

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 (O₃)** formed from NO_x and VOCs. Ozone (O₃) 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.

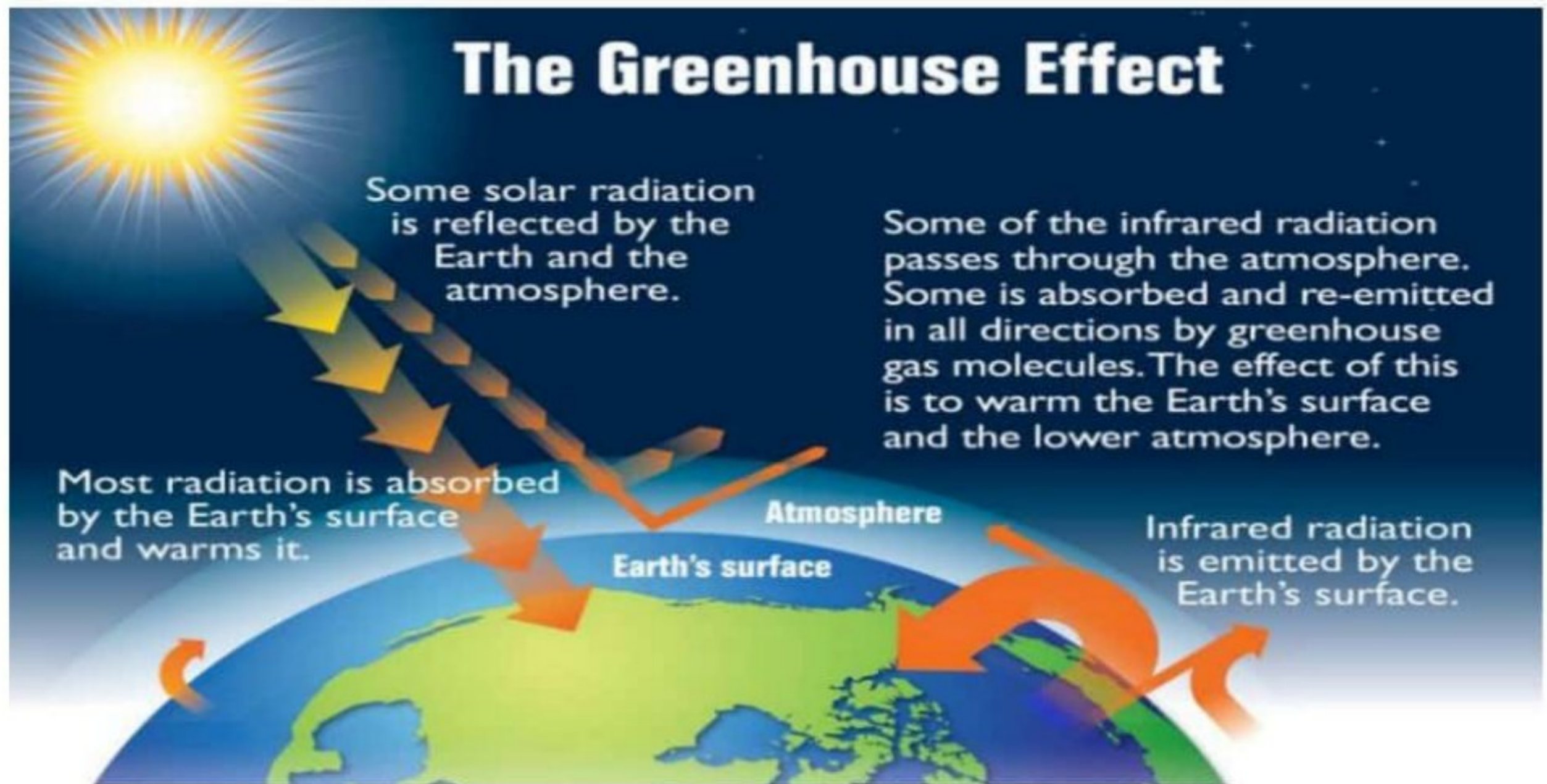
The Albedo Effect

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.

