Uttar Pradesh Rajarshi Tandon Open University

DCEVS-105
Environmental Pollution

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COURSE INTRODUCTION

In this course learner will to know about environmental pollution. The introduction of dangerous materials or pollutants into the environment that has a negative impact on wildlife, ecosystems, and human health is referred to as environmental pollution. Air, water, soil, noise, thermal, and radioactive contamination are only a few of the several types of pollution. The main sources of air pollution include emissions from automobiles, factories, and the combustion of fossil fuels. When toxic substances, garbage, or dangerous chemicals find their way into rivers, lakes, or the ocean, water pollution happens. The main causes are plastic trash, agricultural runoff, and industrial discharge. Deforestation, pesticide use, and inappropriate industrial waste disposal all contribute to soil pollution. The detrimental rise in noise levels brought on by automobiles, machinery, and urbanization is known as noise pollution. Thus here in this course the types of pollutions and their effects and controlled are discussed into the following blocks:

Block-1 covers the concept, sources and effects of Water and Air Pollution

Block-2 discussed the Soil, Noise and Radioactive Pollution their sources and effects

Block-3 briefly discussed the Effects and Control of Pollution

Black-1

Introduction

Unit-1: This unit cover the definition of pollution and pollutants, their sources and sinks, their classification, and the distinction between contaminants and pollutants.

Unit-2: Water pollution definition and origins, forms of water pollution, impacts of water pollution on India's rivers and potable water, and water pollution measurements are discussed in this unit. The type and sources and its effects of water pollution are briefly discussed.

Unit-3: Air pollution definition and origins, atmospheric composition, air pollution types, acid rain, particle matter, air pollution influencing factors, and air pollution control measures.

Unit-1: Introduction of Pollutant

Contents

1.1. Introduction

Substances or agents that infiltrate the environment and injure or disturb ecosystems, live animals, or man-made structures are known as pollutants. There are both natural and man-made ways for it to get into the environment. Pollution might be caused by atoms, molecules, and particles. Although the supply of pollutants changes based on their nature once they are released into the atmosphere, soil, or water, it is helpful to group them into the following categories: While secondary pollutants are created by combining primary pollutants with outside sources, primary pollutants are released into the environment directly. They can be natural or man-made and come in a variety of forms, including gases, liquids, and solids. Carbon monoxide, sulfur dioxide, nitrogen oxides, particulate matter, ozone, volatile organic compounds, heavy metals, pesticides, and plastics are some of the most common pollutants. They can be caused by industrial activity, vehicular emissions, agricultural practices, garbage disposal, or natural events such as volcanic eruptions.Pollution has serious consequences for human health, biodiversity, air quality, water quality, and overall environmental sustainability.By changing the rate at which plant or animal species grow, interfering with the use of resources by humans, affecting human health or well-being, or affecting property values, a pollutant can cause either short-term or long-term harm. Certain pollutants will not persist in the environment indefinitely since they are biodegradable. Some pollutants' degradation products, such as DDE and DDD generated by DDT breakdown, are polluting in their own right. Different types of pollutants include: Nitrogen oxides (NOx), Sulfur oxides (SOx), Particulate matter (PM), Ground level ozone (O3), Volatile organic compounds (VOCs), heavy metals, and Peroxyacyl nitrates (PANs) etc. There are numerous classifications for pollutants. For instance, it can occasionally be crucial to distinguish between fund and stock pollution. Classifying them according to more specific characteristics, such organic, particle, pharmaceutical, and so on, is an additional strategy. Assimilative capacity, often referred to as absorptive capacity, is the ability of the environment to absorb a large number of discharges without causing noticeable harm; when this ability is exceeded, pollutant produces pollution.

Objectives:

After reading this unit, the learner will be able to know

- The pollution and pollutants and its characteristics
- Source and sink, fate and routes of pollutants
- Classification of pollutants and its effected on environment

1.2. Definition of pollution

Pollution is also defining any harmful substances (solid, liquid, or gas) or form of energy (such as heat, sound, or radioactivity) that introduce into the environment. These substances can be dispersed, diluted, decomposed, recycled, or stored in a harmless form and course adverse affected on nature and living beings. **"Pollution is the introduction of substances (or energy) that causes adverse changes in the environment and living entities:**Pollution does not always result from the presence of chemical compounds such as particles. Sound, heat, and light are all forms of energy that can pollute the environment. These compounds that pollute are referred to as pollutants. Pollution, even in little levels, has an impact on the ecological equilibrium. Pollutants can work their way up the food chain and finally into the human body. Continue reading to learn about the many types of pollution and its repercussions. Pollution is classified according to its impact on the environment. Each category of pollution has unique repercussions and sources. Main types of pollution are:

- Water Pollution
- Air Pollution
- Soil Pollution
- Thermal Pollution
- Radioactive Pollution
- Noise Pollution
- Light Pollution

Pollutants may be natural, such as volcanic ash. They can also be caused by human activities, such as industrial waste or runoff. The three main types of pollution, as defined by the environment, are air pollution, water pollution, and land contamination. Pollutants degrade the quality of air, water, and land Modern culture is also concerned with certain types of pollution, such as noise pollution, light pollution, and plastic pollution. Pollution of any form can be harmful to the environment and wildlife, as well as to human health and well-being. Pollution comes in a variety of forms, the most of which are caused by humans. Globalisation, with humanity's ongoing demand for natural resources, has also contributed to pollution. Though the standard of living has greatly improved, other new challenges have emerged that are steadily affecting human health and the environment. In this post, we will look at the meaning, causes, and types of pollution. Furthermore, we will examine the effects of pollution on human health and the ecosystem.

Indoor air pollution is the contamination of air quality within and around buildings and structures. Indoor air pollution is a genuine and dangerous problem since it contains significantly more toxins than outdoor air. Solvents, molds, smoking, pesticides, gasses, and pet dander are some of the most frequent types of indoor air pollutants. Most dwellings will have some degree of indoor air pollution. Indoor air quality (IAQ) is a measure of how the air inside a building affects the health and comfort of its occupants. Indoor air pollution has been a more serious issue in recent years as dwellings have gotten more energy efficient. There are various elements in both rural and urban regions that contribute to indoor pollution; indoor pollution is ten times greater than outside air pollution because enclosed rooms stimulate the buildup of potential contaminants more than open ones.

Outdoor air is also known as ambient air. Outdoor air pollution is commonly caused by emissions from combustion processes in motor vehicles, solid fuel burning, and industries. Other causes of pollution include wildfire smoke, windblown dust, and biogenic emissions from vegetation (pollen and mould spores). Emissions from combustion processes in motor vehicles, solid fuel burning, and industries are the most frequent sources of outdoor pollution. In addition, smoke from bushfires, windblown dust, and biogenic emissions from vegetation (pollen and mold spores) are considered outdoor pollutants. However, carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter of various size fractions, and sulfur dioxide) are all abundant in outdoor air and can be harmful to human and environmental health. Outdoor pollution can come from stationary or mobile sources.

1.3. Pollutants and its characteristics

Pollutants are chemicals or agents, natural or man-made that enters the environment and cause harm or discomfort to living species, ecosystems, or human-made structures. They can be gasses, liquids, or solids, and their presence can have a variety of negative consequences on both the environment and human health. Many contaminants enter the environment in various ways, have diverse and sometimes unique health impacts, and are present in varying concentrations. It is difficult to summarize these for each chemical, however they may be found on the individual pages for each pollutant. Pollutants can be divided into three categories based on the phase with examples:

a) **Solid:** Solid materials include metals, polymers, wood, leaves, human and animal waste, among others.

b) **Liquid:** Liquid oil and other petroleum particles (e.g., gasoline, diesel, kerosene), human/animal excrement, chemicals (e.g., acids, bases), etc.

c) **Gaseous:** Gases include hydrogen supplied, carbon dioxide, carbon monoxide, nitrogenous gases (NOx), sulfurous gases (SOx), and so on.

d) **Biological:** pollen, bacteria, fungi, worms, viruses, and so on

On the basis of their chemical composition it may be

a) **Inorganic Pollutants**: Inorganic pollutants are primarily composed of heavy metals, which are harmful or dangerous even at low quantities. Examples of heavy metals include arsenic, mercury, lead, and chromium. They can enter the body via water, food, or air, causing health problems. Inorganic gases pollutants are also noxious gases pollutants like NO_x, SO_x, CO, H_2S, NH_4^+, Cl, HF, NCl, PO_x, NCN, Br, and mercaptonetc.

b) **Organic Pollutants**: Organic pollution is a form of chemical pollution generated by carbon pollutants such as liquid manure, sewage treatment sludge, and DDT. It is also persistent in nature and is harmful substances that harm human health and the environment worldwide. Most POPs manufactured in one country can and do impact people and wildlife far from where they are utilized and released, as they can be transferred by wind and water.

On the basis of existence in nature

a) **Quantitative Pollutants:** Quantitative pollutants are compounds that are naturally present in the environment but are classified as pollutants when their concentration (quantity) increases owing to human activity. Carbon dioxide is a typical quantifiable pollutant; consider smog caused by car emissions and fossil fuel consumption in cities.

b) **Qualitative pollutant:** This category includes compounds that are not naturally present in the environment, but are generated by people and pollute it. For example, pesticides, insecticides, etc.

On the basis of the form in which they persist

a) **Primary pollutants:** Pollutants are defined as any physical or chemical element that has a negative impact on living beings or nature. Any substance that is generated or emitted from a source is known as a primary pollutant. Primary pollutants can be caused by natural events (such as sandstorms and volcanic eruptions) or by human activity. For example, prominent primary pollutants include smoke, fumes, ash, dust, sulphur oxides, nitrogen oxides, carbon oxides, particulate matter, methane, ammonia, chlorofluorocarbons, toxic metals etc.

b) **Secondary pollutants:** Secondary pollutants are contaminants that form in the atmosphere. These pollutants do not come directly from a source (such as a vehicle or a power plant). Instead, they arise when pollutants produced from these sources combine with molecules in the atmosphere to produce a new pollutant. Primary pollutants are those that are discharged into the environment directly from a source. Smog, ozone, sulphur trioxide, nitrogen dioxide. Photochemical song, organic aerosol (haze) are examples secondary pollutants.

On the basis of disposal

a) **Bio-degradable:** Bio-degradable pollutants are those that disintegrate naturally, such as residential or municipal sewage. Natural organic compounds can be lowered to safe levels through decomposition, removal, or consumption. Natural mechanisms such as biological or microbiological action, as well as manmade systems like sewage treatment plants, can affect levels. Degradable pollutants fall into two categories:

   i. ***Rapidly degradable or non-persistent pollutants:*** Rapidly degradable or non-persistent pollutants are degrading quickly. Sewage and garbage from animals and plants decompose more quickly. Domestic wastewater can be swiftly decomposed by natural processes. However, issues arise when the input into the environment exceeds the breakdown capacity.

   ii. ***Slowly Degradable or Persistent Pollutant***: These toxins degrade slowly. Pollution levels appear to remain constant throughout time. Degradation of manufactured chemicals and radioactive elements, such as Iodine 137, Strontium 90, and Plutonium 239,are takes long time for degradation

b) **Non-biodegradable pollutants:** Non-biodegradable pollutants are toxins that do not breakdown naturally or degrade slowly, such as DDT or aluminum cans. These are not broken down by natural processes, such as the work of microorganisms. Most of these pollutants collect in the environment and are physiologically enhanced when they pass through food chains in an under-composed condition. These can also react with other molecules in the environment to form poisons. These can be further subdivided into two further classes.

   i. **Waste:** e.g., glass, plastic, phenolics, aluminum cans, etc.

   ii. **Poisons:** e.g., radio-active substances, pesticides, smog gases, heavy metals like mercury, lead and their salts.

<u>Characteristics of pollutants</u>

1. Pollutants can be gases (e.g., carbon monoxide), liquids (e.g., oil spills), or solids (e.g., plastic waste), with varying chemical compositions that influence their environmental behavior and impacts.
2. Many pollutants are toxic in nature, which means they injure living beings such as humans, animals, and plants.

3. Some contaminants remain in the environment for long periods of time, accumulating and endangering ecosystems and human health.
4. Certain pollutants, particularly those that are fat-soluble, can accumulate in the tissues of living species as they ascend the food chain, resulting in larger concentrations at higher trophic levels.
5. Pollutants can travel through many environmental media, including air, water, and soil, spreading across large distances and damaging ecosystems well beyond their point of origin.
6. Pollutants can come from both natural causes, such as volcanic eruptions or wildfires, and human activities, such as industrial processes, transportation, agriculture, and waste disposal.

1.4. Source and sink of pollutants

In environmental science, "source" refers to the origin or point of release of pollutants into the environment, while "sink" refers to a location or process where pollutants are removed or stored from the environment. Pollution always has a source and a sink. The source is where pollution originates, i.e. where it is released into the environment. The sink is where the pollution ends up, which could be a portion of the environment or people or animals that are contaminated or injured. Source as the term is self-explanatory is the process where the pollutant is generated.

On the basis of origin of pollutant there are two sources:

- **Anthropogenic sources**-Fossil fuel burning, Cement production
- **Natural**-Volcanic eruption, dust storm, Lightning(in case of ozone)

On the basis of location of pollutant there are two sources

- **Point Sources:** These are specific, identifiable locations where pollutants are discharged into the environment, such as industrial facilities, wastewater treatment plants, or exhaust pipes from vehicles.

Non-point Sources: These are diffuse sources of pollution that are more challenging to identify and control, such as runoff from agricultural fields carrying pesticides and fertilizers, or urban runoff containing pollutants washed off from roads and parking lots during rainstorms.

On the basis of movement of pollutant there are two sources:

- **Stationary sources:** such as power plants, oil refineries, industrial facilities, and factories.
- **Area sources:** such as agricultural areas, cities, and wood burning fireplaces.

Sources and sinks determine the amounts of pollutants and greenhouse gases in the atmosphere. Chemical loss and deposition processes are examples of sinks, while direct emissions and chemical synthesis serve as sources. Some air pollutants, such as reactive nitrogen and ozone, have a deleterious impact on ecosystem health and soil carbon storage when removed from the atmosphere via deposition processes. Thus, determining the sources and sinks of air pollutants and greenhouse gases is critical for developing emission control measures to reduce air pollution, environmental damage, and climate change.

A sink is a location where a resource is used. It is the processes such as chemical loss and deposition. Sinks are a critical component in the continuing balance that determines the concentration of each greenhouse gas in the atmosphere. A carbon sink, for example, may be the ocean (which absorbs and stores carbon from other sections of the carbon cycle) or photosynthesis (which transforms atmospheric carbon to plant material).

- **Atmospheric Sinks:** The atmosphere can act as a sink for pollutants through processes like deposition, where pollutants are removed from the air and deposited onto surfaces via dry deposition (settling) or wet deposition (precipitation).
- **Water Bodies**: Bodies of water, such as rivers, lakes, and seas, can operate as pollutant sinks by settling contaminants out of the water column and accumulating in bottom sediments.
- **Soil:** Soil can act as a pollution sink through mechanisms such as adsorption (pollutants cling to soil particles) and microbial degradation (microorganisms break down pollutants into less dangerous compounds).
- **Biota:** Pollutants can be absorbed in living creatures through processes such as bioaccumulation and bio magnifications, allowing them to act as sinks.

Self-assessment questions

Q.1. Define pollutions and its types.

Q.2. Discuss the source of biodegradable pollutants

Q.3. What do you mean by Quantitative Pollutants

1.5. Classification of pollutants

Pollutants are classed in a variety of ways based on their source, chemical makeup, impact, and the environmental media affected. This is a common classification:

Primary vs. Secondary Pollutants:

- **Primary Pollutants**: Primary pollutants are compounds that are immediately released into the atmosphere from a variety of sources, contributing to air pollution. These contaminants have a negative impact on human health, ecosystems and the environment. Understanding their sources, characteristics, and implications is critical for reducing their negative effects and improving air quality. Pollutants are defined as any physical or chemical element that has a negative impact on living beings or nature. Any substance that is generated or emitted from a source is known as a primary pollutant. Primary pollutants can be caused by natural events (such as sandstorms and volcanic eruptions) or by human activity. For example, the key primary pollutants are Particulate matter, oxides of sulfur, oxides of nitrogen, oxides of carbon, particulate matter, methane, ammonia, chlorofluorocarbons and toxic metals etc.
- **Secondary Pollutants:** Secondary pollutants are not directly discharged into the atmosphere, but rather result from chemical interactions involving main pollutants, atmospheric elements, and other precursors. These molecules contribute to air pollution and have negative consequences for human health, ecosystems, and the environment. Understanding the production, sources, and effects of secondary pollutants is critical for successful air quality management and pollution control activities. One of the most frequent secondary pollutants is ground-level ozone (O_3), which is produced when nitrogen oxides (NOx) and volatile organic compounds (VOCs) combine in the presence of sunlight. Vehicle emissions, industrial activities, and natural sources all emit NOx and VOCs into the atmosphere. These precursors react photochemically, particularly in urban areas with significant traffic and industrial activity, resulting in the generation of ozone. Ground-level ozone can cause respiratory problems, worsen asthma, and harm crops and vegetation. When primary pollutants react in the atmosphere or with other pollutants, they produce secondary pollutants. Thus, secondary pollutants are those pollutants that are created after a certain source is released into the

atmosphere rather than being directly emitted from that source. Secondary pollutants are difficult to control since they are synthesized in numerous ways. Secondary pollutants can occur naturally in the environment and produce problems such as photochemical song. Other examples of secondary pollutants include ozone and secondary organic aerosol (haze). These are formed in the atmosphere through chemical reactions involving primary pollutants and other atmospheric components. Examples include ground-level ozone (O3) formed from nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight.

Chemical Composition:

- **Gaseous pollutants:** Gaseous pollutants are compounds in the form of gases that are released into the atmosphere by a variety of sources, contributing to air pollution. These pollutants have a major impact on human health, ecosystems, and the environment. Understanding their causes, features, and impacts is critical for efficient air quality management and pollution control. One of the most common gaseous pollutants is carbon monoxide (CO), a colorless, odorless gas created by incomplete combustion of carbon-containing fuels such as gasoline and wood. The primary sources of CO emissions are automobile exhaust, industrial activities, and household heating systems. CO interferes with the blood's ability to transport oxygen, causing headaches, dizziness, and even death in high amounts. Nitrogen oxides (NOx) are another type of gaseous pollution that includes molecules like NO2 and NO. NOx emissions come from combustion processes in automobiles, power plants, and industrial sites. These pollutants contribute to the production of ground-level ozone, acid rain, and secondary particle matter. Sulfur dioxide (SO_2) is produced by the combustion of sulfur-containing fossil fuels such as coal and oil, as well as industrial operations such as metal smelting and paper manufacture. SO_2 can cause respiratory difficulties, acid rain, and damage to vegetation and buildings. It contributes to the creation of sulfate aerosols, which have an impact on regional climate and air quality. Volatile organic compounds (VOCs) are a wide range of carbon-based substances that evaporate into the atmosphere. VOC emissions come from car exhaust, industrial processes, and household items like paints and solvents. VOCs lead to the development of ground-level ozone, secondary organic aerosols, and hazardous air pollutants, all of which are harmful to human health and the environment.

- **Particulate Matter (PM):** Particulate matter (PM) is one of the most frequent main pollutants, consisting of microscopic solid particles or liquid droplets hanging in the air. These particles vary in size and composition, with some visible (like dust) and others invisible (like smoke). Natural sources of PM include wildfires and volcanic eruptions, but human activities like as car emissions, industrial processes, and building also play a significant role. These are solid or liquid particles suspended in the air, including dust, soot, smoke, and aerosols.

- **Heavy Metals:** Heavy metal pollutants are metallic elements with high atomic weights that can impair both human health and the environment. Lead, mercury, cadmium, arsenic, and chromium are some of the most common heavy metals of concern. These contaminants enter the environment as a result of a variety of human activities, including mining, industrial processes, fossil fuel combustion, and inappropriate electronic waste disposal. Lead was historically widely used in gasoline, paint, and plumbing materials, but it is harmful to the nervous system and can cause developmental delays and cognitive impairment, especially in children. Mercury, which is predominantly emitted by coal-fired power stations and industrial operations, accumulates in the food chain and poses dangers to neurological development, particularly in fetuses and babies. Cadmium, which is emitted during industrial activities such as mining and battery manufacturing, can cause kidney damage and increase the risk of cancer with prolonged exposure. Arsenic, which occurs naturally in some geological formations and is generated during mining and agricultural operations, is a carcinogen that can pollute drinking water and food supplies. Chromium, which is utilized in a variety of industrial operations such as stainless steel manufacture, has been linked to respiratory problems and an increased risk of lung cancer.

- **Organic Pollutants:** Organic pollutants are substances that include carbon atoms linked to hydrogen atoms and are commonly obtained from live organisms or man-made sources. These pollutants have the potential to remain in the environment for extended periods of time, posing major threats to human health and ecosystems. Polycyclic aromatic hydrocarbons (PAHs) are a common organic contaminant produced by the incomplete combustion of organic materials such as fossil fuels, wood, and tobacco. PAHs are carcinogenic and can accumulate in soil, water, and air, endangering human and environmental health. Pesticides, which include insecticides, herbicides, and fungicides, are another type of organic pollutant frequently employed in agriculture to control pests and boost crop yields. These pesticides, however, can seep into groundwater, contaminate surface water bodies, and kill non-target creatures like as bees, birds, and aquatic life. Polychlorinated biphenyls (PCBs), dioxins, and furans are persistent organic pollutants (POPs) that were once widely utilized in manufacturing processes but have since been prohibited or limited due to their hazardous properties. Even at low quantities, these substances can bio accumulate in the food chain, causing health concerns to humans and wildlife.

Environmental Media Affected:

- **Air Pollutants:** Pollutants present in the atmosphere, including gases and particulate matter.
- **Water Pollutants:** Contaminants found in surface water bodies like rivers, lakes, and oceans, including chemicals, nutrients, and microbial pathogens.
- **Soil Pollutants:** Contaminants present in soil, such as heavy metals, pesticides, and industrial chemicals.
- **Noise Pollution:** Unwanted or harmful sound that disrupts the environment and affects human health and wildlife.

Effects on Health and Environment:

- **Toxic Pollutants:** Toxic pollutants are compounds that are harmful to human health, ecosystems, and the environment because of their inherent toxicity, persistence, and bioaccumulation. These contaminants can come from a variety of sources, including industrial processes, transportation, agricultural, and domestic items. Pollutants can have substantial health consequences even at low quantities. Lead exposure, for example, can result in neurological damage, developmental delays, and cardiovascular issues, whereas mercury can impede neurological development and harm the nervous system. Persistent organic pollutants (POPs) include polychlorinated biphenyls (PCBs), dioxins, and some pesticides. These compounds can remain in the environment for long periods of time, accumulate in the food chain, and have negative health consequences such as cancer, reproductive problems, and immune system suppression. Other toxic pollutants include volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and air toxics like benzene and formaldehyde, which can contribute to respiratory issues, cancer, and other health problems.
- **Greenhouse Gases:** Greenhouse gases (GHGs) are atmospheric gases that trap heat emitted from the Earth's surface, causing the greenhouse effect and contributing to global warming and

climate change. Carbon dioxide (CO_2) is the most abundant greenhouse gas (GHG), released mostly by the combustion of fossil fuels for energy production, transportation, and industrial operations. CO_2 persists in the atmosphere for centuries, building throughout time and contributing to long-term climate change. Other important greenhouse gas emissions include methane (CH_4) from cattle farms, rice paddies, landfills, and natural gas production. Nitrous oxide (N_2O), emitted by agricultural operations such as fertilizer use and livestock waste, as well as industrial processes and fossil fuel burning, is another powerful GHG that contributes to global warming. Human-made fluorinated gases, including hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF_6), are synthetic greenhouse gases used in refrigeration, air conditioning, and electronics. While they are present in lower concentrations than CO_2, methane, and nitrous oxide, they have exceptionally high warming potential and can greatly contribute to climate change if released into the atmosphere.

Self-assessment questions

Q.1. What do you means by primary pollutants?

Q.2. Discuss the chemical composition of Gaseous pollutants.

Q.3. What are GHG? Discuss its role in atmosphere.

1.6. Contaminants

Contaminants are compounds that exist in an environment where they do not occur naturally or where their presence surpasses natural levels, causing harm to human health, ecosystems, or the environment. Contaminants can come from a variety of sources, including industrial activity, agricultural practices, urban runoff, trash disposal, and natural processes like volcanic eruptions or rock weathering. They can take many forms, including chemicals, bacteria, heavy metals, and radioactive compounds. Contaminants endanger human health when exposed through the air, water, soil, food, or direct touch. To safeguard public health and environmental quality, pollutants are frequently managed and mitigated through monitoring, clean-up, and regulatory procedures. Pollutants are a subset of contaminants that particularly refer to compounds that cause harm or discomfort in the environment, whereas contaminants include a larger spectrum of substances found at increased levels in the environment. The basics different between pollutants and contaminants are following:

Pollutants	Contaminants
Pollutants specifically refer to substances or agents introduced into the environment that cause harm or discomfort to living organisms, ecosystems, or human-made structures. They can be natural or human-made and can include gases, liquids, or solids	Contaminants, on the other hand, refer to substances that are present in an environment where they are not naturally found or where their presence exceeds natural levels. Contaminants can include pollutants but also encompass other substances, such as microorganisms, heavy metals, and radioactive materials.
The term "pollutants" typically emphasizes substances that have adverse effects on the environment and human health, often due to their toxicity or persistence in the environment.	Contaminants" has a broader scope and can include substances that may not necessarily cause harm but are present in concentrations higher than natural background levels, raising concerns about potential impacts.

The term "pollutants" is commonly used in the context of environmental pollution and regulatory frameworks aimed at controlling and mitigating pollution.	Contaminants" is often used in scientific and technical contexts to describe the presence of unwanted substances in environmental media such as air, water, soil, and food.

1.7. Summary

Pollutants are chemicals or agents, either natural or man-made, that enters the environment and injures or disturb living creatures, ecosystems, or man-made structures. They might be gases, liquids, or solids, and their existence can have a variety of negative impacts on the environment and human health. In environmental science, the term "source" refers to the point at which pollutants are released into the environment, whereas "sink" refers to the site or process at which pollutants are collected or stored. Addressing main pollutants necessitates a combination of regulations, technical improvements, and public education initiatives. Strategies include raising vehicle emissions requirements, supporting greener energy sources, adopting pollution-control systems in industry, and encouraging sustainable agriculture practices. Secondary pollutants necessitate comprehensive air quality management methods that prioritize the reduction of precursor emissions such as NOx, VOCs, SO_2, and ammonia. Measures include enacting higher emissions rules for automobiles and industries, encouraging greener technologies and fuels, and reducing energy use through efficiency improvements. Pollutants are a subset of contaminants that particularly refer to compounds that cause harm or discomfort in the environment, whereas contaminants comprise a larger spectrum of substances that exist at increased levels in the environment. Heavy metal contamination necessitates rigorous laws on industrial emissions, proper waste management methods, and remediation initiatives to clean up contaminated locations. Monitoring and minimizing heavy metal exposure through water treatment and pollution control technologies is also critical to protecting public health and the environment. Organic pollutant contamination necessitates regulatory action to limit their use, promote safer alternatives, and establish pollution prevention and repair plans. Proper hazardous waste disposal and wastewater treatment are also required to reduce organic pollutant emissions and preserve the environment. Reducing our dependency on fossil fuels, switching to renewable energy sources, increasing energy efficiency, enhancing agricultural practices, and implementing laws and regulations that limit emissions are all necessary to combat GHG emissions. By setting emission reduction goals and promoting sustainable development practices, international cooperation and agreements—like the Paris Agreement—play a significant role in the fight against climate change.

1.8. Terminal questions

Q.1. What do you understand by pollution?

Answer:--

Q.2. What are pollutants? Define its characteristics.

Answer:--

Q.3. What are indoor and outdoor pollutants?

Answer:--

Q.4. Discuss the type's pollutants and their sources.

Answer:--

Q.5. What do you know about the source and sink of pollutants?

Answer:--

Q.6. What are the contaminants?

Answer:--

Q.7. Write the difference between pollutants and contaminants.

Answer:--

1.9. Further suggested Readings

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Unit-2: Water Pollution

Contents

2.1. Introduction

The planet continues to remind us that water is essential to life by causing more severe droughts. It is a resource that all living things rely on, and it is also necessary for all social and economic advancement, the generation of energy, and climate change adaptation. However, we are currently up against an enormous obstacle. How can we clean up our canals, lakes, reservoirs, seas, and rivers. When unwanted substances usually chemicals or microorganisms, enter a stream, river, lake, ocean, aquifer, or other body of water, the quality of the water is reduced and becomes dangerous for both humans and the environment. Pollution is a major cause of many illnesses and fatalities, especially in poor nations. Even in wealthy nations where piped water supplies guarantee that water pollution poses less direct risks to human health, many lakes and rivers are poisoned. Numerous factors can contribute to pollution, and these factors are frequently divided into point and nonpoint sources. Point source pollution originates from a single, easily identified source, such as a ship discharging waste or a sewer pipe. Water runoff collects dispersed pollutants from the ground and is the source of nonpoint source pollution. The World Health Organization (WHO) defines contaminated water as having had its composition changed to the point where it is no longer appropriate. In other words, it is contaminated water that is dangerous to drink or use for basic needs like farming and that also contains cholera, dysentery, diarrhea, typhoid, and poliomyelitis, which kill more than 500,000 people every year worldwide. Bacteria, viruses, parasites, plastics, phosphates, nitrates, pharmaceuticals, fertilizers, pesticides, and even radioactive elements are the main contaminants that can be discovered in water. Since these substances don't always result in a hue shift in the water, they are often unseen pollutants. Aquatic life and small amounts of water are assessed to determine the water quality. Sometimes nature is to blame, such as when mercury leaks from the Earth's crust and contaminates the oceans, rivers, lakes, canals, and reservoirs.

Objectives:

After reading this unit, the learner will be able to know

- the water pollution, water pollutant, it sources and effects on living beings.
- the physical and chemical properties of water and factors effecting the quality of water
- the effects of water pollutants on river water and potable water
- Measure and control of water pollution

2.2. Properties of water

The basic molecule known as water is created when oxygen and hydrogen combine in a 2:1 ratio. Water is said to be a universal solvent. Water, which has the chemical formula H_2O, is a reactive material with typical characteristics. Depending on the temperature, water exists in three different forms in nature: liquid, gas, and solid. Since water is a common and innocuous element in nature, it makes up between 70% and 90% of our bodies. The water in our bodies is associated with macromolecules and cell organelles that are necessary for the biological features of membranes, ribosomes, proteins, and nucleic acids, among many other components. Water is known to be an excellent solvent due to its polar nature. Because it is polar, water is known to be a great solvent. Water can produce two different kinds of ions: hydronium ions and hydroxide ions. Water molecules have partial positive and partial negative charges in their molecular form because they include hydrogen on one side and oxygen on the other. Water's nature makes it more reactive with other molecules. The molecular characteristics of water are unique. In comparison to other hydride molecules, the liquid phase of water has a high boiling temperature, melting point, vaporization, specific heat capacity, and surface tension. Equal electron sharing by covenant bonding forms the building blocks of water molecules. It features sp3 hybridization and hydrogen tetrahedral arrangement, which creates a net dipole in water with partially positive and partially negative charge characteristics at the ends of the molecules that contain the two hydrogen atoms and the unshared electron, as seen in Fig. Furthermore, because oxygen and hydrogen share electrons unevenly, hydrogen-oxygen bonds have a dipolar property. But because there is an equal amount of partially positive and negative charge on both sides, the molecule's net charge is zero. It is called a dipole molecule as a result. The exact H-O-H analysis is defined by spectroscopic and X-ray research as 104.5°, and the intra-atomic distance between hydrogen and oxygen is 0.0965 nm. Two molecules of water approach one another and experience electrostatic attraction because the hydrogen atom has a partial positive charge and the oxygen atom has a partial negative charge. In the same way that the positive charge of one water molecule's hydrogen atom attracts the negative charge of another water molecule's oxygen, the partially negative charge of one water molecule's oxygen atom repels the positive charge of another water molecule's hydrogen atom. The electronic range in both molecules was also redistributed in tandem with this. Hydrogen bonding is the term used to describe this interaction of the two hydrogen atoms. These are the only characteristics that give liquid water its remarkable internal cohesiveness. Compared to covalent connections, hydrogen bonding is comparatively weaker. Each water molecule has four neighboring hydrogen bonds. Since the water molecules are arranged in a tetrahedral pattern, their neighboring molecules likewise exhibit this configuration. Water molecules are attracted to one another through hydrogen bonds in the tetrahedral crystalline lattice of ice, which is really another form of water. Water molecules are cohesive despite having a low molecular weight (18 g/mole) and a high melting and boiling point. It is the ideal thermal agent for actively metabolizing cells and tissue due to its high specific heat and high evaporation. Hydrophilic molecules are those that dissolve readily in water and are typically charged, or polar molecules. Nonpolar solvents, however, dissolve nonpolar compounds like lipids and wax, among others, easily, but they are poor solvents for polar molecules. As an illustration, NaCl (polar) dissolves easily in water by stabilizing and hydrating the Na^+ and Cl^- ions. Aspartic acid, lactic acid, glucose, and glycine are examples of polar compounds that dissolve readily in water. Although the gases O_2, N_2, and CO_2 are non-polar by nature, in an aqueous solution, CO_2 gas produces carbonic acid (H_2CO_3). The gases H_2S and NH_3 both dissolve in water and are important to organisms biologically. These inherent attractions are modest and non-specific. It was created when two charged atoms stood closely together at 3–4 Å. They play a significant role in biological systems but are weaker and less specific than hydrogen bonds and electrostatic bonds. Van der Waals forces, which result from an atom's bounding electrons being attracted to other molecules, are present in all forms of molecules. There is very little attraction between two atoms while they are far apart; this attraction increases as the atoms draw closer. It must be known that lots of properties of water molecules are govern by its uncharged form as (H_2O). While to understand their properties we should know the ionization of water as to hydrogen ion $[H^+]$ and hydroxide ion $[OH^-]$.

2.3. Water pollution

The discharge of contaminants into lakes, streams, rivers, estuaries, and oceans that are so enormous as to obstruct ecosystems' natural processes or the water's useful applications is known as water pollution. When substances that could be harmful to human health or the environment contaminate water bodies, including rivers, lakes, or wetlands, this is known as "water pollution." This kind of pollution is a major global cause of disease and death, particularly in developing countries. Many lakes and rivers are contaminated, even in affluent countries where piped water supply ensure that water pollution offers less direct dangers to human health. The only fresh water that is readily available and fit for human consumption comes from lakes, streams, and the like. But if it had been of excellent quality, the percentage of it would have been enough to meet the needs of living things. Nonetheless, one of the most important environmental issues is water contamination. Water becomes contaminated when it comes into contact with things like oil, heat, hazardous industrial chemicals, leftovers from agriculture, and wastes from people and animals. The majority of our water resources, including subsurface water reserves and ponds, lakes, streams, rivers, seas, and oceans. Numerous factors can contribute to pollution, and these factors are frequently divided into point and nonpoint sources. Point source pollution originates from a single, easily identified source, such as a ship discharging waste or a sewer pipe. Water runoff collects dispersed pollutants from the ground and is the source of nonpoint source pollution. Water gets polluted naturally as well as intentionally or man-made reasons. For example fluoride a severe pollutant, which causes knock-knee disease, occurs naturally in water bodies but it also results from industrial operations such as ceramic businesses, phosphate fertilizer plants and aluminium manufacturers. In India, the agricultural sector uses around 84% of water, the industrial sector 12%, and the household sector 4%. Despite our seventy seven years of independence. It is not fortunate for Indians to have access to safe and clean drinking water. The water problem is one of the biggest issues facing the country and the world. Pure, safe, and clean drinking water is unavailable to more than 60% of Indians. Water pollution can come from a variety of sources, such as chemical or oil spills, industrial waste, fertilizers and pesticides that wash off agricultural land into rivers, sewage that ends up in rivers and seas, heavy metals that seep out of the earth or plastics that decompose in water.

2.4. Source of water pollution

There are numerous ways and sources of water pollution. Water pollution from feedlots, pastures, and croplands may be a result of agriculture. Landfills, mining, and oil drilling might all be significant contributors to water contamination. Construction, industry, and storm and sanitary sewers are other human-caused sources of water contamination. There are other causes of surface water pollution, but the two main ones are as follows:

(a) **Point and Non-point Sources:** The phrase "point source pollution" refers to contamination originating from a single source. Examples include septic system leaks, oil and chemical spills, illegal dumping, and wastewater (sometimes called effluent) that is released by a business, oil refinery, or wastewater treatment facility, either legally or illegally. Sources that directly release pollutants or effluents into different freshwater bodies are known as point sources. Domestic and industrial trashes are two examples of this type of garbage. A facility's discharge into a body of water is subject to EPA regulations to prevent point source contamination. The non-point sources of contaminated water, on the other hand, are dispersed or cover a wide region. The majority of the poisons found in lakes and streams come from this kind of source, which disperses pollutants indirectly through changes in the ecosystem. Nonpoint causes of pollution include diffuse types of contamination. These could be storms, agricultural runoff, or rubbish that is blown into streams from the land.

(b) **Natural and Anthropogenic Sources:** Another word for pollution is an increase in the concentration of naturally occurring chemicals. Natural sources are the origins of this rise. One such natural source is siltation, which comprises sand, soil, and mineral particles. Point sources are discrete and limited, such as home sewage systems or sewage from certain industries. These sources are easily recognized and can be monitored, in contrast to nonpoint sources, which are dispersed and dependent on various natural and anthropogenic causes, such as surface runoff from roads, streets, and rivers.

Self-assessment questions

Q.1. What makes water a polar molecule?

Q.2. What is water pollution?

Q.3. Name two sources of water pollution.

2.5. Causes of Water Pollution

Water is very vulnerable to pollution. Since water dissolves more substances than any other liquid on Earth, it is known as the "universal solvent." That's why we have Kool-Aid and bright blue waterfalls. For the same reason, water becomes contaminated so easily. Toxic elements from farms, cities, and factories can dissolve into and combine with water, causing pollution.

- **Untreated sewage water**: The UN says that a startling 80% of wastewater worldwide is re-released into the environment untreated, utilizing advanced monitoring techniques. As a result, it is without a doubt the primary cause of water pollution, exposing nearby plants, animals, and people to possible pathogens that are present in contaminated drinking water sources.
- **Agriculture Runoff:** Fertilizers, insecticides, and herbicides, all of which contain chemicals have become essential for increasing agricultural yields and guaranteeing that there will be

enough food to feed everyone on the planet. Nevertheless, during and after times of intense rainfall, the nutrients in these products may be carried into rivers, lakes, and streams.

- **Oil spillages:** Since the world has been relying on fossil fuels for a large portion of its energy needs for centuries, it should come as no surprise that there have been a number of high-profile instances of oil spills causing water pollution. Thousands of animals perished in the 2010 Deepwater Horizon explosion, which was an exceptionally horrific event.
- **Dumping:** While scientific and technological advancements made by humans in recent decades have been impressive, these advancements have not come without a cost. Regretfully, a lot of individuals just toss stuff out, which allows it to wind up in our water sources, without considering the environment when doing so.

2.6. Categories of Water Pollution

Groundwater: In essence, underground water reserves known as aquifers are filled by precipitation that percolates into the ground through cracks, fissures, and other porous areas. One of our most precious but least visible natural resources, groundwater, is produced by this process. Nearly 40% of Americans get their drinking water from groundwater that is pumped to the earth's surface. In isolated places, it is some people's only source of freshwater. When contaminants, such as fertilizers and pesticides, as well as waste from septic tanks and landfills, seep into an aquifer, the groundwater becomes unfit for human use. Groundwater pollution removal can be costly, difficult, or even impossible. Contaminated aquifers may remain unusable for hundreds or even thousands of years.

