporous beads that are insoluble in water and organic solvents. The most widely used base-materials are polystyrene and polyacrylate. The diameter of the beads is in the range of 0.3 to 1.3 mm. The beads are composed of around 50% water, which is dispersed in the gel-structured compartments of the material



Since water is dispersed homogenously throughout the bead, water-soluble materials can move freely in and out. To each of the monomer units of the polymer, so called “functional

groups” are attached. These functional groups can interact with water-soluble species, especially with ions. Ions are either positively charged (cations) or negatively charged (anions). Since the functional groups are also charged, the interaction between ions and functional groups is exhibited via electrostatic forces. Positively charged functional groups interact with anions and negatively charged functional groups interact with cations.

The binding force between the functional group and the attached ion is relatively weak. The exchange can be reversed by another ion passing across the functional group. This process can be repeated continually, with one exchange reaction following another.

The main component of ion exchange equipment is a microporous exchange resin, which is supersaturated with a loosely held solution. For water softening, this is usually done with sulfonated polystyrene beds that are supersaturated with sodium to cover the bed surface. As water passes through this resin bed, ions attach to the resin beads releasing the loosely held solution into the water.

After a time, the beds become saturated and the exchange resin must be regenerated or recharged. To regenerate, the ion exchange resin is flushed with a salt brine solution. The sodium ions in the salt brine solution are exchanged with the ions, which are flushed out with wastewater.

Reverse Osmosis process:

Reverse Osmosis (RO) is a water treatment process that removes contaminants from water by using pressure to force water molecules through semipermeable membrane. During this process, the contaminants are filtered out and flushed away, leaving clean, delicious drinking water

Reverse osmosis water treatment **separates molecules and ions from their solutions**, and is used in the production of potable, ultrapure and process water. Veolia Water Technologies South Africa, as part of its **total water solutions supply**, manufactures high-quality reverse osmosis membranes and chemicals, and will design, install and commission your entire reverse osmosis water treatment plant.

By applying external pressure, reverse osmosis drives a given solution through a **semi-permeable membrane** designed to overcome its osmotic pressure. Under normal osmotic circumstances, the solution would travel from lower saline concentration to high concentrations.

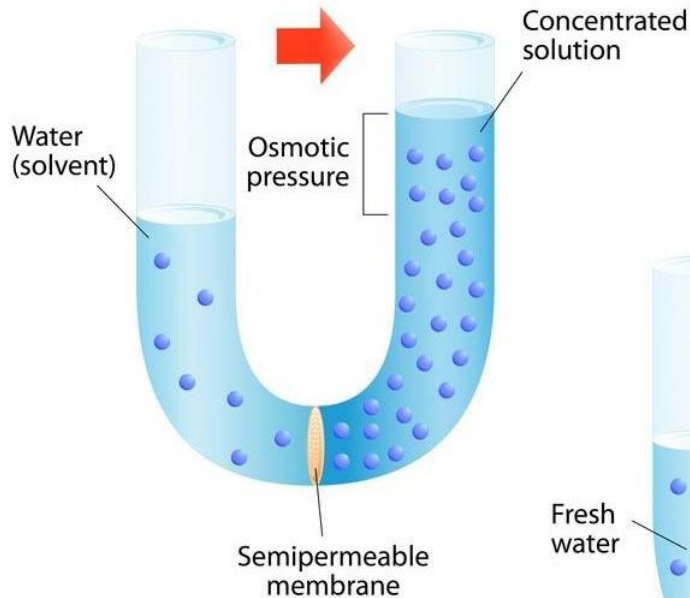
The largest application of reverse osmosis water treatment is desalination - the production of potable water from seawater - which provides a fundamental water source for some of the world's major cities. **Veolia's reverse osmosis water treatment** installations account for about **15% of the world's total desalination capacity**, and include one of the world's largest-capacity reverse osmosis plants used for desalination. The plant, in Ashkelon, Israel, provides 330 000 m³/day of potable water to the country.

Apart from desalination, **reverse osmosis water treatment** is also used extensively in:

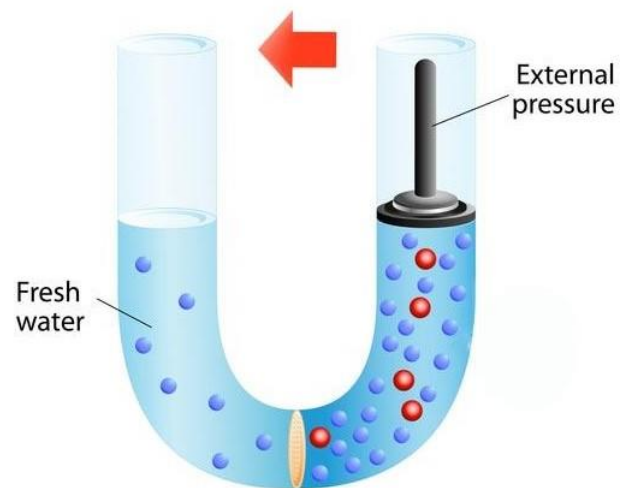
- The production of process and potable water

- Polishing and demineralisation of boiler feed water and pharmaceutical water
- The rehabilitation and recycling of process and municipal effluent

Osmosis



Reverse osmosis



Osmosis is defined as the process of molecules passing through a semi-permeable membrane from a less-concentrated solution into a more-concentrated solution.

An example of osmosis from nature is the roots of plants drawing water from the soil.

Reverse osmosis is simply the opposite of that process.

Molecules are forced through a semi-permeable membrane to form a less concentrated solution.

Essentially, the membrane acts like a type of filter as it has extremely tiny pores that help remove microscopic contaminants from the water you drink by straining them out.

In the case of reverse osmosis drinking water systems, the semi-permeable membrane only lets water molecules through while other contaminants are collected and flushed away.

How Reverse Osmosis Filtration Works

There's a bit more to the process when using a reverse osmosis system to purify drinking water.

If you've ever seen an R.O. system, you've likely noticed the three cylindrical canisters on a manifold. One of these is the membrane and the other two are carbon filters. Let's take a closer look at what each of these cartridges do.

Step 1- Pre-filtration

The first step in purifying water with reverse osmosis is meant to protect the membrane. It removes larger sediment, including some dissolved solids, and helps reduce chlorine. This first cartridge is referred to as the sediment filter or carbon block filter. It helps conserve the membrane, which can get clogged by excess sediment or damaged by exposure to too much chlorine, which you'll find in municipal water.

Reverse osmosis works best when you start with good water and then make it great. That's why you should never use a reverse osmosis system with hard water unless it is under 10 grains per gallon. If your water is too hard, start with one of our other water treatment solutions.

The Reverse Osmosis Membrane

Following the initial filtration comes the real magic of an R.O. system.

Your water is forced through the semi-permeable membrane under pressure. The membrane is a synthetic plastic material that allows the passage of water molecules. However, sodium, chlorine, and calcium as well as larger molecules like glucose, urea, bacteria and viruses cannot pass.

We have reverse osmosis drinking water systems that are tested and certified for reduction of:

- lead
- arsenic
- copper
- nitrates and nitrites
- chromium (hexavalent & trivalent)
- selenium
- fluoride
- radium
- barium

- cadmium
- cyst (cryptosporidium)
- total dissolved solids (TDS)
- **Steps 3 & 4:- Post Filtration and Final Polish**
 - Before your home's water is ready to drink, it goes through a second carbon filter (or post filter), which removes any remaining contaminants in the unlikely case they slipped past the membrane.
 - Then the water fills up a storage tank where it waits until you're ready to use it.
 - Finally, there's the in-line activated carbon filter, which gives your water one last polish as it comes out your faucet. This is used to remove any remaining odors or flavours that may come from the system hoses or the holding tank.
 - The polish is a "just in case" step to make sure the water you drink tastes incredibly fresh

Physical Treatment and Biological Treatment of Sewage

Sewage or municipal waste should not be directly passed into rivers, streams and other water bodies because it not only contains human excreta and other organic wastes but a number of pathogenic microbes. It is made less polluting by passing it through sewage treatment plants (STPs). Here heterotrophic microbes naturally present in sewage carry out the process of decomposition. There are three stages of this treatment; primary, secondary and tertiary. Primary treatment is physical, secondary biological and tertiary chemical. Waste water can be passed into rivers after secondary treatment.

Primary or Physical Treatment:

It is the process of removal of small and large, floating and suspended solids from sewage through two processes of filtration and sedimentation. First floating and suspended matter is removed through sequential filtration with progressively smaller pore filters. The filtrate is then kept in large open settling tanks where grit (sand, silt, small pebbles) settles down.

Aluminium or iron sulphate is added in certain places for flocculation and settling down of solids. The sediment is called primary sludge while the

supernatant is called effluent. The primary sludge traps a lot of microbes and debris. It is subjected to composting, land fill or anaerobic digestion to produce biogas and manure.

Secondary or Biological Treatment:

There are several methods of secondary treatment, e.g., oxidation tanks, trickling filter system and activated sludge system. In activated sludge system, the primary effluent is taken to aeration tanks. Liquid is constantly agitated mechanically. Air is also pumped into it. Some activated sludge of the previous operation is inoculated to hasten decomposition. A large number of aerobic heterotrophic microbes grow in the aeration tank.

They include bacteria of different types, some filamentous fungi, yeasts and protozoan. They form flocs. Flocs are masses of bacteria held together by slime and fungal filaments to form mesh like structures. The microbes digest a lot of organic matter, converting it into microbial biomass and releasing a lot of minerals.

This reduces Biochemical Demand or BOD. As the BOD of the waste matter is reduced to 10-15% of raw sewage, it is passed into settling tank. In settling tank, the bacterial flocs are allowed to undergo sedimentation. The effluent or supernatant is generally passed into natural waters like rivers and streams. It can also be treated chemically to further purify it.

The sediment of settling tank is called activated sludge. A part of it is used as inoculum in aeration tanks. The remaining is passed into a large tank called anaerobic sludge digesters. They are designed for continuous operation. The aerobic microbes present in the sludge get killed. Anaerobic microbes digest the organic mass as well as aerobic microbes (bacteria and fungi) of the sludge.

They are of two types, non-methanogenic and methanogenic. Methanogenic bacteria produce marsh gas which is a mixture of gases containing methane, H_2S and CO_2 . The mixture also called biogas is inflammable and is a source of energy. The spent sludge can be used as manure or part of compost.

HEALTH EFFECTS OF DRINKING WATER

- When the body is functioning at its best, you will feel great and be happy

- These are the benefits of using good quality of drinking water
Without water, there is no life.
- The comparative scarcity of water first suppresses and eventually kills some aspects of our bodies.
- Water is the primary source of energy in the body.
- Water generates electric and magnetic energy inside a cell in the body that provides energy to live.
- Water is an adhering agent within the cell structure.
- Water prevents damage in the DNA, and makes repairing mechanisms more efficient, making the DNA less abnormal.
- Water increases in a large way the efficacy of the immune system in the bone marrow, that is, where the immune system is formed, including its efficiency against cancer.
- Water is a main dissolvent for all foods, vitamins, and minerals. It is used in the breaking down of foods into small particles and eventually metabolizing and digesting them.
- Water energizes foods and the particles of foods capable of providing the body with this energy during digestion. This is why food without water has absolutely no energy value for the body.
- Water helps increase the rate of the body in regards to the absorption of essential substances in foods.
- Water is used for the transportation of all substances within the body.
- Water increases the efficacy of red blood cells in gathering of oxygen in the lungs.
- When water reaches a cell, it provides it with cellular oxygen and takes residual gases to the lungs for their elimination.
- Water cleanses toxic residues from different parts of the body and carries them to the liver and the kidneys for their elimination.
- Water is the main lubricant in joint cavities and helps prevent arthritis and back pain.]
- Water is used in the spinal discs so that they are “water cushions for the absorption of impacts”.
- Water is the best laxative in the prevention of constipation.
- Water helps reduce the risk of heart attacks and brain damage.
- Water prevents arterial blockage in the heart and brain.
- Water is essential for the cooling system of the body (sweating) and the heating (burning calories).
- Water gives us power and electrical energy for all our brain functions, especially for thinking.
- Water is directly necessary for the efficient fabrication of all the neurotransmitters, like serotonin.
- Water is directly necessary for the production of all the hormones produced in the brain, including melatonin.
- Water can help prevent ADHD in kids and adults.
- Water does not only increase work efficiency, but also increases attention span.
- Water is better than any other drink in the world to wake us up, and it has no side effects.

- Water helps reduce stress, anxiety, and depression.
- Water restores normal sleep schedules.
- Water helps reduce fatigue; it gives us youthful energy.
- Water makes the skin softer and helps reduce the effects of aging.
- Water makes the eyes more lustrous and bright.
- Water helps prevent glaucoma.
- Water normalizes the fabrication of blood in the bone marrow, which helps prevent leukemia and lymphoma.
- Water is absolutely vital for making the immune system more efficient in different areas to combat infections and fight cancerous cells.
- Water thins the blood and prevents blood clots.
- Water diminishes premenstrual cramps and hot flashes.
- Water and the heartbeat create dilution and waves that keep things from settling and forming deposits in the bloodstream.
- The human body does not have water stored up to take advantage of during dehydration. For this reason, you should drink water regularly throughout the day.
- Dehydration impedes the production of sex hormones, one of the main causes of impotence and the loss of libido.
- Potable water separates the sensations of hunger and thirst.
- To lose weight, drinking water is the best way to do so. Drink the much-needed water and lose weight without dieting. Also, you should not eat too much all at once when you feel hungry, in fact, you may just be thirsty.
- Dehydration creates toxic sediment deposits in the tissue spaces, joints, kidneys, liver, brain, and skin. Water will get rid of those deposits.
- Water reduces the feeling of morning sickness during pregnancy.
- Water is part of brain and body functions. It increases the capacity to achieve goals and intentions.
- Water helps prevent memory loss as we age. This helps reduce the risk of Alzheimer's, multiple sclerosis, Parkinson's, and Lou Gehrig's Disease.
- Water helps reduce addictive impulses, including those of caffeine, alcohol, and some medications.

WATER TREATMENT TECHNOLOGIES

1. Membrane Filtration Technology

There are two classes of membrane treatment systems that should be discussed: low-pressure membrane systems (such as microfiltration and ultrafiltration) and high-pressure membrane systems (such as nanofiltration and reverse osmosis). Low-pressure membranes, including microfiltration (MF) and ultrafiltration (UF), are operated at pressures ranging from 10 to 30 psi, whereas high-pressure membranes, including nanofiltration (NF) and reverse osmosis (RO), are operated at pressures ranging from 75 to 250 psi

Low-Pressure Membranes

If there is a "Cinderella" story of a water treatment technology it is that of the application of low-pressure membranes for surface water treatment. The idea of using low-pressure membrane filtration for surface water treatment began developing in the early 1980s. At the time, low-pressure membranes had long been used in the food-processing industry as

nonchemical disinfectants. During the latter half of the 1980s, several research projects were initiated by west coast water utilities (East Bay Municipal Utilities District and Contra Costa Water District), the American Water Works Association (AWWA) Research Foundation, and other organizations to evaluate MF and UF for municipal surface water treatment. The studies clearly showed that both MF membranes (with a nominal pore size of 0.2 μm) and UF membranes (with a nominal pore size of 0.01 μm) are highly capable of removing particulate matter (turbidity) and microorganisms. In fact, the research results showed that, when it came to these contaminants, membrane-treated water was of much better quality than that produced by the best conventional filtration plants. Figure 11-2 shows an example plot of turbidity removal by an MF membrane. The majority of treated-water samples had a turbidity level near the limit of the on-line turbidimeter (less than 0.05 Nephelometric Turbidity Units (NTU)). In addition, membrane filtration (both MF and UF) was proven to be an "absolute barrier" to *Giardia* cysts and *Cryptosporidium* oocytes when the membrane fibers and fittings were intact. Finally, the particular UF membranes tested by Jacangelo et al. (1995) were also proven to act as absolute barriers to viruses because of their nominal pore size of 0.01 μm .

As a surface water treatment technology, low-pressure membrane filtration has several advantages over conventional filtration and chlorination. These include smaller waste stream, lower chemical usage, smaller footprint, greater pathogen reduction, no disinfection byproduct formation, and more automation. For a while it was also believed that low-pressure membrane filtration is highly susceptible to excursions in raw water turbidity. However, pilot- and full-scale operational data have demonstrated that low-pressure membranes can treat turbidity excursions as high as several hundred NTUs with manageable impacts on process operation and efficiency (Yoo et al., 1995). All of the above advantages greatly favor membrane filtration over conventional filtration with chlorine.

High-Pressure Membranes

As noted earlier, included in this category are nanofiltration (NF) and reverse osmosis (RO) membranes. NF membranes are actually thin-film composite Re membranes that were developed specifically to cover the pore size between Re membranes (<1 nm) and UF membranes (>2 nm) (Matsuura, 1993)--hence the name nanofiltration. at higher flux and lower pressure than traditional cellulose acetate (CA) RO membranes. In fact, NF membranes are sometimes referred to as "loose" RO membranes and are typically used when high sodium rejection, which is achieved by RO membranes, is not required, but divalent ions (such as calcium and magnesium) are to be removed

Currently, NF membranes are being considered as a total organic carbon (TOC) removal technology in surface water treatment. The idea is to install NF membranes downstream of media filtration in order to maintain a very low solids-loading rate on the membranes. Although NF membranes have been designated by the U. S. Environmental Protection Agency (EPA) as one of two best available technologies (BATs) for meeting stage 2 of the Disinfectants/Disinfection Byproducts Rule, they have not been applied for

surface water treatment at full scale. To date, pilot studies have been conducted to evaluate the applicability of NF membrane filtration downstream of media filtration during surface water treatment with mixed results

RO membranes have long been used for desalination of seawater around the world. These membranes can consistently remove about 99 percent of the total dissolved solids (TDSs) present in the water, including monovalent ions such as chloride, bromide, and sodium. However, for a long time these membranes were predominantly made from CA and required operating pressures at or greater than 250 psi. Recent innovations in Re membrane manufacturing have developed a new class of Re membranes, called TFC membranes that can achieve higher rejection of inorganic and organic contaminants than CA Re membranes while operating at substantially lower pressures (100 to 150 psi). In addition, CA Re membranes commonly require acid addition to lower the pH of the water to a range of 5.5 to 6.0 to avoid hydrolysis of the membrane material. TFC RO membranes do not hydrolyze at neutral or high pH and therefore do not require pH depression with acid addition. It should be noted that the need for pH depression for preventing the precipitation of salts on the membrane surface (such as CaCO_3) may still be necessary in some cases depending on the quality of the water being treated and the availability of suitable antiscalents.

TFC RO membranes are currently being evaluated for water reclamation. Results from ongoing pilot studies have shown that TFC RO membranes can achieve greater than 90 to 95 percent rejection of nitrate and nitrite, compared to 50 to 70 percent removal with CA Re membranes. The same pilot studies also show that the TOC concentration in the effluent of TFC Re membranes can be as low as 25 to 50 g/L.

Two-Stage Membrane Filtration

From the above discussion it is apparent that low-pressure membranes are highly effective for particulate removal, while high-pressure membranes are effective for dissolved matter removal (both organic and inorganic). Conceptually, combination of the two membrane systems in series (MF or UF followed by NF or RO) would provide a comprehensive treatment process train that is capable of removing the vast majority of dissolved and suspended material present in water. Such a treatment train is commonly termed "two-stage membrane filtration." Other names include "integrated membrane systems" or "dual-stage membrane filtration." The only material that is believed to pass through such a treatment train includes low-molecular-weight organic chemicals. However, compared to existing treatment, a two-stage membrane filtration process (possibly coupled with PAC addition) would produce far superior water quality. The main concern about such highly treated water is that it may be more corrosive. Special corrosion inhibition measures for low-TDS waters of this kind require further development.

Ultraviolet Irradiation Technology

Ultraviolet (UV) irradiation technology is primarily used in the water and wastewater treatment industry as a disinfection process that capitalizes on the germicidal effect of UV light in the wavelength range of 250 to 270 nm (EPA, 1996). The process is commonly designed such that water flows in a narrow region around a series of UV lamps. The microorganisms in the water are inactivated through exposure to the UV light. The process is compact since the time of exposure (which translates into hydraulic retention time) is commonly measured in seconds. The process works on the principle that UV energy disrupts the DNA of the microorganisms and prevents it from reproducing. UV irradiation technology has been used since the 1950s at approximately 500 drinking water facilities in the United States, and more than 1,500 facilities in Europe. However, the process can certainly be scaled up to large-scale applications since it is currently applied at large-scale wastewater treatment plants for final effluent disinfection.

There are four types of UV technologies of interest to the water industry: low-pressure, low-intensity (LP-LI) UV technology; low-pressure, medium-intensity (LP-MI) UV technology; medium-pressure, high-intensity (MP-HI) UV technology; and pulsed-UV (PUV) technology. Approximately 90 percent of the UV installations in North America have LP-LI UV technology, with some dating back to the 1970s. The power output of LP-LI UV lamps commonly varies from 40 to 85 W. Another unique characteristic of low-pressure lamps is that they emit a monochromatic light at a wavelength of 254 nm. EPA's design manual is specifically based on and tailored to LP-LI UV technology. The primary advantage of LP-LI UV lamps is their high efficiency. The primary disadvantage is their low power, which results in the need for a large number of lamps for a small plant. For example, a typical secondary wastewater effluent would require approximately 40 LP-LI UV lamps per MGD of peak capacity. Considering that a significant labor effort is required to clean and maintain UV lamps, the application of LP-LI UV technology at large scale is not desirable.

Advanced Oxidation Technology

The term "advanced oxidation processes" (AOPs) was first used by Glaze et al. (1987) and Aieta et al. (1988) to describe a process that produces hydroxyl radicals (OH) for the oxidation of organic and inorganic water impurities. AOPs include a number of processes. However, three main AOPs are discussed herein: ozone, ozone with hydrogen peroxide addition, and UV irradiation with hydrogen peroxide addition. AOPs can have multiple uses in water treatment. Examples include oxidation of synthetic organic chemicals, color, taste-and-odor-causing compounds, sulfide, iron, and manganese and destruction of DBP precursors prior to the addition of chlorine. However, Trussell and Najm have demonstrated that AOPs may not be good candidates (i.e., cost effective) for DBP precursor de

destruction. In this paper the application of each of the above processes in municipal water treatment is briefly discussed, and some of the challenges facing each process are presented.

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Ozone with Hydrogen Peroxide Addition

When hydrogen peroxide (H_2O_2) is added to ozonated water, it reacts with the molecular ozone, which accelerates the formation of hydroxyl radicals. Therefore, in an ozone- H_2O_2 process the goal is to increase the concentration of hydroxyl radicals, which is a stronger oxidizer than molecular ozone, and consequently rapidly reduce the concentration of molecular ozone. Therefore, hydrogen peroxide is added to an ozone process if it is used as an oxidation process but not as a disinfection process, which relies on the prevalence of a high concentration of molecular ozone.

The ozone- H_2O_2 process is used for the destruction of taste-and-odor-causing compounds, color removal, and destruction of micropollutants, such as volatile

organic compounds pesticides, and herbicides. Stoichiometric analysis suggests that the optimum H_2O_2 -to-ozone ratio is approximately 0.3:1 (mg/mg). However, pilot-and full-scale studies have shown that the optimum ratio is more on the order of 0.5:1 to 0.6:1 mg/mg

Currently, the conventional design of an ozone- H_2O_2 treatment process is one in which hydrogen peroxide is fed as a liquid to the influent water and an ozone-rich gas is fed through fine-bubble diffusers at the bottom of a contactor.

Irradiation with Hydrogen Peroxide Addition

In the presence of UV light, hydrogen peroxide decomposes to form hydroxyl radicals. Addition of hydrogen peroxide to the influent of a UV irradiation process is currently being used for the destruction of micropollutants from groundwater, but it can also be used for the same purposes as other AOPs, which include the destruction of taste-and-odor-causing compounds and the removal of color. The reaction between UV and hydrogen peroxide to form hydroxyl radicals is substantially slower than that between ozone and hydrogen peroxide. However, in many groundwater remediation efforts, the simplicity of a UV irradiation system has been favored over the complexity of an ozone generation and feed system. However, owing to the slow hydroxyl-radical formation reaction in UV- H_2O_2 systems, the process must be operated with an excess of high concentration of hydrogen peroxide (5 to 20 mg/L hydrogen peroxide residual). Therefore, for this process to be used in drinking water treatment, either the process should be modified to utilize less hydrogen peroxide or a treatment process should be installed downstream to quench the hydrogen peroxide residual to acceptable levels (<0.5 mg/L) before the water is put into the distribution system. The various options available for quenching the hydrogen peroxide residual include chlorine, thiosulfate, sulfite, or granular-activated carbon.

