Course: EMT 307 (Environmental Pollution Studies)   (3 units)
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MODULE 1: AIR

UNIT 1: AIR COMPOSITION

TABLE OF CONTENTS

1.0 Introduction

Air is a mixture of gases comprising the Earth's atmosphere. The mixture contains a group of gases of nearly constant concentrations and a group with concentrations that are variable in both space and time-period.

2.0 Objectives

By the end of this unit, student should be able to:

i. know the major gases in the atmosphere;
ii. know the important trace gases in air and
iii. understand the significance of ozone layer and water vapor.

3.0 Main Content

This section deals with identification gases, its important roles in the space sustenance.

3.1 Major Gases

The most common atmospheric gas, nitrogen (N_2) is largely inert, meaning that it does not readily react with other substances to form new chemical compounds. The next most common gas, oxygen (O_2), is required for the respiration (breathing) of all animal life on Earth, from humans to bacteria. In contrast to nitrogen, oxygen is extremely reactive. It participates in oxidation, examples of which include apples turning from white to brown after being sliced, the rusting of iron, and the very rapid oxidation reaction known as fire. Just less than 1% of the atmosphere is made up of argon (Ar), which is an inert noble gas, meaning that it does not take part in any chemical reactions under normal circumstances. Together, these three gases account for 99.96% of the atmosphere. The remaining 0.04% contains a wide variety of trace gases, several of which are crucial to life on Earth. The atmospheric gases of steady concentration (and their proportions in percentage by volume) are as follows in Table 1 according to britannica.com

Table 1: Atmospheric Gases

Gases	Percentage by volume
Nitrogen (N_2)	78.084
Oxygen (O_2)	20.946
Argon (Ar)	0.934
Helium (He)	0.000524
Methane (CH_4)	0.0002
Krypton (Kr)	0.000114
Hydrogen (H_2)	0.00005
Nitrous Oxide (N_2O)	0.00005
Xenon (Xe)	0.0000087

Source: **https://www.britannica.com/science/air**

3.1.1 Nitrogen

Nitrogen is a non-metallic element of Group [Va] of the periodic table. It is a colourless, odourless, tasteless gas. It is the most plentiful element in Earth's atmosphere and is a constituent of all living matter. About four-fifths of Earth's atmosphere is nitrogen, which was isolated and recognized as a specific substance during early investigations of the air. Carl Wilhelm Scheele, a Swedish chemist, showed in 1772 that air is a mixture of two gases, one of which he called "fire air," because it supported combustion, and the other "foul air," because it was left after the "fire air" had been used up. The "fire air" was, of course, oxygen and the "foul air" nitrogen.

During this time-period, nitrogen also was recognized by a Scottish botanist, Daniel Rutherford (who was the first to publish his findings), by the British chemist Henry Cavendish, and by the British clergyman and scientist Joseph Priestley, who, with Scheele, is given credit for the discovery of oxygen. Later work showed the new gas to be a constituent of nitre, a common name for potassium nitrate (KNO_3), and, accordingly, it was named nitrogen by the French chemist Jean-Antoine-Claude Chaptal in 1790. Nitrogen was first considered a chemical element by Antoine-Laurent Lavoisier, whose explanation of the role of oxygen in combustion eventually overthrew the phlogiston theory, an erroneous view of combustion that became popular in the early 18th century. Thus, the inability of nitrogen to support life (Greek: zoe) led Lavoisier to name it azote, still the French equivalent of nitrogen. Among the elements, nitrogen ranks sixth in cosmic abundance (Source).

3.1.2 Oxygen

Oxygen is another non-metallic chemical element of Group (VIa, or the oxygen group) of the periodic table. It is also colourless, odourless, and tasteless gas, essential to living organisms, being taken up by animals, which convert it to carbon dioxide; plants, in turn, utilize carbon dioxide as a source of carbon and return the oxygen to the atmosphere. Oxygen forms compounds by reaction with practically any other element, as well as by reactions that displace elements from their combinations with each other; in many cases. These processes are accompanied by the evolution of heat and light and in such cases are called combustions.

Its most important compound is water, Oxygen was discovered about 1772 by a Swedish chemist, Carl Wilhelm Scheele, who obtained it by heating potassium nitrate, mercuric oxide, and many other substances. An English chemist, Joseph Priestley, independently discovered oxygen in 1774 by the thermal decomposition of mercuric oxide and published his findings the same year, three years before Scheele published. In 1775–80, French chemist Antoine-Laurent Lavoisier, with remarkable insight, interpreted the role of oxygen in respiration as well as combustion, discarding the phlogiston theory, which had been accepted up to that time; he noted its tendency to form acids by combining with many different substances and accordingly named the element oxygen (oxygène) from the Greek words for "acid former." At 46 percent of the mass, oxygen is the most plentiful element in Earth's crust. The proportion of oxygen by volume in the atmosphere is 21 percent and by weight in seawater is 89 percent. In rocks, it combines with metals and nonmetals in the form of oxides that are acidic (such as those of sulfur, carbon, aluminum, and phosphorus) or basic (such as those of calcium, magnesium, and iron) and as salt-like compounds that may be regarded as formed from the acidic and basic oxides, as sulfates, carbonates, silicates, aluminates, and phosphates.

3.2 Important Trace Gases

3.2.1 Carbon dioxide

Carbon dioxide (CO_2) affects Earth's climate and plays a large support role in the biosphere, the collection of living things that populate Earth's surface. Only about 0.0325% of the atmosphere is CO_2. Carbon dioxide is required by plant life for photosynthesis, the process of using sunlight to store energy as simple sugars, upon which all life on Earth depends. Carbon dioxide is also one of a class of compounds called greenhouse gases. These gases are made up of molecules that absorb and emit infrared radiation, which is felt as heat. The solar energy radiated from the sun is mostly in the visible range, within a narrow band of wavelengths. This radiation is absorbed by Earth's surface, and then re-radiated back out to space not as visible light, but as longer wavelength infrared radiation. Greenhouse gas molecules absorb some of this radiation before it escapes to space, and re-emit some of it back toward the surface. In this way, these gases trap some of the escaping heat and increase the overall temperature of the atmosphere. If the atmosphere had no greenhouse gases, it is estimated that Earth's surface would be 90°F (32°C) cooler.

3.2.2 Water vapor

Water vapor is found in the atmosphere in small and highly variable amounts. While it is nearly absent in most of the atmosphere, its concentration is about 4% in a very warm, humid areas close to the earth surface. Despite its relative scarcity, atmospheric water probably has more of an impact on Earth than any of other major gases, aside from oxygen. It is an element of the hydrologic cycle, the process that moves water between the oceans, the land surface waters, the atmosphere, and the polar ice caps. Water cycle drives erosion and rock weathering, determines Earth's weather, and sets up climate conditions that make land areas dry or wet, habitable or inhospitable. When cooled sufficiently, water vapor forms clouds by condensing to liquid water droplets, or, at lower temperatures, solid ice crystals. Besides creating rain or snow, clouds affect Earth's climate by reflecting some of the energy coming from the sun, making the planet somewhat cooler. Water vapor is also an important greenhouse gas. It is concentrated near the surface and is much more prevalent near the tropics than in the polar region**.**

3.2.3 Ozone

Ozone (O_3) is found almost exclusively in a layer about (15–60 km) in altitude. At lower altitudes, ozone gas is irritating to eyes and skin and chemically attacks rubber and plant tissue. Nevertheless, it is vital to life on Earth because it absorbs most of the high-energy radiation from the sun that is harmful to plants and animals. A portion of the energy radiated by the sun lies in the ultraviolet (UV) region. This shorter wavelength radiation is responsible for suntans and is sufficiently powerful to harm cells, cause skin cancer, and burn skin. The ozone molecules, along with molecules of O_2, absorb nearly all the high-energy UV rays, protecting Earth's surface from the most damaging radiation. The first step in this process occurs high in the atmosphere, where O_2 molecules absorb very high energy UV radiation. Upon doing so, each absorbing molecule breaks up into two oxygen atoms. The oxygen atoms eventually collide with another O_2 molecule, forming a molecule of ozone, O_3 (a third molecule is required in the collision to carry away excess energy). Ozone in turn may absorb UV of slightly longer wavelength, which removes one of its oxygen atoms and leaves O_2. The free oxygen atom, being very reactive, will almost immediately recombine with another O_2, forming more ozone. The last two steps of this cycle repeat themselves but do not create any new chemical compounds; they only act to absorb ultraviolet radiation. The amount of ozone in the stratosphere is small. If it were all transported to the surface, the ozone gas would form a layer about in (2.5–4.0 mm) thick. This layer, as thin as it is, is sufficient to shield Earth's occupants from harmful solar radiation.

3.3 Aerosols

In addition to gases, the atmosphere has a wide variety of suspended particles known collectively as aerosols. These particles may be liquid or solid and are small enough that they may require very long times to settle out of the atmosphere by gravity. Examples of aerosols include suspended soil or desert sand particles, smoke particles from wildfires, salt particles from evaporated ocean water, plant pollen, volcanic dust, and particles formed from the pollution created by coal burning power plants. Aerosols significantly affect atmospheric heat balance, cloud growth, and optical properties.

The particles in aerosols cover a wide range of sizes. Raindrops suspended in a cloud are about 0.04–0.24 in (1–6 mm) in diameter. Fine desert sand and cloud droplets range in diameter down to about 0.0004 in (0.01 mm). Sea salt particles and smoke particles are 1/100th of this, about 0.0001 mm, or 0.1 micrometer, in diameter (1 micrometer = one thousandth of a millimeter). Smallest of all are the particles that form when certain gases condense—that is, when several gas molecules come together to form a stable cluster. These are the Aitkin nuclei, whose diameters can be measured down to a few nanometers (1 nanometer = one millionth of a millimeter).

The size of some aerosol particles allows them to efficiently scatter sunlight and create atmospheric haze. Under some conditions, aerosols act as collecting points for water vapor molecules, encouraging the growth of cloud droplets and speeding the formation of clouds. They may also play a role in Earth's climate. Aerosols are known to reflect a portion of incoming solar radiation back to space, which lowers the temperature of Earth's surface. Current research is focused on estimating how much cooling is provided by aerosols, as well as how and when aerosols form in the atmosphere.

4.0 Summary

In this unit we have leant that:

i. The ozone molecules, along with molecules of O_2, absorb nearly all the high- energy UV rays, protecting Earth's surface from the most damaging radiation.
ii. Aerosols are known to reflect a portion of incoming solar radiation back to space, which lowers the temperature of earth's surface.
iii. The most common atmospheric gas, nitrogen (N_2) is largely inert, meaning that it does not readily react with other substances to form new chemical compounds.

5.0 Conclusion

The air has a special place among the conditions necessary for life. The air is a mixture of several gases. The air encompasses the earth from all sides. The air surrounding the Earth is called the atmosphere. The atmosphere is an integral part of our Earth. It is connected with the earth due to the gravitational force of the earth. It helps in stopping the ultra violet rays harmful for the life and maintains the suitable temperature necessary for life. The air is essential for the survival of all forms of life on the earth. You cannot imagine any kind of life in the absence of it.

6.0 Tutor Marked Assignments

1. Justify the significance of ozone to life on Earth.
2. What are aerosols?

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UNIT 2: AIR POLLUTION

TABLE OF CONTENTS

1.0 Introduction

Air pollution is the release into the atmosphere of various gases, finely divided solids, or finely dispersed liquid aerosols at rates that exceed the natural capacity of the environment to dissipate and dilute or absorb them. These substances may reach concentrations in the air that cause undesirable health, economic, or aesthetic effects.

2.0 Objectives

By the end of this unit, student should be able to:

i. understand the meaning of air pollution;
ii. know the anthropogenic sources of air pollution and
iii. natural sources of air pollution.

3.0 Main Content

3.1 Sources of Air Pollution

Air pollution can be human-made or occur naturally in the environment. Human-made pollutants are caused by fossil fuel combustion, industrial and manufacturing, waste-burning, dust from traffic, smoke, and exhaust from vehicles, ships and airplanes, for example, Fires from brush/forest clearing are also a major source of pollution in the form of smoke and black carbon. There are also a variety of natural causes, such as: volcano eruptions that emit large amounts of sulfur and other atmospheric gaseous elements, and dust storms that contribute considerably to airborne particulate matter. Weather patterns can transfer pollutants, both through human-made and natural, over long distances and across regions.

3.1.1 Vehicle exhaust fumes

The number one source of air pollution in city environments is vehicle exhaust fumes, which happen to release high amounts of carbon monoxide. It’s no surprise then that carbon monoxide also happens to be the largest air pollutant in the United States. Millions of vehicles are operated on a daily basis in the US alone, each one leaving its own carbon footprint on the environment. This is why hybrid and fully electric vehicles are making a splash in the automobile marketplace. In some other countries of the world especially in sub-Saharan Africa, vehicle’s exhaust fumes, which happen to release high amounts of carbon monoxide, and contribute in no small measure to air pollution.

3.1.2 Fossil fuel-based power plants

In addition to vehicle exhaust pollution, fossil fuels also present a large scale problem when they’re burned for energy in power plants. Chemicals like sulfur dioxide are released during the burning process, which travel straight into the atmosphere. These types of pollutants react with water molecules to yield something known as acid rain. This is one of the reasons that alternative energy sources, such as nuclear, solar, and wind are being explored in greater detail. They tend to release much less pollutants into the environment to produce equivalent amounts of energy.

3.1.3 Exhaust from industrial plants and factories

Similar to exhaust being released from vehicles, heavier machinery located inside big factories and industrial plants also emit pollutants into the air. Industrial plants can be found pretty much everywhere in the world, so the spreading of air pollution is basically global.

3.1.4 Construction and agricultural activities

On a daily basis, dirt and dust is kicked up into the atmosphere from excavating and demolition type construction activities. Switching focus to agricultural activities, ammonia is a frequent byproduct that happens to be one of the most dangerous gases in any given environment. There are also various types of nasty chemicals that get placed into the atmosphere from pesticides, herbicides and fertilizers, which are being used at increasingly higher rates especially here in Nigeria where agricultural activities are the mainstay and source of livelihood of population in the hinterlands.

3.1.5 Natural causes

When people think pollution, they almost always blame other people. Let’s not forget that the Earth is one of the biggest polluters itself, though. Volcanoes, forest fires, and dust storms are nature-born events that dump massive amounts of air pollution into the environment.

3.1.6 Household/Domestic activities

Forget about outdoor pollution. What about the pollution that takes place inside our own homes? Common household chemicals notably bleach, without proper ventilation is a primary source of indoor air pollution. Smoking tobacco through the use of cigarettes and cigars also releases toxic pollutants into the air. It’s often easier to think of outdoor pollution as the primary danger on a wide scale level, but don’t dismiss the little everyday activities that also impact our health.

4.0 Summary

In this unit we have leant that:

i. Smoking tobacco through the use of cigarettes and cigars also releases toxic pollutants into the air.

ii. Volcanoes, forest fires, and dust storms are nature-born events that dump massive amounts of air pollution into the environment.

iv. Weather patterns can transfer pollutants, both human-made and natural, over long distances and across regions.

5.0 Conclusion

Air pollution can be human-made or occur naturally in the environment. The number one source of air pollution in city environments is vehicle exhaust fumes, which happen to release high amounts of carbon monoxide. In addition to vehicle exhaust pollution, fossil fuels also present a wider scale problem when they're burned for energy in power plants.

6.0 Tutor Marked Assignments

1. Identify three anthropogenic (man-made) causes of air pollution and explain them.
2. What is air pollution?

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UNIT 3: TYPES OF AIR POLLUTION

TABLE OF CONTENTS

1.0 Introduction

Air pollution is the release into the atmosphere of various gases, finely divided solids, or finely dispersed liquid aerosols at rates that exceed the natural capacity of the environment to dissipate and dilute or absorb them. These substances may reach concentrations in the air that cause undesirable health, economic, or aesthetic effects. Air pollution is divided into two namely; outdoor and indoor air pollution

2.0 Objectives

By the end of this unit, student should be able to:

i. understand the types of air pollution;
ii. know the meaning of criteria pollutants and
iii. air toxics.

3.0 Main Content

3.1 Outdoor Air Pollution

Outdoor air pollution is a growing problem. Its estimate indicates that urban outdoor air pollution has risen by eight percent globally between 2008 and 2013. Urbanization, which is often associated with rising air pollution, is increasing too, by 2050, up to two thirds of the global population is expected to live in urban areas (WHO, 2016). This estimation is already a reality in 2021 especially in the war prone countries, Nigeria for instance is becoming urbanized as result of unabated insurgency in the rural areas. Consequently, there are high influx of population from countryside to urban areas for safety. Unless action is taken to control outdoor air pollution, studies show that outdoor air pollution will become the leading cause of environment-related child death by 2050.

Air pollution can be high in parts of North America and Europe, but it has improved slightly over the past decade with new environmental regulations and progress in technology. Meanwhile, China and India have been frequently cited as areas where air pollution is at its worst.

In some cities in Asia, it has exceeded 20 times the World Health Organization (WHO) guidelines. Nevertheless, there is considerable variation within those countries both regionally and locally, especially in recent years. In Beijing, for example, latest estimates show an improvement compared to previous years. In fact, data from WHO (2016) unveil a striking new analysis: the most polluted city in the world (by PM10 measurements) is Onitsha, Nigeria. Two other Nigerian cities, Kaduna and Aba, are also among the top 10 most polluted cities. Zabol, Iran, is the most polluted city by PM2.5 measurements. Asian cities continue to occupy the majority of the top of the list for PM2.5 measurements.

3.2 Indoor Air Pollution

Burning of solid fuels for household cooking, heating and lighting is a major cause of household, or indoor, air pollution. Indoor air pollution puts nearly 3 billion people worldwide at risk of ill health and early death. Indoor pollutants include particulate matter (PM10 and PM2.5), mould, dust mites and bacteria, as well as chemicals and Volatile Organic Compounds (VOCs) [such as formaldehyde and benzene] from paints, personal care products and building materials. The effects of indoor air pollution kill more children globally than outdoor air pollution, especially in Africa and Asia. Eighteen of the nineteen countries where 95 per cent or more of the population use solid fuels for cooking are in sub-Saharan Africa.

3.3 Criteria Pollutants

Clean, dry air consists primarily of nitrogen and oxygen, 78 percent and 21 percent respectively, by volume. The remaining 1 percent is a mixture of other gases, mostly argon (0.9 percent), along with trace (very small) amounts of carbon dioxide, methane, hydrogen, helium, and more. Water vapour is also a normal, though quite variable, component of the atmosphere, normally ranging from 0.01 to 4 percent by volume; under very humid conditions the moisture content of air may be as high as 5 percent.

The gaseous air pollutants of primary concern in urban settings include sulfur dioxide, nitrogen dioxide, and carbon monoxide; these are emitted directly into the air from fossil fuels such as fuel oil, gasoline, and natural gas that are burned in power plants, automobiles, and other combustion sources. Ozone (a key component of smog) is also a gaseous pollutant; it forms in the atmosphere via complex chemical reactions occurring between nitrogen dioxide and various volatile organic compounds (e.g., gasoline vapours).

Airborne suspensions of extremely small solid or liquid particles called “particulates” (e.g., soot, dust, smokes, fumes, mists), especially those less than 10 micrometres (μm; millionths of a metre) in size, are significant air pollutants because of their very harmful effects on human health. They are emitted by various industrial processes, coal- or oil-burning power plants, residential heating systems, and automobiles. Lead fumes (airborne particulates less than 0.5 µm in size) are particularly toxic and are an important pollutant of many diesel fuels.

The six major air pollutants aforementioned have been designated by the U.S. Environmental Protection Agency (EPA) as “criteria” pollutants—criteria meaning that the concentrations of these pollutants in the atmosphere are useful as indicators of overall air quality. The sources, acceptable concentrations, and effects of the criteria pollutants are summarized in the table.

Except for lead, criteria pollutants are emitted in industrialized countries at very high rates, typically measured in millions of tons per year. All except ozone are discharged directly into the atmosphere from a wide variety of sources. They are regulated primarily by establishing ambient air quality standards, which are maximum acceptable concentrations of each criteria pollutant in the atmosphere, regardless of its origin. The six criteria pollutants are described in subsequent sections.

3.3.1 Fine particulates

The very small fragments of solid materials or liquid droplets suspended in air are called particulates. Except for airborne lead, which is treated as a separate category, they are characterized on the basis of size and phase (i.e., solid or liquid) rather than by chemical composition. For example, solid particulates between roughly 1 and 100 µm in diameter are called dust particles, whereas airborne solids less than 1 µm in diameter are called fumes. The particulates of most concern with regard to their effects on human health are solids less than 10 µm in diameter, because they can be inhaled deep into the lungs and become trapped in the lower respiratory system. Certain particulates, such as asbestos fibres, are known carcinogens (cancer-causing agents), and many carbonaceous particulates—e.g., soot—are suspected of being carcinogenic. Major sources of particulate emissions include fossil-fuel power plants, manufacturing processes, fossil-fuel residential heating systems, and gasoline-powered vehicles.

3.3.2 Carbon monoxide

Carbon monoxide is an odourless, invisible gas formed as a result of incomplete combustion. It is the most abundant of the criteria pollutants. Gasoline-powered highway vehicles are the primary source, although residential heating systems and certain industrial processes also emit significant amounts of this gas. Power plants emit relatively little carbon monoxide because they are carefully designed and operated to maximize combustion efficiency. Exposure to carbon monoxide can be acutely harmful since it readily displaces oxygen in the bloodstream, leading to asphyxiation (oxygen deprivation) at high enough concentrations and exposure times.

3.3.3 Sulfur dioxide

A colourless gas with a sharp, choking odour, sulfur dioxide is formed during the combustion of coal or oil that contains sulfur as an impurity. Most sulfur dioxide emissions come from power-generating plants; very little comes from mobile sources. This pungent gas can cause eye and throat irritation and harm lung tissue when inhaled.

Sulfur dioxide also reacts with oxygen and water vapour in the air, forming a mist of sulfuric acid that reaches the ground as a component of acid rain. Acid rain is believed to have harmed or destroyed fish and plant life in many thousands of lakes and streams in parts of Europe, the northeastern United States, southeastern Canada, and parts of China. It also causes corrosion of metals and deterioration of the exposed surfaces of buildings and public monuments.