Surface water: The blue regions on an Earth map, such as rivers, lakes, and oceans, are fueled by surface water, which comprises more than 70% of the world. In the United States, sources other than the ocean, or freshwater, provide more than 60% of the water used in homes. But there's a whole lot of that water at risk. Nearly half of our rivers and streams and more than one-third of our lakes are contaminated and unfit for swimming, fishing, or drinking, according to the most recent national water quality measurements from the U.S. Environmental Protection Agency. In these freshwater sources, nutrient pollution, which includes phosphates and nitrates, is the most prevalent type of contamination. Despite being essential for plant and animal growth, these nutrients have become a major source of pollution due to fertilizer runoff and farm waste. Additionally, industrial and municipal waste sources release toxins into the environment. There is also the careless waste that corporations and individuals dump directly into rivers.

Ocean water: Eighty percent of marine pollution, often known as ocean pollution, originates on land, either along the coast or far inland. Pesticides, fertilizers, and heavy metals are among the pollutants that streams and rivers transport from towns, farms, and industries into our bays and estuaries before being released into the ocean. Meanwhile, storm drains and sewers allow wind-borne marine debris, particularly plastic, to enter. Furthermore, our oceans are continuously receiving carbon pollution from the atmosphere due to periodic degradation caused by small- and large-scale oil spills and leaks. The ocean absorbs up to 25% of the carbon emissions that humans emit.

Self-assessment questions

Q.1. How agriculture runoff effects water?

Q.2. Examples of hazardous chemicals that seep into water?

Q.3. What is the most significant cause of water pollution?

2.7. Types of water pollutions

When foreign substances contaminate our rivers, lakes, reservoirs, streams, oceans, or seas and adversely affect their quality, it is referred to as water pollution. However, depending on the specific body of water and the amount of contamination present, this phenomenon can take on a variety of shapes. Water pollution can be categories into two types

- **Fresh water pollution**
- **Marine water pollution**

2.7.1. Fresh water pollution

The term "freshwater pollution" describes the introduction of toxic materials into freshwater sources, such as lakes, streams, rivers, and groundwater, rendering them unfit for human consumption, recreational use, farming, or the maintenance of aquatic life. Freshwater pollution mostly affects inland bodies of water, as opposed to marine contamination, which affects oceans and seas. Industrial discharges, agricultural runoff, urban runoff, wastewater disposal, and mining activities are significant sources of contamination in freshwater. Some of the major types of water fresh water pollution afflicting the world today are:

- **Surface water pollution**: Surface water pollution occurs when a pollutant finds its way into a lake, pond, or river. Pathogens, nutrients, plastics, chemicals (heavy metals, pesticides, antibiotics), discharges of industrial waste, and people disposing of waste into streams are the main causes of surface water pollution. One of the main causes of surface water contamination is urban storm water runoff, which also has the ability to contaminate groundwater. These pollutants show seasonal fluctuations in their concentration and distribution, which are dependent on a number of factors.
- **Groundwater pollution:** This is a reference to the enormous H_2O reserves found in underground streams and reservoirs. Groundwater can eventually become contaminated when chemicals, heavy metals, and other pollutants are allowed to seep into the soil.
- **Surface water pollution:** Water pollution can be of two types: point source (originating from a specific location, like an oil tanker spill or industrial effluent) or non-point source (arising from multiple locations, like precipitation, flooding, or agricultural runoff). This is arguably the most prevalent type of pollution that affects water bodies.
- **Chemical pollution:** This can happen in any of the situations mentioned above, but chemicals are the particular pollutant in question. Since these materials are frequently utilized in so many different daily human activities, some chemicals will inevitably find their way into our water supplies through washing.
- **Nutrient pollution:** There are elements in certain compounds, such phosphate, nitrogen, and ammonia. These substances have the potential to disrupt the balance of nutrients in the water and favor the growth of certain species over others when they enter aquatic ecosystems.
- **Microbiological pollution:** This kind of pollution doesn't always have negative effects and can happen spontaneously. However, higher concentrations of microorganisms (viruses, bacteria, and protozoa) in the water are a result of industrialization and human density. Many of these microbes have the potential to spread fatal illnesses.
- **Suspended matter pollution:** Particles that are either too large or too persistent to dissolve in water are referred to as suspended matter pollution. Normally, these pollutants either sink to the bottom of the water in the form of sludge or build up on the surface as a thick scum.

2.7.2. Marine water pollution: The term "marine water pollution" describes the discharge of dangerous materials into seas, oceans, and other saltwater bodies, which has a negative impact on ecosystems, human health, and marine life. Human activity on land and in the ocean is one of the many possible origins of this pollution. The following are some of the main causes of pollution in marine waters:

- **Oil Spills**: Illegal oil dumping, shipping mishaps, and unintentional or intentional releases of crude oil or refined petroleum products can have catastrophic consequences on marine ecosystems. When oil covers the water's surface, fish, seabirds, marine animals, and other aquatic life are all harmed. Additionally, it can contaminate coasts, causing environmental harm that lasts a long time.
- **Plastic Pollution:** One of the main causes of marine pollution is plastics, especially single-use products like bottles, bags, and packaging. A lot of the time, incorrect disposal, littering, or insufficient waste management systems allow plastic garbage to end up in the ocean. Plastics degrade into smaller fragments in the water known as micro plastics, which marine creatures consume and which can build up throughout the food chain to threaten the health of the ecosystem.
- **Chemical Contamination:** A variety of chemical contaminants can be introduced into maritime habitats by shipping operations, sewage discharges, industrial activities, and agricultural runoff. Pesticides, fertilizers, industrial chemicals, heavy metals, and medications are some examples of these contaminants. Chemical pollution can harm marine life, upend marine ecosystems, and pollute seafood that is eaten by humans, posing a health risk.
- **Nutrient Pollution**: The process of eutrophication, or nutrient enrichment in marine environments, is brought on by an abundance of nutrients from sewage discharge, industrial operations, and agricultural runoff. This may lead to detrimental algal blooms, a decrease in oxygen levels, and the deterioration of coastal environments including seagrass beds and coral reefs. Fish deaths, a decrease in biodiversity, and a decline in water quality can all result from eutrophication.
- **Marine Debris:** Metals, glass, rubber, wood, and other types of trash also have an impact on marine environments, in addition to plastics. Ghost gear, or abandoned or lost fishing gear, is a persistent environmental hazard to marine life that can entangle marine animals, harm coral reefs, and linger in the ecosystem for years.

Self-assessment questions

Q.1. What are the main types of water pollution?

Q.2. How does chemical pollution affect aquatic life?

Q.3. What are some common sources of microbiological contamination in water?

2.8. Effects of water pollutants

2.8.1. On River water.

Water pollution can affect river water in a wide range of ways, affecting human health as well as the ecosystem. Here are a few outcomes:

- **Aquatic Life:** Industrial chemicals, herbicides, heavy metals, and other pollutants can be harmful to aquatic life. They have the ability to interfere with fish, invertebrates, and other aquatic animals' growth, development, and reproductive processes. Certain pollutants cause bio magnifications when they travel up the food chain by building up in the tissues of living things, which eventually affects higher trophic levels.

- **Biodiversity Loss:** The variety of aquatic species that live in rivers might decrease as a result of water pollution. Pollution-sensitive species may disappear, resulting in a decline in biodiversity and an ecological imbalance. The entire ecosystem may be impacted by this loss, which could have a domino effect on energy flow, nutrient cycling, and ecological stability.

- **Habitat Degradation:** River ecosystems can be negatively impacted by sediments, fertilizers, and pollutants. This can lead to the death of plants alongside riverbanks, changes to stream channels, and disturbance of riparian zones. As a result of habitat degradation, aquatic creatures have less access to adequate habitat, which lowers ecosystem resilience and causes population decreases.

- **Altered Water Quality:** Pollutants can lower the pH, temperature, turbidity, and dissolved oxygen levels in rivers, among other factors that affect water quality. Overnutrient inputs can cause eutrophication, which can result in fish mortality, oxygen deprivation, and algal blooms. Chemical contaminants have the ability to change the pH balance of water, rendering it unfit for use by some species.

- **Economic Impact:** impact aquaculture and fisheries, resulting in lower fish stocks and financial losses for fishing communities. Furthermore, expensive treatment procedures might be necessary to make contaminated water acceptable for consumption and other applications. Deteriorated water quality and diminished aesthetics may also have an adverse effect on tourism and leisure activities.

- **Ecosystem Services Lost:** Rivers offer a variety of ecosystem services that are vital to human welfare, such as flood control, nitrogen cycling, water supply, and recreation. These functions can be jeopardized by water pollution, which also lowers ecosystems' resilience and capacity to support human populations.

2.8.2. On Potable water: Potable water, or water fit for human consumption, can suffer greatly from contaminants in the water. These effects have the potential to affect water treatment procedures, endanger human health, and require expensive interventions to guarantee the security and caliber of drinking water. A multifaceted strategy is needed to address water contaminants in drinkable water. This strategy should include public education and awareness campaigns, strong water treatment procedures, pollution control measures, source water protection, and monitoring and testing procedures. We can preserve water resources, protect public health, and guarantee that everyone has access to safe and clean drinking water by controlling and reducing water pollution. The following are some of the main ways that water pollution affects drinkable water:

- **Health Risks**: When ingested, contaminants such bacteria, viruses, protozoa, and chemical pollutants can lead to a variety of waterborne illnesses and health issues. Among the pathogens that can cause vomiting, diarrhoea, and other infections include Giardia, Cryptosporidium, and Escherichia coli (E. coli). Chemical pollutants, including industrial chemicals, pesticides, heavy metals, and disinfection by-products (DBPs), can have long-term negative impacts on health, including cancer, as well as acute poisoning.

- **Taste and Odor:** Some pollutants can give drinkable water strange tastes, smells, or colors that make it unappealing and unfit for human consumption. Consumer acceptance of tap water can be negatively impacted by unpleasant tastes and odors caused by organic compounds, chemicals generated from algae, and industrial contaminants.

- **Water Treatment Challenges:** It may be difficult for water treatment facilities to adequately eliminate or neutralize some of the contaminants found in sources of raw water. Disinfectants such as chlorine can react with pollutants such as dissolved organic matter, pharmaceutical residues, and disinfection by-products to generate hazardous by-products. Certain pollutants, like emerging contaminants and micro plastics, might also be difficult to eliminate with standard treatment procedures, necessitating more sophisticated approaches.

- **Increased Treatment Costs:** In order to treat contaminated water to satisfy potable water requirements, more treatment procedures, specialized equipment, and higher operating costs are frequently needed. To efficiently remove certain contaminants, advanced treatment techniques such filtration, ozonation, activated carbon adsorption, and membrane technologies could be required. Utility and consumer prices for water treatment may increase as a result of these treatment modifications.

- **Infrastructure Degradation:** A number of pollutants, including industrial wastes and corrosive chemicals, can harm the pipelines, pumps, and storage tanks that make up the water distribution infrastructure. Infrastructure deterioration and scaling can raise maintenance and replacement costs for water utilities, cause leaks and water loss, and impair the quality of the water.

- **Public Perception and Trust**: Events involving contamination and water quality issues might make people less trusting of municipal utilities and water supply. The belief that the water is unsafe for consumption can make people rely more on bottled water, home filtration systems, or other sources of water, which can have negative effects on the environment and increase expenses.

- **Environmental Impact**: Beyond issues with human health, pollutants released into water sources may have downstream effects on the ecosystem. Aquatic ecosystems are susceptible to contaminant accumulation, which can have an impact on biodiversity, aquatic life, and ecosystem function. Nutrients and chemical contaminants can cause eutrophication, algal blooms, and oxygen depletion, which can cause habitat loss and ecological deterioration.

2.8.3. On human health.

Water pollution is lethal. It was actually the cause of 1.8 million deaths, according to a 2015 study that was published in The Lancet. Additionally, drinking tainted water can make you sick. Approximately 1 billion people get sick from drinking tainted water every year. Moreover, low-income communities are disproportionately vulnerable since their homes are often closest to the most polluting businesses. Waterborne pathogens, which are bacteria and viruses that cause disease and are found in human and animal waste, are one of the primary sources of illness from contaminated drinking water. Giardiasis, cholera, and typhoid fever can all be spread via contaminated water. Hazardous microorganisms can contaminate rivers in affluent countries by runoff from cities and farms, as well as accidental or unlawful releases from sewage treatment facilities. Every year, millions of Americans become ill with Legionnaires ‘disease, a severe form of pneumonia that is transmitted via water sources including cooling towers and piped water. Cases have been documented everywhere from Disneyland in California to the Upper East Side of Manhattan.

A sobering reminder of the possible risks connected to industrial and chemical contaminants in our water is provided by the situation facing the people of Flint, Michigan, where the recent lead contamination tragedy was caused by decaying water infrastructure and cost-cutting efforts. The problem goes far beyond Flint and is not limited to lead because a variety of chemical contaminants, such as pesticides, nitrate fertilizers, heavy metals like arsenic and mercury, and others, are contaminating our water sources. When these poisons are consumed, they can lead to a number of health issues, such as cancer, hormone imbalances, and cognitive impairment. Particularly at risk are youngsters and pregnant women. Even swimming it might be risky. According to EPA estimates, 3.5 million Americans are annually exposed to coastal waters contaminated with sewage, which can lead to hepatitis, pinkeye, skin rashes, and respiratory illnesses.

2.8.4. On the environment.

A complex web of bacteria, fungi, plants, and animals that interact directly or indirectly with one another is essential to the survival of healthy ecosystems. When one of these animals is harmed, it can have a cascading impact that threatens entire aquatic ecosystems. In a lake or marine setting, newly added nutrients stimulate the growth of plants and algae, lowering the water's oxygen content and producing an algal bloom. Lack of oxygen in the water, or eutrophication, can lead to "dead zones," or places with almost no life at all, and suffocate plants and animals. In certain cases, these harmful algal blooms can also release neurotoxins that harm animals, such as whales and sea turtles.

Self-assessment questions

Q.1. How do chemical pollutants affect human health?

Q.2. What impact do heavy metals like lead and mercury have on aquatic life?

Q.3. How does nutrient pollution contribute to algal blooms?

2.9. Control Measures of water pollution

Controlling water contamination is undoubtedly one of the most important issues. The world's vital water resources are becoming increasingly contaminated, and in the absence of swift and well-directed action, diseases, environmental degradation, and economic stagnation are all becoming worse. As one of the main contributors to water-borne illnesses, treating sewage is a crucial responsibility. The elimination of dangerous microbes, objects that needed oxygen, and suspended sediments were the main techniques used for a very long time to treat municipal waste in the form of sewage. The solid residue from sewage may now be disposed of more effectively thanks to municipal treatment methods. This waste water is treated in three stages: primary, secondary, and tertiary. During first treatment, a large amount of the sewage's suspended particles and inorganic material are eliminated. The secondary stage accelerates natural biological processes to remove organic material. If water is to be recycled, the third line of treatment is performed. Here, 99% of the sediments are removed, and several chemical processes are used to ensure that there are no toxins in the water.

(a) **Primary Treatment:** Waste water is treated by sedimentation, coagulation, and filtration before being dumped in a river or steam boiler. This is what we call primary treatment. The water must undergo tertiary and secondary therapies, which are further processing steps, if it is to be fit for human consumption. In order to treat water initially, the following steps are taken:

i. **Sedimentation:** Large tanks made specifically for that purpose are used to finish this step. In order to allow silt, clay, and other materials to fall to the bottom and allow water to gradually drain away, the contaminated water is allowed to settle. Fine particles must be removed in the next step because they don't settle.

ii. **Coagulation:** The process of mixing colloidal solution with tiny particles to create large particles is called coagulation. To finish this process, potash alum and additional special substances called coagulants, or flocculants, are added. The large particles are either moved to the next stage or sink to the bottom.

iii. **Filtration:** To filter out suspended particles, flocculants, bacteria, and other organisms, water is run through a bed of sand, finely divided coal, or fibrous materials. The term "sludge" refers to all of the impurities that are collected during these phases.

(b) **Secondary or Biological Treatment**: Further treatment is necessary if the water is unfit for human consumption. This is accomplished through secondary or biological treatment. A commonly used method that encourages the growth of different bacteria that need oxygen and nutrients is to let tainted water spread over a large bed of pebbles and gravel. A fast-moving food chain develops over time. The steps involved are as follows:

i. **Softening:** Hard waters that have undergone this treatment are free of unwanted calcium and magnesium cataions. Water is either run through cataion exchangers or treated with lime and soda ash to precipitate Ca2+ ions as carbonates. Water becomes softer as a result.

ii. **Aeration:** By pushing air through it, soft water is exposed to the air during this process, which gives the water more oxygen. This promotes organic matter's bacterial breakdown into innocuous by-products like carbon dioxide and water. Oxygen decreases carbon dioxide and other substances. Water quality is still unfit for human consumption. It is necessary to eradicate the harmful and other germs.

(c) **Tertiary Treatment:** Water is truly being disinfected by the tertiary treatment. The most often used disinfectant to eradicate bacteria is chlorine. Chlorine, however, also combines with organic debris that may be present in water to produce unwanted chlorinated hydrocarbons, which are hazardous and may cause cancer. Therefore, before flowing chlorine gas through water, it is preferable to minimize the organic matter in the water. Reverse osmosis, ozone gas treatment, and UV radiation are further disinfection techniques. Other approaches to addressing the issue of water contamination include:

(d) **Management Practices:** Reducing pollutant discharges and storm water velocity and flow are essential for effective management of urban runoff. Urban runoff is lessened by local governments using a range of storm water control strategies. These methods, referred to as best management practices, can be concentrated on enhancing water quality or controlling the amount of water used.

(e) **Education or awareness:** The first step in tackling an issue is raising awareness of it. Increased public knowledge can have a beneficial effect.

Self-assessment questions

Q.1. What are the main stages of waste water treatment?

Q.2. How does coagulation help in the primary treatment of wastewater?

Q.3. Why is tertiary treatment important for water disinfection?

2.10. Summary

When dangerous substances are released into the environment, pollution results. Pollutants are the name for these dangerous substances. Natural pollutants include things like ash from volcanoes. They may also be the result of human activities, such as factory runoff or waste. A stream, river, lake, ocean, aquifer, or other body of water loses quality and becomes unsafe for humans or the environment when it is contaminated by hazardous materials, usually chemicals or bacteria. Our health is at risk due to the widespread problem of water pollution. When harmful substances are released into oceans, seas, and other marine ecosystems, they endanger marine life, destroy the environment, and pose health risks to people. This phenomenon is known as marine water pollution. Both land-based and ocean-based sources can contribute to the wide category of pollutants known as marine pollution. Every living creature depends on water to survive. Apart from domestic use, water is essential for farming, business, fishing, tourism, and other sectors. Water supply has reduced as a result of urbanization, industrialization, and population growth. Additionally, the water's quality is being damaged as a result of the increasing pollution. Both pollution and life eventually come down to personal choice. We can put up with dead rivers, beaches covered in sewage, and fish that is too toxic to eat. Alternatively, we may collaborate to maintain environmental cleanliness for the benefit of living things such as plants, animals, and humans. Each of us can contribute to the reduction of water pollution by using eco-friendly detergents, avoiding oil down the drain, using fewer pesticides, and other small actions. In order to preserve our rivers and oceans a little bit cleaner, we can also participate in community service by volunteering for beach clean-ups or rubbish pickups. Additionally, as nations and continents, we may work to enact legislation that will make pollution more difficult to commit to and lessen global pollution. Together, we can reduce pollution and improve the quality of life on Earth.

2.11. Terminal questions

Q.1. What is water pollution? Where does water pollution come from?

Answer:--

Q.2. Define the fresh water pollution and its effects on environments.

Answer:--

Q.3. How do we detect water pollution?

Answer:--

Q.4. What is eutrophication, what causes it and what are the dangers.

Answer:--

Q.5. Discuss the types of water pollution in India, it cause and effects.

Answer:--

Q.6. Discuss the control measure of water pollution.

Answer:--

2.12. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011.
2. A text Book of Environment Studies, Asthana, D. K. and Asthana, M. 2006, S. Chand &Co.
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Unit-3: Air Pollution

Contents

3.1. Introduction

Our planet's distinctive atmosphere serves as a support system. Air quality assesses the acceptability of air for breathing by humans, plants, and animals. A human inhales approximately 14,000 gallons of air per day. Poor air quality can impact current and future generations' quality of life by influencing health, the environment, the economy, and the livability of cities. Good outdoor air quality is essential to our health. A healthy environment is crucial for the right to life, affecting both humans and other species. Violation of the right to a healthy environment may result in a violation of the fundamental right to life. Pollutants have been shown to significantly impact life on the planet and are expected to continue to do so. Pollution has been shown to harm humans, animals, plants, and the environment. Chemicals released into the air eventually react with rain or snow, resulting in water and land pollution. Air pollution refers to the presence of contaminants such as dust, gas, mist, odor, smoke, or vapor in the outdoor environment that are harmful to human, plant, or animal life, or interfere with the enjoyment of life and property. Air pollution can be personal, occupational, or community-based. Personal air pollution can occur when individuals are exposed to dust, fumes, smokes, smog, or gases. Occupational air pollution occurs when an individual is exposed to harmful concentrations of aerosols, vapors, and gases in their workplace. Volatile compounds from the soil, as well as those that reach lakes and rivers evaporate and become air pollutants. Pesticides applied on land become air pollutants and settle on land or water due to wind transport. To facilitate conversation, it may be helpful to divide topics into categories. Air pollution has a significant impact on both humans and animals, including vegetation. Basic utilities such as clean air, water, nutritious food, clothing, and space are essential for a comfortable life.

Objectives:

After reading this unit, learner will able to know the

- The Ambient Air and atmospheric composition of air
- Air pollution: types, sources and its effect on living beings
- The causes of air pollution like acid rain and smog formation and its effects on nature and human beings
- Particulate matter and its characteristics measure, control and effect of air pollution

3.2. Ambient Air

Ambient air is the air that surrounds us in the Earth's atmosphere, usually outside and away from direct sources of pollution. Air is a mixture of nitrogen, oxygen, carbon dioxide, water vapors, and other gases that collectively form the atmosphere. The composition of air can vary depending on location and altitude, but on average, it is composed of, Nitrogen(N_2): 78.08%, Oxygen (O): 20.95%, Argon (Ar): 0.93%, Carbon dioxide (CO_2): 0.04%, Neon (Ne), Helium (He), Methane (CH_4), Krypton (Kr), Hydrogen (H_2), and Xenon (Xe): together they make up less than 1% of the atmosphere. There are also trace amounts of other gases, such as water vapor, ozone, and contaminants. It's vital to highlight those human activities, such as burning fossil fuels or industrial processes, can influence the composition of air, resulting in a rise in the concentration of greenhouse gases like carbon. Ambient air quality has a significant impact on both human health and the environment. Air quality can be impacted by pollutants produced by a range of sources, such as industrial processes, vehicle emissions, and natural events like wildfires. Carbon monoxide, sulphur dioxide, nitrogen oxides, particulate matter, ozone, and volatile organic compounds are examples of common pollutants. Cardiovascular diseases, respiratory difficulties, and other health problems can result from exposure to these pollutants. Environmental preservation and public health depend on ambient air quality monitoring and regulation. To reduce pollution levels, governments and organizations employ air quality monitoring stations and create regulations. Additionally, efforts to reduce emissions from industry, transportation, and other sources aim to enhance ambient air quality while reducing the adverse effects on the environment and human health.

What is ambient air pollution?

Ambient air pollution, according to the World Health Organization (WHO), is made up of potentially harmful particles that are emitted by homes, businesses, and vehicles. Fine particulate matter is the contaminant that affects human health the most out of all. Most fine particulate matter is produced by burning biomass, fuel in power plants, homes, businesses, and automobiles. Fine particulate matter is a contributing factor in 15% of ischemic heart disease and stroke, 8% of deaths from chronic obstructive pulmonary disease (COPD), and 25% of deaths from lung cancer, according to the World Health Organization. Modern technologies can be used to monitor airborne particles. These sensors track important regulatory criteria such ambient air PM-10 and PM-2.5 mass concentrations. Monitoring for aerosols and dust within a specific area, whether for research or routine input, can apply a range of industry-proven particulate matter technologies, including gravimetric sampling, light scattering, beta attenuation, and inertial weighing TEOM technologies.

National Ambient Air Quality Standards (NAAQS):

An air quality standard defines clean air by stating the highest concentration of a pollutant that can exist in outdoor air for a specific period of time without posing a health risk to the general public. The US Environmental Protection Agency (EPA) is mandated by the Clean Air Act Amendments of 1970 to set primary National Ambient Air Quality Standards (NAAQS) to safeguard public health and secondary NAAQS to safeguard plants, forests, crops, and materials from harm brought on by exposure to six air pollutants. Contaminants include lead, carbon monoxide, nitrogen oxides, sulphur oxides, particulate matter, and ozone. Identification of the contaminants, their emission sources, and their effects on the environment and human health are critical to the fight against air pollution. The National Ambient Air Quality Standards Gazette of India (E) has been modified by the Central Pollution Control Board. The following are the goals of air quality standards:

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

The table below compares air quality level recommendations from 2005 and 2021 for the contaminants listed above. These definitions help to understand the table:

Pollutant	Averaging time	Air quality levels as per 2005 guidelines	Air quality levels as per 2021 guidelines
PM2.5 µg/m³	Annual	10	5
	24-hour	25	15
PM10 µg/m³	Annual	20	15
	24-hour	50	45
O_3 µg/m³	Peak Season	-	60
	8-hour	100	100
NO_2 µg/m³	Annual	40	10
	24-hour	-	25
SO_2 µg/m³	24-hour	20	40
CO mg/m³	24-hour	-	4

Self-assessment questions

Q.1. What is ambient air?

Q.2. How does ambient air quality impact human health?

Q.3. What factors influence the composition of ambient air?

3.3. Air pollution

Pollutants in the atmosphere are referred to as "air pollution." Any solid, liquid, or gaseous material, including noise—that is present in the atmosphere in amounts that could endanger people, other living things, plants, property, or the environment is referred to as an air pollutant. Air pollution is also defined as any physical, chemical, or biological change in the air. Humans, animals, and plants are all greatly impacted by air pollution brought on by smoke, dust, and harmful gases. A certain proportion of gases are present in the atmosphere. An envelope of gases, the earth's atmosphere reaches a height of 200 kilometres. The atmosphere protects life on Earth from the harsh environment of outer space. The troposphere is the lowest atmosphere It accounts for approximately 70% of the atmosphere's mass. It has three types of gaseous components: major, minor, and trace.

It is hazardous to survival if the composition of these gases changes. Global warming is the term used to describe how this imbalance in the gaseous composition has raised the earth's temperature. Though it has long been a problem, air pollution was widely believed to only harm industrial urban regions. Due to its effects on the ozone layer in the stratosphere, the greenhouse effect, forest degradation, and the acidity of lakes and coastal waters, air pollution is now considered a global problem. The following are the causes of urban air pollution:

- power generation
- transportation
- industry, manufacturing, and processing
- residential heating
- waste incineration

Air pollution can be classified as personal, occupational, or community pollution. Exposure to dust, fumes, smokes, smog, and gases can be considered personal air pollution. Occupational air pollution refers to an individual's exposure to potentially dangerous concentrations of aerosols, vapors, and gases in his work environment. Community air pollution from various sources, chemicals, and variables has negative social, economic, and health impacts. Community air pollution impacts not just persons, but also the entire environment, including plants, animals, buildings, property, and wealth. Carbon monoxide, chlorine, halogenated solvents, hydrocarbons, hydrogen sulphide, nitrous oxide, and sulphur dioxide are the most common gaseous air pollutants.

Incineration produces several pollutants, including carbon monoxide (CO), sulphur dioxide (SO2), nitrogen oxides (NOx), volatile organic compounds (VOCs), suspended particulate matter (SPM), and metal particles. Additionally, waste incineration generates chlorinated dioxins and furans from the combustion of chlorine-containing organic compounds. Industrial installations include asphalt plants, boiling and heating systems, cement, fertilizer, mineral acid, paper, pulp, thermal and nuclear power plants, sewage treatment plants, and engineering facilities.

Stationary sources of urban air pollution include asphalt plants, boiler and heating installations, cement and fertilizer manufacture, mineral acid manufacturing, paper and pulp manufacturing, thermal and nuclear power plants, sewage treatment facilities, engineering workshops, and so on. Automobiles, including cars, scooters, trucks, and buses, contribute to air pollution on urban highways. An average adult requires approximately 14kg of air, 1.5kg of food, and 2kg of water every day.

A man can last 5 weeks without eating, 5 days without drinking, and only a few minutes without air. So, in order to survive, one must breathe in air. Humanity must preserve a clean and pollution-free environment. Air pollution impacts both humans and animals, including plants. Air pollution is a major environmental concern in today's society. Carbon dioxide in the atmosphere is primarily produced by combustion, fermentation, putrefaction, fog, and animal respiration. The level of CO2 in the atmosphere contributes to the greenhouse effect and global warming. If the proportion surpasses 1.5, it may result in nausea, headaches, depression, and other symptoms. CO2 concentrations of 5% or more can be fatal.

Self-assessment questions

Q.1. What is air pollution?

Q.2. How does air pollution affect human health and the environment?

Q.3. What are the main causes of air pollution?

3.3. Sources of air pollution

The majority of air pollutants originate from geophysical, biological, and atmospheric sources. They have a substantial impact on worldwide air pollution. This truth should not lead to complacency regarding man-made air pollution. In nature, biogenic contaminants are constantly released and disposed away. Life on Earth evolved in harmony with external stimuli. The steady state varies over hundreds of millions of years, much like climatic change. There are four major categories of air pollution sources:

- **Mobile sources** – such as cars, buses, planes, trucks, and trains
- **Stationary sources** – such as power plants, oil refineries, industrial facilities, and factories.
- **Area sources** – such as agricultural areas, cities, and wood burning fireplaces
- **Natural sources** – such as wind-blown dust, wildfires, and volcanoes
- **Man Made Sources-**such as population, deforestation, burning of fossil fuels and fires, emissions from vehicles, rapid industrialization, and agricultural activities.

Mobile sources of air pollution include emissions from automobiles and other modes of movement. These sources include automobiles, trucks, buses, motorbikes, airplanes, ships, railroads, and off-road equipment such as construction machines and agricultural vehicles. Mobile sources significantly contribute to air pollution in cities and suburbs, particularly in places with dense populations and large traffic volumes. The combustion of fossil fuels, particularly gasoline and diesel, in internal combustion engines is the principal cause of mobile pollution. These pollutants include NOx, CO, VOCs, PM, and greenhouse gasses such as CO_2. Mobile source emissions may also contain hazardous air pollutants such as benzene and formaldehyde, both of which are harmful to human health.

Stationary sources of air pollution are fixed installations or sources that exhaust pollutants into the environment from a single area. These sources can include power plants, industrial operations (such as factories and refineries), commercial businesses, domestic heating systems, and trash disposal sites. Stationary sources, as opposed to mobile sources, remain in the same position.

Stationary sources generate a wide range of pollutants, including sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOCs), particulate matter (PM), heavy metals (such as mercury and lead), and greenhouse gases (such as CO_2 and methane). The type and amount of pollutants discharged are determined by the activities and processes occurring at the source.

Area sources of air pollutants are diffuse or distributed sources of emissions that cover a vast geographic area rather than originating from a single location or facility. These sources all contribute to air pollution in a region, but their emissions are dispersed over a large area. Area sources can include a wide range of activities and sources, including: Residential heating, Commercial and institutional activities, Agricultural activities, Construction and land development activities and Road dust and transportation etc.

Natural causes of air pollution release a wide range of substances into the atmosphere through natural processes. These sources existed long before human activities had any significant impact on air quality. Some significant natural sources of air pollution include volcanic eruptions, wildfires, dust storms, biogenic emissions, and sea spray, among others. However, volcanic emissions include sulphur dioxide (SO_2), hydrogen sulphide (H_2S), carbon dioxide (CO_2), and ash particles, all of which can contribute to air pollution and have an impact on air quality across long distances. Wildfires triggered by lightning or other natural sources emit smoke, ash, and other pollutants into the atmosphere. Wildfire smoke contains particulate matter, carbon monoxide (CO), volatile organic compounds (VOCs), and other contaminants that can deteriorate air quality and endanger the health of adjacent communities. Dust storms can emit huge volumes of particulate matter and other pollutants into the atmosphere, resulting in poor air quality and limited visibility. Natural processes in forests, wetlands, and other ecosystems emit biogenic gases into the atmosphere, including volatile organic compounds (VOCs) and methane (CH4).Breaking waves and marine processes emit sea spray into the atmosphere, which contains salt particles, organic compounds, and other contaminants. Sea spray aerosols can have an impact on cloud formation, atmospheric chemistry, and air quality near coastlines.

Man-made sources include population growth, deforestation, fossil fuel combustion, car emissions, industrialization, and agriculture. Rapid population growth is a leading cause of air pollution. Pollution causes global warming and emits greenhouse gasses. This results in a rise in sea level. A rise in global warming raises the potential of lower food grain production. Population growth leads to decreased forest cover and loss of wildlife species. Deforestation affects the balance of CO_2 and O_2 in nature. Plants purify the air by absorbing CO_2 for photosynthesis and releasing O_2 for animal respiration, hence releasing CO_2 utilized by plants. Conventional energy sources include wood, coal, and fossil fuels. Coal, oil, and natural gas, also known as fossil fuels, generate around 97% of the energy used in homes and factories. Industries rely on fossil fuels like coal, wood, and petroleum to generate energy for machinery and other uses. The incomplete combustion of this fuel creates smoke with fine particles less than 100μ in diameter. These are carbon particles and metals. Dust, resins, tars, aerosols, solid oxides, sulphates, nitrates, and so on. Coarse particles more than 200μ in diameter. Gravity makes it easy to remove carbon particles and heavy dust from the air. This process produces nitrogen molecules such as NO, NO_2, and N_2O, as well as halogens and radioactive elements. Automobile exhaust contributes about 75% of total air pollution. Automobiles, including cars, scooters, motors, taxis, and trucks, generate toxic gasses such as carbon monoxide, nitrogen oxides, hydrocarbons, leaded gas, and particulate lead owing to incomplete combustion of gasoline and diesel. When exposed to sunlight, these gases combine with nitrogen oxides to generate photochemical smog. Chemical, paper, and pulp mills, metallurgical facilities and smelters, petroleum refineries, mining, and synthetic rubber are among the industries responsible for 20% of total air pollution. These industries release a variety of gases and chemicals in their smoke, both inorganic and organic. The most common pollutants include CO_2, CO, SO_2, H_2S, NO, NO_2, and so on. Biocides used in agriculture, such as pesticides, insecticides, and herbicides, contribute to air pollution by distributing hazardous substances via wind. Spraying crops pollutes the air, endangering human and animal health.

Self-assessment questions

Q.1. What are the natural sources of air pollution?

Q.2. How do human activities contribute to air pollution?

Q.3. What is the difference between primary and secondary sources of air pollution?

3.5. Types of air pollutants

There are two types of air pollutants:

Primary air pollutants

Pollutants are defined as any physical or chemical element that has a negative impact on living beings or nature. Any substance that is generated or emitted from a source is known as a primary pollutant. Natural occurrences (such as sandstorms and volcanic eruptions) as well as human activity can both produce primary pollutants. Primary pollutants include sulphur oxides, nitrogen oxides, carbon oxides, particulate matter, methane, ammonia, chlorofluorocarbons, hazardous metals, and others.

Secondary air pollutants

When primary pollutants react in the atmosphere or with other pollutants, they cause secondary pollutants to form. Thus, secondary pollutants are those pollutants that are generated after a certain source is released into the atmosphere rather than being directly emitted from it. Secondary pollutants are difficult to control since they can synthesize in a variety of ways. Secondary pollutants can naturally occur in the environment and produce problems, such as photochemical song, among others. Secondary pollutants include ozone and secondary organic aerosol (haze).

3.6. Acid Rain

The phenomenon known as "acid rain" occurs when acid precipitates as rain. The phrase "acid rain" was first used in 1872 by Robert Angus Smith. Because of the dissolved carbon dioxide, it has a slight acidity. An overabundance of H+ ions in a water solution is referred to as acid. Anions like $2SO_4$-and NO_3^-, as well as, to a lesser extent, Cl^- and organic anions like acetate (CH_3COO-) and format, are usually responsible for balancing hydrogen ions. In addition to being very acidic—that is, having a higher concentration of hydrogen ions than regular rain acid rain might appear as snow, sleet, fog, or dew. Both people and the ecosystem are harmed by acid rain. Fossil fuel combustion and vehicle emissions of sulphur dioxide and nitrogen oxides are the main causes of acid rain, also known as acid precipitation. Acid rain precipitation is also influenced by other natural occurrences, including forest fires, biological deterioration, oceans, and volcanoes. In Scandinavia, the effects of acid rain on freshwater bodies and plants were initially identified in the 1970s and 1980s. The chemical makeup of air pollutants and environmental moisture is what causes acid rain and acid precipitation.

Winds can carry SO_2 and NO_X over large distances and across borders, making acid rain a da nger for everyone, not just those living near these sources. Acidic deposition happens in two forms: dry deposition and wet deposition. Wet deposition is any type of precipitation that removes acids from the atmosphere and deposits them on the earth's surface. In the absence of precipitation, harmful particles and gasses stick to the ground as dust and smoke.

Wet deposition: Acid can fall as rain, sleet, hail, snow, or fog.

Dry deposition: Acidic gasses and particles are deposited on soil, vegetation, and water on the earth's surface.

Acid rain formation is a chemical phenomenon that occurs when air gasses released from various resources mix with water to generate acid rain. For example, nitrogen oxide reacts with oxygen to generate nitrogen dioxide, and nitrogen dioxide dissolves in water to form nitric acid, which is washed down as acid rain.

$$2NO(g) \quad + \quad O_2(g) \quad \rightarrow \quad 2NO_2$$

$$2NO_2(g) \quad + \quad H_2O\ (I) \rightarrow \quad HNO_2 + \ HNO_3$$

However, the major form of acid rain occurs when sulphur dioxide reacted with oxygen to form sulphur trioxide, which further dissolves in water to produce sulphuric acid.

$$SO_2(g) \quad + \quad {}^1/_2\, O_2(g) \rightarrow \quad SO_3(g)$$

$$SO_3(g) \quad + \quad H_2O(I) \rightarrow H_2SO_4\ (aq.)$$

Self-assessment questions

Q.1. What causes acid rain?

Q.2. How does acid rain affect the environment?

Q.3. What steps can be taken to reduce acid rain?

3.7. Particulate matter:

Particulate matter is a microscopic particle formed by air components. Particulate matter is a discrete mass of any liquid or solid material in the atmosphere with tiny dimensions. They range in size from 0.001 um to several hundred um and have a wide surface area, making them ideal for absorbing diverse inorganic and organic gaseous compounds, which boosts heterogeneous phase reactions in the environment, including scattering of life. Particulate matter influences the climate by forming clouds and smokes. It also absorbs solar radiation and reduces visibility. Particles floating in the atmosphere range in size from a few nanometers to tens of micrometers, spanning four orders of magnitude. Larger solid particles break up mechanically to generate the biggest particles, known as the coarse fraction (or mode). Wind-blown dust from mining operations, uncovered soil, unpaved roadways, and agricultural processes are examples of these particles. Approximately two thousand million tons of particulate matter are released annually by natural resources. Human activity releases about 450 million tons of particulate matter annually. Based on their size, industrial processes and other kinds of particulate matter are divided into the following groups:

Smoke: Smoke particulates are made up of solid and liquid particles ranging in size from 0.05 to 1.0 microns and are primarily emitted by vehicles.

- **Dust**: Dust is made up of small solid particles that range in size from 1 to 100 microns (u). Sand from sandblasting, sawdust from woodworking, coal, and other sources all contribute to the formation of dust particles.
- **Mists:** Mists are liquid particles generated by the condensation of a vapor with a size smaller than 10 microns. For example:

$$SO_2(\text{gas}) \rightarrow^{22\,°C} \quad SO_3\ (\text{liquid})$$

- **Spray:** It is composed of quid particles formed by the current liquid process of mechanical disintegration, such as atomization.
- Fumes: Fumes are typically produced through the condensation of various chemical reactions, such as sublimation, distillation, and calcinations.