Ion Exchange Technology

Ion exchange technology has been used in the chemical and environmental engineering fields for a long time. However, its use has been mostly limited to water softening (Ca^{2+} and Mg^{2+} removal), either at the water treatment plant or as a point-of-use treatment process and for industrial applications, such as the production of fully demineralized water. However, with new limits being set on several inorganic chemicals, Ionexchange technology is finding new applications in water treatment. Some of the primary candidates for removal with ion exchange include nitrate, arsenic, selenium, barium, radium, lead, fluoride, and chromate. Surveys conducted in the early 1980s showed that 400 communities exceeded the nitrate MCL of 10 mg/L as nitrogen and 400 communities exceeded the fluoride MCL of 4 mg/L. A new contaminant recently discovered in groundwater is perchlorate (ClO_4^-), which is a component of solid-rocket fuel. The California Department of Health Services has adopted a perchlorate action level of 18 g/L. Ion exchange technology is ideal for the removal of perchlorate ion from contaminated groundwater.

The technology is commonly designed as a fixed-bed process in which a synthetic resin is packed. As water passes through the resin bed, contaminant

Ions present in the water are exchanged with ions on the resin surface, thus removing the contaminant ions from the water and concentrating them on the resin. The resin is frequently regenerated to remove the contaminant from the resin surface and replenish it with the original exchange ion. There are four primary types of IX resins: strong acid cationic (SAC) resin, weak acid cationic (WAC) resin, strong base anionic (SBA) resin, and weak base anionic (WBA) resin

Biological Filtration

All of the technologies discussed above are physical and/or chemical processes. In fact, the water treatment industry depends solely on physical and/or chemical processes to meet water quality goals. Utilization of biological processes in water treatment has been frowned on by the industry because of concern about the introduction of microorganisms to water. However, this barrier has been broken by the introduction of biological filtration as the most effective process for the production of biologically stable water. This was specifically driven by concern about the increase in the concentration of biodegradable organic matter (BOM) as a result of ozonating natural waters. There is concern that higher BOM levels may result in increased potential for biological regrowth in the distribution system. Therefore, implementing biological filtration in the water treatment plant reduces BOM concentrations in the water before it is introduced into the distribution system. Several plants in the United States currently use biological filtration after ozonation.

Ecological effects of pesticides

Pesticides are included in a broad range of organic micro pollutants that have ecological impacts. Different categories of pesticides have different types of effects on living organisms, therefore generalization is difficult. Although terrestrial impacts by pesticides do occur, the principal pathway that causes ecological impacts is that of water contaminated by pesticide runoff. The two principal mechanisms are bioconcentration and biomagnification.

Bioconcentration: This is the movement of a chemical from the surrounding medium into an organism. The primary "sink" for some pesticides is fatty tissue ("lipids"). Some pesticides, such as DDT, are "lipophilic", meaning that they are soluble in, and accumulate in, fatty tissue such as edible fish tissue and human fatty tissue. Other pesticides such as glyphosate are metabolized and excreted.

Biomagnification: This term describes the increasing concentration of a chemical as food energy is transformed within the food chain. As smaller organisms are eaten by larger organisms, the concentration of pesticides and other chemicals are increasingly magnified in tissue and other organs. Very high concentrations can be observed in top predators, including man.

The ecological **effects** of pesticides (and other organic contaminants) are varied and are often inter-related. Effects at the organism or ecological level are usually considered to be an early warning indicator of potential human health impacts. The major types of effects are listed below and will vary depending on the organism under investigation and the type of pesticide. Different pesticides have markedly different effects on aquatic life which makes generalization very difficult. The important point is that many of these effects are chronic (not lethal), are often not noticed by casual observers, yet have consequences for the entire food chain.

- Death of the organism.
- Cancers, tumors and lesions on fish and animals.
- Reproductive inhibition or failure.
- Suppression of immune system.
- Disruption of endocrine (hormonal) system.
- Cellular and DNA damage.
- Teratogenic effects (physical deformities such as hooked beaks on birds).
- Poor fish health marked by low red to white blood cell ratio, excessive slime on fish scales and gills, etc.
- Intergenerational effects (effects are not apparent until subsequent generations of the organism).
- Other physiological effects such as egg shell thinning.

These effects are not necessarily caused solely by exposure to pesticides or other organic contaminants, but may be associated with a combination of environmental stresses such as eutrophication and pathogens. These associated stresses need not be large to have a synergistic effect with organic micro pollutants.

Ecological effects of pesticides extend beyond individual organisms and can extend to ecosystems. Swedish work indicates that application of pesticides is thought to be one of the most significant factors affecting biodiversity. It was found that the continued decline of the Swedish partridge population is linked to changes in land use and the use of chemical weed control. Chemical weed control has the effect of reducing habitat, decreasing the number of weed species, and of shifting the balance of species in the plant community. Swedish studies also show the impact of pesticides on soil fertility, including inhibition of nitrification with concomitant reduced uptake of nitrogen by plants. These studies also suggest that pesticides adversely affect soil micro-organisms which are responsible for microbial degradation of plant matter (and of some pesticides), and for soil structure.

MODULE-III

(OIL IN FRESH AND MARINE WATER)

Oil Pollution (Causes, Effects, Preventive and Control Measures)

Introduction:

Oil Pollution is the resultant contamination of environment due to the introduction/presence of oil in excessive quantity. Oil pollution is most common in large water bodies like seas and oceans. Oil spill occurs due to the release of a liquid petroleum hydrocarbon into the aquatic environment. Marine water is especially affected by this form of pollution. Oil pollution is primarily a man-made pollution and is a result of human irresponsible activities.

Oil pollution is mainly because of crude oil. Ships and tankers carrying crude oil across the oceans may cause deadly oil spills in marine water due to various causes, leakage being the most common one. The quantity of oil spills matter when it comes to the significance of oil and water pollution. During marine accidents, the oil spills quantity is enormous. Spillages in such large quantities occur on a regular basis.

Also, shallow water oil spills can be more dangerous than deep water ones sometimes. Oil combines with mud and other dirty substances and sinks to the bottom of the water bodies. As a result of this, the oil tends to stay at the bottom for ages causing harmful effects on the marine life living on the bed of the sea

When very large amount of oil pollution occurs, it is extremely tedious to clean up the water afterwards. Measures taken to reverse the pollution affects may prove futile, if action is not taken at the right time. So it is wise to take preventive measures rather than treatment ones. Prevention is an important action step but awareness precedes this step.

Without actually having the knowledge of the disasters that this kind of pollution is capable of causing, prevention is seldom seen necessary. Here, we would discuss the detailed account of oil pollution which should serve as an eye opener for all to take control measures more seriously. The cause and effect scenario of oil pollution need to be studied in-depth and only then will the necessary preventive action would seem like the need ed

Causes and Source

The various causes of oil pollution are listed below:

1. **Breakage of oil tankers (oil ships):** Mechanical breakage of oil tankers can lead to oil spillage in extremely large quantities. If a tanker breaks down in shallow land, abrasion leading to a hole in the tanker might take place during mechanical and aggressive attempts to get the tanker out of the shoreline. Also, when bunker oil or lubricating oil (required for engines) is being loaded in to any ship, the loading hose can also undergo mechanical breakage leading to oil spillage incidents.

2. **Oil pipe leakage:** Oil pipe leakages are common and cause a lot of oil pollution. Huge pipelines are laid all across the world and their slightest leakage can prove to be of grave danger to water bodies. Offshore drilling waste should be handled with care and their proper and lawful disposal should be ensured.
3. **Drilling activities:** Drilling activities lead to severe oil pollution. Industries after oil extractions dump the drilling wastes into water bodies. This is extremely detrimental for natural water sources. Companies act irresponsible towards the environment and carry out improper disposal of drilling waste.
4. **Human transport or recreational activities:** Oil spills may be a result of water sports as well as motor transport on water. Fuel leaks from jet skis, speed boats, etc. can also lead to oil spills. Some water bodies have regular motor traffic on them. These water bodies tend to have concentrated oil pollution in their water due to constant oil pollution.
5. **Unskilled Manpower:** Unprofessional, careless and unskilled man-power can also be a risk factor for oil pollution. They might do a clumsy job of loading or unloading the crude oil cargo which may prove to be dangerous. Also, applying shortcuts and not following the lawful protocol for cleaning, loading, supervising and unloading, when handling crude oil tankers is often seen among the crew members.
6. **Failing to check failures:** It is important to check for any failing equipment or parts of a marine vessel before giving it a green signal for making a sea voyage. Any potential failure incidents should be immediately addressed and not look past. Even minute failures can create havoc later. Failing engines in the middle of the sea can lead to substantial oil pollution.
7. **Natural causes beyond human control:** Natural calamities like storms and tsunamis have also led to many oil spillage and ship accidents. This is beyond human control and causes maximum damage to marine water. Climatic conditions are something that cannot be bypassed when talking about marine life.
8. **Operational oil spills:** In any ship, bilge is a space found under the ship engines, at the very base. It is for gathering oil, greasy dirt and water. When the bilge is pumped out by the ship crew, the oil and water separates. The oily waste is supposed to be stocked into a designated holding tank, which is to be thrown out at the next available port. The water that is left over (having oil traces in negligible quantities) is pumped into the ocean after passing it through an oil water separator. This extensive procedure is done to ensure that only traces amount of oil is being pumped out overboard. Hence, if an oil slick is found around a ship, it shows that the ship has not followed the right lawful procedure and has illegally pumped out more oil into the ocean than it is permitted to.
9. **Cleaning of tanks:** When oil tanks of ships are cleaned, there is high risk of oil spillage in the ocean water. Before loading the new cargo of crude oil into their ship, the ship crew usually cleans the cargo tanks. After thorough cleaning of the cargo oil tank with chemicals and water, the remnant oil residue floats on the water at the very base of the cargo tank. This water is normally channeled to an oil water separator to separate only the cargo oily residue at the cargo tank bottom. The fresh crude oil cargo can ideally be loaded over the left over old cargo oil. However, some crew members tend

to pump out the remnant old cargo oil residue overboard into the ocean water. This is strictly illegal and should not be encouraged at any cost. This leads to discharging of tons of dirty oil residue into the marine water to cause oil pollution.

10. **Run offs from land pollution:** Polluting human activities on land may also contribute to water oil pollution. The vehicular oil leaks on land may also get washed off into seas, oceans and other natural water bodies leading to oil pollution.

Effects

The effect of oil pollution is disastrous, especially on the aquatic flora and fauna. Given below are various possible adverse effects of oil pollution.

1. **Damage to ecosystem:** Oil pollution is a major threat to our ecosystem, especially the aquatic ecosystem. Ecological impact of oil spills on the aquatic animals depends on the location of the oil spills and also on the sensitivity of the local organisms to oil pollution. Oil spills greatly decrease animal breeding population and also harm their nesting habitats. This leads to the consequent shrinkage of the local prey population thus unbalancing the aquatic food chain and ecosystem. Plants in the water also cannot survive in poisonous oily environment and die a premature death, ahead of their life cycles.
2. **Damaging effect marine biodiversity:** Marine biodiversity will get greatly affected by oil pollution. Oil spills can cause potential harm to the marine birds. Their feathers get coated with the oily water which hampers with the water repelling property of their plumage. This might increase their chances of drowning in water as their buoyancy might considerably decrease. Also, aquatic animals and birds and mammals may tend to ingest the oily contaminated water which could mean harm to their health by poisoning them. Oil spills are also dangerous for fish and shellfish. Oil ruins the insulating capability of furry mammals like sea otters. This may adversely affect their body temperature maintenance. Oil spill happens all over the sea and the location decides the injury or death rate of the birds and animals. It is a pity how human activities are constantly upsetting the marine biodiversity.
3. **Economic loss:** Oil spillage if happens in high concentrations is very difficult to clean, no matter how much effort is invested into it. Also, the cleanliness regime is anything but cheap. Huge amount of money need to be spent to tidy up the oil spillage mess and then also the result may not be 100% satisfactory. Oil pollution is proportional to considerable economic loss. Also, spillage of crude oil is of great loss as crude oil is precious and very expensive.
4. **Altering the water temperature:** The oil layer present at the surface of water will tend to absorb more heat from sun rays and may significantly increase the surface water temperature. Also, it might block the sunlight from reaching into the depths of water with uneven heat distribution across the depths of the water body. This can alter the natural hydrodynamics of the water bodies which may lead to lesser oxygen supply at certain depths of water.

5. **Effect on coastal areas:** The shore lines and sandy beaches in coastal areas may also be an indirect victim of oil water pollution. The oil contaminated water is usually swept across the shoreline by the waves in high tides. This makes the beaches dirty and unsafe for the human population as well. Thus, coastal areas are continuously contaminated due to oil pollution.
6. **Degrades water quality:** Oil pollution seriously degrades the water quality on a long-term basis. Being insoluble in water, oily water always exists as bi-layer. Also, at the shore lines, the current of waves might even turn the oily water into a turbid oil water emulsion (wherein the oil and water exist as a single turbid phase due to constant mechanical mixing forces). This degrades the quality of water further.
7. **Tourism industry affected:** Tourism industry is greatly affected by oil spills and oil pollution. Due to increasing oil pollution on beaches and shorelines, recreational activities of tourists like boating, swimming, diving, adventure sports are taking a back seat. Unclean and unhealthy water will repel tourists from undertaking these activities completely.
8. **Industry problems:** Many industries use clean water from natural water bodies for cooling purposes. Industries like power plants, nuclear plants and desalination plants need constant water supply from surface waters. These industries may also pose a risk of getting oily and contaminated water due to oil pollution. This may lead to contamination in their pipes and might not yield effective cleaning too.

Preventive & Control Measures:

In order to deal with oil pollution, it is essential to take sufficient preventive and control measures around the globe. Water is the most important natural resource and it's quality is of utmost importance. Thus, preserving the natural purity of water should be of top priority. Since oil pollution is a major water pollutant, let us see some important measures as to how to control and prevent the same.

1. **Use of Trained people:** Drilling should only be done by highly skilled and trained people. This will prevent the otherwise unwanted oil pollution.
2. **Proper quality checks:** Quality cannot be compromised when it comes to ships and oil tankers in marine waters. Their mechanical parts and equipment need to pass strict quality checks to be proven safe against any oil spill hazards. Extra attention is required while installing the pipes in tankers. Any probable leakage issue should be eliminated before it sets out on the sea.
3. **Efficient Disaster Management Plan:** Government of all countries worldwide should treat oil pollution seriously and come up with a suitable disaster management plan to deal with this problem. Local environmental agencies should also step up their action plans towards the recovery of polluted water bodies. A plan should be developed to direct the restoration process and incorporate things like coral and plantation reconstruction, shoreline improvements and transport restrictions across water bodies. Public access to severely affected coastlines should be restricted to avoid human health hazards.

4. **Bioremediation:** When bacteria are used to clean up oil spills in the marine environment, it is termed as bioremediation. Bioremediation is a process that uses natural decomposers and plant enzymes to treat the contaminated water. Certain specific bacteria come of use when thinking of bioremediation of hydrocarbons present in oil and gasoline.
5. **Regular inspection of oil sites:** Regular skimmers need to be employed in marine water to monitor and control oil spills. Skimmers are boats that help scoop the spilled oil from the surface of the polluted water. This way immediate action can be taken in case of accidents to avoid long-term damage in serious proportions. Even if certain operational carelessness can be avoided with stricter rules, the accidents cannot be predicted nor dodged. Hence, employing an emergency team is the way to go.
6. **24/7 emergency team:** The government should have a 24/7 emergency team ready for any marine accidents and oil spill incidents. An effective team will facilitate immediate cleanup of the mess that any such incidents might cause.
7. **Laws and Regulations:** Several laws and regulations have been operational since long in most of the countries, but still oil pollution has been on the rise. The laws should be implemented on ground level and facilities should be checked regularly for proper maintenance and documentation of their procedures for discharge as well as loading. Also, mock drills should be mandatory for all vessels, so as to be prepared to clean up oil spills in emergency situations.
8. **Chemical treatment:** The oil spills in the water bodies can be cleaned up the chemical way. Using sorbents (big sponges which absorb oil) oil spills can be cleaned. Also, chemical dispersants effectively break down oil into its corresponding chemical constituents.
9. **Physical methods:** Physical methods can also be employed for cleaning oil spills. Vacuum trucks can suck up spilled oil from the beaches and the surface of water. Oil spills in beaches may also contaminate ocean water. So, shovels and road machinery can be used to clean up oil on the beach. Oil contaminated sand and gravel can be picked up and moved away, so that the waves hitting the shores do not pick up the oily residues to cause oil water pollution. Floating barriers called 'booms' can also be used to prevent oil pollution. This is usually done by planting a large boom around a leaking oil tanker to collect it before it causes massive water contamination.
10. **Leaving it undisturbed:** If the amount of oil spill is not of mammoth proportions and the area of oil spill has no potential risk of polluting coastal areas, marine industries, etc., it is best to be left alone. Oil is naturally degraded by a combination of sun, wave action, water temperature and natural microbes, over time. This phenomenon is called 'Weathering'. Thin surface films of oil can easily be cleansed by natural weathering.

Behavior and Fate of Oil

1. Crude oil, and refined products, in the marine environment are subject to physical, chemical, and biological processes that change their composition and environmental impact.
2. The weathering of crude oil involves evaporation or volatilization, emulsification,

dissolution, and oxidation (chemical, photo-, and microbial).

3. The horizontal transport or movement of crude oil is accomplished through spreading, advection, dispersion, and entrainment, whereas the vertical transport of oil involves dispersion, entrainment, Langmuir circulation, sinking, overwashing, partitioning, and sedimentation.
4. Crude oil from seeps and spills of persistent oils often form tar residues or tarballs that become stranded on the shoreline.
5. Conceptual and computer models aid in predicting the behavior and fate of oil and oil products in the marine environment.
6. The ultimate fate of oil and oil products in the environment depends on their composition, source, and persistence. Seeps, spills to surface water, deepwater subsea releases, and diffuse (non-point) sources behave in different ways.

PROCESSES THAT AFFECT THE IMPACT OF OIL RELEASES

1. Weathering

Following an oil spill or any other event that releases crude oil or crude oil products into the marine environment, weathering processes begin immediately to transform the materials into substances with physical and chemical characteristics that differ from the original source material.

2. Evaporation

In many oil spills, evaporation is the most important process in terms of mass balance. Within a few days following a spill, light crude oils can lose up to 75 percent of their initial volume and medium crudes up to 40 percent. In contrast, heavy or residual oils will lose no more than 10 percent of their volume in the first few days following a spill. Most oil spill behavior models include evaporation as a process and as a factor in the output of the model.

Despite the importance of the process, relatively little work has been conducted on the basic physics and chemistry of oil spill evaporation. The particular difficulty with oil evaporation is that oil is a mixture of hundreds of compounds, and this mixture varies from source to source and over time. Much of the work described in the literature focuses on “calibrating” equations developed for water evaporation. Initial prediction of oil evaporation was carried out by using water evaporation

In all of this previous work, boundary-layer regulation was assumed to be the primary mechanism for petroleum evaporation. This assumption was never tested by experimentation. Subsequently, the boundary regulation is slight for petroleum evaporation in the thin layers typically found on surface oil slicks, and a simple equation can be used to model evaporation:

$$\text{Percentage evaporated} = C(T) \ln(t) \text{ ----- (1)}$$

where C is a constant that can be empirically-determined or predicted on the basis of distillation data, T is temperature, and t is time. Empirical equations for many oils

have been determined, and the equation parameters found experimentally for the evaporation of oils can be related to commonly available distillation data for the oil. For example,

$$\text{Percentage evaporated} = 0.165 (\text{percent D}) \ln(t) \text{ ----- (2)}$$

where percent D is the percentage (by weight) distilled at 180°C and t is time in minutes, can be used for oil evaporation prediction

3. Emulsification

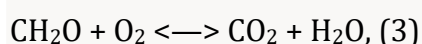
Emulsification is the process of formation of various states of water in oil, often called “chocolate mousse” or “mousse” among oil spill workers. These emulsions significantly change the properties and characteristics of spilled oil. Stable emulsions contain between 60 and 85 percent water thus expanding the volume by three to five times the original volume of spilled material. The density of the resulting emulsion can be as great as 1.03 g/mL compared to a starting density ranging from about 0.95 g/mL to as low as 0.80 g/mL. Most significantly, the viscosity of the oil typically changes from a few hundred to a few hundred thousand milli Pascal-seconds, a typical increase of three orders of magnitude. This increase in viscosity can change a liquid petroleum product into a heavy, semi-solid material. Emulsification, if it occurs, has a great effect on the behavior of oil spills at sea. As a result of emulsification, evaporation slows spreading by orders of magnitude, and the oil rides

4. Dissolution

Dissolution is the chemical stabilization of oil components in water. Dissolution accounts for only a small portion of oil loss, but it is still considered an important behavior parameter because the soluble components of oil, particularly the smaller aromatic compounds, are more toxic to aquatic species than the aliphatic components. Modeling interest in dissolution is directed at predicting the concentrations of dissolved components in the water column. Most models in existence do not separate the dissolution component. The entrainment model is sometimes used but fails to distinguish between dispersion and dissolution.

5. Oxidation

Crude oil is a complex mixture of organic compounds, mostly hydrocarbons. Oxidation alters these mixtures by creating new compounds and by rearranging the distribution of residual compounds, based on their susceptibility to the oxidative process. The ultimate oxidative fate of all of the organic compounds, given an unrestricted supply of oxygen and time, is conversion to carbon dioxide and water, as expressed in the following equation:



where CH₂O is a symbol for all organic compounds. Not only is this the basic reaction for oxidation (to the right), it is the reaction known as “respiration

6. Photo -oxidation in Sea Water

Photo -oxidation is a family of light-catalyzed reactions that oxidize the reduced carbon in petroleum hydrocarbons. These reactions include both direct photoreactions, where the reactant absorbs light energy, to form a less stable intermediate, and indirect photoreactions, where other chemical species in solution absorb light energy. Both produce reactive intermediates (e.g., solvated electrons, hydroxy radicals) that attack the hydrocarbon molecule or transfer energy directly to the reactant hydrocarbon. The necessary ingredients for photooxidation are radiation and light-absorbing molecules (chromophores). Because few petroleum hydrocarbons absorb sunlight efficiently, most photooxidation occurs via indirect photoreactions. The formation of singlet oxygen from the energy transfer of the triplet excited state of natural organic matter in sea water provides the dominant oxidant for this reaction. Heterogeneous photooxidation, in which reactions occur at the liquid-solid and liquid-liquid interfaces, may also be important. Heterogeneous photolysis of adsorbed species on natural particulate matter may result from direct photochemistry, surface semiconductor redox reactions, or photosensitized reactions on the surfaces of algal cells. Heterogeneous photolysis at the oil-water interface (i.e., surface petroleum slicks) is complex due to the large number of chromophores and reactants that change in absolute and relative abundance during photooxidation

7. Microbial Oxidation

There are generally two biological fates of petroleum in marine systems. Both utilize the same metabolic pathway, respiration, but have different end points. The first process utilizes hydrocarbons as a carbon source to produce energy, while subsequently degrading the long-chained molecules. Microorganisms, primarily bacteria and fungi, and to a lesser extent, heterotrophic phytoplankton, are responsible for these processes. The metabolic process is called oxidative phosphorylation, or respiration, and is the most energetically favorable metabolic pathway to make energy. The second biological process is primarily a detoxification mechanism in response to exposure to oil whereby an organism metabolizes the hydrocarbons to more water-soluble products that can be excreted from the body.

Biodegradation of hydrocarbons has been considered one of the principal removal mechanisms in the aquatic environment. Much of the earlier research was based on laboratory experiments that elucidated the metabolic pathways for degradation, environmental influences on oil degradation rates, and rates of oxidation.

There are several energetically favorable metabolic pathways to degrade hydrocarbons that are utilized by different types of microorganisms, including oxidative phosphorylation or respiration (heterotrophic bacteria, fungi, and heterotrophic phytoplankton), nitrate reduction (denitrifiers), and sulfate reduction. Complete microbial oxidation of oil produces CO_2 and H_2O often from the breakdown of smaller alkanes and cyclic hydrocarbons. More complex hydrocarbons, such as branched alkanes and multicyclic compounds (polycyclic aromatic and aliphatic hydrocarbons), require multiple metabolic pathways for degradation and likely involve a consortium of bacterial strains

8. Sinking and Sedimentation

Sinking is the mechanism by which oil masses that are denser than the receiving water are transported to the bottom. The oil itself may be denser than water, or it may have incorporated enough sediment to become denser than water. Sedimentation is the sorption of oil to suspended sediments that eventually settle out of the water column and accumulate on the seafloor. There is a significant difference in the relative amount of oil incorporated by the two processes; sinking oil may contain a few percent sediment, whereas contaminated sediments accumulating on the seafloor will contain at most a few percent oil (McCourt and Shier, 2001). Sedimentation requires a mechanism for oil to become attached to sediments. One mechanism is ingestion of small oil droplets dispersed in the water column by zooplankton and excretion of oil in fecal pellets that then sink to the seafloor.

9. Over washing

Over washing is the temporary submergence of oil below the water surface. The oil can be described as “floating” just below the water surface. Environment Canada conducted several studies in the 1980s to investigate the factors influencing oil submergence as part of an overall program on the behavior of spilled oil. Equations for over washing were developed by Mackay et al. (1986) and have been used in some models to predict this process. There have been no significant advances in the theory of over washing since this work.