3.3.4 Nitrogen dioxide

Of the several forms of nitrogen oxides, nitrogen dioxide, a pungent, irritating gas is of most concern. It is known to cause pulmonary edema, an accumulation of excessive fluid in the lungs. Nitrogen dioxide also reacts in the atmosphere to form nitric acid, contributing to the problem of acid rain. In addition, nitrogen dioxide plays a role in the formation of photochemical smog, a reddish brown haze that often is seen in many urban areas and that is created by sunlight-promoted reactions in the lower atmosphere. Nitrogen oxides are formed when combustion temperatures are high enough to cause molecular nitrogen in the air to react with oxygen. Stationary sources such as coal-burning power plants are major contributors of this pollutant, although gasoline engines and other mobile sources are also significant.

3.3.5 Lead

Inhaled lead particulates in the form of fumes and dusts are particularly harmful to children, in whom even slightly elevated levels of lead in the blood can cause learning disabilities, seizures, or even death. Sources of airborne lead particulates include oil refining, smelting, and other industrial activities. In the past, combustion of gasoline containing a lead-based antiknock additive called tetraethyl lead was a major source of lead particulates. In many countries there is now a complete ban on the use of lead in gasoline. In the United States, lead concentrations in outdoor air decreased more than 90 percent after the use of leaded gasoline was restricted in the mid-1970s and then completely banned in 1996.

3.4 Air Toxics

Hundreds of specific substances are considered hazardous when present in trace amounts in the air. These pollutants are called air toxics. Many of them cause genetic mutations or cancer; some cause other types of health problems, such as adverse effects on brain tissue or fetal development. Although the total emissions and the number of sources of air toxics are small compared with those for criteria pollutants, these pollutants can pose an immediate health risk to exposed individuals and can cause other environmental problems.

Most air toxics are organic chemicals, comprising molecules that contain carbon, hydrogen, and other atoms. Many are volatile organic compounds (VOCs), organic compounds that readily evaporate. VOCs include pure hydrocarbons, partially oxidized hydrocarbons, and organic compounds containing chlorine, sulfur, or nitrogen. They are widely used as fuels (e.g., propane and gasoline), as paint thinners and solvents, and in the production of plastics. In addition to contributing to air toxicity and urban smog, some VOC emissions act as greenhouse gases and, in so doing, may be a cause of global warming. Some other air toxics are metals or compounds of metals—for example, mercury, arsenic, and cadmium.

In many countries, standards have been set to control industrial emissions of several air toxics. The first hazardous air pollutants regulated in the United States (outside the workplace environment) were arsenic, asbestos, benzene, beryllium, coke oven emissions, mercury, radionuclides (radioactive isotopes), and vinyl chloride. In 1990 this short list was expanded to include 189 substances. By the end of the 1990s, specific emission control standards were required in the United States for "major sources"—those that release more than 10 tons per year of any of these materials or more than 25 tons per year of any combination of them.

Air toxics may be released in sudden and catastrophic accidents rather than steadily and gradually from many sources. For example, in the Bhopal disaster of 1984, an accidental release of methyl isocyanate at a pesticide factory in Bhopal, Madhya Pradesh state, India, immediately killed at least 3,000 people, eventually caused the deaths of an estimated 15,000 to 25,000 people over the following quarter-century, and injured hundreds of thousands more. The risk of accidental release of very hazardous substances into the air is generally higher for people living in industrialized urban areas. Hundreds of such incidents occur each year, though none has been as severe as the Bhopal event.

Other than in cases of occupational exposure or accidental release, health threats from air toxics are greatest for people who live near large industrial facilities or in congested and polluted urban areas. Most major sources of air toxics are so-called point sources—that is, they have a specific location. Point sources include chemical plants, steel mills, oil refineries, and municipal waste incinerators. Hazardous air pollutants may be released when equipment leaks or when material is transferred, or they may be emitted from smokestacks. Municipal waste incinerators, for example, can emit hazardous levels of dioxins, formaldehyde, and other organic substances, as well as metals such as arsenic, beryllium, lead, and mercury. Nevertheless, proper combustion along with appropriate air pollution control devices can reduce emissions of these substances to acceptable levels.

Hazardous air pollutants also come from "area" sources, which are many smaller sources that release pollutants into the outdoor air in a defined area. Such sources include commercial dry-cleaning facilities, gasoline stations, small metal-plating operations, and woodstoves. Emission of air toxics from area sources are also regulated under some circumstances.

Small area sources account for about 25 percent of all emissions of air toxics. Major point sources account for another 20 percent. The rest more than half of hazardous air-pollutant emissions come from motor vehicles. For example, benzene, a component of gasoline, is released as unburned fuel or as fuel vapours, and formaldehyde is one of the by-products of incomplete combustion. Newer cars, however, have emission control devices that significantly reduce the release of air toxics.

4.0 Summary

In this unit we have leant that:

i. Sulfur dioxide reacts with oxygen and water vapour in the air, forming a mist of sulfuric acid that reaches the ground as a component of acid rain.
ii. Hundreds of specific substances are considered hazardous when present in trace amounts in the air.
iii. Except for lead, criteria pollutants are emitted in industrialized countries at very high rates, typically measured in millions of tons per year

5.0 Conclusion

Outdoor air pollution is a growing problem. Recent estimates indicate that urban outdoor air pollution has risen by 8 per cent globally between 2008 and 2013. The effects of indoor air pollution kill more children globally than outdoor air pollution, especially in Africa and Asia. Air toxics may be released in sudden and catastrophic accidents rather than steadily and gradually from many sources.

6.0 Tutor Marked Assignments

1. What are fine particulates and their sources?
2. Describe the impact of acid rain on the ecosystem.

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Observation:
Must of the very germane issues raised in 3.1 section require references to strengthen citation.

UNIT 4: IMPACTS OF AIR POLLUTION

TABLE OF CONTENTS

1.0 Introduction

Air pollution is the release into the atmosphere of various gases, finely divided solids, or finely dispersed liquid aerosols at rates that exceed the natural capacity of the environment to dissipate and dilute or absorb them. These substances may reach concentrations in the air that cause undesirable health, economic, or aesthetic effects. Air pollution is a familiar environmental health hazard. We know what we're looking at when brown haze settles over a city, exhaust billows across a busy highway, or a plume rises from a smokestack. Some air pollution is not seen, but its pungent smell alerts you.

2.0 Objectives

By the end of this unit, student should be able to:

i. know the effects of air pollution on man;
ii. animals and the
iii. ecosystem

3.0 Main Content

3.1 Effects of Air Pollution

3.1.1 Acid rain

When air pollution, specifically sulfur oxides and nitrogen oxides, are released into sky through fossil fuel burning, it creates the phenomenon known as acid rain. Water, high in the atmosphere, combines with these chemicals and becomes acidic in nature. It then scatters the ground, disguised as normal rainfall. Acid rain has been known to cause harm to humans and animals alike, and even damage crops.

3.2.2 Increased global warming

Air pollution directly accelerates the rate at which global warming happens by depleting the Ozone layer. Global warming refers to the increased temperatures Earth continues to experience. These higher temperatures lead to the melting of the polar ice caps and icebergs, which elevates sea levels and creates concern for the human race.

3.2.3 Health challenges

Air pollution is known to cause irritation in the eyes, lungs, nose, and throat. It creates respiratory problems and exacerbates existing conditions such as asthma and emphysema.
When continually exposed to air pollution, humans become at higher risk for cardiovascular disease. Air filled with toxins can have a number of adverse effects on the arteries, and have even been a contributor to heart attacks.
Globally, 3.7 million deaths were attributable to ambient air pollution (AAP) in 2012. About 88% of these deaths occur in low- and middle-income (LMI) countries, which represent 82% of

the world population. The Western Pacific and South East Asian regions bear most of the burden with 1.67 million and 936,000 deaths, respectively. About 236,000 deaths occur in the Eastern Mediterranean region, 200,000 in Europe, 176,000 in Africa, and 58,000 in the Americas. The remaining deaths occur in high-income countries of Europe (280,000), Americas (94,000), Western Pacific (67,000), and Eastern Mediterranean (14,000).

3.1.4 Wildlife endangerment

Most diseases and conditions that humans are susceptible to, animals are as well. Air pollution creates many of the same issues that humans face. Heavily polluted areas force inhabitants to seek new homes, which can negatively impact the ecosystem. Toxic chemicals also deposit over surfaces of water that can lead to the endangerment of marine life animals.

4.0 Summary

In this unit we have leant that:

i. Air pollution directly accelerates the rate at which global warming happens by depleting the Ozone layer.
ii. Globally, 3.7 million deaths were attributable to ambient air pollution (AAP) in 2012.
iii. Air pollution is a familiar environmental health hazard.

5.0 Conclusion

Air pollution is known to cause irritation in the eyes, lungs, nose, and throat. Acid rain has been known to cause harm to humans and animals alike, and even damage crops.

6.0 Tutor Marked Assignments

1. How does air pollution endanger wildlife?
2. Describe the impact of acid rain on man and animals.

7.0 References and other Resources

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UNIT 5: SOLUTIONS TO AIR POLLUTION

TABLE OF CONTENTS

1.0 Introduction

Air pollution is global challenge, hence, countries around the world are inventing various tackling measures to mitigate numerous forms of air pollution. China, for example, is making strides in cleaning up smog-choked skies from years of rapid industrial expansion, partly by closing or canceling coal-fired power plants. In the U.S., California has been a leader in setting emissions standards aimed at improving air quality, especially in places like famously hazy Los Angeles. And a variety of efforts aim to bring cleaner cooking options to places where hazardous cook stoves are prevalent.

In any home, people can safeguard against indoor air pollution by increasing ventilation, testing for radon gas, using air purifiers, running kitchen and bathroom exhaust fans, and avoiding smoking. When working on home projects, look for paint and other products low in volatile organic compounds.

To curb global warming, a variety of measures need to be taken, such as adding more renewable energy and replacing gasoline-fueled cars with zero-emissions vehicles such as electric ones. On a larger scale, governments at all levels are making commitments to limit emissions of carbon dioxide and other greenhouse gases. The Paris Agreement, ratified on November 4, 2016, is one effort to combat climate change on a global scale. And the Kigali Amendment seeks to further the progress made by the Montreal Protocol, banning heat-trapping hydrofluorocarbons (HFCs) in addition to CFCs (Chlorofluorocarbons).

2.0 Objectives

By the end of this unit, student should be able to:

i. know how to control particulates;
ii. the meaning of carbon sequestration and
iii. the difference between absorption and adsorption.

3.0 Main Content

3.1 Control of Air Pollution

Air pollution control refers to the methods or processes employed to reduce or eliminate the emission into the atmosphere of substances that can harm the environment or human health. It was not until the middle of the 20th century, however, that meaningful and lasting attempts were made to regulate or limit emissions of air pollutants from stationary and mobile sources and to control air quality on both regional and local scales. The atmosphere is susceptible to pollution from natural sources as well as from human activities. Some natural phenomena, such as volcanic eruptions and forest fires, may have not only local and regional effects but also long-lasting global ones. Nevertheless, only pollution caused by human activities, such as industry and transportation, is subject to mitigation and control. The best way to protect air quality is to reduce the emission of pollutants by changing to cleaner fuels and processes. Pollutants not eliminated in this way must be collected or trapped by appropriate air-cleaning devices as they are generated and before they can escape into the atmosphere.

3.2 Control of Particulates

Airborne particles can be removed from a polluted airstream by a variety of physical processes. Common types of equipment for collecting fine particulates include cyclones, scrubbers, electrostatic precipitators, and bag house filters. Once collected, particulates adhere to each other, forming agglomerates that can readily be removed from the equipment and disposed of, usually in a landfill. In general, cyclone collectors are often used to control industrial dust emissions and as pre-cleaners for other kinds of collection devices. Wet scrubbers are usually applied in the control of flammable or explosive dusts or mists from such sources as industrial and chemical processing facilities and hazardous-waste incinerators; they can handle hot airstreams and sticky particles. Electrostatic precipitators and fabric-filter bag houses are often used at power plants. Important particulate characteristics that influence the selection of collection devices include corrosivity, reactivity, shape, density, and especially size and size distribution (the range of different particle sizes in the airstream).

3.2.1 Cyclones

A cyclone (Figure 1) removes particulates by causing the dirty airstream to flow in a spiral path inside a cylindrical chamber. Dirty air enters the chamber from a tangential direction at the outer wall of the device, forming a vortex as it swirls within the chamber. The larger particulates, because of their greater inertia, move outward and are forced against the chamber wall. Slowed by friction with the wall surface, they then slide down the wall into a conical dust hopper at the bottom of the cyclone. The cleaned air swirls upward in a narrower spiral through an inner cylinder and emerges from an outlet at the top. Accumulated particulate dust is periodically removed from the hopper for disposal.

Cyclones are best at removing relatively coarse particulates. They can routinely achieve efficiencies of 90 percent for particles larger than about 20 micrometres (µm; 20 millionths of a metre).

Figure 1: Cyclone

Source: Encyclopaedia Britannica, 2000.

3.2.2 Scrubbers

Devices called wet scrubbers trap suspended particles by direct contact with a spray of water or other liquid. In effect, a scrubber washes the particulates out of the dirty airstream as they collide with and are entrained by the countless tiny droplets in the spray. Several configurations of wet scrubbers are in use. In a spray-tower scrubber, an upward-flowing airstream is washed by water sprayed downward from a series of nozzles. The water is re-circulated after it is sufficiently cleaned to prevent clogging of the nozzles. Spray-tower scrubbers can remove 90 percent of particulates larger than about 8 µm. Venturi scrubbers are the most efficient of the wet collectors, achieving efficiencies of more than 98 percent for particles larger than 0.5 µm in diameter. Scrubber efficiency depends on the relative velocity between the droplets and the particulates. Venturi scrubbers achieve high relative velocities by injecting water into the throat of a venturi channel—a constriction in the flow path—through which particulate-laden air is passing at high speed.

3.2.3 Electrostatic precipitators

Electrostatic precipitation is a commonly used method for removing fine particulates from airstreams. In an electrostatic precipitator (Figure 2), particles suspended in the airstream are given an electric charge as they enter the unit and are then removed by the influence of an electric field. The precipitation unit comprises baffles for distributing airflow, discharge and collection electrodes, a dust clean-out system, and collection hoppers. A high voltage of direct current (DC), as much as 100,000 volts, is applied to the discharge electrodes to charge the particles, which then are attracted to oppositely charged collection electrodes, on which they become trapped.

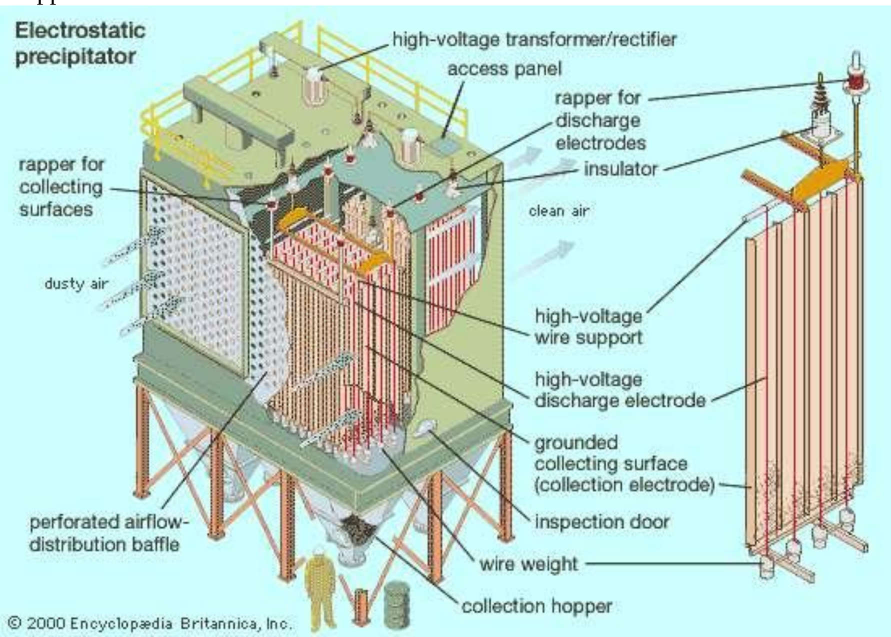

Figure 2: Electrostatic precipitator

Source: Encyclopedia Britannica, 2000.

Particles that stick to the collection plates are removed periodically when the plates are shaken, or "rapped." Rapping is a mechanical technique for separating the trapped particles from the plates, which typically become covered with a 6-mm (0.2-inch) layer of dust.

3.2.4 Bag-house filters

One of the most efficient devices for removing suspended particulates is an assembly of fabric-filter bags, commonly called a bag-house. A typical bag-house comprises an array of long, narrow bags—each about 25 cm (10 inches) in diameter—that are suspended upside down in a large enclosure. Dust-laden air is blown upward through the bottom of the enclosure by fans.

Particulates are trapped inside the filter bags, while the clean air passes through the fabric and exits at the top of the bag-house. A fabric-filter dust collector can remove very nearly 100 percent of particles as small as 1 μm and a significant fraction of particles as small as 0.01 μm.

3.3 Control of Gases

Gaseous criteria pollutants, as well as volatile organic compounds (VOCs) and other gaseous air toxics, are controlled by means of three basic techniques: absorption, adsorption, and incineration (or combustion). These techniques can be employed singly or in combination. They are effective against the major greenhouse gases as well. In addition, a fourth technique, known as carbon sequestration can also be applied

3.3.1 Absorption

In the context of air pollution control, absorption involves the transfer of a gaseous pollutant from the air into a contacting liquid, such as water. The liquid must be able either to serve as a solvent for the pollutant or to capture it by means of a chemical reaction.

Wet scrubbers similar to those described above for controlling suspended particulates may be used for gas absorption. Gas absorption can also be carried out in packed scrubbers, or towers, in which the liquid is present on a wetted surface rather than as droplets suspended in the air. A common type of packed scrubber is the countercurrent tower. After entering the bottom of the tower, the polluted airstream flows upward through a wetted column of light, chemically inactive packing material. The liquid absorbent flows downward and is uniformly spread throughout the column packing, thereby increasing the total area of contact between gas and liquid. Thermoplastic materials are most widely used as packing for countercurrent scrubber towers. These devices usually have gas-removal efficiencies of 90–95 percent.

Sulfur dioxide in flue gas from fossil-fuel power plants can be controlled by means of an absorption process called flue gas desulfurization (FGD). FGD systems may involve wet scrubbing or dry scrubbing. In wet FGD systems, flue gases are brought in contact with an absorbent, which can be either a liquid or a slurry of solid material. The sulfur dioxide dissolves in or reacts with the absorbent and becomes trapped in it. In dry FGD systems, the absorbent is dry pulverized lime or limestone; once absorption occurs, the solid particles are removed by means of baghouse filters

3.3.2 Adsorption

Gas adsorption, as contrasted with absorption, is a surface phenomenon. The gas molecules are sorbed—attracted to and held—on the surface of a solid. Gas adsorption methods are used for odour control at various types of chemical-manufacturing and food-processing facilities, in the recovery of a number of volatile solvents (e.g., benzene), and in the control of VOCs at industrial facilities.

Activated carbon (heated charcoal) is one of the most common adsorbent materials. It is very porous and has an extremely high ratio of surface area to volume. Activated carbon is particularly useful as an adsorbent for cleaning airstreams that contain VOCs and for solvent recovery and odour control. A properly designed carbon adsorption unit can remove gas with an efficiency exceeding 95 percent.

Adsorption systems are configured either as stationary bed units or as moving bed units. In stationary bed absorbers, the polluted airstream enters from the top, passes through a layer, or bed, of activated carbon, and exits at the bottom. In moving bed adsorbers, the activated carbon moves slowly down through channels by gravity as the air to be cleaned passes through in a cross-flow current.

3.3.3 Incineration

The process called incineration or combustion chemically; rapid oxidation can be used to convert VOCs (Volatile Organic Compounds) and other gaseous hydrocarbon pollutants to carbon dioxide and water. Incineration of VOCs and hydrocarbon fumes usually is accomplished in a special incinerator called an afterburner. To achieve complete combustion, the afterburner must provide the proper amount of turbulence and burning time, and it must maintain a sufficiently high temperature. Sufficient turbulence, or mixing, is a key factor in combustion because it reduces the required burning time and temperature. A process called direct flame incineration can be used when the waste gas is itself a combustible mixture and does not need the addition of air or fuel.

An afterburner typically is made of a steel shell lined with refractory material such as firebrick. The refractory lining protects the shell and serves as a thermal insulator. Given enough time and high enough temperatures, gaseous organic pollutants can be almost completely oxidized, with incineration efficiency approaching 100 percent. Certain substances, such as platinum, can act in a manner that assists the combustion reaction. These substances, called catalysts, allow complete oxidation of the combustible gases at relatively low temperatures.

Afterburners are used to control odours, destroy toxic compounds, or reduce the amount of photochemically reactive substances released into the air. They are employed at a variety of industrial facilities where VOC vapours are emitted from combustion processes or solvent evaporation (e.g., petroleum refineries, paint-drying facilities, and paper mills).

3.3.4 Carbon sequestration

The best way to reduce the levels of carbon dioxide in the air is to use energy more efficiently and to reduce the combustion of fossil fuels by using alternative energy sources (e.g., nuclear, wind, tidal, and solar power). In addition, carbon sequestration can be used to serve the purpose. Carbon sequestration involves the long-term storage of carbon dioxide underground, as well as on the surface of Earth in forests and oceans. Carbon sequestration in forests and oceans relies on natural processes such as forest growth. However, the clearing of forests for agricultural and other purposes (and also the pollution of oceans) diminishes natural carbon sequestration. Storing carbon dioxide underground—a technology under development that is also called geo-sequestration or carbon capture and storage—would involve pumping the gas directly into underground geologic "reservoir" layers. This would require the separation of carbon dioxide from power plant flue gases (or some other source)—a costly process.

3.4 Air Quality Index

Air Quality Index (AQI) is a standardized summary measure of ambient air quality used to express the level of health risk related to particulate and gaseous air pollution (Kowalska et al., 2009). The AQI is an index for reporting daily air quality. It tells you how clean or polluted your air is, and what associated health effects might be a concern for you. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air. US Environmental Protection Agency calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality.

The six levels of health concern and what they mean are:

i. Good" AQI is 0 to 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
ii. Moderate" AQI is 51 to 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.
iii. Unhealthy for Sensitive Groups" AQI is 101 to 150. Although general public is not likely to be affected at this AQI range, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air.
iv. Unhealthy" AQI is 151 to 200. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects.
v. Very Unhealthy" AQI is 201 to 300. This would trigger a health alert signifying that everyone may experience more serious health effects.
vi. Hazardous" AQI greater than 300. This would trigger a health warnings of emergency conditions. The entire population is more likely to be affected. All these information can be summarized in a tabular manner as shown in Table 1.