Source of particulate matter:

The particulate matters are release from natural and anthropogenic sources

a) **Natural sources:** particulate matter release form different natural resources in which some are as volcanic actions, forest fire, wind, soil erosion etc. are sources of particulate matter.

b) **Anthropogenic sources:** combustion of fossil fuels, industrial operations, transportation, industrial fugitive process etc. is the sources of emission of particulate matter by manmade process.

There are two forms of particulate matter such as inorganic and organic particulate Matter:

Inorganic particulate matter: This is also two types such as physical and chemical. Physical methods involving in formation of particulate matter

- Dispersion process: mainly yield dispersion process example dusts.
- Adhesion of small particles by chemical process by yields particles of the size ranging from 10 u to 20 u.

- Natural resources also produce dispersed aerosols from sea sprays, windblown and dust during cultivation and volcanic dust etc.
- By coagulation, aggregation, separation, absorption also results in formation of particulates matter.
- Chemical methods involved in formation of particulate matter: they are generally originated from metallic oxides, sulphides and carbonates etc.

Organic particle matter:

- Organic particle matter comes from wind, automobiles, and vegetation.
- Polycyclic aromatic hydrocarbons (PAHs) such as chrysene, benzo fluoranthene, and benzo pyrine are examples of organic particulate matter that is carcinogenic.
- It is primarily found in urban environments and has an upper atmosphere concentration of approximately 20 ug/m3.
- PAHs are produced by the breakdown of high molecular weight compounds found in fuels and plant materials, resulting in $C_{10}H_{22}$. PAN compounds continue to be formed.

Self-assessment questions

Q.1. What is particulate matter (PM), and how is it classified?

Q.2. What are the health effects of inhaling particulate matter?

Q.3. How can particulate matter pollution be controlled?

3.8. Factors effecting air pollution

Certain factors exacerbate air pollution. Basically, these are characteristics that inhibit air circulation and concentrate air effluent in specific locations. The factors that are responsible to increase the concentration of pollutant in ambient air environment are

- Calm weather,
- High-level emission sources from sources
- Temperature inversions,
- Buildings and other contraction activities
- Rough road and narrow streets
- Old and unmaintained vehicles
- Population Growth
- Growth in Industrial Sector
- Growth in power sector
- Agricultural Waste Burning

On the other hand, a number of circumstances have been demonstrated to lower total air pollution levels. These are the variables that encourage air movement and eliminate pollutants. These include high-level emission sources like smoke stacks and rain, thick vegetation, and windy or turbulent weather.

3.9. Effects of Air Pollution on Environment

It is impossible to quantify the full scope of potential and actual damage produced by all types of air pollution. Air pollution has a significant impact on plant evolution by impeding photosynthesis in many circumstances, with substantial implications for the purification of the air we breathe. It also contributes to the development of acid rain, which is atmospheric precipitation in the form of rain, frost, snow, or fog that is produced by the combustion of fossil fuels and converted by interaction with water steam in the atmosphere. However, here are the primary consequences:

- **Global warming:** Global warming is expected to raise average global temperatures by 3°C to 8°C over the next 100 years if current trends continue. This will impact regional climates, plant and animal distribution, and disrupt agriculture and food production.
- **Formation of photochemical smog:** Photochemical smog is formed when pollutants like hydrocarbons and nitrogen oxides combine with sunlight. Photochemical smog is a gas mixture resulting from photochemical processes. The name "smog" is derived from two words: smoke and fog. It produces a yellowish brown haze, which decreases vision, especially during the winter. It emits toxic gases, causing respiratory problems and allergies.
- **Formation of Acid rain:** When sulphur dioxide and nitrogen oxides react with atmospheric water to generate sulphuric and nitric acids, acid rain is the result. When it rains, these acids fall. We call this phenomenon acid rain. Acid rain has a pH between 3 and 6. Nitric acid, sulphuric acid, and weak carbonic acid make up acid rain. Among its detrimental impacts on the environment are respiratory and skin conditions, decreased plant productivity, changes in soil pH, leaching, harm to aquatic life, and damage to marble structures and monuments (like the Taj Mahal).
- **Formation of Aerosols:** Aerosols are created through the dispersion of solid or liquid materials in the atmosphere. A thick layer of aerosols in the troposphere can block solar energy, influencing meteorological conditions. Aerosols are also deposited on the leaves, influencing photosynthesis. Aerosols spread organic metallic contaminants far and wide.
- **Ozone depletion:** Ozone (O_3) can be found in the stratosphere of the atmosphere. Ozone absorbs UV rays in the sun's energy, protecting us from their damaging effects. However, hydrocarbons such as chlorofluorocarbons. CFCs break ozone molecules, depleting the ozone layer. Ozone holes in the atmosphere allow UV radiation to reach the earth's surface. UV rays have been linked to greater rates of skin cancer in Australia and New Zealand compared to other places.

Self-assessment questions

Q.1. How does population growth impact air quality?

Q.2. What are the effects of air pollution on plants and animals?

Q.3. How does air pollution contribute to climate change?

3.10. Measure and control of air pollution

Various technologies and tools are used to sample and measure air pollution concentrations. Techniques include chromatography, infrared spectroscopy, fluorescence, spectrophotometry, and atomic absorption spectroscopy. Industries are mostly responsible for releasing pollutants that contribute to air pollution. Determining pollutant concentrations is crucial for analyzing pollution levels and implementing management strategies to improve the environment. Urban regions have a higher concentration of air pollutants than rural areas since they are closer to industries. Using proper methodology and analytical techniques in air studies can provide valuable information for estimating the qualitative composition of contaminants. It aids in understanding atmospheric dynamics and the interactions of certain contaminants. It also aids in determining the exposure rate and accumulation of contaminants in live organisms.

Controlling global air pollution will be a long-term challenge. Air pollution is addressed at various levels, including global, local, residential, and workplace. However, the effort is dispersed geographically, with programs primarily limited to wealthier nations. Here are some efficient strategies for controlling air pollution:

- Source Correction Methods
- Pollution Control equipment
- Diffusion of Pollutant in Air
- Vegetation
- Zoning

A. **Source Correction Methods:**

Industries contribute significantly to air pollution. Pollution can be prevented and reduced at the source. By carefully analyzing the early stages of design and development in industrial processes, approaches with the lowest potential for air pollution can be chosen to achieve air pollution management at the source. The source rectification methods are:

(i) Substitution of raw materials.

(ii) Process Modification.

B. **Pollution Control Equipment:**

Preventing pollutant emissions is not always effective for pollution control at the source. Then it is important to install pollution control equipment to eliminate the gaseous pollutants from the primary gas stream. Pollution control equipment includes:

- **Gravitational Settling Chamber:** These chambers remove particles larger than 50 µm from contaminated gas streams.
- **Cyclone separators:** Cyclone separators, also known as reverse flow cyclones, use centrifugal force to filter particulate debris from polluted gas
- **Fabric Filters (Baghouse Filters):** A fabric filter system passes polluted gas through a fabric to remove particle pollutants and allow clear gas to pass through. The particulate matter remains in the form of a thin dust coating on the insides of the bag.
- Electrostatic Precipitators: These devices remove electrically charged particulates from contaminated gases using an electrical field.
- Wet collectors, also known as scrubbers, remove particle contaminants from contaminated gas streams by converting them into liquid droplets. Common wet scrubbers include Spray Tower, Venturi Scrubber, and Cyclone Scrubber.

C. Pollutant Diffusion In Air:

Air pollution can also be controlled by diluting toxins in the atmosphere. Pollution occurs when the amount of pollutants released exceeds the environment's ability to absorb them. Small amounts of pollutants can easily diffuse into the atmosphere, making pollution less noticeable. Tall stacks can disperse pollutants in the high atmosphere, reducing ground-level pollution.

D. Vegetation:

Plants use CO2 and release oxygen during photosynthesis, helping to reduce air pollution. Certain plants, such as Ficus variegate and Phascolus Vulgaris may repair gaseous pollutants like CO. Pinus, Pyrus, Juniperus, and Vitis plants reduce air pollution by metabolizing nitrogen oxides. Plant plenty of trees, especially in high-risk locations for pollution.

E. Zoning:

Air pollution can be controlled through city planning. Zoning separates industries from residential areas. Heavy industries should not be positioned too close together. Establish new industries distant from existing ones wherever possible.

Self-assessment questions

Q.1.What are some common strategies to reduce air pollution?

Q.2. How can governments enforce air quality regulations?

Q.3. What role can individuals play in reducing air pollution?

3.11. Summary

Globally, air pollution is a serious environmental issue. When some contaminants are present in large amounts and cause harm or undesirable effects, air pollution occurs. These include adverse effects on the environment, property, and human health. Both natural and man-made sources have the potential to contaminate the atmosphere. Significant environmental degradation has occurred in recent decades as a result of population growth, urbanization, and industrialization. In excess of WHO air quality guidelines, harmful pollutants such sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and total suspended particulates matter (TSPM) are released (WHO, 2005). Emissions of pollutants from industry and automobile exhaust lead to discomfort, a rise in airborne diseases, a decline in productivity, and a degradation of urban areas' artistic and cultural legacy. Techniques for reducing air pollution involve the use of pollution control devices. By removing the pollutants and transforming them into less dangerous contaminants, control equipment recovers a valuable substance for future use. Cyclones, scrubbers, bag house filters, and electrostatic precipitators are common pieces of equipment used to capture tiny particles. Analytical techniques are used by continuous monitoring equipment to evaluate air pollution levels and their environmental effects. Air pollution may be tracked by these sensors both indoors and outside. Among the tools utilized are meteorological instruments, air meters, continuous emission monitoring, and concentration measurement.

3.12. Terminal questions

Q.1. What is the air pollution; discuss types, sources and its effects on environment.

Answer:---

Q.2. Discuss the ambient air quality and its role in nature.

Answer:---

Q.3. Discuss the Atmospheric composition of air.

Answer:---

Q.4. Discuss the various sources of air pollution.

Answer:---

Q.5. Discuss acid rain and its effects on human life.

Answer:---

Q.6. What are the particulate matters?

Answer:---

Q.7. Discuss the measure and control of air pollution.

Answer:---

3.13. Suggested Readings

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3. Atmosphere, Weather and Climate, Barry, R. G. 2003, Routledge Press, UK.

4. Ecology: Theories and Applications (4th Edition) by Peter Stilling; Prentice Hall.

5. Biodiversity: a beginner’s guide, john I. spicer, One world Publications.

Black-2

Introduction

Unit-4: This unit cover the physiochemical and biological characteristics of soil, factors influencing soil pollution, definition and causes of soil pollution, and measures of soil pollution.

Unit-5: This unit cover the noise pollution definition, noise exposure level, noise pollution impacts, noise pollution measurement, and noise pollution control.

Unit-6: This unit cover the radioactive pollution definition and sources, nuclear pollution, radiation sources, biological impacts of radiation, and control techniques.

Unit-4 : Soil pollution

Contents

4.1. Introduction

Soil is often defined as the earths loose surface as identifiable by the original rocks and minerals from which it is formed during the weathering process. The term SOIL was taken from the Latin word "SOLUM" that means FLOOR. Soil is the thin, outermost layer of the earth's stony surface. Soil's main components include air, water, minerals, organic and inorganic stuff. The soil's organic content is digested by microorganisms, resulting in biomass that is mixed in the soil, and the inorganic stuff is obtained by weathering of parent rocks.

Whitney (1892): Soil is a nutrient bin which supplies all the nutrients required for plant growth.

Hilgard (1892): Soil is more or less a loose and friable material in which plants, by means of their roots, find a foothold for nourishment as well as for other conditions of growth"

Dokuchaiev (1900): Russian scientist - Father of soil science - Soil is a natural body composed of mineral and organic constituents, having a definite genesis and a distinct nature of its own.

Joffe (1936): "Soil is a natural body of mineral and organic constituents differentiated into horizons - usually unconsolidated - of variable depth which differs among themselves as well as from the underlying parent material in morphology, physical makeup, chemical properties and composition and biological characteristics".

- For a Layman soil is dirt or debris
- For an Agriculturist soil is a habitat for plant growth (to grow crops)
- For a mining engineer, soil is the debris that covers the rocks.
- For a Civil Engineer, soil is a material that forms the road bed or home bed.

For a homeowner, soil is a mellow, loamy, or hard material.

Soil science is the study of soil as a natural resource on the earth's surface, including soil formation, categorization, and mapping, as well as the physical, chemical, biological, and fertility qualities of soils, and how these features relate to soil usage and management. The science that deals with soil as a natural resource on the surface of the planet, encompassing pedology (soil genesis, categorization, and mapping), physical, chemical, biological, and fertility aspects of soil, and these features in connection to their management for crop production.

Soil pollution is the poisoning of soil with abnormally high amounts of hazardous chemicals. It is a severe environmental concern since it poses numerous health risks. For example, exposure to benzene-rich soil raises the risk of developing leukemia. The image below depicts soil discolorations caused by pollution. It is critical to recognize that all soils include substances that are hazardous/toxic to humans and other living organisms. However, the concentration of such compounds in unpolluted soil is so low that they pose no damage to the surrounding ecology. When one or more of these poisonous compounds are present in sufficient concentrations to harm living organisms, the soil is considered to be polluted.

Soil pollution is a chemical degradation process that depletes fertile soils, with consequences for global food security and human health. Soil contamination impedes progress toward the Sustainable Development Goals (SDGs), which include attaining zero hunger, eradicating poverty, ensuring healthy lives and human well-being, slowing and reversing land degradation and biodiversity loss, and making cities safe and resilient. The majority of pollutants come from human activities and ends up in the environment as a result of unsustainable manufacturing chains, consumption patterns, or poor waste disposal procedures.

4.2. Soil pollution overviews

Soil pollution is defined as the presence of hazardous compounds (pollutants or contaminants) in soil in concentrations high enough to endanger human health and/or the environment. In other worlds, soil pollution refers to anything that contaminates the soil and lowers its quality. It occurs when contaminants degrade soil quality and make it uninhabitable for microorganisms and microorganisms that live in it.

Soil contamination or pollution can result from either human activity or natural causes. However, it is primarily owing to human activity. Pesticides, herbicides, ammonia, petroleum hydrocarbons, lead, nitrate, mercury, naphthalene, and other substances that are present in excess can cause soil pollution.

Even if the levels of contaminants in soil are not high enough to constitute a risk, soil pollution is defined as occurring when the levels of contaminants in soil exceed the levels that should naturally be present. Soils can get contaminated with a variety of substances as a result of both direct (point source pollution) and indirect (diffuse) inputs, such as flooding and air deposition. Polluted soils are also a secondary source of toxins into the surrounding air, surface waterways, groundwater, and, ultimately, oceans.

Soil is essential for providing nutrients and water to plants and animals. The nutritional power of soil is an indicator of its fertility. Soil productivity is defined as crop or animal biomass per unit area, whereas biomass yield is primarily determined by soil and crop management practices. Consequently, there exists a dynamic equilibrium between the crop and the soil. The disruption of this dynamic equilibrium causes soil degeneration, followed by deterioration. This is known as soil contamination. Thus, soil pollution is defined as the introduction of any type of materials or energy into the soil that causes a change in the soil's characteristics or, more broadly, its chemical or biological balance, which has a negative impact on plant growth and animal health.

Soil deterioration (pollution) is caused by both natural and human activity. Major human activities that have hastened soil contamination include soil exposure due to deforestation, overgrazing, intense cultivation, mining, various developmental activities (such as dam and industry construction), and solid waste disposal.

Soil erosion occurs as a result of these reasons, resulting in a loss of soil fertility and a decrease in the depth and volume of the subsurface water table. Landslides have become more common on the slopes of the Aravalli Hills and the Himalayas due to soil degradation. Soil erosion washes away the uppermost layer of soil, damaging not only the productivity of the eroded land but also other productive land by causing it to be deposited on top of it and so destroyed.

Soil pollution has increasingly become a big concern that we must address in order to create a healthier ecosystem. Weathering of the earth's crusts by various processes results in the production of soil, which accumulates over generations. The soil is home to a major portion of bacterial biodiversity, as well as other microscopic and macroscopic living organisms.

However, let us analyze our own country, India. The Indian economy is heavily reliant on agriculture. As a result, agriculture, fisheries, and cattle growth are all top priorities for Indians. As a result, in order to achieve surplus output, crops must be protected from damage caused by insects, weeds, rodents, and other crop diseases.

4.3. Sources of soil pollution

Soil contamination can be natural or man-made, and it can have occurred decades or recently. Certain contaminants are typically associated with certain activities, such as pesticide use in agriculture or radionuclides from nuclear power plants, while others may be created by a variety of pollution sources. Soil contamination sources are usually divided into two types: natural and artificial.

4.3.1. Natural Sources:

As the name implies, these are the natural resources that produce soil pollution. They include the following natural processes:

- **Soil erosion:** The wear and loss of a field's top soil layer is referred to as soil erosion. The physical stresses of wind and water on the soil, as well as agricultural techniques like tillage, are the main causes of soil erosion. In addition to lowering farmland productivity, soil erosion contaminates nearby lakes, marshes, and watercourses. Because of geological and pedological processes that are independent of human activity, soils naturally contain trace elements, radionuclides, asbestos, and other pollutants. For soil microbes, plants, and animals, certain elements, such as iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), nickel (Ni), boron (B), selenium (Se), and molybdenum (Mo) are essential micronutrients. There is no known metabolic function for other elements, such as lead (Pb), cadmium (Cd), and mercury (Hg). When there is no anthropogenic impact, trace elements, which are normally present in trace amounts, pose no health or environmental hazards. However, because of their very high concentrations of trace elements, several types of rocks are highly toxic to both humans and other animals. Weathering and pedogenetic processes can lead to increased concentration in soils.
- **Land Degradation:** Soil pollution from land degradation is a serious environmental problem that endangers ecosystems, agriculture, and human health. It happens when contaminants such as heavy metals, pesticides, industrial waste, and excessive fertilizers enter the soil, lowering fertility and production. Deforestation, overgrazing, unsustainable agricultural methods, and urbanization

contribute to land degradation by depleting topsoil, which is essential for plant development. Industrial activity and inappropriate waste disposal contribute greatly to soil contamination by releasing toxic substances into the environment. Overuse of chemical fertilizers and pesticides in agricultural areas causes poisons to accumulate and leak into the soil and groundwater, compromising food safety and water quality. Furthermore, mining activities deplete the soil of its natural vegetation, leaving barren, filthy landscapes. Soil contamination harms biodiversity by disturbing microbes and plants that keep the soil healthy. It also diminishes the soil's capacity to retain carbon, hastening climate change. Furthermore, dirty soil can impair human health by contaminating crops and water sources. To address soil contamination, sustainable land management methods must be implemented, as well as tougher waste disposal restrictions and the promotion of organic farming. Reforestation and bioremediation can help alleviate the effects of soil contamination while maintaining long-term ecological balance.

- **Landslides**: Soil pollution caused by landslides is a frequently disregarded environmental concern with serious effects for ecosystems and human livelihoods. Landslides happen when dirt, rock, and debris flow down slopes, which are frequently caused by natural phenomena like severe rains, earthquakes, or volcanic activity, as well as human activities like deforestation, mining, and construction. During a landslide, displaced soil and debris may transport contaminants from different sources, including industrial waste, agricultural chemicals, and sewage, into the surrounding region. These pollutants can contaminate previously unaffected soils, lowering fertility and affecting local ecosystems. Landslides may also expose underlying layers of soil containing naturally occurring harmful compounds, such as heavy metals, degrading soil quality even more. The aftermath of a landslide frequently causes sedimentation in rivers and water bodies, spreading contaminants downstream and damaging aquatic ecosystems and water supplies. Polluted soils reduce crop production and may endanger human health through the food chain. Landslide-induced soil pollution must be addressed through integrated techniques such as reforestation, slope stabilization, sustainable land-use planning, and enhanced drainage systems. Restoring impacted regions using soil remediation techniques and effective waste management can assist to reduce long-term environmental damage.
- **Earthquake:** Soil pollution produced by earthquakes is a serious but largely overlooked environmental issue. Earthquakes alter the natural structure of the land, displacing vast volumes of soil, rock, and debris. This movement can expose deep soil layers containing dangerous compounds like heavy metals or other naturally occurring toxins, which can then leak into the surface soil and groundwater. Additionally, earthquakes frequently cause infrastructure damage, such as the rupture of pipelines, storage tanks, and industrial facilities. This can result in the release of toxic items including oil, chemicals, and untreated sewage into the soil. In metropolitan locations, building collapse and poor waste management during post-earthquake recovery can lead to additional contamination by releasing debris, plastics, and other pollutants into the soil. The ensuing soil contamination has an impact on agriculture by lowering soil fertility and polluting crops, causing health hazards. It can also affect water quality in neighboring rivers and aquifers, hurting ecosystems and complicating recovery efforts. Addressing soil contamination produced by earthquakes necessitates immediate action, including adequate spill containment and cleanup, soil rehabilitation, and sustainable land-use practices. Developing earthquake-resistant infrastructure and emergency response systems can also help to reduce the environmental impact of future seismic disasters.
- **Volcanic eruptions:** The deposition of volcanic ash can make the soil more acidic, disrupting the pH equilibrium and impeding plant growth. Heavy metals and hazardous substances can remain in the soil, creating dangers to crops, livestock, and human health via bioaccumulation in the food

chain. Furthermore, volcanic gasses such as sulfur dioxide can react with water to generate acid rain, reducing soil quality across a large area. Lava flows can sterilize and harden soil, making it unsuitable for cultivation and natural plants for decades. Furthermore, the abrupt covering of productive land with ash and debris can result in erosion and sedimentation, further reducing soil productivity.

- **Floods**: Flood-induced soil contamination is a major environmental concern that has an impact on agriculture, ecosystems, and human health. Floodwaters frequently transport pollutants from a variety of sources, including industrial sites, agricultural regions, and urban areas, depositing them on the soil when the water recedes. Heavy metals, pesticides, fertilizers, sewage, oil, and hazardous compounds are examples of pollutants that can cause soil pollution. Flooding can mix untreated sewage with soil, introducing pathogens and organic debris that degrade soil quality and endanger human health. In agricultural areas, runoff from flooded fields may contain excessive levels of fertilizer and pesticides, which build up in the soil and upset its natural nutrient balance. Industrial locations contribute to soil contamination by releasing harmful chemicals, oils, and heavy metals transported by floodwaters.

Anthropogenic Sources.

This category of soil contamination is due to man-made materials. Some major anthropogenic sources are:

- **Industrial activities:** Soil pollution induced by industrial operations is a serious environmental hazard with long-term consequences for ecosystems, agriculture, and human health. Hazardous substances such as heavy metals, poisonous chemicals, oils, and radioactive elements are frequently released into the environment by industries due to incorrect waste disposal, accidents, and emissions. These contaminants build up in the soil, affecting its structure, fertility, and biological activity. Heavy metals including lead, cadmium, and mercury are major pollutants produced by industrial activities such as mining, metal refining, and battery manufacturing. These metals remain in the soil and can seep into groundwater, polluting water supplies. Chemical manufacturing and petroleum industries contribute to soil pollution by emitting hydrocarbons and volatile organic compounds, which degrade soil quality and endanger human health. Industrial waste dumping and leaks from storage facilities worsen soil pollution, especially in urban and industrial areas. Polluted soil is unproductive for agriculture because toxins can be absorbed by crops, affecting the food chain and jeopardizing public health.

- **Agricultural activities**: Since modern fertilizers and pesticides were available, the use of chemicals in agriculture has expanded dramatically in order to boost crop productivity and reduce crop disease. Soil contamination caused by organic fertilizers occurs when these chemicals are overused or improperly handled, resulting in low soil quality and environmental harm. Organic fertilizers, such as manure, compost, and bio-waste, include nutrients such as nitrogen, phosphorus, and potassium, which promote plant development. However, excessive application might upset the soil's natural equilibrium and result in pollution. When organic fertilizers are used in high quantities, the surplus nutrients may not be taken by the plants. Instead, they collect in the soil, changing its chemical composition and perhaps causing nutrient imbalances. This can disrupt soil microbes and diminish overall fertility. Furthermore, excessive nitrogen and phosphorus from organic fertilizers can seep into surrounding water bodies, causing eutrophication, which reduces oxygen levels and affects. Improperly prepared or polluted organic fertilizers may potentially introduce pathogens, heavy metals, or toxic organic compounds into the soil, endangering crops and human health. Furthermore, the decomposition of organic fertilizers can produce greenhouse gases such as methane and nitrous oxide, which contribute to climate change.

i. **Pesticides:** Pesticides, as defined by the International Code of Conduct on Pesticide Management (FAO and WHO, 2014), are "any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying, or controlling any pest, or regulating plant growth." Pesticide persistence and mobility in the environment will have an impact on human health and food chain entrance. Pesticides are manmade poisonous compounds that kill many sorts of pests and insects, causing agricultural damage, but they also have significant environmental consequences. They are often insoluble in water and non-biodegradable. As a result, these compounds will not breakdown over time and will continue to accumulate in soil. As a result, the concentration of these compounds will rise as they move from lower to higher trophic levels along the food chain. As a result, it will cause numerous metabolic and physiological abnormalities in humans. Paul Muller discovered Dichloro Diphenyl Trichloroethane (DDT), which led to the development of second-generation pesticides. Chemicals related to DDT, such as dieldrin, eldrin, heptachlor, chlordane, mirey, and endusulfan, were produced. Although the potential insecticidal qualities of these organochloride enhanced crop output while reducing pest damage, large-scale deposition of residual organic chlorides in soil crops or animal tissues had negative consequences. Most countries have banned the use of DDT due to the environmental risks it poses.

ii. **Chlorinated Organic toxins:** The detrimental effects of DDT and other chemicals prompted the development of less lasting organic and more biodegradable substances, such as carbamates and organophosphates. These compounds, however, behave as nerve poisons, making them more toxic to humans. It resulted in pesticides that caused the deaths of field workers in several agricultural fields.

iii. **Herbicides**: The industries gradually began producing herbicides such as sodium arsenite ($Na3AsO3$), sodium chlorate ($NaClO3$), and so on. Herbicides degrade within a few months. However, even they have an impact on the environment and are not environmentally friendly. Although they are not as hazardous as organochlorides, the majority of herbicides are poisonous.

iv. Inorganic Fertilizers

In agriculture, synthetic chemical compounds called inorganic fertilizers are widely employed to boost crop yields by supplying essential nutrients like nitrogen (N), phosphorous (P), and potassium (K). Despite the fact that chemical fertilizers significantly boost food production, their overuse or improper application can contaminate soil, leading to long-term health and environmental problems. mineral fertilizers: Through their root systems, plants take up water and nutrients from the soil solution. The decomposition of soil organic matter, fungal hyphae, mineral dissolution, mineral desorption, and microbial activity can all naturally produce these nutrients from the soil. External inputs can also be used to supplement the soil with nutrients. Mineral, synthetic, inorganic, and organic fertilizers have all been crucial in providing enough nutrients to boost agricultural yields around the world. However, overuse of this nutrient can occasionally alter the physical and chemical characteristics of soil, making it hazardous for crops.

- Low price contrasted with perceived lack of downside to excessive use, as compared with decreased yields;

- Lack of updated and accurate fertilizer recommendations for many crops, particularly tree crops;
- Lack of awareness and training on the use of the product.

When nitrogen fertilizer is used excessively, nitrogen is lost from the soil by surface runoff, erosion, volatilization, denitrification, and leaching to groundwater. Phosphorus can be lost from croplands through runoff or erosion as a result of excessive fertilizer application. A large amount of phosphorus lost by erosion or runoff causes eutrophication of nearby water bodies from agricultural areas. organic fertilizers Animal manure, compost, septic and sewage sludge, municipal biosolids, and food processing wastes are examples of organic fertilizers that are frequently utilized in agriculture. By enriching the soil with organic carbon and releasing nutrients gradually, the application of organic fertilizer improves soil health. Growing interest in organic farming practices and the consumption of food grown organically have led to an increase in the usage of organic fertilizers. Recycling agricultural organic waste is also seen as an environmentally responsible and sustainable method of disposal.

Causes of Soil Pollution by Inorganic Fertilizers

1. **Over application:** Farmers often use fertilizers in quantities exceeding the soil's absorption capacity, leading to nutrient accumulation and toxicity.
2. **Leaching and Runoff:** Excess fertilizers seep into the groundwater or are washed away by rain, contaminating nearby soil and water bodies.
3. **Chemical Composition:** Fertilizers contain salts and compounds that can alter the soil's natural chemical balance.
4. **Improper Timing**: Applying fertilizers during periods of heavy rainfall or without considering soil conditions increases the risk of pollution.

- **Wastewater for irrigation:** Irrigation with untreated wastewater can contribute to the accumulation of trace elements and organic contaminants such as POPs and PFAS, as well as represent a source of dangerous pathogens, and pharmaceuticals and personal care products (Islam *et al.*, 2018; Woldetsadik *et al.*, 2017). Only a few countries have reported the direct used of non-treated wastewater for irrigation, whose volume is greatly variable, reaching 4 million of cubic meter per year in Mexico. Consumption of food irrigated with untreated wastewater can pose a high risk for human health due to the potential exposure to pathogens and uptake and accumulation of trace elements in the edible parts of the crops
- **Waste disposal:** Every human being produces a certain amount of personal waste products as urine and faces. Due to the growing population this amount is very huge. Through the sewer systems it is taken out of cities and usually the sewer system ends at the landfill. At these landfills, the biological waste pollutes the soil and water. Disposal of plastics, cans, and other solid waste falls into the category of soil pollution. Disposal of electrical goods such as batteries causes an adverse effect on the soil due to the presence of harmful chemicals. For instance, lithium present in batteries can cause leaching of soil.
- **Accidental oil spills**: Unintentional oil spills have terrible effects on the environment and the economy and are a major source of soil degradation. Hydrocarbons and other hazardous substances are released into the earth during oil spills, which happen when petroleum products are extracted, transported, or stored. These contaminants significantly alter the characteristics of soil, reducing its fertility and suitability for plant life. Oil spills coat soil particles, forming a hydrophobic layer that decreases aeration and water infiltration two processes vital to

microbial and plant life. Oil's hydrocarbons are harmful to soil microbes, which are essential to preserving the health of the soil. Long-term contamination can result from the accumulation of heavy metals and persistent organic pollutants found in oil in the soil. Additionally, oil-contaminated soils have the potential to leak harmful chemicals into groundwater and adjacent bodies of water, putting aquatic ecosystems and water supplies at risk. Oil spills harm crops and lower output in agricultural areas, which presents financial difficulties for farmers. Additionally, people who are exposed to oil-contaminated soil may experience long-term health hazards from carcinogenic chemicals, respiratory problems, and skin irritation.

- **Acid Rain:** Acid rain-induced soil pollution is a serious environmental problem that has an adverse effect on ecosystems, plant growth, and soil quality. Sulphuric and nitric acids are produced when sulphur dioxide (SO_2) and nitrogen oxides (NO_x), which are mostly emitted by burning fossil fuels, mix with atmospheric water vapor to form acid rain. The chemical makeup of the soil is changed when this acidic precipitation hits the ground. Acid rain causes the pH of the soil to drop, increasing its acidity and upsetting the delicate balance of vital nutrients. It lowers the soil's fertility and hinders plant growth by removing essential elements like calcium, magnesium, and potassium. Furthermore, it releases harmful metals like lead and aluminium into adjacent water bodies, which can damage aquatic ecosystems, microbes, and plant roots. Additionally, acid rain slows down nutrient cycling and organic matter decomposition by interfering with the soil's natural microbial activity. The soil's capacity to sustain productive agriculture and healthy plants is diminished by this deterioration.
- **Urban Activities:** Lack of proper waste disposal, regular constructions can cause excessive damage to the soil due to lack of proper drainage and surface run-off. These waste disposed of by humans contain chemical waste from residential areas. Moreover leaking of sewerage system can also affect soil quality and cause soil pollution by changing the chemical composition of the soil. However, the root cause of soil pollution is often one of the following:
    - Agriculture (excessive/improper use of pesticides)
    - Excessive industrial activity
    - Poor management or inefficient disposal of waste

4.4. Types of Soil Pollutants

Soil pollution is made up of pollutants and toxins. The primary contaminants in soil are biological agents and some human activities. Soil contaminants are the by-products of soil pollutants that contaminate the soil. Human activities that poison the soil include agricultural techniques that use pesticides on crops, as well as municipal or industrial wastes and radioactive emissions that contaminate the soil with numerous hazardous substances. Soil pollutants are chemicals that contaminate soil, lowering its quality, fertility, and overall ecological health. They can be classified into numerous types according to their origin and composition

- **BIOLOGICAL AGENTS**

Biological agents function inside the soil to introduce manures and digested sludge (derived from human, bird, and animal excrement) into the soil.

- **Pathogens:** Pathogens are bacteria, viruses, and parasites found in untreated sewage or animal waste
- **Invasive Species**: Non-native plants or bacteria disrupt ecosystems.

- **AGRICULTURAL PRACTICES**

The soil of the crops is polluted to a large extent with pesticides, fertilizers, herbicides, slurry, debris, and manure.

- Pesticides: These include insecticides, herbicides, and fungicides, all of which can stay in the soil and harm non-target organisms.
- Hydrocarbons: These come from oil spills, fuel leaks, and industrial discharges, which have hazardous impacts on land and water. Polychlorinated biphenyls (PCBs) are persistent organic contaminants found in electrical equipment.
- Phenols: Found in industrial waste and hazardous to soil microbes. Radioactive substances such as Radium, Thorium, Uranium, Nitrogen, etc. can infiltrate the soil and create toxic effects.

- **URBAN WASTE**

Urban waste is waste gathered from the residential and industrial regions of cities and towns. It can contain a wide range of products, including food, packaging, electronics, and building materials. When urban garbage is not adequately managed or collected, it can cause major health problems.

- **RURAL WASTE**

Rural populations generate similar sorts of garbage, but in lesser numbers, making it more difficult and expensive to collect, recycle, or dispose of in an environmentally responsible way. If the wastes are not collected for proper environmental management, they are likely to be thrown indiscriminately in the countryside or disposed of in an uncontrolled open dump. To reduce quantities, wastes may be burned in the open, with uncontrolled fires emitting harmful pollutants such as partially combusted particulates carrying contaminants such as PCDDs and PCDFs, which can damage soils across short and long distances.

- **INDUSTRIAL WASTE**

Paper mills, oil refineries, sugar factories, petroleum industries, and other entities manufacture steel, pesticides, textiles, pharmaceuticals, glass, cement, petroleum, and other products.

4.5. Physiochemical properties soil

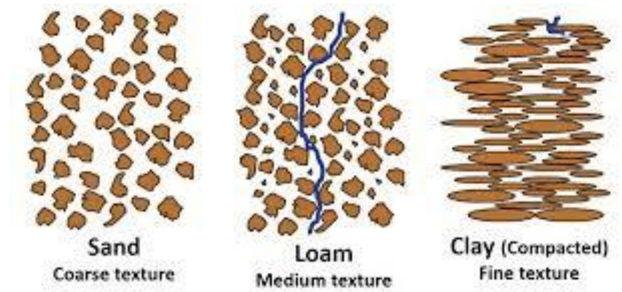
Soil is a complex and dynamic natural resource with a variety of physical qualities that affect plant development, water retention, and nutrient supply. Understanding soil's physical properties is critical for successful land management, agriculture, and environmental conservation. These qualities influence how soil interacts with water, air, and living creatures and they are essential for soil fertility, drainage, and overall health. Soil texture, structure, porosity, bulk density, water-holding capacity, consistency, and colour are its key physical qualities. Let's go over each of these features in detail.

Soil Texture

Soil texture is the relative quantities of sand, silt, and clay in a soil sample. It determines the soil's ability to retain moisture, nutrients, and oxygen, as well as its drainage and root penetration. One of the most important aspects influencing soil behaviour is soil texture, which is controlled by the size of individual soil particles.

Sand: Sand particles are the biggest, with sizes ranging from 0.05 to 2 millimetres. Sand is highly permeable, which means it drains water rapidly and does not retain moisture effectively. As a result, sandy soils have reduced nitrogen retention capacity and require frequent fertilization in agricultural systems.

Silt: Silt particles are smaller than sand, measuring from 0.002 to 0.05 millimetres. Silt soils retain moisture better than sandy soils, but they can get compacted rapidly, decreasing aeration and root growth. Silt is more fruitful than sand because it contains more nutrients.



Clay: Clay particles have the tiniest sizes, less than 0.002 millimeters. Clay soils have low permeability (water drains slowly) and a high nutrient-holding capacity. They are, however, easily waterlogged and may result in poor root development if not carefully controlled. Clay soils can also develop hard crusts when dry, limiting root penetration.

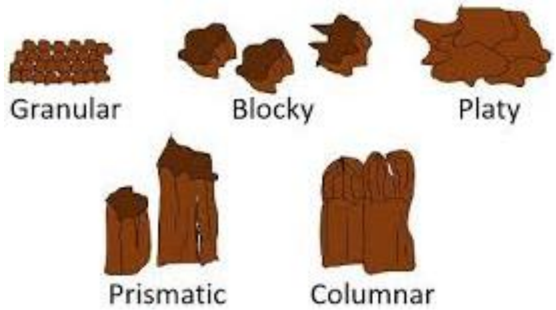
Soil texture is often categorized into kinds depending on sand, silt, and clay content. Loam is considered the best soil texture for most plants since it has a balanced mix of sand, silt, and clay. Loamy soils offer strong water retention, appropriate drainage, and a high nutrient-holding capacity.

Texture Triangle: The proportions of sand, silt, and clay in soil can be plotted on a texture triangle, allowing the soil to be classified depending on texture. A soil containing 40% sand, 40% silt, and 20% clay is classed as loam.

Soil structure

Soil structure refers to the arrangement and grouping of soil particles into aggregates known as peds. These aggregates control how water, air, and roots travel through the soil. The structure of the soil influences its permeability, aeration, and water retention. Soil structure can be divided into various categories, including:

Granular Structure: Found primarily in surface soils, this structure is composed of tiny, rounded aggregates that allow for great water infiltration and root growth. Granular soils are abundant in productive agricultural fields with high organic content.



Blocky Structure: The soil aggregates in this structure are angular and block-shaped. Blocky soils have moderate permeability and are usually found in subsurface levels. While the blocks provide good drainage, they may limit root growth if the soil becomes too compacted.

Platy structure: Platy structure refers to the formation of thin, flat plates by soil particles. These soils have low permeability, which means water has trouble draining through them. Platy structure is commonly present in compacted soils and can cause poor root growth.Prismatic and columnar formations: Found in arid and semi-arid environments, these structures are made up of vertical, prism-shaped aggregates that can limit water entry. These soils may also be susceptible to erosion.

Soil porosity

Soil porosity is the volume of empty spaces (pores) between soil particles. These pores contain both water and air, which are required for plant growth and soil life. Soil with high porosity allows for good water infiltration and drainage, whereas soils with low porosity can get compacted, resulting in poor aeration and root development.

The texture and structure of the soil determine its porosity. Sandy soils often have bigger pores, resulting in high porosity but low water retention. Clay soils, on the other hand, have smaller pores, resulting in decreased porosity but better water retention.

Pore Spaces in soil can be divided into:

- **Macropores**: Large pores that allow for the movement of air and the rapid drainage of water. These are essential for plant root development and the exchange of gases in the soil.
- **Micropores**: Small pores that hold water and nutrients. Micropores are important for water retention and provide moisture to plants during dry periods.

Bulk Density

Bulk density refers to the mass of dirt per unit volume, measured in grams per cubic centimeter (g/cm^3). It is a measure of soil compaction based on the number of solid particles present in a particular volume of soil. Bulk density is affected by soil texture, structure, and organic matter content.

- **Low Bulk Density**: Soils with low bulk density are loose and well-aerated, allowing for adequate root penetration and water infiltration. These soils are often rich in organic matter and have greater overall health.
- **High Bulk Density**: High bulk density implies compacted soil, which can impede water transport and root development. Heavy machinery, overgrazing, and poor soil management practices can all lead to compaction.