The principal cause of over washing is the action of waves and near-surface turbulence. Two other factors are also very important: the density of the oil must be close to that of water and the oil must become viscous enough so that the slick breaks up into discrete masses such as tar balls.

Over washing is particularly important because submerged oil is difficult to see visually or with remote sensors, making it difficult to detect the oil, track its path, and make accurate trajectory predictions. During the *Nestucca* spill, the oil broke into tar balls that became over washed and could not be visually tracked. Finally, it is very difficult to recover submerged oil using standard skimming equipment.

There are three mechanisms by which submerged oil can resurface:

- (1) the density of the water increases, as in an estuary where the oil moves from fresh water to salt water
- (2) the turbulence of the water surface ceases, when the wind dies down or a river plume enters a bay and
- (3) the oil becomes stranded on a shoreline.

10. Bioavailability

Organisms are exposed to petroleum hydrocarbons in the marine environment. They are not exposed to the total amount of hydrocarbons in the water and sediment,

however, because some portions of the chemical occur in forms not accessible to the organisms. The processes controlling bioavailability have been reviewed by. Partitioning strongly affects the mechanisms and magnitude of exposure of aquatic organisms to hydrocarbons. Dissolved hydrocarbons can diffuse across gill and cell membrane surfaces, and those associated with particles can be ingested during feeding. If oil droplets are present in the water column, marine filter feeders are exposed to PAH by direct uptake of the oil. Unlike other nonpolar compounds such as polychlorinated biphenols (PCBs) and certain pesticides, PAH sometimes bioaccumulate in the food chain depending on the metabolic rate of the organism.

11. Deepwater release fates

Based on the work cited above, several important aspects of the fates of deep water releases have become apparent:

7. The majority of the oil in most deep water releases will rise to the surface although it may take several hours. Theoretical calculations of a light-weight oil suggest that, at most, 10 percent might dissolve under perfect conditions. For a diesel and a light medium crude, found that it took about an hour for hydrocarbons to appear at the surface when released from 800 m of water.
8. The surface slick formed once the oil reaches the surface will be thinner than that seen during a shallow-water release or a surface release. This is due in part to the fractionation of oil droplets that results in a staged arrival of the oil at the surface and in part to diffusion or dispersion of the oil as it rises.
9. Much if not all of the natural gas (85 percent methane or more) associated with the oil will likely be dissolved in the water column, regardless of whether hydrate forms or not. This is due to the high solubility of methane in sea water at the high pressures and cold temperatures found in deeper water.

Biodegradation of Hydrocarbon

Hydrocarbon (HC) group of compounds consist of hydrogen and carbon in their structure. As petrochemical industries are flourishing worldwide, HC contamination has become one of the major environmental problems faced globally. Environment is particularly being contaminated with accidental releases of petroleum products. Some of the HC compounds can prove carcinogenic and neurotoxic to different life forms. Bioremediation is a promising approach for the treatment of HC contaminated locations as it is cost effective and can lead to complete mineralization. Bioremediation strategy exploits the metabolic pathways of living organisms (mainly microorganisms) for biodegradation of organic pollutants, leading to their partial or complete mineralization into carbon dioxide, water, and inorganic compounds. Degrading organisms may use the pollutant molecules as an energy source and for deriving building blocks for synthesis of their cellular components. In the process they transform the complex organic contaminants to simpler (may be less toxic) forms, which can further be utilized by other organisms. HC degradation often requires the presence of oxygen as the initial degradation occurs by the action of oxygenase enzymes

Factors Affecting HC Biodegradation

Several environmental factors influence biodegradation of petroleum HC such as temperature, pH, nutrient and oxygen availability, salinity, pressure, and light. Bioavailability of contaminant is also an important aspect of biodegradation. Presence of HC degrading populations of microbes at sufficiently high levels is a prerequisite for an effective bioremediation. Occurrence and abundance of microorganisms in environment depend on availability and diversity of carbon sources. Surface soil has high organic matter but subsurface and deep layers has lower organic content. Because of a low amount of organic matter organisms in these regions are often dormant. Various physicochemical factors affecting HC degradation are described below

• Oxygen availability:

HC degradation takes place both in presence and absence of oxygen. However aerobic conditions are more favourable as oxygenases are the primary enzymes needed for degradation to occur. Oxygenases function in presence of oxygen, so degradation rates are higher in aerobic conditions as compared to those under anaerobic conditions.

• Nutrient availability:

The process of biodegradation can be enhanced by addition of essential nutrients such as nitrogen and phosphorous. In case of petroleum oil spills where nitrogen shortages can be acute; carbon, nitrogen and phosphorous are added in the ratio of approximately 100: 10: 1 (C: N: P)

Temperature: HC degradation is known to occur over a wide temperature range (psychrophilic to mesophilic) from close to zero degrees to up to more than 30°C. Bacteria can adapt to temperature fluctuations in order to maintain metabolic activity, however seasonal temperature fluctuations in the natural environment have been shown to affect the rate at which degradation occurs

• **pH:** Highest rates of degradation are generally observed at neutral pH. However microorganisms growing on HC have been isolated from historically contaminated sites even at pH 2-3.

• **Salinity:** Salt concentration has varied effect on HC degradation depending on the type of environment and the type of organisms involved. Higher salt concentrations tend to inhibit degradation. The ability of variation in salinity to affect the rate of HC degradation appears to be dependent on the natural variation in salinity regime of the sample source

• **Light:** Availability of light can have a positive impact on HC degradation by photosynthetic microbes such as algae. Light can also degrade petroleum compounds by direct photochemical action. Physical properties of petroleum compounds are affected due to the photochemical reactions. Emulsion formation and the solubility of petroleum fractions may get altered by light

TREATMENT OF OIL SPILLS IN MARINE WATER

Oil spills are a very dangerous occurrence for the marine ecosystem is affected and the marine life-forms' existence gets unnecessarily threatened. Since exploration of oil from oceanic resources has become a must and oil spills end up occurring accidentally, as a result, it becomes important to employ various oil spill cleanup methods.

There are different methodologies that can be adopted for the purpose of cleaning up oil spills. Some of the few important and commonly used methods can be explained as follows:

1. Using Oil Booms

Oil booms are a very popular method of controlling oil spills. There are various kinds of oil booms that have been designed for various areas where the oil spillage might occur, leading to a quite thorough oil spill cleanup.

2. Using Sorbents

Sorbents mean sponges that are placed on the surface of the spillage affected area. These sorbents suck and absorb the oil from the surface of the water leading to an oil spill cleanup.

3. Burning In-situ

In simple terms, this means burning of the oil on the site where the spillage has occurred. The burning has to be done quite promptly before the oil spill can spread to a larger area. But the most important disadvantage of such an on-site burning is that the exhaust that is released contains toxic particles that can cause damage to the

4. Using dispersers

This method involves using dispersers to disperse the oil spillage in the water. Even though the method sounds and looks unconventional, it is one of the highly recommended oil spill cleanup methods. The dispersers help to hasten the growth of micro-organisms which help to diffuse the components of the oil spilt in the water.

5. Skimming

As the name suggests, skimming involves the removal of the oil spillage with the help of tools and equipments from the surface of the water. The most important aspect to be noted that only lighter oils can be separated and removed from the water in this method of cleaning up oil spills. This is because the density of oil will tend to be lighter than the density of water.

6. Using Hot water and huge force

In this method, huge force of the hot water is used to push the oil spilt back into the water. Then with the help of the skimming tools and equipments, the oil spill cleanup operation takes place.

7. Using Manual labour

People in the coastal areas and beaches can help to accelerate the oil spill cleanup operation. By using simple tools like spades and shovels, removing and isolating the area affected by oil spillage is possible.

8. Using Technological aid

By using cranes and tractors, the oil spillage area in beaches and coastal areas can be cleaned. If it is not possible to carry out the oil spill cleanup operation, there itself they can be taken to labs and other equipped areas where the oil spill can be separated from the sand and other items generally found in the beaches and coastal areas.

9. Using natural methods

The simplest method of dealing with the oil spill cleanup operation is to make use of the components of nature like the sun, the wind, the weather and the tides. The particles of the oil spill, in due course of time evaporate because of the constancy of these elements. This also forms the most cost-efficient and the slowest method of cleaning up oil spills.

With the help of these methods of oil spill clean-up, the task and its hugeness do not affect the optimism of the person. Just like one makes use of the broom, these methods are adapted to clean affected and problematic areas at a much higher level. However, it can be hoped that since many shipping companies are getting aware of the risks and problems caused to the oceanic atmosphere, the requirement of such oil spill clean-up methods will reduce in the days to come.

Water pollution caused by use of fertilizers and pesticides

Overview

Fertilizers and pesticides both have definite purpose associated with their use. Both types of chemical tend to increase yields, and thus make a significant difference in food production, particularly in countries that struggle periodically with famines. On the other hand, they both can cause water pollution when erosion carries the chemicals off of farms along with eroded soils after each rainfall. There is also concern by some authorities that pesticides pose a risk, not only to

nontarget animal and plant species, but to humans as well.

Positive Effects of Fertilizers

There is no doubt that fertilizers increase yields of crops around the world. Use of modern fertilizers exploded after World War II. New, ammonia-based fertilizers also fed the process of specialization that was occurring in agriculture. Farmers rotated crops less, which led more quickly to soil exhaustion. Norman Borlaug, the father of the 1960s Green Revolution, which vastly expanded food production and helped stave off world hunger, has argued that modern farming, including the use of fertilizers and herbicides, could “double or triple food production” in Africa. Increased yields also reduce the need for conversion of wild lands to agriculture, contributing to the conservation of biodiversity.

Negative Effects of Fertilizers

The downside of fertilizers is that some portion inevitably washes into waterways along with eroded sediments. This nonpoint source runoff occurs nationwide, and the nitrogen fertilizer finds its way into rivers, lakes and the ocean where it causes eutrophication and “dead zones” that kill aquatic life. Eutrophication is a process whereby nitrogen feeds an algal bloom, but when the short-lived algae die, decomposing bacteria then consume most of the available oxygen, suffocating aquatic life. Additionally, use of artificial fertilizers in place of animal or “green” manure--cover crops plowed into the soil--eventually can deplete soils of organic matter, making them lose their ability to hold water and more subject to erosion.

Positive Effects of Pesticides

According to the National Institute of Environmental Health Sciences, the term pesticide includes chemicals used to control insects, fungi and weeds. Pesticides serve many functions, some of which are more essential to society than others. Pesticides can prevent crop failure, control invasive plants, or promote a uniformly green lawn. Some pesticides reduce blemishes on fruit and vegetables, ensuring that a greater proportion of the crop is marketable.

Negative Effects of Pesticides

According to the National Institute of Environmental Health Sciences, pesticides have as yet incompletely understood effects on humans. Most people are exposed to a certain level of pesticides. Farmers who experience routine exposure to pesticides have exhibited neurological symptoms such as headache and hand tremors. Children, in particular, may be more susceptible to negative effects resulting from pesticide exposure. Pesticide runoff can have devastating effects on nontarget organisms as well. For example, roundup, an extremely common herbicide used in agriculture, is highly toxic to fish and amphibians. The National Coalition for Pesticide-Free Lawns says, “Of 30 commonly used lawn pesticides,

19 are linked with cancer or carcinogenicity, 13 are linked with birth defects, 21 with reproductive effects, 26 with liver or kidney damage, 15 with neurotoxicity, and 11 with disruption of the endocrine system."

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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

10. 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.

11. 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.

12. 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 of 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.

13. 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.

14. 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

15. 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.

16. 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.

17. 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.

18. 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.

19. 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

pitched in. Industries have been given regulations for the disposal of hazardous waste, which aims at minimizing the area that becomes polluted. Organic methods of farming are being supported, which do not use chemical laden pesticides and fertilizers. Use of plants that can remove the pollutants from the soil is being encouraged. However, the road ahead is quite long and the prevention of soil pollution will take many more years.

HOW TO PREVENT SOIL POLLUTION (SOIL CONSERVATION)

A) Biological method –

(i) Crop related (ii) Forestry related.

(i) Crop related:

20. Crop rotation – It implies frequent succession of crop on the same portion of land in a given time-frame. Crop mixes such as wheat, mustard, Arhar, Groundnut, maize+ cowpea etc., can be grown. Thus, after a harvest of one crop there is another growing up or covering the soil so that the soil is never bare or exposed.

21. Planting along the contours – Leguminous plants, cowpea and cereal crops can be grown in a particular way to check soil erosion. This helps farmers get maximum profit with least investment and increases the fertility of the soil.

22. Strip cropping – This reduces the velocity of water flow and prevents erosion.

23. Steep farming – This prevents erosion by reducing sludge. This leads to the use of hilly land for cultivation.

24. Crop Residues – By laying a thin layer of 10-15 cm of crop residues in farming, erosion and vaporization can be prevented. With this method, Rabi crop can be increased up to 30 percent. After a crop we should leave the stubble in the field. Then untimely rains and wind don't destroy much.

25. Protector Belt – By planting trees and bush in the right angle, depending on the direction of wind along the fields, the erosion caused by wind can be stopped.

26. Use of fertilizers – Use of dung manure, clarinet or compost, green manure and other organic composts reduce soil erosion.

(ii) Forest implantation method:

Forests are very helpful in preventing soil erosion. There are two functions under this-

27. First, develop forests in new areas for increasing the soil fertility and formation. This reduces the erosion of rain water and air.

28. Second, new forestry should be adopted where there is excessive pollution of forests, excessive animal feed and surface degradation.

B) Mechanical method

This method is relatively expensive but effective too.

- 29. Contour holding system – In this, the fields are planted in the right direction of the sloping direction, so that the water flowing through the slopes cannot erode the soil.
- 30. Making bunds – Bunds across the slopes prevent erosion in excessive sloping place.
- 31. Gully control – (i) By stopping the flooding water (ii) by increasing the vegetative cover and (iii) creating new pathways for runoff.

Government efforts for soil conservation

Soil erosion results in the sealing of soil surface giving lower infiltration rates and increased runoff. There are many areas worldwide where erosion has led to serious degradation of the land and made it unfit for crop production. With the introduction of the first Five Year Plan in India, many steps were taken in this direction. The problem area is being identified with the help of remote sensing technology.

A nationwide introduction of forestry has been initiated in different areas. It also includes social forestry. In Rajasthan, Indira Gandhi Canal Project, Dessert Development Program and Wasteland Plantation Research Centre etc. have been started.

Jhum cultivation, a traditional form of shifting cultivation or rotational agro-forestry has been started with 100% central assistance in North Eastern states, Andhra Pradesh and Orissa. Apart from this, many programs are being conducted directly and indirectly for soil conservation.

Organic Farming

Organic farming is a good option for reducing soil pollution. If the fertile capacity of the land is reduced, the day is not far when the problem of getting food will become common. To avoid this, we should try to safeguard the environment and reduce soil pollution. We should promote such farming where there is no harm to the environment. Today, in most industrial agriculture, there is excessive use of chemical fertilizer and insecticides. Though many types of pollutants are responsible for destroying the fertility of the land, excessive use of chemical fertilizers is one of the main reasons.

In chemical fertilizers, phosphate, nitrogen and other chemicals are polluting the environment and groundwater resources of land. The most dangerous pollutants are bioactive chemicals, due to which the micro-organisms of climate and soil are being destroyed resulting in decreased quality of soil. Toxic chemicals enter the diet chain, so that they reach up to the top consumer.

The use of organic chemicals in the last thirty years has increased by more than 11 times. In India alone every year, there is a use of approximately 100,000 tons of biochemical. The best way to reduce the use of these chemicals and reduce soil pollution is by organic farming.

In organic farming in place of chemical fertilizers, insecticides and weeds, bacterial fertilizer nutrients such as compost, green manure, bacterial culture, organic manure, bio-pesticides and bio-agents are used. The fertility of the land remains for a long time and the environment is also not polluted and farmers also benefit from the increase in the quality of the crop. In many areas of the country, farmers have started gradually adopting organic farming, which has increased the quality of their crops and their earnings have more than doubled. Farmers in Madhya Pradesh, Sikkim, Tamil Nadu, along with Rajasthan and some areas of Punjab have even begun a campaign to adopt organic farming to make the environment clean and safe.

Soil Erosion

Erosion literally means “to wear away”. You might have noticed that in summer, when wind blows it carries away sand and soil particles. Similarly flowing water removes some amount of soil along with it. This removal of top layers of soil by wind and water is called soil erosion. The top layers of soil contain humus and mineral salts, which are vital for the growth of plants. Thus, erosion causes a significant loss of humus and nutrients, and decreases the fertility of soil.

Causes of soil Erosion

There are several causes of soil erosion.

1. Natural causes; and
 2. Anthropogenic causes (human generated causes)
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3. **Natural Causes of Soil Erosion:** Erosion of soil takes place due to the effect of natural agents like wind and water. High velocity winds over lands, without vegetation, carry away the loose top soil. Similarly in areas with no or very little vegetation, pouring raindrops carry away the soil.
 4. **Anthropogenic Causes of Soil Erosion:** Besides the natural agents, there are some human activities, which cause soil erosion. Let us know about them.
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2. **Deforestation:** If the forests are cut down for timber, or for farming purposes, or construction then the soil is no longer protected from the effect of falling rains. Consequently, the top soil is washed away into the rivers and oceans

3. **Poor farming methods:** Improper tillage and failure to replace humus after successive crops and burning the stubble. The short, stiff stalks of grain or hay remaining on a field after harvesting of weeds reduce the water-holding capacity of the soil. So the soil becomes dry and can be blown away as dust.
4. **Overgrazing:** Overgrazing by flocks of cattle, buffaloes, goats and sheep leave very little plant-cover on the soil. Their hooves make the soil dry and soil can be blown away easily.

Conservation of Soil

Soil conservation means checking soil erosion and improving soil fertility by adopting various methods.

5. **Maintenance of soil fertility:** The fertility can be maintained by adding manure and fertilizers regularly as well as by rotation of crop.
6. **Control on grazing:** Grazing should be allowed only on specified areas.
7. **Reforestation:** Planting of trees and vegetation reduces soil erosion.
8. **Terracing:** Dividing a slope into several flat fields to control rapid run of water. It is practiced mostly in hilly areas.
9. **Contour ploughing:** Ploughing at right angles to the slope allows the furrows to trap water and check soil erosion by rain water.

Soil Classification – Urvara vs Usara

32. In India, soil had been classified from the ancient period itself even though it was not as detail as the modern classifications.
33. In the **ancient period**, the classification was based on only two things; whether the soil is fertile or sterile. Thus the classification were:
34. Urvara [fertile]
35. Usara [sterile]

Soil Classification – Agencies involved

36. In the modern period, when men started to know about the various characteristics of soil they began to classify soil on the basis of texture, colour, moisture etc.
37. When the **Soil survey of India** was established in **1956**, they studied soils of India and their characteristics.
38. **The National Bureau of Soil Survey and the Land Use Planning**, an institute under the control of Indian Council of Agriculture Research did a lot of studies on Indian soil.

Major classification of Indian soils

39. Alluvial soil [43%]

- 40. Red soil [18.5%]
- 41. Black / regur soil [15%]
- 42. Arid / desert soil
- 43. Laterite soil
- 44. Saline soil
- 45. Peaty / marshy soil
- 46. Forest soil
- 47. Sub-mountain soil
- 48. Snowfields

Alluvial soil:

- 49. Mostly available soil in India (about 43%) which covers an area of 143 sq.km.
- 50. Widespread in northern plains and river valleys.
- 51. In peninsular-India, they are mostly found in deltas and estuaries.
- 52. Humus, lime and organic matters are present.
- 53. Highly fertile.
- 54. Indus-Ganga-Brahmaputra plain, Narmada-Tapi plain etc are examples.
- 55. They are depositional soil – transported and deposited by rivers, streams etc.
- 56. Sand content decreases from west to east of the country.
- 57. New alluvium is termed as **Khadar** and old alluvium is termed as **Bhangar**.
- 58. **Colour:** Light Grey to Ash Grey.
- 59. **Texture:** Sandy to silty loam or clay.
- 60. Rich in: potash
- 61. Poor in: phosphorous.
- 62. Wheat, rice, maize, sugarcane, pulses, oilseed etc are cultivated mainly.

Red soil:

- 63. Seen mainly in low rainfall area.
- 64. Also known as **Omnibus group**.
- 65. Porous, friable structure.
- 66. Absence of lime, kankar (impure calcium carbonate).
- 67. **Deficient in:** lime, phosphate, manganese, nitrogen, humus and potash.
- 68. **Colour:** Red because of Ferric oxide. The lower layer is reddish yellow or yellow.
- 69. **Texture:** Sandy to clay and loamy.
- 70. Wheat, cotton, pulses, tobacco, oilseeds, potato etc are cultivated.

Black soil / regur soil:

- 71. Regur means **cotton** – best soil for cotton cultivation.
- 72. Most of the Deccan is occupied by Black soil.
- 73. Mature soil.
- 74. High water retaining capacity.
- 75. Swells and will become sticky when wet and shrink when dried.
- 76. **Self-ploughing** is a characteristic of the black soil as it develops wide cracks when dried.

77. **Rich in:** Iron, lime, calcium, potassium, aluminum and magnesium.

78. **Deficient in:** Nitrogen, Phosphorous and organic matter.

79. **Colour:** Deep black to light black.

80. **Texture:** Clayey.

Laterite soil:

81. Name from Latin word 'Later' which means Brick.

82. Become so soft when wet and so hard when dried.

83. In the areas of high temperature and high rainfall.

84. Formed as a result of high leaching.

85. Lime and silica will be leached away from the soil.

86. Organic matters of the soil will be removed fast by the bacteria as it is high temperature and humus will be taken quickly by the trees and other plants. Thus, humus content is low.

87. **Rich in:** Iron and Aluminum

88. **Deficient in:** Nitrogen, Potash, Potassium, Lime, Humus

89. **Colour:** Red colour due to iron oxide.

90. Rice, Ragi, Sugarcane and Cashew nuts are cultivated mainly.

Desert / arid soil:

91. Seen under Arid and Semi-Arid conditions.

92. Deposited mainly by wind activities.

93. High salt content.

94. Lack of moisture and Humus.

95. Kankar or Impure Calcium carbonate content is high which restricts the infiltration of water.

96. Nitrogen is insufficient and Phosphate is normal.

97. **Texture:** Sandy

98. **Colour:** Red to Brown.

Peaty / marshy soil:

99. Areas of heavy rainfall and high humidity.

100. Growth of vegetation is very less.

101. A large quantity of dead organic matter/humus which makes the soil alkaline.

102. Heavy soil with black colour.

Forest soil:

103. Regions of high rainfall.

104. Humus content is less and thus the soil is acidic.

Mountain soil:

105. In the mountain regions of the country.

106. Immature soil with low humus and acidic.

Physical Properties of the Soil

Soil physical properties affect the appearance and feel of a soil.

The major soil physical properties are:

Soil Texture

Soil Structure

Soil Consistence/Soil Strength

Soil Color

Soil Permeability

Soil Temperature

(a) Soil Texture

107. Each soil separate represents a distinct physical size group. Mineral particles less than 2 millimetres in equivalent diameter and ranging between specified size limits. The names and sizes of the soil separates recognized in the United States are as follows:

Very Coarse Sand	2.0 - 1.0 mm
Coarse Sand	1.0 - 0.5 mm
Medium Sand	0.5 - 0.25 mm
Fine Sand	0.25 - 0.10 mm
Very Fine Sand	0.10 - 0.05 mm
Silt	0.05 - 0.002 mm
Clay	0.002 mm

Modifiers that are used for coarse materials that are greater than 2 mm.

gravels 2mm - 3 in
cobbles 3 in - 10 in
stones 10 in - 24 in
boulders 24 in

A soil's texture is then the relative proportion of sand, silt, and clay. Together, the three

separates must add up to be 100%. The organic matter is not a part of the soil's texture. Since there is such a large number of combinations that could occur, soil scientists group similar amounts of sand, silt and clay into groups called soil textural classes. Texture also influences:

porosity (amount and size of pores)

plant available water holding capacity

(b)	Soil	Structure
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Structure is the arrangement of primary sand, silt and clay particles into secondary aggregates called peds or structural units which have distinct shapes and are easy to recognize. These differently shaped aggregates are called the structural type.

There are 5 basic types of structural units:

Platy: Plate-like aggregates that form parallel to the horizons like pages in a book.

1. This type of structure may reduce air, water and root movement.
2. Common structure in an E horizon and usually not seen in other horizons.

Blocky: Two types--angular blocky and sub-angular blocky

1. These types of structures are commonly seen in the B horizon.
2. Angular is cube-like with sharp corners while sub-angular blocky has rounded corners.

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.

Granular: Peds are round and pourous, spheroidal. This is usually the structure of A horizons.

Structur less: No observable aggregation or structural units.

1. Single grain-sand
2. Massive-solid mass without aggregates

Grade of structure - Describes stability of the aggregates.

1. structureless
2. weak

3.moderate

4.strong

Class of structure - Describes size of the aggregates.

- very fine
- fine
- medium
- coarse
- very coarse

The size of each category varies with the type of structure.