Table 1: Air Quality Index

AQI Value	AQI Category
0-50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive Groups
151-200	Unhealthy
201-300	Very unhealthy
301-500	Hazardous

4.0 Summary

In this unit we have leant that:

Comment [PA1]:

i. Carbon sequestration involves the long-term storage of carbon dioxide underground, as well as on the surface of Earth in forests and oceans.
ii. Activated carbon (heated charcoal) is one of the most common adsorbent materials.
iii. One of the most efficient devices for removing suspended particulates is an assembly of fabric-filter bags, commonly called a bag-house.

5.0 Conclusion

Air pollution control refers to the methods or processes employed to reduce or eliminate the emission into the atmosphere of substances that can harm the environment or human health. Only pollution caused by human activities, such as industry and transportation, is subject to mitigation and control. The best way to protect air quality is to reduce the emission of pollutants by changing to cleaner fuels and processes. Pollutants not eliminated in this way must be collected or trapped by appropriate air-cleaning devices as they are generated and before they can escape into the atmosphere.

6.0 Tutor Marked Assignments

1. Explain carbon sequestration.
2. In terms of gaseous criteria pollutants control, differentiate between absorption and adsorption.

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MODULE 2: NOISE

UNIT 1: NOISE POLLUTION

TABLE OF CONTENTS

1.0 Introduction

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

Noise has always been an important environmental problem for man. In ancient Rome, rules existed as to the noise emitted from the ironed wheels of wagons which battered the stones on the pavement, causing disruption of sleep and annoyance to the Romans. In Medieval Europe, horse carriages and horse-back riding were not allowed during night time in certain cities to ensure a peaceful sleep for the inhabitants. However, the noise problems of the past are incomparable with those of modern society. An immense number of cars regularly cross our cities and the countryside. There are heavily laden lorries with diesel engines, badly silenced both for engine and exhaust noise, in cities and on highways day and night. Aircraft and trains add to the environmental noise scenario. In industry, machinery emits high noise levels and amusement centres and pleasure vehicles distract leisure time relaxation.

2.0 Objectives

By the end of this unit, student should be able to:

i. understand the meaning of environmental noise;

ii. know the different sources of noise and
iii. the extent of environmental noise problem.

3.0 Main Content

3.1 What is Noise?

Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources, except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood. Typical neighbourhood noise comes from premises and installations related to the catering trade (restaurant, cafeterias, discotheques, etc.); from live or recorded music; from sporting events including motor sports; from playgrounds and car parks; and from domestic animals such as barking dogs. The main indoor sources are ventilation systems, office machines, home appliances and neighbours. Although many countries have regulations on community noise from road, rail and air traffic, and from construction and industrial plants, few have regulations on neighbourhood noise. This is probably due to the lack of methods to define and measure it, and to the difficulty of controlling it. In developed countries, too, monitoring of compliance with, and enforcement of, noise regulations are weak for lower levels of urban noise that correspond to occupationally controlled levels (>85 dB LAeq,8h; Frank 1998).

The extent of the community noise problem is large. In the European Union about 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dBA daytime; and 20% is exposed to levels exceeding 65 dBA (Lambert and Vallet 1994). When all transportation noise is considered, about half of all European Union citizens live in zones that do not ensure acoustical comfort to residents. At night, it is estimated that more than 30% is exposed to equivalent sound pressure levels exceeding 55 dBA, which are disturbing to sleep. The noise pollution problem is also severe in the cities of developing countries and is caused mainly by traffic.

Population growth, urbanization and to a large extent technological development are the main driving forces, and future enlargements of highway systems, international airports and railway systems will only increase the noise problem. Viewed globally, the growth in urban environmental noise pollution is unsustainable, because it involves not simply the direct and cumulative adverse effects on health. It also adversely affects future generations by degrading residential, social and learning environments, with corresponding economic losses (Berglund 1998). Thus, noise is not simply a local problem, but a global issue that affects everyone (Lang 1999; Sandberg 1999) and calls for precautionary action in any environmental planning situation.

3.2 Sound and Noise

Physically, there is no distinction between sound and noise: sound is a sensory perception evoked by physiological processes in the auditory brain. The complex pattern of sound waves is perceptually classified as “Gestalts” and are labeled as noise, music, speech, etc. Consequently, it is not possible to define noise exclusively on the basis of the physical parameters of sound. Instead, it is common practice to define noise simply as unwanted sound. However, in some situations noise may adversely affect health in the form of acoustical energy.

3.3 Sources of Noise

This section describes various sources of noise that can affect a community. Namely, noise from industry, transportation, and from residential and leisure areas. It should be noted that equal values of LAeq, T (LAeq is the A-weighted, equivalent continuous sound level in decibels measured over a stated period of time, LAeq,T where T is the measurement time. Most community and industrial noise measurements are A-weighted so the LAeq descriptor is widely used) for different sources do not always imply the same expected effect.

3.3.1 Industrial noise

Mechanized industry creates serious noise problems. It is responsible for intense noise indoors as well as outdoors. This noise is due to machinery of all kinds and often increases with the power of the machines. Sound generation mechanisms of machinery are reasonably well understood. The noise may contain predominantly low or high frequencies, tonal components, be impulsive or have unpleasant and disruptive temporal sound patterns. Rotating and reciprocating machines generate sound that includes tonal components; and air-moving equipment tends also to generate noise with a wide frequency range. The high sound pressure levels are caused by components or gas flows that move at high speed (for example, fans, steam pressure relief valves), or by operations involving mechanical impacts (for example, stamping, riveting, road breaking). Machinery should preferably be silenced at the source.

Noise from fixed installations, such as factories or construction sites, heat pumps and ventilation systems on roofs, typically affect nearby communities. Reductions may be achieved by encouraging quieter equipment or by zoning of land into industrial and residential areas. Requirements for passive (sound insulating enclosures) and active noise control, or restriction of operation time, may also be effective.

3.3.2 Transportation noise

Transportation noise is the main source of environmental noise pollution, including road traffic, rail traffic and air traffic. As a general rule, larger and heavier vehicles emit more noise than smaller and lighter vehicles. Exceptions would include: helicopters and 2- and 3-wheeled road vehicles. The noise of road vehicles is mainly generated from the engine and from frictional contact between the vehicle and the ground and air. In general, road-contact noise exceeds engine noise at speeds higher than 60 km/h. The physical principle responsible for generating noise from tire-road contact is less well understood. The sound pressure level from traffic can be predicted from the traffic flow rate, the speed of the vehicles, the proportion of heavy vehicles, and the nature of the road surface. Special problems can arise in areas where the traffic movements involve a change in engine speed and power, such as at traffic lights, hills, and intersecting roads; or where topography, meteorological conditions and low background levels are unfavourable (for example, mountain areas).

Railway noise depends primarily on the speed of the train, but variations are present depending upon the type of engine, wagons, and rails and their foundations, as well as the roughness of wheels and rails. Small radius curves in the track, such as may occur for urban trains, can lead to very high levels of high-frequency sound referred to as wheel squeal. Noise can be generated in stations because of running engines, whistles and loudspeakers, and in marshaling yards because of shunting operations. The introduction of high-speed trains has created special noise problems with sudden, but not impulsive, rises in noise. At speeds greater than 250 km/h, the proportion of high-frequency sound energy increases and the sound can be perceived as similar to that of overflying jet aircraft. Special problems can arise in areas close to tunnels, in valleys or in areas where the ground conditions help generate vibrations. The long-distance propagation of noise from high-speed trains will constitute a problem in the future if otherwise environment-friendly railway systems are expanded.

Aircraft operations generate substantial noise in the vicinity of both commercial and military airports. Aircraft takeoffs are known to produce intense noise, including vibration and rattle. The landings produce substantial noise in long low-altitude flight corridors. The noise is produced by the landing gear and automatic power regulation, and also when reverse thrust is applied, all for safety reasons. In general, larger and heavier aircraft produce more noise than lighter aircraft.

3.3.3 Construction noise and building services noise

Building construction and excavation work can cause considerable noise emissions. A variety of sounds come from cranes, cement mixers, welding, hammering, boring and other work processes. Construction equipment is often poorly silenced and maintained, and building operations are sometimes carried out without considering the environmental noise consequences. Street services such as garbage disposal and street cleaning can also cause considerable disturbance if carried out at sensitive times of day. Ventilation and air conditioning plants and ducts, heat pumps, plumbing systems, and lifts (elevators), for example, can compromise the internal acoustical environment and upset nearby residents.

3.3.4 Domestic noise and noise from leisure activities

In residential areas, noise may stem from mechanical devices (e.g. heat pumps, ventilation systems and traffic), as well as voices, music and other kinds of sounds generated by neighbours (e.g. lawn movers, vacuum cleaners and other household equipment, music reproduction and noisy parties). Aberrant social behavior is a well-recognized noise problem in multifamily dwellings, as well as at sites for entertainment (e.g. sports and music events). Due to predominantly low-frequency components, noise from ventilation systems in residential buildings may also cause considerable concern even at low and moderate sound pressure levels.

The use of powered machines in leisure activities is increasing. For example, motor racing, off-road vehicles, motorboats, water skiing, snowmobiles etc., and these contribute significantly to loud noises in previously quiet areas. Shooting activities not only have considerable potential for disturbing nearby residents, but can also damage the hearing of those taking part. Even tennis playing, church bell ringing and other religious activities can lead to noise complaints.

Some types of indoor concerts and discotheques can produce extremely high sound pressure levels. Associated noise problems outdoors result from customers arriving and leaving. Outdoor concerts, fireworks and various types of festivals can also produce intense noise. The general problem of access to festivals and leisure activity sites often adds to road traffic noise problems. Severe hearing impairment may also arise from intense sound produced as music in headphones or from children's toys.

4.0 Summary

In this unit we have leant that:

i. Aircraft operations generate substantial noise in the vicinity of both commercial and military airports.
ii. Building construction and excavation work can cause considerable noise emissions.
iii. Transportation noise is the main source of environmental noise pollution, including road traffic, rail traffic and air traffic.

5.0 Conclusion

Physically, there is no distinction between sound and noise: sound is a sensory perception evoked by physiological processes in the auditory brain. It is common practice to define noise simply as unwanted sound. In residential areas, noise may stem from mechanical devices (e.g. heat pumps, ventilation systems and traffic), as well as voices, music and other kinds of sounds generated by neighbours (e.g. lawn movers, vacuum cleaners and other household equipment, music reproduction and noisy parties).

6.0 Tutor Marked Assignments

1. Explain transportation noise.
2. Describe noise in terms of building construction.

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UNIT 2: NEGATIVE HEALTH EFFECTS OF NOISE

TABLE OF CONTENTS

1.0 Introduction

The perception of sounds in day-to-day life is of major importance for human well-being. Communication through speech, sounds from playing children, music, natural sound in parklands, parks and gardens are all examples of sounds essential for satisfaction in everyday life. According to the International Programme on Chemical Safety in World Health Organization (1994), an adverse effect of noise is defined as a change in the morphology and physiology of an organism that results in impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or increases the susceptibility of an organism to the harmful effects of other environmental influences. This definition includes any temporary or long-term lowering of the physical, psychological or social functioning of humans or human organs.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the role of noise in sleep disturbance
ii. the cardiovascular and physiological effects induced by noise and
iii. other effects of noise.

3.0 Main Content

3.1 Hearing Impairment Induced by Noise

Hearing impairment is typically defined as an increase in the threshold of hearing. It is assessed by threshold audiometry. Hearing handicap is the disadvantage imposed by hearing impairment sufficient to affect one's personal efficiency in the activities of daily living. It is usually expressed in terms of understanding conventional speech in common levels of background noise (International Organization for Standardization (ISO, 1990). Worldwide, noise-induced hearing impairment is the most prevalent irreversible occupational hazard. In the developing countries, not only occupational noise, but also environmental noise is an increasing risk factor for hearing impairment. In 1995, at the World Health Assembly, it was estimated that there are 120 million persons with disabling hearing difficulties worldwide (Smith 1998). It has been shown that men and women are equally at risk of noise-induced hearing impairment (ISO 1990; Berglund & Lindvall 1995).

The ISO Standard 1999 (ISO 1990) gives a method for calculating noise-induced hearing impairment in populations exposed to all types of noise (continuous, intermittent, and impulse) during working hours. Noise exposure is characterized by LAeq over 8 hours (LAeq,8h). In the

Standard, the relationships between LAeq,8h and noise-induced hearing impairment are given for frequencies of 500–6 000 Hz, and for exposure times of up to 40 years. These relations show that noise-induced hearing impairment occurs predominantly in the high-frequency range of 3000–6 000 Hz, the effect being largest at 4 000 Hz. With increasing LAeq,8h and increasing exposure time, noise-induced hearing impairment also occurs at 2 000 Hz. But at LAeq,8h levels of 75 dBA and lower, even prolonged occupational noise exposure will not result in noise-induced hearing impairment (ISO 1990).

The ISO Standard 1999 (ISO 1990) specifies hearing impairment in statistical terms (median values, and percentile fractions between 0.05 and 0.95). The extent of noise-induced hearing impairment in populations exposed to occupational noise depends on the value of LAeq,8h and the number of years of noise exposure. However, for high LAeq,8h values, individual susceptibility seems to have a considerable effect on the rate of progression of hearing impairment. For daily exposures of 8–16 h, noise-induced hearing impairment can be reasonably well estimated from LAeq,8h extrapolated to the longer exposure times (Axelsson et al. 1986). In this adaptation of LAeq,8h for daily exposures other than 8 hours, the equal energy principle is assumed to be applicable. For example, the hearing impairment due to a 16 h daily exposure is equivalent to that at LAeq,8h plus 3 dB (LAeq,16h = LAeq,8h + 10*log10 (16/8) = LAeq,8h + 3 dB. For a 24 h exposure, LAeq,24h = LAeq,8h + 10*log10 (24/8) = LAeq,8h + 5 dB).

Another sensory effect that results from noise exposure is tinnitus (ringing in the ears). Commonly, tinnitus is referred to as sounds that are emitted by the inner ear itself (physiological tinnitus). Tinnitus is a common and often disturbing accompaniment of occupational hearing impairment (Vernon and Moller 1995) and has become a risk for teenagers attending pop concerts and discotheques (Hetu & Fortin 1995; Passchier-Vermeer et al. 1998; Axelsson & Prasher 1999). Noise-induced tinnitus may be temporary, lasting up to 24 hours after exposure, or may have a more permanent character, such as after prolonged occupational noise exposure. Sometimes tinnitus is due to the sound produced by the blood flow through structures in the ear.

3.2 Interference with Speech Communication

Noise interference with speech comprehension results in a large number of personal disabilities, handicaps and behavioural changes. Problems with concentration, fatigue, uncertainty and lack of self-confidence, irritation, misunderstandings, decreased working capacity, problems in human relations, and a number of stress reactions have all been identified (Lazarus 1998). Particularly vulnerable to these types of effects are the hearing impaired, the elderly, children in the process of language and reading acquisition, and individuals who are not familiar with the spoken language (e.g., Lazarus 1998). Thus, vulnerable persons constitute a substantial proportion of a country’s population.

Most of the acoustical energy of speech is in the frequency range 100–6 000 Hz, with the most important cue-bearing energy being between 300–3 000 Hz. Speech interference is basically a masking process in which simultaneous, interfering noise renders speech incapable of being understood. The higher the level of the masking noise, and the more energy it contains at the most important speech frequencies, the greater will be the percentage of speech sounds that become indiscernible to the listener.

Speech levels vary between individuals because of factors such as gender and vocal effort. Moreover, outdoor speech levels decrease by about 6 dB for a doubling in the distance between talker and listener. Speech intelligibility in everyday living conditions is influenced by speech level, speech pronunciation, talker-to-listener distance, sound pressure levels, and to some extent other characteristics of interfering noise, as well as room characteristics (e.g. reverberation). Individual capabilities of the listener, such as hearing acuity and the level of attention of the listener, are also important for the intelligibility of speech. Speech communication is affected also by the reverberation characteristics of the room. For example, reverberation times greater than 1s produce loss in speech discrimination. Longer reverberation times, especially when combined with high background interfering noise, make speech perception more difficult.

3.3 Sleep Disturbance

Uninterrupted sleep is known to be a prerequisite for good physiological and mental functioning of healthy persons (Hobson 1989); sleep disturbance, on the other hand, is considered to be a major environmental noise effect. It is estimated that 80-90% of the reported cases of sleep disturbance in noisy environments are for reasons other than noise originating outdoors. For example, sanitary needs; indoor noises from other occupants; worries; illness; and climate (e.g. Reyner and Horne 1995).

The primary sleep disturbance effects are: difficulty in falling asleep (increased sleep latency time); awakenings; and alterations of sleep stages or depth, especially a reduction in the proportion of REM-sleep (REM = rapid eye movement) (Hobson 1989). Other primary physiological effects can also be induced by noise during sleep, including increased blood pressure; increased heart rate; increased finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and an increase in body movements (cf. Berglund and Lindvall 1995). For each of these physiological effects, both the noise threshold and the noise-response relationships may be different. Different noises may also have different information content and this also could affect physiological threshold and noise-response relationships (Edworthy 1998).

Exposure to night-time noise also induces secondary effects, or so-called after effects. These are effects that can be measured the day following the night-time exposure, while the individual is awake. The secondary effects include reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance (Öhrström 1993a; Passchier-Vermeer 1993; Carter 1996; Pearsons et al. 1995; Pearsons 1998).

Noise annoyance during the night-time increased the total noise annoyance expressed by people in the following 24 hours. Various studies have also shown that people living in areas exposed to night-time noise have an increased use of sedatives or sleeping pills. Other frequently reported behavioural effects of night-time noise include closed bedroom windows and use of personal hearing protection. Sensitive groups include the elderly, shift workers, persons especially vulnerable to physical or mental disorders and other individuals with sleeping difficulties.

Questionnaire data indicate the importance of night-time noise on the perception of sleep quality. A Japanese investigation was conducted for 3 600 women (20–80 years old) living in eight roadside zones with different road traffic noise. The results showed that four measures of perceived sleep quality (difficulty in falling asleep; waking up during sleep; waking up too early; feelings of sleeplessness one or more days a week) correlated significantly with the average traffic volumes during night-time. An in-depth investigation of 19 insomnia cases and their matched controls (age, work) measured outdoor and indoor sound pressure levels during sleep (Kageyama et al. 1997). The study showed that road traffic noise in excess of 30 dB LAeq for nighttime induced sleep disturbance, consistent with the results of Öhrström (1993b).

Special attention should also be given to the following considerations:
a. Noise sources in an environment with a low background noise level. For example, night-traffic in suburban residential areas.
b. Environments where a combination of noise and vibrations are produced. For example, railway noise, heavy duty vehicles.
c. Sources with low-frequency components. Disturbances may occur even though the sound pressure level during exposure is below 30 dBA.

3.4 Cardiovascular and Physiological Effects

Epidemiological and laboratory studies involving workers exposed to occupational noise, and general populations (including children) living in noisy areas around airports, industries and noisy streets, indicate that noise may have both temporary and permanent impacts on physiological functions in humans. It has been postulated that noise acts as an environmental stressor. Acute noise exposures activate the autonomic and hormonal systems, leading to temporary changes such as increased blood pressure, increased heart rate and vasoconstriction. After prolonged exposure, susceptible individuals in the general population may develop permanent effects, such as hypertension and ischaemic heart disease associated with exposures to high sound pressure levels (for a review see Passchier-Vermeer 1993; Berglund & Lindvall 1995). The magnitude and duration of the effects are determined in part by individual characteristics, lifestyle behaviours and environmental conditions. Sounds also evoke reflex responses, particularly when they are unfamiliar and have a sudden onset.

3.5 Mental Health Effects

Mental health is defined as the absence of identifiable psychiatric disorders according to current norms (Freeman 1984). Environmental noise is not believed to be a direct cause of mental illness, but it is assumed that it accelerates and intensifies the development of latent mental disorder. Studies on the adverse effects of environmental noise on mental health cover a variety of symptoms, including anxiety; emotional stress; nervous complaints; nausea; headaches; instability; argumentativeness; sexual impotency; changes in mood; increase in social conflicts, as well as general psychiatric disorders such as neurosis, psychosis and hysteria. Large-scale population studies have suggested associations between noise exposure and a variety of mental health indicators, such as single rating of well-being; standard psychological symptom profiles; the intake of psychotropic drugs; and consumption of tranquilizers and sleeping pills.

3.6 The Effects of Noise on Performance

It has been documented in both laboratory subjects and in workers exposed to occupational noise, that noise adversely affects cognitive task performance. Laboratory and workplace studies showed that noise can act as a distracting stimulus. Also, impulsive noise events (e.g. sonic booms) may produce disruptive effects as a result of startle responses. In the short term, noise-induced arousal may produce better performance of simple tasks, but cognitive performance deteriorates substantially for more complex tasks (i.e. tasks that require sustained attention to details or to multiple cues; or tasks that demand a large capacity of working memory, such as complex analytical processes). Some of the effects are related to loss in auditory comprehension and language acquisition, but others are not (Evans & Maxwell 1997). Among the cognitive effects, reading, attention, problem solving and memory are most strongly affected by noise. The observed effects on motivation, as measured by persistence with a difficult cognitive task, may either be independent or secondary to the aforementioned cognitive impairments.

For aircraft noise, it has been shown that chronic exposure during early childhood appears to impair reading acquisition and reduces motivational capabilities. Of recent concern are concomitant psychophysiological changes (blood pressure and stress hormone levels). Evidence indicates that the longer the exposure, the greater the damage. It seems clear that daycare centers and schools should not be located near major sources of noise, such as highways, airports and industrial sites.

4.0 Summary

In this unit we have leant that:

i. Acute noise exposures activate the autonomic and hormonal systems.
ii. Environmental noise is not believed to be a direct cause of mental illness, but it is assumed that it accelerates and intensifies the development of latent mental disorder.
iii. Noise-induced tinnitus may be temporary, lasting up to 24 hours after exposure.

5.0 Conclusion

Noise interference with speech comprehension results in a large number of personal disabilities, handicaps and behavioural changes. Noise annoyance during the night-time increased the total noise annoyance expressed by people in the following 24 hours. Laboratory and workplace studies showed that noise can act as a distracting stimulus.