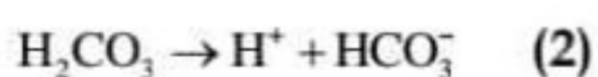
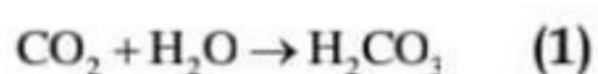
Measurement of Acid Rain

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.

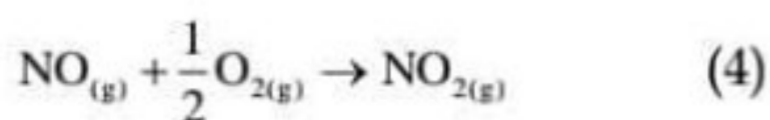
The level of acidity can be determined using high-tech devices or using litmus paper. When litmus paper is exposed to a substance, it changes color depending on the acidity: red for acidic, blue for basic, and a variety of colors for anything in Natural Acidity of Rainwater.

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.



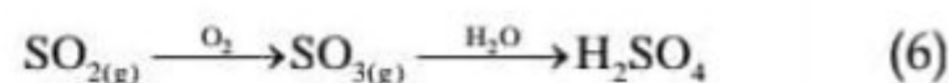
Nitric oxide (NO), which also contributes to the natural acidity of rainwater, is formed during lightning storms by the reaction of nitrogen and oxygen, two common atmospheric gases (Equation 3). In air, NO is oxidized to nitrogen dioxide (NO₂) (Equation 4), which in turn reacts with water to give nitric 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.



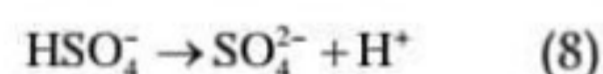
Acidity of Polluted Rainwater

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 (*Emiliana 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(O₂) molecule, which then independently reunite with other types of molecules to form ozone. The ozone layer has been shielding life on planet earth for billions of years, but it's now being worn out by human activities.

People began to value the importance of the ozone layer when scientists released 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

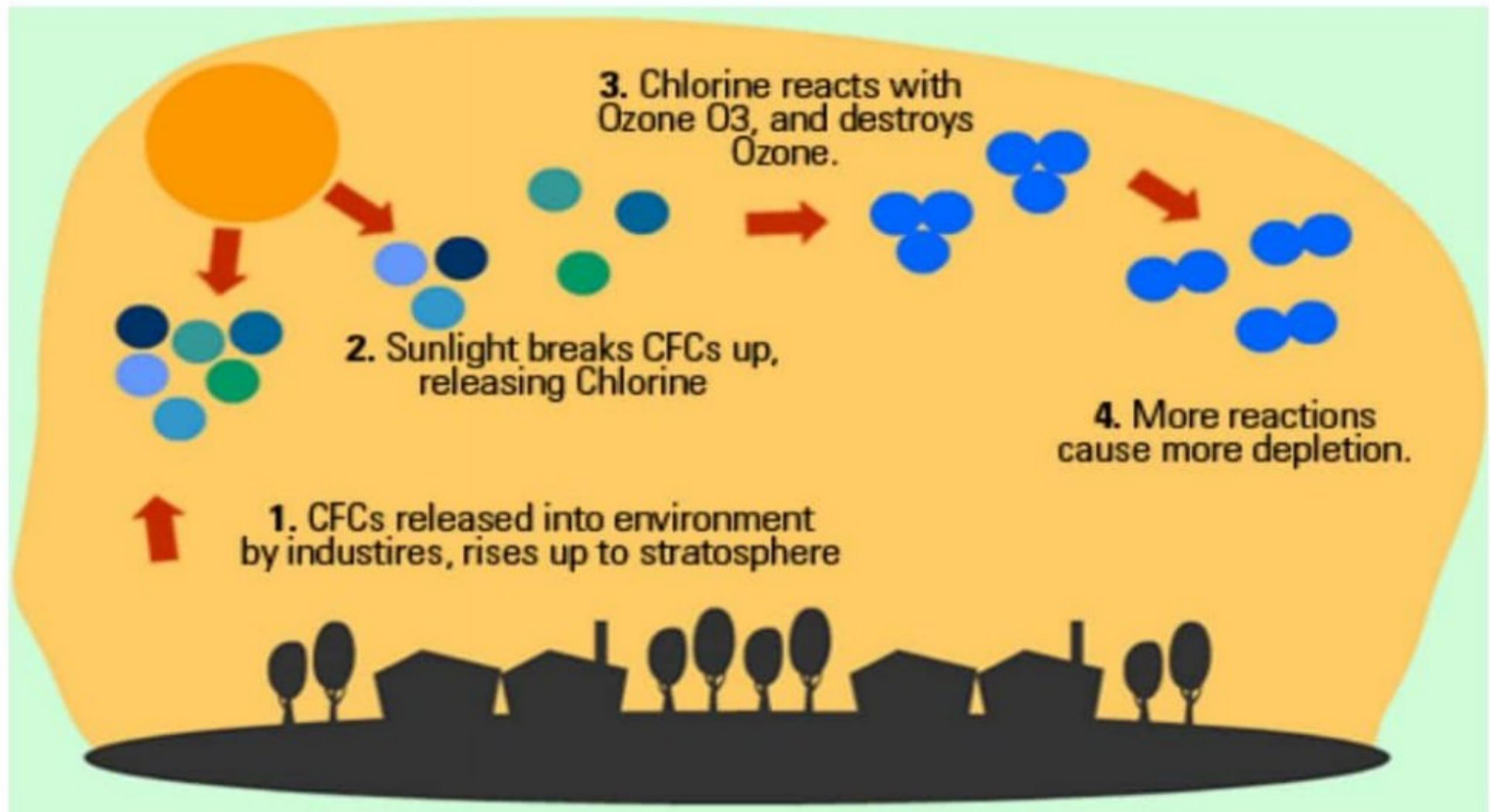
The Montreal Protocol formed in 1989 helped a lot in the limitation of Chlorofluorocarbons (CFCs). However, the protocol never covered nitrous oxide, which is a known harmful chemical that can destroy the ozone layer. Nitrous oxide is still in use today. Governments must take action now and outlaw nitrous 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/ m3
Nitrogen Dioxide	1 hour	400 ug/ m3