Formation of soil structure

- freeze / thaw
- wetting / drying
- root pressure
- microorganisms
- cementing by clay, organic matter, iron and aluminum compounds

Importance of Soil Structure

- Increases infiltration of water, thus reducing runoff and erosion and increases the amount of plant available water.
- Improves seedling emergence, root growth and rooting depth.
- Large continuous pores increase permeability.

Soil Colour

- It is the most obvious and easily determined soil property

It has little direct effect on the soil, but is an indicator of soil properties. However, there are many things we can tell about the soil by observing the color.

- Soil color and soil temperature: dark colored soils absorb more heat so they warm up quicker and have higher soil temperatures.
- Soil color and parent material: generally dark parent material will develop into dark soils.
- Soil color and drainage: soil drainage refers to the length of time a soil is waterlogged. Not how fast the soil is drained.

Relationship to Drainage

Soil Color is very important in determining a soils drainage and depth to the water table. It can be very important in predicting land use hazards.

Soil Drainage: refers to the length and duration of saturation.

it is not a measure of how fast water drains from the soil.

Drainage Classes

- Well drained - no gray colors throughout the B horizon
- Mod. Well drained - gray colors or mottles in the lower B horizon
- Somewhat poorly drained - gray colors in the upper B horizon. Mottles also seen
- Poorly drained - gray colors throughout the entire B horizon

Soil

Permeability

Permeability is the ability of soil to transmit water or air. Expressed as cm of water/hour

Soil permeability vs Soil drainage

Permeability is the speed of air and water movement in a soil -- this is affected by texture and structure

- if permeability is high : water moves quickly
- if permeability is low : water moves slowly

1. Drainage is the frequency and duration of saturation. The time that the soil is waterlogged and this is affected by landscape position and permeability

Another way to view this is; drainage refers to the amount of oxidation which has taken place in the soil and permeability

- A sand could be permeable, but in a low landscape position and be poorly drained.
- A clay could be very permeable, but in a low landscape position and be poorly drained.
- A clay could be impermeable but well drained because it is at the top of a hill.

Factors affecting permeability

Pore size present in the soil

Water moves faster through larger pores than smaller pores. - the bigger the pore the more material it will move.

- Pore Continuity

High permeability - contains pores which are continuous and large enough for air and water to pass through.

- continuous
- discontinuous

Just because a soil contains a large amount of pores doesn't mean it is permeable. The pores could be discontinuous or very small.

Any factor that will affect pore size or continuity of pores will affect permeability.

This means soil permeability is related to soil texture and soil structure.

- texture

Pores size decreases with smaller particle size. As the size of the separates decrease so does the pore size, but remember that the surface area will increase quickly.

Textural class Permeability

Sand	very high
Sandy loam	
silt, loam	high
silt loam	med-low
Clay	Low

Soil Consistence

Expresses cohesive and adhesive forces holding soil particles together; varies with moisture content. Describes the resistance of a soil at various moisture contents to mechanical stress or manipulation.

Described at three moisture levels:

- Wet

Stickiness (non-sticky, slightly sticky, sticky, very sticky)

Plasticity (non-plastic, slightly plastic, plastic, very plastic)

- Moist

Very friable, friable, firm, very firm

- Dry

Consistence indicates

- amount and type of clay material
- condition for tillage
- potential for compaction

Consistence is the resistance of the soil to deform or rupture. Soil consistence is the forces of cohesion and adhesion that are holding the peds together. It refers to the degree of plasticity and stickiness of the soil. Soil consistence is affected by the type and amount of clay that is in the soil. Soil consistence indicates:

- where are zones that may restrict root growth and seedling

emergence.

- whether a soil is likely to develop compacted zones; ruts, crusts, hardpans etc.

Factors	Affecting	Soil	Consistence
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The major Factors

Water Content

Soil Texture

Soil Density

Water Content - this is the most important.

- Soil particles will move more easily when in a wet soil. Water will act as a lubricant
- Strength increases as the soils dries out.
- Soils will compact, become denser, if tilled, trampled, driven over, etcwhen wet.

If a soil is worked or tilled when wet:

- soil has low strength; particles will be easily moved.
- under wheels will be compacted (bulk density increases).
- large pores are destroyed; cracks between peds and old root channels are squashed.
- as soils dries, its strength increases. Roots may not be able to push particles aside.
- root growth may be restricted
- these systems are more susceptible to drought and may not get all fertilizer that is present.

Soil Texture

- soil strength increases with increasing clay content
- clayey soils are stronger than sandy soils.

Soil Density

As density increases so does soil strength. You have more material in the same area which makes it harder for the plant root to grow.

Measurements of Pore Space

(a)Soil Bulk Density

- it is a measure of how compact or dense a soil is.
- it is weight of soil divided by the total volume (lbs/ft³ or g/cm³ or mg/cm³)

Density = mass (weight) / volume

Bulk Density

- relates weight of solids to total volume of soil including solids and pores.
- affected by both the nature of solids and the volume of pores.
- Bulk Density = weight of oven dry soil divided by the soil volume
- If a 100 cubic cm soil sample has an oven-dry weight of 150 grams

$$\begin{aligned}\text{Soil Bulk Density} &= \frac{\text{Overdry Weight}}{\text{Volume}} \\ &= \frac{150 \text{ g}}{100 \text{ cm}^3} \\ &= 1.5 \text{ g / cm}^3\end{aligned}$$

Bulk density is affected by the solids and porespace

- high pore space = low bulk density
- low pore space = high bulk density
- fine textures silt loams, clay, clay loam - generally lower bulk density 1-1.6 g/cc
- sandy soils may range 1.2 - 1.8 g/cc
- strong structure (well granulated topsoil) - low bulk density
- high organic matter = low bulk density

As bulk density increases:

1. soil strength increases -
2. pore space decreases
3. soils become more compact

MODULE-IV (HAZARDOUS WASTE)

Introduction

Hazardous waste means any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances.

Definition:

1. Any solid waste, other than radioactive wastes, which by reasons of physical and/or chemical or reactive or toxic, explosive, corrosive or other characteristics causing danger or likely to cause danger to health or environment whether alone or when coming in contact with other waste or environment.

2. Waste substances, which are generated in the process included in column 2 of Schedule-1 and consist of wholly or partly of the waste substances referred to in column-3 of the same schedule. (as many as 42 types of processes and corresponding wastes have been identified).

3. Waste substances which consists wholly or partly of substances indicated in Schedule-2 unless the concentration of the substances is less than the limit indicated in the same schedule: and (wastes are categorized in five categories Class A, B, C, D & E depending on concentration limits, Class E does not have any concentration limit).

4. Waste substances indicated in Part-A of the Schedule-3 unless they do not possess any of the hazardous characteristics in Part- B of the same Schedule. (Part-A of Schedule-3 consists Lists A & B of the wastes to be applicable only for imports and exports. Part-B presents a list of hazardous characteristics).

- Any substance that is present in the environment or released into the environment causing substantial damage to public health and welfare of the environment is called hazardous substance.
- Any hazardous substance could exhibit any one or more of the following characteristics: **toxicity, ignitability, corrosivity or reactivity** (explosive). Thus, any waste that contains hazardous or very hazardous substance is called hazardous waste.
- Hazardous wastes can originate from various sources such as: house-hold, local areas, urban, industry, agriculture, construction activity, hospitals and laboratories, power plants and other sources.
- The hazardous waste when disposed of release a number of environmentally unfriendly substance(s).
- Hospitals generate hazardous wastes that contain disinfectants and other harmful chemicals, and also pathogenic micro-organisms. Such wastes also require careful treatment and disposal. The use of **incinerators** (destroy, especially waste material, by burning) is crucial to disposal of hospital waste.

Nature and sources of Hazardous Waste:

Characteristics of hazardous waste include ignitability, reactivity, corrosivity, and

toxicity. Categories and sources of hazardous waste are discussed. Nuclear waste comes from nuclear power plants and weapons reprocessing operations and to a lesser extent from natural sources.

- Ignitability that is, whether the waste causes or enhances fire.
- Corrosivity that is, whether the waste destroys the tissues or metal
- Toxicity that is, whether the substance pollutes water supplies and threatens the health.
- Reactivity that is, whether the substance reacts violently or causes explosion.

Previous12345...15Next

To indicate its reason for listing a waste, EPA assigns a hazard code to each waste listed below:

(T)	-	Toxic	Waste
(H)	-	Hazardous	Waste
(I)	-	Ignitable	Waste
(C)	-	Corrosive	Waste
(R) - Reactive Waste			

Characteristics of Hazardous Waste

1. Ignitability

Wastes that are hazardous due to the ignitability characteristic include liquids with flash points below 60 °C, non-liquids that cause fire through specific conditions, ignitable compressed gases and oxidizers. EPA assigned D001 as the waste code for ignitable hazardous wastes.

2. Corrosivity

Wastes that are hazardous due to the corrosivity characteristic include aqueous wastes with a pH of less than or equal to 2, a pH greater than or equal to 12.5 or based on the liquids ability to corrode steel. EPA assigned D002 as the waste code for i hazardous wastes.

3. Reactivity

Wastes that are hazardous due to the reactivity characteristic may be unstable under normal conditions, may react with water, may give off toxic gases and may be capable of detonation or explosion under normal conditions or when heated. EPA assigned D003 as the waste code for reactive hazardous wastes.

4. Toxicity

Wastes that are hazardous due to the toxicity characteristic are harmful when ingested or absorbed. Toxic wastes present a concern as they may be able to leach from waste and pollute groundwater. The toxicity of a waste is determined by the Toxicity Characteristic

Sources of Hazardous Waste

The term hazardous waste often includes by-products of industrial, domestic, commercial, and health care activities. Rapid development and improvement of various industrial technologies, products and practices may increase hazardous waste generation.

Most hazardous wastes are produced in the manufacturing of products for consumption or further industrial application. Hazardous waste sources include industry, institutional establishments, research laboratories, mining sites, mineral processing sites, agricultural facilities and the natural environment. All sources that

discharge liquid, gaseous or solid wastes that fit the above definition can be regarded as sources of hazardous wastes. Some major sources are agricultural land and agroindustry, households, mines and mineral processing sites, health care facilities, commercial facilities, institutional facilities, industrial sites, solid waste disposal sites, contaminated sites and building materials. Major hazardous waste sources and their pollution routes in the environment are listed below.

Agricultural land and agro-industry: Hazardous wastes from agricultural land and agro-industry can expose people to pesticides, fertilizers and hazardous veterinary product wastes. Farms are a major source of these wastes, and agrochemicals can leach into the environment while in storage or can cause damage after their application.

Domestic: Households stock various hazardous substances such as batteries and dry cells, furniture polishes, wood preservatives, stain removers, paint thinners, rat poisons, herbicides and pesticides, mosquito repellents, paints, disinfectants, and fuels (i.e. Kerosene) and other automotive products. These can present a variety of dangers during storage, use and disposal.

Mines and mineral processing sites: Mining and mineral processing sites handle hazardous products that are present in the additives, the products and the wastes.

Health care facilities: Health care facilities are sources of pathological waste, human blood and contaminated needles. Specific sources of these wastes include dentists, morticians, veterinary clinics, home health care, blood banks, hospitals, clinics and medical laboratories.

Commercial wastes: Commercial waste sources include gasoline stations, dry cleaners and automobile repair shops (workshops). The types of hazardous wastes generated by these sources depend on the services provided.

Institutional hazardous waste sources: Institutional hazardous waste sources are mainly research laboratories, research centers and military installations. Some military installations are used for the manufacture and storage of ammunition, and they are also used as testing grounds for military hardware. Military establishments also carry out activities that generate other types of hazardous wastes of household, commercial and industrial nature. Hazardous wastes are created by many industrial activities. For example, the hazardous wastes from the petroleum fuel industry include the refinery products (fuels and tar), impurities like phenol and cyanides in the waste stream, and sludge flushed from the storage tanks.

Solid waste disposal sites: These are mainly disposal sites for municipal solid waste, but hazardous wastes that have not been properly separated from other wastes are also at these sites. In developing countries, solid waste disposal sites are a major source of pollutant-laden leachate to surrounding areas, as well as recyclable materials for scavengers, who can collect and resell waste materials that have been exposed to or that contain hazardous substances.

Contaminated sites: These are sites that are contaminated with hazardous wastes due to activities that use or produce hazardous substances or due to accidental spills. Former sites of industries that used or produced hazardous materials belong to this group. Building

materials: Roofs and pipes made of materials incorporating asbestos, copper, or other materials may present a source of hazardous waste.

Classification of Hazardous Waste:

From a practical standpoint, there are far too many compounds, products and product combinations that fit within the broad definition of hazardous waste. For this reason, groups of waste are considered in the following five general categories:

(i) Radioactive substance: Substances that emit ionizing radiation are radioactive. Such substances are hazardous because prolonged exposure to radiation often results in damage to living organisms. Radioactive substances are of special concern because they persist for a long period. The period in which radiation occurs is commonly measured and expressed as half-life, i.e., the time required for the radioactivity of a given amount of the substance to decay to half its initial value. For example, uranium compounds have half-lives that range from 72 years for U232 to 23,420,000 years for U236. The management of radioactive wastes is highly controlled by national and state regulatory agencies. Disposal sites that are used for the long-term storage of radioactive wastes are not used for the disposal of any other solid waste.

(ii) Chemicals: Most hazardous chemical wastes can be classified into four groups: synthetic organics, inorganic metals, salts, acids and bases, and flammables and explosives. Some of the chemicals are hazardous because they are highly toxic to most life forms. When such hazardous compounds are present in a waste stream at levels equal to, or greater than, their threshold levels, the entire waste stream is identified as hazardous.

(iii) Biomedical wastes: The principal sources of hazardous biological wastes are hospitals and biological research facilities. The ability to infect other living organisms and the ability to produce toxins are the most significant characteristics of hazardous biological wastes. This group mainly includes malignant tissues discarded during surgical procedures and contaminated materials, such as hypodermic needles, bandages and outdated drugs. This waste can also be generated as a by-product of industrial biological conversion processes. **Flammable wastes:** Most flammable wastes are also identified as hazardous chemical wastes. This dual grouping is necessary because of the high potential hazard in storing, collecting and disposing of flammable wastes. These wastes may be liquid, gaseous or solid, but most often they are liquids. Typical examples include organic solvents, oils, plasticizers and organic sludges.

(v) Explosives: Explosive hazardous wastes are mainly ordnance (artillery) materials, i.e., the wastes resulting from ordnance manufacturing and some industrial gases. Similar to flammables, these wastes also have a high potential for hazard in storage, collection and disposal, and therefore, they should be considered separately in addition to being listed as hazardous chemicals. These wastes may exist in solid, liquid or gaseous form.

vi) Household hazardous wastes: Household wastes such as cleaning chemicals, batteries, nail polish etc. in MSW constitute hazardous waste. Especially batteries contain mercury which are alkaline which is dangerous enough to kill people. Generic household hazardous material includes no chlorinated organic, chlorinated organic, pesticides, latex paint, oil based paints, waste oil, automobile battery and household battery.

Effect of Hazardous

The different ways a person can come into contact with hazardous chemicals are called exposure pathways. There are three basic exposure pathways: inhalation, ingestion, and skin contact. Inhalation is breathing or inhaling into the lungs. Ingestion is taking something in by mouth. Skin contact occurs when something comes in direct contact with the skin. Ingestion can be a secondary exposure pathway after skin contact has occurred, if you put your hands in your mouth and transfer the chemical from your hands to your mouth.

The Environmental Protection Agency (**EPA**) has developed informational summaries on selected chemicals to describe how people might be exposed to these chemicals and how exposure to them might affect their health.

Water. Exposure can occur when people drink contaminated groundwater or surface water, or accidentally ingest it while swimming or showering. Direct skin contact also is an exposure pathway that occurs during activities like swimming and showering.

Soil, Sediment, or Dust. People can be exposed to hazardous chemicals in soil, sediment, or dust if they accidentally ingest it, breathe it in, or have direct skin contact. Children are highly susceptible to these exposure pathways. In their daily activities, children have a tendency to have frequent hand-to-mouth contact and introduce non-food items into their mouths.

Air. Exposure can occur when people breathe in hazardous chemical vapours or air that is contaminated by hazardous chemicals or dust.

Food. People can be exposed to hazardous chemicals through the food they eat. Food contamination can occur if the food has come into contact with hazardous chemicals. It can also occur further down the food chain such as through eating contaminated fish. Exposure, the chemical getting into or on your body, has to occur to make you sick or cause adverse health effects, or have any effect on your health. If you are not exposed to the chemical, it cannot make you sick. Also, even if exposure has occurred, adverse health effects may not occur.

Adverse health effects are dependent on the factors of the exposure. Factors that play a part in whether or not adverse health effects may result from an exposure are:

- the **type** of chemical;
- the **amount** or **dose** (the amount or level of a chemical a person was exposed to);
- the **duration** (how long did exposure occur); and
- the **frequency** (how many times the person was exposed).

Also, the occurrence of adverse health effects can depend on the way the chemical enters your body. Some chemicals rapidly absorb through skin, others not at all. Health effects also depend on the toxicity of the chemical that entered your body. Some chemicals are very toxic in small amounts; others are only toxic in large

volumes. Also, people respond to chemical exposure in different ways. Some people may be exposed to a chemical and not get sick. Other people may be more sensitive to chemicals and get sick more rapidly or have more severe reactions than others. Certain variables play a role in a person's susceptibility to exposure and adverse health effects such as age, gender, genetics, pregnancy or other health conditions.

Treatment of Hazardous Waste:

Hazardous waste can be treated by chemical, thermal, biological, and physical methods. Chemical methods include ion exchange, precipitation, oxidation and reduction, and neutralization. Among thermal methods is high-temperature incineration, which not only can detoxify certain organic wastes but also can destroy them.

Hazardous Waste Treatment Technologies:

Even with after vigorous hazardous waste reduction program, there will still be large quantities of hazardous wastes that will require treatment and disposal. The treatment technologies have been categorised as physical, chemical, biological, thermal, or stabilisation/fixation. Physical treatment processes include gravity separation, phase change systems, such as air and steam stripping of volatiles from liquid wastes, and various filtering operations, including carbon adsorption.

Physical treatment methods:

Adsorption: Adsorption on activated carbon occurs when a molecule is brought up to its surface and held there by physical and /or chemical forces. This process is reversible, thus allowing activated carbon to be regenerated and reused by proper application of heat and steam, or solvent.

The factors that relate to adsorption capacity are:

- Greater surface area produces greater adsorption capacity [e.g: Activated carbon has large surface area (500-1500 m² /g)]
- Absorptivity increases as the solubility of the solute (in solvent) decreases. Thus, for hydrocarbons, adsorption increases with molecular weight
- For solutes with ionisable groups, maximum adsorption will be achieved at a pH corresponding to minimum ionisation.
- Adsorption capacity decreases with increasing temperature.

One additional point to be noted is that biological activity usually takes place in a carbon bed. If the concentration of the adsorbed species is high enough and the material is biodegradable and nontoxic to the bacteria, then biological activity may significantly increase the effective removal capacity.

Removal through adsorption by activated carbon has been applied to non-aqueous waste stream such as petroleum fraction, syrups, vegetable oils, and pharmaceutical preparations. Colour removal is the most common objective in such cases. Current waste treatment applications are limited to aqueous solutions.

Resin adsorption: Waste treatment by resin involves two basic steps:

- (1) contacting the liquid waste stream with resin and allowing the resin to adsorb the solutes from the solution; and
- (2) subsequently regenerating the resins by removing the adsorbed chemicals, by simply washing with proper solvent.

The adsorption of a nonpolar molecule on to a hydrophobic resin (e.g., styrene divinylbenzene-based resin) results primarily from the effect of Vander Waal's forces. In other cases, other type of interactions such as dipole interaction and hydrogen bonding are important. In a few cases ion exchange mechanism may be involved. For the removal of organic dye wastes from water, two different resins were employed: In this case the waste stream is first contacted with a normal polymeric adsorbent and then with an ion exchange resin.

Sedimentation: Sedimentation is a physical process whereby particles suspended in a liquid settle by means of gravity. The fundamental elements of most sedimentation processes are:

- a basin or container of sufficient size to maintain the liquid to be treated in a relatively quiescent state for a specified period of time

- a means of directing the liquid to be treated into the above basin in a manner conducive to settling.

- a means of physically removing the settled particles from the liquid.

Sedimentation can be either a batch or a continuous process. Continuous processes are by far the most common, particularly when large volumes of liquid are to be treated. This technique has been widely used in the removal of heavy metals from iron and steel industry waste water; removal of fluoride from aluminium production waste water; and removal of heavy metals from waste water from copper smelting and from metal finishing industry and waste water stream from organic chemicals.

Electro-dialysis: The electro dialysis involves the separation of an aqueous stream (more concentrated in electrolyte than the original) and a depleted stream. Success of the process depends on special synthetic membranes, usually based on ion exchange resins, which are permeable only to a single type of ion. Cation exchange membranes permit passage only of positive ions, under the influence of electric field, while anion exchange membranes permit passage only of negatively charged ions. The feed water is passed through compartments formed by the spaces between alternating cation-permeable and anion permeable membranes held in a stack. At each end of the stack is an electrode having the same area as the membranes. A dc potential applied across the stack causes the positive and negative ions to migrate in opposite directions. This technique has already been discussed in detail under water treatment This technique has been used for desalination to produce potable water from brackish well water. In food industry electro dialysis is used for desalting whey. The chemical industry uses this technique for enriching or depleting solutions, and for removing mineral constituents from product streams.

Reverse osmosis: This technique which is most widely used consists of a membrane permeable to solvent but impermeable to most dissolved species, both organic and inorganic. These devices use pressure to force the contaminated water against the

semipermeable membrane. The membrane acts as a filter, allowing the water to be pushed through the pores, but restricting the passage of larger molecules that are to be removed. Cellulose acetate membranes were used in the past, but nowadays polysulphides and polyamides are increasingly popular for use at high pH values. Because of the susceptibility of the membranes to chemical attack and fouling, and the susceptibility of the flow system to plugging and erosion, it is common to pre-process the feed water to remove oxidising materials. The reverse osmosis technique has been widely used for desalination of sea or brackish water. It has also been successfully used in the treatment of electroplating rinse waters, not only to meet effluent discharge standards, but also to recover concentrated metal salt solutions for reuse. It has also been used for treatment of waste stream from paper and food processing industries.

Solvent extraction: Solvent extraction is the separation of the constituents of a liquid solution by contact with another immiscible liquid. If the substances comprising the original solution distribute themselves differently between the two liquid phases, a certain degree of separation will result and this may be enhanced by the use of multiple contacts. The major application of solvent extraction to waste treatment has been in the removal of phenol from by-product water produced in coal coking, petroleum refining, and chemical synthesis that involve phenol. The use of supercritical fluids (SCFs) most commonly CO₂ as extraction solvent, has been one of the more promising approaches to solvent extraction. SCFs are fluids existing at or above the lowest temperature at which condensation may occur. Above the critical temperature certain fluids exhibit characteristics that enhance their solvent properties. Organic materials, which are only slightly soluble in particular solvents at room temperature, become completely miscible with the solvent when under supercritical conditions. The excellent solvent properties result from the rapid mass transfer ability and the very low density that characterises an SCF. Major advantages of SCFs are short residence times with no char formation. Some of the important application of these SCFs, has been in the extraction of organohalide pesticide from soil, extraction of oil from emulsions used in aluminium and steel processing, and regeneration of spent activated carbon. Supercritical ethane has been used to purify waste oils contaminated with PCBs, metals and water.

Distillation: Distillation is expensive and energy intensive and can probably be justified only in cases where valuable product recovery is feasible (e.g., solvent recovery). This technique has only limited application in the treatment of dilute aqueous hazardous wastes.

Evaporation: Evaporation process is used for the treatment of hazardous waste such as radioactive liquids and sludges and concentrating of plating and paint solvent waste among many other applications. It is capable of handling liquids, slurries and sometimes sludges, both organic and inorganic, containing suspended or dissolved solids or dissolved liquids, where one of the components is essentially non-volatile. It can be used to reduce waste volume prior to land fill disposal or incineration.

The major disadvantages of evaporation are high capital and operating costs and high energy requirements. This process is more adaptable to waste waters with high concentrations of pollutants. **Filtration:** Filtration is well-developed economical process used in the full scale treatment of many industrial waste waters and waste sludges. Energy requirements are relatively low, and operational parameters are well defined. However, it

is not a primary treatment process and is often used in conjunction with precipitation, flocculation, and sedimentation to remove these solids.

Flocculation: The various phenomena that occur during flocculation can be grouped in to two sequential mechanisms.

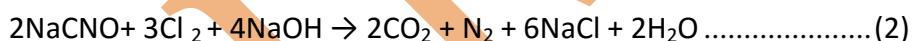
- Chemically induced destabilisation of repulsive surface related forces, thus allowing particles to stick together when they touch and
- Chemical bridging and physical enmeshment between the non-repelling particles, allowing for the formation of large particles.