6.0 Tutor Marked Assignments

1. State primary sleep disturbance effects.
2. Describe the effects of noise on human performance.

7.0 References and other Resources

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UNIT 3: NOISE CONTROL MEASURES

TABLE OF CONTENTS

1.0 Introduction

An integrated noise policy should include several control procedures: measures to limit the noise at the source, noise control within the sound transmission path, and protection at the receiver's site, land-use planning, education and raising of public awareness. Ideally, countries should give priority to precautionary measures that prevent noise, but they must also implement measures to mitigate existing noise problems.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. how road traffic noise can be reduced;
ii. the role of education and public awareness in noise management and
iii. other noise control measures.

3.0 Main Content

3.1 Mitigation Measures

The most effective mitigation measure is to reduce noise emissions at the source. Therefore, regulations with noise level limits for the main noise sources should be introduced.

3.1.1 Road traffic noise

Limits on the noise emission of vehicles have been introduced in many countries (Sandberg 1995). Such limits, together with the relevant measuring methods, should also be introduced in other regions of the world. Besides these limits a special class of "lownoise trucks" has been introduced in Europe. These trucks follow state-of-the-art noise control and are widely used in Austria and Germany (Lang 1995). Their use is encouraged by economic incentives; for example, low-noise trucks are exempted from a night-time ban on certain routes, and their associated taxes are lower than for other trucks.

However, the main noise from traffic on highways is rolling noise. This may be reduced by quiet road surfaces (porous asphalt, "drain asphalt") or by selection of quiet tires. Road traffic noise may also be reduced by speed limits, provided the limits are enforced. For example, reducing the speed of trucks from 90 to 60 km/h on concrete roads would reduce the maximum sound pressure level by 5 dB, and the equivalent sound pressure level by 4 dB. Decreasing the speed of cars from 140 to 100 km/h would result in the same noise reduction (WHO 1995). In the central parts of cities a speed limit of 30 km/h may be introduced. At 30 km/h cars produce maximum sound pressure levels that are 7 dB lower, and equivalent sound pressure levels that are 5 dB lower, than cars driving at 50 km/h.

Noise emission from road traffic may be further reduced by a night-time ban for all vehicles, or especially for heavy vehicles. Traffic management designed to ensure uniform traffic flow in towns also serves to reduce noise. "Low-noise behaviour" of drivers should be encouraged as well, by advocating defensive driving manners. In some countries, car drivers use their horns frequently, which results in noise with high peak levels. The unnecessary use of horns within cities should be forbidden, especially during night-time, and this rule should be enforced.

3.1.2 Railway noise and noise from trams

The main noise sources are the engine and the wheel-rail contact. Noise at the source can be reduced by well-maintained rails and wheels, and by the use of disc brakes. Sound pressure levels may vary by more than 10 dB, depending on the type of railway material. Replacement of steel wheels by rubber wheels could also reduce noise from railways and trams substantially. Other measures include innovations in engine and track technology (Moehler 1988; Öhrström and Skånberg 1996).

3.1.3 Aircraft noise

The noise emission of aircraft is limited by International Civil Aviation Organization (ICAO, 1993) which estimates maximum potential sound emissions under certification procedures. In many countries, non-certified aircraft (i.e. aircraft not fulfilling the ICAO requirements) are not permitted and such aircraft may not be registered again. The use of low-noise aircraft may also be encouraged by setting noise-related charges (that is, landing charges that are related not only to aircraft weight and capacity, but also to noise emission). Night-time aircraft movements should be discouraged where they impact residential communities. Particular categories of aircraft (such as helicopters, rotorcraft and supersonic aircraft) pose additional problems that require appropriate controls.

3.1.4 Machines and equipment

Noise emission has to be considered a main property of all types of machines and equipment. Control measures include design, insulation, enclosure and maintenance. Consumers should be encouraged to take noise emission into account when buying a product. Declaring the A-weighted sound power level of a product would assist the consumer in making this decision. The introduction of sound labeling is a major tool for reducing the noise emission of products on the market.

3.1.5 Education and public awareness

Noise abatement policies can only be established if basic knowledge and background material is available, and the people and authorities are aware that noise is an environmental hazard that needs to be controlled. It is, therefore, necessary to include noise in school curricula and to establish scientific institutes to study acoustics and noise control. People working in such institutes should have the option of studying in other countries and exchanging information at international conferences. Dissemination of noise control information to the public is an issue for education and public awareness. Ideally, national and local advisory groups should be formed to promote the dissemination of information, to establish uniform methods of noise measurement and impact assessment, and to participate in the development and implementation of educational and public awareness programmes.

3.1.6 Land use planning

Land use planning is one of the main tools for noise control and includes:
a. Calculation methods for predicting the noise impact caused by road traffic, railways, airports, industries and others.
b. Noise level limits for various zones and building types. The limits should be based on annoyance responses to noise.
c. Noise maps or noise inventories that show the existing noise situation. The construction of noise-sensitive buildings in noisy areas, or the construction of noisy buildings in quiet areas may thus be avoided.

4.0 Summary

In this unit we have leant that:

i. Road traffic noise may also be reduced by speed limits, provided the limits are enforced.
ii. The use of low-noise aircraft may also be encouraged by setting noise-related charges.
iii. Land use planning is one of the main tools for noise control

5.0 Conclusion

With careful planning, noise exposure can be avoided or reduced. A sufficient distance between residential areas and an airport will make noise exposure minimal, although the realization of such a situation is not always possible. Noise abatement policies can only be established if basic knowledge and background material is available, and the people and authorities are aware that noise is an environmental hazard that needs to be controlled.

6.0 Tutor Marked Assignments

1. Explain how noise emission from road traffic can be reduced.
2. Describe how effective land planning can serve as a noise control measure.

7.0 References and other Resources

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UNIT 4: NOISE POLICIES IN DIFFERENT COUNTRIES

TABLE OF CONTENTS

1.0 Introduction

Noise regulatory standards can set the reference point for emission control and abatement policies at the national, regional or municipal levels, and can thus strongly influence the implementation of noise control policies. In many countries, exceeding regulatory standards is linked to an obligation to develop abatement action plans at the municipal, regional or national levels (low-noise implementation plans). Such plans have to address all relevant sources of noise pollution.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. noise policy in Argentina;
ii. United States of America and
iii. other countries of the world.

3.0 Main Content

3.1 Examples of Noise Policies in Different Countries

Different countries have adopted a range of policies and regulations for noise control. A number of these are outlined in this section as examples.

3.2 Argentina

In Argentina, a national law recently limited the daily 8-h exposure to industrial noise to 80 dB, and it has had beneficial effects on hearing impairment and other hearing disorders among workers. In general, industry has responded by introducing constant controls on noise sources, combined with hearing tests and medical follow-ups for workers. Factory owners have recruited permanent health and safety engineers who control noise, supply advice on how to make further improvements, and routinely assess excessive noise levels. The engineers also provide education in personal protection and in the correct use of ear plugs, mufflers etc.

At the municipal level two types of noise have been considered. Unnecessary noise, which is forbidden; and excessive noise, which is defined for neighbourhood activities (zones), and for which both day and night-time maximum limits have been introduced. The results have been relatively successful in mitigating unwanted noise effects. At the provincial level, similar results have been accomplished for many cities in Argentina and Latin America.

3.3 Australia

In Australia, the responsibility for noise control is shared primarily by state and local governments. There are nationally-agreed regulatory standards for airport planning and new vehicle noise emissions. The Australian Noise Exposure Forecast (ANEF) index is used to describe how much aircraft noise is received at locations around an airport (DoTRS 1999). Around all airports, planning controls restrict the construction of dwellings within the 25 ANEF exposure contour and require sound insulation for those within 20 ANEF. Road traffic noise limits are set by state governments, but vary considerably in both the exposure metric and in maximum allowable levels. New vehicles are required to comply with stringent design rules for noise and air emissions. For example, new regulation in New South Wales adopts LAeq as the metric and sets noise limits of 60 dBA for daytime, and 55 dBA for night-time, along new roads. Local governments set regulations restricting noise emissions for household equipment, such as air conditioners, and the hours of use for noisy machines such as lawn mowers.

3.4 South Africa

In South Africa, noise control is more than three decades old. It began with codes of practice issued by the South African Bureau of Standards to address noise pollution in various sectors of the country. In 1989, the Environment Conservation Act made provision for the Minister of Environmental Affairs and Tourism to make regulations for noise, vibration and shock (DEAT 1989). These regulations were published in 1990 and local authorities could apply to the Minister to make them applicable in their areas. Later, the act was changed to make it obligatory for all authorities to apply the regulations. However, according to the new Constitution of South Africa of 1996, legislative responsibility for noise control rests exclusively with provincial and local authorities. The noise control regulations will apply to local authorities in South Africa as soon as they are published in the provinces. This will not only give local authorities the power to enforce the regulations, but also place an obligation on them to see that the regulations are enforced.

3.5 United States of America

Environmental noise was not addressed as a national policy issue in the USA until the implementation of the Noise Control Act of 1972. This congressional act directed the US Environmental Protection Agency to publish scientific information about noise exposure and its effects, and to identify acceptable levels of noise exposure under various conditions. The Noise Control Act was supposed to protect the public health and well-being with an adequate margin of safety. This was accomplished in 1974 with the publication of the US EPA "Levels Document" (US EPA 1974). It addressed issues such as the use of sound descriptions to describe sound exposure, the identification of the most important human effects resulting from noise exposure, and the specification of noise exposure criteria for various effects. Subsequent to the publication of the US EPA "Levels Document", guidelines for conducting environmental impact analysis were developed (Finegold et al. 1998). The day-night average sound level was thus established as the predominant sound descriptor for most environmental noise exposure.

4.0 Summary

In this unit we have leant that:

i. In South Africa, noise control began with codes of practice issued by the South African Bureau of Standards to address noise pollution in various sectors of the country.
ii. In Australia, the responsibility for noise control is shared primarily by state and local governments.
iii. Environmental noise was not addressed as a national policy issue in the USA until the implementation of the Noise Control Act of 1972.

5.0 Conclusion

It is evident from these examples that noise policies and regulations vary considerably across countries and regions. Moves towards global noise policies need to be encouraged to ensure that the world population gains the maximum health benefits from new developments in noise control.

6.0 Tutor Marked Assignments

1. Is there any need for a noise control policy in a country like Nigeria?
2. Describe noise control in Australia.

7.0 References and other Resources

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UNIT 5: ANALYSIS OF THE IMPACT OF ENVIRONMENTAL NOISE

TABLE OF CONTENTS

1.0 Introduction

The concept of an Environmental Noise Impact Analysis (ENIA) is central to the philosophy of managing environmental noise. An ENIA should be required before implementing any project that would significantly increase the level of environmental noise in a community (typically, greater than a 5dB increase). The first step in performing an ENIA is to develop a baseline description of the existing noise environment. Next, the expected level of noise from a new source is added to the baseline exposure level to produce the new overall noise level. If the new total noise level is expected to cause an unacceptable impact on human health, trade-off analyses should then be performed to assess the cost, technical feasibility and community acceptance of noise mitigation measures. It is strongly recommended that countries develop standardized procedures for performing ENIAs (Finegold et al. 1998; SABS 1998).

2.0 Objectives

By the end of this unit, student should be able to understand:

i. how to estimate the population of people at risk of noise;
ii. how to assess adverse health effects of noise and

iii. calculate exposure-response relationship.

3.0 Main Content

3.1 Assessment of Adverse Effects of Noise on Human Health

In setting noise standards, the adverse health effects from which the population is to be protected need to be defined. Health effects range from hearing impairment to sleep disturbance, speech interference to annoyance. The distinction between adverse and non-adverse effects sometimes poses considerable difficulties. More serious noise effects, such as hearing impairment or permanent threshold shift, are generally accepted as adverse. Consideration of health effects that are both temporary and reversible, or that involve functional changes with uncertain clinical significance, requires a judgement on whether these less-serious effects should be considered when deriving guideline values. Judgements as to the adversity of health effects may differ between countries, because of factors such as cultural backgrounds and different levels of health status.

3.2 Estimation of the Population at Risk

The population at risk is that part of the population in a given country or community that is exposed to enhanced levels of noise. Each population has sensitive groups or sub-populations that are at higher risk of developing health effects due to noise exposure. Sensitive groups include individuals impaired by concurrent diseases or other physiological limitations and those with specific characteristics that make them more vulnerable to noise. The sensitive groups in a population may vary across countries due to differences in medical care, nutritional status, lifestyle and demographic factors, prevailing genetic factors, and whether endemic or debilitating diseases are prevalent.

3.3 Calculation of Exposure-Response Relationships

In developing standards, regulators should consider the degree of uncertainty in the exposure-response relationships provided in the noise guidelines. Differences in the population structure (age, health status), climate (temperature, humidity) and geography (altitude, environment) can influence the prevalence and severity of noise-related health effects. In consequence, modified exposure-response relationships may need to be applied when setting noise standards.

3.4 Assessment of Risks and their Acceptability

In the absence of distinct thresholds for the onset of health effects, regulators must determine what constitutes an acceptable health risk for the population and select an appropriate noise standard to protect public health. This is also true in cases where thresholds are present, but where it would not be feasible to adopt noise guidelines as standards because of economical and/or technical constraints. The acceptability of the risks involved, and hence the standards selected, will depend on several factors. These include the expected incidence and severity of the potential effects, the size of the population at risk, the perception of related risks, and the degree of scientific uncertainty that the effects will occur at any given noise level. For example, if it is suspected that a health effect is severe and the size of the population at risk is large, a more cautious approach would be appropriate than if the effect were less troubling, or if the population were smaller. Again, the acceptability of risk may vary among countries because of differences in social norms, and the degree of adversity and risk perception by the general population and stakeholders. Risk acceptability is also influenced by how the risks associated with noise compare with risks from other pollution sources or human activities.

4.0 Summary

In this unit we have leant that:

i. More serious noise effects, such as hearing impairment or permanent threshold shift, are generally accepted as adverse.
ii. The first step in performing an ENIA is to develop a baseline description of the existing noise environment.
iii. In the absence of distinct thresholds for the onset of health effects, regulators must determine what constitutes an acceptable health risk for the population.

5.0 Conclusion

The concept of an environmental noise impact analysis (ENIA) is vital to the philosophy of managing environmental noise. In setting noise standards, the adverse health effects from which the population is to be protected need to be defined.

6.0 Tutor Marked Assignments

1. Describe the concept of environmental noise impact analysis (ENIA).
2. Explain the role of population structure (age, health status) in the prevalence and severity of noise-related health effects.

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MODULE 3: LAND

UNIT 1: LAND RESOURCES

TABLE OF CONTENTS

1.0 Introduction

Land is an essential natural resource, both for the survival growth, and development of humanity, and for the maintenance of all terrestrial ecosystems. Over millennia, people have become progressively more expert in exploiting land resources for their own ends. The limits on these resources are finite while human demands on them are not. Increased demand, or pressure on land resources, shows up as declining crop production, degradation of land quality and quantity, and competition for land. Attention should now be focused on the role of humankind as stewards rather than exploiters, charged with the responsibility of safeguarding the rights of unborn generations and of conserving land as the basis of the global ecosystem.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the meaning of land resources;
ii. various functions of land and
iii. land availability.

3.0 Main Content

3.1 Land and its Endowments

Land is not regarded simply in terms of soils and surface topography, but encompasses such features as underlying superficial deposits, climate and water resources, and also the plant and animal communities which have developed as a result of the interaction of these physical conditions. The results of human activities, reflected by changes in vegetative cover or by structures, are also regarded as features of the land. Changing one of the factors, such as land use, has potential impacts on other factors, such as flora and fauna, soils, surface water distribution and climate. Changes in these factors can be readily explained by ecosystem dynamics and the importance of their relationships in planning and management of land resources has become increasingly evident.

3.1.1 Definitions of Land Resources, Land Use and Land Cover

Land and Land Resources refer to a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below the earth’s surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associated groundwater and geo-hydrological reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.) (FAO/UNEP, 1997).

Land Use is characterized by the arrangements, activities and inputs by people to produce, change or maintain a certain land cover type. (Di Gregorio and Jansen 1998). Land use defined in this way establishes a direct link between land cover and the actions of people in their environment.

Land Cover is the observed (bio) physical cover on the earth's surface (Di Gregorio and Jansen 1998)

3.2 Functions of Land

The basic functions of land in supporting human and other terrestrial ecosystems can be summarized as follows:

i. a store of wealth for individuals, groups, or a community
ii. production of food, fibre, fuel or other biotic materials for human use
iii. provision of biological habitats for plants, animals and micro-organisms
iv. co-determinant in the global energy balance and the global hydrological cycle, which provides both a source and a sink for greenhouse gases
v. regulation of the storage and flow of surface water and groundwater
vi. storehouse of minerals and raw materials for human use
vii. a buffer, filter or modifier for chemical pollutants
viii. provision of physical space for settlements, industry and recreation
ix. storage and protection of evidence from the historical or pre-historical record (fossils, evidence of past climates, archaeological remains, etc.)
x. enabling or hampering movement of animals, plants and people between one area and another

In the terminology of environmental economics, land can be regarded as a stock renewable resource. Land resources do not easily fit into the categories of renewable or non-renewable. In general, they are slowly renewable; however, their rate of degradation far exceeds their natural rate of regeneration. In practical terms, this means that land that is lost to degradation is not naturally replaced within a human time frame, resulting in a loss of opportunities for the next generation.

3.3 Land, Population and Management Strategies

The potential production of arable land and its susceptibility to degradation are dependent on the management strategies employed and on inherent soil and other characteristics. In agriculture-dependent societies this combination of factors determines potentially the population that can be supported and the standard of living. When population increases in a given area, the increased demand on production can induce stress and consequent degradation of the land resource. If no other source of income can be tapped (e.g. by migration to urban areas) people's standards of living decrease. However, if improved management strategies (including technologies) are available, either the standard of living may rise or more people can be supported at the same standard of living without deterioration of the natural resource base. It follows that an ample supply of land of suitable quality and appropriate production technologies are essential if the increasing demands of a growing population are to be met.

3.4 Availability of Land

Land is not evenly distributed either between countries or within countries, and the difference in access to land relative to population need is more significant than global totals. Land is becoming more and more scarce as a resource, and this is particularly true of land available for primary production of biomass or for conservation related purposes. Competition for land among different uses is becoming acute and conflicts related to this competition more frequent and more complex. This competition is often most apparent on the peri-urban fringe, where the continuing pressures of urban expansion compete with agricultural enterprises, and with recreational demands. Such situations frequently lead to rapid increases in the economic value of land, and land tenure becomes an important political issue.

Many factors associated with global change directly or indirectly influence how land is used. These include biophysical influences, such as changes in climate or natural or human-induced disasters, as well as socio-economic aspects such as trade liberalization, the globalization of markets, decentralization of decision making, privatization, and the widening gap between the "haves" and the "have-nots".

4.0 Summary

In this unit we have leant that:

i. Land resources do not easily fit into the categories of renewable or non- renewable.

ii. Land serves as a storage and protection of evidence from the historical or pre-historical record (fossils, evidence of past climates, archaeological remains, etc.).

iii. Changing one of the factors, such as land use, has potential impacts on other factors, such as flora and fauna, etc.

5.0 Conclusion

Land encompasses such features as underlying superficial deposits, climate and water resources, and also the plant and animal communities which have developed as a result of the interaction of these physical conditions. Land is a store of wealth for individuals, groups, or a community.

6.0 Tutor Marked Assignments

1. State five functions of land.
2. Define land resources.

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UNIT 2: STATUS OF LAND

TABLE OF CONTENTS

1.0 Introduction

The world's net cultivated area has grown by 12 percent over the last 50 years, mostly at the expense of forest, wetland and grassland habitats (Food and Agriculture Organization 2011). At the same time, the global irrigated area has doubled. The distribution of these land and water assets is unequal among countries. Although only a small proportion of the world's land and water is used for crop production, most of the easily accessible and (thus economic) resources are under cultivation or have other ecologically and economically valuable uses. Thus the scope for further expansion of cultivated land is limited. Only parts of South America and sub-Saharan Africa still offer scope for some expansion.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. land distribution and suitability around the world;
ii. land resources in rainfed agriculture and
iii. rainfed productivity and production gaps.

3.0 Main Content

3.1 Land Distribution, Use and Suitability around the World

The global land area is 13.2 billion ha. Of this, 12 percent (1.6 billion ha) is currently in use for cultivation of agricultural crops, 28 percent (3.7 billion ha) is under forest, and 35 percent (4.6 billion ha) comprises grasslands and woodland ecosystems (FAO 2011). Low-income countries cover about 22 percent of the land area. Land use varies with climatic and soil conditions and human influences.

Deserts prevail across much of the lower northern latitudes of Africa and Asia. Dense forests predominate in the heartlands of South America, along the seaboards of North America, and across Canada, Northern Europe and much of Russia, as well as in the tropical belts of Central Africa and Southeast Asia.

Cultivated land is a leading land use (a fifth or more of the land area) in South and Southeast Asia, Western and Central Europe, and Central America and the Caribbean, but is less important in sub-Saharan and Northern Africa, where cultivation covers less than a tenth of the area

FAO defines land suitability for agriculture in terms of capacity to reach potentially attainable yields for a basket of crops. Assuming well-adapted production systems are used, currently cultivated land is mostly of prime (28 percent of the total) or good quality (53 percent). The highest regional proportion of prime land currently cultivated is found in Central America and the Caribbean (42 percent), followed by Western and Central Europe (38 percent) and Northern America (37 percent). For high-income countries as a whole, the share of prime land in currently cultivated land is 32 percent. In low-income countries, soils are often poorer and only 28 percent of total cultivated land is classed as prime.

3.2 Land Resources in Rainfed Agriculture

Rainfed agriculture is the predominant agricultural production system worldwide. As practiced in highland areas and in the dry and humid tropics, it is the system in which poorer smallholder farmers predominate and where the risks of resource degradation are highest. Soil nutrient availability in many rainfed lands tends to below, and sloping terrain and patterns of rainfall and runoff contribute to erosion. High temperatures and low and erratic precipitation often make soil moisture availability inadequate, and techniques to improve water availability (such as water harvesting) are expensive. Higher levels of input and management can increase productivity, but many farmers cannot afford the costs or risks. All these factors affecting land and water for rainfed agriculture as practiced by the poor contribute to their vulnerability and to their food insecurity.

3.3 Rainfed Productivity and Production Gaps

The productivity of rainfed cropping is measured by yields (production per unit of area). Productivity varies enormously, and is highly sensitive to factors other than soil and water – for example, the availability and affordability of technologies and inputs, access to market, and the local financial returns.