Water-Holding Capacity

Water-holding capacity is the ability of soil to retain water after it has been saturated and excess water has been drained. This characteristic is affected by soil texture and porosity. Soils with a high clay concentration have a higher water-holding capacity, whereas sandy soils drain fast and retain less water. The water-holding capacity of soil is critical for ensuring that plants have enough moisture. Drought stress can occur when the soil is unable to hold adequate water. Conversely, if soil retains too much water, it can cause waterlogging, suffocating plant roots and damaging harvests.

Field Capacity: This is the amount of water a soil can hold after excess water has drained away. It represents the ideal moisture level for plant growth, where water is available for uptake but there is no waterlogging.

Wilting Point: This is the point at which water in the soil is no longer available to plants, leading to wilting and eventual plant death.

Soil Consistency

Soil consistency relates to the soil's resistance to deformation and compaction, as well as its ease of crumbling or compacting. It is a measure of the soil's structural integrity that is affected by moisture levels.

- **Friable Consistency**: Soils with this consistency are loose and easy to break apart, with good aeration and easy root penetration.
- **Firm Consistency**: Soils with firm consistency are more compacted and harder to break apart. These soils may resist root penetration and require additional tilling or aeration.
- **Sticky or Plastic Consistency**: Soils with high clay content may become sticky when wet, making it difficult for roots to grow and for water to drain properly.

Soil Color

Soil color is determined by mineral composition, organic matter, moisture levels, and drainage conditions. Soil color can provide important hints regarding soil qualities.

- **Dark Brown or Black**: Indicates high organic matter content, common in fertile soils rich in decomposed plant material.
- **Red or Yellow**: Typically associated with the presence of iron oxides, indicating good drainage and well-aerated conditions.
- **Gray or Bluish**: Often a sign of poor drainage, waterlogged conditions, or the presence of iron and manganese in reduced states.

4.6. Biological Properties of Soils

Soil is more than just an inert medium for plant growth; it is a dynamic, living habitat. Soil's biological features pertain to the creatures that live there, their relationships, and the processes they drive. These qualities are critical for maintaining soil health, fertility, and ecosystem function. Soil creatures, ranging from microorganisms such as bacteria and fungus to bigger species such as earthworms and insects, perform critical roles in nutrient cycling, soil structure, and plant development. Understanding soil's biological characteristics contributes to sustainable land management, agricultural productivity, and environmental conservation. In this context, we look at the various components of soil biology and how they interact to affect soil function.

Soil microorganisms:

Soil microorganisms are the tiniest and most abundant creatures in the soil, and they play a critical role in soil health. These microorganisms include bacteria, fungus, actinomycetes, algae, protozoa, and viruses. They are involved in a variety of biological activities, including decomposition, nutrient cycling, and the breakdown of organic waste.

Bacteria: Bacteria are the most common bacteria in the soil. They are essential for processes like nitrogen fixation, organic matter degradation, and nutrient conversion. Nitrogen-fixing bacteria, such as Rhizobium and Azotobacter, transform atmospheric nitrogen into forms that plants can utilize. Other bacteria, such as nitrifying bacteria, help convert ammonia into nitrates, which are required for plant nutrition.

Fungi: Fungi help break down complex organic compounds like lignin and cellulose, which are tough for most species to digest. Mycorrhizal fungi develop symbiotic associations with plant roots, which improves nutrient uptake, particularly phosphorus, and increases plant tolerance to diseases and environmental stress.

Actinomycetes: These bacteria-like organisms are involved in the breakdown of organic matter and the formation of humus, which improves soil structure. Actinomycetes also produce antibiotics and other bioactive compounds that can suppress soil-borne pathogens.

Protozoa: Protozoa are single-celled organisms that feed on bacteria, fungi, and other small organisms. By grazing on these microorganisms, protozoa help regulate microbial populations and release nutrients like nitrogen and phosphorus into the soil, making them available to plants.

Viruses: While their role in soil is less understood, viruses in the soil can infect bacteria and other microorganisms, potentially influencing microbial populations and nutrient cycling.

Soil Fauna

Soil fauna refers to bigger soil-dwelling creatures such as earthworms, insects, nematodes, and arthropods. These microorganisms are essential for soil aeration, mixing, and nutrient cycling. They also interact with microbes and shape soil structure by forming channels, facilitating water infiltration, and increasing nutrient availability.

- **Earthworms**: Earthworms are frequently referred to as "nature's plows" due to their capacity to burrow into the ground, forming channels that enhance soil structure and facilitate improved aeration and water infiltration. They break down organic materials into tiny bits and add nutrients to the soil by consuming it. Excreta, or earthworm castings, are nutrient-rich and increase soil fertility. Additionally, earthworms create shelters in their tunnels, which promotes the activity of other soil creatures.

- **Insects**: Important soil fauna include insects such as termites, ants, and beetles. They aid in the breakdown of plant matter, converting it to humus. For instance, termites greatly aid in the cycling of organic matter by breaking down strong plant material like cellulose. Additionally, insects aid in soil aeration and supply food for predators within the soil ecosystem.

- **Nematodes**: Nematodes are tiny roundworms that are crucial to the cycle of nutrients. While some nematodes consume the roots of plants, others feed on fungi, bacteria, or other nematodes. Nematodes aid in the breakdown of organic matter and control microbial populations.

- **Arthropods**: Arthropods, such as mites, millipedes, and centipedes, are crucial decomposers. They aid in the creation of humus by decomposing plant and animal materials. By incorporating organic matter into the soil and creating channels for air and water to reach plant roots, arthropods also enhance the structure of the soil.

Soil Organic Matter (SOM)

Soil organic matter (SOM) consists of decomposed plant and animal residues, as well as microorganisms and their byproducts. SOM is a key component of soil's biological properties, and it plays a central role in maintaining soil fertility, structure, and moisture retention.

Decomposition: Microorganisms, fungus, and soil fauna are responsible for the breakdown of organic matter. This process releases nutrients that are essential for plant growth by dissolving complex organic molecules into simpler ones. Humus, a stable organic substance that enhances soil structure, water retention, and nutrient-holding capacity, is also produced as a result of the breakdown of plant matter.

Humus: The decomposition of plant and animal matter produces humus, a stable, black form of organic matter. By strengthening aggregation, decreasing compaction, and binding soil particles together, it improves soil structure. The soil's cation-exchange capacity (CEC), or its capability to retain vital elements like calcium, magnesium, and potassium, is also enhanced by humus.

Nutrient Cycling: Organic debris is broken down by soil organisms, which also return nutrients to the soil in forms that plants can use. Plants are guaranteed a steady supply of vital elements like potassium, phosphorus, and nitrogen thanks to this nutrient cycle. Reduced soil fertility and erosion can result from the loss of soil organic matter, which is an essential component of healthy soils and can be caused by inadequate land management, deforestation, or excessive tillage.

Soil Biodiversity and Ecosystem Services

The diversity and quantity of organisms found in soil, such as bacteria, fungus, protozoa, nematodes, earthworms, and insects, is referred to as soil biodiversity. In order to sustain soil health and deliver ecosystem services, soil biodiversity is essential. Processes including nutrient cycling, organic matter breakdown, pest control, and soil aeration are all influenced by interactions among soil organisms.

Nutrient Cycling: The cycling of nutrients in the soil, which guarantees that plants have access to vital minerals and nutrients, is the responsibility of soil biodiversity. To support plant growth, a variety of microbial communities break down organic materials into nutrients that plants may use, such potassium, phosphorus, and nitrogen.

Soil Structure: Soil structure is developed and maintained by organisms such as fungi, ants, and earthworms. Their burrowing efforts improve soil aeration, water retention, and root development by establishing routes that let water and air into the soil.

Pest Control: Organisms in the soil aid in controlling pest populations. Plant-feeding nematodes and insect larvae can be controlled by nematodes and predatory insects. Furthermore, the prevalence of plant illnesses can be decreased by helpful soil bacteria outcompeting harmful germs.

Carbon Sequestration: By converting organic matter into stable humus, soil organisms also contribute to the sequestration of carbon. By retaining carbon in the soil for extended periods of time, this mechanism helps slow down climate change.

4.7. Humus

The black, organic, and nutrient-rich substance called humus is created when plant and animal debris breaks down in soil. It is an essential part of soil fertility, encouraging plant development, preserving soil structure, and supporting ecosystems. Humus is a persistent source of organic matter because it is stable and impervious to additional breakdown. Soil organisms like bacteria, fungi, and earthworms break down organic matter, including fallen leaves, dead plants, and animal remains, to create humus. There are multiple steps in the process:

- **Litter Decomposition:** Microorganisms break down organic debris into simpler molecules. Humification: These substances change chemically and biologically to create stable, decay-resistant humic substances.
- **Stabilization:** Humus undergoes a chemical complex that results in the formation of colloidal particles that attach to soil minerals.

Characteristics of Humus

- **Color**: Humus is dark brown or black, contributing to the soil's dark color.
- **Texture**: It has a soft, spongy texture, improving soil aeration and water retention.
- **Chemical Properties**:
    - **Cation Exchange Capacity (CEC)**: Humus holds nutrients in a form available to plants, enhancing soil fertility.
    - **Buffering Capacity**: It helps stabilize soil pH, protecting plants from extreme acidity or alkalinity.

Importance of Humus

- **Improves Soil Fertility**: Humus stores essential nutrients like nitrogen, phosphorus, and sulfur, releasing them gradually for plant uptake.
- **Enhances Soil Structure**: It binds soil particles into aggregates, improving porosity, water infiltration, and resistance to erosion.
- **Increases Water Retention**: The spongy nature of humus allows it to retain moisture, reducing the need for frequent irrigation.
- **Supports Microbial Activity**: It provides energy and nutrients for soil microorganisms, which play a vital role in nutrient cycling.
- **Carbon Sequestration**: Humus acts as a long-term storage for carbon, mitigating greenhouse gas emissions and supporting climate regulation.

4.8. Factors Affecting Soil Pollution

When dangerous items like chemicals, heavy metals, or waste products are added to the soil, it degrades and loses some of its properties, which is known as soil pollution. The degree and intensity of soil contamination are influenced by a number of variables and can change depending on environmental factors, natural processes, and human activity. The main elements influencing soil pollution are listed below:

1. Sources of Pollutants

- **Industrial Activities**: Pollutants such as heavy metals, solvents, and hazardous compounds are released into the soil by factories, mining, and energy production.
- **Agricultural Practices**: Overuse of artificial fertilizers, insecticides, and herbicides pollutes soil with chemicals that upset its natural equilibrium.
- **Waste Disposal**: Poor handling of hazardous and solid waste, such as plastics, e-waste, and

untreated sewage, can pollute soil.

- **Accidental Spills**: Localized but serious pollution can result from chemical leaks, oil spills, and other mishaps.

2. Types of Pollutants

- **Chemical Composition**: Long-lasting pollutants that are difficult to remove from soil include hydrocarbons, synthetic compounds, and heavy metals (lead, mercury, and arsenic).
- **Biodegradability**: Over time, non-biodegradable contaminants like plastics and industrial chemicals build up in the soil and harm it over time.

3. Climate and Weather Conditions

- **Rainfall and Runoff**: While surface runoff can move pollutants from one place to another, heavy rainfall can cause pollutants to soak into the soil.
- **Temperature**: High temperatures hasten microbial activity and chemical reactions, which may speed up the breakdown of organic contaminants or increase their mobility.

4. Soil Characteristics

- **Texture**: Clay-rich soils tend to contain contaminants but are more likely to accumulate over time, while sandy soils have higher permeability, allowing pollutants to enter rapidly.
- **pH Levels**: The mobility and bioavailability of contaminants are influenced by the pH of the soil. For example, heavy metals may become more soluble in acidic soils, increasing their toxicity.
- **Organic Matter Content**: Over time, soils with a higher organic matter concentration may accumulate hazardous materials but can also bind pollutants, decreasing their mobility.

5. Land Use Practices

- **Urbanization**: Expanding cities and infrastructure development lead to increased construction waste, chemical runoff, and reduced natural vegetation, exacerbating soil pollution.
- **Deforestation**: Clearing forests exposes soil to erosion and allows pollutants to spread more easily.
- **Overgrazing**: Livestock overgrazing can lead to soil compaction and degradation, making it more susceptible to pollution.

6. Agricultural Inputs

- **Overuse of Fertilizers**: Excessive nitrogen and phosphorus-based fertilizers can lead to nutrient imbalances and soil acidification.
- **Pesticides and Herbicides**: Persistent chemical residues accumulate in the soil, harming beneficial organisms and contaminating groundwater.
- **Irrigation Practices**: Poor irrigation management can lead to waterlogging and salinization, further degrading soil quality.

7. Natural Disasters

- **Flooding**: Floodwaters can transport pollutants into agricultural fields and urban areas, contaminating the soil.
- **Volcanic Eruptions**: Lava and ash deposits introduce heavy metals and other harmful

elements into the soil.

- **Earthquakes and Landslides**: These can expose buried pollutants or spread contaminants to new areas.

8. Human Activities and Negligence

- **Illegal Dumping**: Dumping industrial, medical, or household waste in unauthorized areas often leads to uncontrolled soil contamination.
- **Mining and Quarrying**: Extraction activities disturb soil layers and introduce toxic substances like arsenic and sulfur.
- **Lack of Regulation**: Weak enforcement of environmental laws allows industries and individuals to dispose of pollutants irresponsibly.

4.9. Measures of Soil Pollution

The loss of soil quality brought on by the entry of dangerous materials including chemicals, heavy metals, and biological pollutants is referred to as soil pollution. Determining the level of contamination, evaluating its effects on the environment, and formulating remediation plans all depend on measuring soil pollution. Soil pollution can be classified into physical, chemical, biological, and ecological aspects and is assessed using a variety of techniques and metrics.

1. Physical Indicators

Physical properties of soil can provide indirect evidence of pollution:

- **Soil Texture and Structure**: Changes in the texture, compaction, or aggregation of the soil could be signs of industrial waste or heavy metal pollution.
- **Soil Color**: Changes in soil color, such as a dark oily appearance, may indicate contamination by hydrocarbons or industrial effluents.
- **Water Holding Capacity**: The soil's capacity to hold water can be diminished by pollutants such as salts or petroleum compounds.

2. Chemical Measures

Chemical analysis is the most direct method to measure soil pollution. Key parameters include:

- **pH Levels**: Acidification or alkalization can occur due to industrial emissions, acid rain, or chemical spills.
- **Electrical Conductivity (EC)**: A high EC denotes salinization, which is frequently brought on by trash or chemicals used in agriculture.
- **Heavy Metals**: Assessing pollution levels is aided by measuring quantities of metals such as lead, arsenic, mercury, and cadmium. Among the methods
    - Atomic Absorption Spectroscopy (AAS)
    - Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
- **Pesticide Residues**: Gas chromatography (GC) and liquid chromatography (LC) are used to detect persistent organic pollutants (POPs).
- **Nitrate and Phosphate Levels**: High levels indicate contamination from agricultural runoff.
- **Total Organic Carbon (TOC)**: Measuring TOC helps determine the presence of organic

pollutants like hydrocarbons.

3. Biological Measures

Biological indicators reflect the impact of pollutants on soil organisms and their activity:

- **Microbial Biomass and Diversity**: Pollution often reduces microbial diversity and biomass in soil.
- **Enzyme Activity**: Activities of enzymes like dehydrogenase, phosphatase, and urease decrease in polluted soils, reflecting reduced biological activity.
- **Bioaccumulation**: Examining pollutant accumulation in organisms like earthworms or plants can indicate contamination levels.
- **Plant Toxicity Tests**: Germination and growth inhibition tests assess the effects of soil pollutants on plant health.

4. Ecological and Risk Assessment Measures

Ecological assessments measure the broader impact of soil pollution:

- **Ecotoxicological Testing**: Assessing the toxic effects of pollutants on soil organisms, plants, and microorganisms.
- **Pollution Load Index (PLI)**: Combines data on multiple pollutants to provide an overall index of soil contamination.
- **Geoaccumulation Index (Igeo)**: Evaluates the degree of heavy metal contamination by comparing concentrations to natural background levels.

5. Remote Sensing and Geospatial Techniques

Modern technologies allow for large-scale and non-invasive soil pollution assessments:

- **Satellite Imaging**: Used to detect land degradation and vegetation stress caused by soil pollution.
- **Geographic Information Systems (GIS)**: GIS maps are used to identify pollution hotspots and monitor spatial distribution over time.

6. Guidelines and Standards

To measure soil pollution effectively, various national and international organizations have established threshold limits for pollutants. Examples include:

- **Environmental Protection Agency (EPA) Guidelines**
- **World Health Organization (WHO) Standards**
- **European Union Soil Quality Directives**

These standards help compare measured pollutant levels against permissible limits, determining the severity of pollution.

4.10. Control of Soil Pollution

The environment, agriculture, and human health are all seriously threatened by soil pollution. Preventive, remedial, and sustainable approaches must be combined to minimize the introduction of toxic compounds into the soil and lessen their negative consequences. Key tactics and techniques for reducing soil pollution are listed below:

1. Prevention of Soil Pollution

Maintaining long-term soil health and reducing soil contamination require sustainable agriculture methods. By using natural inputs like compost, green manure, and biological pest control, organic farming does away with the need for artificial fertilizers and pesticides. Crop rotation and cover crops reduce the chance of erosion and pollution, restore soil fertility, and stop nutrient loss. By applying pesticides and fertilizers just where needed and minimizing chemical runoff, precision agriculture makes use of technology to maximize resource utilization. Trees and crops are combined in agroforestry to improve soil structure, decrease erosion, and increase water retention. No-till farming and other conservation tillage techniques reduce soil disturbance, protect organic matter, and stop pollution from sediment runoff. While integrated pest management (IPM), which combines mechanical and biological pest control techniques, lowers chemical usage, proper irrigation management avoids salinization and waterlogging. These methods safeguard soil from contamination and deterioration while ensuring sustainable cultivation.

2. Remediation of Polluted Soil

Toxins and heavy metals can be absorbed and eliminated from the soil by using plants like poplar trees, mustard, and sunflowers. Use microorganisms to improve soil health and decompose organic contaminants. In extreme pollution situations, remove pollutants from soil using water or chemical solutions. To evaporate and eliminate volatile contaminants like hydrocarbons, apply heat to the soil. Use chemical agents to immobilize and decrease the mobility of heavy metals in soil.

3. Regulations and Policy Implementation

Controlling soil pollution requires effective laws and regulations. Guidelines for trash disposal and pollution management are established by environmental regulations such as the Environmental Protection Act of India and the U.S. Clean Water Act. Hazardous waste and persistent organic pollutants (POPs) are governed by international accords including the Basel Convention and the Stockholm Convention. Governments set limits on allowable pollutants, penalize infractions, and encourage monitoring through their agencies. Public education increases awareness of soil health, and incentives promote sustainable industrial and agricultural operations. Continuous monitoring and remedial technology research guarantee compliance, promoting long-term environmental protection and sustainable soil management. To identify and remediate contamination early, conduct routine soil testing. Additionally, define and track hotspots for soil pollution using Geographic Information Systems (GIS). Encourage sustainable practices and inform people about the origins and consequences of soil pollution. Promote involvement in recycling and waste segregation initiatives.

4. Sustainable Practices

In order to avoid and manage soil pollution, sustainable methods are essential. By using compost and natural pest management, organic farming reduces the need for chemical fertilizers and pesticides. By combining crops and trees, agroforestry enhances soil structure and lowers erosion. Crop rotation and cover crops improve soil health and preserve nutrient balance. By minimizing soil disturbance, conservation tillage protects organic matter. Vegetation is restored by afforestation and reforestation:

5. Technological Solutions

Innovative approaches to soil pollution monitoring, prevention, and remediation are made possible by technological solutions. Real-time soil quality monitoring is made possible by soil sensors and remote sensing technologies, which effectively identify contaminants like heavy metals or chemical residues. Whereas bioremediation depends on microbes to decompose organic pollutants, phytoremediation uses certain plants to absorb pollutants. While thermal remediation uses heat to remove volatile contaminants like hydrocarbons, soil washing using water or chemical agents aids in the removal of pollutants. By introducing nanoscale materials, nanotechnology improves soil repair and neutralizes pollutants. Bioreactors and filtration technologies are examples of advanced waste treatment systems that stop municipal and industrial waste from contaminating soil. Predicting contamination trends and locating pollution hotspots are made easier with the use of machine learning algorithms and Geographic Information Systems (GIS).

Apart from that some practice can be useful in soil pollution control:

- **i.** Biodegradable waste should be separated and be use to generate biogas.
- **ii.** Animal and agriculture waste can be used for biogas production.
- **iii.** Construct transfer station for discharge site.
- **iv.** Use filters in industries to collect fly ash and other suspended matter.
- **v.** Low lying areas (ditches) preferable used as dumping grounds for industrial waste.
- **vi.** Recover waste from waste so that it will produce some useful product.
- **vii.** Use of bio fertilizer rather than chemical fertilizers.
- **viii.** Mining waste can be reduced by the application of modern technology.
- **ix.** Avoid use of DDT like pesticide, residue of which remains year's together in soil or in food chain.
- **x.** Adopt organic farming.

4.11. Summary

The term "soil pollution" describes the presence of toxic materials in soil that lower fertility, deteriorate soil quality, and damage ecosystems. Although natural forces may also play a role, human activity is the primary cause of this problem. Management of soil contamination is a global problem since it impacts biodiversity, jeopardizes human health, and hinders agricultural output. Toxins such as phosphates, nitrates, and persistent organic pollutants (POPs) are introduced into the soil by the overuse of chemical fertilizers, insecticides, and herbicides. Industries contaminate surrounding soils by releasing garbage, heavy metals (lead, mercury, and cadmium), and dangerous chemicals into the environment. Soil pollution is a result of landfills and the unlawful disposal of industrial and domestic trash, including plastics and e-waste. Unintentional oil spills release hydrocarbons into the soil, altering its composition and microbiological life. Volcanic eruptions, floods, and landslides are examples of events that can upset the balance of the soil and introduce harmful elements. Soil pollution has far-reaching consequences:

- **Reduced Soil Fertility**: The accumulation of harmful substances disrupts nutrient cycles, impairing agricultural productivity.
- **Water Contamination**: Pollutants seep into groundwater or are carried to water bodies through runoff, harming aquatic ecosystems.
- **Health Hazards**: Contaminated soils can transfer toxins to crops, leading to food chain contamination and diseases like cancer, respiratory issues, and developmental disorders.
- **Loss of Biodiversity**: Soil organisms, critical for decomposition and nutrient cycling, are adversely affected, disrupting ecosystems.
- **Climate Impact**: Degraded soils release stored carbon, contributing to global warming.

A serious environmental problem that affects agriculture, the environment, and human health is soil pollution. In order to reduce soil contamination and protect this vital resource for coming generations, society must embrace sustainable habits, enforce laws, and use technology.

4.12. Terminal questions

Q.1. Discuss soil pollutions and types of Soil Pollutants.

Answer:---

Q.2. Discuss about biological agents of soil.

Answer:---

Q.3. Write physical properties of soil with examples.

Answer:---

Q.4. What are humus and why it is useful in plant growths?

Answer:---

Q.5. Write that factor effecting the soil pollution.

Answer:---

Q.6. Control of soil pollution with suitable examples.

Answer:---

4.13. Further suggested readings

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Unit-5: Noise pollution

Contents

5.1 Introduction

The word noise comes from the Latin word nausea, meaning seasickness. Noise is described as, "the unwanted, unpleasant or disagreeable sound that causes discomfort to all living beings". According to statistics, environmental noise has been doubling every ten years since the industrial revolution. Decibels (dB), which are the tenth part of the longest unit of measurement for sound intensity, are used. The smallest sound that a human ear can detect is one decibel. The Latin word 'nausea', which describes a condition in which one feels the want to vomit, is the root of the English word noise. The unwanted and disagreeable sound that makes people uncomfortable is called noise. Decibels are used to quantify sound intensity. Even a sound as feeble as one decibel can be heard by the human ear. Noise pollution has become a source of concern as civilizations' noise levels have increased. Vehicles, aircraft, industrial machines, loudspeakers, crackers, and other items are among the most common sources. When utilized at excessive volumes, other equipment such as televisions, transistors, and radios add to noise pollution.

In addition to harming living things, other types of contamination can also be dangerous. It is regarded by the World Health Organization (WHO) as one of the most significant environmental hazards to human health. According to the European Environment Agency (EEA), noise causes more than 72,000 hospitalizations and 16,600 premature deaths in Europe alone each year. It hurts animals as well as people. According to the National Park Service (NPS) in the United States, noise pollution has a major negative influence on the environment and damages species. Noise pollution has the potential to cause species extinction by interfering with mating and rearing cycles.

Objectives:

After reading this unit, learner will be able to know

- the noise pollution, it sources and level
- the effects of noise pollution on human health and animals
- the measurements and control of noise level

- the legal provisions and act for noise pollution

5.2. Noise pollution overviews

The term "noise pollution" refers to excessive noise levels in the surrounding area. There are several factors that contribute to noise pollution, including noise from traffic, urbanization, industry, residential areas, and recreation. In actuality, laws like the Air Pollution and Water Pollution Act are required to manage it. The wealthy nations of the globe have already passed particular legislation to reduce noise pollution.

Noise has become one of the major environmental pollutants in recent years. Noise pollution harms human and animal health by creating unwanted or uncomfortable sounds in the environment. It is an unseen peril. Despite being invisible, it exists both on land and underwater. The environment, wildlife, and human health are all harmed by noise pollution. Numerous factors contribute to noise pollution, such as workplaces, industrial facilities, trains, airplanes, and outdoor building projects. Not every sound qualifies as noise pollution. Noise pollution is defined by the World Health Organization (WHO) as noise levels more than 65 decibels (dB). Noise levels above 75 decibels (dB) are deemed harmful, and noise levels beyond 120 dB are deemed painful. Therefore, it is advised that noise levels be kept below 65 dB during the day and that ambient noise levels above 30 dB at night make it impossible to sleep peacefully. Air molecules vibrate to produce sound waves, which travel from a source of noise to the eardrum. The loudness (amplitude) and pitch of the wave are frequently used to describe sound. Decibels (dB) are logarithmic numbers used to measure loudness, often known as sound pressure level, or SPL. With frequencies between 120 and 140 dB causing discomfort, the normal human ear can detect sounds from 0 decibels (hearing threshold) to about 140 decibels (pain threshold).Building construction activities can produce SPLs of up to 105 dB at the source, whereas the ambient SPL in a library is about 35 dB, while the SPL inside a moving bus or subway train is about 85 dB. As one gets farther away from the source, SPLs get smaller. The energy contained in a sound wave is measured in decibels. The decibel levels of the noise sources are shown via the decibel meter. Sound energy is quantified by frequency and amplitude and travels in waves.

Amplitude measures how powerful a wave is. Decibels (dBA) are used to measure sound pressure. The softest level a person can hear is 0 dBA. Normal speaking voices are roughly 65 decibels. A rock concert can be around 120 decibels. Sounds that are 85 decibels or higher might permanently harm your ears. Increased sound pressure reduces the time required to inflict damage. A sound at 85 decibels (dBA) can cause irreversible damage after 8 hours, whereas a sound at 100 decibels (dBA) can harm hair cells within 30 minutes of exposure. Frequency is measured by the number of sound vibrations per second. A healthy ear can hear sounds at frequencies ranging from 20 Hertz (20 cycles per second) to 20,000 Hertz. The lowest a key on the piano is 27 Hz. The middle C note on the piano produces a 262 Hertz tone. The piano's highest key is 4186 Hertz.

In reality, it must be managed by legislation such as the Air Pollution and Water Pollution Act. The world's wealthiest countries have already enacted specific laws to lessen noise pollution. In England, there is a "Noise Abatement Act" from 1960. According to Section 2 of this law, loudspeakers cannot be used for any of the following: (a) promoting any type of trade, business, or entertainment; or (b) between nine p.m. and eight a.m. There are a few exceptions, as when the fire department and police employ loudspeakers. Rules for the control and mitigation of noise in the US were created by the "Noise Pollution and Abatement Act" of 1970.

Self-assessment questions

Q.1. What are the main sources of noise pollution?
Q.2. How does noise pollution affect human health and the environment?

Q.3. What are some legislative measures taken to control noise pollution?

5.3. Sources of Noise Pollution:

The sources of noise pollution are classified into two broad categories: Internal and external sources of noise pollution.

1. **External pollution sources of noise:** The environment is contaminated by noise for a number of important reasons. These sources are very difficult to control. They consist of:

    - **Industrial sources:** There is now more noise pollution as a result of industrialization. Among the industries represented are metal factories, printing presses, engineering firms, and textile mills. Most companies utilize large, noisy machines that can produce a lot of noise. Their usage of machinery like generators, exhaust fans, grinding mills, and compressors increases the ambient noise level. Workers in these situations run serious health risks if they don't take the right safety measures, such wearing earplugs to lessen the impact of noise.

    - **Vehicles for transportation:** In urban settings, the automotive revolution has been identified as a major source of environmental noise. In the modern period, there are more trucks, buses, trains, and other vehicles, which leads to more traffic. Impatient people who are trapped in traffic will constantly beep their horns to try to get the car in front of them to move. For commuters, bystanders, and the environment at large, these actions produce awful cacophony for the local population. The issue of noise in urban areas is greatly exacerbated by airplanes. Jet jets typically take off and land in residential areas because most airports are situated close to them.

    - **Poor urban planning:** Poor urban planning is a common problem in developing nations, leading to crowded housing, narrow spaces, limited industry growth, and insufficient parking spots. Battles over social and basic amenities, noise from small manufacturing businesses, parking space disputes, family disputes from nearby homes, and children's play all contribute to environmental noise when cities are poorly planned.

    - **Public address systems:** At public events such as protests, strikes, elections, and both religious and secular groups, loud addressing systems are frequently utilized. The state's laws against public noise pollution are regularly broken by those who plan such events. Noise pollution is exacerbated by loud music and public address systems at social events such as religious crusades and parties. Due to the buying and selling activities, as well as the use of loudspeakers and megaphones to advertise goods or services, open markets usually result in high levels of noise pollution.

    - **Agriculture machine**: Noise levels as high as 90 dB to 98 dB have been recorded in farms that use heavy machinery and equipment. Thrashers, tube wells, tractors, drillers, motorized tillers, and harvesters are among the items of equipment used.

    - **Military equipment:** Heavy noise pollution is caused by artillery tanks, rocket launches, military aviation drills, explosions, and shooting practices. The noises of jet engines make deafening impacts, and in extreme situations, they cause window panes to shatter and crack in old dilapidated buildings near their take-off and landing locations, or when they fly past them.

2. **Indoor sources of noise:**

    - **Inside building services**: They are noises produced by human activity within a home or structure. These issues might also arise from building and office activities. Noise pollution is caused by inside building services such as construction, workshops, and automotive maintenance. The equipment utilized in these occupations generates excessive noise, which can be annoying and impair hearing

- **Household activities:** Household noises include banging doors, children playing, furniture movement, infant crying, and loud disputes. Household entertainment equipment, including Hi-Fi systems, televisions, and loudspeakers, can contribute to noise levels during indoor activities. Household equipment such as pressure cookers, vacuum cleaners, washing machines, sewing machines, mix-grinders, desert coolers, exhausts fans, and air-conditioners all generate significant noise.

Self-assessment questions

Q.1. What are the two broad categories of noise pollution sources?

Q.2. How does industrialization contribute to noise pollution?

Q.3. Why is transportation considered a major external source of noise pollution?

5.4 Noise permissible limit in India

The Noise Pollution (Regulation and Control) Rules, 2000, which establish the permissible noise levels, are enforced by the Central Pollution Control Board (CPCB) in India. These rules outline the maximum decibel levels that are permitted in particular areas and at particular times. In India, the following noise levels are generally considered acceptable: The Noise Pollution (Regulation and Control) Rules, 2000, which establish the permissible noise levels, are enforced by the Central Pollution Control Board (CPCB) in India. These rules outline the maximum decibel levels that are permitted in particular areas and at particular times. In India, the following noise levels are generally considered acceptable:

Industrial Areas:

- Daytime (6:00 AM to 10:00 PM): 75 decibels (dB) for industrial areas.
- Nighttime (10:00 PM to 6:00 AM): 70 dB for industrial areas.
- **Commercial Areas:**
- Daytime: 65 dB for commercial areas.
- Nighttime: 55 dB for commercial areas.
- **Residential Areas:**
- Daytime: 55 dB for residential areas.
- Daytime: 55 dB for residential areas.
- **Silence Zones:**
- Daytime: 50 dB for silence zones.
- Nighttime: 40 dB for silence zones.

Hospitals, schools, courts, and places of worship that have been declared as silence zones by the relevant state or local authorities are examples of such locations. It's crucial to remember that these are only guidelines; local or state governments may have additional rules governing acceptable noise levels. Furthermore, there can be rules and acceptable noise levels for particular activities, like construction or festivals that must be adhered to.

It's essential to consult the local laws and policies established by the relevant state pollution control boards or municipal authorities if you have special concerns about noise pollution in a particular area of India.

Self-assessment questions

Q.1. What are the permissible noise levels for industrial areas during the daytime and night-time?

Q.2. How do permissible noise levels vary between commercial and residential areas?

Q.3. What are silence zones, and what are their permissible noise limits?

5.5 Noise exposure level

Noise exposure level is a measurement of the intensity and duration of noise exposure during a given time period, usually represented in decibels (dB). It is a significant parameter for determining the possible effects of noise on human health and safety. To prevent hearing loss and other detrimental health effects, the Occupational Safety and Health Administration (OSHA) in the United States, for instance, sets permissible exposure limits (PELs) for noise exposure in the workplace. The noise exposure level takes into consideration the duration of exposure as well as the noise intensity (in dB). For instance, a person's noise exposure level will be calculated differently if they are exposed to a continuous noise level of 85 dB for eight hours every day than if they are exposed to a higher noise level for the same amount of time. Long-term exposure to high noise levels in the workplace endangers workers' hearing health. To reduce these dangers, regulatory authorities such as the United States' Occupational Safety and Health Administration (OSHA) have developed acceptable exposure limits (PELs). NEL calculations consider both the intensity of the noise and the time of exposure, ensuring that workers are not exposed to harmful noise levels above legal limits. NEL is calculated using multiple factors, including the sound pressure level (SPL) in decibels, the length of exposure, and any adjustments for intermittent or impulsive noise. For continuous noise, the NEL can be computed using the following formula:

$$L\text{EX}=L\text{Aeq,T}+10\log10(8T)$$

Where LAeq,Tis the equivalent continuous A-weighted sound pressure level over the duration T (in hours). This formula ensures that the NEL increases logarithmically with increasing exposure time, reflecting the cumulative effect of noise on hearing health.

Time to reach 100% noise dose	Exposure level per NIOSH REL	Exposure level per OSHA PEL
8 hours	85 dBA	90 dBA
4 hours	88 dBA	95 dBA
2 hours	91 dBA	100 dBA
1 hour	94 dBA	105 dBA
30 minutes	97 dBA	110 dBA
15 minutes	100 dBA	115 dBA

In addition to work settings, NEL is useful in assessing noise exposure in transportation, leisure activities, and residential locations. For example, airports and highways frequently encounter excessive noise levels as a result of aircraft and automotive activity. Monitoring NEL in these areas enables authorities to deploy noise abatement methods and lessen the negative effects on adjacent communities. Furthermore, NEL assessments are critical for understanding the effects of noise pollution on public health. Chronic exposure to ambient noise, such as traffic noise or industrial operations, has been related to a variety of health problems, including cardiovascular disease, sleep disruption, and cognitive impairment. By assessing NEL in impacted areas, governments can design targeted actions to reduce noise pollution and promote public health.

Noise-Induced Hearing Loss, or NIHL, occurs when you listen to loud noises. These sounds can be long-lasting, such as during a concert, or short-lived, such as from gunfire. Three things increase your chance of NIHL:

- How loud the noise is
- How close you are to the noise
- How long you hear the noise

Noise levels are measured using sound level meters. Decibels, or dBAs, are the unit of measurement for noise levels. It gets louder the higher the noise intensity. You can spend as much time as you desire listening to sounds that are 70 dB or less. You run the danger of losing your hearing if you spend more than eight hours listening to sounds that are 85 dB loud. Hearing loss might occur more quickly when noise levels exceed 85 dB. For every 3 dB rise in noise levels above 85 dBA, the safe listening time is shortened by 50%. For instance, you can spend up to eight hours listening to sounds at 85 dB. It is safe to listen to the same sounds for four hours if the volume exceeds 88 dB. Sound level meters are used to measure noise levels. We measure noise levels in decibels, or dBAs. The higher the noise level, the louder it becomes. You can listen to noises at 70 decibels or lower for as long as you like. If you listen to sounds at 85 decibels for more than 8 hours, you risk losing your hearing. Hearing loss might occur more quickly when noise levels exceed 85 dB. For every 3 dB rise in noise levels above 85 dBA, the safe listening time is shortened by 50%. For instance, you can spend up to eight hours listening to sounds at 85 dB. It is safe to listen to the same sounds for four hours if the volume exceeds 88 dB.

Self-Assessment Questions

Q.1. What are the permissible noise levels for industrial areas during the daytime and night-time?

Q.2. How do permissible noise levels vary between commercial and residential areas?

Q.3. What are silence zones, and what are their permissible noise limits?

5.6. Effect of noise pollution

Noise pollution, caused by excessive and unwanted sound, has a considerable negative impact on human health and well-being in many areas of life. These impacts have physical, psychological, and even social implications, contributing to a variety of health issues and lowering overall quality of life.

a. **Effect of Noise pollution on human health:** Noise pollution has serious consequences for human health and well-being, impacting hearing, sleep, mental health, cardiovascular function, cognitive performance, and social cohesiveness. Sound insulation, urban planning initiatives, noise laws, and public awareness campaigns are all effective noise pollution mitigation tactics that create quieter surroundings and safeguard human health. Noise pollution can harm human health in the following ways:

   - **Hypertension:** Hypertension, often known as high blood pressure, is a prevalent health issue that can be caused by a variety of variables such as lifestyle, genetics, and environmental exposures. Among these environmental factors, noise pollution has emerged as a key contributor to hypertension, especially in metropolitan and densely populated areas where high levels of noise are common. Hypertension is a direct outcome of noise pollution, which causes raised blood levels over time.

- **Hearing loss:** Prolonged exposure to excessive noise levels might cause irreversible hearing impairment. Constant exposure to loud noise, such as from industrial machinery, building activities, or traffic, harms fragile structures in the inner ear, resulting in sensor neural hearing loss. This can hamper communication, lower job performance, and reduce enjoyment of daily activities.
- **Sleeping disorders:** Noise pollution disrupts and deprives sleep by interfering with sleep cycles. The ability to fall asleep, stay asleep, and progress to the restorative stages of sleep can all be hampered by even modest levels of noise. Long-term sleep deprivation raises the chance of developing chronic illnesses like obesity, diabetes, and heart disease and causes fatigue, irritability, and poor cognitive function.
- **Cardiovascular issues:** Prolonged exposure to noise pollution has been associated to cardiovascular disorders such as hypertension, coronary artery disease, and stroke. Elevated noise levels stimulate the sympathetic nervous system and enhance cardiovascular stress, resulting in increased blood pressure, heart rate variability, and inflammation. Long-term exposure to traffic noise has been linked to an increased risk of cardiovascular death.
- **Social Isolation and Disruption**: Noise pollution can interrupt social connections and reduce the quality of community life. Excessive noise levels in residential areas limit outdoor recreational opportunities, impede contact among neighbours, and destroy a sense of community. Furthermore, noise complaints and disagreements among residents can cause social stress and community problems.
- **Stress and Anxiety:** An elevated heart rate, elevated blood pressure, and the release of stress hormones like cortisol and adrenaline are all physiological stress reactions brought on by prolonged exposure to noise. Anxiety disorders, depression, and other mental health issues can result from prolonged stress caused by noise pollution. Children who are exposed to noise pollution may exhibit behavioural problems and find it difficult to focus in class.
- **Cognitive Impairment:** Noise pollution decreases cognitive function and performance, including memory, attention, and problem-solving ability. Exposure to environmental noise, particularly during important stages of cognitive development, has been proven in studies to degrade scholastic achievement in children and reduce productivity and decision-making ability in adults.
- **Emotion and Behavioural Change:** This differs from cognitive thinking. Excessive noise disrupts calm and might cause annoyance and rage. People in this state often experience headaches, which can worsen with persistent noise exposure. Increased stress can lead to emotional outbursts and violent behaviour. Anxiety has been linked to this type of conduct. This habit reduces work efficiency, making it difficult to focus and attain goals.
- **Reproduction Problems:** Research suggests that pregnant women who are exposed to noise pollution during their pregnancy are more likely to have children with low birth weight. Pregnancy stress affects both the mother and the unborn child.

b. **Effects of Noise Pollution on Animals:** Noise pollution affects a variety of wildlife species and can upset natural ecosystems. It can obstruct an animal's ability to feed, mate, and communicate, which lowers the likelihood of successful reproduction and population decreases. For instance, too much noise can cause birds to modify their singing or nesting habits, which can hinder their ability to draw partners and procreate. Whales and dolphins are examples of marine species that depend on sound for foraging, communication, and navigation.