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/m3-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/m3-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.

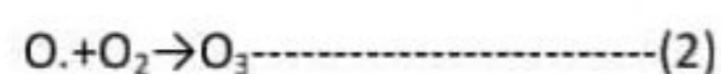
Both the primary and secondary pollutants in photochemical smog are highly reactive. These oxidizing compounds have been linked to a variety of negative health outcomes; ozone, for example, is known to irritate the lungs. Smog is a particular health danger in some of the world's sunniest and most populated 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:

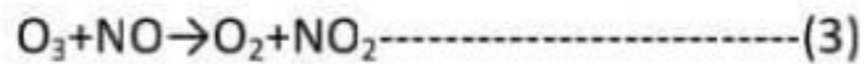
1. Nitrogen Dioxide (NO_2) from vehicle exhaust, is photolyzed by ultraviolet (UV) radiation ($h\nu$) from the sun and decomposes into Nitrogen Oxide (NO) and an oxygen radical:



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

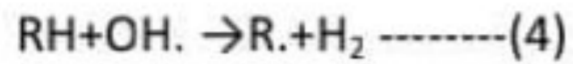


3. Under normal conditions, O₃ reacts with NO, to produce NO₂ and an oxygen molecule:



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

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

All 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 algaecides, 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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- 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:

$$\text{Initial DO} = 8.2 \text{ mg/L}$$

$$\text{Final DO} = 4.4 \text{ mg/L}$$

$$\text{Sample size} = 5 \text{ mL}$$

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

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

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 irresponsibly 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 spillages 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 separate. 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 pre mature death, ahead of their life cycles.
2. **Damaging effect marine biodiversity:** Marine biodiversity will get great 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.

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

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,

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."

Water pollution caused by use of fertilizers and pesticides

Overview

Fertilizers and pesticides both have definite pros 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."

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)
 3. **Natural Causes of Soil Erosion:** Erosion of soil takes places 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.
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

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.

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:

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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.

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

(T)	-		Toxic	Waste
(H)	-	Acute	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

WasteThe 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.

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.