In sub-Saharan Africa, yields have changed little since the 1960s, and increases in production have come almost entirely from land expansion. Rainfed maize yields, for example, have remained constant at around 1t/ha. In Latin America and the Caribbean, by contrast, yields for rainfed maize tripled over the same period, from little more than 1t/ha to over 3t/ha. Average wheat yields across Europe more than doubled (2t/ha to over 5t/ha).

3.4 Land and Water Resources in Irrigated Agriculture

Irrigated systems have expanded in recent years to bring water control, which, together with rapid increases in water productivity, has greatly boosted agricultural production and incomes. However, most irrigated farming systems are performing well below their potential, and there is considerable scope for improving land and water productivity. Groundwater abstraction has provided an invaluable source of ready irrigation water, but has proved almost impossible to regulate. As a result, agriculture withdrawals of groundwater are intensifying and some key aquifers are being depleted. Water quality is deteriorating, with impacts from irrigation on both surface and groundwater, and the salinization of irrigated lands is a growing problem.

4.0 Summary

In this unit we have leant that:

i. In low-income countries, soils are often poorer and only 28 percent of total cultivated land is classed as prime.
ii. Groundwater abstraction has provided an invaluable source of ready irrigation water.

iii. FAO defines land suitability for agriculture in terms of capacity to reach potentially attainable yields for a basket of crops.

5.0 Conclusion

Land use varies with climatic and soil conditions and human influences. Soil nutrient availability in many rainfed lands tends to below, and sloping terrain and patterns of rainfall and runoff contribute to erosion.

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6.0 Tutor Marked Assignments

1. Explain the significance of land resources in rainfed agriculture.
2. Discuss how land expansion is contributing to increase agricultural production in sub Saharan Africa.

7.0 References and other Resources

Food and Agriculture Organization (2011). The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London.

UNIT 3: FORESTS AND RANGELANDS

TABLE OF CONTENTS

1.0 Introduction

FAO's Global forest resources assessment provides regular estimates of the state of the world's forests, their extent and health, and the status of their socio-economic and environmental functions (FAO 2010).

Rangelands extend over all latitudes, and are usually characterized by low biomass production due to constraints related to soil, temperature and water availability.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the importance of forests;
ii. importance of rangelands and
iii. challenges confronting rangelands and their users.

3.0 Main Content

3.1 Forests

In 2010, forests covered approximately 4 billion ha. Deforestation arising mainly from the conversion of tropical forests to agricultural land has recently shown signs of decreasing, but still continues at an alarming rate. Around 13Mha (million hectare) of forest were converted to other uses or lost through natural causes each year in the last decade, compared with 16Mha per year in the 1990s. However, during the last decade, the net reduction in forest areas has been significantly limited by large scale tree planting estimated at 5.2Mha per year during the first decade of the 21st century. Net losses of forested land were concentrated in South America, sub-Saharan Africa, Southeast Asia and Oceania, while the US, India, China, Russia and several European countries showed net gains in forested land. Primary forests account for 36 percent of forest area, but have decreased by more than 40Mha since 2000. Reduction in primary forests may have important impacts on forest biodiversity.

3.1.1 Importance of forests

Forests play a crucial role in the hydrological cycle, which is why they must be taken into consideration when analyzing water issues at landscape level. They capture and store water, prevent soil erosion, and serve as natural water purification systems. Forests influence the amount of water availability, regulate surface and groundwater flows, and ensure high water quality. Moreover, forests and trees contribute to the reduction of water-related risks such as landslides, local floods and droughts, and help prevent desertification and salinization. Forested watersheds and wetlands supply three-quarters of the world’s accessible fresh water to satisfy domestic, agricultural, industrial and ecological needs (FAO 2008).

3.2 Rangelands

Rangelands extend over all latitudes, and are usually characterized by low biomass production due to constraints related to soil, temperature and water availability. They cover some 25 percent of the global land area, and include the drylands of Africa (66 percent of the total continental land area) and the Arabian Peninsula, the steppes of Central Asia and the highlands of Latin America (Nori and Neely 2009). Vegetation is mostly dominated by natural plant communities of perennial and annual species, including grasses, shrubs and trees. By their nature, rangelands are fragile ecosystems and when mismanaged readily result in degradation, loss of biodiversity and water retention capacity, carbon emissions and reduced productivity.

The extent and trends in rangelands are hard to assess. Global statistics indicate that the total area of rangelands was 3.43 billion ha in 2000, and decreased slightly to 3.36 billion ha by 2008. The reasons for these minor changes cannot be easily identified, though may include poor data, desertification and encroachment of agriculture. Large-scale conversion of drier grasslands to crops and inappropriate management has had unfortunate consequences, such as the 'dust bowl' of the Great Plains of the USA in the 1920s and 1930s. In the mid-20th century, drylands were widely cultivated in the USSR, but crop production was also unsustainable in that region (Boonman and Mikhalev 2005) and these lands are now reverting to rangelands.

3.2.1 Importance of rangelands

The contribution that rangelands make to the maintenance of ecosystem functions and biodiversity is important. In addition to providing feed for livestock, they play an important role as a habitat for wildlife, for water retention and for the conservation of plant genetic resources. The flora of rangelands is rich: about 750 genera and 12 000 grass species. These ecosystems are also important for the maintenance of fauna; for example, grasslands contain 11 percent of the world's endemic bird areas (White et al. 2000: 40), and contribute to the maintenance of pollinators and other insects that have important regulating functions. Ecosystem benefits, especially regulating services such as water infiltration and purification, climate regulation (e.g. carbon sequestration) and pollination, have begun to be assigned an economic value, and systematic data-gathering in rangelands of both developed and developing countries should be a global priority.

3.2.2 Challenges facing rangeland and their users

Over 600 million people depend on rangelands for their livelihoods (FAO 2011). Pastoral societies have developed strategies that continuously adapt to limited, highly variable and unpredictable resource endowments (e.g. by migratory livestock rearing), but both the rangelands and their users are also vulnerable to the changes brought by demographic pressure, conversion of cropland and climate change. Fluctuations in rainfall and drought are recurring problems in rangelands – for example, 70 million people in the Horn of Africa, many of whom are pastoralists, suffer from long-term chronic food insecurity (FAO 2000). Table 1: lists major pastoral systems and illustrates how they evolve with time.

Table 1 Regional zonation of pastoral systems

Zone	Main Species	Status
sub-Saharan Africa	Cattle, camel, sheep, goats	Declining due to advancing agriculture
Mediterranean	Small ruminants	Declining due to enclosure and advancing agriculture
Near East and South-Central Asia	Small ruminants	Declining in some areas due to enclosure and advancing agriculture
India	Cattle, camel, sheep, goats	Declining due to advancing agriculture but peri-urban livestock production

		expanding
Central	Yak, camel, horse, sheep, goats	Expanding following de-collectivization
Circumpolar	Reindeer	Expanding following de-collectivization in Siberia, but under pressure in Scandinavia
North America	Sheep, cattle	Declining with increased enclosure of land and alternative economic opportunities
Andes	Llama, alpaca	Contracting llama production, due to expansion of road systems, and European-model livestock production but expansion of alpaca wool production

Source: Blench (1999)

4.0 Summary

In this unit we have leant that:

i. Forests play a crucial role in the hydrological cycle.
ii. The contribution that rangelands make to the maintenance of ecosystem functions and biodiversity is important.
iii. Net losses of forested land were concentrated in South America, sub-Saharan Africa, Southeast Asia and Oceania.

5.0 Conclusion

Forests influence the amount of water availability, regulate surface and groundwater flows, and ensure high water quality. Fluctuations in rainfall and drought are recurring problems in rangelands – for example, 70 million people in the Horn of Africa, many of whom are pastoralists, suffer from long-term chronic food insecurity.

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6.0 Tutor Marked Assignments

1. Highlight the importance of forests.
2. What are the challenges facing rangeland and their users?

7.0 References and other Resources

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UNIT 4: SOCIO-ECONOMIC DEPENDENCY ON LAND RESOURCES

TABLE OF CONTENTS

7.0 References and other Resources

1.0 Introduction

As agriculture becomes more productive, output per unit of land and per capita grows, incomes can be expected to rise, poverty reduces and food security (economic and physical access to safe and nutritious food) improves, leading to reinvestment in the rural economy. In general, more intensive agriculture through irrigation has often arisen where the variability of rainfed production has proved intolerable. However, intensive agriculture has not always resulted in more rural employment and in many cases public agencies with limited budgets have had to make choices about the most desirable styles of agriculture.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the links between poverty and access to land;
ii. land allocation system and
iii. production intensification strategies.

3.0 Main Content

3.1 The links between Poverty, access to Land and Water, and Land Degradation

Worldwide, the poorest either have no land or have the lowest access to land and water, and low access to land is a predictor of poverty. In addition, poor resource management and type of farming system are also linked to poverty. The poorest often have the least diversified farming systems. However, not all the poor live in lands considered degraded. Worldwide, only 16 percent of the poor live in degraded areas. Small changes in ecosystem health, in poor and populous areas have a significant effect irrespective of the current ecosystem status and are heavily dependent on ecosystem health and the small surpluses they obtain can be wiped out by small negative changes in system health.

A wide variety of monetary and non-monetary indicators have been used to assess poverty levels (Coudouel et al. 2002). FAO uses stunting among young children as a poverty-related chronic undernourishment measure (Gross et al. 1996; FAO and FIVIMS 2003). Indeed, where a single indicator of poverty is sought, 'stunting prevalence is one of the most reliable and most suitable indicators for monitoring and assessing poverty' (Simondon 2010). In sub-Saharan Africa as a whole, nearly half (45 percent) of the rural population are classified as poor.

The concentrations of rural poverty can be linked to marginal lands where access to land and water is uncertain. Commonly, poor farmers are locked in a poverty trap of small, remote plots with no secure tenure, poor-quality soils and high vulnerability to land degradation and climatic uncertainty. At the same time, technologies and farming systems within their reach are typically low-management, low-input systems that often contribute to resource degradation. However, improved farming systems can modify the relationship between land and water resources and poverty: the likelihood of being poor is much lower (less than half) when improved farming systems are employed (Hussain and Hanjra 2004). Thus, improving land and water tenure arrangements and management practices in these areas is likely to have a direct positive impact on food insecurity and poverty (Lipton 2007).

3.2 Intensification and Poverty Reduction

The rapid productivity gains of the green revolution in Asia during the second half of the 20th century was achieved through technologies of nitrogen-responsive, short season cultivars and application of irrigation. It helped create a 'springboard' out of poverty in Asia, and provided the foundation for the broader economic and industrial development that has occurred in the last 20 years (World Bank 2005, Huang et al. 2006). Empirical evidence for a sample of 40 countries shows that for each 1 percent improvement in crop productivity, poverty fell by 1 percent and the human development index rose by 0.1 percent (Irz et al. 2001). However, it is important to emphasize that distribution of the benefits from increased production are not always equitable. In many cases it is the poorest losing both land and employment as a result of production intensification strategies, which could lower commodity prices locally and reduce income for poorer producers not engaged with farm intensification.

3.3 Systems of Land Allocation

Land management is underpinned by systems of allocation and tenure that provide access, security and incentives for profitable and sustainable use. Traditional land tenure systems may include protected rights, but often they are communally held. However, the pace of demographic and economic growth has created stresses over allocation and security of tenure, resulting in disputes over land and sometimes spilling over into conflict. In many cases, this has led to widespread appropriation of communal rights by the powerful. At the same time, a variety of modern land tenure institutions have emerged. Formal and informal land tenure systems now overlap, although incorporating traditional institutions into modern ones remains a challenge. Such institutional adaptation has tended to lag behind the economic and social changes it was intended to accommodate. Arguably, the lack of secure tenure combined with rigid land markets has resulted in under-investment in the use of resources.

4.0 Summary

In this unit we have leant that:

i. In many cases it is the poorest losing both land and employment as a result of production intensification strategies.
ii. Land management is underpinned by systems of allocation and tenure that provide access, security and incentives for profitable and sustainable use.
iii. The concentrations of rural poverty can be linked to marginal lands where access to land and water is uncertain.

5.0 Conclusion

Worldwide, the poorest either have no land or have the lowest access to land and water, and low access to land is a predictor of poverty. Commonly, poor farmers are locked in a poverty trap of small, remote plots with no secure tenure, poor-quality soils and high vulnerability to land degradation and climatic uncertainty.

6.0 Tutor Marked Assignments

1. Justify the link between rural poverty and marginal lands.
2. Explain how proper land use can lead to poverty reduction and at the same time increase food security

7.0 References and other Resources

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UNIT 5: LAND POLLUTION, CAUSES, EFFECTS AND SOLUTIONS

TABLE OF CONTENTS

1.0 Introduction

Land pollution is the deposition of solid or liquid waste materials on land or underground in a manner that can contaminate the soil and groundwater, threaten public health, and cause unsightly conditions and nuisances.

The waste materials that cause land pollution are broadly classified as municipal solid waste (MSW, also called municipal refuse), construction and demolition (C&D) waste or debris, and hazardous waste.

MSW includes nonhazardous garbage, rubbish, and trash from homes, institutions (e.g., schools), commercial establishments, and industrial facilities. Garbage contains moist and decomposable (biodegradable) food wastes (e.g., meat and vegetable scraps); rubbish comprises mostly dry materials such as paper, glass, textiles, and plastic objects; and trash includes bulky waste materials and objects that are not collected routinely for disposal (e.g., discarded mattresses, appliances, pieces of furniture).

C&D waste (or debris) includes wood and metal objects, wallboard, concrete rubble, asphalt, and other inert materials produced when structures are built, renovated, or demolished.

Hazardous wastes include harmful and dangerous substances generated primarily as liquids but also as solids, sludges, or gases by various chemical manufacturing companies, petroleum refineries, paper mills, smelters, machine shops, dry cleaners, automobile repair shops, and many other industries or commercial facilities.

In addition to improper disposal of MSW, C and D waste, and hazardous waste, contaminated effluent from subsurface sewage disposal (e.g., from septic tanks) can also be a cause of land pollution.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. those factors that cause land pollution;
ii. effects of land pollution and
iii. how to control land pollution.

3.0 Main Content

3.1 Causes of Land Pollution

3.1.1 Deforestation and soil erosion

Deforestation carried out to create drylands is one of the major concerns. Land that is once converted into dry or barren land will be difficult to be made fertile again. Land conversion, meaning the alteration or modification of the original properties of the land to make it use-worthy for a specific purpose, is another major cause. It hampers the land immensely.

3.1.2 Agricultural activities

With the growing human population, the demand for food has increased considerably. Farmers often use highly toxic fertilizers (to supplement insufficient nutrients in the soil) and pesticides to get rid of insects, fungi and bacteria from their crops. However, with the overuse of these chemicals, they result in contamination and poisoning of soil.

3.1.3 Mining activities

During extraction and mining activities, several land spaces are created beneath the surface. We constantly hear about land caving in, which is nothing but nature's way of filling the spaces left out after mining or extraction activity.

3.1.4 Overcrowded landfills

Each household produces tonnes of garbage each year. Garbage like aluminum, plastic, paper, cloth, wood is collected and sent to the local recycling unit. Items that cannot be recycled become a part of the landfills that hamper the beauty of the city and cause land pollution.

3.1.5 Industrialization

Due to an increase in demand for food, shelter, and house, more goods are produced. This has resulted in the creation of more waste that needs to be disposed of. In order to meet the demand of the growing population, more industries were developed, which led to deforestation. Research and development paved the way for modern fertilizers and chemicals that were highly toxic and led to soil contamination.

3.1.6 Construction activities

Due to urbanization, a large number of construction activities are taking place, which has resulted in huge waste articles like wood, metal, bricks, plastic that can be seen by naked eyes outside any building or office which is under construction.

3.1.7 Nuclear waste

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

3.1.8 Sewage treatment

A large amount of solid waste is leftover once the sewage has been treated. The leftover material is then sent to the landfill site, which ends up polluting the environment.

3.1.9 Littering

Littering is a common problem, whether it is in a city or a rural area. People just throw their garbage on the ground without caring about the adverse effects on the environment.
A common instance is that people just throw their cigarette butt on the ground every time. Since cigarettes contain elements harmful to the environment, it leads to land contamination.

3.2 Effects of Land Pollution

3.2.1 Destruction of topsoil

Soil pollution is another form of land pollution, where the upper layer of the soil or the topsoil's composition is damaged or becomes altered. This is caused by the overuse of chemical fertilizers, soil erosion triggered by running water and other pest control measures, leading to loss of fertile land for agriculture, forest cover, fodder patches for grazing, etc. The regeneration process takes at least 500 years for 2.5 centimeters of topsoil.

3.2.2 Groundwater poisoning

When harmful substances from industrial processes, chemicals are improperly disposed of on the land or in illegal landfills or storages, the chemicals and other substances could end up in the groundwater system. The process is called leaching. It can happen on farms, industrial sites, and landfills and affect the health of animals, plants and also humans.

3.2.3 Drinking water problem

Drinking water is highly affected by land pollution. Nearly 50% of the world's population does not have access to safe drinking water, and each year water-based diseases cause up to 10 million deaths.

3.2.4 Change in climate patterns

The effects of land pollution are very hazardous and can lead to the loss of ecosystems altering balance of nature. When land is polluted, it directly or indirectly affects the climate patterns.

3.2.5 Environmental impact

When deforestation is committed, the tree cover is compromised. This leads to a steep imbalance in the rain cycle. A disturbed rain cycle affects a lot of factors. Most importantly, the green cover is reduced. Trees and plants help balance the atmosphere; without them, we are subjected to various concerns like Global warming, the greenhouse effect, irregular rainfall and flash floods, among other imbalances.

3.2.6 Effect on human health

The land, when contaminated with toxic chemicals and pesticides, lead to potentially fatal problems like skin cancer and human respiratory ailments in particular. Globally, 9,500 people are diagnosed with skin cancer every day. The toxic chemicals can reach our body through foods and vegetables that we eat as they are grown in polluted soil. Land pollution also caused developmental deficiency in children. Chemicals, such as lead that are commonly found in contaminated soil and water, can impact a child's cognitive development even when the exposure is very low.

3.2.7 Effect on wildlife

The animal kingdom has suffered most in the past decades. They face a serious threat with regard to the loss of habitat and natural environment. The constant human activity on land is leaving it polluted, forcing these species to move further away and adapt to new regions or die trying to adjust. Several species are also pushed to the verge of extinction, due to no homeland.

3.2.8 Water nutrient enrichment

Chemicals that are frequently used on agricultural farms, such as nitrogen, end up benefitting the crops only in a small proportion. The rest ends up in water populated by fish, algae, and other life forms. As the nutrient-heavy water saps up most of the oxygen in the water, it leaves little oxygen for fish and other marine life. The water in that situation becomes unable to support most life forms.

3.2.9 Causes air pollution

Landfills across the city keep on growing due to an increase in waste and are later burned, which leads to air pollution. They become home for rodents, mice, etc., which in turn transmit diseases.

3.3 Control of Land Pollution

A number of ways have been suggested to curb the pollution rate. Attempts to clean up the environment require plenty of time and resources. Some the steps to reduce soil pollution according to Mishra et al. (2016) are:

i. Ban on use of plastic bags below 20microns thickness.
ii. Recycling of plastic wastes.
iii. Ban on deforestation.
iv. Encouraging plantation programmes.
v. Encouraging social and agro forestry programmes.
vi. Undertaking awareness programmes.
vii. Reducing the use of chemical fertilizer and pesticides.
viii. Recycling paper, plastics and other materials.
ix. Ban on use of plastic bags, which are a major cause of pollution.
x. Reusing materials.
xi. Suitable and safe disposal of wastes including nuclear wastes.
xii. Chemical fertilizers and pesticides should be replaced by organic fertilizers and pesticides.
xiii. Encouraging social and agro forestry programs.
xiv. Undertaking many pollution awareness programs.

4.0 Summary

In this unit we have leant that:

i. The effects of land pollution are very hazardous and can lead to the loss of ecosystems altering balance of nature.

ii. The waste materials that cause land pollution are broadly classified as municipal solid waste (MSW, also called municipal refuse), construction and demolition (C and D) waste or debris, and hazardous waste.
iii. Recycling paper, plastics and other materials is one of the ways to control land pollution.

5.0 Conclusion

Land pollution is the deposition of solid or liquid waste materials on land or underground in a manner that can contaminate the soil and groundwater, threaten public health etc. The land, when contaminated with toxic chemicals and pesticides, lead to potentially fatal problems like skin cancer and human respiratory ailments in particular. Chemical fertilizers and pesticides should be replaced by organic fertilizers and pesticides as a way of controlling land pollution.

6.0 Tutor Marked Assignments

1. Mention and explain five ways to control land pollution.
2. What are the effects of land pollution?

7.0 References and other Resources

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MODULE 4: WATER

UNIT 1: WATER RESOURCES

TABLE OF CONTENTS

6.0 Tutor Marked Assignments
7.0 References and other Resources

1.0 Introduction

Water serves a range of productive, environmental and social purposes in the agricultural sector and wider economy. Governments, water managers and consumers/users have a role to ensure that mechanisms and actions are in place to make certain that water is allocated and used to achieve socially and economically beneficial and efficient outcomes in a manner that is environmentally effective and sustainable. But management of water resources is being severely tested with rising food and energy prices, growing competition for water resources between different users, an expanding global population, and concerns related to climate change. The anticipated growth in world population from 7 billion currently to 9 billion by 2050, will involve a major expansion in demand for water, not only for use in agriculture but for drinking, sanitation, industry, the energy sector, as well as to meet demands for environmental improvements of ecosystems and associated recreational and cultural uses.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. several uses of water;
ii. groundwater resources and
iii. water volume and cycle.