- **Reduction in Feeding Patterns:** Certain birds and animals, such as dolphins, whales, and bats, use their keen sense of hearing, or echolocation, to guide their movements, find food, and avoid predators. This has been neutralized by noise pollution, which drowns out all other sounds. Animals migrate out of their normal habitats in greater numbers as a result, seeking out calmer areas where they may feed comfortably. As a result, several animal species have gradually gone extinct. They go to unsuitable habitats elsewhere and eventually perish there.

- **Slow Reaction Time:** When adversity arises, some animals, like hermit crabs, tortoises, and turtles, retreat inside their shells. Boats or human activities immediately indicate trouble that should prompt their removal. Long-term noise pollution has warped this pattern, particularly in crabs.

- **Disruption of ecological balance:** By changing migratory patterns, feeding habits, and predator-prey interactions, noise pollution can upset the delicate balance of ecosystems. Noise can also have an effect on pollination since it can make it more difficult for pollinators to find flowers, which can have an influence on biodiversity and plant reproduction.

- **Reduction in Production:** Both wild and domesticated animals are less productive when there is noise around them. When milking, cows who are in a noisy environment yield less milk. They become agitated and often stop producing milk out of discomfort and fear. Noise also has a negative impact on chickens. In loud situations, the number of eggs laid by layers drastically decreases.

- **Behavioural Change:** Just like us, wild animals also exhibit behavioural changes in response to the degree of noise or calm in the environment. All animals experience increased levels of hostility as a result of noise, and surprisingly, birds have also been observed to get agitated. Their inability to communicate due to noise may cause them to behave in ways like cannibalism.

- **Disturbs Echolocation in Sea Animals:** Dolphins and other sea mammals belonging to the Cetacean family use echolocation for communication, navigation, and partner finding. They are especially susceptible to louder noises. Therefore, many of their primary cognitive actions and functions are disrupted by the increased noise that interferes with echolocation. Sonar systems pose a unique challenge due to their high sound intensity of up to 235 decibels.

- **Death:** Larger creatures may live in noisy environments. For tiny marine creatures, like the various varieties of shellfish known as cephalopods, the situation is different. The sounds produced by passing ships have a significant impact on these aquatic species. Large ships can kill them if they pass slowly over the areas they use as habitat. Compressed air "bullets" are shot very fast and deep into the water during seismic surveys in an attempt to find oil resources at the ocean's bottom. This creates a great deal of noise for the surrounding aquatic habitat.

- **Adaptation:** While some creatures are unable to survive in a noisy environment, the remaining animals either pass away or persevere despite difficult circumstances. The survival of the animals is what guarantees the survival of their species. As a result, animals are gradually adjusting to living in cities. Animals are employing higher frequencies to overpower the noise levels, in place of the customary calling sounds between males and females.

- **Impacts on overall quality of life:** Both people and wildlife may have lower quality of life as a result of noise pollution. It can limit recreational opportunities, lessen pleasure of outdoor areas, and add to a general feeling of discomfort and aggravation.

Regulation and reduction of noise levels are necessary to lessen the detrimental effects of noise pollution, particularly in sensitive locations like residential neighbourhoods, hospitals, and natural ecosystems. To reduce the negative impacts of noise pollution on humans and other living things, it is crucial to implement sound insulation, raise awareness of the issues, and promote noise control methods.

Self-Assessment Questions

Q.1. How does noise pollution contribute to cardiovascular diseases such as hypertension and stroke?

Q.2. In what ways does prolonged exposure to noise pollution impact cognitive functions and mental health?

Q.3. How does noise pollution disrupt animal behaviour, and what are its consequences on ecological balance?

5.7 Noise measurements equipment

To evaluate and quantify the noise levels in various environments, a variety of equipment is utilized for noise measurements. Here are a few tools for measuring noise that are frequently used:

- **Sound-Level Meter (SLM):** The sound pressure level (SPL) is measured in decibels (dB) using a portable device known as a sound-level meter. It consists of a microphone that records sound, an electronic circuit that processes the signal, and a display that shows the measured SPL. SLMs can provide data in real time as well as average and peak readings over a specified time period.

- **Integrating Sound-Level Meter:** This kind of sound-level meter averages and integrates the sound levels over a given amount of time, usually measured in intervals of one minute or one second. Because it takes into account changes in noise levels over time, it offers measurements that are more precise.

- **Noise Dosimeter**: An individual can measure and evaluate their personal exposure to noise by using a portable instrument called a noise dosimeter. Usually, it's employed to gauge noise exposure over a long duration, like a whole work shift. Dosimeters provide measures like peak sound level (Lmax), equivalent continuous sound level (Leq), and time-weighted average (TWA) noise exposure. They also measure and accumulate noise levels over time.

- **Octave Band Analyser:** Specific frequency bands are measured for sound levels using an octave band analyser. It separates the spectrum of audible frequencies into bands of one octave, usually 20 Hz to 20 kHz. This kind of analyser is helpful for determining the spectral content of noise since it gives information about how sound energy is distributed across various frequency ranges

- **FFT Analyser:** Sound signal frequency content is analysed and shown using Fast Fourier Transform (FFT) analysers. They offer a visual depiction of the sound spectrum that illustrates the energy levels at various frequencies. Applications for more sophisticated noise measurement frequently use FFT analysers.

- **Vibration Meter:** There are situations where vibrations produced by machinery or equipment are linked to noise. Vibration levels are measured, and the intensity and frequency content of the vibrations are reported using a vibration meter. Vibration-induced noise is measured and tracked using this kind of equipment.

- **Data Logging Equipment:** Data loggers are gadgets that keep track of noise levels for a long time. They can be used to record noise data over time in conjunction with dosimeters or sound-level meters. Equipment for data logging is useful for long-term noise study and monitoring.

It is crucial to utilize calibrated instruments that adhere to applicable standards and regulations while doing noise measurements. Furthermore, the factors of interest (such as sound pressure level, frequency content, personal exposure, etc.) and the environment being evaluated determine which specific equipment should be chosen for the assessment.

Self-Assessment Questions

Q.1. What is the primary function of a Sound-Level Meter (SLM), and how does it measure noise levels?

Q.2. How does a Noise Dosimeter help in assessing long-term noise exposure in workplaces?

Q.3. What is the significance of an Octave Band Analyser in analyzing noise frequency content?

5.8. Methods of noise pollution control

Noise pollution control is the process of putting plans and policies into action to lessen or eliminate excessive and unwanted noise in the environment. Noise pollution can be managed in a number of ways, including lowering the volume, wearing earplugs, shutting off appliances when not in use, planting more trees, performing routine maintenance on vehicles and machinery, and other strategies. By controlling noise, the harmful impact that noise pollution has on everyone's health can be lessened.

Source Control: The goal of this approach is to stop or minimize noise at its source. It entails putting in place technologies that reduce noise, employing quieter machinery and equipment, and implementing noise control techniques during the design and manufacturing processes. Using quieter air conditioning systems and adding mufflers to cars are two examples.

- **Soundproofing and Insulation:** To lessen the amount of sound that travels from the source into the surrounding surroundings, soundproofing techniques are used. This entails the use of sound-absorbing materials including insulation, double-glazed windows, and acoustic panels. One can also build sound barriers, such as walls or fences, to obstruct the direct path of sound.

- **Land-use Planning:** By separating noisy sources from regions that are sensitive to noise, proper land-use planning helps avoid noise pollution. This entails zoning laws and urban planning techniques that create buffer zones and prohibit the placement of railroads, airports, highways, and noisy businesses close to hospitals, schools, and residential areas.

- **Traffic Management:** Efficient traffic management has the potential to drastically lower noise pollution. Implementing traffic calming strategies to reduce vehicle noise, such as speed bumps, roundabouts, and speed limits, encouraging public transportation to lessen the number of cars on the road, and enforcing laws against loud vehicles are some of the measures.
- **Noise Barriers and Enclosures:** To stop sound from spreading, physical barriers like walls and fences can be built around noisy sources like industrial regions, roads, and construction sites. The noise can also be contained by enclosing noisy machinery or equipment inside soundproof enclosures or structures.
- **Education and Awareness:** Public education of the detrimental effects of noise pollution and the promotion of proper behaviour are two strategies to lessen noise. By teaching individuals about safe equipment use, noise control methods, and lowering noise levels in residential areas, voluntary noise reduction can be accomplished.
- **Legal Regulations:** Regulations and standards pertaining to noise pollution can be set and enforced by governments. These rules may specify the maximum noise levels that are appropriate for certain kinds of activities, the duration of noisy activities, and the consequences of breaking them. Police departments are able to keep an eye on noise levels and prosecute offenders accordingly.
- **Noise Monitoring and Assessment:** Monitoring noise levels on a regular basis in different settings makes it easier to pinpoint issues and assess how well noise management strategies are working. Sound-level meters and other noise-measuring tools can be used for monitoring in order to make sure that rules are followed and to help with decision-making.

Self-Assessment Questions

Q.1. What is the primary objective of Source Control in noise pollution management, and how is it implemented?

Q.2. How does proper Land-Use Planning contribute to reducing noise pollution in urban areas?

Q.3. Explain the role of Traffic Management in minimizing noise pollution and provide examples of effective strategies.

5.9. Legal provisions and Act for Noise Pollution

Numerous factors contribute to noise pollution, including traffic, urbanization, industry, residential areas, and leisure activities. Noise has become one of the major environmental pollutants in recent years. In actuality, laws like the Air Pollution and Water Pollution Act are required to manage it. The wealthy nations of the globe have already passed particular legislation to reduce noise pollution. There is a "Noise Abatement Act" from 1960 in England. Section 2 of this legislation prohibits loudspeakers from being used for any of the following purposes: (a) advertising any kind of entertainment, trade, or business; or (b) between nine p.m. and eight a.m. A few exceptions have been made, such as when using loudspeakers.

Aside from this, the United States of America has specific laws to control noise pollution, such as the Federal Noise Control Code of 1972, the New York Noise Control Code of 1972, and the Chicago Noise Control Regulations of 1971; Great Britain has the Control of Pollution Act of 1974, which covers noise in Part III; Japan has the Noise Control Laws of 1968.

India has enacted a number of state-level regulations that forbid the use and play of loudspeakers, such as the Bihar Control of the Use and Play of Loudspeaker Act, 1955. Section 3 of the Act states the following: (a) Within a certain radius of a hospital or a structure housing a telephone exchange, no one is allowed to use or play a loudspeaker. (b) As close as is necessary to any legally recognized educational institution or student housing facility. A written report from any police officer or a complaint submitted by the victim shall result in the recognition of an infraction under the Act, as stated in Section 6. In accordance with Rule 21 of the Bihar and Orissa Motor Vehicle Rules, 1930, a motor vehicle driver is only allowed to honk their horn to protect other drivers in traffic and not continuously. (b) No motor vehicle may have cut-out exhaust whistles, sirens, klaxons, electric horns, or any other similar device in the districts where the District Magistrate has the authority to issue notifications in this regard.

Rule 5.5 of the Delhi Motor Vehicles Rules, 1940, specifies that "no matter what, vehicles shall be fitted with any mullioned horn giving a succession of different tones or with any other sound producing devices giving an unduly harsh, shrill, loud, or alarming noise." As stated in Rule 5.6, "Every motor vehicle shall be fitted with a device (hereinafter referred to as a silencer) which reduces the noise that would otherwise be made by an escape of exhaust gases from the engines as far as reasonable and practicable" or by the use of an expansion chamber. "Every motor vehicle shall be so constructed and maintained as not to cause undue noise when in motion," in accordance with Rule 5.9.

The Punjab Motor Vehicles Rules of 1940 now include the Delhi Motor Vehicles Rules of 1940. Both Section 6(b) of the 1986 "Environment (Protection) Act" and Section 2 of the 1981 "The Air (Prevention and Control of Pollution) Act" address noise on a national scale. Noise, like air and water, is pollution in India, as per the "Environment (Protection) Act" of 1986. The right steps are being taken to draft rules and regulations to curb the nation's increasing noise pollution problem. In 2000, the Indian government developed a series of rules known as the "Noise Pollution (Regulation and Control) Rules, 2000" that solely dealt with noise pollution.

“The Noise Pollution (Regulation and Control) Rules, 2000”

The noise level in any zone cannot be higher than what is allowed by the rules. A written approval from an official authority is required before using a loudspeaker for a public address. Only enclosed places, such as auditoriums, conference rooms, community halls, and banquet halls, may utilize loudspeakers for internal communication. Anyone found in violation of the Act between 10:00 p.m. and 6:00 a.m. in any area covered by the silent zone may be subject to fines. Playing music, turning on sound amplifiers, blowing a horn, beating a drum, or performing mime, musicals, or crowd-drawing performances are a few examples of such infractions.

Sources and impacts of noise pollution

Table 5.1: Noise limits for domestic appliance

Domestic appliances	**Limits in dB (A) sound pressure level at 1 meter distance from the operating appliance**
Milling machine	95
Break room	69
Part department	78
Lunch	69

In addition to the sources listed in Table 40.2 above, other factors that have contributed to the rise in environmental noise pollution include congestion brought on by urbanization and population growth, as well as community events like festivals, weddings, public and political gatherings, and religious ceremonies.

- **Noise from loud speakers:** The use of loud speakers for events such as political meetings, weddings, religious rituals, musical evenings, advertising, etc. is the most disruptive type of noise, especially for urban dwellers. Although the use of loud speakers is subject to administrative restrictions, laws are rarely strictly implemented. Using loud horns near hospitals disrupts both patients and physicians during vital procedures. Teachers' ability to do their duties is hampered by loud horn sounds in school zones. The permitted power amplifier intensity should be modified to suit the audience, and the noise level outside the noise source premises should not be increased by more than 5 dB above the ambient noise level.
- **Noise due to cracker bursting:** The Central Pollution Control Board's 1989–1990 Annual Report states that crackers that make an impulsive noise of more than 90 dB five meters from the point of bursting should be prohibited from being made and sold. (b) It should be illegal to make and pop linked crackers; (c) it should be illegal to pop crackers between 9:00 p.m. and 6:00 a.m., except for public celebrations.
- **Noise due to Vehicle**: Examples of noise from individual cars include horn use, exhaust noise, slamming door noise, and engine noise. The noise level of the engine and transmission is determined by the support that is utilized for the moving parts. A more sophisticated and efficient noise-dampening system is a feature of superior grade. Mounting systems are becoming better, even in less priced cars. To minimize exhaust noise without sacrificing engine power production, an efficient silencing technology has been employed.
- **Noise due to Train:** One of the main causes of worry has been the noise produced by steam engines, fast trains, and railroad operations. The locations where railroad lines cross residential areas have been shown to have the loudest noises. Compared to train noise, aircraft traffic noise is more disagreeable. Noise intensity of 50–65 dB per 24 hours, which is equivalent to at least one dB(A). Furthermore, it irritates the specific observer as an incident, and after the train has passed the location, the background noise level returns to normal.
- **Noise due satellites and airplanes:** This source of noise pollution is already a significant problem and has been increasing worse over the past few years, particularly around international airports. The growing use of large, long-range jet aircraft is the main cause of this problem. The development of supersonic aircraft, the use of scare tactics, and the quick rise in air traffic all contribute to aviation noise.
- **Noise from Construction and civil engineering works**: Noise levels from factories are generally far lower than those from building sites. There are two main causes for this. One is that when construction is taking place, such as when building roads, bridges, or buildings, noise pollution levels are higher. The second is that civil engineering machinery is inherently noisy. The equipment items that produce the most noise are shown in Table 40.4.

Table 5.2: **Noise level generation by equipment using during construction and civil engineering**

Equipment	**Noise level t 15m**
Tractor-scrape	93 dB
Rock drill	87 dB

Unruffled concrete breaker	85 dB
Hand-held tree saw	82 dB
Large rotary diesel compressor	80 dB
1 1/2 tone dumper truck Diesel	75 dB
Concrete mixer	75 dB

Self-Assessment Questions

Q.1. What are the major sources of noise pollution, and how do they impact the environment and human health? Provide examples.

Q.2. How do Noise Barriers and Enclosures help in controlling noise pollution? Explain their effectiveness with suitable examples.

Q.3. Discuss the significance of legal regulations in noise pollution control. Mention key laws implemented in different countries to address this issue.

5.10. Summary

Noise pollution is a significant environmental issue that impacts human health and well-being as well as the natural environment. It characterizes excessive and undesirable loud noises that disrupt everyday life and the balance of the environment. This summary provides an overview of the sources, impacts, and potential solutions of noise pollution. Noise pollution has a detrimental effect on people's health. Tinnitus and hearing loss are two auditory disorders that can arise from prolonged exposure to loud noises. It can also lead to stress, sleep disturbances, cardiac problems, impaired cognitive function, and mental health issues like sadness and anxiety. Children are particularly vulnerable to the detrimental effects of noise pollution since it can hinder their general development, learning, and concentration. The origins of noise pollution are diverse. Transportation-related noise includes noise from trains, airplanes, and cars. Industries, noisy events, and construction all produce a lot of noise. The issue is made worse by noise from homes, businesses, and recreational activities in the neighbourhood. Workers' health and safety are at danger due to occupational noise in places of employment such factories, building sites, and transportation sectors. There are negative consequences of noise pollution for wildlife and the environment. Animal behaviour and communication patterns are upset, which affects migration routes, reproductive success, and ecosystem health. Because they depend on sound for orientation, communication, and feeding, marine life including whales and dolphins is especially susceptible to underwater noise pollution.

5.11. Termination questions

Q.1: What is noise pollution and how does it affect the environment and human health?

Answer:--

Q.2: Briefly go over the acceptable levels of background noise.

Answer:--

Q.3: Write the noise permissible limit in India.

Answer:---

Q.4: Discuss the control measures of noise pollution.

Answer:---

Q.5: Write the methods of noise pollution control.

Answer:---

5.12. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011.

2. A text Book of Environment Studies, Asthana, D. K. and Asthana, M. 2006, S. Chand & Co.

3. Atmosphere, Weather and Climate, Barry, R. G. 2003, Routledge Press, UK.

4. Ecology: Theories and Applications (4th Edition) by Peter Stiling; Prentice Hall.

5. Biodiversity: a beginner’s guide, John I. Spicer, One world Publications.

Unit-6: Radioactive pollution

Contents

6.1. Introduction

The deposition or presence of radioactive materials on surfaces or in solids, liquids, or gasses (including the human body) if their presence is unintentional or undesirable is known as radioactive contamination, also known as radiological contamination. The radioactive decay of the pollutants, which releases dangerous ionizing radiation like beta or alpha particles, gamma rays, or neutrons, makes such contamination dangerous. The concentration of pollutants, the energy of the radiation being produced, the kind of radiation, and the proximity of the contamination to bodily organs all influence the degree of hazard. The length, kind, and intensity of radiation all affect how risky it is for one's health. The most dangerous radiation from an external source is penetrating radiation, which includes gamma rays, X-rays, neutrons, and beta particles. The top layers of skin act as a shield against low penetrating radiation, such as alpha particles, so there is little external risk. Both humans and the ecosystem are seriously at risk from high levels of pollution. The body's several metabolisms are impacted by radioactive materials. Iodine has an impact on the spleen, bone marrow, lymph nodes, skin cancer, sterility, eyes, and lungs. Strontium has the capacity to build up in the bones, where it can cause tissue deterioration and ultimately to bone cancer.

Objectives: After reading this unit, the learner will able to know

- the radioactive pollution, its source, cause and effects
- the nuclear pollution, its source, cause and effects
- the biological effects of radiations
- the measures and control of radioactive pollution

6.2. Radioactive pollution

The discharge of radiation or high-energy particles into the environment is known as radioactive pollution. This kind of pollution can come from man-made sources like nuclear power plants, nuclear weapons testing, and radioactive material-using medical operations, or it can come from natural sources like cosmic radiation. The kind, level, and length of radiation exposure all affect how radioactive pollution affects a person's health. While long-term exposure to lower radiation levels can increase the risk of cancer and other chronic diseases, exposure to high radiation levels can have acute health effects, including radiation sickness and even death. Conversely, thermal pollution is the discharge of heated air or water into the environment, usually as a result of power plants or industrial processes. This may result in temperature variations in bodies of water, which may have an adverse effect on aquatic ecosystems and the creatures that depend on them. Reduced water oxygen levels, altered biological event timing, and the extinction or displacement of specific species are all potential consequences of thermal pollution. Furthermore, thermal pollution can have an impact on people's health, especially in places where people utilize water for leisure or drinking.

The three types of radioactive radiation are beta, gamma, and alpha. Of them, beta radiation has an intermediate effect, while alpha and gamma radiation have the greatest and lowest effects, respectively. While gamma particles can be blocked by large lead plates, alpha particles can be blocked by a sheet of paper. The blood and internal organs may be impacted by an unintentional alpha particle injection. The only time radiation is damaging to the body is when it comes into direct contact with it; otherwise, radioactivity remains harmless. There are two categories of causes of radioactive pollution: man-made and natural. Nuclear fuel and fission products will contaminate the surrounding air, soil, people, plants, and animals after an atmospheric nuclear weapon detonation or a nuclear reactor containment breach. Any rags used to clean up the spill might become contaminated if a vial containing radioactive substance, such as urinal nitrate, spilled. The Bikini Atoll, the Rocky Flats Plant in Colorado, the vicinity of the Fukushima Daiichi nuclear accident, the vicinity of the Chernobyl accident, and the vicinity of the Mayak accident are examples of areas that have experienced extensive radioactive contamination.

6.3. Sources of radioactive pollution

A multitude of factors may contribute to radioactive contamination. It could happen as a result of radioactive liquids, particles, or gasses leaking. For instance, people walking around could disperse radioactive materials used in nuclear medicine if they are accidently spilled or due to ignorance. Two things can lead to radioactivity:

1. **Naturally:** Naturally occurring radioactivity is what it sounds like, it happens in our surroundings. Rocks and soil do contain trace amounts of certain radioactive elements, such as uranium and thorium. It is interesting to note that nuclides, like carbon-14, are produced by cosmic rays and are present in all living things, including people.
    i. One of the natural sources of radioactive pollution is atomic radioactive materials. Radon gas is regularly emitted into the atmosphere during uranium mining. With a half-life of 1602 years, radium 226 is the father of radon-222 ($t_{½}$ = 3.82 days). Along with uranium isotopes, radium-226 is widely dispersed in rocks, sediments, and soils. Natural or background radiation is the term for the radioactive radiation that originates from these organic sources.
    ii. High energy ionizing electromagnetic radiation is known as cosmic rays. The stars in our galaxy produce cosmic rays through nuclear processes, mostly in their centers. Cosmic rays from space are continuously entering the planet.
    iii. Radioactive radiation can also originate from naturally existing radioisotopes, such as radon-222, which is found in minute amounts in soil.
    iv. The lithosphere contains radioactive materials such as carbon (C-40) and potassium (K-40) isotopes, radium, uranium, and thorium.
2. **Man-made:** When a nuclear weapon is discharged or a nuclear reactor's containment is breached,

man-made radiation results. In such cases, fission products and radioactive fuel remnants will poison every living thing within a certain radius of the nuclear event. This could take the shape of radioactive dust or even surface-found particles.

1. Waste radioactive materials are produced by nuclear power plants. Low to medium radiation may be produced by nuclear waste produced by nuclear power facilities. The air, water, and soil get contaminated as a result. Because radioactive wastes cannot be broken down chemically or biologically, they are dangerous. The main sources of man-made nuclear waste in the surrounding oceans in Europe are nuclear power stations. These plants have been linked to radioactive contamination as far away as Greenland.
2. Radioactive ores must be crushed and processed in order to produce radioactive byproducts during the mining and refining of radioactive elements like uranium and thorium.
3. Numerous industrial, medical, and scientific operations rely on the nuclear fuel cycle.
4. Two of the most well-known nuclear mishaps in history occurred in 1979 at the Three Mile Island nuclear power facility near Harrisburg, Pennsylvania, and in 1986 at a former Soviet nuclear power plant from Chernobyl. Even now, the impacts are still noticeable.
5. As a result of modernization, radioisotope use has expanded in a number of ways to boost output and obtain information that isn't attainable in any other way.
6. Nuclear methods are employed in environmental control quite frequently. Nuclear procedures, which frequently involve radioisotopes, allow for continuous analysis and quick responses, which provide consistent flow and analytical data availability. As a result, expenses are decreased and product quality is raised.

6.4 Sources of radiations

Energy traveling across space is called radiation. Either a stream of energetic particles or electromagnetic waves, or radiations, can carry energy. There are two kinds of these radiations.

- Non-ionizing radiations:
- Ionizing radiations

1. **Non-ionizing radiations:** Longer wavelength electromagnetic waves, ranging from radiowaves to near ultraviolet light, are known as non-ionizing radiations. These waves are energetic enough to cause the atoms and molecules in the medium they are traveling through to vibrate more quickly. They lack the energy to become ionized.
2. **Ionizing radiations:** High intensity electromagnetic radiations, such as gamma rays, x-rays, and short wavelength ultra violet radiations, are known as ionizing radiations. Radioactive decay produces energetic rays such as (α, β and γ etc) that can ionize the atoms and molecules in the medium they travel through, converting them into charged ions. Radioactive decay is the process that produces alpha (α), beta (α), and gamma (ε) radiations. These radiations are released when the unstable nuclei disintegrate on their own. Certain other nonradioactive atoms may be affected by these rays (radiations) to become radioactive (unstable) and release radioactive radiations.

6.5 Nuclear pollution

Nuclear pollution is also known as radiation pollution and is a result of improper nuclear waste disposal and nuclear power plant meltdowns or explosions. Nuclear power plant meltdowns or explosions, as well as inappropriate nuclear waste disposal practices, are the causes of nuclear contamination, sometimes referred to as radiation pollution. The 1986 meltdown at the Chernobyl Nuclear Plant, which rendered the surrounding area uninhabitable for both humans and wildlife, is one of the most well-known instances of nuclear pollution. Another instance is the 2011 Fukushima Nuclear Plant meltdown, which was brought on by a major tsunami that was set off by the earthquake that happened on March 11 of that same year. Both incidents led to radioactive contamination. Radiation exposure from this kind of pollution is directly associated with DNA damage and a variety of cancer types. Radiation can damage the DNA in our cells. High doses of radiation can cause Acute Radiation Syndrome (ARS) or Cutaneous Radiation Injuries (CRI). High doses of radiation could also lead to cancer later in life.

- **Nuclear Accidents**: Notable nuclear accidents that have caused substantial discharges of radioactive materials into the environment include the Fukushima Daiichi nuclear disaster in 2011 and the Chernobyl nuclear accident in 1986. These mishaps had a significant impact on the environment and human health in addition to the immediate communities around the plants.

  Chernobyl Disaster (1986): One of the most catastrophic nuclear accidents in history occurred at the Chernobyl Nuclear Power Plant in Ukraine (then part of the Soviet Union). A combination of design flaws, operator errors, and inadequate safety protocols led to a massive explosion and fire in Reactor No. 4. The accident released a significant amount of radioactive material into the atmosphere, contaminating large areas of Ukraine, Belarus, Russia, and other parts of Europe. The long-term health effects and environmental impact of the Chernobyl disaster are still being studied.

  Fukushima Daiichi Nuclear Disaster (2011): Following a powerful earthquake and tsunami off the coast of Japan, the Fukushima Daiichi Nuclear Power Plant experienced multiple meltdowns, hydrogen explosions, and releases of radioactive material. The accident resulted in the evacuation of tens of thousands of residents from the surrounding areas and widespread environmental contamination. The Fukushima disaster reignited global concerns about nuclear safety and disaster preparedness.

  Three Mile Island Accident (1979): The partial meltdown of a reactor at the Three Mile Island Nuclear Generating Station in Pennsylvania, USA, remains the most significant nuclear accident in the United States. Although the reactor containment vessel largely contained the release of radioactive material, the incident raised concerns about nuclear safety and emergency response procedures.

  Other Nuclear Accidents: Several other nuclear accidents and incidents have occurred around the world, ranging from minor leaks and contamination events to more serious accidents resulting in significant releases of radiation. These include incidents at facilities such as the Mayak Production Association in Russia, the Wind scale Fire in the United Kingdom, and the Tokaimura nuclear fuel processing facility in Japan.

- **Nuclear Weapons Testing:** Significant amounts of radioactive elements have been discharged into the atmosphere, soil, and water as a result of past nuclear weapons testing. Even though many testing operations have been cancelled or drastically scaled back, the legacy of nuclear testing continues to contaminate the environment in some areas. The experimentation and detonation of nuclear devices for military reasons, mainly to evaluate the efficiency, yield, and design of nuclear weapons, is referred to as nuclear weapons testing. Numerous nations have carried out these experiments since the creation of nuclear weapons during World War II. The following are important details about the testing of nuclear weapons: During the Cold War, nuclear weapons testing increased significantly, especially between the US and the USSR. Extensive testing programs were carried out by both nations to enhance and expand their nuclear arsenals. There are four types of nuclear weapons testing: atmospheric, subterranean, underwater, and space. In the early stages of nuclear development, atmospheric tests—this involved setting off nuclear devices in Earth's atmosphere were frequently conducted. However, because of worries about radioactive

- **Nuclear Waste**: Contamination of soil, groundwater, and surface water can result from improper disposal of nuclear waste. For thousands of years, radioactive waste is still dangerous, and handling it carefully is necessary to avoid contaminating the environment or endangering people. Radioactive waste is produced by activities related to the nuclear fuel cycle. The handling of radioactive material that emits radiation is one factor that sets nuclear waste apart from other types of trash. The public has to be convinced that radioactive waste management is safe before nuclear energy can be approved. Nuclear wastes are not always as dangerous or challenging to handle as other toxic industrial pollutants.

Wastes generated at nuclear power plants

Low- and intermediate-level radioactive waste (LILW) is produced in nuclear power plants when a variety of components leak radionuclides that are produced during fission and activation or are contaminated by fuel or cladding surfaces. Radionuclides are collected and released from spent fuel storage pools in addition to the reactor coolant system. The removal of components (primarily activated solids, such as stainless steel containing cobalt-60 and nickel-63) or operational wastes (such as radioactive liquids, filters, and ion-exchange resins contaminated by fission products from liquid coolant circuits) is the primary source of waste during the refuelling or maintenance of a nuclear power plant. All nations are taking or plan to take steps to minimize trash arising in order to reduce the volumes of waste that need to be temporarily stored and to minimize disposal expenses. When dealing with low-level waste, which has a big volume but little radiation activity, the volume reduction is especially alluring. Administrative changes, such as switching from paper towels to hot air dryers and introducing long-lasting, reusable protective apparel, among other things, can yield major improvements, as can general "housekeeping" improvements. They basically fall into two categories: primary wastes, which include expended radiation sources and radioactively contaminated metallic devices. Secondary wastes from a range of operational processes, including filter cartridges, organic ion exchange resins, cellulosic and fibrous materials, and protective rubber and plastic wear.

6.6 Radioactive waste

Hazardous waste containing radioactive substances is called radioactive waste. Numerous processes, such as nuclear power generation, nuclear research, nuclear medicine, rare-earth mining, and the recovering of nuclear weapons, can produce radioactive waste. To safeguard the environment and public health, government organizations control how radioactive waste is stored and disposed of. There are three categories for radioactive waste: low-level (LLW), intermediate-level (ILW), and high-level (HLW). Paper, tools, rags, and clothing are examples of low-level waste. These items have a small amount of radioactivity, mostly short-lived; intermediate-level waste (ILW) has a large amount of radioactivity and needs some shielding; and high-level waste (HLW) is highly radioactive and blazing due to decay heat, so it needs cooling and shielding. In nuclear reprocessing facilities, approximately 96% of spent nuclear fuel is reprocessed back into mixed-oxide and uranium-based fuels. Minor actinides and fission products make up the remaining 4%. The latter are made up of a mixture of medium- and medium-lived fission products, such as strontium-90 and caesium-137, and long-lived fission products, such as seven, whose half-life range from hundreds of thousands to millions of years. The heavy elements that make up minor actinides up until that point are different from neutron capture, which produced uranium and plutonium. They are often radiotoxic since they are alpha emitters with half lifetimes ranging from years to millions of years. All of those elements have suggested uses as well as somewhat existing ones, but industrial scale reprocessing using the PUREX process discards them as waste along with the fission products. After that, the waste is transformed into a ceramic that resembles glass and is kept in a deep geological repository. The type of waste and radioactive isotopes it contains must determine how long radioactive waste must be stored. Short-term methods for storing radioactive waste have included segregation and storage on or close to the surface. Reuse and transformation are preferred methods for reducing the inventory of high-level waste (HLW), while burial in a deep geological depository is a fortunate solution for long-term storage. There are legal, financial, and radioactive contamination concerns when recycling spent nuclear fuel if chemical separation techniques are unable to produce very high purity. Additionally, elements could be found in both advantageous and problematic isotopes; hence, using expensive and energy-intensive isotope splitting to extract them would be unfeasible at this time. The International Atomic Energy Agency's (IAEA) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management is presented, along with an overview of the amounts of radioactive waste and management strategies for the majority of developed nations as part of the joint reviews that occur on a regular basis.

Source of Radioactive waste.

Sources of radioactive waste are numerous. The majority of waste in nations possessing nuclear power plants, nuclear fuel treatment plants, or nuclear armament comes from the nuclear fuel cycle and the reprocessing of nuclear weapons. In addition, naturally occurring radioactive materials (NORM) that can become concentrated as a result of the processing or consumption of coal, gas, and oil, as well as some minerals, are additional sources. These include industrial and medical wastes.

a. Front end:

The front end waste of the nuclear fuel cycle is typically uranium extraction waste that emits alpha particles. It frequently includes radium and the by-products of its disintegration. The radioactivity of uranium dioxide (UO2) enhanced by mining is a thousand times or more than that of granite used in construction. Uranium hexafluoride gas (UF6) is produced by purifying yellowcake (U3O8). It undergoes enrichment as a gas, raising the U-235 level from 0.7% to roughly 4.4% (LEU). After that, it is transformed into a hard ceramic oxide (UO2) that may be collected and used as reactor fuel. Depleted uranium (DU), essentially the U-238 isotope with ~0.3% U-235 essence, is the primary by-product of enhancement. Either as U3O8 or as UF6, it is reserved. Some find employment in applications like anti-tank shells and, in one instance, a sailboat keel, where their extremely high density makes them essential. It is also used to dilute, or down blend, highly heightened uranium from weapons stocks that is currently being diverted to become reactor fuel, together with plutonium to create mixed oxide fuel (MOX).

B. Back end:

The back end of the nuclear fuel cycle primarily consists of spent fuel rods, taken fission products that release gamma and beta radiation, and actinides that release alpha particles, such as neptunium-237 (2.144 million years), plutonium-238 (87.7 years), americium-241 (432 years), and uranium-234 (which has a half-life of 245 thousand years). On occasion, some neutron emitters, such as californium (241 years), are also released into the atmosphere. These isotopes are produced in nuclear reactors.

6.7 Biological Effects of radiation

Exposure to any type of ionizing radiation (α and β particles, γ-rays and X-rays) can prove harmful and even lethal. The two types of effects are:

i. Genetic

ii. Nongenetic or body damage.

Genes and chromosomes are changed in genetic damage. Its impact could show up as distortions in the off-plane segments. Genetic material, or DNA (deoxyribonucleic acid), changes or breaks. When there are nongenetic repercussions, the damage manifests itself right away as burns, birth deformities, tumours, miscarriages, leukemia, or cancer of one or more organs.

The effects and dosages of radiation

The following variables determine the biological harm that radiation causes.

i. the time of exposure

ii. the intensity of radiation

iii. the type of ionizing radiation (i.e. its penetration power)

iv. whether the radiation is emanating from outside or inside the human body

On account of these factors the absorbed (or simply doses dose) designated as D, of the radiation to be the amount of energy deposited into a region of the body divided by the mass of the portion of the body that absorbed the radiation

The MKS unit of absorbed dose is ‘gray’ (Gy), thus one gray is one joule of energy deposited per kg of mass. More traditional unit of absorbed doses is radiation absorbed dose (rad). One rad is equivalent to 0.01 Gy. A particle's ability to inflict biological harm is dependent on both the overall energy deposited and the rate of energy loss per unit of distance travelled. Alpha particles, for instance, cause far more harm than other particles. The effect is quantified as energy deposited per unit more than that of an electron (quality factor Q = 0 for electrons and 20 for alpha particles). The absorbed dosage D multiplied by the quality factor Q yields the human equivalent dose H, which indicates the biological impact: H = QD. The Sievert, or Sv, is the MKS unit of the human equivalent dosage. The rem, or radiation equivalent in man (1 rem = 0.01 Sv), is a conventional unit of measurement for human equivalent dosage. When exposed to low levels of radiation, such the background radiation we encounter on a daily basis (less than 1 millisiem), the cells heal quickly. The cell may not be able to heal the damage at greater dosages (up to 100 rem); instead, it may either die or undergo permanent alteration.

When exposed to high levels from the outside, alpha () and beta (ε) particles can burn skin, but they cannot enter the skin to cause internal injury. On the other hand, if a radioactive isotope that may release alpha or beta particles is swallowed or inhaled by the body, the particles may seriously harm surrounding tissues. They might have an impact on cell division and lead to the development of tumours. Compared to alpha particles of the same energy, beta particles do less inside harm to the body. High energy neutrons and gamma (ε) rays are so permeable that they can easily enter the body and destroy cells from the outside as well as the inside.

6.8 Measures from nuclear radiation

To reduce the effects due to both natural and artificial radiations:

i. Atomic explosions should not be carried out in the atmosphere.

ii. Closed cycle coolant systems can be used in nuclear reactors to prevent coolant loss of radioactivity.

iii. It is necessary to dispose of radioactive waste from nuclear weapons programs or reactors in a way that will cause the least amount of harm. Initially, the wastes might be briefly held somewhere to give the initial burst of highly powerful radiation time to pass through natural decay. To prevent leakage, radioactive waste should always be packed in double-walled containers. In reprocessing plants, some of the valuable isotopes produced during reactor fission may be recycled in the second stage. Lastly, it is necessary to construct a permanent storage facility for the wastes in deep, underground mines that are stable geologically.

iv. Production and use of radioisotopes should be minimum and only for very essential use because radioisotopes once produced cannot be destroyed by any means except by the passage of time.

v. The number of nuclear installations should be minimized so as to limit the emission of radio-pollutants.

vi. Fission reactions should be minimized.

vii. In nuclear mines, wet drilling may be used and tailings properly sealed and protected for radiation leakage.

viii. Industrial wastes contaminated with radionuclides are disposed off carefully in specially built tanks.

ix. Working places where radioactive emissions are possible should have high chimneys and good ventilation system.

6.9. Summary

The existence of radioactive materials in the environment that endanger ecosystems and human health because they release ionizing radiation is known as radioactive pollution. Nuclear power plants, nuclear weapons testing, specific industrial processes, medicinal and scientific uses, and nuclear calamities like Chernobyl and Fukushima are some of the sources. Severe side effects include genetic mutations, cancer, and acute radiation sickness. Even though nuclear power facilities are built with safety precautions to prevent radioactive material from leaking out, accidents, leaks, and inappropriate disposal of radioactive waste can nevertheless pollute the environment. If not adequately managed, some industrial activities, such uranium mining and processing, can leak radioactive materials into the environment. Applications in medicine and science: If radioactive materials are not managed and disposed of properly, their use in medical diagnosis, treatment, and research may also contribute to radioactive contamination.