Chemicals used for flocculation include alum, lime, ferric chloride, ferrous sulphate and poly electrolytes. Poly electrolytes consist of long chain, water soluble polymers such as polyacrylamides. They are used either in conjunction with inorganic flocculants, or as primary flocculating agent. The inorganic flocculants such as alum, upon mixing with water, the slightly higher pH of water causes them to hydrolyse to form gelatinous precipitates of aluminium hydroxide. It is partially because of their large surface area, they are able to enmesh small particles, and thereby create larger particles. Once suspended particles have been flocculated into larger particles, they usually can be removed from the liquid by sedimentation, provided that a sufficient density difference exists between the suspended matter and the liquid.

Chemical treatment of hazardous wastes:

(a) Chemical Oxidation and reduction:

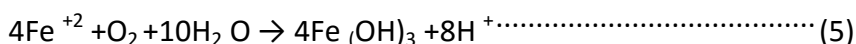
(I) Oxidation reduction methods provide another important chemical treatment alternative for hazardous wastes. One important chemical redox treatment involves the oxidation of cyanide wastes from metal finishing industry, using chlorine in alkali solution. In this reaction CN⁻ is first converted to a less toxic cyanate. Further chlorination oxidises the cyanate to simple carbondioxide and nitrogen gas.



II) Another important redox treatment process is the reduction of hexavalent chromium Cr(VI) to trivalent chromium Cr(III) in large electroplating operations. Sulphur dioxide is used as the reducing agent and the reactions are as follows.



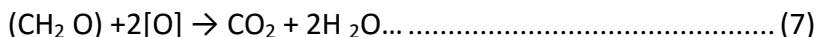
III) Iron (II) in solution can be precipitated as ferric hydroxide by oxidation of



(IV) In a similar way sulphur dioxide is oxidised to sulphuric acid



(V) A large variety of oxidisable contaminants in waste water and sludges are oxidised by ozone which can be generated on site by an electrical discharge through dry air or oxygen.

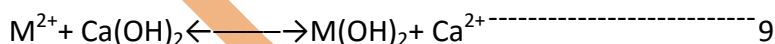


(b) Ozonolysis:

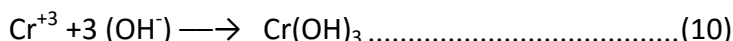
Ozone is a very powerful oxidising agent. Although this process has not been demonstrated in any full-scale facility, its application to TCDD and PCBs is quite promising. With respect to TCDD it was demonstrated that if the dioxins were suspended as an aerosol combined with CCl_4 , 97% degradation for the destruction of polychlorinated phenols and pesticides. In both the cases the key requirements were to concentrate the TCDD in a medium where they were susceptible to attack and provide a free radical for reaction with dioxin molecule.

©Acid-base neutralisation: Hazardous wastes are categorised as corrosive when their solution pH is less than 2 or more than 12.5. Such wastes can be chemically neutralised. Generally acidic wastes are neutralised with slaked lime $[\text{Ca}(\text{OH})_2]$ in a continuously stirred chemical reactor. The rate of addition of lime is controlled by feedback control system which monitors pH during addition. Lime is least expensive and is widely used for treating acidic wastes. Since the solubility of lime in water is limited, solution of excess lime does not reach extremely high pH values. Alkaline wastes may be neutralised by adding sulphuric acid. It is a relatively inexpensive acid. For some applications acetic acid is preferable since it is nontoxic and biodegradable. Alkaline wastes can also be neutralised by bubbling gaseous carbon dioxide forming carbonic acid. The advantage of CO_2 is that it is often readily available in the exhaust gas from any combustion process at the treatment site. Many waste treatment processes like oxidation/reduction, adsorption, wet air oxidation, ion-exchange, stripping and biochemical treatment require prior pH adjustment

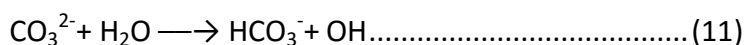
(d) Chemical precipitation: This technique can be applied to almost any liquid waste stream containing a perceptible hazardous constituent. By properly adjusting pH, the solubility of toxic metals can be decreased, leading to the formation of a precipitate that can be removed by settling and filtration. Quite often lime $[\text{Ca}(\text{OH})_2]$ or caustic soda is used for precipitation of the metal ions as metal hydroxides. For example, the following reaction suggests the use of lime to precipitate the metal as hydroxide.



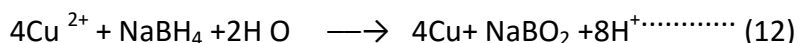
Chromium is precipitated as hydroxide.



Sodium carbonate also has been used to precipitate metals as hydroxides ($\text{Fe}(\text{OH})_3 \cdot \text{XH}_2\text{O}$), carbonates (CdCO_3), basic carbonate salts ($2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$). Carbonate ion hydrolyses in water to give hydroxide ion

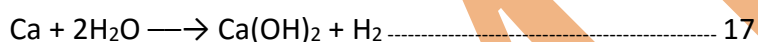
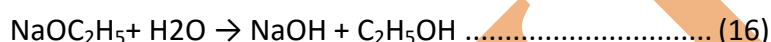
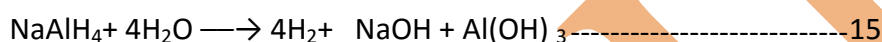
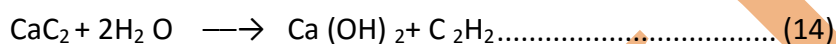
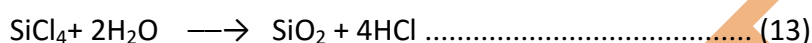


Even lower concentrations of metals in the effluent can be removed by precipitating them as sulphides. Ferrous sulphide can be used as a safe source of sulphide ion to produce sulphide precipitates with other metals that are less soluble than ferrous sulphide. Reducing agents such as sodium borohydride can be used to precipitate the metal ions from solution in the elemental form.



(e) Hydrolysis:

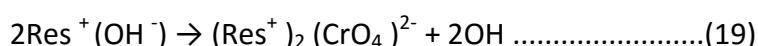
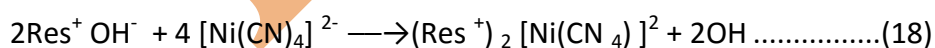
Hydrolysis treatment can be given to those hazardous waste constituents which are very reactive with water. Examples of those substances are halides, carbide, hydride, alkoxide, and active metal



(f) Ion exchange:

Ion exchange is judged to have some potential for the application of interest in situations where it is necessary to remove dissolved inorganic species. However other competing processes i.e precipitation, flocculation and sedimentation are broadly applicable to mixed waste streams containing suspended solids and a spectrum of organic and inorganic species. These competing processes also usually are more economical. The use of ion exchange is therefore limited to situations where polishing step was required to remove an inorganic constituent that could not be reduced to satisfactory levels by preceding treatment processes.

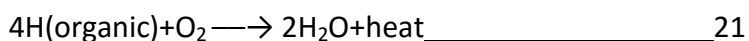
One example for this is the use of anion exchanges for the removal of anionic nickel cyanide complex and chromate ions from waste solutions.



Ion -exchange resins have also been used in the removal of radionuclides from radioactive wastes

(g) Thermal treatment methods:

Thermal incineration is a process that uses high-temperature thermal oxidation to convert a waste to a less bulky, less toxic or less noxious material. It can be considered as a volume-reduction process in that many of the component elements of organic materials, including the most common ones (carbon, hydrogen and oxygen) are converted wholly or partially to gaseous form, leaving only the non-combustible inorganic volume. The principal products of incineration are carbon dioxide water vapour and ash.



Reaction such as (20) and (21) destroy organic matter and generate heat required for the cleavage of C-C bonds in organochlorine compounds. In case of non-inflammable organochloride wastes supplemental fuel such as methane or petroleum-liquid is necessary to incinerate them. The hazardous products of incineration are compounds of sulphur, nitrogen, halogen and heavy metals (mercury, arsenic, selenium, lead and cadmium). If the gaseous combustion products of incineration contain undesirable compounds, air pollution control equipment is required. The solid and liquid effluents may require treatment prior to ultimate disposal or discharge. The most critical factors that determine complete combustion of hazardous wastes are

- (i) high combustion temperatures above about 900o C to ensure that the thermally resistant compounds react
- (ii) availability of sufficient amount of oxygen for combustion.
- (iii) sufficient residence time to allow the reactions to occur.

Performance of hazardous wastes incinerators: Performance of hazardous-waste incinerators can be measured in terms of destruction removal efficiency (DRE). DRE accounts for both the destruction in the combustion chambers(s) and the removal of organics in any air-pollution control equipment. DRE can be calculated as the percentage of mass difference of input(feed) and output (stack emission) waste constituents through the incinerator. DRE has been defined on a compound-specific basis and thus must be calculated for each constituent of interest separately. According to RCRA (Resource conservation and Recovery Act) requirement, a minimum DRE of 99.99 percent for most of organic compounds and a DRE of 99.9999 percent for dioxins and dibenzo furans should be achieved for efficient combustion.

Advantages of incineration: The basic process technology is available and reasonably well developed. Incineration can be scaled to handle large volumes of liquid waste. It is the best known method for the disposal of "mixed wastes". It is an excellent disposal method for biologically hazardous wastes. Large areas of land are not required.

Disadvantages of incineration: The equipment is costly. The ash may or may not be toxic,

but must be disposed of properly. The gaseous and particulate products of combustion may be hazardous and should be controlled by air pollution control technology.

(h) Wet air oxidation: It is the aqueous phase oxidation of dissolved or suspended organic substances at elevated temperatures (150-325°C) and pressures (2000 kPa to 20,000 kPa) water. Which makes up the bulk of the aqueous phase, serves to catalyse the oxidation reactions so they proceed at relatively low temperature, and at the same time serves to moderate the oxidation rates removing excess heat by evaporation. It also acts as excellent heat transfer medium, which enables the wet air oxidation process to be thermally self-sustaining with relatively low organic feed concentrations. The high pressures allow high concentration of oxygen to be dissolved in water and the high temperature assist the reaction to occur.

In wet air oxidation, the waste is pumped into the system with high-pressure pump and mixed with air from an air compressor. The waste is passed through a heat exchanger and then to a reactor where atmospheric oxygen reacts with the organic matter waste, sometimes in the presence of catalysts. The oxidation is accomplished by a temperature increase. The gas and liquid phases are separated. System pressure is controlled to maintain the reaction temperature. The process can be used for the removal of cyanide from electroplating waste solutions.



(i) Photolysis:

In photolysis, chemical bonds are broken under the influence of light. In primary photochemical process, the target species is converted to an electronically excited state, usually a diradical, which is sufficiently energetic to undergo chemical reaction. The fate of the excited molecule and therefore the effectiveness of a photolysis treatment process, depends on its chemical structure and on the medium in which it is carried out. For the photolysis process to be effective in the treatment of hazardous wastes stream, the radiation source must be sufficiently energetic, must be absorbed by the target species and the final photochemical products must be less toxic. To date much of the research work on the treatment of highly toxic wastes has centred on two types of constituents: polychlorinated biphenyls (PCBs) and chlorinated dibenzo-p-dioxins (CDDs) eg: tetrachloro-dibenzo-p-dioxin (TCDD). The three requirements of photolysis of TCDD are 1) Dissolution in a light transmitting film 2) presence of organic hydrogen odour and 3) ultraviolet light. In such photolysis reactions initially a reactive intermediate such as HO• is formed which participate in chain reactions that lead to the destruction of the compound.

Biodegradation of Hazardous Waste:

The biodegradation of hazardous waste is carried out in the following steps

1. Aerobic Phase – In this phase, the enzymes and decomposition chemicals act as a catalyst to the biofilm coating the plastic. During this time, aerobic microbes are becoming established and moisture is building up in the refuse. Standard plastic moisture absorption

capability is relatively small, but the additive causes further swelling, weakening the polymer bonds. This creates molecular spaces for microbial growth, which begins the aerobic degradation process in which oxygen is converted to CO₂.

2. Anaerobic, Non-Methanogenic Phase – After oxygen concentrations have declined sufficiently, the anaerobic processes begin. During the initial stage (hydrolysis), the microbe colonies eat the particulates, and through an enzymatic process, reduce large polymers into simpler monomers. The organic additive causes additional swelling and opening of the polymer chain and increased quorum sensing. This further excites the microbes to increase their colonization and consumption of the polymer chain. As time progresses, acidogenesis occurs where the simple monomers are converted into fatty acids. CO₂ production occurs rapidly at this stage.

3. Anaerobic, Methanogenic Unsteady Phase – The microbe colonies continue to grow, eating away at the polymer chain and creating increasingly larger molecular spaces. During this phase acetogenesis occurs, converting fatty acids into acetic acid, carbon dioxide and hydrogen. As this process continues, CO₂ rates decline and hydrogen production eventually ceases.

4. Anaerobic, Methanogenic Steady Phase – The final stage of decomposition involves methanogenesis. As colonies of microbes continue to eat away at the remaining surface of the polymer, acetates are converted into methane and carbon dioxide, and hydrogen is consumed. The process continues until the remaining element is humus. This highly nutritional soil creates an improved environment for the microbes and enhances the final stage of decomposition.

Disposal of Hazardous Waste:

These are the following methods adopted for the disposal of hazardous waste

1. Preventing or reducing waste generation: Extensive use of new or unnecessary products is the root cause of unchecked waste formation. The rapid population growth makes it imperative to use second-hand products or judiciously use the existing ones because if not, there is a potential risk of people succumbing to the ill effects of toxic wastes. Disposing of the wastes will also assume formidable shape. A conscious decision should be made at the personal and professional level to judiciously curb the menacing growth of wastes.

2. Recycling: Recycling serves to transform the wastes into products of their own genre through industrial processing. Paper, glass, aluminium, and plastics are commonly recycled. It is environmentally friendly to reuse the wastes instead of adding them to nature. However, processing technologies are pretty expensive.

3. Incineration: Incineration features combustion of wastes to transform them into base components, with the generated heat being trapped for deriving energy. Assorted gases and inert ash are common by-products. Pollution is caused by varied degrees' dependent on nature of waste combusted and incinerator design. Use of filters can check pollution. It

is rather inexpensive to burn wastes and the waste volume is reduced by about 90%. The nutrient rich ash derived out of burning organic wastes can facilitate hydroponic solutions. Hazardous and toxic wastes can be easily being rid of by using this method. The energy extracted can be used for cooking, heating, and supplying power to turbines. However, strict vigilance and due diligence should be exercised to check the accidental leakage of micro level contaminants, such as dioxins from incinerator lines.

4. Composting: It involves decomposition of organic wastes by microbes by allowing the waste to stay accumulated in a pit for a long period of time. The nutrient rich compost can be used as plant manure. However, the process is slow and consumes a significant amount of land. Biological reprocessing tremendously improves the fertility of the soil.

5. Sanitary Landfill: This involves the dumping of wastes into a landfill. The base is prepared of a protective lining, which serves as a barrier between wastes and ground water, and prevents the separation of toxic chemicals into the water zone. Waste layers are subjected to compaction and subsequently coated with an earth layer. Soil that is non-porous is preferred to mitigate the vulnerability of accidental leakage of toxic chemicals. Landfills should be created in places with low groundwater level and far from sources of flooding. However, a sufficient number of skilled manpower is required to maintain sanitary landfills.

6. Disposal in ocean/sea: Wastes generally of radioactive nature are dumped in the oceans far from active human habitats. However, environmentalists are challenging this method, as such an action is believed to spell doom for aquatic life by depriving the ocean waters of its inherent nutrients.

Hazardous Waste Management:

Hazardous waste is generated by all sectors of Irish society, from large industry, healthcare to small businesses, households and farms. It is for the most part managed by a professional hazardous waste industry and is treated appropriately and in accordance with legal requirements. Large quantities of hazardous waste are generated, and there is scope to reduce this generation of waste through waste prevention programmes. Around half of Irish hazardous waste is exported for treatment. There are some problems with so-called 'unreported' hazardous waste in Ireland, where small amounts of consumer hazardous waste are produced in households and small businesses and can be inappropriately managed.

The objectives of the hazardous waste management plans are as follows

- To prevent and reduce the generation of hazardous waste by industry and society generally;
- To maximise the collection of hazardous waste with a view to reducing the environmental and health impacts of any unregulated waste;
- To strive for increased self-sufficiency in the management of hazardous waste and to minimise hazardous waste export;
- To minimise the environmental, health, social and economic impacts of

hazardous waste generation and management.

The following is a summary of the recommendations:

1. Prevention

Prevention projects to reduce the generation of hazardous waste in certain priority sectors (pharmachem, agriculture, healthcare, households, publishing & printing and transport) should continue to be led by the EPA under the National Waste Prevention Programme. Prevention initiatives should be incorporated into Regional Waste Management Plans and the Green Public Procurement Action Plan should provide for the substitution and reduction in use of hazardous materials. Waste characterisation studies of certain waste streams are also recommended to evaluate the reduction of the hazardous content of such wastes

2. Collection

A comprehensive and accessible network of local drop-off facilities for householders and small businesses is recommended to tackle the problem of “unreported” hazardous waste. Enforcement activities should continue to focus on issues such as unauthorised burning of waste oil in order to increase collection and prevent environmental pollution. The potential for producer responsibility obligations for a number of hazardous waste streams should be given priority consideration.

3. Self-sufficiency

The objective of moving towards increased self-sufficiency and minimising exports continues to be recommended, where it is strategically/environmentally advisable, and technically and economically feasible. If Ireland were to become self-sufficient, suitable hazardous waste treatment options would be required.

4. Regulation

Consolidation of waste legislation and cooperation in enforcement is recommended. A review of waste licensing/permitting legislation is recommended in order to establish a proportionate regulatory mechanism, including relief, to facilitate collection, transport and temporary storage of certain hazardous wastes from small sources pending proper treatment.

5. Legacy issues

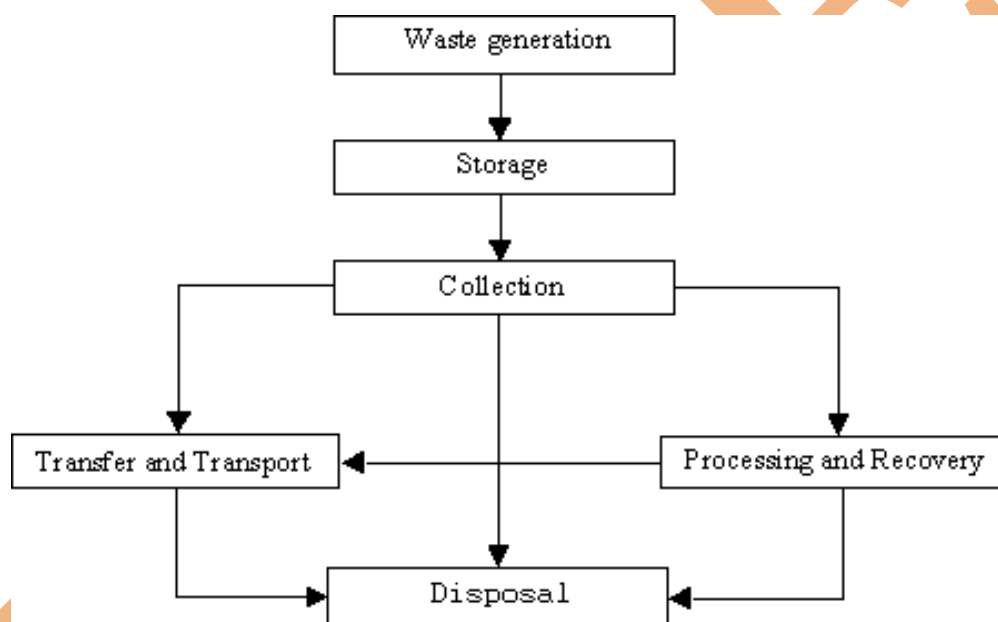
Old waste disposal sites, especially those that to a significant extent may have involved the disposal of hazardous waste, should continue to be managed (i.e. identified, risk assessed and regularised) in accordance with the Code of Practice drawn up by the EPA’s Office of Environmental Enforcement and relevant legislation, where required.

6. Guidance and awareness

A key aspect of proper hazardous waste management is guidance and awareness. During implementation of the second Plan, the EPA developed prevention resources for certain sectors. Such resources should continue to be disseminated (e.g. the Green Healthcare Programme). Local authorities and relevant sectoral organisations should also avail of appropriate media (e.g. social media) to inform the public and small businesses of hazardous waste collection services.

7. Implementation

Policy makers, regulators, product producers, importers, generators and holders of hazardous waste all play a vital role in ensuring that the generation of such materials is minimised, and the materials are collected and treated correctly in accordance with the waste hierarchy.



NATURAL HAZARDS AND NATURAL DISASTERS

Introduction

"Hazard always arises from the interplay of social and biological and physical systems; disasters are generated as much or more by human actions as by physical events."

A hazard is distinguished from an extreme event and a disaster. A natural hazard is an extreme event that occurs naturally and causes harm to humans or to other things that we care about, though usually the focus is on humans (which, we

might note, are anthropocentric). An extreme event is simply an unusual event; it does not necessarily cause harm. Note that many hazards have both natural and artificial components. Because hazards are threats of harm mainly to human systems, human activities play a large role in how severe a hazard is. For example, when large numbers of people crowd into floodplains and low-lying areas, they are putting themselves in harm's way, increasing the severity of potential floods. Similarly many major cities are built in coastal areas faces the threat of rising sea levels, a hazard being caused by global climate change. The severity of the impacts from a natural hazard depends on both the physical nature of the extreme event and on the details of human development decisions. Most hazardous process is also Geologic Processes.

Geologic processes effect every human on the Earth all of the time, but are most noticeable when they cause loss of life or property. If the process that poses the hazard occurs and destroys human life or property, then a natural disaster has occurred. Among the natural hazards and possible disasters to be considered are:

- Earthquakes
- Volcanic Eruptions
- Tsunami
- Landslides
- Subsidence
- Floods
- Droughts
- Hurricanes
- Tornadoes
- Asteroid
- Impacts

Classification of Natural Hazards and Disasters

Natural Hazards and the natural disasters that result can be divided into several different categories:

- Geologic Hazards - These are the main subject of this course and include:
 - Earthquakes
 - Volcanic Eruptions
 - Tsunami
 - Landslides
 - Floods
 - Subsidence
 - Impacts with space objects
- Atmospheric Hazards - These are also natural hazards but processes operating in the atmosphere are mainly responsible. They will also be considered in this course, and include:
 - Tropical Cyclones
 - Tornadoes
 - Droughts

- Severe Thunderstorms
- Lightening
- Other Natural Hazards - These are hazards that may occur naturally, but don't fall in to either of the categories above. They will not be considered to any great extent in this course, but include:
 - Insect infestations
 - Disease epidemics
 - Wildfires

Natural Hazards can also be divided into catastrophic hazards, which have devastating consequences to huge numbers of people, or have a worldwide effect, such as impacts with large space objects, huge volcanic eruptions, world-wide disease epidemics, and world-wide droughts. Such catastrophic hazards only have a small chance of occurring, but can have devastating results if they do occur.

Natural Hazards can also be divided into rapid onset hazards, such as Volcanic Eruptions, Earthquakes, Flash floods, Landslides, Severe Thunderstorms, Lightening, and wildfires, which develop with little warning and strike rapidly. Slow onset hazards, like drought, insect infestations, and disease epidemics take years to develop.

Anthropogenic Hazards

These are hazards that occur as a result of human interaction with the environment. They include Technological Hazards, which occur due to exposure to hazardous substances, such as radon, mercury, asbestos fibers, and coal dust. They also include other hazards that have formed only through human interaction, such as acid rain, and contamination of the atmosphere or surface waters with harmful substances, as well as the potential for human destruction of the ozone layer and potential global warming.

Effects of Hazards

Hazardous process of all types can have primary, secondary, and tertiary effects.

- Primary Effects occur as a result of the process itself. For example, water damage during a flood or collapse of buildings during an earthquake, landslide, or hurricane.
- Secondary Effects occur only because a primary effect has caused them. For example, fires ignited as a result of earthquakes, disruption of electrical power and water service as a result of an earthquake, flood, or hurricane, or flooding caused by a landslide into a lake or river.

Tertiary Effects are long-term effects that are set off as a result of a primary event. These include things like loss of habitat caused by a flood, permanent changes in the position of river channel caused by flood, crop failure caused by a volcanic eruption etc.

Vulnerability to Hazards and Disasters

- Vulnerability is the way a hazard or disaster will affect human life and property
Vulnerability to a given hazard depends on:
- Proximity to a possible hazardous event
- Population density in the area proximal to the event
- Scientific understanding of the hazard
- Public education and awareness of the hazard
- Existence or non-existence of early-warning systems and lines of communication
- Availability and readiness of emergency infrastructure
- Construction styles and building codes
- Cultural factors that influence public response to warnings
- In general, less developed countries are more vulnerable to natural hazards than are industrialized countries because of lack of understanding, education, infrastructure, building codes, etc. Poverty also plays a role since poverty leads to poor building structure, increased population density, and lack of communication and infrastructure.
- Human intervention in natural processes can also increase vulnerability by
- Development and habitation of lands susceptible to hazards, for example, building on floodplains subject to floods, sea cliffs subject to landslides, coastlines subject to hurricanes and floods, or volcanic slopes subject to volcanic eruptions.
- Increasing the severity or frequency of a natural disaster. For example: overgrazing or deforestation leading to more severe erosion (floods, landslides), mining groundwater leading to subsidence, construction of roads on unstable slopes leading to landslides, or even contributing to global warming, leading to more severe storms.
- Affluence can also play a role, since affluence often controls where habitation takes place, for example along coastlines, or on volcanic slopes. Affluence also likely contributes to global warming, since it is the affluent societies that burn the most fossil fuels adding CO₂ to the atmosphere.