3.0 Main Content

3.1 Water Volume and Cycle

An estimated 1.4 × 1018 cubic meters (m^3) of water on Earth, is more than 97% is in the oceans (Shiklomanov and Rodda 2003). Approximately 35 × 1015m^3 of Earth's water is
fresh water, of which about 0.3% is held in rivers, lakes, and reservoirs (Shiklomanov and Rodda 2003). The remainder of the fresh water is stored in glaciers, permanent snow, and groundwater aquifers. Earth's atmosphere contains about 13 × 1012m^3 of water and is the source of all the rain that falls on Earth (Shiklomanov and Rodda 2003). Yearly, about 151,000 quads (159,300 exajoules) of solar energy cause evaporation that moves about 577 × 1012 m3 of water from Earth's surface into the atmosphere. Of this evaporation, 86% is from the oceans (Shiklomanov 1993). Although only 14% of the water evaporation is from land, about 20% (115 × 1012 m^3 per year) of the world's precipitation falls on land, with the surplus water returning to the oceans through rivers
(Shiklomanov 1993). Thus, each year, solar energy transfers a significant portion of water from oceans to land areas. This aspect of the hydrologic (water) cycle is vital not only to agriculture but also to human life and natural ecosystems (Pimentel et al. 2004a)

3.2 Groundwater Resources

Approximately 30% (11 × 1015 m^3) of all fresh water on Earth is stored as groundwater. The amount of water held as groundwater is more than 100 times the amount collected in rivers and lakes (Shiklomanov and Rodda 2003). Most groundwater has accumulated over millions of years in vast aquifers located below the earth's surface. Aquifers are replenished slowly by rainfall, with an average recharge rate that ranges from 0.1% to 3% per year (Pimentel et al. 2004a). Assuming an average recharge rate of 1%, this leaves only 11 × 1013 m^3 of water per year available for sustainable use worldwide. World groundwater aquifers provide approximately 23% of the water used throughout the world (USGS 2003a).

3.3 Water Availability

Although water is considered a renewable resource because it is replenished by rainfall, its availability is finite in terms of the amount available per unit of time in any one region. The average precipitation for most continents is about 700 millimeters (mm) per year (7 million liters [L] per hectare [ha] per year), but this amount varies among and within continents (Shiklomanov and Rodda 2003). In general, water in a nation is considered scarce when its availability drops below 1 million L per capita per year (Engleman and LeRoy 1993). Thus, Africa is relatively arid, despite its average rainfall of 640 mm per year, because its high temperatures and winds foster rapid evaporation (Pimentel et al. 2004a). Regions that receive low rainfall (less than 500 mm per year) experience serious water shortages and inadequate crop yields. For example, 9 of the 14 Middle Eastern countries (including Egypt, Jordan, Saudia Arabia, Israel, Syria, Iraq, and Iran) have insufficient fresh water (Myers and Kent 2001, UNEP 2003). When managing water resources, the total agricultural, societal, and environmental system must be considered (Pimentel et al. 2004b)

3.4 Uses of Water

Some researchers have described the "green" and "blue" concept of water.
"Green water" is used to denote effective rainfall or soil moisture that is used directly by plants, while "blue water" denotes water in rivers, lakes, aquifers, or reservoirs. "Blue water" generally refers to water that can be delivered for irrigation or made available for alternative uses, while "green water" must be used directly from the soil profile. Other uses of water are shown in Figure 1. The blue-green concept has helped increase public awareness of an important dimension of water resource management. The terms "green water" and "blue water" generate easily recallable images of soil moisture and stored surface water in a manner that is likely to be helpful to many public officials and agency staff members.

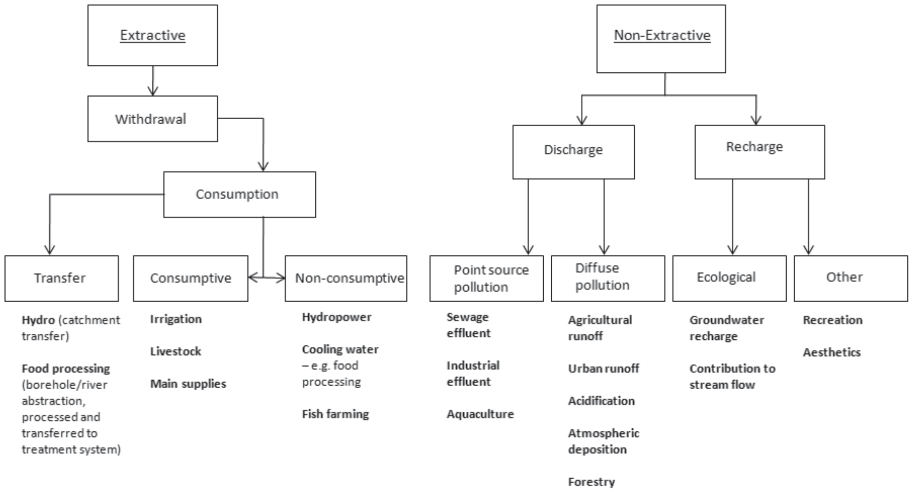

Figure 1: Uses of water
Source: Adapted from Moran and Dann (2008).

4.0 Summary

In this unit we have leant that:

i. Green water is used to denote effective rainfall or soil moisture that is used directly by plants.
ii. Blue water denotes water in rivers, lakes, aquifers, or reservoirs.
iii. The anticipated growth in world population from 7 billion to 9 billion by 2050, will involve a major expansion in demand for water.

5.0 Conclusion

Approximately 30% (11 × 1015 m^3) of all fresh water on Earth is stored as groundwater. The amount of water held as groundwater is more than 100 times the amount collected in rivers and lakes (Shiklomanov and Rodda 2003). Approximately 35 × 1015m^3 of Earth's water is fresh water, of which about 0.3% is held in rivers, lakes, and reservoirs (Shiklomanov and Rodda 2003). The remainder of the fresh water is stored in glaciers, permanent snow, and groundwater aquifers.
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6.0 Tutor Marked Assignments

1. State five uses of water.
2. Discuss the concept of blue water.

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UNIT 2: WATER ECONOMICS

TABLE OF CONTENTS

1.0 Introduction

Emphasis is being placed by many countries to improve the economic and environmental performance of the water system through providing economic incentives by taking into account the cost, value, price and demand for water in agriculture (Molle and Berkoff, 2007a). Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources" (Molle and Berkoff, 2007b).

2.0 Objectives

By the end of this unit, student should be able to understand:

i. unique economic features of water;
ii. value and cost of water and
iii. virtual water and water footprints.

3.0 Main Content

3.1 Distinct Economic Features of Water

There are some distinctive economic features that make the supply and demand for water more complex than other economic goods and services, including (Hanemann, 2006; Thompson, 2006):

i. Private (extraction) and public good (stewardship) characteristics of water imply different allocation mechanisms. When water is used on a farm it is a private good, but when left in situ, such as a lake or wetland, it is a public good for which private markets are generally absent. Moreover, water is largely used by the private sector (farms, households, industry) but its ownership and delivery is normally in the public domain;
ii. Mobility of water, in that it flows, leaches, evaporates, and has the opportunity to be reused, which makes it distinctive as a commodity compared to land, for example. Moreover, agriculture can contribute positively to the hydrological cycle, for example, through groundwater recharge and water purification functions; it can, however, also contribute to surface water and groundwater pollution and through excessive extraction may lead to diversion of water from supporting ecosystems;
iii. Heterogeneity of water in terms of space, quality and variability over time (seasonal and annual), which presents challenges in terms of matching supply and demand and structuring legal and institutional arrangements, as a given quantity of water is not the same as another available at a different location, point in time, quality and probability of occurrence;

iv. Critical nature of water is evident in terms of sustaining human life and agricultural production, but beyond minimum thresholds to maintain life and farming this notion conveys no information on the productivity or value of water, for example, the marginal value of applying 80 or 90 cm of water to irrigate cotton; and, the
v. Complex and multi-layered institutional and governance arrangements for water resources, reflected in the national institutions and governance of water resources (and in some cases cross national border structures) and sub-national regional and local governments (water user associations) management of water, while the governance of surface water and groundwater are often separated.

3.2 Value and Cost of Water

Value of water, is the sum of the economic and intrinsic value.
The ***economic value*** includes the:

i. *Value to users* of water for productive activities, such as irrigated farming;
ii. *Net benefits of return flows* of water diverted for agriculture and other users, which may also include groundwater recharge, although thesebenefits will depend on the lost to evapotranspiration;
iii. *Net benefits from indirect use,* such as drinking water for domestic purposes and providing habitat for flora and fauna, although these benefits can be offset by various negative environmental externalities, such as salinisation of soils and pollution of water from farm chemicals used in irrigation; and,
iv. *Adjustment for social objectives and values,* such as the additional increase in commodity production gained from irrigation, higher employment and benefits for rural development.

The ***intrinsic value*** of water is linked to the attributes of water that are the most difficult to assign values, for example, the aesthetics of waterscapes and recreational attributes.

• ***Cost of water,*** consists of three elements:

i. full supply cost
ii. full economic cost, and
iii. the full cost:

The ***full supply costs*** are the costs associated with supplying water to consumers without considering either the externalities of water consumption (positive or negative) or alternate uses of water (opportunity costs). These costs consist of two elements, which are also important in terms of measuring agricultural support for irrigation including:

i. *Operation and maintenance costs,* associated with daily running of the water supply system, such as electricity for pumping, labour and repair costs;
ii. *Capital costs,* covering both capital for renewal investment of existing infrastructure and new capital investment costs, such as building a new dam and canal network.

The ***full economic costs*** are the sum of the supply costs, plus the:

i. *Opportunity (or resource) costs,* which address the cost of one consumer depriving another of the use of the water if that other use has a higher value for the water, although opportunity costs are zero when there is no alternate use, that is no shortage of water, while opportunity costs also apply to issues of environmental quality already discussed; and, the

ii. *Economic cost of externalities*, consisting of positive externalities, for example the groundwater recharge benefits from irrigation; and negative externalities, typically upstream diversion of water or the release of pollutants downstream within an irrigation system.

The ***full costs*** are the sum of full supply and economic costs, plus environmental externalities. While economic externalities cover costs to producers and consumers upstream and downstream, environmental externalities are associated with costs to public health and ecosystems.

The economic value of water, however, covers goods and services that are not usually marketed, such as the net benefits from return water flows (e.g. groundwater recharge) and indirect use (e.g. wetlands or pollution); social values (e.g. rural employment); and intrinsic values (e.g. recreational, scenic, and cultural attributes). While economists have tools to provide proxy values for these non-marketed goods and services (e.g. contingent valuation) there application to guide policy decisions can be difficult.

3.3 Cost of Supplying Water

The cost of supplying water has several distinctive features compared to other commodities:

i. Water is bulky and expensive to transport relative to its value per unit of weight, unlike electricity, where there is usually a national grid;
ii. There are significant economies of scale in water supply, such as the use of a dam to store surface water, while the physical capital in the water industry is typically long lived, for example, irrigation canals; and,
iii. Water supply projects are usually designed to meet multiple needs (e.g. agriculture, hydroelectric power, urban use), which makes defining the marginal benefit very difficult, as in many uses an additional unit of water may have little value at certain times, but considerable value at others.

3.4 Virtual Water

The term “virtual water” began appearing in the water resources literature in the mid-1990s. Professor Tony Allan of London University chose the term to describe the water used to produce crops traded in international markets. During the 15 years since its inception, the virtual water concept (or metaphor, symbol) has been very helpful in gaining the attention of public officials and policy makers responsible for encouraging wise use of limited water resources.

Several authors have conducted empirical analyses of “virtual water flows” between countries, by comparing the water requirements of crops and livestock products involved in international trade, concluding that some countries are “net importers of virtual water,” while others are “net exporters.” They also suggest that, based on the virtual water concept, water-short countries should import water intensive goods and services, while water-abundant countries should export water intensive products. This line of reasoning, while simple, is not based on a legitimate conceptual framework. Hence, the policy recommendations that follow from this form of virtual water analysis can be incorrect and misleading.

The fundamental shortcoming of the virtual water concept that prevents it from serving as a valid policy prescriptive tool is the lack of an underlying conceptual framework. Some researchers have incorrectly described virtual water as analogous to, or consistent with the economic theory of comparative advantage. The virtual water concept is applied most often when discussing or comparing water-short and water-abundant countries. By focusing on the water resource endowment, alone, virtual water represents an application of absolute advantage, rather than comparative advantage. For this reason, policy prescriptions that arise from virtual water discussions are not those that will maximize the net benefits of engaging in international trade. Comparative advantage is the pertinent economic concept, and virtual water considers only absolute advantage.

3.5 Water Footprints

The notion of water footprints describes the volume of water required to support production and consumption in selected regions or countries, and to assess whether a region or country is consuming resources in a sustainable or unsustainable fashion, from a global perspective. Water is one of many inputs in those activities. Hence, estimated water footprints are somewhat one-dimensional, as they depict the use of only one resource. In addition, water footprints do not describe the implications of water use. Rather, they consider only the amounts of water used in production and consumption activities. Hence, ecological water footprint analysis is not sufficient for determining optimal policy alternatives, as it does not account of the net benefits generated as resources are consumed.

Water footprints enable one to compare estimated water use, per person or in aggregate across countries, but they are inadequate for evaluating the incremental costs, benefits, or environmental impacts of water use. For this reason, empirical estimates of water footprints do not provide sufficient information for assessing environmental implications or determining policy goals and strategies pertaining to water resources. Like the virtual water concept, water footprints bring helpful attention to important policy issues, but they lack the conceptual foundation and breadth required to support policy analysis.

4.0 Summary

In this unit we have leant that:

i. Water is bulky and expensive to transport relative to its value per unit of weight, unlike electricity, where there is usually a national grid.
ii. Water supply projects are usually designed to meet multiple needs (e.g. agriculture, hydroelectric power, urban use), which makes defining the marginal benefit very difficult.
iii. Water footprints enable one to compare estimated water use, per person or in aggregate across countries.

5.0 Conclusion

The costs and benefits of water use depend largely on the opportunity (scarcity) costs of water resources and the ways in which water is combined with other inputs in production and consumption. The full supply costs are the costs associated with supplying water to consumers without considering either the externalities of water consumption (positive or negative) or alternate uses of water (opportunity costs).

6.0 Tutor Marked Assignments

1. Discuss the concept of virtual water.
2. Discuss the concept of water footprints.

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UNIT 3: WATER AND AGRICULTURE

TABLE OF CONTENTS

6.0 Tutor Marked Assignments
7.0 References and other Resources

1.0 Introduction

Plants require water for photosynthesis, growth, and reproduction. The water used by plants is non-recoverable, because some water becomes a part of the chemical makeup of the plant and the remainder is released into the atmosphere (Pimentel et al. 2004b). The processes of carbon dioxide fixation and temperature control require plants to transpire enormous amounts of water. The processes of carbon dioxide fixation and temperature control require plants to transpire enormous amounts of water. Various crops use water at rates between 300 and 2000 L per kilogram (kg) dry matter of crops produced (Pimentel et al. 2004a). The average global transfer of water into the atmosphere by vegetation transpiration from terrestrial ecosystems is estimated to be about 64% of all precipitation that falls to Earth (Pimentel et al. 2004a).

The minimum soil moisture essential for crop growth varies. For instance, US potatoes require soil moisture levels of 25% to 50%; alfalfa, 30% to 50%; and corn, 50% to 70% (Pimentel et al. 2004a). Rice in China is reported to require at least 80% soil moisture (Pimentel et al. 2004a). Rainfall patterns, temperature, vegetative cover, high levels of soil organic matter, active soil biota, and water runoff all affect the percolation of rainfall into the soil, where it is used by plants.

The water required by food and forage crops ranges from about 300 to 2000 L per kg dry crop yield (Pimentel et al. 2004a). . For instance, in the United States, 1 ha of corn, with a yield of approximately 9000 kg per ha, transpires about 6 million L water per ha during the growing season (Pimentel et al. 2004a), while an additional 1 million to 2.5 million L per ha of soil moisture evaporate into the atmosphere (Pimentel et al. 2004a). This means that the growing season for corn production requires about 800 mm rainfall (8 million L per ha). Even with annual rainfall of 800 to 1000 mm in the US Corn Belt, corn frequently suffers from insufficient water during the critical summer growing period (Pimentel et al. 2004a).

A hectare of high-yielding rice requires approximately 11 million L water per ha for an average yield of 7 metric tons (t) per ha (Pimentel et al. 2004a). On average, soybeans require about 6 million L water per ha for a yield of 3.0 t per ha (Pimentel et al. 2004a). In contrast, wheat, which produces less plant biomass than either corn or rice, requires only about 2.4 million L per ha of water for a yield of 2.7 t per ha. Under semiarid conditions, yields of non-irrigated crops, such as corn, are low (1.0 to 2.5 t per ha) even when ample amounts of fertilizers are applied (Pimentel et al. 2004a).

2.0 Objectives

By the end of this unit, student should be able to understand:

i. energy use in irrigation;
ii. soil salinization and waterlogging in irrigation and
iii. water runoff and soil erosion.

3.0 Main Content

3.1 Irrigated Crops and Land Use

World agriculture consumes approximately 70% of the fresh water withdrawn per year (UNESCO 2001). Only about 17% of the world's cropland is irrigated, but this irrigated land produces 40% of the world's food (FAO 2002).Worldwide, the amount of irrigated land is slowly expanding, even though salinization, waterlogging, and siltation continue to decrease its productivity (Gleick 2002). Despite a small annual increase in total irrigated area, the irrigated area per capita has been declining since 1990 because of rapid population growth (Postel 1999, Gleick 2002).

3.2 Energy Use in Irrigation

Irrigation requires a significant expenditure of fossil energy both for pumping and for delivering water to crops. Overall, the amount of energy consumed in irrigated crop production is substantially greater than that expended for rainfed crops (Pimentel et al. 2004b). For example, irrigated wheat requires the expenditure of more than three times the energy needed to produce rainfed wheat. Rainfed wheat requires an energy input of only about 4.2 million kilocalories (kcal) per ha per year, while irrigated wheat requires 14.3 million kcal per ha per year to supply an average of 5.5 million L water (Pimentel et al. 2004a). Delivering 10 million L water from surface water sources to irrigate 1 ha of corn requires the expenditure of about 880 kilowatt-hours (kWh) of fossil fuel per ha. In contrast, when irrigation water must be pumpedfrom a depth of 100 m, the energy cost increases to 28,500 kWh per ha, or more than 32 times the cost of surface water (Gleick 1993).

The costs of irrigation for energy and capital are significant. The average cost to develop irrigated land ranges from $3800 to $7700 per ha (Postel 1999). Thus, farmers must not only evaluate the costs of developing irrigated land but also consider the annual costs of irrigation pumping. For example, delivering 7 million to 10 million L water per ha costs $750 to $1000 (Pimentel et al. 2004a). About 150,000 ha of agricultural land in the United States have already been abandoned because of high pumping costs (Pimentel et al. 2004a).

3.3 Soil Salinization and Waterlogging in Irrigation

With rainfed crops, salinization is not a problem because the salts are naturally flushed away. But when irrigation water is applied to crops and returns to the atmosphere through plant transpiration and evaporation, dissolved salts concentrate in the soil, where they inhibit plant growth. The practice of applying about 10 million L irrigation water per ha each year results in approximately 5 t salts per ha being added to the soil (Bouwer 2002). The salt deposits can be flushed away with added fresh water, but at a significant cost (Bouwer 2002). Worldwide, approximately half of all existing irrigated soils are adversely affected by salinization (Hinrichsen et al. 1998). The amount of world agricultural land destroyed by salinized soil each year is estimated to be 10 million ha (Pimentel et al. 2004a). In addition, drainage water from irrigated cropland contains large quantities of salt.

Waterlogging is another problem associated with irrigation. Over time, seepage from irrigation canals and irrigated fields causes water to accumulate in the upper soil levels (Pimentel et al. 2004b). Because of water losses during pumping and transport, approximately 60% of the water intended for crop irrigation never reaches the crop (Wallace 2000). In the absence of adequate drainage, water tables rise in the upper soil levels, including the plant root zone, and crop growth is impaired. Such irrigated fields are sometimes referred to as “wet deserts” because they are rendered unproductive (Pimentel et al. 2004a). For example, in India, waterlogging adversely affects 8.5 million ha of cropland and results in the loss of as much as 2 million tons grain every year (Pimentel et al. 2004a). To prevent both salinization and waterlogging, sufficient water and adequate soil drainage must be available to ensure that salts and excess water are drained from the soil.

3.4 Water Runoff and Soil Erosion

Because more than 99% of the world’s food comes from the land, an adequate global food supply depends on the continued availability of productive soils (FAO 1998). Erosion adversely affects crop productivity by reducing the availability of water; by diminishing soil nutrients, soil biota, and soil organic matter; and by decreasing soil depth (Pimentel et al. 2004a). The reduction in the amount of water available to growing plants is considered the most harmful effect of erosion, because eroded soil absorbs 87% less water through infiltration than uneroded soil (Pimentel et al. 2004a). Soybeans and oats intercept approximately 10% of the rainfall in areas where they are planted, whereas tree canopies intercept 15% to 35% (Pimentel et al. 2004a). Thus, the removal of trees increases water runoff and reduces water availability. Given a total rainfall of 800 mm per year, a water runoff rate of about 30% causes significant water shortages for growing crops such as corn, ultimately lowering crop yields (Pimentel et al. 2004a).

4.0 Summary

In this unit we have leant that:

i. The reduction in the amount of water available to growing plants is considered the most harmful effect of erosion.
ii. Irrigation requires a significant expenditure of fossil energy both for pumping and for delivering water to crops.
iii. The processes of carbon dioxide fixation and temperature control require plants to transpire enormous amounts of water.

5.0 Conclusion

Rainfall patterns, temperature, vegetative cover, high levels of soil organic matter, active soil biota, and water runoff all affect the percolation of rainfall into the soil, where it is used by plants. With rainfed crops, salinization is not a problem because the salts are naturally flushed away.

6.0 Tutor Marked Assignments

1. Explain energy use in irrigation.
2. Why is waterlogging a problem that is associated with irrigation?

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UNIT 4: WATER, CLIMATE CHANGE AND CONFLICTS OVER WATER USE

TABLE OF CONTENTS

1.0 Introduction

The Intergovernmental Panel on Climate Change (IPCC) report on climate change and water (Bates et al., 2008), concluded that "observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies." Climate change's main water-related impacts with regard to agriculture are expected by the IPCC to be felt in terms of shifting and more variable hydrological regimes. IPCC also projects a decline in the melt water from major Asian mountain ranges where more than one-sixth of the world's population currently lives. Climate change is expected to affect the function and operation of existing water infrastructure (e.g. irrigation systems) as well as water management. Moreover, current water management practices may not be robust enough to cope with the impacts of climate change on, for example, water supply reliability, flood risk, agriculture and ecosystems. Specifically concerning agriculture, the IPCC projects that changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilization.

The rapid increase in freshwater withdrawals for agricultural irrigation and for other uses that have accompanied population growth has spurred serious conflicts over water resources both within and between countries (FAO 2000).