Strict laws, safe handling and disposal of radioactive materials, observation, efforts to create safer technology, and the promotion of renewable energy sources are all part of prevention. Radioactive pollution can have serious, long-lasting repercussions. Both humans and animals can experience acute radiation sickness, cancer, genetic abnormalities, and other health issues as a result of high amounts of ionizing radiation exposure. The consequences on ecosystems can last for decades or even centuries, and substantial cleanup efforts may be necessary in contaminated locations.

Strict laws, appropriate storage and disposal of radioactive materials, and ongoing environmental radiation level monitoring are all necessary to prevent radioactive pollution. Furthermore, initiatives to advance renewable energy sources, enhance waste management procedures, and create safer nuclear technology can all aid in lowering the risks related to radioactive pollution.

6.10. Terminal question

Q.1: Define radioactive pollution and its sources

Answer:--

Q.2: Discuss the nuclear pollution and effects on human life.

Answer:--

Q.3: is radiation absorbed dose (rad)?

Answer What:---

Q.4: What as the effect of radiations on human body?

Answer:--

Q.5: What are the factors or which the biological damage by radioactive radiations depends?

Answer:--

Q.6: What is the radioactive waste? Discuss radioactive waste release during war.

Answer:--

Q.7: Discuss the waste discharge form war.

Answer:--

6.11 Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011.
2. A text Book of Environment Studies, Asthana, D. K. and Asthana, M. 2006, S. Chand & Co.
3. Atmosphere, Weather and Climate, Barry, R. G. 2003, Routledge Press, UK.
4. Ecology: Theories and Applications (4th Edition) by Peter Stiling; Prentice Hall.
5. Biodiversity: a beginner’s guide, John I. Spicer, One world Publications.

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Introduction

Unit-7: This unit cover the definition, origins, causes, management, and measurement of thermal pollution.

Unit-8: This unit cover the impacts of environmental pollution on agriculture, metal toxicity and its consequences on humans, and the effects of heavy metal pollution on natural water and soil.

Unit-9: This unit cover the water treatment methods, oxidation ponds, air samplers, fluidized bed reactors, sequencing batch reactors, bioscrubbers, biotrickling filters, and reforestation.

Unit-7: Thermal Pollution

Contents

7.1. Introduction

Pollution is caused by a variety of sources, including rubbish, carbon emissions from human activities, and other things. Thermal pollution is often overlooked. However, thermal pollution is a severe and continuous threat to our modern society. Thermal pollution occurs when water from a natural source is collected by an industry or other man-made organization and heated or cooled. The water is then reintroduced into the natural resource, changing the oxygen concentration and potentially harming adjacent ecosystems and communities. Human activities can cause dramatic temperature fluctuations in any natural body of water, whether the ocean, lake, river, or pond. This phenomenon is referred to as thermal pollution. This usually happens when a facility or plant uses water from a natural source and alters its temperature. Typically, they use it to improve the way their products are manufactured or to cool their machines. This huge migration of thermal pollution is typically created by wastewater treatment plants or enterprises producing a variety of items. Even after governments and citizens have taken several steps to regulate how plants use water in order to successfully control and sustain thermal pollution, the effects of the pollution remain.

Objectives

After reading this unit, learner will able to know

- The Thermal pollution, its sources and effects
- The Causes and effects of thermal pollution
- The Standards for thermal pollution and its role in thermal management

7.2. Thermal pollution

Thermal pollution is the term used to describe the significant temperature changes that occur in natural water systems, such as rivers, lakes, and seas, as a result of human activities. Aquatic ecosystems' natural temperature homeostasis is frequently disturbed by the discharge of warm water from factories, power plants, and urban runoff. Water does not shift from its liquid state even when it absorbs large amounts of heat. Its high heat capacity makes it suitable for use as a coolant in a variety of industries. Heat release into the atmosphere can modify other variables that are harmful to living species, including humans, or have a negative impact on the optimal temperature ranges.

The warm temperature reduces the levels of DO (Dissolved Oxygen) in water. The decrease in DO can create suffocation for plants and animals such as fish, amphibians and copepods, which may give rise to anaerobic conditions. Warmer water allows algae to flourish on surface of water and over the long term growing algae can decrease oxygen levels in the water. Change in water temperature results in alteration in species composition and heat resistant species invade the area. Species sensitive to heat migrate out of the area. Excessively high temperatures can result in the release of immature eggs or hinder normal development of specific eggs. Overheating can prevent some eggs from maturing normally or result in the release of immature eggs.

Thermal pollution is defined as "the accumulation of unusable heat from human activities that disrupts ecosystems in the natural environment" or "the degradation of water quality caused by any process that alters ambient water temperature."

Thermal pollution is a substantial physical stressor on aquatic ecosystems that can worsen the impacts of chemical pollution while also causing problems in and of itself. Cooling water from condensers is a significant source of heat produced by businesses. The process, by which human activity introduces excessive heat into bodies of water, with detrimental impacts on aquatic ecosystems and the environment, is known as thermal pollution. Typically, electricity generation, urbanization, and industrial processes are the sources of this kind of pollution.

7.3. Causes of Thermal Pollution

Natural phenomena including volcanoes, wildfires, and underwater thermal vents can all cause thermal pollution. However, it typically occurs when a facility or industrial activity produces hot effluent after using a large amount of natural water.

- **Industrial effluents:** The pulp, paper, sugar, and textile industries release large amounts of cooling water and effluents into adjacent waters. In urbanized watersheds, stream temperatures can be considerably raised by heat from wastewater treatment plant effluents. These effluents are similar to those from other businesses. Water is contaminated by sudden and large releases of organic matter, which lowers dissolved oxygen levels and damages aquatic life.
- **Sewage:** Untreated domestic wastewater is dumped into lakes, rivers, and streams. The receiving waters' dissolved O_2 content drops as a result of the wastes' elevated temperature and organic load. Anaerobic and anoxic conditions eventually arise from this, leading to the abrupt death of aquatic life.
- **Power Plants and Industrial Facilities:** Thermal pollution is mostly caused by thermoelectric power plants that run on waste materials like biomass, coal, natural gas, or nuclear energy. The usual location of power plants is near a river, lake, or ocean since these bodies of water offer a consistent supply. This is transformed into steam, which powers turbines to produce energy. Additionally, water is used to cool the extremely hot machinery. Heat is absorbed by the water, and what doesn't evaporate is usually released back into the surrounding environment. Thermal pollution is caused by a variety of industrial facilities, including steel mills, chemical plants, pulp and paper mills, and petroleum refineries, in addition to power plants. In addition, they discharge hot water and use water to cool machinery. Once-through cooling is the process of drawing heated water for industrial use from a lake, ocean, or river and then releasing it back to its source. It has long been recognized to have a negative impact on marine and aquatic habitats. Once-through cooling results in the outflow of warmer frequently contaminated water, which changes habitats and kills fish and larvae that become stuck against

intake screens.

- **Nuclear power plants (NPPs):** Nuclear power plants (NPPs), which include drainage from hospitals, research institutes, nuclear tests, and explosions, release a large amount of heat as well as traces of dangerous radionuclide's into neighboring waterways. Emissions from nuclear reactors and processing plants contribute to rising water temperatures. Aquatic life and flora are impacted by power plant heated effluents, which are released at a temperature 10˚C higher than receiving waters. Nuclear power plants' cooling water discharge is one of the main local sources of thermal pollution due to the high amounts of energy generated per facility. Additionally, compared to other plant types with comparable power generation, nuclear power plants need 30–100% more cooling water.

- **Coal-fired power plants:** Coal-fired power plants use water from nearby lakes or rivers to cool their condenser coils. The heated water is poured into lakes and streams, raising the temperature by 15˚C. Heated effluent lowers the dissolved oxygen content of water, killing aquatic organisms. Sudden temperature changes generate "thermal shock," which can wipe out aquatic life. Globally, coal-fired power plants account for more than 46% of thermal emissions into rivers, whereas nuclear power plants account for more than one-third.

- **Desalination Plants:** Once-through cooling is also employed by desalination plants. A significant portion of the seawater utilized for desalination is discharged back into the ocean as effluent, frequently with a higher temperature. Massive volumes of heated, saline wastewater are dumped into shallow coastal regions by desalination plants that are grouped together in several parts of the world. This can greatly increase the salinity and temperature of saltwater. Not all wastewater is cleaned up before being dumped into bodies of water. Given that farm runoff is frequently warmer than the streams, lakes, or ocean it flows into, untreated sewage, urban rainwater, and agricultural runoff can all lead to thermal pollution in adjacent water sources.

- **Soil Erosion:** Soil erosion also contributes to thermal pollution by raising water levels and exposing them to more sunlight, which raises their temperature. Apart from the normal soil erosion, there is also a possibility of erosion along the banks of streams, which exposes the water to additional solar radiation and raises the temperature of the water. The rise in water temperature has the potential to cause anaerobic conditions and heightened microbial activity in aquatic biomes, but it may also cause certain creatures to perish since warm pools of water are insufficient for their survival.

- **Deforestation:** Usually, vegetation and trees shade lakes, ponds, and rivers from direct sunshine. These bodies of water absorb more heat when there is deforestation because they are exposed to direct sunshine. In addition to giving various bodies of water shade, trees and other vegetation cover reflect back and absorb solar radiation. This would reduce the amount of heat in the atmosphere and stop thermal pollution in the numerous bodies of water close to the forests. Deforestation releases greenhouse gases into the atmosphere, which causes global warming. The greater the air temperature, the higher the water temperature.

- **Runoff from Paved Surfaces:** Surface waters can be warmed by urban runoff from paved surfaces such as highways and parking lots. During warmer seasons, pavement gets fairly hot, resulting to warm runoff that flows into sewers and water bodies. Urban runoff from concrete surfaces like highways and parking lots can warm water. During the summer, the pavement becomes quite hot, causing heated runoff into sewer systems and bodies of water. Some studies have found that permeable pavements can successfully reduce thermal pollution from storm water runoff by minimizing heat exchange between the pavement and the near-surface air. It will not only minimize the heat island effect, but also the volume of storm water runoff, thereby improving water quality. The maximum temperature of a permeable concrete surface is said to be approximately 8 °C lower than that of impermeable asphalt. Storm water flow from permeable pavement was cooler than that from impermeable asphalt pavement (IAP).

- **Natural Causes:** Warm lava can be released by volcanoes and geothermal activity beneath the seas and oceans, increasing the temperature of bodies of water. A lot of heat can also be released into the oceans by lightning. This suggests that the water source's overall temperature will increase, which could have detrimental effects on the environment.
- **Retention Ponds:** Thermal shock can also occur in retention ponds, which absorb a significant amount of solar heat energy due to their shallow depth and tiny size. It's like putting a hot pitcher of water into a bathtub full of water and causing the temperature to raise a few degrees Fahrenheit when poured directly into a river, lake, or bay.

Self-Assessment Questions

Q.1. What are the major sources of thermal pollution, and how do they impact aquatic ecosystems? Provide examples.

Q.2. Explain how industrial activities, including power plants and desalination plants, contribute to thermal pollution. What measures can be taken to mitigate their impact?

Q.3. How do natural causes such as volcanic activity and geothermal events contribute to thermal pollution? Compare their effects to human-induced sources.

7.4 Effects of thermal pollution:

Aquatic species and the physicochemical characteristics of water are both significantly impacted by thermal pollution. Viscosity, density, vapor pressure, surface tension, gas solubility, and diffusion rates are all impacted by temperature. Thermal stratification is created when heated water, which has a low density, spreads across the water's surface. Oxygen cannot enter the deeper strata due to the stratification. Higher temperatures cause a decrease in the density and viscosity of water, which increases the sedimentation of suspended particulates. Hotter temperatures also accelerate the pace at which water evaporates. For every 10ºC increase in temperature, the rate of chemical reactions usually doubles. BOD levels are also raised by temperature. As temperatures rise, so do photosynthesis and plant growth rates. At first glance, a rise in plant growth could seem beneficial, but more living plants mean more dead ones. The bacterial population grows as a result of the buildup of dead plants, and it also uses oxygen, increasing the demand for oxygen as oxygen becomes less available.

1. As temperature increases, the concentration of dissolved oxygen (DO) decreases along with gas solubility. Fish, amphibians, copepods, and other plants and animals may suffocate due to a decrease in DO, which could result in anaerobic circumstances. Additionally, the growth of algae on the water's surface is encouraged by warmer water.
2. Metal compounds, lower DO, and rising temperatures can combine to create toxic circumstances for higher species, leading to fish kills. The consistent flow of high-temperature discharge from industry has resulted in a tremendous rise in contaminants thrown into natural water bodies. These toxins may be chemicals or radiation, which can have a harmful impact on the environment and render them susceptible to a wide range of ailments.
3. Temperature affects the physiology, metabolism, and biochemical activities of aquatic animals, including respiration, digesting, excretion, and overall development. Temperature

changes cause total disruption in the entire ecosystem. Many aquatic organisms are sensitive to temperature differences as little as one degree Celsius, which can cause significant changes in organism metabolism and other detrimental cellular biology implications.

4. Thermal pollution can affect fish's regular reproductive cycles. Optimal temperature effects a wide range of fish behaviors, including nest building, spawning, hatching, migration, and reproduction. Thermal pollution modifies the temperature gradient of water bodies, which affects aquatic life. Excessive temperatures may cause immature eggs to be released or prevent certain eggs from maturing normally.

5. Higher temperatures can increase the solubility of hazardous substances for organisms. Thus, the temperature shift, the resulting drop in DO and increase in metal concentrations, and the synergistic impact of mixing hypoxic water and reduced metal compounds all contribute to a cascade of death in the stream's ecology. Continuous exposure to heat causes the creation of a new ecosystem constituted of thermally adapted species..

6. Thermal pollution increases enzyme activity, causing organisms to consume more food than necessary if the environment remains unaltered. It disrupts the stability of the food chain, alters species composition, and may even promote faunal migration as species try to adjust to shifting thermal conditions.

7. Thermal pollution causes immediate mortality in aquatic creatures. An increase in water temperature exhausts microorganisms, decreasing fish life spans. Fish die when their respiratory and neurological systems fail above a specific temperature.

8. Biodiversity loss occurs when species tolerant of warmer water are replaced by others unable to adapt. This shift is frequently followed by a general decline in species richness. Attached algae in heated effluents, for example, have been shown to boost biomass while decreasing species diversity.

9. Lake stratification: Thermal pollution affects the lake's thermal regime more in the winter than in the summer. The heat discharged into the lake in winter at ambient temperatures below 4˚C mixes down through the water column and lingers in the lake hypolimnion throughout the next summer, impacting the seasonal mixing regime. In turn, the heat that the lake absorbs over the summer is successfully released into the atmosphere by evaporation and infrared radiation at its surface.

10. Wind-induced currents drive horizontal dispersion of thermal plumes. Near-shore regions close to the emitting source are especially sensitive to thermal pollution because heat plumes can be trapped by coastal currents rather than disseminated across the ocean body.

7.5 Standards for thermal pollution

In 2015, India's Central Pollution Control Board (CPCB) developed guidelines for thermal discharges from thermal power plants. The condenser cooling water cannot be more than 10ºC higher than the intake water temperature. Thermal water pollution can be minimized by pre-cooling warm water before discharge. The four basic principles of heat loss are: conduction, convection, radiation, and evaporation. In the energy generation industry, cooling ponds and cooling towers are common methods for cooling water. The water from condensers is stored in clay ponds, where natural evaporation reduces the temperature. Once cooled, the water is either recirculated or released into a neighbouring body of water. Alternatively, heated waste water might be used to benefit other businesses. Waste heat can be used in a variety of purposes, including greenhouses, agriculture, aquaculture, and interior heating.

Self-Assessment Questions

Q.1. What are the primary sources of thermal pollution, and how do they impact aquatic ecosystems?

Q.2. How does deforestation contribute to thermal pollution, and what are its consequences on water bodies?

Q.3. Explain the role of industrial facilities in thermal pollution. What strategies can be used to mitigate their impact?

7.6. Control of thermal pollution

The negative effects of thermal pollution on the aquatic ecosystem in the future need solutions. To optimize benefits, a number of solutions have been proposed and developed for converting thermal effluents from power plants into usable heat sources. Thermal discharge into water bodies can be regulated using the following methods:

1) Cooling Ponds

The best method for controlling heat discharge is to use cooling ponds or reservoirs. Heated effluents in cooling ponds decrease the volume and area of water while releasing heat into the atmosphere. Evaporation is the process by which cooling towers release hot water's heat into the atmosphere. Most of the heat that is absorbed in a cooling tower is expelled into the atmosphere through evaporation. It is less attractive and inefficient in terms of air-water contact, even though it is the most straightforward and economical method of chilling water.

i) Wet cooling tower: Hot water from the condenser (reactor) is allowed to spray on the baffles. Cool, high-velocity air flows from the sidewalls, eliminating heat and cooling the water.

ii) Dry cooling tower: Hot water travels through lengthy spiral pipes. A fan blows cool air over the hot pipes, cooling the water. This cold water can be recycled.

2) Cooling Towers

The cooling technique involves returning water to the water body after it has passed through the condenser and been chilled. As a result, cooling towers are designed to regulate water temperature, making the cooling process more effective. Cooling towers are primarily used to dissipate recovered waste heat, resulting in reduced thermal pollution.

i) Cooling ponds: Cooling ponds are the most efficient way to cool thermal discharges. Heated effluents on the surface of cooling ponds maximize heat dispersion into the atmosphere while reducing water area and volume.

ii) Spray ponds: Water discharged from condensers can enter the ponds using sprayers. Water is sprayed in small droplets from the nozzles. Heat from the fine droplets dissipates into the atmosphere.

3) Artificial Lake

An artificial lake is a man-made water body that serves as a substitute for a natural one. The hot effluents can be thrown into the lake from one end, and water can be drawn from the other for cooling. However, because heat is lost through evaporation, these lakes must be supplied on an ongoing basis. Actually, artificial lakes and ponds use evaporation or convection to cool the water. The heated effluents can be dumped into the lake from one end, while water for cooling can be obtained from the other. Finally, the heat is removed through evaporation.

4. Water Recycling

If water recycling is used in plants and factories, thermal pollution will be greatly decreased. Every business or plant should pledge not to spill coolant water back into bodies of water. Instead, it will be recycled for further use.

5. Afforestation near rivers, seas, and other bodies of water: Trees surrounding water sources help to absorb harsh sun rays and keep them from falling directly onto the water, keeping it from boiling up. Planting more trees can also assist to reduce soil erosion since their dense roots hold the soil in place and prevent erosion.

6. Public Awareness: Making more people aware of the issue of thermal pollution would be immensely beneficial in the long run. Group discussions with representatives from various firms and industries can be arranged to address the effects of thermal pollution on aquatic life and the environment.

Self-Assessment Questions

Q.1. How do cooling ponds help regulate thermal pollution, and what are their advantages and disadvantages?

Q.2. Explain the working mechanism of cooling towers in reducing thermal pollution. How do wet and dry cooling towers differ?

Q.3. What role does afforestation play in mitigating thermal pollution, and how does it benefit aquatic ecosystems?

7.7. Summary

Water can absorb a large quantity of heat while remaining liquid. Its high heat capacity makes it appropriate for use as a coolant in a wide range of industries. Heat can be classified as a pollutant when it enters an environmental system and violates normal temperature ranges or indirectly affects other factors that endanger species, including humans. Whatever the meaning, "thermal pollution" can be either "an accumulation of unusable heat from human activities that disrupts ecosystems in the natural environment" as well as being defined "as the degradation of water quality by any process that changes ambient water temperature." Thermal pollution is a major physical stressor on aquatic ecosystems; it is not only hazardous on its own, but it can amplify the impacts of chemical pollution.

Condenser cooling water is responsible for a major amount of industrial heat generation. Water is mostly utilized as a coolant in the energy generation industry, including thermal power plants, nuclear power plants, petroleum refineries, steel mills, chemical plants, paper and pulp mills, and so on. The increase of heat induces physical, chemical, and biological changes in the receiving water bodies. Soil erosion and shoreline deforestation both contribute to thermal water pollution, but to a lower extent. Soil degradation makes the water turbid, which increases the amount of light absorbed and so raises the water temperature. Deforestation near coastlines worsens the situation in two ways. First, it promotes soil erosion, and second, it increases the quantity of light that reaches the water, both of which elevate its temperature.

7.8. Terminal questions

Q.1. What is the thermal pollution? Discuss the sources of thermal pollution.

Answer:---

Q.2. Who nuclear power plants play significance role in thermal pollution.

Answer:--

Q.3. Discuss the role of cooling water to reduce thermal pollution. .

Answer:--

Q.4. Discuss it cause and effects of thermal power

Answer:--

Q.5. Discuss the how to control thermal pollution.

Answer:--

Q.6. Discuss the Standards for thermal pollution.

Answer:--

7.9. Further suggested readings

1. Waste treatment and disposal, Williams, Paul T. John Wiley Publishers, 2013.
2. E-waste: Implications, regulations and management in India and Current global best practices, TERI press, Johri, Rakesh.
3. Bio- medical waste management, Sahai, Sushma, APH Publishing.
4. Electronic waste management, design, analysis and application, R E Hester, Cambridge Royal Society of Chemistry.
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Unit-8: Effects of Environmental Pollution

8.1 Introduction

Environmental pollution is the poisoning of the natural environment with various toxins, which has a negative impact on living beings and ecosystems. This global issue has risen in importance due to its widespread impact on human health, biodiversity, and the planet's overall well-being. One of the most obvious consequences of environmental contamination is a detrimental effect on human health. Air pollution from automobiles, factories, and the use of fossil fuels can lead to respiratory problems including asthma and bronchitis. Furthermore, exposure to pollutants including particulate matter and volatile organic compounds has been linked to heart disease, cancer, and even neurological problems. Water pollution, mostly caused by industrial discharge, agricultural runoff, and poor waste disposal, endangers human populations by contaminating drinking water supplies and spreading waterborne diseases such as cholera and dysentery. Furthermore, environmental contamination is a major danger to biodiversity. Contaminants brought into ecosystems upset delicate ecological balances, causing the extinction of plant and animal species. Pollution in water bodies can lead to fish deaths and the degradation of aquatic habitats, affecting entire food chains. Pesticides and herbicides used in agriculture not only damage the soil and water, but they also kill important insects, birds, and other wildlife, reducing biodiversity and ecosystem resilience. Another issue with environmental pollution is its impact on climate change. Greenhouse gas emissions, primarily carbon dioxide and methane from fossil fuel combustion and deforestation, trap heat in the Earth's atmosphere, resulting in global warming. This phenomenon causes catastrophic weather events, rising sea levels, agricultural disturbances, and habitat loss for a wide range of species. Climate change exacerbates the impacts of pollution, creating a vicious cycle of environmental degradation. Furthermore, environmental degradation has a social impact, particularly on underprivileged people and underdeveloped countries. People living in disadvantaged areas are frequently subjected to pollution-related health concerns due to their proximity to industrial facilities and lack of access to clean supplies. Furthermore, pollution can harm ecosystems that support livelihoods, such as fisheries and agriculture, jeopardizing food security and aggravating poverty. Addressing environmental contamination involves coordinated actions at the local, national, and international levels. Implementing strict environmental standards and investing in cleaner technologies can assist to reduce pollution from industry. Promoting sustainable agricultural and waste management methods can help to decrease soil and water contamination. Transitioning to renewable energy sources and boosting energy efficiency can also help to reduce greenhouse gas emissions and mitigate the effects of climate change. Individual activities, such as decreasing one's carbon footprint, conserving water, and properly disposing of waste, are also important in combating pollution. Education and awareness programs can help communities make educated decisions and advocate for environmental protection.

8.2 Effects of heavy metal pollution

Heavy metal pollution is defined as the contamination of the environment, particularly soil, water, and air, by metallic elements with high atomic weights and densities. These metals, which include lead, mercury, cadmium, arsenic, and chromium, occur naturally but become hazardous when their concentrations exceed allowed levels due to human activities such as industrial operations, mining, and inadequate waste management. Heavy metal contamination has a wide-ranging impact, including major ramifications for ecosystems, human health, and the economy.

Human health is negatively impacted by heavy metal exposure. Over time, heavy metals are known to accumulate in the body and lead to a number of health problems. For instance, exposure to lead can cause cardiovascular disease in adults, developmental delays in children, and neurological problems. Damage to the nerves, renal failure, and even death can result from mercury overdose. Likewise, exposure to cadmium has been linked to lung cancer, osteoporosis, and kidney damage. Because it can result in skin sores, respiratory issues, and a variety of cancers, drinking water poisoning from arsenic is a serious health risk. Human populations are seriously threatened by the ingestion or inhalation of heavy metal particles, especially in areas with high pollution levels.

Metals accumulate in plants, water, and soil, making their way up the food chain and impacting organisms at every trophic level. Aquatic species, such as fish and shellfish, have the ability to store mercury in their tissues, putting aquatic ecosystems and people who consume contaminated seafood at risk. Additionally, heavy metals can disrupt the microbial communities in the soil, inhibit plant growth, and reduce crop yields, endangering food security and agricultural productivity. Furthermore, because sensitive species cannot survive in contaminated settings, heavy metal poisoning may be a factor in the extinction of biodiversity.

Heavy metal contamination also has a substantial economic impact. Remediating contaminated sites, such as former industrial regions and mining sites, necessitates significant financial resources and technical skills. Clean-up procedures frequently include soil clean-up, water treatment, and the implementation of containment measures to prevent contamination from spreading further. Furthermore, heavy metal pollution can lower agricultural output and result in financial losses for farmers due to contaminated soil and crops. The impact on the fisheries and aquaculture industries can be significant, as consumers may shun seafood from dirty waterways, resulting in financial losses for fishing communities. Heavy metal pollution requires comprehensive methods that include regulation, remediation, and prevention. Strict environmental rules and standards for industrial emissions and waste management are required to reduce heavy metal leakage into the environment. Soil washing, phytoremediation, and bioremediation are three remediation procedures that can assist remove heavy metals from contaminated locations while also restoring ecosystem health. Furthermore, public awareness and education campaigns are critical for encouraging sustainable practices and decreasing human exposure to heavy metals.

8.2.1. On natural water

Natural water bodies like rivers, lakes, streams, and oceans are significantly impacted by environmental pollution, which has a number of detrimental effects on aquatic ecosystems, biodiversity, and human health. Natural water supply contamination is a serious worldwide problem brought on by a range of pollutants from domestic, commercial, and agricultural sources. Maintaining water quality and developing efficient mitigation strategies require an understanding of how environmental contamination affects natural water. The deterioration of water quality is among the most obvious consequences of environmental contamination on natural water. Water can become contaminated by heavy metals, pesticides, fertilizers, industrial chemicals, and untreated sewage, which can alter the water's chemical composition and physical characteristics. High amounts of nutrients from agricultural runoff, can cause eutrophication, which is characterized by excessive algae growth, decreasing oxygen levels, and destruction of aquatic habitats. This phenomenon disturbs aquatic ecosystems, resulting in fish deaths, biodiversity loss, and food chain collapse. Furthermore, environmental contamination can introduce harmful compounds into natural water sources, endangering aquatic species and human health. Heavy metals such as lead, mercury, cadmium, and arsenic accumulate in sediment and aquatic species, biomagnifying as they ascend the food chain. Fish and shellfish can become contaminated with these hazardous metals, endangering human health and animals. Pesticides and herbicides used in agriculture can also seep into water bodies, causing harm to aquatic organisms like fish, amphibians, and aquatic plants. These toxins can affect physiological functions, hinder reproduction, and weaken immune systems, causing population decreases and environmental disruptions. Furthermore, environmental degradation in natural water can have far-reaching consequences for ecosystem dynamics and biodiversity. Contaminants cause changes in water chemistry, disrupt nutrient cycles, and impair habitat quality, making it harder for native species to survive. Invasive species, which are frequently tolerant of pollution and capable of outcompeting native species, may thrive in contaminated water bodies, increasing biodiversity loss. Changes in species composition and abundance can have a significant impact on ecosystem stability, resilience, and the provision of ecosystem services such as water purification, nitrogen cycling, and flood regulation.

Heavy metals are defined as elements with densities of more than 5.0 g/cm3 and atomic masses more than 20.Copper (Cu), chromium (Cr), zinc (Zn), cadmium (Cd), arsenic (As), nickel (Ni), cobalt (Co), mercury (Mg), lead (Pb), and other toxic heavy metals pose serious health risks. The United States Environmental Protection Agency has identified 13 metals (arsenic, antimony, chromium, cadmium, beryllium, lead, copper, zinc, selenium, mercury, nickel, thallium, and silver) as dangerous heavy metals. Heavy metals are classified as essential or non-essential depending on biological systems. Heavy metals are necessary for biological activity and are found in the bodies of living species (humans, animals, and plants) as trace micronutrients such as nickel, iron, and zinc. Non-essential heavy metals, such as lead, cadmium, and mercury, are elements that are not required by the biological system yet serve as poisons. The significance of heavy metals varies among organisms, including bacteria, plants, and mammals. Conversely, because of their physiological and biochemical functions in biological systems, heavy metals are found naturally in the environment and are thought to be essential to life. If they above a particular threshold, they also have detrimental effects on health. Hg, Pb, As, Cr, and Cd are the most toxic heavy metals and have a major effect on the health of ecosystems. Additionally, heavy metals lower soil fertility and upset the microbiological balance of the soil. The several sources of heavy metals and their possible impacts are discussed in this article.

Heavy metals such as zinc, cadmium, mercury, lead, and copper pose major risks to the aquatic ecosystem and its biota. Because fishes are more vulnerable to heavy metal pollution, they accumulate in their tissues and have toxic effects on fish health. Heavy metal pollution is considered a poisoning agent for fish. These metals can have a significant impact on a fish's critical functions and reproduction, weakening the immune system and causing pathological alterations. As a result, fish are utilized as bio-indicators, which play an important role in monitoring heavy metal contamination. Harmful metals infiltrate freshwater bodies, destroying aquatic organisms and posing an ecological threat. The trophic level trading potentially hazardous and catastrophic metals in the natural human ways of life, particularly in fish, has enormous repercussions for human health. Fish tissue usage for arsenic (As) exceeded security levels for fishermen in complete streams, although cadmium (Cd) surpassed at Chenab and Upper Indus, and lead (Pb) for Chenab anglers. The results reveal that all metal contaminations from streams eventually reach at the Arabian, which may represent a risk to the marine environment on a national and global scale.

The biological and physicochemical properties of water determine its quality. Changes in pH, temperature, and the concentrations of essential and non-essential trace metals can render water unsafe for human consumption. The hydrological characteristics of water sources, geological processes, regional environmental characteristics, and geochemistry all have an impact on the quality of water. Groundwater is commonly used for drinking all around the world. The surface is used for both personal and industrial purposes. Numerous natural and man-made mechanisms contribute to water pollution from heavy metals. Industrial sources of heavy metal pollution in water include the steel, coal, and food processing sectors; plastics; leather tanning; and metallurgical operations. Dangerous metals Waste from homes and farms is another source of water contamination. In addition to contaminating water, heavy metal ions like Cr (VI), Cd (II), Pb (II), As (V and III), Hg (II), Ni (II), and Cu (II) can harm human health in a variety of ways, including kidney and stomach damage, skin and stomach cancer, mental disorders, and adverse reproductive system impacts. As a result, heavy metal contamination of water must be evaluated and eliminated. Numerous physicochemical methods are available for removing heavy metals from water, but they are expensive and generate a lot of secondary contaminants. It is believed that biological methods are both cost-effective and environmentally advantageous for eliminating metallic contaminants from water. In this review, we focused on the toxicity of heavy metals, their contamination of water, and environmentally appropriate bioremediation methods. Heavy metal contamination in many water sources, particularly surface and groundwater has a detrimental effect on the human population. Hazardous metallic pollutants have increased in aquatic habitats as a result of industrial development, urban landscape expansion, and the use of chemical fertilizers in agriculture, as well as industrial wastewater, urban drainage networks, and storm water runoff management systems. The presence of heavy metal contamination lowers the quality of the water. Heavy metal contamination in water can be detected using two techniques: inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption spectroscopy (AAS).

- **Water Contamination**: Heavy metals can enter natural water bodies through sources such as industrial discharges, mining activities, agricultural runoff, and atmospheric deposition. Once in the water, they can persist for long periods, contaminating surface water and groundwater. This contamination can render water unfit for various purposes, including drinking, irrigation, and aquatic habitat support.
- **Ecological Impacts:** Aquatic habitats can suffer significant consequences from heavy metal pollution. Because these contaminants have an impact on the diversity and health of aquatic creatures, they have the potential to upset the equilibrium of aquatic communities. Through bioaccumulation and bio magnification along the food chain, heavy metals can build up in the tissues of fish, invertebrates, and plants. This may lead to environmental imbalances, changed community dynamics, and decreased numbers of vulnerable species.
- **Toxicity to Aquatic Life:** Heavy metals are highly toxic to many aquatic organisms, even at

low concentrations. They can interfere with essential physiological processes such as respiration, reproduction, and growth. Fish and other aquatic organisms exposed to heavy metals may exhibit symptoms such as tissue damage, developmental abnormalities, and impaired behaviour. Chronic exposure to heavy metals can lead to population declines and ecosystem degradation.

- **Bioaccumulation and Bio magnification:** Heavy metals have the potential to bio accumulate in the tissues of aquatic organisms, particularly in long-lived species such as fish. As predators consume contaminated prey, heavy metals can biomagnify, leading to higher concentrations in top predators. This bio magnification increases the risk of exposure to toxic levels of heavy metals for organisms at higher trophic levels, including humans who consume contaminated fish and seafood.

- **Water Quality Degradation:** Heavy metal pollution degrades water quality, affecting its suitability for various uses. Contaminated water may have elevated levels of heavy metals, which can pose risks to human health through direct ingestion, as well as through the consumption of contaminated food and water. Additionally, heavy metals can impair the aesthetic and recreational value of water bodies, impacting tourism and recreational activities. Human Health Risks: Human populations are at serious danger for health problems due to heavy metal contamination in natural water sources. Long-term exposure to heavy metals including lead, mercury, and arsenic can result in a number of health difficulties, such as cancer, kidney damage, cardiovascular disease, neurological disorders, and developmental problems. Communities that depend on polluted water sources for agriculture, drinking, and fishing are more susceptible to these negative health effects.

- **Economic Impacts:** Heavy metal pollution can have economic consequences for communities dependent on natural water resources. Contaminated water bodies may suffer declines in fisheries, leading to losses in income and livelihoods for fishing communities. Additionally, tourism and recreational activities may be affected by degraded water quality, resulting in economic losses for businesses and local economies.

- **Remediation Challenges:** The persistence and extensive distribution of heavy metal pollutants make addressing their pollution in natural water bodies extremely difficult. Complex and expensive treatments including chemical treatment, sediment capping, and dredging may be necessary for remediation operations. For remediation operations to be successful and future pollution accidents to be avoided, long-term monitoring and management techniques are crucial.

8.2.2. On natural soil:

In addition to endangering human health, heavy metal-contaminated soil damages groundwater, produces phytotoxicity in plants, and lowers soil and agricultural productivity. Since plant roots absorb the majority of heavy metals, their subsequent build-up in the food chain poses a serious risk to the health of both humans and animals. Heavy metal-contaminated soil has become a source of concern for agricultural experts as agricultural product safety advances. Heavy metals are metalloids that are harmful to biological systems. Lead, cadmium, mercury, arsenic, and chromium are among the heavy metals that naturally reside in the Earth's crust but can build up in soil due to a number of man-made and natural processes. Developing successful mitigation strategies requires an understanding of how heavy metals affect natural soil. Copper (Cu), nickel (Ni), chromium (Cr), lead (Pb), cadmium (Cd), mercury (Hg), iron (Fe), and arsenic (As) are the most prevalent heavy metals found in the environment. Heavy metal pollution in soil can result from natural weathering of rocks and minerals, as well as human activity including mining, industrial processes, and the use of fertilizers and pesticides. Heavy metals can remain in the soil for long periods of time, endangering soil health, plant growth, water quality, and human well-being.

Soil pollution is one of the most significant consequences of heavy metals on natural soil. Heavy metal concentrations in soil can make it unsuitable for agriculture, reducing crop growth and yield. Soil contamination can also upset the equilibrium of microbial populations, which is critical for nutrient cycling, soil fertility, and general ecosystem health. Heavy metals have the potential to hinder the growth of helpful soil microbes while stimulating the expansion of detrimental ones, resulting in soil ecological imbalance. In addition to soil and plant contamination, heavy metals can leach into groundwater and surface water, contaminating both. This endangers aquatic ecosystems and people populations that rely on these water supplies for drinking, agriculture, and industrial use. Heavy metals in water bodies can accumulate in sediments, damaging benthic creatures and perhaps entering the food chain, causing bio magnification and posing health concerns to aquatic organisms and humans. Pb is a hazardous metal with poor mobility but high bioavailability. Pb remains on the soil's surface for a long period. Cadmium and its compounds can migrate through soil, but their mobility is dependent on a number of parameters, including soil pH and the amount of organic matter present in the surrounding environment. Furthermore, cadmium bonds closely to organic matter, becoming stationary in the soil, being absorbed by plants, and eventually entering the food chain. Heavy metal-contaminated soil has an elevated concentration of heavy metals, insufficient nutrient and organic content, low water retention capacity, and low cation exchange capacity. Furthermore, the rise in heavy metals concentration in the soil leads in harmful consequences in the soil.

Table 2: Heavy metals effects on soil

Heavy metals	Effects on soil
Lead (Pb)	• Abnormalities in the metabolic function of organisms • Shortage of soil macronutrients like Phosphorus • Affect soil enzyme activities: Decrease urease, catalase, invertase, and acid phosphatase activity • Interrupts water balance, enzyme activity and mineral nutrition • Reduces soil productivity.
Cadmium (Cd)	• Abnormalities in the metabolic function of organisms. • harm the protease, urease, and alkaline phosphatase activity • Reduce the availability of soil N and S for crop production
Zinc (Zn)	• Phytotoxic and can directly affect soil fertility • Decrease the microbial biomass N • Shortage of soil macronutrients like Phosphorus

Copper (Cu)	• Reduced the availability of soil N and S for crop production • Inhibit the activity of β-glycosidase more than the activity of cellulose. • Decrease the microbial biomass N
Mercury (Hg)	• Abnormalities in the metabolic function of organisms

The ecological consequences of heavy metal contamination in natural soil are extensive. Heavy metals can disturb ecosystems by changing species composition, lowering biodiversity, and degrading ecosystem services including nitrogen cycling and decomposition. Some heavy metals, such as mercury, can accumulate and biomagnify, causing concentrations to rise steadily up the food chain, resulting in higher exposure levels in top predators and apex consumers.

8.2.3. Effect of heavy metal on natural soil:

Food safety, soil health, and crop output can all be adversely affected by heavy metal contamination in agriculture. In addition to human activities like mining, industrial emissions, and the use of tainted water, fertilizers, and pesticides, natural processes like rock and mineral weathering can also cause heavy metals like lead, cadmium, arsenic, mercury, and chromium to accumulate in soil. Food security and sustainable agriculture may suffer greatly as a result of these contaminants. First, crop growth and productivity may be directly impacted by heavy metal contamination. Plants absorb heavy metals from the soil, and high levels of these contaminants can limit plant growth, diminish crop yields, and degrade the quality of agricultural produce. Heavy metals disrupt critical physiological processes in plants, such as photosynthesis, food uptake, and water transport, resulting in stunted growth, chlorosis, and reduced biomass production. This has a direct impact on farm productivity and can lead to economic losses for farmers. Furthermore, heavy metal contamination in agriculture poses a threat to food safety and public health. Crops produced in contaminated soil can collect dangerous quantities of heavy metals in their edible portions, including fruits, vegetables, cereals, and tubers. Eating these tainted crops can lead to serious health issues like cancer, kidney damage, neurological diseases, and digestive issues. Pregnant women and children are particularly susceptible to heavy metal exposure, which may have long-term effects on their development and health. Heavy metal contamination jeopardizes soil health and fertility, worsening agricultural issues. Soil contaminated with heavy metals may become less productive over time as vital soil functions such as nutrient cycling, microbial activity, and organic matter decomposition are impaired. This can result in soil degradation, erosion, and the loss of arable land, diminishing soils' ability to support healthy plant development and sustainable agricultural operations. Furthermore, the environmental effects of heavy metal poisoning in agriculture may extend beyond the boundaries of individual farms. Polluted fields can create runoff that contaminates nearby water bodies, harming the environment and contaminating the water. Heavy metal bioaccumulation endangers aquatic ecosystems and people populations that rely on these water supplies for drinking, irrigation, and recreational purposes. Furthermore, aerial movement of these toxins from agricultural areas can contribute to air pollution and the continuous spread of heavy metal contaminants across landscapes.