1. Earthquake

- Earthquakes are one of the most destructive of natural hazards. An earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large areas, occurs all of a sudden and is unpredictable. They can cause large scale loss of life and property and disrupts essential services such as water supply, sewerage systems, communication and power, transport, etc. They not only destroy villages, towns and cities but the aftermath leads to destabilize the economy and social structure of the nation.

Facts about Earthquake

An earthquake is the movement or trembling of the ground produced by the sudden displacement of rock in the Earth's crust. Earthquakes result from crustal strain, volcanism, landslides, and collapse of caverns. Stress accumulates in

response to tectonic forces until it exceeds the strength of the rock. The rock then breaks along a preexisting or new fracture called a fault. The rupture extends outward in all directions along the fault plane from its point of origin (focus). The rupture travels in an irregular manner until the stress is relatively equalized. If the rupture disturbs the surface, it produces a visible fault on the surface. Earthquakes are recorded by seismograph consisted of a seismometer, a shaking detector and a data recorder. The moment magnitude of an earthquake is conventionally reported, or the related and mostly obsolete Richter magnitude, with magnitude 3 or lower earthquakes being mostly imperceptible and magnitude 7 causing serious damage over large areas. Intensity of shaking is measured on the modified Mercalli scale. In India Medvedev-Sponheuer-Karnik scale, also known as the MSK or MSK-64, which is a macroseismic intensity scale, is used to evaluate the severity of ground shaking on the basis of observed effects in an area of the earthquake occurrence. Due to earthquake seismic waves are generated and measurements of their speed of travel are recorded by seismographs located around the planet.

Causes of Earthquakes

An Earthquake is a series of underground shock waves and movements on the earth's surface caused by natural processes within the earth's crust. To learn more about the occurrence of this event lets know more about the interior of the earth. Earthquakes are caused by natural tectonic interactions within the earth's crust and it is a global phenomenon. They may arise either due to the release of energy from the strained rock inside the Earth or tectonic movements or volcanic activity. The sudden release of accumulated energy or stresses in the earth or sudden movement of massive land areas on the earth's surface cause tremors, commonly called earthquakes

Seismic Waves

Large strain energy released during an earthquake travel as seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface. These waves are of two types - body waves and surface waves; the latter is restricted to near the Earth's surface. Body waves consist of Primary Waves (P-waves) and Secondary Waves (S-waves), and surface waves consist of Love waves and Rayleigh waves. Under P-waves, material particles undergo extensional and compressional strains along the direction of energy transmission, but under Swaves, oscillate at right angles to it. Love waves cause surface motions similar to that by Swaves, but with no vertical component. Rayleigh wave makes a material particles oscillate in an elliptic path in the vertical plane (with horizontal motion along direction of energy transmission).

Magnitude

Magnitude is a quantitative measure of the actual size of the earthquake. Professor Charles Richter noticed that (a) at the same distance, seismograms (records of earthquake ground vibration) of larger earthquakes have bigger wave amplitude than those of smaller earthquakes; and (b) for a given earthquake, seismograms at farther distances have a smaller wave amplitude than those at close distances. This

prompted him to propose the now commonly used magnitude scale, the Richter scale. It is obtained from the seismograms and accounts for the dependence of waveform amplitude on epicentral distance. This scale is also called Local Magnitude scale. There are other magnitude scales, like the Body Wave Magnitude, Surface Wave Magnitude and Wave Energy Magnitude. These numerical magnitude scales have no upper and lower limits; the magnitude of a very small earthquake can be zero or even negative.

Intensity

Intensity is a qualitative measure of the actual shaking at a location during an earthquake, and is assigned as Roman Capital Numerals. There are many intensity scales. Two commonly used ones are the Modified Mercalli Intensity (MMI) Scale and the MSK Scale. Both scales are quite similar and range from I (least perceptible) to XII (most severe). The intensity scales are based on three features of shaking - perception of people and animals, performance of buildings, and changes in natural surroundings. The distribution of intensity at different places during an earthquake is shown graphically using isoseismals, lines joining places with equal seismic intensity.

Classification of earthquake

Classification of earthquake is based on several parameters. Based on scale of magnitude (M), earthquake may be of the Micro ($M < 3.5$) or macro ($M > 3.5$) type.

- Depending upon the extent of energy released and strength of the ground shaking it may be of several types, like moderate, strong, very strong, great and very great earthquake.
- Depending upon the scale of damage, the earthquake may be of various types, such as Less damaging earthquake, Moderate damaging earthquake, and catastrophic earthquake.
- Depending upon the focal depth (h) of the event, it could be a shallow earthquake ($d < 70$ km); intermediate depth earthquake ($70 < h < 300$ km); the deep earthquake ($300 < h < 700$ km).
- Depending upon the location of events in different tectonic settings, earthquake may be of intra-plate, inter-plate, and sub-oceanic earthquake.
- Depending upon involvement of other agencies / phenomena with earthquake genesis, it may be of several types, such as Reservoir induced; Fluid-driven earthquake; Tsunamigenic earthquake, and volcanic earthquake.
- Depending upon the type of faulting involved during earthquake genesis, earthquake may be categorized into several categories, such as normal faulting, reverse faulting, thrust faulting, and mega-thrust earthquake.
- Depending upon the frequency content, the earthquake may be of Low-Frequency tremors or high – Frequency tremors.
- Depending upon the epicenter distance (distance between earthquake main shock and the recording stations), the earthquake may be classified into Local, Regional and Global earthquake.

Intensity scale

It manifests the degree of damage, which gets diminished as we go away from the main shock source zone and the reverse is also true. Mercalli intensity scale The Mercalli intensity scale is a seismic scale used for measuring the intensity of an earthquake. It measures the effects of an earthquake, and is distinct from the moment magnitude usually reported for an earthquake (sometimes described as the obsolete Richter magnitude), which is a measure of the energy released. The intensity of an earthquake is not totally determined by its magnitude.

Scale quantifies the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale from I (not felt) to XII (total destruction). Values depend upon the distance to the earthquake, with the highest intensities being around the epicentre area. Data gathered from people who have experienced the quake are used to determine an intensity value for their location. The Mercalli (Intensity) scale originated with the widely-used simple ten-degree Rossi-Forel scale which was revised by Italian volcanologist, Giuseppe Mercalli in 1884 and 1906.

In 1902 the ten-degree Mercalli scale was expanded to twelve degrees by Italian physicist Adolfo Cancani. It was later completely re-written by the German geophysicist August Heinrich Sieberg and became known as the Mercalli-Cancani-Sieberg (MCS) scale. The Mercalli-Cancani-Sieberg scale was later modified by Harry O. Wood and Frank Neumann in 1931 as the Mercalli-Wood-Neumann (MWN) scale. It was later improved by Charles Richter, the father of the Richter magnitude scale. The scale is known today as the Modified Mercalli scale (MM) or Modified Mercalli Intensity scale (MMI).

Modified Mercalli Intensity Scale

The lower degrees of the Modified Mercalli Intensity scale generally deal with the manner in which the earthquake is felt by people. The higher numbers of the scale are based on observed structural damage

The small table is a rough guide to the degrees of the Modified Mercalli Intensity scale. The colors and descriptive names shown below differ from those used on certain shake maps in other articles

Magnitude Typical Maximum Modified Mercalli Intensity

1.0 - 3.0	I
3.0 - 3.9	II - III
4.0 - 4.9	IV - V
5.0 - 5.9	VI - VII
6.0 - 6.9	VII - IX
7.0 and higher	VIII or higher

Modified Mercalli scale intensities that are typically observed at locations near the epicentre of the earthquake. The correlation between magnitude and intensity is far from total, depending upon several factors, including the depth of the earthquake,

terrain, population density, and damage. For example, on May 19, 2011 an earthquake of magnitude 0.7 in Central California, United States 4 km deep was classified as of intensity III by the United States Geological Survey (USGS) over 100 miles (160 km) away from the epicentre (and II intensity almost 300 miles (480 km) from the epicentre), while a 4.5 magnitude quake in Salta, Argentina 164 km deep was of intensity I.

Earthquake Early Warning

Earthquake early warning (EEW) can provide a few seconds to tens of seconds warning prior to ground shaking during an earthquake. Several countries, such as Japan, Taiwan, Mexico have adopted this methodology based on the fact that such warning can

- (1) rapidly detect the initiation of an earthquake.
- (2) determine the size (magnitude) and location of the event
- (3) predict the peak ground motion expected in the region around the event.
- (4) Issued a warning to people in locations that may expect significant ground motion. Prediction of an earthquake is still a subject of speculations yet several schools of thoughts are available. In the effort to predict earthquakes, people have tried to associate an impending earthquake with such varied phenomena as seismicity patterns, electromagnetic fields, weather conditions and unusual clouds, radon or hydrogen gas content of soil or ground water, water level in wells, animal behaviour, and the phases of the moon.

Mitigation measures

When an earthquake strikes a building is thrown mostly from side to side, and also up and down along with the building foundation the building structure tends to stay at rest, similar to a passenger standing on a bus that accelerates quickly. Building damage is related to the characteristics of the building, and the duration and severity of the ground shaking. Larger earthquakes tend to shake longer and harder and therefore cause more damage to structures.

Structural

No buildings can be made 100% safe against earthquake forces. Instead buildings and infrastructures can be made earthquake resistant to a certain extent depending upon serviceability requirements. Earthquake resistant design of buildings depends upon providing the building with strength, stiffness and inelastic deformation capacity, which are great enough to withstand a given level of earthquake-generated force. This is generally accomplished through the selection of an appropriate structural configuration and the careful detailing of structural members, such as beams and columns, and the connections between them. There are several different experimental techniques that can be used to test the response of structures to verify their seismic performance, one of which is the use of an earthquake shaking table (a shaking table, or simply shake table). This is a device for shaking structural models or building components with a wide range of

simulated ground motions, including reproductions of recorded earthquakes time-histories.

Non-structural

The non-engineered traditional construction commonly practiced in different areas of the country depends greatly on the respective local context of the area. In other words, the technologies vary significantly from area to area. These technologies have evolved and as a result have got optimized. In India an overwhelming majority of houses, are of non-engineered load bearing type. These structures, especially houses, have been traditionally built over the past century or longer, using the locally available materials and the locally practiced technologies that have been most common in the area, including stone, bricks, earth, lime and timber for walls, and clay tiles, stone or mud for roofing supported on under-structure made of local timber such as Teak, Acacia, Neem, Deodar, Pine and also Bamboo. In the recently built structures one also finds a mix of the traditional and new materials/technology such as cement, concrete and steel. The structures have a pitched roof or flat roof, and are single story or double story. After earthquake, significant effort was taken to repair and strengthening of damaged buildings. A guideline for Repair and strengthening guide for earthquake damaged low rise domestic buildings in Gujarat is made.

VOLCANIC ERUPTION

A volcano is a vent or chimney which transfers molten rock known as magma from depth to the Earth's surface. Magma erupting from a volcano is called lava and is the material which builds up the cone surrounding the vent.

About Volcano

A volcano is a vent or chimney which transfers molten rock known as magma from depth to the Earth's surface. Magma erupting from a volcano is called lava and is the material which builds up the cone surrounding the vent.

A volcano is active if it is erupting lava, releasing gas or generates seismic activity. A volcano is dormant if it has not erupted for a long time but could erupt again in the future. Once a volcano has been dormant for more than 10 000 years, it is termed extinct.

The explosiveness of a volcanic eruption depends on how easily magma can flow and the amount of gas trapped within the magma. Large amounts of water and carbon dioxide are dissolved in magma causing it to behave in a similar way to gas expanding in fizzy drinks, which forms bubbles and escapes after opening.

As magma rises quickly through the Earth's crust, gas bubbles form and expand up to 1000 times their original size.

Volcanoes can be different in appearance with some featuring perfect cone shapes while others are deep depressions filled with water. The form of a volcano provides a clue to the type and size of its eruption which is controlled by the characteristics and composition of magma. The size, style and frequency of

eruptions can differ greatly but all these elements correlated to the shape of a volcano.

EFFECTS OF VOLCANOES

A volcano eruption is one of the most impressive events in the planet and the effects of volcanoes and their eruptions could be felt as far away as a different continent. The type of effects of volcanoes depends on the size of the eruption. Some volcanoes could be erupting and not cause much damage even to people nearby while others are so massive that should they erupt they could trigger a world sized catastrophe. So what type of disturbances would you see if there was a massive eruption today? To answer that question, we need to be clear about the type of volcano that we are talking about. Volcano eruptions are measured in what is called VEI or Volcano Eruption Index which goes to a most powerful eruption of a VEI8.

An Explosive Eruption

If there were an explosive eruption in your area the effects of volcanoes could be devastating. During an explosive eruption the volcano will spew lava, magma and volcanic material which could travel several miles away from the mountain. The explosiveness of the eruption could also cause pyroclastic flows which would destroy anything within their path. The ash could also cause severe damage to structures depending on the amount of it and those who breathe it in would be at risk of choking on it.

Effects on the Environment

There are several ways in which effects of volcanoes can be felt on the environment. Even smaller eruptions can have a measureable effect. That is because while an eruption is taking place gases are released by the volcano. Some of the gases which are released into the air include carbon monoxide, carbon dioxide, sulphur dioxide, fluorine, chlorine, hydrogen sulphide and others. The effects of volcanoes on the environment depend on climate patterns, the overall scale of the eruption and how much the gases spread. Another problem the environment is the ash that is released when a volcano erupts. Depending on the size of the eruption you could be looking at a volcanic winter.

Effects of Super volcanoes

Out of all the effects of volcanoes on the daily life of people, the one that is the scariest is what is known as the super volcano. These volcanoes are the ones that will reach the VEI8 and VEI7 rankings in the scale. These are also volcanoes which are very massive and could destroy most of the life on earth if they were to erupt today.

In the case of the super volcano in Yellowstone Park several states and their citizens would stand no chance against the lava flow and the ash. However, those are not the only people that would be affected. During the explosion a lot of ash would be released into the atmosphere, dropping temperatures by an average of

well over 20 degrees Fahrenheit worldwide. That would cause crops and vegetation to die which would mean no food for animals or people.

LANDSLIDING

About Landslide

Landslides are among the many natural disasters causing massive destructions and loss of lives across the globe. According to a survey study by the International Landslide Centre at Durham University, UK, 2,620 fatal landslides occurred between 2004 to 2010. These landslides resulted in the death of over 32,322 people. The figure does not include landslides caused by earthquakes. This research result is astonishing considering the number of people killed by landslides. It is, thus, paramount to know the causes and warning signs of a potential landslide to minimize losses.

A landslide, sometimes known as landslip, slope failure or slump, is an uncontrollable downhill flow of rock, earth, debris or the combination of the three. Landslides stem from the failure of materials making up the hill slopes and are beefed up by the force of gravity. When the ground becomes saturated, it can become unstable, losing its equilibrium in the long run. That's when a landslide breaks loose. When people are living down these hills or mountains, it's usually just a matter of time before disaster happens.

Causes of Landslides

While landslides are considered naturally occurring disasters, human-induced changes in the environment have recently caused their upsurge. Although the causes of landslides are wide ranging, they have two aspects in common; they are driven by forces of gravity and result from failure of soil and rock materials that constitute the hill slope:

Natural Causes of Landslides

1. **Climate:** Long-term climatic changes can significantly impact soil stability. A general reduction in precipitation leads to lowering of water table and reduction in overall weight of soil mass, reduced solution of materials and less powerful freeze-thaw activity. A significant upsurge in precipitation or ground saturation would dramatically increase the level of ground water. When sloped areas are completely saturated with water, landslides can occur. If there is absence of mechanical root support, the soils start to run off
2. **Earthquakes:** Seismic activities have, for a long time, contributed to landslides across the globe. Any moment tectonic plates move, the soil covering them also moves along. When earthquakes strike areas with steep slopes, on numerous occasion, the soil slips leading to landslides. In addition, ash debris flows instigated by earthquakes could also cause mass soil movement.
3. **Weathering:** Weathering is the natural procedure of rock deterioration that leads to weak, landslide-susceptive materials. Weathering is brought about by

the chemical action of water, air, plants and bacteria. When the rocks are weak enough, they slip away causing landslides.

4. **Erosion:** Erosion caused by sporadic running water such as streams, rivers, wind, currents, ice and waves wipes out latent and lateral slope support enabling landslides to occur easily.
5. **Volcanoes:** Volcanic eruptions can trigger landslides. If an eruption occurs in a wet condition, the soil will start to move downhill instigating a landslide. Stratovolcano is a typical example of volcano responsible for most landslides across the globe.
6. **Forest fires:** Forest fires instigate soil erosion and bring about floods, which might lead to landslides
7. **Gravity:** Steeper slopes coupled with gravitational force can trigger a massive landslide.

Human causes of landslides

1. **Mining:** Mining activities that utilize blasting techniques contribute mightily to landslides. Vibrations emanating from the blasts can weaken soils in other areas susceptible to landslides. The weakening of soil means a landslide can occur anytime.
2. **Clear cutting:** Clear cutting is a technique of timber harvesting that eliminates all old trees from the area. This technique is dangerous since it decimates the existing mechanical root structure of the area.

Effects of Landslides

1. **Lead to economic decline:** Landslides have been verified to result in destruction of property. If the landslide is significant, it could drain the economy of the region or country. After a landslide, the area affected normally undergoes rehabilitation. This rehabilitation involves massive capital outlay. For example, the 1983 landslide at Utah in the United States resulted in rehabilitation cost of about \$500 million. The annual loss as a result of landslides in U.S. stands at an estimated \$1.5 billion.
2. **Decimation of infrastructure:** The force flow of mud, debris, and rocks as a result of a landslide can cause serious damage to property. Infrastructure such as roads, railways, leisure destinations, buildings and communication systems can be decimated by a single landslide.
3. **Loss of life:** Communities living at the foot of hills and mountains are at a greater risk of death by landslides. A substantial landslide carries along huge rocks, heavy debris and heavy soil with it. This kind of landslide has the capacity to kills lots of people on impact. For instance, Landslides in the UK that happened a few years ago caused rotation of debris that destroyed a school and killed over 144 people including 116 school children aged between 7 and 10

years. In a separate event, NBC News reported a death toll of 21 people in the March 22, 2014, landslide in Oso, Washington.

4. **Affects beauty of landscapes:** The erosion left behind by landslides leaves behind rugged landscapes that are unsightly. The pile of soil, rock and debris downhill can cover land utilized by the community for agricultural or social purposes.
5. **Impacts river ecosystems:** The soil, debris, and rock sliding downhill can find way into rivers and block their natural flow. Many river habitats like fish can die due to interference of natural flow of water. Communities depending on the river water for household activities and irrigation will suffer if flow of water is blocked.

Types of Landslides

- **Falls:** Falls are sudden movements of loads of soil, debris, and rock that break away from slopes and cliffs. Falls landslides occur as a result of mechanical weathering, earthquakes, and force of gravity.
- **Slides:** This is a kind of mass movement whereby the sliding material breakaways from underlying stable material. The kinds of slides experienced during this type of landslide include rotational and transitional. Rotational slides are sometimes known as slumps since they move with rotation. Transitional slides consist of a planer or 2 dimensional surface of rupture. They involve landslide mass movement following a roughly planar surface with reduced rotation or backward slanting. Slides occur when the toe of the slope is undercut. They move moderately, and the consistency of material is maintained.
- **Topples:** Topple landslides occur when the topple fails. Topple failure encompasses the forward spinning and movement of huge masses of rock, debris, and earth from a slope. This type of slope failure takes place around an axis near or at the bottom of the block of rock. A topple landslide mostly lead to formation of a debris cone below the slope. This pile of debris is known as a Talus cone.
- **Spreads:** They are commonly known as lateral spreads and takes place on gentle terrains via lateral extension followed by tensile fractures.
- **Flows:** This type of landslide is categorized into five; earth flows, debris avalanche, debris flow, mudflows, and creep, which include seasonal, continuous and progressive. Flows are further subcategorized depending upon the geological material, for example, earth, debris, and bedrock. The most prevalent occurring landslides are rock falls and debris flow. The study of landslides is critical considering the annual economic losses they bring. Globally, landslides result in expenditure of billions of dollars towards rehabilitation of affected areas. Due to these astonishing annual losses, most governments have instituted bodies to deal specifically with landslides. For example, the U.S. government created the National Landslide Information Centre to collect and distribute all kinds of data related to landslides. The body

is intended to cater to landslide researchers, geotechnical practitioners involved in landslide mobilization and other individuals and organizations focused on landslide hazard analysis and mitigation. The aim is to reduce the financial burden and deaths from landslides.

CYCLONES - (A CLIMATIC DISASTERS)

About Cyclones

Location, location, location! This is especially important when we're talking about ocean storms because the location of the storm determines what we call it. For example, if the storm occurs in the Atlantic Ocean and Northeast Pacific, it's called a hurricane. If the exact same type of storm occurs in the Northwest Pacific, this is a typhoon. And if we find those same storms in the South Pacific and Indian Ocean, these are called tropical cyclones.

Cyclone refers to any spinning storm that rotates around a low-pressure center. The low-pressure center is also referred to as the 'eye' of the storm, which is well known for being eerily calm compared with the areas under the spinning 'arms' of the storm. You could say that the eye is watching what's going on down below, so it needs a clear path, but the arms are where all the action happens because this is where the storm is throwing out all of its rain and wind.

Types of Cyclones

The term 'cyclone' actually refers to several different types of storms. They occur in different places, and some occur over land while others occur over water or sea. What they all have in common is that they are spinning storms rotating around that low-pressure center.

1. Tropical cyclones are what most people are familiar with because these are cyclones that occur over tropical ocean regions. Hurricanes and typhoons are actually types of tropical cyclones, but they have different names so that it's clear where that storm is occurring. Hurricanes are found in the Atlantic and Northeast Pacific; typhoons are found in the Northwest Pacific. If you hear 'tropical cyclone,' you should assume that it's occurring in the South Pacific or Indian Ocean, but for this lesson, we'll use it to refer to all types of tropical ocean cyclones.

We can also further describe tropical cyclones based on their wind speeds. They are called category 1, 2, 3, 4 or 5, increasing with intensity and wind speed as the number increases. A category 1 cyclone is the weakest, with wind speeds of 74-95 mph. A category 5 cyclone, on the other hand, is extremely dangerous and has the potential for major damage. Category 5 cyclones have wind speeds of 155 mph and above!

2. Polar cyclones are cyclones that occur in Polar Regions like Greenland, Siberia and Antarctica. Unlike tropical cyclones, polar cyclones are usually stronger in winter months. As you can see, these storms really do prefer the colder weather! They also occur in areas that aren't very populated, so any damage they do is usually pretty minimal.

3. A mesocyclone is when part of a thunderstorm cloud starts to spin, which may eventually lead to a tornado. 'Meso' means 'middle', so you can think of this as the mid-point between one type of storm and the other. Tornadoes all come from thunderstorm clouds, but not all thunderstorm clouds make tornadoes. In order for a tornado to occur, part of that cloud has to spin, and though you can't really see this happening, this is the intermediate, or 'meso' step from regular cloud to dangerous spinning cloud running along the ground.

Formation of a Cyclone

Even though they form over different areas, cyclones tend to come about in the same way and revolve around that low-pressure eye. Warm air likes to rise, and as it rises, it cools. Cool air can't hold as much moisture as warm air, so that water gets squeezed out of the condensing air and a cloud begins to form. If the warm air rises very quickly, this creates an updraft.

Likewise, if the water in the cloud builds up enough, it may fall back to the ground as rain and draw cool air down with it as a downdraft. When they work together, that warm updraft and cool downdraft create a storm cell. As this process continues, the cloud grows and we eventually get a large thunderstorm cloud.

This thunderstorm cloud is now ready to diversify into other storms like tropical cyclones and tornadoes. But this can't happen unless the air in the cloud starts spinning horizontally. If this occurs over the tropical ocean, this is called a tropical depression. This is like a baby tropical cyclone, with wind speeds less than 39 mph.

If it starts spinning even faster and has wind speeds between 40-73 mph, we have a tropical storm. If the storm grows even larger over the tropical ocean and has wind speeds above 74 mph, we have our full-grown hurricane, typhoon or cyclone, depending on where that storm is found.

Harmful Effects of Cyclones and Hurricanes

- i. Tropical cyclones cause heavy rainfall and landslides.
- ii. They cause a lot of harm to towns and villages, causing severe damage to kuccha houses. Coastal businesses like shipyards and oil wells are destroyed.
- iii. They harm the ecosystem of the surrounding region.
- iv. Civic facilities are disturbed.
- v. Agricultural land is severely affected, especially in terms of water supply and soil erosion.
- vi. It causes harm to human, plant and animal life.
- vii. Communication systems are badly affected due to cyclones.