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the effects of climate change on water and agriculture;
ii. countries that are having conflict over water use and

iii. how dry land ecosystems are threatened by water scarcity.

3.0 Main Content

3.1 Climate Change, Water and Agriculture

Climate change can also have a dual effect on irrigated agriculture. This may occur through both higher water demands by agriculture and an expansion of the area irrigated. These developments are due to both general climate change (higher temperatures and lower precipitation) and climate variability leading to an increase in extreme events, especially the frequency of droughts.

The key conclusions from the IPCC's report (2008) on climate change and water and of particular relevance to water resources and agriculture are listed below.

i. Observed warming over several decades has been linked to changes in the large-scale hydrological cycle.
ii. Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes and parts of the tropics, and decreases in some subtropical and lower mid-latitude regions (likely/very likely).
iii. By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics (high confidence).
iv. Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas (likely/very likely).
v. Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution (high confidence).
vi. Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits (high confidence).
vii. Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilization.
viii. Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defenses, drainage and irrigation systems – as well as water management practices (high/very high confidence).
ix. Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems (very high confidence).
x. Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions (very likely).
xi. Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies.
xii. Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs.

xiii. Water resources management clearly impacts on many other policy areas, e.g., energy, health, food security and nature conservation.

xiv. Several gaps in knowledge exist in terms of observations and research needs related to climate change and water

3.2 Climate Variability

Climate variability is also a concern in terms of changes in the seasonality of precipitation, which is of particular importance for agriculture as it affects the timing of annual rainfall patterns or periods of snow pack melt, necessitating the restructuring of irrigation storage systems. Better understanding of climate variability and extension of risk management approaches in agriculture to existing climate variability, can help build a more solid foundation for addressing climate change in the future.

3.3 Desertification: The Challenges of Water in Drylands and the United Nations Convention to Combat Desertification Response

The world's drylands include desert, grassland, savannah and woodland, in climates ranging from the hottest deserts to the coldest arctic regions. Most of the dryland ecosystems are fragile, and suffer from water scarcity and low productivity. Dryland resources are increasingly threatened, as results of inappropriate management practices and overpopulation. The fight against desertification is also a fight against rural poverty and food insecurity, which are all strongly inter-related.

The United Nations Convention to Combat Desertification (UNCCD) is the centerpiece in the international community's efforts to combat desertification in the drylands. It was adopted in 1994, entered into force in 1996 and currently has 194 parties. The UNCCD recognizes the physical, biological and socio-economic aspects of desertification, the importance of redirecting technology transfer so that it is demand-driven, and the involvement of local communities in combating desertification and land degradation. The core of the UNCCD is the development of action programmes by national governments in cooperation with development partners. A strategic plan of action and framework was devised in 2008 to promote the mainstreaming and upscaling of sustainable land management (SLM) practices and enabling policies, in synergy with the food security, climate change and biodiversity agendas. These programmes aim to build collaboration among the concerned line agencies, and strengthen farmer and pastoralist organizations, along with decentralized capacities. They promote secured land tenure arrangements, new market opportunities (including green products), as well as participatory land use planning, research and extension programmes.

Action on the ground to combat desertification includes the upscaling of a number of practices based on sustainable intensification, such as conservation agriculture and no-tillage techniques, crop rotations and intercropping, integrated pest management, agro-forestry and reforestation schemes, and pasture improvement with planned grazing processes. Improved water management is promoted through the implementation of water harvesting and small-scale irrigation investments, at watershed and village levels.

3.4 Conflicts over the Use of Water

In part, the conflicts over water are due to the sharing of fresh water by countries and regions: There are currently 263 trans-boundary river basins sharing water resources (UNESCO 2001). Worldwide, such conflicts have increased from an average of 5 per year in the 1980s to 22 in 2000 (GEF 2002). In 23 countries for which data are available, the cost of conflicts related to the agricultural use of water was an estimated $55 billion between 1990 and 1997 (GEF 2002). At least 20 nations obtain more than half their water from rivers that cross national boundaries (Gleick 1993), and 14 countries receive 70% or more of their surface water resources from rivers that are outside their borders (Alavian 2003, Cech 2003). For example, Egypt obtains 97% of its fresh water from the Nile River, the second longest in the world, which is also shared by 10 other countries (Alavian 2003). Indeed, the Nile River is so overused that during parts of the year little or no fresh water reaches the Mediterranean Sea (Pimentel et al. 2004a). Historically, the Middle East has had more conflicts over water than any other region, largely because it has less available water per capita than most other regions, and all of its major rivers cross international borders (Gleick et al. 2002). Furthermore, the human populations in Middle Eastern countries are increasing rapidly, some having doubled in the last 20 to 25 years, placing additional stress on the difficult political climate (PRB 2003). The distribution of river water also creates conflicts between the water needs of several US states and between the needs of the United States and Mexico. Six states (California, Nevada, Colorado, New Mexico, Utah, and Arizona) and Mexico all depend on Colorado River water. In a normal year, little water reaches Mexico, and little or no water reaches the Gulf of California (Postel et al. 1996, Gleick 2000).

4.0 Summary

In this unit we have leant that:

i. Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability.
ii. The conflicts over water are due to the sharing of fresh water by countries and regions.
iii. Climate change is expected to affect the function and operation of existing water infrastructure (e.g. irrigation systems) as well as water management.

5.0 Conclusion

Climate change's main water-related impacts with regard to agriculture are expected by the IPCC to be felt in terms of shifting and more variable hydrological regimes. Climate variability is also a concern in terms of changes in the seasonality of precipitation, which is of particular importance for agriculture as it affects the timing of annual rainfall patterns.

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6.0 Tutor Marked Assignments

1. Citing relevant examples, explain what normally leads to conflict over water use among countries.
2. Explain how climate change can impact irrigated agriculture.

7.0 References and other Resources

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UNIT 5: WATER POLLUTION

TABLE OF CONTENTS

1.0 Introduction

Water pollution is the release of substances into subsurface groundwater or into lakes, streams, rivers, estuaries, and oceans to the point where the substances interfere with beneficial use of the water or with the natural functioning of ecosystems. In addition to the release of substances, such as chemicals or microorganisms, water pollution may also include the release of energy, in the form of radioactivity or heat, into bodies of water. Water pollution (Figure 1) affects plants and organisms living in these bodies of water and in almost all cases the effect is damaging not only to individual species and populations, but also to the natural communities.

Figure 1: Water pollution
Source: oneworldenvironmental.com/waterpollution.jpg

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the meaning of water pollution;
ii. various types of water pollutants and
iii. effects of water pollution.

3.0 Main Content

3.1 Sources of Water Pollution

Water pollution can come from two sources:

1. Point source and

2. Non-point source

Point sources of pollution are those which have direct identifiable source. Example includes pipe attached to a factory, oil spill from a tanker, effluents coming out from industries. Point sources of pollution include wastewater effluent (both municipal and industrial) and storm sewer discharge and affect mostly the area near it. Whereas non-point sources of pollution are those which arrive from different sources of origin and number of ways by which contaminants enter into groundwater or surface water and arrive in the environment from different non identifiable sources. Examples are runoff from agricultural fields, urban waste etc. Sometimes pollution that enters the environment in one place has an effect hundreds or even thousands of miles away. This is known as trans-boundary pollution. One example is the radioactive waste that travels through the oceans from nuclear reprocessing plants to nearby countries.

3.2 Water Pollutants

Water bodies can be polluted by a wide variety of substances, including pathogenic microorganisms, putrescible organic waste, plant nutrients, toxic chemicals, sediments, heat, petroleum (oil), and radioactive substances. Several types of water pollutants are discussed below.

3.2.1 Domestic sewage

Domestic sewage is the primary source of pathogens (disease-causing microorganisms) and putrescible organic substances. Because pathogens are excreted in faeces, all sewage from cities and towns is likely to contain pathogens of some type, potentially presenting a direct threat to public health. Putrescible organic matter presents a different sort of threat to water quality. As organics are decomposed naturally in the sewage by bacteria and other microorganisms, the dissolved oxygen content of the water is depleted. This endangers the quality of lakes and streams, where high levels of oxygen are required for fish and other aquatic organisms to survive. Sewage-treatment processes reduce the levels of pathogens and organics in wastewater, but they do not eliminate them completely

Domestic sewage is also a major source of plant nutrients, mainly nitrates and phosphates. Excess nitrates and phosphates in water promote the growth of algae, sometimes causing unusually dense and rapid growths known as algal blooms. When the algae die, oxygen dissolved in the water declines because microorganisms use oxygen to digest algae during the process of decomposition. Anaerobic organisms (organisms that do not require oxygen to live) then metabolize the organic wastes, releasing gases such as methane and hydrogen sulfide, which are harmful to the aerobic (oxygen-requiring) forms of life. The process by which a lake changes from a clean, clear condition with a relatively low concentration of dissolved nutrients and a balanced aquatic community to a nutrient-rich, algae-filled state and thence to an oxygen-deficient, waste-filled condition is called eutrophication. Eutrophication is a naturally occurring, slow, and inevitable process. However, when it is accelerated by human activity and water pollution (a phenomenon called cultural eutrophication), it can lead to the premature aging and death of a body of water.

3.2.2 Toxic waste

Waste is considered toxic if it is poisonous, radioactive, explosive, carcinogenic (causing cancer), mutagenic (causing damage to chromosomes), teratogenic (causing birth defects), or bioaccumulative (that is, increasing in concentration at the higher ends of food chains). Sources of toxic chemicals include improperly disposed wastewater from industrial plants and chemical process facilities (lead, mercury, chromium) as well as surface runoff containing pesticides used on agricultural areas and suburban lawns (chlordane, dieldrin, heptachlor).

3.2.3 Sediment

Sediment (e.g., silt) resulting from soil erosion can be carried into water bodies by surface runoff. Suspended sediment interferes with the penetration of sunlight and upsets the ecological balance of a body of water. Also, it can disrupt the reproductive cycles of fish and other forms of life, and when it settles out of suspension it can smother bottom-dwelling organisms.

3.2.4 Thermal pollution

Heat is considered to be a water pollutant because it decreases the capacity of water to hold dissolved oxygen in solution, and it increases the rate of metabolism of fish. Valuable species of game fish (e.g., trout) cannot survive in water with very low levels of dissolved oxygen. A major source of heat is the practice of discharging cooling water from power plants into rivers; the discharged water may be as much as 15 °C (27 °F) warmer than the naturally occurring water.

3.2.5 Petroleum (oil) pollution

Petroleum (oil) pollution occurs when oil from roads and parking lots is carried in surface runoff into water bodies. Accidental oil spills are also a source of oil pollution—as in the devastating spills from the tanker Exxon Valdez (which released more than 260,000 barrels in Alaska's Prince William Sound in 1989) and from the Deepwater Horizon oil rig (which released more than 4 million barrels of oil into the Gulf of Mexico in 2010). Oil slicks eventually move toward shore, harming aquatic life and damaging recreation areas.

3.2.6 Agrochemical pollution

Improper disposal of pesticides from field farms and excessive fertilizer application contribute a lot of pollutants to water bodies and soils. Some of the pesticides are: DDT (Dichlorodiphenyltrichloroethane), Aldrin, Dieldrin, Malathion, Hexachloro Benzene etc. Pesticides reach water bodies through surface runoff from agricultural fields, drifting from spraying, washing down of precipitation and direct dusting and spraying of pesticides in low lying areas polluting the water quality. Most of them are non-biodegradable and persistent in the environment for long period of time. These chemicals may reach human through food chain leading

3.2.7 Industrial wastes

Some industries such as steel and paper industries are situated along river bank for their huge requirement amount of water in manufacturing processes and finally their wastes containing acids, alkalies, dyes and other chemicals are dumped and poured down into rivers as effluents.

3.3 Groundwater and Ocean

Groundwater: water contained in underground geologic formations called aquifers, is a source of drinking water for many people. For example, a lot of people in Nigeria depend on groundwater for their domestic water supply. Although groundwater may appear crystal clear (due to the natural filtration that occurs as it flows slowly through layers of soil), it may still be polluted by dissolved chemicals and by bacteria and viruses. Sources of chemical contaminants include poorly designed or poorly maintained subsurface sewage-disposal systems (e.g., septic tanks), industrial wastes disposed of in improperly lined or unlined landfills or lagoons, leachates from unlined municipal refuse landfills, mining and petroleum production, and leaking underground storage tanks below gasoline service stations. In coastal areas, increasing withdrawal of groundwater (due to urbanization and industrialization) can cause saltwater intrusion: as the water table drops, seawater is drawn into wells.

Although estuaries and oceans contain vast volumes of water, their natural capacity to absorb pollutants is limited. Contamination from sewage outfall pipes, from dumping of sludge or other wastes, and from oil spills can harm marine life, especially microscopic phytoplankton that serve as food for larger aquatic organisms. Sometimes, unsightly and dangerous waste materials can be washed back to shore, littering beaches with hazardous debris. By 2010, an estimated 4.8 million and 12.7 million tons (between 5.3 million and 14 million tons) of plastic debris had been dumped into the oceans annually, and floating plastic waste had accumulated in Earth’s five subtropical gyres that cover 40 percent of the world’s oceans.

Another ocean pollution problem is the seasonal formation of “dead zones” (i.e., hypoxic areas, where dissolved oxygen levels drop so low that most higher forms of aquatic life vanish) in certain coastal areas. The cause is nutrient enrichment from dispersed agricultural runoff and concomitant algal blooms. Dead zones occur worldwide; one of the largest of these (sometimes as large as 22,730 square km [8,776 square miles]) forms annually in the Gulf of Mexico, beginning at the Mississippi River delta.

3.4 Effects of Water Pollution

3.4.1 Effects of water pollution on human health

The presence of heavy metals such as Fluoride, Arsenic, Lead, Cadmium, Mercury, petrochemicals, chlorinated solvents, pesticides and nitrates in water affects human health (Singh and Gupta 2016)..

i. Fluoride in water is essential for protection against dental carries and weakening of the bones. Concentration below 0.5 mg/l causes dental carries and mottling of teeth but exposure to higher levels above 0.5 mg/l for 5-6 years may lead to adverse effect on human health leading to a condition called fluorosis (Singh and Gupta 2016).

ii. Arsenic is a very toxic chemical that reaches the water naturally or from wastewater of tanneries, ceramic industry, chemical factories and from insecticides such as lead arsenate, effluents from fertilizers factories and from fumes coming out from burning of coal and petroleum. Arsenic is highly dangerous to human health causing respiratory cancer, arsenic skin lesion from contaminated drinking water in some districts of West Bengal, India. Long exposure leads to bladder and lungs cancer.
iii. Lead is implicated in contaminated drinking water source from pipes, fitting, solder, household plumbing systems. In human being, it affects the blood, central nervous system and the kidneys. Child and pregnant women are mostly prone to lead exposure.
iv. Mercury is used in industries such as smelters, manufactures of batteries, thermometers, pesticides, fungicides etc. The best known example of Mercury pollution in the oceans took place in 1938 when a Japanese factory discharged a significant amount of mercury into Minamata Bay, contaminating the fish stocks there. It took several years to show its effects. By that time, many local people had eaten the fish and around 2000 were poisoned, hundreds of people were left dead and disabled (Akio 1992) and the cause for death was named as "Minamata disease" due to consumption of fish containing methyl mercury. It causes chromosomal aberrations and neurological damages to human. Mercury shows biological magnification in aquatic ecosystems.
v. Cadmium reaches human body through food crop from soil irrigated by affected effluents. Friberg et al. (1974) noted that long term consumption of rice from affected fields by the people living in areas contaminated by cadmium in regions of Japan, resulted into many renal diseases like "itai-itai disease", nephritis and nephrosis.

Water borne diseases: Microorganisms play a major role in water quality and the microorganisms that are concerned with water borne diseases are *Salmonella sp*., *Shigella sp*., *Escherichia coli* and *Vibrio cholera* (Adetunde and Glover 2010). All these cause typhoid fever, diarrhoea, dysentery, gastroenteritis and cholera. The most dangerous form of water pollution occurs when faeces enter water supply. Many diseases are perpetuated by the faecal-oral route of transmission in which the pathogens are shed only in human faeces (Adetunde and Glover 2010). Presence of faecal coliforms of *E. coli* is used as an indicator for the presence of any of these water borne pathogens (Adetunde and Glover 2010). Larry (2006) suggested that ground water contamination is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more than 14,000 people daily, and the majority of them being children under 5 years old. In recent years, the widespread reports of pollutants in groundwater have increased public concern about the quality of groundwater. Children are generally more vulnerable to intestinal pathogens and it has been reported that about 1.1 million children die every year due to diarrhoeal diseases (Steiner et al. 2006).

3.4.2 Effects of water pollution on plants

The following are the effects of water pollution on plants according to Singh and Gupta (2016):

i. Acid deposition: Many acidic substances and aerosols released into the atmosphere from industrial or domestic sources of combustion from fossil fuels finally fall down to ground and reach the water bodies along with run-off rainwater from polluted soil surfaces thereby causing acidification of water bodies by lowering its pH . In many countries chemical substances like sulphates, nitrates and chloride have been reported to make water bodies such as lakes, river and ponds acidic.

ii. Nutrient deficiency in aquatic ecosystem: Population of decomposing microorganisms like bacteria and fungi decline in acidified water which in turn reduces the rate of decomposition of organic matter affecting nutrient cycling. The critical pH for most of the aquatic species is 6.0. The diversity of species decline below this pH whereas the number and abundance of acid tolerant species increases. Proliferation of filamentous algae rapidly forms a thick mat at the initial phase of the acidification of water. Diatoms and green algae disappear below pH 5.8. Cladophora is highly acid tolerant species and is abundant in acidic freshwater bodies. Macrophytes are generally absent in acidic water as their roots are generally affected in such water resulting in poor plant growth. *Potamogeton pectinalis* is found in acidified water. It is observed that plants with deep roots and rhizomes are less affected while plants with short root systems are severely affected in acidic water.

iii. Effects of organic matter deposition: Organic matter from dead and decaying materials of plants and animals is deposited directly from sewage discharges and washed along with rainwater into water bodies causing increase in decomposers / microbes such as aerobic and anaerobic bacteria. Rapid decomposition of organic matter increase nutrient availability in water favouring the luxuriant growth of planktonic green and blue-green algal bloom. In addition many of the macrophytes like *Salvinia*, *Azolla*, *Eicchhornia* etc. grow rapidly causing reduced penetration of light into deeper layer of water body with gradual decline of the submerged flora. This condition results in reducing the dissolved Oxygen and increase in the biological oxygen demand (B.O.D). The B.O.D of unpolluted fresh water is usually below 1mg/l while that of organic matter polluted water is more than 400 mg/l.

iv. Effects of agricultural chemicals: Chemicals from fertilizers, pesticides, insecticides, herbicides etc. applied to crops in excess are washed away with rainwater as runoff, then enter into soil and finally arrive at water bodies. Chemicals from fertilizers result in eutrophication by enrichments of nutrients. Ammonium from fertilizers is acidic in nature causing acidification of water. Similarly pesticides, herbicides and insecticides also cause change in pH of water bodies. Most common effect of these substances is the reduction in photosynthetic rate. Some may uncouple oxidative phosphorylation or inhibit nitrate reductase enzyme. The uptake and bioaccumulation capacities of these substances are great in macrophytic plants due to their low solubility in water.

v. Effects of industrial wastes: Effluents from industries contain various organic and inorganic waste products. Fly ash form thick floating cover over the water thereby reducing the penetration of light into deeper layers of water bodies. Fly ash increases the alkalinity of water and cause reduced uptake of essential bases leading to death of aquatic plants. Liquid organic effluents change the pH of water and the specific toxicity effects on the aquatic plants vary depending on their chemical composition. There may be synergistic, additive or antagonistic interactions between metals with respect to their effects on plants however these effects are reduced in hard and buffered freshwater bodies.

vi. Effects of silt deposition: Deposition of silt in water bodies occurs as a result of erosion carrying silt laden water. It increases the turbidity of water and reduces light penetration in deep water causing decline in abundance of submerged plants. Siltation inhibits the growth of aquatic plants. Abundance of phytoplankton is affected due to reduction in surface exchange of gases and nutrients. Plants that are tolerant to turbidity are abundant followed by those that are intermediate and the least tolerant species. Plants such as *Polygonum*, *Sagittaria* etc. are found to grow in dominance.

vii. Phytotoxicity effects on plants: When chemical pollutants build up in aquatic or terrestrial environments, plants can absorb these chemicals through their roots. Phytotoxicity occurs when toxic chemicals poison plants. The symptoms of phytotoxicity in plants include poor growth, dying seedlings and dead spots on leaves. For example, mercury poisoning which many people associate with fish can also affect aquatic plants, as mercury compounds build up in plant roots and bodies result in bioaccumulation.

viii. Effects of oil spillage: Oil pollution due to spillage of oil tankers and storage containers prevents oxygenation of water and depletes the oxygen content of the water body by reducing light transmission inhibiting the growth of planktons and photosynthesis in macrophytes.

ix. Eutrophication: Nutrient enrichment in aquatic water bodies leads to eutrophication which is a process whereby water bodies receive excess inorganic nutrients, especially Nitrogen and Phosphorus, stimulating excessive growth of plants and algae.

3.5 Water Pollution Prevention

There are several ways of preventing water pollution. Some of them are discussed below:

3.5.1 Green agriculture

Globally, agriculture accounts for 70% of water resources, so it is essential to have climate-friendly crops, efficient irrigation that reduces the need for water and energy-efficient food production. Green agriculture is also crucial to limit the chemicals that enter the water.

3.5.2 Wastewater treatment

Wastewater treatment consists of removing pollutants from wastewater through a physical, chemical or biological process. The more efficient these processes are, the cleaner the water becomes.

3.5.3 Air pollution prevention

Air pollution has a direct impact on water contamination as 25% of human induced CO_2 emissions are absorbed by oceans. This pollution causes a rapid acidification of our oceans, and threatens marine life and corals. Preventing air pollution is the best way to prevent this from happening.

3.5.4 Storm water management

Storm water management is the effort to reduce runoff of rainwater or melted snow into streets, lawns and other sites and the improvement of water quality" according to the US Environmental

Protection Agency (EPA). It is important to avoid pollutants from contaminating the water and helps to use water more efficiently.

3.5.5 Plastic waste reduction

80% of plastic in our oceans is from land sources. In order to reduce the amount of plastic entering our ocean, we need to both reduce our use of plastic globally, and to improve plastic waste management.