Farmers, legislators, scientists, and other stakeholders must work together to implement integrated policies and tackle the issue of heavy metal contamination in agriculture. Reducing heavy metal levels in polluted soils and lessening their effects on agriculture can be accomplished by putting soil management techniques like phytoremediation, remediation, and soil testing into practice. Furthermore, encouraging sustainable farming methods, lowering the need for chemical inputs, and improving the resilience and health of the soil can help stop additional pollution and protect the environment, human health, and food security. In order to ensure that agriculture remains viable over the long term in the face of heavy metal contamination, safe and sustainable agricultural methods must be promoted through regulatory actions, monitoring initiatives, and public awareness campaigns.

Certain heavy metals, including mercury, lead, cadmium, silver, and chromium, can act as plant nutrients depending on their concentration in the environment. Other heavy metals, such as those released by human activities, can still have hazardous consequences in small amounts.Several factors influence heavy metal uptake and accumulation in plant tissue, including pH, organic matter, and temperature, humidity, and nutrition availability. According to this study, whereas Cu, Ni, and Pb accumulated more in the winter, Cd, Zn, Cr, and Mn were found to be absorbed and accumulated more in spinach during the summer. Heavy metals were most likely released into the soil solution for potential plant uptake during the summer months as a result of the rate at which organic matter degraded. Heavy metals can impact plants in a variety of ways, as illustrated in the table.

Table 3: Heavy metals effects on crops /plants

Heavy Metals	**Effects on crops**
Lead (Pb)	Seed germination by gradually slowing down the seed germination Abnormality of plant metabolism, morpho-physiological features, plant growth, and productivity Reduce plant growth, resulting in malformation of cellular structure, lowering chlorophyll biosynthesis, imbalance hormones, and induce over-production of reactive oxygen species (ROS); which can cause oxidative stress within plant cells and readily attack biological structures and biomolecules, thus result in metabolic dysfunction Reduce soil productivity
Cadmium (Cd)	Cause many abnormalities in different parts of the plant such as roots, shoots, leaf, fruit, and also increased dry to fresh mass ratio (DM / FM) in all organs Can exhibits adverse effects on sugar content and amino acids in some plant species by strengthening their concentration, indicating inhibition of starch hydrolysis Imbalance the macro and micronutrients by augmenting the macronutrients and reducing micronutrients in *Aeluropuslittoralis* Leading to less assimilation of photosynthetic carbon when interact with various photosynthetic complexes. Also, Cd bothers the guard cell regulation thus affecting the water status of the plant Poisoning the soil and this affects the production of phytochelatins due to obstruction of the transporter/channel for loading other elements and an imbalance of plant nutrients
Zinc (Zn)	Phytotoxic and can directly affect crop yield Affects the growth of pea plants

Copper (Cu)	Reduced the availability of soil N and S for crop production Inhibit the activity of β-glycosidase more than the activity of cellulose

It was anticipated that increased sweating would result in a higher assimilation of heavy metals such as Cd, Zn, Cr, and Mn during the summer, whereas low humidity and high ambient temperature during the winter would produce a higher accumulation rate of heavy metals. It is possible to stop additional contamination and protect food security, human health, and the environment by supporting sustainable agriculture practices, lowering reliance on chemical inputs, and improving soil health and resilience. In order to ensure the long-term sustainability of agriculture in the face of heavy metal contamination, regulatory measures, monitoring programs, and public awareness campaigns are also crucial.

Self-Assessment Questions

Q.1. What are the major sources of heavy metal pollution, and how do they contribute to environmental contamination?

Q.2. Explain the effects of heavy metal pollution on human health and aquatic ecosystems.

Q.3. What are some effective methods for reducing heavy metal contamination in water and soil?

8.3 Heavy metal toxicity on human

Heavy metals are among the most dangerous elemental contaminants, posing a serious threat to people. The periodic table's lower right corner usually contains transition metals and a few representative elements such as lead and tin. Heavy metals, such as iron, and toxic metals, such as cadmium and mercury, are not needed ingredients. The majority of them attach to sulphur groups in enzymes, inhibiting their function. Heavy metals can bind to protein carboxylic acid ($-CO_2H$) and amino ($-NH_2$) groups. Cadmium, copper, lead, and mercury ions can bind to cell membranes and impede transport pathways through the cell wall.

8.3.1. Acute toxicity:

Acute toxicity is induced by a high dose of a metal over a short period of time. Clinical effects usually appear within a few hours or days after initial exposure. Metals, due to their generally disruptive effects on cell membranes, can create a variety of localized effects at the initial point of contact. Acute metal poisoning through the oral route can result in nausea, vomiting, and damage to the intestinal mucosa and digestive tract. Metal inhalation can result in nose and throat irritation, coughing, wheezing, and lung damage. Acute dermal exposure might result in a localized rash, skin irritation, and discoloration. Certain metals are known to target specific organs or systems. High lead levels can cause neurological symptoms, such as convulsions or coma, and alter the haematological system, affecting heme production. Acute mercury poisoning can have toxic consequences. The form found in the body varies. Exposure to substantial concentrations of elemental or methyl mercury is more likely to affect the central nervous system than inorganic mercury due to differences in brain transport. Methyl mercury's lipophilic nature allows it to easily pass the blood-brain barrier, unlike inorganic mercury. Mercury vapor can easily pass membranes.

8.3.2. Chronic Toxicity:

Long-term exposure to low levels of some metals can lead to progressive symptom development, which may be less severe than acute occurrences. Chronic exposure to some metals can cause carcinogenicity, as explained in the next section. Furthermore, certain metals may be retained in biological tissues for long periods of time. Lead can displace calcium in developing bones, resulting in long-term storage and delayed release of the metal. This can have dangerous effects that remain long after the exposure is over.

Chronic exposure to metals can cause kidney and liver damage and reduced function, as these organs are responsible for harmful metal concentration, detoxification, and elimination. Chronic metal overexposure is associated with mucosal deterioration as well as inhibition of hepatic and renal enzymes. Chronic exposure to lead, chromium, mercury, and cadmium can cause kidney damage. The liver, which stores and excretes copper, is also susceptible to harm from chronic copper exposure. Several metals are known to specifically affect the central nervous system. Chronic manganese exposure can result in a neurological illness similar to Parkinson's disease, characterized by abnormal behaviour and a "masklike" facial expression. Lead poisoning can result in learning disabilities, behavioural problems, hyperactivity, lethargy, and ataxia. Chronic mercury exposure can cause hyperactivity, even psychosis.

8.3.3. Carcinogenicity

Certain metals, such as beryllium, cadmium, hexavalent chromium, and nickel compounds, have been found to cause cancer in humans and animals when inhaled. Arsenic is classified as a human carcinogen by the IARC (International Association for Research), despite equivocal findings on cancer in animals. Lead has been shown to cause cancer in animals but not in people. Other metals, such as copper, zinc, and mercury, are not thought to cause cancer. Certain metals, such as beryllium, cadmium, hexavalent chromium, and nickel compounds, have been found to cause cancer in humans and animals when inhaled. The International Association for Research on Cancer (IARC) lists arsenic as a human carcinogen, however animal studies are ambiguous. Lead has been shown to cause cancer in animals but not in people. Other metals, such as copper, zinc, and mercury, are not thought to cause cancer. Each carcinogenic metal appears to have a unique mode of action. In cells, hexavalent chromium transforms into trivalent chromium, producing adducts with DNA and proteins. Biologically active carcinogens are likely reactive intermediates of chromium (+6) reduction. Nickel ions build up inside cells, generating oxygen radicals that appear to be responsible for the genotoxic damage associated with nickel carcinogenicity. Arsenic is most likely a non-genotoxic indirect carcinogen that promotes oncogene expression and inhibits DNA repair.

8.3.4. Toxicity of selected metals

i. Arsenic

Arsenic is often found in natural surroundings, especially in minerals. It is most typically found in sulphide ores in trivalent and pentavalent complexes. Arsenic concentrations range from 3mg/kg in the earth's crust and igneous rocks to 93mg/kg in coal, with an average of 17.7mg. Brown coal can contain up to 1500 mg/kg. Arsenic trioxide is a by-product of the extraction of copper and lead from sulphide ores. It is extracted from flue dust in a relatively pure form. Arsenic has been employed in the production of insecticides, but this is diminishing. Glassware, alloy and pigment production, and semiconductors are among the many applications for arsine gas ($AsH3$). Arsenic is a by-product of metal extraction, particularly lead, copper, and gold. Arsenic absorption symptoms include severe abdominal pain, bloody diarrhoea, and a garlic-like stench on the breath. Occupational exposure to arsenic compounds takes place mainly among workers, especially those involved in the processing of copper, gold, and lead ores. In agriculture, one formerly frequent exposure was through application of arsenic as an insecticide, Lead arsenate is the most common form, with calcium arsenate, sodium arsenite, cupric arsenite, and cupric acetoarsenate occurring less commonly. Arsenicals are widely used as herbicides, desiccants for cotton harvesting, fungicides, rodenticides, insecticides, algaecides, and wood preservatives. These uses are largely obsolete due to occupational and environmental concerns. Marine fish and shellfish are an important source of arsenic exposure for humans. Fish arsenic levels can exceed 1mg/kg, typically around 10µg, but can be significantly higher if taken with polluted water or food. Arsenic (As) in food, especially fish and other substances, is readily absorbed through the gastrointestinal tract. The main biological monitoring method for arsenic exposure is to measure inorganic arsenic, monomethylarsonic acid, and cacodylic acid in urine. This eliminates contamination from seafood or water with high arsenic levels, which can occur when analyzing total arsenic levels. Urinary concentrations primarily reflect recent exposure.

Arsenic compounds have a wide range of toxicity. Arsine gas, a colorless and non-irritating gas created by combining arsenic compounds with acid, is the most lethal form of arsenic. The chemical equation for this reaction is shown by the generic equation:

$$A-AsX+H-Y \rightarrow AsH3+A-X+A-Y$$

Where As is arsenic, A is the anion of arsenic salt, H is acid, X is the cation of arsenic salt, and Y is the acid's salt. The organic arsenic [V] (arsenate, As^{5+}) forms are less hazardous than the inorganic arsenic [III] (Arsenate, As^{3+}) forms, owing to their lower solubility. $As^{5}{}_{+}$ compounds are well absorbed through the gastrointestinal tract, and As^{3+} compounds are more lipid soluble (dermal absorption). Arsenic replaces phosphorus in bone and binds to sulfydryl groups on proteins. Because of its widespread use as a poisoning agent, arsenic toxicity has received extensive research. Multiple organs and systems are affected.

- Cardiovascular (vasodilation causes reflex arteriolar constriction and myocardial depression).
- Gastrointestinal issues, including vesicle development and bleeding.
- Kidney (acute tubular necrosis, oliguria, proteinuria, and haematuria)
- Skin symptoms include erythema, brittle fingernails, oedema, pigmentation, pyoderma, and skin.
- Nervous system disorders (myelin degeneration, encephalopathy, paraasthesias) liver (hepatic fatty degeneration, cirrhosis).

ii. Beryllium:

Beryllium is the 35th most prevalent element in the earth's crust, with an average concentration of approximately 6mg/kg. Water contains minimal beryllium due to its adsorption on mineral grain surfaces during weathering and soil formation, which prevents clay minerals from capturing it. The lung is the most damaged organ, with dyspnoea and cough developing to chronic granulomatous illness, akin to sarcoidosis and miliarytuberculosis.Blood and urine beryllium levels have yet to be proven as a reliable indicator of exposure. Currently, detecting this metal in blood or urine merely implies exposure. Except for emerald (chromium-containing beryl) and aquamarine (iron-containing beryl), only two beryllium minerals are economically valuable. Emissions of beryllium during manufacturing and usage are less significant than emissions from coal and fuel oil burning, which have natural average levels of 1.8-2.2mg beryllium/kg dry weight.

iii. Cadmium

Cadmium is discharged into the environment through a variety of industrial and home processes. The combustion of fossil fuels (coal, diesel, gasoline, etc.), incineration of industrial waste (particularly Cd-containing batteries and plastics), metal alloy production, electroplating, and phosphate fertilizer manufacturing are among the most common. These discovered heavy metals in the aquatic environment are of great concern because they represent considerable risks to human health and the ecological system when present in concentrations above the allowable limit. Continuous heavy metal emissions into the aquatic environment are considered non-biodegradable and long-lasting in nature. As a result, major efforts are required to develop effective treatment systems for eliminating heavy metal ions from wastewater. Cadmium is mostly used in battery production, metal plating, and plastics as pigments and stabilisers, all of which can lead to human exposure. Cadmium can be found in solder, pigments, and some alloys. It may also appear in vapors from the smelting or welding of other metals. In welders, acute poisoning causes a Parkinsonism-like neurological condition as a late result. Despite a susceptibility to pulmonary disease, renal failure is the most common adverse health outcome of prolonged Cd exposure. Cadmium toxicity can also cause osteoporosis by producing renal tubular dysfunction, which leads to increased urine calcium and phosphate losses, as well as a direct effect on bone osteoblast and osteoclast activity. About 10% of the available dosage is absorbed by the respiratory and digestive systems. Cadmium is transported throughout the body by metallothionein, a low-molecular-weight plasma protein. The kidneys and liver contain around half of the body's cadmium load.

Cadmium removal is slow, with half-lives varying from 16 to 33 years. Itai-itaibyo (ouch-ouch sickness) is a severe arthralgia and osteomalacia syndrome that affects postmenopausal Japanese women. It is caused by cadmium contamination in the diet, as well as low calcium and vitamin D intake. Acute toxic effects are similar to metal fume fever (see below) for inhalation and gastroenteritis for oral exposure. Chronic exposure primarily affects the kidney, with proteinuria being the most common outcome. This is the result of proximal tubular damage.

Chronic cadmium poisoning causes proteinuria and damages the proximal tubules of the kidney, resulting in the production of kidney stones. Cd is unable to form a free radical directly, but it can generate a significant number of free radicals indirectly, including the superoxide radical, hydroxyl radical, and nitric oxide, according to reports. A fascinating mechanism describing the indirect role of cadmium in free radical production was presented a year ago. In this process, cadmium is believed to substitute iron and copper in numerous cytoplasm and membrane proteins (e.g., ferritin, apoferritin). Cadmium is one of the most hazardous metals in drinking water, with strong human carcinogenic properties and occupational exposure to malignancies of the lung, prostate, pancreas, and kidney. Cadmium may possibly play a role in the etiology of human pancreatic cancer and renal carcinoma.Cadmium levels can be measured in whole blood, which is more informative than serum since it binds to red blood cells. Cadmium in blood indicates current exposure rather than long-term exposure. Cadmium can also be detected in urine, which is a more reliable measure of body burden than short-term exposure. Cadmium's long half-life (10-30 years) contributes to this phenomena.

iv. Chromium

Chromium is an essential commercial material with numerous applications. The metal is present in all oxidation states from [II] to [VI], but only in trivalent [III] and hexavalent [VI] compounds. It is of practical value. Of these, the hexavalent form is 100-1000 times more hazardous than the majority of trivalent chemicals. Chromite is the most important mineral containing chromium. Southern Africa holds approximately 95% of the world's economically exploitable chromite resources. Chromium metal is primarily utilized in the manufacture of special (stainless) steels. It is also used for electroplating other metals. High quantities of chromium in cement may induce contact dermatitis. Chromium compounds are employed as paint pigments and dyes, as a catalyst, in the production of magnetic tape, tanning, and wood impregnation as a wood preservative, safety match manufacturing, and other applications. Chromium exists in two forms: hexavalent chromium [VI] (chromous, Cr^{6+}), and trivalent chromium [III] (chromic, Cr^{3+}). Because of their insolubility, compounds none the latter state are quite safe. Chromium exposure occurs in various industries, including as electroplating, concrete, tanning, safety match, and pigment manufacturing. Chromium exposure can also occur while using dichromate compounds. Absorption occurs through the gastrointestinal tract and lungs, with potential systemic effects after skin exposure. Approximately 60% of an ingested dose is eliminated in urine within 8 hours. Chromium compounds are harmful due to their strong oxidizing capabilities, which convert the hexavalent compound to the trivalent form after absorption into the body. Chromium compounds can irritate the skin and mucous membranes, as well as cause cutaneous and pulmonary sensitizations.

Common skin conditions include dermatitis, chromium ulcers, nasal septum corrosion, conjunctivitis, and lacrimation. Hexavalent chromium compounds cause cancer. There is some indication that the specific carcinogenic agents are short-lived pentavalent chromium [V] intermediates, which have been demonstrated to be directly genotoxic. Exposure to hexavalent chromium causes red blood cells to absorb it and then reduce it to the trivalent species. Differential chromium levels in plasma and red cells may be a sensitive indicator of hexavalent exposure, although further research is needed.

Chromium inhalation exposure mostly affects the respiratory tract in humans. Occupational exposure to chromium (+6) and/or chromium (+3) in several industries has been linked to respiratory problems. Workers exposed to chromium have reported irritation, impaired pulmonary function, and nasal septum perforation. Chronic exposure to chromium compounds can cause respiratory issues in animals.

Chromium (+6) compounds showed positive for genotoxicity in several systems, including in vivo, cell culture, and bacterial. The genotoxicity evidence suggests that chromium (+6) is not directly genotoxic, but rather that its genotoxicity is caused by its intracellular reduction to chromium (+3), which may be the most genotoxic form of chromium. Chromium (+3) binds to DNA both in vitro and in vivo, but does not cause DNA damage.

iv. Lead

Lead is a naturally occurring blueish-gray metal found in the earth's crust. Lead can interact with other compounds to create lead salts. These compounds are water-soluble, although elemental lead is not. Lead is utilized in the manufacturing of batteries, ammunition, metal items, and scientific and medical equipment. The majority of lead mobilized in the environment is the result of human activity. Lead exposure, even at low levels, can have negative neurological effects in fetuses and children. Low blood lead levels (10-20 μg/dL) have been linked to impaired learning ability.Lead has an effect on the hematological system by influencing the activity of three enzymes involved in heme production. Impaired heme synthesis leads to lower hemoglobin levels and anemia. Prolonged lead exposure has been linked to adverse effects in workers and children. Lead exposure, whether acute or chronic, can harm the kidneys. Acute lead exposure can cause reversible damage to proximal tubular cells. Prolonged exposure can cause nephritis, interstitial fibrosis, and tubular atrophy.

v. Mercury:

Mercury can exist in the environment as metallic, elemental, inorganic, or organic molecules. Mercury metal is a liquid used in thermometers and certain electrical switches. Metallic mercury will evaporate to some extent at normal temperature, producing mercury vapor. Vaporization rises as temperatures rise. Mercury may react with other elements to create both inorganic and organic molecules. Inorganic mercury compounds can serve as fungicides, antiseptics, and preservatives. The toxicity of mercury varies depending on the chemical. When compared to inorganic mercury compounds, alkyl mercury compounds such as methyl mercury pose a significant risk. In humans, inorganic mercury salts are typically absorbed less than 10% via the gastrointestinal tract, whereas methyl mercury is absorbed more than 90%. Mercury is distributed differently in mammals depending on whether it is in alkyl or inorganic form. Inorganic forms frequently have a red blood cell/plasma ratio of less than 2, but organic forms have a ratio of approximately 10, indicating a longer physiological half-life. Organic mercury prefers the brain and kidneys, but inorganic mercury concentrates in the kidneys through filtration and reabsorption. Mercury can be excreted in urine (minor) or feces (major) depending on the type, dosage, and time after exposure. Breathing mercury fumes from dental fillings can expose individuals to metallic (elemental) mercury. Exposure to metallic mercury and its fumes in interior air can occur from spills or electrical switches.

vi. Copper

Copper is a relatively common element that occurs naturally in rocks and minerals and spreads throughout the environment as a result of both natural and human activity. Copper is present in soil in concentrations ranging from 10 to 80 ppm. The primary sources of copper in wastewater and soil include electroplating, paint, metal finishing, mining activities, and chemical manufacture, fertilizer, and pigment industries.

Copper is an essential Industrial workers who use cobalt to make heat-resistant alloys may develop 'hard metal pneumoconiosis' due to chronic exposure. Workers who use cobalt as a defoaming agent may develop cardiomyopathy (sometimes known as beer drinker's cardiomyopathy).

Lead is an ancient metal that has been utilized for many purposes throughout thousands of years. Some of the ancient uses of lead (such as lead sheet for roof lining) continue to this day. Some usages, such as white lead in paint, have been discontinued due to toxicological concerns, while others have been developed for current purposes.

All biological systems require the metal aluminium, which plants use as a fertilizer for photosynthesis. B-hydroxylases, quercetinase, ceruloplasmine, cytochromoxidase, mono-aminoxidase, superoxydismutase, ascorbic acid oxidase, and tyrosine are among the enzymes that require copper as a cofactor. Along with erythropoiesis and haemoglobin synthesis, copper is recognized to have an impact on immune function. The expression of genes encoding metal-binding proteins is linked to the Cu(II) ion. It produces copper organic complexes, which are essential for controlling copper mobility in plants, and is closely associated with organic matter. Plants normally have copper concentrations between 2 and 20 parts per million. The ability of copper to cycle between Cu(I) and Cu(II) explains its usefulness in biological systems. Copper is an electron acceptor/donor in critical redox reactions such as mitochondrial respiration, melanin production, and collagen cross-linking. As an important nutrient, it is incorporated into a number of metalloenzymes, which are involved in hemoglobin creation, drug/xenobiotic metabolism, carbohydrate metabolism, catecholamine biosynthesis, the cross-linking of collagen, elastin, hair keratin, and the antioxidant defense system. Humans are exposed to copper through their food, drink, respiration, and consumption of compounds or substances containing copper. Although the diet is the main source of copper intake, the average dietary requirement for copper is rarely exceeded by the amount of copper in the diet. The primary source of excess copper is drinking water. Some of the toxicity of copper may be explained by its oxidation potential. When copper levels are high, it can oxidize lipids and other macromolecules, causing oxidative damage to biological systems. Moreover, Wilson's disease, a metabolic illness, can arise from dangerous levels of copper building up due to a genetic incapacity to remove it. The consumption of copper-contaminated drinking water can lead to major health concerns. Consuming copper-contaminated drinking water can result in major health concerns such as hemolysis, liver and kidney damage, and fever with influenza syndrome. Copper exposure also causes environmental issues. For example, a trace amount of copper is poisonous enough to kill fish living tissues, further disrupting the aquatic food chain.

vii. Mercury

One of the ubiquitous water pollutants is mercury. In humans, toxicity of mercury involves severe neurological disturbances manifested (in order of severity) by loss of sensation in the extremities, an unsteady gait, slurred speech, tunnel vision, loss of hearing, convulsions, madness, and death. In the past, most mercury contamination resulted from the dumping of inorganic mercury into lakes, streams, and seas. Although inorganic mercury is toxic, it is not easily assimilated by biological organisms. However, under the most dramatic case of mass mercury poisoning attributed to consumption of fish and other seafood contaminated with methyl mercury occurred in 1956 in Japan. A mercury catalyst used in a chemical plant was discarded as waste sludge into Minamata Bay. The mercury was converted

By aquatic biota to methyl mercury, and eventually toxic amounts of it accumulated in fish and shellfish anaerobic conditions it is converted into extremely toxic methyl and dimethylmercury. These compounds penetrate biological membranes readily and subsequently undergo bioaccumulation. On the basis of the investigation of the Minamata Bay incident, the World Health Organization (WHO) established the human toxic dose of mercury in fish at 4300 ng/kg/day. To be on the safe side, WHO recommended that human uptake of mercury should not exceed 430 ng/kg per day. Because small children and fetuses are more sensitive than adults, they should not beexposed even to such small doses.

viii. Nickel

The primary sources of nickel in water, air, and soil are natural and industrial processes, such as electroplating, dying, storage batteries, porcelain enameling, pigment, and steel manufacture. The solubility of nickel salts in water is high. The typical concentration of nickel in drinking water is around 2 μg/L. About 2 μg of nickel are consumed daily by the average adult through water. About 170 μg of nickel are consumed daily through meals. Because of its poor absorption from food or water, nickel does not cause toxicity when consumed, according to the data that is currently available.

Nickel is a nutritionally essential trace metal for at least several animal species, micro-organisms and plants. Although nickel is an essential micronutrient for animals and takes part in synthesis of vitamin B12, Nickel and its compounds have many industrial and commercial uses, and the progress of industrialization has led to increased emission of pollutants into ecosystems.

Inhalation exposure in occupational settings is a primary route for nickel-induced toxicity, and may cause toxic effects in the respiratory tract and immune system. The tolerance limit of nickel in drinking wateris 0.01mg L^{-1}, and for industrial wastewater, it is 2.0 mg L^{-1}. The higher concentration of nickel causes cancer in lungs, nose, and bones and it may also cause nausea, and dry cough. In plant tissues, the concentrations of Ni may vary rapid respiration, headache and cyanosis from 0.1 to 5.0 ppm (dry wt. basis) with a threshold range of toxicity of 40-246 ppm, depending on plant species[51]. The most common symptoms of nickel toxicity in plants are inhibition of growth, chlorosis, necrosis and wilting.Asthma, conjunctivitis, inflammatory responses to implants and prostheses containing nickel, and systemic reactions following parenteral injection of nickel-contaminated fluids and drugs are other symptoms of nickel hypersensitivity. [Ni(CO)4], or nickel carbonyl, is a highly poisonous gas. This one is not an exception to the rule that the toxicity of metal carbonyls depends on both the metal's toxicity and the carbonyl's capacity to release extremely harmful carbon monoxide gas. In air, it is explosive. Because nickel is used in jewelry for pierced ears, it is a major contributor to contact allergies. Itchy red skin is a common symptom of nickel allergy that affects pierced ears.

ix. Zinc

About 75 ppm of zinc is found in the earth's crust, while the average amount of zinc in soil is 64 ppm, with a range of 5-570 ppm. In ores, zinc is generally found in combination with other metals like copper and lead. Certain foods and dietary supplements naturally contain zinc, an important mineral. Children should take 5–10 mg per day, while adults should take 12–15 mg. Many cold lozenges and other over-the-counter medications marketed as cold treatments also include zinc.

Zinc is naturally present in air, soil, and water, primarily in the $^{+2}$ oxidation state. It is a bluish-white metal that can mix with several other elements. Zinc sulfide makes up the vast majority of zinc ore. Zinc is an important trace element in the diet. Zinc divides into sediments or suspended solids in water by sorption. Zinc sorption in soil is influenced by its solubility and soil characteristics, including pH, redox potential, and cation exchange potential. Zinc is typically found in microscopic dust particles in the air. Humans are exposed to small amounts of zinc in food and drinking water each day. Levels in air are generally low and fairly constant.

Zinc is a trace and active element in constitution of various enzymes. Zinc also plays a role as an antioxidant and is involved in protein metabolism, stimulation of assimilation of vitamins and immune activation. Zinc can be considered as one of the most important trace elements due to construction and manufacturing cellular mechanisms. Zinc also supports normal growth and development during pregnancy, childhood, and adolescence and is required for proper sense of taste and smell. For normal skeletal growth, it helps in improvements of brain function (including memory), helps alleviate benign prostatic hypertrophy and aid in the synthesis of insulin (most diabetic have low level of zinc). Research on people with acrodermatitis enteropathica, a hereditary condition that causes excessive zinc metal absorption, has shed a lot of light on the functional consequences of zinc deficiency. These include deficiencies in the immune, neurological, gastrointestinal, and skin systems. Lethargy, apathy, delayed wound healing, loss of taste and smell, poor appetite, childhood hyperacidity, diabetes, stretch marks on the skin, acne, constricted prostate, painful joints, white spots on the fingernails, dark skin pigmentation, hair loss, and poor circulation are all signs of zinc deficiency. Vomiting, diarrhea, fatigue, and the development of copper and/or iron deficiency anemia are symptoms of zinc toxicity.

x. Cobalt

The major anthropogenic sources of environmental cobalt included mining and processing (smelting) of cobalt-bearing ores, the use of cobalt-containing sludge or phosphate fertilizers on soil, the disposal of cobalt containing waste, and atmospheric deposition from activities such as the burning of fossil fuels and smelting and refining of metals. A trace amount of the natural earth element cobalt can be found in plants and in our food. Human blood has a cobalt concentration of 1.04 parts per million. Cobalt is said to have been isolated by Swedish chemist George Brandt. In the environment, it typically coexists with other metals like copper, nickel, manganese, and arsenic. Cobalt is a key component of vitamin B12, often known as cobalamin. A normal person requires less than 10 milligrams of cobalamin daily. Cobalamin insufficiency is uncommon because the vitamin B12 is found in almost all animal tissues. It is the only known biomolecule with a strong carbon-metal link. Cobalamine is required for DNA synthesis, red blood cell production, nervous system maintenance, as well as child growth and development. Few proteins exist in which cobalt is directly coordinated by the protein structure. Methionine amino peptidase and nitrile hydratase are two examples of such proteins.Cobalt has also been used to treat anemia by stimulating the production of red blood cells.

Cobalt is less hazardous than many other metals found in soil. Exposure to extremely high quantities of cobalt can have health consequences. Workers exposed to high quantities of cobalt in the air have reported pulmonary effects such as asthma, pneumonia, and wheezing. The concentration of cobalt in living plants is determined by the species, soil concentration, and a variety of other environmental conditions. The average cobalt concentration found in terrestrial plants is 0.48 µg g-1. Freshwater vascular plants have mean cobalt concentrations of 0.32 and 0.37 µg g-1 dry weights in unpolluted and polluted settings, respectively. Cobalt is needed for nitrogen fixation by free-living bacteria, blue-green algae, and symbiotic systems, as well as the growth of many marine algae species, including diatoms, cryophytes, and dinoflagellates.

Self-Assessment Questions

Q.1. What are the most common heavy metals that cause toxicity in humans, and how do they enter the human body?

Q.2. Describe the major health effects associated with long-term exposure to heavy metals such as lead, mercury, and arsenic.

Q.3. What are some effective strategies for preventing and treating heavy metal toxicity in humans?

8.4 Summary

Because of the negative impacts that environmental contamination of heavy metals is producing globally, it is becoming a major issue and a growing problem. The fast expanding agricultural and metal industries, inappropriate waste disposal, fertilizers, and pesticides are all contributing factors to the inorganic pollutants that end up in our rivers, soils, and environment. This overview explains how pollutants reach the ecosystem and what happens to them once they do. Certain metals affect biological processes and growth, whilst others accumulate in one or more organs and can cause a variety of serious diseases, including cancer. Heavy metal contamination poses a major hazard to the health of natural water bodies, aquatic ecosystems, and humans. Soil pollution is one of the most significant effects of heavy metals on natural soil. High concentrations of heavy metals can make soil unfit for farming, which will have an impact on crop output and growth. Soil contamination can disrupt the balance of microbial populations, which is required for nutrient cycling, soil fertility, and overall ecosystem health. Heavy metals' tendency to restrict the growth of beneficial soil bacteria while boosting the growth of harmful ones can cause soil ecological imbalances. Remedial actions, sustainable water management strategies, and effective pollution prevention techniques are necessary to lessen the effects of heavy metal pollution and protect ecosystem health, water quality, and human health. Working together, government organizations, businesses, communities, and other interested parties can tackle this difficult environmental problem and make sure that natural water resources are managed sustainably. Heavy metals can contaminate water by seeping into surface and groundwater in addition to contaminating soil and plants. Aquatic ecosystems and human populations that depend on these water supplies for industrial, agricultural, and drinking needs are at risk from this. In water bodies, heavy metals can build up in sediments, which can impact benthic creatures and perhaps enter the food chain. This can cause biomagnifications, endanger human and aquatic health, and harm aquatic life.

8.5 Terminal questions

Q. 1. What are heavy metals, and why are they considered pollutants?

Answer:---

Q. 2. How do heavy metals enter natural ecosystems, including soil and water bodies?

Answer:---

Q. 3. What are the primary sources of heavy metal pollution in the environment?

Answer:---

Q. 4. What are the main effects of heavy metal pollution on soil health and fertility?

Answer:---

Q. 5. How does heavy metal pollution impact human health?

Answer:---

Q. 6. What is the potential health risks associated with long term exposure to copper, lead and mercury for humans?

Answer:---

8.6. Further suggested readings

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Unit-9: Environmental Pollution Control

Contents

9.1. Introduction

Controlling environmental pollution usually entails designing transportation infrastructure to reduce pollution and managing land development. Land development management, transportation system design, and environmental planning are all critical to the control of environmental pollution. Environmental pollution is defined by the Basic Law for Environmental Pollution Control as any activity by businesses or individuals that has a direct causal relationship and negatively impacts the environment or health of others in a particular area. Environmental problems including pollution, noise, and land subsidence were brought on by increased industrialization. Sumitomo Metal Mining created the first pollution control system in history. Municipal governments in Japan began implementing post-war environmental pollution control measures in the 1950s. The first official efforts were taken in 1959 when the Tokyo Metropolitan Government created the Factory Pollution Control Ordinance. The term "environmental pollution control" describes the wide range of methods, tools, regulations, and procedures intended to lessen or completely stop the discharge of hazardous pollutants into the environment. Air pollution, water pollution, soil contamination, and noise pollution are only a few of the several types of pollution. Technology has a significant impact in reducing pollution. To effectively capture, treat, and dispose of contaminants, a range of methods are available. Scrubbers and catalytic converters are examples of air pollution control systems that extract dangerous substances from industrial emissions. The preservation of the environment, human health, and general quality of life all depend on efficient pollution control methods. In addition to global concerns including biodiversity loss, global warming, and stratospheric ozone depletion, environmental pollution management laws also address pollution of the air, water, and land. Humanity's relationship with nature has been exemplified by decades of contemporary environmental conservation and pollution reduction initiatives. Natural environmental changes have the potential to occur again and seriously hurt people. The most effective way to reduce pollution is usually prevention. This means reducing or stopping the production of pollutants at their origin. Potential tactics include energy-efficient procedures, the use of substitute materials, and cleaner production methods.

Objectives:

After reading this unit, learner will be able to

- Explain Techniques used in water treatment
- Explain Oxidation ponds and its role in waste water treatment
- To discuss the Fluidized bed reactors
- To discuss air control techniques like Air samplers, Sequencing batch reactor
- also explain the Bioscrubbers and biotrickling filters

9.2. Techniques used in water treatment

Water treatment is the process of eliminating pollutants from both wastewater and domestic water. It consists of physical, chemical, and biological techniques for the removal of pollutants. Its goal is to generate an environmentally safe fluid waste stream and solid trash suitable for disposal or reuse.

9.2.1. Drinking water treatment plant

a. Screening:

Screening is a fundamental treatment step in wastewater treatment plants that separates big objects and debris from raw sewage or influent water. It entails passing wastewater through screens with varied size apertures to capture and hold solid objects including sticks, rags, plastics, and other big trash. Screens can be coarse or fine, depending on the size of the particles they need to remove. Following screening, the wastewater is subjected to additional treatment techniques such as sedimentation, filtering, or biological treatment. Screening protects downstream equipment from damage and blockage while also preventing the accumulation of big materials in treatment operations, resulting in more effective and efficient treatment overall. Screening is done to remove heavy suspended solids from water, such as plants, stones, animals, and trees. Screening is commonly used to remediate surface water. Screening is completed with the assistance of

- **Coarse Screen:** Coarse screening in wastewater treatment is the process of removing big particles from influent water using screens with wider apertures. It protects downstream equipment and ensures effective treatment by removing bulky solids before processing.
- **Fine Screen:** Fine screening in wastewater treatment uses screens with narrower apertures to collect finer particles such as hair, grit, and tiny solids from influent water. It improves treatment efficiency by removing tiny particles that coarse screens may not catch, resulting in cleaner effluent and safeguarding downstream equipment from damage and blockage.

b. Aeration:

There are two main types of aerators based on the mechanism of aeration. They are those forming drops or thin sheet of water, exposed to atmosphere and those forming bubbles of air, which rise in water. Spray type, waterfall or multiple trays and cascade type are the common types coming under the first category while diffusion aerators fall under the second category. Spray aerators have one or more spray nozzles connected to a pipe manifold. Water moves through the pipe under pressure, and leaves each nozzle in a fine spray and falls through the surrounding air, creating a fountain affect. Spray aeration is successful in oxidizing iron and manganese and increases the dissolved oxygen in the water.

- **Cascade Aerators:** The main premise of cascade aerators is to disperse the water as much as possible and allow it to flow over impediments in order to create turbulence and modify the surfaces of the water that come into contact with the atmosphere.
- **Cone Aerators:** Cone aerators are typically used to convert ferrous to ferric iron and manganese before filtration. The aerator's architecture is similar to that of CONE AERATORS, with water being pumped to the tops of the cones and then let to cascade down through them.

c. Floculation:

Flocculants or flocculating agents are chemicals that promote flocculation by causing colloids and other suspended particles in liquids to aggregate, forming a floc. Flocculants are used in water treatment processes to improve the sedimentation or filterability of small particles. Coagulation is the effect produced by the addition of chemicals called coagulants to a colloidal dispersion resulting in particle destabilization. Coagulants when thoroughly mixed with water form a precipitate called floc.

d. Sedimentation:

Sedimentation is a natural or controlled process in which solid particles separate from a liquid or gas by gravity. Water treatment uses sedimentation basins to remove suspended particles from the water. As water enters the basin, its velocity decreases, allowing heavier particles to settle to the bottom. The cleared water is then collected on the top. Sedimentation removes larger particles such as sand, silt, and organic compounds, hence improving water quality. However, it may not be effective in removing extremely small particles or dissolved chemicals. To effectively treat water, sedimentation basins must be properly constructed and maintained. Sedimentation is a geological process in which solid particles (sediments) are deposited by wind, water, or ice, resulting in the formation of sedimentary layers throughout time. This process is necessary for shaping the Earth's surface, which results in the production of various landforms such as river deltas, beaches, and sedimentary rock formations.

e. Filtration:

Filtration in wastewater treatment is passing wastewater through different media to remove pollutants and toxins. Specific contaminants are targeted by various filtering methods, including sand, activated carbon, and membrane filtration. Sand filtering captures bigger particles and debris, whereas activated carbon absorbs organic substances and pollutants. Membrane filtration uses semi-permeable membranes to filter sediments and pathogens from water. Filtration improves water quality by removing suspended particles, organic matter, bacteria, and other contaminants. It is critical in the production of treated wastewater that can be discharged or reused. Regular maintenance and monitoring are required to guarantee that filtration systems in wastewater treatment plants function effectively.

- **Activated Carbon Filtration**: Activated carbon filtration is a popular method for extracting impurities and pollutants from liquids and gasses. It uses activated carbon, a porous type of carbon with a large surface area (measured in square meters per gram). This porous structure enables activated carbon to adsorb a wide variety of compounds onto its surface.Activated Carbon Filtration is a well-established technology that works by absorbing undesirable molecules, primarily taste and odor, as well as some dangerous pollutants and organic compounds.
- **Ultraviolet (Uv) Water Filters**: UV filters can destroy the majority of bacteria and viruses that travel through them, but they cannot remove chemical contaminants from the water. Because the treatment is ineffective outside of the treatment region, the treated water should be used right away. UV filters are a wastewater treatment system that uses ultraviolet (UV)

radiation to disinfect and sterilize water. UV light breaks the DNA of microorganisms such as bacteria, viruses, and protozoa, preventing reproduction and causing them to die. This method effectively removes hazardous microorganisms from wastewater, making it safe to release or reuse. UV filtering does not require the addition of chemicals, making it environmentally friendly. However, it requires regular monitoring and maintenance to ensure consistent performance.