Management and Mitigation of Cyclones and Hurricanes.

- i. Coastal areas should be well prepared to meet eventualities that arise from cyclones.
- ii. Houses should be constructed such that they can withstand the heavy rainfall and forceful winds.
- iii. Shelter beds should be created to check soil erosion and speed of winds.

- iv. Remote sensing techniques should be used to forecast cyclones appropriately.
- v. When a cyclone does occur, rescue and relief operations should be in place.

El Niño–Southern Oscillation (ENSO)

What is the El-Niño Southern Oscillation?

El Niño–**Southern Oscillation** (ENSO) is an irregularly periodical variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting much of the tropics and subtropics. The warming phase is known as El Niño and the cooling phase as La Niña.

The El Niño-Southern Oscillation (ENSO) is a naturally occurring phenomenon that involves fluctuating ocean temperatures in the equatorial Pacific. The warmer waters essentially slosh, or oscillate, back and forth across the Pacific, much like water in a bath tub. For North America and much of the globe, the phenomenon is known as a dominant force causing variations in regional climate patterns. The pattern generally fluctuates between two states: warmer than normal central and eastern equatorial Pacific SSTs (El Niño) and cooler than normal central and eastern equatorial Pacific SSTs (La Niña).

Often, sea surface temperatures (SSTs) are used to identify this oscillation, but it is important to understand that changes in sub-surface ocean temperatures are the first to respond to an oncoming change in the ENSO phase. For instance, when ENSO is transitioning into a warm phase the sub-surface temperatures begin to warm above average, while a shallow layer of near average temperature remains at the surface. Eventually, the surface ocean temperatures will respond to the warming of the sub-surface temperatures, and a warm phase of the ENSO cycle ensues. The same cycle occurs, only opposite, for the cool phase of ENSO. When temperatures in the ENSO region of the Pacific are near average it is known as ENSO neutral, meaning that the oscillation is neither in a warm nor cool phase. Typically, atmospheric patterns during ENSO neutral are controlled more by other climate patterns (NAO, PNA) that vary on shorter timescales.

El Niño (Warm Phase)

The warm phase of the ENSO cycle features warmer than normal SSTs across the central and eastern equatorial Pacific along with:

- Weaker low-level atmospheric winds along the equator
- Enhanced convection across the entire equatorial Pacific
- Effects are strongest during northern hemisphere winter due to the fact that ocean temperatures worldwide are at their warmest. This increased ocean warmth enhances convection, which then alters the jet stream such that it becomes more active over parts of the U.S. during El Niño winters. This results in enhanced precipitation across the southern U.S
- In the southeast, winter temperatures are often cooler than normal
- During hurricane season (June to November), the jet stream is aligned in such a way that the vertical wind shear is increased over the Caribbean and Atlantic.

The increased wind shear helps to prevent tropical disturbances from developing into hurricanes

La Niña (Cool Phase)

This phase of the ENSO cycle features cooler than normal SSTs across the central and eastern equatorial Pacific along with:

- Stronger low-level atmospheric winds along the equator
- Decreased convection across the entire equatorial Pacific results in a more suppressed southern jet stream. Consequently, the southern U.S., including NC, sees less precipitation
- In the U.S., winter temperatures are often warmer than normal in the southeast, and cooler than normal in the Northwest
- During hurricane season (June to November), upper level winds are much lighter, and therefore more favourable for hurricane development in the Caribbean and Atlantic

Why are "El-Niño" and "La-Niña" so named?

"El-Niño" is named after a Peruvian Christmas festival where the warming of the waters off Peru is said to occur near the birthday of "The Boy" (El Niño), or the Christ child. Meteorologists thus named the phenomenon the "El-Niño Southern Oscillation", or ENSO for short. The reverse phenomenon, the cooling of the eastern Pacific waters, was at first called "Anti-El-Niño", until it was realized that this literally meant the Anti-Christ! To avoid this unfortunate connotation, it was renamed "La-Niña" (or "The Girl").

Southern Oscillation Index

The Southern Oscillation Index, or SOI, gives an indication of the development and intensity of El Niño or La Niña events in the Pacific Ocean. The SOI is calculated using the pressure differences between Tahiti and Darwin.

Sustained negative values of the SOI below 7 often indicate El Niño episodes. These negative values are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean, a decrease in the strength of the Pacific Trade Winds, and a reduction in winter and spring rainfall over much of eastern Australia and the Top End. You can read more about historical El Niño events and their effect on Australia in the [detailed analysis of past El Niño events](#).

Sustained positive values of the SOI above +7 are typical of a La Niña episode. They are associated with stronger Pacific trade winds and warmer sea temperatures to the north of Australia. Waters in the central and eastern tropical Pacific Ocean become cooler during this time. Together these give an increased probability that eastern and northern Australia will be wetter than normal. You can read more about historical La Niña events and their effect on Australia in the [detailed analysis of past La Niña events](#).

THUNDERSTORMS

Florida has more thunderstorms per year than any other state in the U.S. or that if you are male you are 4.6 times more likely to get struck by lightning than if you are female? Or that sound travels one mile in five seconds, so if you hear a lightning strike you can figure out how far away it was by counting the seconds until you hear the thunder clap

Thunderstorms are amazing and interesting events! Thunderstorms can occur almost anywhere and are the beginnings of some other dangerous storms like hurricanes and tornadoes. But just what is a thunderstorm, and how does it form? A thunderstorm is a storm with lightning and thunder. They are caused by an updraft, which occurs when warm, moist air rises vertically into the atmosphere. The updraft creates a cumulus cloud, which will eventually be the thunderstorm cloud.

Updrafts can occur anywhere warm, wet air raises quickly, which is why most people, no matter where they live, have experienced a thunderstorm at some point in their life. However, some places, like Florida, are more prone to thunderstorms because the conditions that create thunderstorms are more common.

The Formation of a Thunderstorm

A warm updraft is just the beginning of a thunderstorm, though. Once the air rises into the atmosphere, it begins to cool. Cool air can't hold as much water as warm air, so as the air cools, the water in the air gets kicked out as condensation and may eventually fall back to the ground as rain. In order for this to happen, though, the cumulus cloud has to grow very tall.

Think about it this way: If you're playing a game of Red Rover and try to break through the human wall on the other side by yourself, you may not be very successful because there's only one of you. But if you get all of your friends to crash into that line of people with you, you'll have greater success because you are a large group with a greater force.

The same is true for water in the thunderstorm cloud. By itself, that single water droplet is not heavy enough to fall back to the ground as rain. But if the cloud is tall enough, that one little droplet will pick up other droplets with it and eventually grow into a large enough water droplet to break through and fall back to Earth.

Just like the updraft was warm air rising upward into the atmosphere, a downdraft is cool air sinking back to the ground. Downdrafts are created by the falling water droplets because they don't just drag other water down with them as they fall; they drag cooler air down with them as well. The combined warm updraft and cool downdraft create a storm cell. As the process of warm air rising and cool air sinking continues, the cloud grows vertically into the shape of an anvil, which is called an anvil head cloud. This is now a full-fledged thunderstorm cloud, ready to storm away!

Thunder and Lightning

As you are probably aware, thunderstorm clouds can produce a lot of thunder and lightning. What you may not know is that these are both produced from the same event. Lightning is what you see, thunder is what you hear. They appear not to occur at the same time because light travels faster than sound, so the image of the lightning reaches your eyes before the sound it creates reaches your ears.

Here's how it works: As the water droplets in the cloud fall downward, they bump into each other, which gives the cloud an electrical charge. The charge, however, is not uniform within the cloud; there is a negative charge in the warm areas and a positive charge in the cool areas. Eventually electricity builds up and electrical energy is released, flowing to the points of opposite charge because opposites attract! Much of this occurs within the cloud, but sometimes it leaves the cloud and heads toward the ground because the ground holds an opposite charge to the lower part of the cloud. When this happens, we get lightning.

If you've ever touched a light bulb that has been on for a while, you know that light produces a lot of energy as heat. When the electrical energy leaves the cloud as lightning, it also releases energy as heat, which warms the air around it. When things heat up, they expand, and as the air expands, it releases a giant sonic boom - the thunder you hear. So you can see that while you may have lightning without thunder, you certainly won't get thunder without a lightning strike.

Types of thunderstorm

Multicell Cluster Storms

A group of cells moving as a single unit, with each cell in a different stage of the thunderstorm life cycle. Multicell storms can produce moderate size hail, flash floods and weak tornadoes.

Multicell Line Storms

Multicell line storms consist of a line of storms with a continuous, well developed gust front at the leading edge of the line. Also known as squall lines, these storms can produce small to moderate size hail, occasional flash floods and weak tornadoes.

Supercells

It is defined as a thunderstorm with a rotating updraft, these storms can produce strong downbursts, large hail, occasional flash floods and weak to violent tornadoes

Causes of thunderstorms

Thunderstorms form when an air mass becomes so unstable that it overturns (convects) violently. "Unstable" means that the air in the lowest layers is unusually warm and humid, or that the upper layers are unusually cool, or oftentimes, both.

Pockets of rising near-surface air in an unstable air mass expand and cool, and as some of the vapor present condenses into a cloud it releases heat, which then makes

the air parcel even warmer, forcing it to rise still higher in the atmosphere.

If the lower level air is sufficiently warm and humid, and the higher altitude air is sufficiently cool, this process continues until a tall convective cloud -- the thunderstorm -- is formed. The result can be a storm extending as high as 40,000 to 60,000 feet (8 to 12 miles). The upper portions of the storm which even in the warm tropics -- are made of ice: ice crystals, graupel, snow, and sometimes hail. About 50% of the rain reaching the surface in a thunderstorm originated as ice in the upper reaches of the storm.

The updrafts in thunderstorms can be very strong -- 50 knots or more -- which can help support the weight of hailstones as they grow. Such updrafts cause extreme turbulence for aircraft, which will only fly through the strongest portions of thunderstorms if the pilots have no other choice. Despite the large stresses this puts on planes (and their passengers), modern jet aircraft are designed to withstand those stresses.

The following enhanced photograph shows the classic supercell thunderstorm, a particularly large, intense, and destructive storm that can produce large hail and tornadoes:

Thunderstorms are most common in the afternoon over land, when daytime heating of the land by the sun causes the lower part of the troposphere to become unstable from higher temperatures and more water vapor in the air.

or, some thunderstorms can form as result of the upper atmosphere becoming unusually cool, due to the approach of an upper air disturbance. In this case storms can form at any time of day, even when there hasn't been daytime heating of the lower atmosphere over land.

There must be sufficient water vapour in order for the storm to form, since cloud and precipitation originates as water vapour. This is the fuel for the thunderstorm. As the storm uses this fuel, it is converted to rainfall. Eventually, the storm stabilizes the atmosphere by using up the excess water vapour and cooling the lower atmosphere, and warming the upper atmosphere.

Technically, lightning must be produced in order for the resulting cloud system to be called a thunderstorm.

Effects of Thunderstorms

- Thunderstorm updrafts and downdrafts result in heavy precipitation. Wind gusts pick up hurricane force, accompanied by thunder and lightning.
- Thunderstorms disrupt human life in more than one way. The felling of millions of trees, deaths due to lightning hazard and wind shear are just some of the dissipation manifestations.
- Thunderstorms commonly result in local atmospheric instability, catastrophic flooding, very strong winds, tornadoes and multi-cell storms.
- These storms have a pronounced effect on the weather over a large area, with energy released at the rate of more than 10,000,000 kilowatt-hours on an

average!

- Thunderstorms occur in varied force, throughout the world. While they are a common occurrence in the tropical rainforest regions, the Polar Regions are not spared either.
- Thunderstorms are commonly associated with the onset of the monsoons. The electrical discharge referred to as lightning is responsible for striking terrestrial structures at the speed of sound. This poses a great threat to human life and property.

Thunderstorms and lightning have always held a myth and mystique about them and have fascinated and terrified human since the dawn of civilization. All thunderstorms produce lightening which often strikes away from the area where it is raining and is known to fall as far as 10 miles away from the rainfall area. Roughly, there are about 1800 thunderstorms occurring at any moment across the world. Though today we have a greater understanding about them after intense study through various methods like weather radars, weather stations and video photography

FLOOD IN INDIA

It is a natural event or occurrence where a piece of land (or area) that is usually dry land, suddenly gets submerged under water. Some floods can occur suddenly and recede quickly. Others take days or even months to build and discharge.

When floods happen in an area that people live, the water carries along objects like houses, bridges, cars, furniture and even people. It can wipe away farms, trees and many heavier items.

Floods occur at irregular intervals and vary in size, duration and the affected area.

It is important to note that water naturally flows from high areas to low lying areas. This means low-lying areas may flood quickly before it begins to get to higher ground.

In this lesson, we shall see more about what causes flooding, the types of flooding, some effects of floods and what we can do before, during and after floods occur.

Causes of flooding.

- **Rains:** Each time there are more rains than the drainage system can take, there can be floods. Sometimes, there is heavy rain for a very short period that result in floods. In other times, there may be light rain for many days and weeks.
- **River overflow:** Rivers can overflow their banks to cause flooding. This happens when there is more water upstream than usual and as it flows downstream to the adjacent low-lying areas (also called a floodplain), there is a burst and water gets into the land.
- **Strong winds in coastal areas:** Sea water can be carried by massive winds and hurricanes onto dry coastal lands and cause flooding. Sometimes this is made worse if the winds carry rains themselves. Sometimes water from the sea resulting from a tsunami can flow inland to cause damage.

- **Dam breaking:** (raptured dam or levee) (Embankments, known as levees, are built along the side of a river and are used to prevent high water from flooding bordering land)
Dams are man-made blocks mounted to hold water flowing down from a highland. The power in the water is used to turn propellers to generate electricity. Sometimes, too much water held up in the dam can cause it to break and overflow the area. Excess water can also be intentionally released from the dam to prevent it from breaking and that can also cause floods. February 26, 1972 - Buffalo Creek Valley, West Virginia the failure of a coal-waste impoundment at the valley's head took 125 lives, and caused more than \$400 million in damages, including destruction of over 500 homes.
- **Ice and snow-melts:** In many cold regions, heavy snow over the winter usually stays un-melted for some time. There are also mountains that have ice on top of them. Sometimes the ice suddenly melts when the temperature rises, resulting in massive movement of water into places that are usually dry. This is usually called a snowmelt flood.

Types of floods

Some would like to see the causes of floods as types of floods, but here we shall look at three major flood types: Flash floods, Rapid on-set floods and slow on-set floods.

- **Flash floods:** This kind occurs within a very short time (2-6 hours, and sometimes within minutes) and is usually as a result of heavy rain, dam break or snow melt. Sometimes, intense rainfall from slow moving thunderstorms can cause it. Flash floods are the most destructive and can be fatal, as people are usually taken by surprise. There is usually no warning, no preparation and the impact can be very swift and devastating.
- **Rapid on-set floods:** Similar to flash floods, this type takes slightly longer to develop and the flood can last for a day or two only. It is also very destructive, but does not usually surprise people like Flash floods. With rapid on-set floods, people can quickly put a few things right and escape before it gets very bad.
- **Slow on-set floods:** This kind is usually as a result of water bodies over flooding their banks. They tend to develop slowly and can last for days and weeks. They usually spread over many kilometres and occur more in flood plains (fields prone to floods in low-lying areas). The effect of this kind of floods on people is more likely to be due to disease, malnutrition or snakebite.

EFFECTS OF FLOODING

Floods can have devastating consequences and can have effects on the economy, environment and people.

- **Economic:** During floods (especially flash floods), roads, bridges, farms, houses and automobiles are destroyed. People become homeless. Additionally, the government deploys firemen, police and other emergency apparatuses to help the affected. All these come at a heavy cost to people and the government. It

usually takes years for affected communities to be re-built and business to come back to normalcy.

- **Environment:** The environment also suffers when floods happen. Chemicals and other hazardous substances end up in the water and eventually contaminate the water bodies that floods end up in. In 2011, a huge tsunami hit Japan, and sea water flooded a part of the coastline. The flooding caused massive leakage in nuclear plants and has since caused high radiation in that area. Authorities in Japan fear that Fukushima radiation levels are 18 times higher than even thought. Additionally, flooding causes kills animals, and others insects are introduced to affected areas, distorting the natural balance of the ecosystem.
- **People and animals:** Many people and animals have died in flash floods. Many more are injured and others made homeless. Water supply and electricity are disrupted and people struggle and suffer as a result. In addition to this, flooding brings a lot of diseases and infections including military fever, pneumonic plague, dermatopathia and dysentery. Sometimes insects and snakes make their ways to the area and cause a lot of havoc. There is also something good about floods, especially those that occur in floodplains and farm fields. Floodwaters carry lots of nutrients that are deposited in the plains. Farmers love such soils, as they are perfect for cultivating some kinds of crops.

DROUGHT A NATURAL DISASTER

Drought is a prolonged dry period in natural climate cycle. It is a slow-onset phenomenon caused by rainfall deficit combined with other predisposing factors.

Drought often results in mass displacements of population.

Drought leads to water and food shortages and is likely to have a long-term environmental, economic and health impact on the population.

Droughts are often predictable: periods of unusual dryness are normal in all weather systems. Advance warning is possible.

Factors affecting drought

Factors influencing the impact of drought are:

- Demographic pressure on the environment;
- Food insecurity;
- Economic systems strictly dependent on agriculture;
- Poor infrastructure e.g. irrigation and water supply and sanitation systems;
- Poor health status of the population before the disaster;
- Time of the year, with the most critical period being before the harvest;
- Absence of warning systems;
- Population displacement;
- Other concurrent situations: economic crisis, political instability, armed conflict.

CLOUDBURST

About cloudburst

- A cloudburst is sudden copious rainfall. It is a sudden aggressive rainstorm falling for a short period of time limited to a small geographical area.
- Meteorologists say the rain from a cloudburst is usually of the shower type with a fall rate equal to or greater than 100 mm (4.94 inches) per hour.
- Generally, cloudbursts are associated with thunderstorms. The air currents rushing upwards in a rainstorm hold up a large amount of water.
- If these currents suddenly cease, the entire amount of water descends on to a small area with catastrophic force all of a sudden and causes mass destruction. This is due to a rapid condensation of the clouds.
- They occur most often in desert and mountainous regions, and in interior regions of continental landmasses.

Definition

A cloudburst is a sudden aggressive downpour within the radius of a couple of kilometres. Though, cloudbursts usually do not last for more than few minutes, they are capable of flooding the entire area. Rainfall from a cloudburst is usually equal to or greater than 100 mm per hour. Cloudbursts are generally associated with thunderstorms. However, the above definition has been given by a particular school of thought. In reality, there is no specific amount of rain associated with a cloudburst, either in time or duration.

How does it happen?

Cloud burst is actually a situation when the inter-molecular forces between the H₂O molecules get very high due to the rapid decrease in the temperature or excess of electrostatic induction in the clouds causing the lighting to remain inside the cloud only, which causes hyperactive energy inside the cloud. The water molecules get denser and denser and get condensed but do not leave the cloud due to excess of electro- forces. As the water concentration get higher and higher and so the weigh gets heavier the water no longer is able to maintain force with the clouds and so they fall and it precipitates. A cloudburst can suddenly dump 72,300 tons of water over one square acre. This is quite a wallop and luckily it does not happen very often. A real cloudburst is very rare. Sometimes we call a sharp shower in the mountains a cloudburst when it really is not. The runoff from the slopes creates such a deluge that it seems that a cloud has burst open like a paper bag.

Of course, even in a real cloudburst, the cloud does not break open. It happens because the rain forming in the cloud has been unable to fall down in a steady shower. Sometimes this happens when the cloud is ready to rain and the ground below is scorching hot. Or maybe a very warm current of air is blowing under the rain cloud. Either of these events causes a strong updraft of warm air. Raindrops find it very hard to fall through a current of rising air. When they start down, up they are whisked again. If this goes on for any length of time, the cloud gets an overload of rain. The drops that should have fallen are returned back up and new drops are being formed all the time. Finally, something happens to change the

situation. The weight of rain is able to break through or maybe the updraft suddenly stops for some reason. Then all the raindrops, new ones and old ones come tumbling down at once. Truly it seems as if the rain clouds burst.

Effect of cloudbursts on hills and plains

The catastrophic nature of cloudbursts differs on the virtue of terrain. In the hills, large volume of water keeps getting momentum as it flows in gushes. On its way, it demolishes everything and gravity of the situation increases due to landslides, mudslides, etc. On the other hand, cloudbursts in the plains only leads to waterlogging and inundation.

Causes a cloudburst.

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Some of the harm from improperly disposed material includes:

- **Affecting Human Populations:** Humans are significantly impacted by exposure to levels of radiation. Oftentimes, this exposure will affect many future generations, as it leads to a number of birth and developmental disabilities. Down syndrome, thyroid cancer, and a number of other issues have been found in people affected by radiation.
- **Affecting Wildlife:** One only need look to the Chernobyl disaster to see what the effects of radiation can be on wildlife in the area. Unfortunately, despite the fact that the event was 30 years ago, most of the animals are deemed to be affected by radioactivity. This manifests in reduced brain sizes, physical deformities, and other concerns that impact the survival of these creatures.
- **Affecting Local Flora:** Plant life is also susceptible to damage from nuclear radioactive waste. After Chernobyl, an entire pine forest needed to be destroyed because it was affected by radiation. Not to mention, radioactive soils and plants dissuade bees and other important creatures from fertilizing and

helping flora grow, which again, serves to impact future generations.

- **Affecting Nuclear Workers:** It goes without saying that those who work around nuclear materials are highly susceptible to negative effects. While rare, nuclear reactor accidents have led to many deaths in the past, both from those exposed and even some of whom were irradiated during the research or testing phases. Improperly stored waste at a nuclear site can also lead to levels of exposure that are beyond what is acceptable for humans.

Various Nuclear Waste Disposal Methods

One of the most recent goals with nuclear waste is to try and reduce the overall amount produced. Mostly, these recommendations take the form of being careful where and how radioactive materials are handled, and using the least amount of nuclear materials possible to do the job needed.

However, when it comes to properly disposing nuclear waste, from low-level to high level, there are certain standard types of making sure it is handled and irradiated properly.

- **Incineration:** Burning radioactive waste is largely done through commercially-operated incinerators developed for this purpose, although certain large companies have the means to do this on their own. Incineration is common with low-level waste, as this material usually consists of clothing or other common items that have simply been contaminated.
- **Storage:** Over time, the radioactivity of nuclear material does decay, so storing this material until it is no longer radioactive is another way to deal with proper nuclear waste disposal. This process, called radioactive decay, depends on the amount of materials and the radioactivity level. Therefore, storage is typically only done with radioactive waste that has a shorter half-life, or the amount of time it takes for the material's radioactivity to be reduced by half. There are commercial storage facilities for this waste, while some approved companies have their own means of storage.
- **Shallow Burial:** Highly radioactive material is hard to bury, but when it comes to mill tailings, these remnants can often be buried in a specially-crafted spot nearby the mill itself. Often, this includes creating a pile of tailings, covering it with a non-permeable material like clay. The pile is often typically buttressed by a mix of rocks and soil so that it doesn't erode.
- **Deep Burial:** While shallow burials can be done with low-level waste, the most common way of disposing of high-level waste is in deep burial pits. Many countries with natural resources follow this procedure of geological disposal, which consists of burying the material deep within the earth. Oftentimes, underground laboratories are built to monitor usage and storage of the materials. However, as of now, there is *no* government that has a facility for this type of disposal, although one is being created in Finland.
- **In water:** At nuclear sites, a common way of storing material is in water. Nearly all of these sites have a special pond or have a special pool constructed, which is a place that they can store fuel that has already been used for the process of generating power.

- **Recycling:** For some radioactive material, such as previously used fuel, certain radioactive elements can be processed or extracted for reuse. Uranium and plutonium elements have long lives, so they can be separated and recycled.
- **The Ocean:** A very small amount of liquid waste that is common when waste is reprocessed to extract usable elements is released into the ocean. This process is highly controlled, and radiation levels are deemed to be so low that they are inconsequential. However, recent agreements between companies that rely on nuclear materials have phased out this procedure.

While these are commonly used ways to dispose nuclear waste, there have been some proposals for alternate methods, although none of have been seriously considered. Some of these alternate disposal forms include:

- **Space Disposal:** The expense related to this is far too prohibitive when compared with the positive effects.
- **Seabed Disposal:** Another proposal was to embed waste deep within the seabed. However, international powers decided that the risk was far greater than the benefits.
- **Long-term aboveground Storage Bunkers:** While some nuclear companies *do* have storage facilities above-ground, these are temporary and meant to make the waste more accessible for reuse, or to have it decay enough for another form of disposal. However, permanent above ground storage has been discarded in favor of deeper burials within the ground.

Sustainable development

What is sustainable development?

"Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs."

The concept of sustainable development can be interpreted in many different ways, but at its core is an approach to development that looks to balance different, and often competing, needs against an awareness of the environmental, social and economic limitations we face as a society.

All too often, development is driven by one particular need, without fully considering the wider or future impacts. We are already seeing the damage this kind of approach can cause, from large-scale financial crises caused by irresponsible banking, to changes in global climate resulting from our dependence on fossil fuel-based energy sources. The longer we pursue unsustainable development, the more frequent and severe its consequences are likely to become, which is why we need to take action now.