- **Sand based water filters**: Sand-based water filters use layers of sand to filter out contaminants and particles. As water passes through the filter, the sand traps suspended particles, silt, and organic detritus. The process employs physical filtration to trap particles within the sand bed. Sand filters can also improve biological filtration since sand includes microorganisms that help break down organic waste. These filters are good at removing bigger particles and increasing water clarity. Regular maintenance, such as backwashing to clean the sand bed, is required to ensure filtration performance. Sand-based water filters are widely employed in swimming pools, drinking water treatment facilities, and wastewater treatment systems.
- **Rapid Sand Gravity Filter**: A rapid sand gravity filter is a type of filter often employed in big municipal supply. Sand, which is inexpensive, inert, long-lasting, and readily available, provides an excellent filter medium for the treatment or pre-treatment of potable water. It is frequently employed in rural areas due to its ease of construction and operation. Such filters consist of a 60-70 cm deep column of fine sand to provide a filtering rate of not more than 200 W mL per hour of water.

f. Disinfection:

Disinfection is a vital step in water treatment that destroys or inactivates harmful microorganisms like bacteria, viruses, and parasites to make water safe to drink. Different disinfection methods are utilized, such as chlorination, UV irradiation, ozonation, and chlorination. Chlorination destroys pathogens by introducing chlorine or chlorine compounds into water, whereas UV irradiation damages germ DNA. Ozonation employs ozone gas to oxidize and disinfect water, whereas chlorination combines chlorine and ammonia to form chloramines, which are powerful disinfectants. Disinfection helps to avoid waterborne infections and maintains the safety of drinking water supplies. Minor techniques of disinfection include:

- **Boiling of water:** Water can be purified simply and effectively by boiling it, which kills unwanted germs. When water hits its boiling point (100°C or 212°F), bacteria, viruses, and parasites are killed, making it safe to drink. Boiling for at least one minute (or more at higher elevations) provides complete disinfection. It is especially useful in emergency situations or when access to clean water is limited. However, boiling does not eliminate chemical pollutants or sediment. Despite its effectiveness, boiling can change the taste and does not improve water turbidity. As a result, it is frequently used in conjunction with other filtration procedures to provide thorough water treatment.
- **Treatment with excess lime**: Excess lime treatment entails adding more lime than is required to elevate the pH of water to a point at which metals and other pollutants precipitate out. Lime softening is a procedure that removes hardness, heavy metals, and some pollutants from water, thereby increasing its quality for consumption and industry.
- **Treatment with ozone:** Ozone treatment is the process of disinfecting and purifying water with ozone gas, a potent oxidizing agent. Ozone oxidizes bacteria, viruses, and organic pollutants, effectively killing them. It also eliminates smells and enhances taste by decomposing organic substances. Ozone treatment is environmentally acceptable because it

leaves no toxic leftovers, thus it is widely utilized in drinking water, wastewater treatment, and a variety of industrial applications.

- **Treatment with iodine and bromine**: Water is disinfected using halogen-based compounds such as iodine and bromine. Both iodine and bromine destroy bacteria, viruses, and other pathogens in water by interrupting their biological processes. They are often utilized in portable water purification tablets and solutions for camping, trekking, and disaster preparedness. However, long-term consumption of iodine or bromine-treated water may pose health hazards, particularly for pregnant women and people with thyroid disorders. As a result, its use is usually limited to short-term or emergency conditions.
- **Treatment with ultra violet rays:** UV ray treatment is the process of disinfecting water by exposing it to UV light. UV light degrades germs' DNA, preventing them from reproducing and rendering them harmless. This method effectively kills bacteria, viruses, and other pathogens without the use of chemicals, making it environmentally benign. UV treatment is extensively used in water purification systems for residential, commercial, and municipal water treatment plants to assure safe drinking water. However, it does not remove chemical pollutants or particles, thus it is frequently used in conjunction with other filtration processes to provide full water treatment.
- **Treatment with potassium permanganate**: Potassium permanganate is used as an oxidizing agent to treat water. Potassium permanganate may effectively remove dissolved iron, manganese, hydrogen sulphide, and organic substances from water by oxidization. It is extensively used in water treatment to remediate groundwater, remove iron and manganese, and manage odors. However, because of its powerful oxidizing qualities and ability to discolor surfaces, it must be used with caution and monitored. Proper handling and dosage control are required to provide efficient treatment and avoid negative impacts on water quality.

g. Softening:

Softening removes hardness from water. The reduction or elimination of hardness from water is known as ironsoftening. When bicarbonates of calcium and magnesium are present in water, the hardness is known as transitory hardness or carbonate hardness, and it can be swiftly removed by boiling or adding lime. If water contains sulphates, chlorates, calcium and magnesium nitrates, it must be treated specifically, such as with lime soda, zeolite, or demineralization. The lime soda process involves adding lime and soda ash to hard water, which then reacts with calcium and magnesium salts to form insoluble precipitates of calcium carbonate and magnesium hydroxide. The zeolite process involves running hard water over a bed of zeolites and (complex silicates of aluminium and sodium), where calcium and magnesium exchange for sodium in the zeolite until sodium is depleted. Demineralization removes minerals from water by first passing it through a bed of cation exchange resins, then through a bed of anion exchange resins.

Self-Assessment Questions

Q.1. What are the main stages involved in the water treatment process, and what is the purpose of each stage?

Q.2. Compare and contrast physical, chemical, and biological water treatment methods. Provide an example of each.

Q.3. What are the advantages and limitations of reverse osmosis as a water purification technique?

9.3. Oxidation ponds

Oxidation ponds, also known as stabilization ponds or lagoons, are shallow, man-made bodies of water used in wastewater treatment. These ponds treat wastewater through natural mechanisms including microbial activity and sunlight exposure. Wastewater flows into oxidation ponds, where it undergoes a variety of biological and chemical reactions. Microorganisms in the pond degrade organic debris in the wastewater via processes such as aerobic and anaerobic digestion. This microbial activity contributes to a lower concentration of contaminants in wastewater, including organic chemicals and pathogens. Additionally, sunshine promotes the growth of algae in the ponds. Algae help in wastewater treatment by absorbing nutrients like nitrogen and phosphorus, which can lead to eutrophication if not removed. Oxidation ponds often include many cells or compartments to accommodate various levels of treatment. The effluent from oxidation ponds is frequently released into receiving water bodies or further cleaned before reuse. Oxidation ponds are a simple and cost-effective wastewater treatment technique, especially in warm climates with plenty of available land. However, their efficacy can be modified by temperature, hydraulic retention duration, and the presence of hazardous chemicals. Proper management and monitoring are required to guarantee that oxidation ponds operate efficiently and meet regulatory standards for effluent quality. Oxidation ponds can work as stirred or plug flow reactors, although mass transport processes are more important than the reactor model chosen. The four main mass transport processes used in oxidation ponds are interception, advection, diffusion, and gravity. Depending on the kind of wastewater being treated, several mechanisms are seen. Oxidation ponds come in four varieties: facultative, anaerobic, maturation, and aerobic (high rate).

Aerobic (high-rate) ponds:

Because of the photosynthetic activity of the algae, aerobic ponds, often referred to as high-rate algal ponds, maintain dissolved oxygen throughout their 30-45 cm depth. The pond's small depth permits aeration from the breeze at night, while photosynthetic activity supplies oxygen during the day (Davis and Cornwell 2008). Aerobic ponds are ideal for low-cost land usage and are very good at eliminating biochemical oxygen demand (BOD). These ponds have a 95% BOD removal efficiency, a detention period of 2–6 days, and a BOD loading rate of 112–225 kg/1000 m3 day.

Anaerobic Ponds:

Anaerobic ponds don't require dissolved oxygen to function. The main by-products of methanogens are carbon dioxide and methane. It is common practice to construct ponds with a depth of 2–5 meters, a detention period of 1–1.5 days, a pH of less than 6.2, temperatures above 15°C, and an organic loading rate of 3000 kg ha/day. Up to 60% of BOD can be eliminated via anaerobic ponds. This efficiency is climate-sensitive, though. The primary motivation for treatment is sedimentation. While bacteria and viruses stick to settling sediments or perish as a result of food loss or the presence of predators, helmets sink to the bottom of the pond.

- **Facultative Ponds:** An anaerobic and aerobic treatment unit is called a facultative pond. An anaerobic bottom zone with anaerobic bacteria, an aerobic top region with bacteria and algae, and a transitional area between anaerobic and aerobic conditions where bacteria can thrive in both situations make up a typical pond. Wastewater from a previously treated source enters the pond if it is used in series. Treatment periods for facultative ponds might vary from two to three weeks because of photosynthetic processes that take place inside the unit and use algae as decomposers. The average depth of a facultative pond is between one and two meters.
- **Maturation Ponds:** As with facultative ponds, the treatment process in maturation ponds is mostly driven by algae. While facultative ponds manage BOD, maturation ponds eliminate fecal coliform, pathogens, and nutrients. With a depth range of 1 to 1.15 meters, the maturation pond is shallower than every other type of pond save the aerobic. Anaerobic conditions are typically maintained in maturation ponds.

Self-Assessment Questions

Q.1. What are oxidation ponds, and how do they function in wastewater treatment?

Q.2. Explain the role of microorganisms in oxidation ponds. How do they contribute to the treatment process?

Q.3. What are the advantages and disadvantages of using oxidation ponds for wastewater treatment?

9.4. Fluidized bed reactors

Chemical reactors known as fluidized bed reactors (FBRs) create a fluidized state by forcing a fluid typically a gas or liquid through granular solid material at high enough speeds to suspend the solid particles. A bed of solid particles behaves like a fluid as a result. Effective mixing and heat transfer are made possible by the large surface area and continuous motion of solid particles in fluidized bed reactors. Catalytic reactions, combustion, gasification, and wastewater treatment are just a few of the industrial processes that use these reactors. A porous plate called a distributor often supports the solid substrate, or the catalytic material that chemical species react on, in a fluidized bed reactor. After that, the fluid is forced through the solid material and into the distributor. The solids stay in place as the fluid passes through the gaps in the material at lower fluid velocities. The reactor will reach a point where the force of the fluid on the solids is enough to balance the weight of the solid material as the fluid velocity rises. This phase occurs at the minimal fluidization velocity and is referred to as incipient fluidization. When this minimum velocity is surpassed, the reactor bed's contents start to expand and swirl, turning the reactor into a fluidized bed reactor. This reactor can have a variety of flow regimes based on the operating settings and solid phase characteristics. Fluidized beds mix better than packed beds due to the solid material's inherent fluid-like properties. This extensive mixing assures a consistent outcome, which is difficult to achieve in other reactor designs. The elimination of radial and axial concentration gradients leads to better fluid-solid contact, which is essential for reaction efficiency and quality. Furthermore, numerous chemical processes require the addition or removal of heat. Local hot or cold spots inside the reaction bed, which are prevalent in packed beds, are avoided in a fluidized environment, such as a fluidized bed reactor. In other reactor designs, temperature fluctuations, particularly hotspots, can cause product degradation. Thus, fluidized bed reactors are suited for exothermic reactions. Thus, fluidized bed reactors are suited for exothermic reactions. Furthermore, the fluidized bed design of these reactors allows them to continuously extract products and inject new reactants into the reaction vessel. Operating in a continuous process mode allows refiners to produce items more efficiently by eliminating start-up conditions in batch operations. However, as with any design, the fluidized bed reactor has constraints that each reactor designer must consider. Because the bed materials grow in the reactor, a larger vessel is often needed than a packed-bed reactor. This larger vessel has a higher initial capital cost. Furthermore, the need for the fluid to suspend the solid material necessitates a higher fluid velocity within the reactor. This demands more pumping power, which raises energy costs. Furthermore, the pressure drop associated with deep beds requires increased pumping power. Furthermore, the high gas velocities found in this type of reactor typically cause fine particles to be entrained.

Basic principles

The solid substrate material (the catalytic material on which chemical species react) in the fluidized bed reactor is often supported by a porous plate known as a distributor. The fluid is subsequently forced into the distributor and up through the solid material. At lower fluid velocities, the solids stay in situ as the fluid moves through the material's gaps. This is called a packed bed reactor. As the fluid velocity increases, the reactor's push on the solids will be adequate to balance the solid material's weight. This stage is known as incipient fluidization, and it occurs at the minimum fluidization velocity. When this minimum velocity is exceeded, the contents of the reactor bed begin to expand and swirl around, much like an agitated tank or boiling pot of water. The reactor is now a fluidized bed. This reactor can have a variety of flow regimes based on the operating settings and solid phase characteristics.

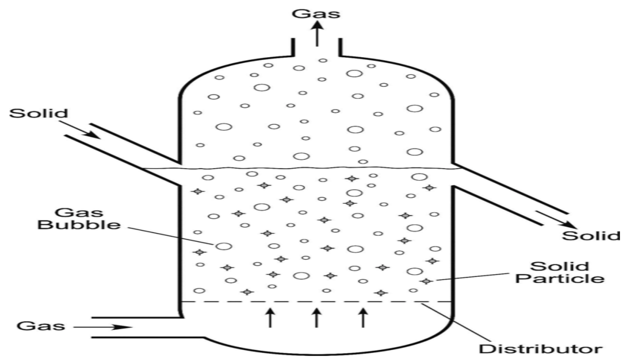


Figure: Schematic of a fluidized bed reactor.

The fluidized bed reactor architecture provides various benefits:

- **Enhanced mass and heat transfer**: The fluidized condition allows for close contact between the reactants and the catalyst, resulting in faster mass and heat transfer.
- **Improved reaction kinetics:** The constant movement of particles ensures that temperature is distributed evenly throughout the reactor, limiting the chance of hot spots.
- **Improved reaction kinetics:** Fluidized bed reactors' high surface area and good mixing qualities allow for faster reaction rates and greater catalyst usage.
- **Flexibility:** Fluidized bed reactors can handle a wide range of feedstock and operate at a variety of temperatures and pressures, making them suitable for a variety of applications.

Self-Assessment Questions

Q.1. What is a fluidized bed reactor, and how does it differ from conventional reactors?

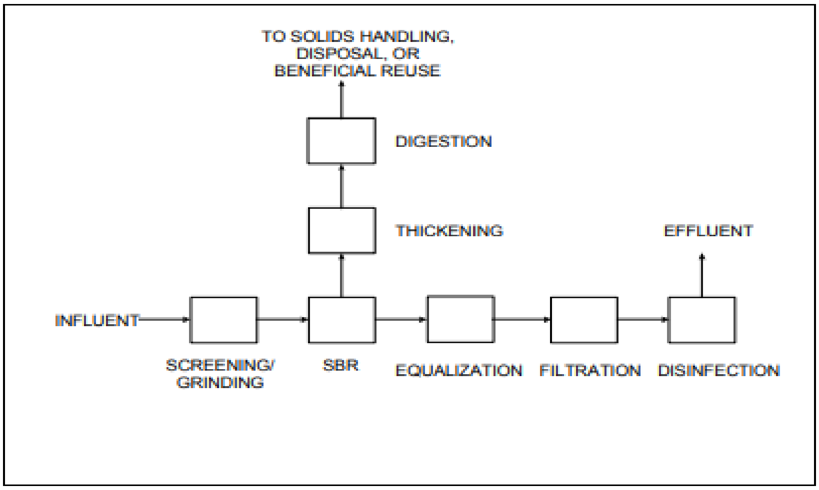
Q.2. Explain the role of fluidization in enhancing mass and heat transfer in a fluidized bed reactor.

Q.3. What are the key advantages and challenges associated with using fluidized bed reactors in industrial processes?

9.5 Sequencing batch reactor (SBR)

The sequencing batch reactor (SBR) is a fill-and-draw activated sludge technology used for wastewater treatment. This technology treats wastewater in a single "batch" reactor, removing unwanted components before disposal. A single batch reactor can perform equalization, aeration, and clarifying functions. To improve system performance, multiple batch reactors are used in a predetermined sequence of processes. SBR systems have effectively treated municipal and industrial wastewater. These systems are ideal for wastewater treatment with low or intermittent flow rates. Sludge settles when aeration is turned off and a drainage mechanism is utilized to remove the supernatant liquor. The numerous therapy stages occur at predetermined and programmable intervals, with each stage constituting a cycle. SBR reactors handle waste water in batches, such as sewage or the output of anaerobic digesters or mechanical biological treatment plants. Oxygen is bubbled through waste water to lower biochemical oxygen demand (BOD) and chemical oxygen demand (COD), preparing it for disposal into sewers or land usage. While SBRs can be configured in a variety of ways, the core technique remains consistent. The installation comprises of at least two identically fitted tanks with a shared inlet that may be swapped between them. The tanks use a "flow through" system, with raw wastewater (influent) entering at one end and treated water (effluent) exiting the other. While one tank is settling or decanting, the other is aerating and filling. At the inlet is a segment. The bio-selector is located at the tank's inlet. This comprises of a succession of walls or baffles that direct the flow either from side to side of the tank or beneath and over successive baffles. This aids in the mixing of entering Influent and returned activated sludge, so initiating the biological digestion process before the liquor enters the tank's main section.

A typical process flow schematic for a municipal wastewater treatment plant using an SBR is shown in Figure 1. Influent wastewater generally passes through screens and grit removal prior to the SBR. The wastewater then enters a partially filled reactor, containing biomass, which is acclimated to the wastewater constituents during preceding cycles. Once the reactor is full, it behaves like a conventional activated sludge system, but without a continuous influent or effluent flow. The aeration and mixing is discontinued after the biological reactions are complete, the biomass settles, and the treated supernatant is removed. Excess biomass is wasted at any time during the cycle. Frequent wasting results in holding the mass ratio of influent substrate to biomass nearly constant from cycle to cycle.



Source: Parsons Engineering Science, 1999.

Figure: 1 Process flow diagram for a typical SBR

Continuous flow systems maintain the mass ratio of influent substrate to biomass by regulating return activated sludge flow rates. Adapt to changing influent flow rates, characteristics, and settling tank underflow concentrations. After the SBR, the "batch" of wastewater may flow to an equalization basin to adjust the flow rate. Additional units can be processed at a predetermined rate. Sometimes wastewater is filtered to eliminate particulates before disinfection.

Advantages

- Equalization, primary clarification (in most situations), biological treatment, and secondary clarification can all be done in a single reactor vessel.
- Operating flexibility and control.
- Minimal footprint.

- Eliminating clarifiers and other equipment could result in capital cost savings.

Disadvantages

- Larger systems require more sophisticated timing units and controls than ordinary systems.
- Sophisticated controls, automated switches, and valves lead to higher maintenance requirements compared to conventional systems.
- Some SBR designs may discharge settled or floating sludge during the DRAW or decant phase.
- Plugging of aeration devices may occur during specific working cycles, depending on the manufacturer's aeration system.
- Equalization may be necessary following SBR, depending on downstream operations.

Self-Assessment Questions

Q.1. What are the main operational phases of a sequencing batch reactor (SBR) in wastewater treatment?

Q.2. How does an SBR differ from a conventional continuous flow activated sludge system?

Q.3. What are the advantages and limitations of using an SBR for wastewater treatment?

9.6 Air samplers

Sampling is the most important phase in environmental investigation. Sampling errors often outnumber analytical procedure errors. A survey found that analytical variance accounted for only 0.1% of overall variance in geochemical samples, whereas sampling variance accounted for 43% and the remaining 53% was due to true geochemical fluctuation. To ensure meaningful interpretation of chemical studies, sampling and analytical variance should not exceed 20% of total variance. Air samplers are devices that gather samples of air for analysis. They are valuable instruments in a variety of sectors, including environmental monitoring, industrial hygiene, public health, and research. Air samplers can collect a variety of airborne particles, such as dust, pollen, mold spores, bacteria, viruses, and other contaminants. These devices are available in a variety of configurations, each tailored to specific applications and sampling purposes.

Standard measurement techniques can be used after collecting appropriate samples. Air is primarily composed of N_2, O_2, and Ar, accounting for 99.9% of dry air. Water vapor, minor and trace gaseous components, aerosol and particulate species are also present. Table 1 lists gases of environmental interest.

Factors considered in an analysis:

a. **Sampling size:** Volume of air sampled depends on minimum chemical concentration that must be measured, sensitivity of measurement, and the information required.

b. **Sampling rate:** Sampling rates vary with sampling devices. Most sampling devices for gaseous constituents have permissible flow rates of 0.003 to 0.03 m3 /min. The collection efficiency should be at least 75%.

c. **Sampling Duration:** Duration of sampling is determined by the information that is desired. A sampling device capable of smooth operation at high flow rates is preferred for short sampling times.

d. **Sample Storage:** Air samples should be protected from heat and light. Care should be taken that the test component does not react with other components. Gaseous samples are sometimes collected by adsorption onto a solid. A vacuum source, a means of measuring the amount of air sampled, and a collector or combinations of collectors are required for sampling air.

Examples of common air samplers are:

a. Particle Samplers:

- These apparatuses collect airborne solid or liquid particles. Depending on the size range of particles they capture, they can be further categorized as PM2.5 (particles with a diameter of 2.5 micrometers or less) or PM10 (particles with a diameter of 10 micrometers or smaller).
- **High-Volume PM10 Sampler (TSP Sampler):** This type of sampler is designed to collect particulate matter with a diameter of 10 micrometers or less, generally known as PM10.
- **Cyclone Respirable Dust Sampler:** Cyclone samplers are commonly employed in occupational settings to collect size-selective respirable dust samples. These samplers typically use a cyclonic airflow pattern to distinguish respirable particles (those that can enter the lower portions of the lungs) from larger particles.
- **Portable PM2.5 Sampler:**For personal exposure investigations, indoor air quality evaluations, and mobile air monitoring campaigns, portable samplers designed especially for gathering tiny particulate matter with a diameter of 2.5 micrometers or less (PM2.5) are needed.
- **Surface Sampling Pump with Filter Cassette:** In some cases, it is important to detect particulate contamination on surfaces rather than in the air. Surface sampling pumps equipped with filter cassettes collect particles deposited on surfaces for further analysis.

b. Microbial Samplers:

Microbial samplers are specialized instruments that gather airborne microorganisms such as bacteria, fungus, viruses, and other biological particles suspended in the atmosphere. These samplers are critical instruments in a variety of industries, including indoor air quality assessments, environmental monitoring, healthcare settings, pharmaceutical manufacturing, and research facilities. Here are some examples of microbiological samplers that are routinely used for different purposes:

- **Impaction samplers** work on the impaction principle, which involves airborne particles being hit onto a solid surface as air passes past the device.
- **Liquid impingers,** also known as microbial air samplers, collect microorganisms from the air using a liquid media. The sampler draws air through it, and microbiological particles are collected by impaction into a liquid solution.
- **Filter-based microbial samplers** use porous filters to collect airborne bacteria as they pass through. Depending on the sampling aims and target microorganisms, these samplers can be equipped with a variety of filters, including membrane filters and gelatin filters.
- **Surface Air System (SAS)** used for microbiological air monitoring in regulated environments like cleanrooms, operating rooms, and pharmaceutical manufacturing facilities.
- **Bioaerosol cyclones** are specialized samplers that gather bioaerosols, such as bacteria, fungus, and viruses, depending on their aerodynamic qualities.

- **Portable Microbial Air Samplers is** small, battery-powered instruments are intended for on-site or field-based microbial air sampling.

c. Gas and Vapor Samplers:

These samplers collect gases and vapors from the air. They are often used to measure pollutants, volatile organic compounds (VOCs), and hazardous gasses in industrial, indoor, and outdoor settings. Gas and vapor samplers, such as passive diffusion badges or active sampling pumps with sorbent tubes, gather and concentrate airborne gases and vapors for analysis. These devices are essential for monitoring indoor air quality, occupational exposures, and environmental contaminants, as they provide critical data for risk assessment and regulatory compliance.

d. High-Volume Samplers:

These samplers can gather enormous volumes of air over a set time period, allowing for precise assessment of low quantities of airborne pollutants. They are frequently employed in ambient air quality monitoring and research activities. High-volume samplers, such the Andersen cascade impact or and the high-volume air sampler (Hi-Vol), capture enormous amounts of air for particulate matter analysis. They are used in ambient air quality monitoring to measure concentrations of PM10, PM2.5, and other pollutants, which helps us understand air pollution levels and their health effects.

e. Passive Samplers:

Unlike active samplers, passive samplers do not require external power or pumps to function. They use natural airflow to take air samples over time. Passive samplers are ideal for long-term monitoring and are widely employed in indoor air quality assessments and environmental investigations. Passive samplers, such as diffusive badges and radial passive samplers, absorb pollutants without requiring active air monitoring. When placed in the environment, they gradually acquire toxins. They are widely used in indoor air quality assessments and environmental monitoring because they are cost-effective, unobtrusive, and allow for long-term sampling of numerous pollutants.

f. Portable Samplers:

These small and lightweight samplers are ideal for on-site or field sampling applications. They are appropriate for environmental monitoring, occupational hygiene evaluations, and emergency response scenarios. Portable samplers, such as the MiniVol or portable gas chromatographs, enable on-site air monitoring in a variety of situations. They're small and battery-powered, making them perfect for field research, emergency response, and personal exposure evaluations.

g. Sequential Samplers:

Sequential samplers gather air samples at several time intervals or from various points within a sampling area. They are excellent for investigating temporal and regional differences in air quality and pollutant concentrations. Sequential samplers, such as the Burkard spore trap, take air samples at regular intervals or from different points within a sampling region. They are widely used in aerobiology and environmental monitoring to measure temporal and spatial fluctuations in airborne particles, allowing researchers to examine allergies, infections, and atmospheric pollutants.

h. Remote Samplers:

These samplers include remote monitoring capabilities, allowing users to take air samples from difficult or hazardous locations without making direct physical contact. Remote samplers, such as the Aeroqual Dust Sentry or the Teledyne API T640, provide remote monitoring features that allow for air sampling in inaccessible or dangerous environments without requiring direct human presence. These devices enable real-time data transmission and processing, allowing for continuous monitoring of air quality at remote places or industrial facilities.

Self-Assessment Questions

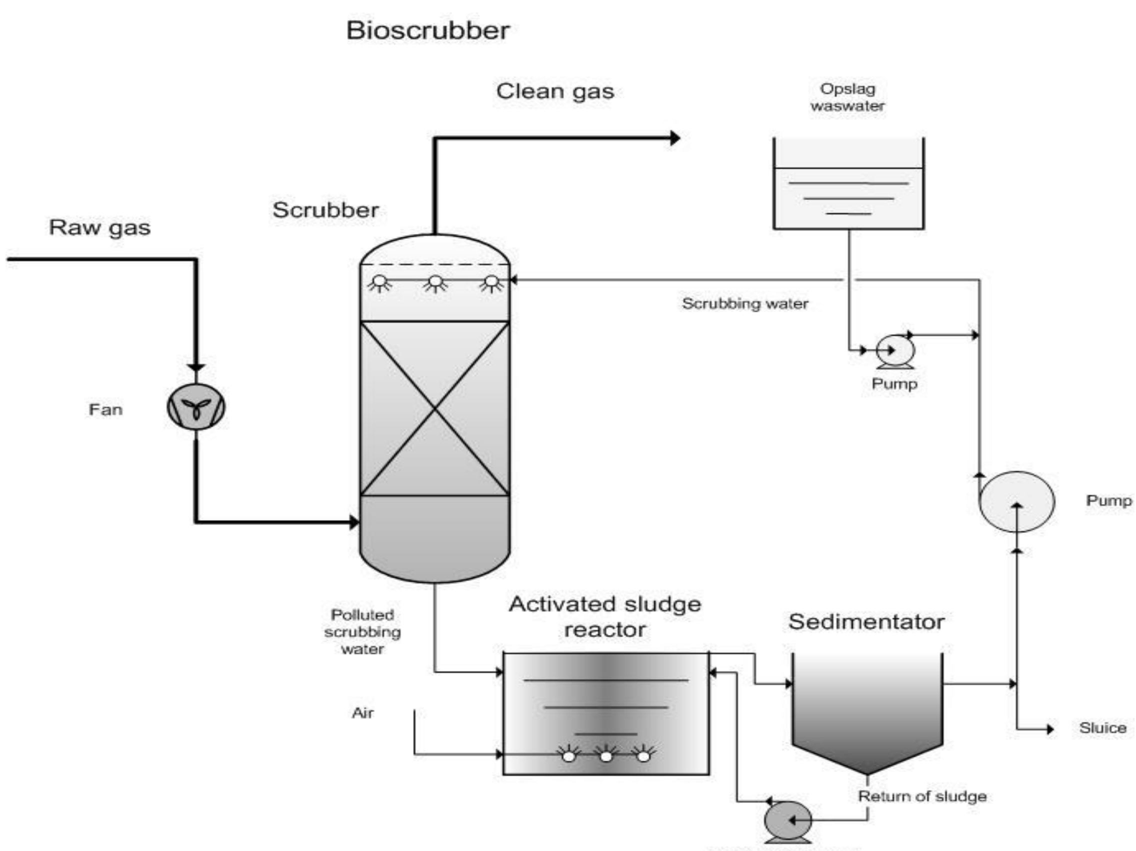
Q.1. What are the different types of air samplers used for monitoring air quality?

Q.2. How does an impaction-based air sampler work, and in what situations is it commonly used?

Q.3. Why is air sampling important in environmental and occupational health monitoring?

9.7. Bio scrubbers

Bio scrubbers are biological air pollution control devices that use microorganisms to remove contaminants from gas streams, primarily exhaust gases. They work by circulating contaminated air through a liquid media, where microbial activity destroys or changes contaminants into harmless by-products. Bio filters are an example of bio scrubbers. Bio scrubbers require continual monitoring of acidity (pH) and temperature within the filter. The pH can be maintained within a wide range; however, if the pH becomes too high or low (depending on your specific system), adjustments may be required. The temperature should be kept between 15°C and 40°C, with an optimal temperature between 30°C and 35°C. Simple pH adjustments can occur as water is recirculated through the system. Microorganisms are kept in a reservoir and cycled with water through the bio scrubber. After passing through the bio scrubber, the solution is treated and recirculated throughout the system, making bio scrubbers water efficient. Treatment of the solution prior to recirculation produces sludge and wastewater. It is critical that sludge and wastewater are collected, stored, managed, and disposed of correctly.



A bio filter is a bed of organic material, such as compost, wood chips, or peat, in which microorganisms grow. Contaminated air flows through the bed, where contaminants are absorbed and digested by the microbial community.

Removed components

- Alcohols: methanol, ethanol, butanol, glycol, diglycol, Phenols
- Aldehydes and ketons: formaldehyde, acetaldehyde, acetone, methylisobutylketon (MIBK), methylethylketon (MEK).
- Carboxyl acids and their esters: EDTA, proponic acid, acetates, methylmetacrylate.
- Heterocyclicalsulphur and nitrogen components, Mercaptans, Amines, H_2S and Chlorophenols
- To a lesser extent: Naphthalene, thioethers

Advantages

Bioscrubbers are environmentally friendly since they use natural biological processes for pollutant removal.

- Compared to traditional air pollution control systems, they usually have reduced operating and maintenance expenses.
- It is the smaller volume of the equipment
- it has Better pH control and More reliable and predictable
- Lower occurrence of toxic concentrations in the water phase.

Disadvantages:

- Only cost-effective for pollutants with a dimensionless Henry's law's coefficient be10w 0.01
- More difficult to attain elimination efficiencies higher than 98%
- Chance of the slowest-growing micro-organisms being washed out;
- Stagnation periods of some days are not permitted
- Disposal of sludge
- More complicated start-up procedure
- Higher operational costs

Self-Assessment Questions

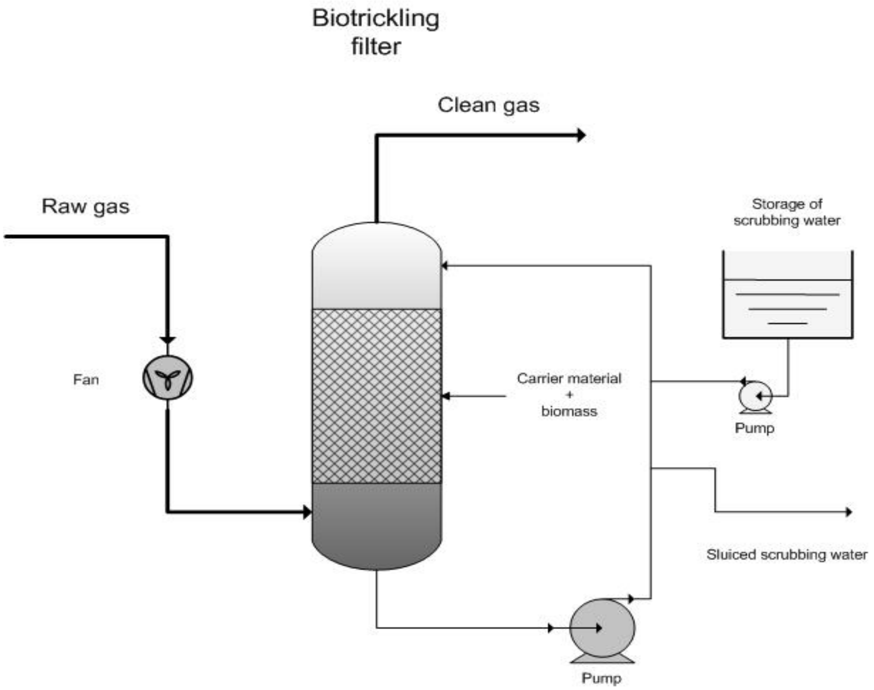
Q.1. What is the primary function of a bioscrubber in air pollution control?

Q.2. How do bioscrubbers differ from traditional chemical scrubbers in gas treatment processes?

Q.3. What are the key biological components used in bioscrubbers, and how do they help in pollutant removal?

9.8. Bio trickling filters

A bio filter and a bioscrubber are combined to create a bio trickling filter. Decomposition-causing bacteria are immobilized on a filter or carrier material. Lava, synthetic foam, or structured plastic packaging are the materials used to make the filter. The structure of the surface must enable biomass to adhere to it effectively. Water is continuously soaked into the transport substance. This implies that the packing should be equally sprayed with water. As pollutants permeate into the liquid film, bacteria break them down. The water receives nutrients to nourish the biomass. Along with breakdown chemicals that could damage the biomass, this water also carries more sludge or biofilm. The water receives nutrients to nourish the biomass. Along with breakdown chemicals that could damage the biomass, this water also carries more sludge or biofilm. It is necessary to assess the pH, nutrition, and salt content of the washing solution that is pumped over the packaging. It is possible to continuously check and adjust the pH. Excessive growth of biofilm can clog the packing of the biotrickling filter. Preferred flows will arise from this, decreasing efficiency and raising pressure drop. It will be necessary to replace the packing if the obstruction is severe. During dimensioning, the load should be kept modest to prevent such obstructions. H2S and NH3 are extracted from gases by water purifying facilities. Two components of the filter will be separated. In the initial phase, autotrophic bacteria eliminate NH3 and H2S. This stage could turn acidic. Heterotrophic bacteria that break down organic odor components are involved in the second phase. For this phase to work well, the pH must be between 7 and 8. Elimination of CS2 and H2S from textile industry waste gases



Removed components

- Hydrocarbons: alcohols, aldehydes and ketons, fatty acids and their esters, phenols, styrene, naphthalene
- Nitrogen components: NOx, NH_3, amines, heterocyclic nitrogen components
- Sulphur-laden components: H_2S, mercaptans, heterocyclic sulphur compounds, carbon disulphide
- Chlorine-laden components: dichloromethane, 1,2-dichloroethane, chlorophenol, trichloroethene, monovinylchloride

Advantages

- Biological decomposition of components; no VOC residual products
- Suitable for decomposition of acid-forming components
- pH checking and correction is possible under certain conditions

- Low pressure drop
- Average investment and operation costs

Disadvantages

- Fluctuations in composition and load of incoming air have serious consequences for the yield
- Components with poor solubility are difficult to treat.
- Toxic and high concentrations of acidic components must be avoided.
- Packing can become blocked by biomass
- More difficult to construct than a biofilters.
- More expensive than a biofilters.
- Waste water flow created.

Self-Assessment Questions

Q.1. What is the primary purpose of a biotrickling filter in air pollution control?

Q.2. How does the microbial biofilm in a biotrickling filter help in the removal of pollutants?

Q.3. What are the advantages of biotrickling filters compared to biofilters in gas treatment applications?

9.9. Afforestation

Afforestation, or the process of planting trees and developing forests in formerly uninhabited areas, is critical for environmental pollution control. The afforestation play following role in environmental pollution control as follows:

- **Air Pollution Mitigation:** Trees operate as natural air filters, absorbing pollutants including carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate matter from the atmosphere via their leaves and bark. Increasing vegetation cover through afforestation can dramatically improve air quality, decreasing respiratory ailments and lessening the effects of climate change.
- **Carbon Sequestration:** Trees are vital for sequestering carbon dioxide, a key greenhouse gas that contributes to global warming. Afforestation increases carbon storage in biomass and soil, which helps to counteract human-caused carbon emissions and regulate atmospheric carbon levels.
- **Soil and Water Conservation:** Afforestation prevents soil erosion by stabilizing slopes and minimizing surface runoff. Tree roots bond soil particles, preventing sedimentation and ensuring water purity. Furthermore, woods serve as natural watersheds, regulating water flow and lowering the risk of flooding and drought.
- **Biodiversity Conservation:** Afforestation increases habitat variety by providing refuge and food for a diverse range of animal and plant species. Forest environments promote biodiversity, hence improving ecosystem resilience and ecological balance.
- **Urban Heat Island Mitigation:**By lowering surface temperatures, improving microclimates, and providing shade, reforestation in urban areas helps to mitigate the urban heat island effect. This reduces health risks associated with heat while also saving electricity for cooling.

Self-Assessment Questions

Q.1 How does afforestation help in reducing the effects of climate change?

Q.2 What are the key differences between afforestation and reforestation?

Q.3 How can afforestation contribute to improving biodiversity in an ecosystem?

9.10. Summary

Environmental pollution control refers to the measures and tactics used to reduce or decrease the release of pollutants into the environment, thereby safeguarding human health, ecosystems, and natural resources. It covers a wide range of approaches aimed at reducing air, water, and soil pollution, as well as noise pollution and waste management. Here are some important areas of environmental pollution control: Environmental pollution control typically requires controlling land development and constructing transportation systems to reduce pollution. Pollution control relies heavily on environmental planning, land development management, and transportation system design. Pollution control technologies have advanced, resulting in the creation of cleaner production processes, emission control devices, and air and water pollution treatment systems. Catalytic converters for autos, scrubbers for industrial pollutants, and effluent treatment plants are a few examples. Overall, environmental pollution control is a multidisciplinary activity that requires collaboration across governments, industry, communities, and individuals to address pollution issues, protect natural resources, and ensure current and future generations' health and well-being. Society may reduce environmental pollution and create a cleaner, healthier, and more sustainable earth by putting in place comprehensive pollution control measures and adopting sustainable practices.

9.11. Terminal questions

Q. 1. What do you know about environmental pollution control?

Answer:--

Q. 2. Discuss the air sampling and air sampler with examples.

Answer:--

Q. 3. Discuss the air controlling device, especially Particle Samplers with examples.

Answer:--

Q. 4. Discuss about Techniques used in water treatment.

Answer:--

Q. 5. What are oxidation ponds, write its advantage and disadvantage?

Answer:--

Q. 6. Discuss about Fluidized bed reactors with examples.

Answer:---

Q. 7. Discuss the Bio-scrubbers with examples.

Answer:---

9.12. Further suggested readings

1. Waste treatment and disposal, Williams, Paul T. John Wiley Publishers, 2013.
2. E-waste: Implications, regulations and management in India and Current global best practices, TERI press, Johri, Rakesh.
3. Bio- medical waste management, Sahai, Sushma, APH Publishing.
4. Electronic waste management, design, analysis and application, R E Hester, Cambridge Royal Society of Chemistry.
5. Solid and Hazardous Waste Management, Rao, M.N. and Sultana, BS Publications, Hyderabad.