Living within our environmental limits is one of the central principles of sustainable development. One implication of not doing so is climate change.

But the focus of sustainable development is far broader than just the environment. It's also about ensuring a strong, healthy and just society. This means meeting the diverse needs of all people in existing and future communities, promoting personal

wellbeing, social cohesion and inclusion, and creating equal opportunity.

Not necessarily. Sustainable development is about finding better ways of doing things, both for the future and the present. We might need to change the way we work and live now, but this doesn't mean our quality of life will be reduced.

A sustainable development approach can bring many benefits in the short to medium term, for example:

Savings - As a result of SDC scrutiny, government has saved over £60m by improving efficiency across its estate.

Health & Transport - Instead of driving, switching to walking or cycling for short journeys will save you money, improve your health and is often just as quick and convenient.

The Concept of Sustainable Development

1. The satisfaction of human needs and aspirations is the major objective of development. The essential needs of vast numbers of people in developing countries for food, clothing, shelter, jobs - are not being met, and beyond their basic needs these people have legitimate aspirations for an improved quality of life. A world in which poverty and inequity are endemic will always be prone to ecological and other crises. Sustainable development requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life.
2. Living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability. Yet many of us live beyond the world's ecological means, for instance in our patterns of energy use. Perceived needs are socially and culturally determined, and sustainable development requires the promotion of values that encourage consumption standards that are within the bounds of the ecological possible and to which all can reasonably aspire.
3. Meeting essential needs depends in part on achieving full growth potential, and sustainable development clearly requires economic growth in places where such needs are not being met. Elsewhere, it can be consistent with economic growth, provided the content of growth reflects the broad principles of sustainability and non-exploitation of others. But growth by itself is not enough. High levels of productive activity and widespread poverty can coexist, and can endanger the environment. Hence sustainable development requires that societies meet human needs both by increasing productive potential and by ensuring equitable opportunities for all.
4. An expansion in numbers can increase the pressure on resources and slow the rise in living standards in areas where deprivation is widespread. Though the issue is not merely one of population size but of the distribution of resources, sustainable development can only be pursued if demographic developments are in harmony with the changing productive potential of the ecosystem.
5. A society may in many ways compromise its ability to meet the essential needs of its people in the future - by overexploiting resources, for example. The

direction of technological developments may solve some immediate problems but lead to even greater ones. Large sections of the population may be marginalized by ill-considered development.

6. Settled agriculture, the diversion of watercourses, the extraction of minerals, the emission of heat and noxious gases into the atmosphere, commercial forests, and genetic manipulation are all examples of human intervention in natural systems during the course of development. Until recently, such interventions were small in scale and their impact limited. Today's interventions are more drastic in scale and impact, and more threatening to life-support systems both locally and globally. This need not happen. At a minimum, sustainable development must not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings.
7. Growth has no set limits in terms of population or resource use beyond which lies ecological disaster. Different limits hold for the use of energy, materials, water, and land. Many of these will manifest themselves in the form of rising costs and diminishing returns, rather than in the form of any sudden loss of a resource base. The accumulation of knowledge and the development of technology can enhance the carrying capacity of the resource base. But ultimate limits there are, and sustainability requires that long before these are reached, the world must ensure equitable access to the constrained resource and reorient technological efforts to relieve the pressure.
8. Economic growth and development obviously involve changes in the physical ecosystem. Every ecosystem everywhere cannot be preserved intact. A forest may be depleted in one part of a watershed and extended elsewhere, which is not a bad thing if the exploitation has been planned and the effects on soil erosion rates, water regimes, and genetic losses have been taken into account. In general, renewable resources like forests and fish stocks need not be depleted provided the rate of use is within the limits of regeneration and natural growth. But most renewable resources are part of a complex and interlinked ecosystem, and maximum sustainable yield must be defined after taking into account system-wide effects of exploitation.
9. As for non-renewable resources, like fossil fuels and minerals, their use reduces the stock available for future generations. But this does not mean that such resources should not be used. In general the rate of depletion should take into account the criticality of that resource, the availability of technologies for minimizing depletion, and the likelihood of substitutes being available. Thus land should not be degraded beyond reasonable recovery. With minerals and fossil fuels, the rate of depletion and the emphasis on recycling and economy of use should be calibrated to ensure that the resource does not run out before acceptable substitutes are available. Sustainable development requires that the rate of depletion of non-renewable resources should foreclose as few future options as possible.
10. Development tends to simplify ecosystems and to reduce their diversity of species. And species, once extinct, are not renewable. The loss of plant and animal species can greatly limit the options of future generations; so sustainable development requires the conservation of plant and animal species.

11. So-called free goods like air and water are also resources. The raw materials and energy of production processes are only partly converted to useful products. The rest comes out as wastes. Sustainable development requires that the adverse impacts on the quality of air, water, and other natural elements are minimized so as to sustain the ecosystem's overall integrity.
12. In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations

LANDFILL

- A landfill is a carefully designed structure built into or on top of the ground, in which trash is separated from the area around it.
- Landfills contain garbage and serve to prevent contamination between the waste and the surrounding environment, especially groundwater.
- Landfills are not designed to break down trash, merely to bury it. That's because they contain minimal amounts of oxygen and moisture, which prevents trash from breaking down rapidly. So landfills are carefully filled, monitored and maintained while they are active and for up to 30 years after they are closed.

What is the difference between a dump and a landfill?

A dump is an open hole in the ground where trash is buried and where animals often swarm. Dumps offer no environmental protection and are not regulated.

A landfill is a carefully designed and monitored structure that isolates trash from the surrounding environment (e.g., groundwater, air, rain). This isolation is accomplished with the use of a bottom liner and daily covering of soil

PARTS OF A LANDFILL

The main components of any secured, permitted landfill are:

- **Bottom liner** — The bottom liner separates and prevents the buried waste from coming in contact with underlying natural soils and groundwater. In Municipal Solid Waste landfills, the bottom liners are generally constructed using some type of durable, puncture-resistant synthetic plastic HDPE (High Density Polyethylene) ranging from 30 to 100 mils thick. The plastic liners may also be designed with a combination of compacted clay soils, along with synthetic plastic.
- **Cells (old and new)** — This is the area in a landfill that has been constructed and approved for disposal of waste. These cells range in size (depending upon total tons of waste received each day at the landfill) from a few acres to as large as 20+ acres. Inside these larger cells are smaller cells known as the daily workface, or sometimes referred to as cells. This is where the waste coming into the landfill for disposal that day is prepared by placing the material in layers or lifts where the waste is then compacted and shredded by heavy landfill

compaction machinery.

- **Leachate collection system** — The bottom of each landfill is typically designed so that the bottom surface of the landfill is sloped to a low point, called a sump. This is where any liquids that are trapped inside the landfill — known in the waste industry as leachate — are collected and removed from the landfill. The leachate collection system typically consists of a series of perforated pipes, gravel packs and a layer of sand or gravel placed in the bottom of the landfill. Once the leachate is removed from the sump, it is typically pumped or gravity-flowed to a holding tank or pond, where it is either treated on site or hauled off site to a public or private wastewater treatment facility.
- **Storm water drainage** — This is an engineered system designed to control water runoff during rain or storm events. This is done by directing the runoff through a series of berms or ditches to holding areas known as sed ponds. In these ponds the runoff water flow is slowed down or held long enough to allow the suspended soil particles to settle out before the water is discharged off site.
- **Methane collection system** — Bacteria in the landfill break down the trash in the absence of oxygen. This process produces landfill gas, which is approximately 50 percent methane. Since methane gas has the potential to burn or explode, it has to be removed from the landfill. To do this, a series of pipes are embedded within the landfill to collect the methane gas. This gas, once collected, can be either naturally vented or control-burned.
- **Cover (or cap)** — Waste that is placed in a cell is required to be covered daily with either six inches of compacted soil or an alternative daily cover. Some examples of alternative daily covers are the application of spray-on cover material, such as foam or a flame-retardant fiber material. Another type of alternative daily cover is large panels of tarpaulin-type material that is laid over the waste at the end of each day and removed the next day before waste is placed. Other areas within the cells that are not to final grade and will not receive placement of additional waste for a period of time may require additional cover. This is known as intermediate cover — generally 12 to 18 inches of soil. Covering (or capping) is performed in order to isolate the waste from exposure to the air, pests (such as birds, rats and mice) and to control odors. When a section of the landfill is finished or filled to capacity, it is permanently covered with a combination of a layer of polyethylene plastic, compacted soil and a layer of topsoil that will support growth of vegetation to prevent erosion.
- **Groundwater monitoring stations** — These stations are set up to directly access and test the groundwater around the landfill for presence of leachate chemicals. Typically a groundwater monitoring system will have a series of wells that are located up-gradient of the landfill disposal area and a series of wells down-gradient. The up-gradient wells test the water quality before it moves under the disposal area in order to get a background analysis of the water. The down-gradient wells then allow testing of the water after it has passed under the disposal area so it can be compared to the quality of the up-gradient wells to make sure there has been no impact or contamination of the groundwater.

THERE ARE THREE MAIN TYPES OF LANDFILLS:

- **Municipal solid waste (MSW) landfill** — A highly engineered, state permitted disposal facility where municipal solid waste (non-hazardous waste generated from single family and multi-family residences, hotels, and the like including commercial and industrial waste) may be disposed of for long-term care and monitoring. All modern MSW landfills must meet or exceed federal subtitle D regulations to ensure environmentally safe and secure disposal facilities.
- **Construction & Demolition landfill**— Construction and demolition (C&D) debris refers to materials produced in the process of construction, renovation and/or demolition of structures, where structures include debris typically includes concrete, asphalt, wood, gypsum wallboard, paper, glass, rubble, and roofing materials. Land clearing debris, such as stumps, rocks, and dirt are also included in some state definitions. C&D debris landfills are classified as non-hazardous and are regulated by states and local governments.
- **Inert landfill** — Inert material consists of earth and earth-like products, concrete, cured asphalt, rock, bricks, yard trimmings, and land clearing debris such as stumps, limbs and leaves. These materials, depending on the state's definition, are allowable by law to be disposed of in inert landfills.

CONVERTING LANDFILL GAS TO ENERGY

Converting landfill gas to energy is how mature landfills deal with the issue of gases created within their facilities. It is an effective means of recycling and reusing a valuable resource. In fact, the U.S. Environmental Protection Agency (EPA) has endorsed landfill gas as an environmentally friendly energy resource that reduces our reliance on fossil fuels, such as coal and oil. Landfill gas-to-energy projects are most successful when partnered with mature MSW landfills, as opposed to new landfills or C&D landfills.

There are three basic types of landfill gas-to-energy facilities:

- **Electric** — Landfill gas is used as a fuel to generate electricity at small power plants at the landfill, or at a nearby industry, with the generated electricity delivered to a utility company.
- **Alternative fuel** — Landfill gas is piped to an industrial or commercial facility, where it is used for heating in place of, or in combination with, fossil fuels such as oil, coal or natural gas.
- **Processed gas** — Landfill gas is processed and cleaned to natural gas quality and delivered to transmission pipelines, to be used in normal applications for natural gas.

Biomedical Waste

Biomedical waste is defined as any kind of waste that contains infectious material (or material that's *potentially* infectious). This definition includes waste generated by healthcare facilities like physician's offices, hospitals, dental practices,

laboratories, medical research facilities, and veterinary clinics.

Medical waste can contain bodily fluids like blood or other contaminants. The 1988 *Medical Waste Tracking Act* defines it as waste generated during medical research, testing, diagnosis, immunization, or treatment of either human beings or animals. Some examples are culture dishes, glassware, bandages, gloves, discarded sharps like needles or scalpels, swabs, and tissue.

Biomedical waste goes by several names that all have the same basic definition. All of the terms below refer to waste created during the healthcare process that's either contaminated or potentially contaminated by infectious material.

- **Medical Waste**
- **Biomedical Waste**
- **Clinical Waste**
- **Bio -hazardous Waste**
- **Regulated Medical Waste (RMW)**
- **Infectious Medical Waste**
- **Healthcare waste**

The terms are used interchangeably, but there's a distinction between general healthcare waste and hazardous medical waste. The WHO categorizes sharps, human tissue, fluids, and contaminated supplies as "bio- hazardous," and non-contaminated equipment and animal tissue as "general medical waste."

Types of Biomedical Waste

The term "Biomedical waste" can cover a wide variety of different byproducts of the healthcare industry. The broadest definition can include office paper and hospital sweeping waste. The most common waste categories are as follows

- **Sharps.** This kind of waste includes anything that can pierce the skin, including needles, scalpels, lancets, broken glass, razors, ampules, staples, wires, and trocars.
- **Infectious Waste.** Anything infectious or potentially infectious goes in this category, including swabs, tissues, excreta, equipment, and lab cultures.
- **Radioactive.** This kind of waste generally means unused radiotherapy liquid or lab research liquid. It can also consist of any glassware or other supplies contaminated with this liquid.

- **Pathological.** Human fluids, tissue, blood, body parts, bodily fluids, and contaminated animal carcasses come under this waste category.
- **Pharmaceuticals.** This grouping includes all unused, expired, and/or contaminated vaccines and drugs. It also encompasses antibiotics, injectables, and pills.
- **Chemical.** These are disinfectants, solvents used for laboratory purposes, batteries, and heavy metals from medical equipment such as mercury from broken thermometers.
- **Genotoxic Waste.** This is a highly hazardous form of medical waste that's either carcinogenic, teratogenic, or mutagenic. It can include cytotoxic drugs intended for use in cancer treatment.
- **General Non-Regulated Medical Waste.** Also called non-hazardous waste, this type doesn't pose any particular chemical, biological, physical, or radioactive danger.

Disposal of Biomedical Waste

On-Site Treatment

The on-site treatment of medical waste is generally limited to large, well-monied hospitals and facilities. On-site treatment is extremely cost-prohibitive. That's because the required equipment is expensive to buy, expensive to maintain, and expensive to manage and run. The regulatory maze around such equipment (and its use) presents yet another barrier to entry.

Off-Site Treatment

Off-site medical waste treatment is a far more cost-effective option for most small and mid-sized medical practices and facilities. Third-party vendors whose main business is healthcare waste collection and disposal have the equipment and training needed to handle the process. Vendors can collect the waste either by truck or by mail.

- **Truck services** require a contract with a specially licensed disposal company to haul the waste away for regular destruction. The waste is hauled in special containers to a dedicated disposal facility.
- **Mail or box services** use the U.S. Postal Service to ship the waste safely to a facility for treatment. This is generally the most cost effective of all the methods. It requires a vendor fully versed and experienced in all special Postal Service regulations and best practices.

Treatment of Biomedical Waste:

No matter where medical waste is processed, it's ultimately treated by incineration,

autoclaving, microwave, biological, or chemical treatment. Incineration, once by far the most popular method, has decreased in usage since the 1990's, as regulation has forced other methods to come online.

Incineration. Before 1997, over 90% of all infectious medical waste was disposed of by incineration. Changes to EPA regulations have led providers to seek other disposal means. This is still the only method used on pathological waste, for example body parts and recognizable tissues.

Autoclaving. Steam sterilization renders bio- hazardous waste non-infectious. After it's been sterilized, the waste can be disposed of normally in solid waste landfills, or it can be incinerated under less-stringent regulation.

Microwaving. Another way to render hazardous healthcare waste non-hazardous is to microwave it with high-powered equipment. As with autoclaving, this method opens up the waste to normal landfill disposal or incineration afterward.

Chemical. Some kinds of chemical waste may be neutralized by applying reactive chemicals that render it inert. This is generally reserved for waste that's chemical in nature.

Biological. This experimental method of treating biomedical waste uses enzymes to neutralize hazardous, infectious organisms. It's still under development and rarely used in practice.

Sources of Biomedical Waste: Medical waste can come from any medical or biological activity or source. For example, the prevention, diagnosis, or treatment of different diseases all can create hazardous waste.

The list of waste-generating facilities below includes all caregiver locations like private physician practices and dental offices, but also veterinary practices, research labs, funeral homes, and anyplace else that meets medical needs.

- Physician Practices
- Retail Health Clinics
- Dental Offices
- Urgent Care Clinics
- Veterinary Practices
- Medical Research Laboratories
- Nursing Homes
- Home Healthcare or Infusion Situations

- Funeral Homes
- Hospitals
- Commercial Offices and Buildings

Philosophy and technology of living with Nature: The important and indeed admirable idea motivating this anthology is that environmental philosophy and the philosophy of technology, two fields that in recent decades have made significant strides, have much in common and ought to be more in conversation with each other than has generally been the case. Yet this collection is a bit of a disappointment, impressive more in its ambition than its carry-through, and leaves one wishing for a deeper investigation of the relationship between the two fields, beginning with more of a serious attempt to define what they actually are and what the connection is between the objects with which they claim to concern themselves.

The trouble starts early, in the first paragraph of the *Introduction*, when editor David Kaplan writes that "Environmental issues inevitably involve technology, and technologies inevitably have environmental impacts. Technology and the environment are like two sides of the same coin" but baseball games inevitably involve pitching, and pitching inevitably has impacts on baseball games, yet it doesn't follow from this that baseball and pitching are two sides of the same coin. Rather the latter is subsumed under the former; the possibility that *this* is the relationship between environmental philosophy and philosophy of technology, or for that matter that each is an aspect of some third field, is never really considered in the articles here. Instead most seem to presuppose a fundamental dualism whereby "environment" (which means "nature") is distinguished from "technology," the former referring to a world prior to and unsullied by human doings, the latter to a built world generated by exactly such doings, with the overlapping subject matter studied by the two fields understood as the impact of these distinct worlds upon each other, focusing on the way technologies affect (and harm) nature on the one hand, and the way nature constrains (causally and normatively) those technologies on the other. Such a dualism treats humans as outside of nature, and thus assumes from the start that human actions (and technologies) are un- or even anti-natural -- a claim that few authors within either field would explicitly accept, and that indeed many explicitly deny, but that nonetheless seems paradoxically central to the way many talk about the issues they investigate. Yet the "environment" most of us inhabit is a pretty thoroughly technological one, while on the other hand the capacity to build technologies seems just as natural to humans as that of honeybees to build hives, which seems to suggest that philosophical investigation of the environment, of nature, and of technology are all concerned with *the same thing*, and that one of the first questions such an investigation might ask is why we think those things are different, even if only in the sense of being "two sides of the same coin." None of the essays in this collection consider this sort of question,

which strikes me as the key one that a self-aware confrontation between environmental philosophy and philosophy of technology ought to examine. Still, a number of potentially interesting issues are raised, and I'll briefly discuss each of the essays, grouping some together that have similar themes.

The first two are by J. Baird Callicott and Don Ihde, each a crucial and even foundational figure in the two respective fields. Each article is interesting but, frankly, each also gives the distinct impression of having been quickly tossed off. Callicott criticizes a tendency among environmental philosophers, beginning with Lynn White's famous argument linking environmental problems to Genesis's ascription to humans of a divinely ordained dominion over nature, to attribute environmental difficulties to modes of thought -- a tendency that, as he notes makes the solution to those difficulties look like merely a matter of developing new ways of thinking, thus (surprise!) giving philosophers a key role in environmentalism. Against this intellectual determinism Callicott contrasts a "technological determinism" (which he points out White actually defended in other work) that puts much less emphasis on the power of ideas and more on the way that technologies themselves affect our understandings of the world. This line of argument is a valuable one, but after that the essay seems to run out of steam, first proposing a vaguely interactionism conception of the relation between ideas and technologies that still seems to give pride of place to ideas, and then ending rather abruptly with some speculations on how digital technologies may be changing worldviews and the suggestion that, rather than philosophers, it is people such as Steve Jobs who will have the most impact on responding to environmental challenges. Ihde's article is similarly suggestive but undeveloped, offering a series of critiques of the tendency towards dystopianism endemic to both the philosophy of technology and environmental philosophy, but without providing any sustained reflection on the connections between those fields. He ends with a vague optimism that certain environmental problems will be amenable to technological solutions, calling for small and incremental advances to improve environmental quality and suggesting the importance of philosophers playing a role in early research and development of technologies. He concludes by writing that "I want to indicate that all enviro-technological problems are complex, ambiguous, and interwoven" (38), which is doubtless true enough but doesn't offer much in the way of fresh insight.

In their more substantive contribution, Kyle Powys Whyte, Ryan Gunderson, and Brett Clarke examine the idea of the "insidiousness" of technology, one they find common in both fields investigated here, and contrast it to a view of technology as a fundamentally neutral tool helpful for solving environmental problems. But when they define insidiousness as "the idea that communities that adopt technological hardware, such as televisions, or rely on technological supply chains, such as global agri-food, cannot stop the erosion of their previous, more intimate relations with the environment" it seems to me that they conflate two distinct theses. The claim that technology is not a value-free tool for satisfying (ahistorical) human

interests is separate from the claim that using it damages prior and "more intimate" relations to the environment, but the authors do not draw that distinction. And even with respect to the first claim they seem to understand it in the intellectually deterministic way that Callicott's essay objects to, writing, for instance (ironically in a discussion of Callicott's work on the Ojibway), that "technology is inevitably associated with the dominant *worldviews* [my emphasis] of the society that created that particular technology" (49) and using this to criticize the impact on indigenous communities of the introduction of foreign technologies. "Store-bought items," they suggest, "in some way contain the ideas and values of the society that produced them within their very substance"; when used in a different society, they write, "the substance of the goods -- i.e., the life ways of another society -- becomes an integral part of the interaction" But to identify technology with a worldview, or the "substance" of a commodity with a "lifeway," is to fall prey to the very idealism that Callicott warned against: technologies are primarily forms of *practice*, not expressions of ideals or values. This idealism leads to trouble at the end of the essay when the authors turn to Marx, arguing that the problem has to do with capitalism and with technologies that "are often developed to service the interest of those in power" (54); what's missing in such a remark is the insight that capitalism and capitalist technologies *make possible* and *produce* those interests and again, that it is technology as a material force, not as expression of a worldview, that makes it "insidious."

Paul Thompson's essay examines "resistance to risky technology" (going back to Ned Ludd), and offers a nuanced discussion of the phenomenon of "social amplification of risk" in which citizens perceive and object to risks to technologies that "rational" scientific assessments fail to confirm. Sometimes, Thompson points out, this is because those assessments consider only certain sorts of risks for instance, the biological ones associated with new bio- or agro-technologies and not (as in the Luddite example) the social, cultural, or economic consequences that those technologies might put into play. Other times, though, such resistance may result from familiar "irrational" cognitive biases or heuristics (loss-aversion, anchoring, etc.). But even the latter, he points out, may have a normative significance -- first, interestingly, because the widespread existence of such biases might suggest them to have had an evolutionary benefit, but secondly also because a commitment to democratic decision-making might mean that expert views, no matter how putatively rational, don't trump the authentically held concerns of citizens. This is especially so, he points out, when some groups of citizens are subject to deep injustices of various kinds: in such cases concerns about risk may also express "wisdom gained from experience with the deceptions of wealthy and well-placed actors who have persistently benefited at the expense of the less powerful and less fortunate majority." Scientific risk assessment, he concludes, must be accompanied with a commitment to "effective responses to injustice on the ground"

Nature-A Silent teacher of Ecology:

Nature, in the broadest sense, is equivalent to the natural world, physical world, or material world. "Nature" refers to the phenomena of the physical world, and also to life in general. It ranges in scale from the subatomic to the cosmic. The term "nature" may refer to living plants and animals, geological processes, weather, and physics, such as matter and energy. The term is often refers to the "natural environment" or wilderness—wild animals, rocks, forest, beaches, and in general areas that have not been substantially altered by humans, or which persist despite human intervention. For, example, manufactured objects and human interaction are generally not considered part of nature, unless qualified as, for example, "human nature" or "the whole of nature". This more traditional concept of "nature" implies a distinction between natural and artificial elements of the Earth, with the artificial as that which has been brought into being by a human consciousness or a human mind.

Have you ever wondered why grey squirrels are taking over from red squirrels? Why some plants and bacteria thrive in soils contaminated with poisonous metals? Whether you can tell the age of a forest, or how different methods of farming affect the survival of British wildlife? The key to answering these questions is in understanding the relationships between living things and their environment. The scientific study of these relationships is called ecology

Ecology explores the interactions between living things and their physical environment, such as temperature or the availability of water. It is also concerned with interactions between living things, such as predation (who is being eaten and by whom), competition (who wins the fight over food, a mate or a home) and mutualism (species surviving through co-operation). These relationships are important in shaping the natural world around us.

With so many different species and environmental influences, unravelling these relationships can be a complicated process, so scientists use a wide range of techniques to explore ecological questions. These include studying individuals or groups in nature, and conducting experiments in controlled environments, such as greenhouses. It can also involve looking at genetic and molecular information, or creating a mathematical model. Whether the study takes place in the countryside, in the laboratory or even 'virtually' on a computer, it is all part of ecology.

Ecological studies are vital in understanding important natural processes such as evolution and climate change. They can also help to solve a wide range of practical problems, from controlling diseases or pests to preventing an endangered species from becoming extinct.



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