3.5.6 Water conservation

Without water conservation, we won't go very far. It is central in making sure the world has better access to clean water. It means being aware that water is a scarce resource, taking care of it accordingly, and managing it responsibly.

3.6 Examples of the Development of National Water Quality Criteria and Guidelines

3.6.1 Nigeria

In Nigeria, the Federal Environmental Protection Agency (FEPA) issued, in 1988, a specific decree to protect, to restore and to preserve the ecosystem of the Nigerian environment. The decree also empowered the agency to set water quality standards to protect public health and to enhance the quality of waters. In the absence of national comprehensive scientific data, FEPA approached this task by reviewing water quality guidelines and standards from developed and developing countries as well as from international organizations and, subsequently, by comparing them with data available on Nigeria's own water quality. The standards considered included those of Australia, Brazil, Canada, India, Tanzania, the United States and the World Health Organization (WHO). These sets of data were harmonized and used to generate the Interim National Water Quality Guidelines and Standards for Nigeria. These address drinking water, recreational use of water, freshwater aquatic life, agricultural (irrigation and livestock watering) and industrial water uses. The guidelines are expected to become the maximum allowable limits for inland surface waters and ground waters, as well as for non-tidal coastal waters. They also apply to Nigeria's trans-boundary watercourses, the rivers Niger, Benue and Cross River, which are major sources of water supply in the country. The first set of guidelines was subject to revision by interested parties and the general public. A Technical Committee comprising experts from Federal ministries, State Governments, private sector organizations, higher educational institutions, nongovernmental organizations and individuals is now expected to review the guidelines from time to time.

3.6.2 Papua New Guinea

In Papua New Guinea, the Water Resources Act outlines a set of water quality requirements for fisheries and recreational use of water, both fresh and marine. The Public Health Drinking Water Quality Regulation specifies water quality requirements and standards relating to raw water and drinking water. The standards were established in accordance with WHO (World Health Organization) guidelines and data from other tropical countries.

3.6.1 Vietnam

In Vietnam, the water management policy of the Government highlights the need for availability of water, adequate in quantity and quality for all beneficial uses, as well as for the control of point and non-point pollution sources. The Government is expected to draw up and to update a comprehensive long-term plan for the development and management of water resources. Moreover, an expected reduction in adverse impacts from pollution sources in upstream riparian countries on the water quality within the Mekong River delta will be based on joint studies and definitions of criteria for water use among riparian countries of the river. A set of national water quality criteria for drinking-water use as well as criteria for fish and aquatic life, and irrigation have been established (ESCAP, 1990). Criteria for aquatic life include: pH (range 6.5-8), dissolved oxygen (> 2 mg l^{-1}), NH_4-N (< 1 mg l^{-1}), copper (< 0.02 mg l^{-1}), cadmium (< 0.02 mg l^{-1}), lead (< 0.01 mg l^{-1}) and dissolved solids (1,000 mg l^{-1}). More recently, allowable concentrations of pesticides in the freshwater of the Mekong delta have been established by the Hygiene Institute of Ho Chi Minh City as follows: DDT 0.042 mg l^{-1}, heptachlor 0.018 mg l^{-1}, lindane 0.056 mg l^{-1} and organophosphate 0.100 mg l-1. According to Dung (1994), the actual concentrations of these pesticides during the period June 1992 to June 1993 were considerably below these criteria.

4.0 Summary

In this unit we have leant that:

i. Improper disposal of pesticides from field farms and excessive fertilizer application contribute a lot of pollutants to water bodies and soils.
ii. Contamination from sewage outfall pipes, from dumping of sludge or other wastes, and from oil spills can harm marine life.
iii. Point sources of pollution are those which have direct identifiable source.

5.0 Conclusion

Water pollution affects plants and organisms living in these bodies of water and in almost all cases the effect is damaging not only to individual species and populations, but also to the natural communities. Water bodies can be polluted by a wide variety of substances, including pathogenic microorganisms, putrescible organic waste, plant nutrients, toxic chemicals, sediments, heat, petroleum (oil), and radioactive substance.

6.0 Tutor Marked Assignments

1. Differentiate between point source and non-point source of water pollution.
2. State the effects of water pollution on plants.

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MODULE 5: OTHER TYPE OF ENVIRONMENTAL POLLUTION

UNIT 1: RADIOACTIVE POLLUTION

TABLE OF CONTENTS

1.0 Introduction

Certain atoms are radioactive, meaning that they emit radioactivity during spontaneous transformation from an unstable isotope to a more stable one. Radioactive pollution results from contamination of the environment with such substances, and may represent a significant health risk to humans and other organisms. Radioactive pollution differs from much conventional pollution in that it cannot be detoxified or broken down into harmless substances. Instead, radioactive materials must be isolated from the environment until their radiation level has decreased to a safe level, a process which requires thousands of years for some materials.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the meaning of radioactive pollution;
ii. various types of radioactive pollution and
iii. examples of radioactive contaminants.

3.0 Main Content

3.1 What is Radioactive Pollution?

Radioactive pollution occurs when there is a presence or depositions of radioactive materials in the atmosphere or environment, especially where their presence is accidental and when it presents an environmental threat due to radioactive decay. The destruction caused by the radioactive materials is because of the emissions of hazardous ionizing radiation (radioactive decay) like beta or alpha particles, gamma rays or neurons in the environment where they exist.

Radioactive pollution can also be defined as the increase in the natural radiation levels caused by human activities. It is estimated that about 20% of radiation we are exposed to is due to human activities. The human activities that can release radiation involve activities with radioactive materials such as mining, handling and processing of radioactive materials, handling and storage of radioactive waste, as well as the use of radioactive reactions to generate energy (nuclear power plants), along with the use of radiation in medicine (e.g. X-rays) and research. But what about microwaves, cell phones, radio transmitters, wireless devices, computers, and other common commodities of today's life?

When we think of radiation, we imagine bombs and nuclear explosions. While these are serious sources of high levels radiation (of high energy), there are many other sources that are much more common, practically ubiquitous, that generate low levels of radiation and which basically remain unnoticed. How many of us think for example of cellular phones as a source of radiation? And yet, the cell phones, cell phone towers, cordless phones, as well as TVs, computers, microwave ovens, broadcast antennas, military and aviation radars, satellites, and wireless internet are all sources of radiation. And so are the common medical X-Rays. Considering this, the picture of radiation pollution significantly expands. From a few explosions and nuclear accidents happening relatively rarely in faraway places, the picture of radiation pollution expands to a complex matrix covering all the Earth and thus involving all of us everywhere.

Radiation is essentially energy that travels and spreads out as it goes. This is referred to as electromagnetic radiation. Examples include visible light, radio waves, microwaves, infrared and ultraviolet lights, X-rays, and gamma-rays. The differences between these various types of radiation consist of some physical properties such as energy, frequency, and wavelength. Thus, there are a variety of electromagnetic radiations. This means that any and all these types of radiation can generate radiation pollution if they are enhanced by human activities. However, the magnitude of the pollution generated varies, with higher-risk pollution generated by radiation of higher energy such as gamma-rays regardless of exposure time. This radiation is generated through detonation of nuclear weapons or in power plants. Therefore, the meaning of radiation pollution is that, while there are ubiquitous sources of radiation, it is mostly the high-energy radiation that causes radiation pollution, carrying serious health risks (such as cancer or death). This is why we will focus on sources for high health-risk radiation when discussing the causes of radioactive pollution and its effects.

3.2 Types of Radioactive Pollution

Based on the frequency with which it occurs, radioactive pollution can be continuous, occasional or accidental.

3.2.1 Continuous pollution

Continuous radioactive pollution is the type of pollution constantly coming from uranium mines, nuclear reactors, and test laboratories, where the radioactive contaminants are always present.

3.2.2 Occasional pollution

Occasional radioactive pollution is the type of pollution that occurs during nuclear tests or during experimental tests on radioactive substances.

3.2.3 Accidental pollution

Accidental radioactive pollution is the type of pollution that occurs when certain experiments involving dangerous substances fail, and the substances used for experimentation get out of control.

3.3 Examples of Radioactive Contaminants

Radioactive materials are those materials or elements that emit radiation, thus they are not stable and get transformed into other radioactive or non-radioactive materials. The harm that they can cause depends on the radioactive elements and their half time function (the time needed for their concentration to be reduced to half due to radioactive decay processes). Basically, the higher the half-time, the lower the effects on human health. Radioactive elements with a short and very short half-time pose a serious threat to human health because of their hazardous effects. Most of the radioactive materials have half-lives of hundreds of thousands of years and, once generated, may persist in the environment for a very long time.

Many radioactive elements (materials) are naturally present in the environment. Most of them are used in nuclear power plants, and as basic components of nuclear weapons. Examples of this type of materials are:

CAESIUM-137: Used for radiation therapy in medicine (to treat cancer).

STRONTIUM-90: Used for thermoelectric generators and portable power sources for space vehicles, weather stations etc.

PLUTONIUM 238: Used as a heat source for radioisotope thermoelectric generators.

URANIUM-235: Used as fuel for nuclear reactors.

COBALT-57 & 60: Used in nuclear medicine.

RADIUM-226: Used for lightning rods.

4.0 Summary

In this unit we have leant that:

i. It is estimated that about 20% of radiation we are exposed to is due to human activities.
ii. Radioactive materials are those materials or elements that emit radiation.
iii. Radioactive pollution differs from much conventional pollution in that it cannot be detoxified or broken down into harmless substances.

5.0 Conclusion

Radioactive pollution occurs when there is a presence or depositions of radioactive materials in the atmosphere or environment. The destruction caused by the radioactive materials is because of the emissions of hazardous ionizing radiation.

6.0 Tutor Marked Assignments

1. Mention and describe three types of radioactive pollution.
2. Mention five radioactive elements and their uses.

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UNIT 2: SOURCES OF RADIOACTIVE POLLUTION

TABLE OF CONTENTS

1.0 Introduction

In the United States for instance, people are typically exposed to about 350 millirems of ionizing radiation per year. On average, 82% of this radiation comes from natural sources and 18% from anthropogenic sources (i.e., those associated with human activities). The major natural source of radiation is radon gas, which accounts for about 55% of the total radiation dose. The principal anthropogenic sources of radioactivity are medical X-rays and nuclear medicine. Radioactivity from the fallout of nuclear weapons testing and from nuclear power plants make up less than 0.5% of the total radiation dose, i.e., less than 2 millirems. Although the contribution to the total human radiation dose is extremely small, radioactive isotopes released during previous atmospheric testing of nuclear weapons will remain in the atmosphere for the next 100 years.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. the various causes of radioactive pollution;
ii. lifestyle and radiation dose and
iii. some nuclear accidents.

3.0 Main Content

3.1 Causes of Radioactive Pollution

Some of the causes of radioactive pollution are discussed below:

3.1.1 Nuclear power plants accidents

Many environmentalists are critical of nuclear power generation. They believe that there is an unacceptable risk of catastrophic accident, that the spread of nuclear energy technology increases the risk of nuclear weapons proliferation, and that the nuclear fuel cycle generates large amounts of unmanageable nuclear waste that will represent a long-term danger to human well-being. In particular, a nuclear reactor can expose an individual who lives on the fence line of the power plant to no more than 10 millirems of radiation per year. Actual measurements at U.S. nuclear power plants have shown that a person who lived at the fence line would actually be exposed to much less that 10 millirems.

Although a nuclear power plant cannot explode like an atomic bomb, accidents can result in serious radioactive pollution. During the past 45 years, there have been a number of not-fully controlled or uncontrolled fission reactions at nuclear power plants in the United States and elsewhere, which have killed or injured power plant workers. These accidents occurred in Los Alamos, New Mexico; Oak Ridge, Tennessee; Richland, Washington; and Wood River Junction, Rhode Island. The most famous case was the 1979 accident at the Three Mile Island nuclear reactor in Pennsylvania, which received a great deal of attention in the press. However, nuclear scientists have estimated that people living within 50 mi (80 km) of this reactor were exposed to less than two millirems of radiation, most of it as iodine-131, a short-lived isotope. This exposure constituted less than 1% of the total annual radiation dose of an average person. However, these data do not mean that the accident at Three Mile Island was not a serious one; fortunately, technicians were able to re-attain control of the reactor before more devastating damage occurred, and the reactor system was well contained so that only a relatively small amount of radioactivity escaped to the ambient environment.

By far, the worst nuclear reactor accident occurred in 1986 in Chernobyl, Ukraine. An uncontrolled build-up of heat resulted in a meltdown of the reactor core and combustion of graphite moderator material in one of the several generating units at Chernobyl, releasing more than 50 million Curies of radioactivity to the ambient environment. The disaster killed 31 workers, and resulted in the hospitalization of more than 500 other people from radiation sickness. According to Ukrainian authorities, during the decade following the Chernobyl disaster an estimated 10,000 people in Belarus, Russia, and Ukraine died from cancers and other radiation-related diseases caused by the accident. In addition to these relatively local effects, the atmosphere transported radiation from Chernobyl into Europe and throughout the Northern Hemisphere.

More than 500,000 people in the vicinity of Chernobyl were exposed to dangerously high doses of radiation, and more than 300,000 people were permanently evacuated from the vicinity. Since radiation-related health problems may appear decades after exposure, scientists expect that many thousands of additional people will eventually suffer higher rates of thyroid cancer, bone cancer, leukemia, and other radiation-related diseases. Unfortunately, a cover-up of the explosion by responsible authorities, including those in government, endangered even more people. Many local residents did not known that they should flee the area as soon as possible, or were not provided with the medical attention they needed.

After the great east-Japan earthquake of magnitude 9.0 and tsunami on the east coast of northern Japan on 11 March 2011, the Fukushima-Daiichi nuclear power station was severely damaged and radioactive material was released to the environment. Approximately 85 000 residents within the 20-km area around the nuclear power station site and some nearby areas were evacuated as a precautionary measure between 11 and 15 March, while the residents living 20–30 km from the station were sheltered in their own homes. Later, in April 2011, the evacuation of another 10 000 people living further to the north-east of the station was recommended because of the elevated levels of radionuclides on the ground. These evacuations greatly reduced the levels of exposure that would have been received by those affected. The consumption of water and certain foodstuffs was temporarily restricted to limit the radiation exposure of the public. In managing the emergency situation at the nuclear power station, some operational staff and emergency response personnel were exposed.

The large amount of radioactive waste generated by nuclear power plants is another important problem. This waste will remain radioactive for many thousands of years, so technologists must design systems for extremely long-term storage. One obvious problem is that the long-term reliability of the storage systems cannot be fully assured, because they cannot be directly tested for the length of time they will be used (i.e., for tens or hundreds of thousands of years). A related problem is that the waste will remain extremely dangerous for much longer than the expected lifetimes of existing governments and social institutions.

3.1.2 Nuclear weapons testing

Nuclear weapons can release large amounts of radioactive materials when they are exploded. Most of the radioactive pollution from nuclear weapons testing is from iodine-131, cesium-137, and strontium-90. Iodine-131 is the least dangerous of these isotopes, although it has a relatively half-life of about eight days. Iodine-131 accumulates in the thyroid gland, and large doses can cause thyroid cancer. Cesium-137 has a half-life of about 30 years. It is chemically similar to potassium, and is distributed throughout the human body. Based on the total amount of cesium already in the atmosphere, all humans will receive about 27 millirems of radiation from cesium-137 over their lifetime. Strontium-90 has a half-life of 38 years. It is chemically similar to calcium and is deposited in bones. Strontium-90 is expelled from the body very slowly, and the uptake of significant amounts increases the risks of developing bone cancer or leukemia.

3.1.3 The use of nuclear weapons as weapons of mass destruction (WMD)

The use of nuclear missiles and atomic bombs, a form of nuclear energy, in the Second World War explains not only the cause but also the damaging nature of radioactive pollution or contamination. The effects of those two strikes in Hiroshima and Nagasaki that prompted the end of the war in 1945 have been seen to date with children born with complications such as mental retardation as well as conditions like autism and other disorders. The number of cancer cases present in the two towns is more than those of the rest of Japan.

3.1.4 Mining

Mining mostly involves the excavation of the mineral ores, which are then broken into smaller, manageable pieces. Radium and Uranium, for instance, are naturally occurring in the environment and are equally radioactive. Hence, mining increases the natural geological processes by moving these materials from underneath the earth to the surface. Other minerals with a hint of radiation are thorium, plutonium, radon, potassium, carbon and phosphorus.

3.1.5 Spillage of radioactive chemicals

There have been instances of spillages over oceans when ships hit glaciers or coral reefs and end up releasing chemicals on waterways and in the atmosphere. The majority of these chemicals, including petroleum products, have a significant level of radiation, which can be detrimental to the environment.

3.1.6 Cosmic rays and other natural sources

These come from the outer space to our planet with intense radiation as their nature, therefore, causing radioactive pollution. Gamma rays, for example, are said to have the highest level of radiation and yet, depending on their intensity, some are not visible to the human eye. The quantity with which the rays hit the earth depends on the altitude of the earth and the geographical location.

There may be terrestrial radiations from radioactive elements present in the earth's crust. These radioactive elements include potassium 40, radium 224, radon 222, thorium 232, uranium 235, uranium 238, and carbon 14 and occur in rocks, soil and water.

There can also be unstable radio-nuclides split into smaller parts emitting energetic radiation that can enter into the body of organisms through the air during respiration.

3.2 Lifestyle and Radiation Dose

People who live in certain regions are exposed to higher doses of radiation. For example, residents of the Rocky Mountains of Colorado receive about 30 millirems more cosmic radiation than people living at sea level. This is because the atmosphere is thinner at higher elevations, and therefore less effective at shielding the surface from cosmic radiation. Exposure to cosmic radiation is also high while people are flying in an airplane, so pilots and flight attendants have an enhanced, occupational exposure. In addition, residents of certain regions receive higher doses of radiation from radon-222, due to local geological anomalies. Radon-222 is a colorless and odorless gas that results from the decay of naturally occurring, radioactive isotopes of uranium. Radon-222 typically enters buildings from their basement, or from certain mineral-containing construction materials. Ironically, the trend toward improved home insulation has increased the amount of radon-222 which remains trapped inside houses.

Personal lifestyle also influences the amount of radioactivity to which people are exposed. For example, miners, who spend a lot of time underground, are exposed to relatively high doses of radon-222 and consequently have relatively high rates of lung cancer. Cigarette smokers expose their lungs to high levels of radiation, since tobacco plants contain trace quantities of polonium-210, lead-210, and radon-222. These radioactive isotopes come from the small amount of uranium present in fertilizers used to promote tobacco growth. Consequently, the lungs of a cigarette smoker are exposed to thousands of additional millirems of radioactivity, although any associated hazards are much less than those of tar and nicotine.

4.0 Summary

In this unit we have leant that:

i. The use of nuclear missiles and atomic bombs, a form of nuclear energy, in the Second World War explains not only the cause but also the damaging nature of radioactive pollution or contamination.

ii. The principal anthropogenic sources of radioactivity are medical X-rays and nuclear medicine.

iii. Cigarette smokers expose their lungs to high levels of radiation, since tobacco plants contain trace quantities of polonium-210, lead-210, and radon-222.

5.0 Conclusion

Although a nuclear power plant cannot explode like an atomic bomb, accidents can result in serious radioactive pollution. By far, the worst nuclear reactor accident occurred in 1986 in Chernobyl, Ukraine. An uncontrolled build-up of heat resulted in a meltdown of the reactor core and combustion of graphite moderator material in one of the several generating units at Chernobyl, releasing more than 50 million Curies of radioactivity to the ambient environment. The disaster killed 31 workers, and resulted in the hospitalization of more than 500 other people from radiation sickness. Personal lifestyle also influences the amount of radioactivity to which people are exposed. For example, miners, who spend a lot of time underground, are exposed to relatively high doses of radon-222 and consequently have relatively high rates of lung cancer.

6.0 Tutor Marked Assignments

1. Explain how personal lifestyle also influences the amount of radioactivity to which people are exposed.
2. Identify and explain five causes of radioactive pollution.

7.0 References and other Resources

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UNIT 3: OCCUPATIONAL EXPOSURE TO RADIATION

TABLE OF CONTENTS

1.0 Introduction

Exposure to ionizing radiation occurs in many occupations. Artificial sources of radiation are commonly used in the manufacturing and service industries, in areas of defense, in research institutions, and in universities, as well as in the nuclear power industry.

Some workers are also exposed to natural sources of radiation in such circumstances that a measure of supervision and protection is required. This is particularly true of exposure to radon in mines and in ordinary premises throughout areas where radon levels are high. With the relatively high dose rates experienced in air travel due to elevated levels of cosmic rays at flying altitudes, some consider that supervision is also required for air crew, although it is less clear to what extent their exposures can readily be reduced.

Many people who are exposed to radiation in their work wear personal monitoring devices (or dosimeters) such as a small photographic film or some thermo-luminescent material in a special holder. There is also increasing use of electronic devices for this purpose. These register the radiation incident on the body from external sources and yield an estimate of the dose received by the wearer.

For airborne activity in the workplace, whether of artificial or natural origin, it is usually best to sample the air that the worker breathes, measure it, and then estimate the internal dose. In some cases, it may be possible to measure activity in excreta and infer the dose or indeed measure the activity in the body directly with sensitive detectors. The objective always is to get the best possible estimate of dose.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. exposure to artificial sources of radiation;
ii. exposure to natural sources of radiation and
iii. average radiation exposure to public and workers.

3.0 Main Content

3.1 Artificial Sources

There are about 800 000 workers in the nuclear industry worldwide, and over 2 million workers exposed in medical facilities. UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) has compiled data on doses received by these workers and others such as industrial radiographers. The collective dose to nuclear industry workers is about 1400 man Sv (Sievert, unit of radiation absorption) while that for medical radiation workers is about 800 man Sv. There are fewer workers in industrial uses of radiation, therefore the collective dose is lower at about 400 man Sv. However, these workers get the highest individual doses in some countries.

The average dose overall to occupationally exposed workers from artificial sources is less than 1 mSv in a year. The average in the nuclear industry tends to be a little higher than this, while the average for medical staff is slightly less.

With the exception of mining, average doses from most types of occupational exposure from artificial sources, including the nuclear industry, are now below about 2 mSv in a year.

Doses in the health professions, medical, dental and veterinary are generally very low, but there are still matters of concern. Some clinical procedures with diagnostic radiology require the physician to be close to the patient and at risk of appreciable exposure. X ray equipment and procedures in veterinary practices are frequently inadequate.

3.2 Natural Sources

Occupational exposure to enhanced natural sources of radiation occurs mainly in mines, buildings and aircraft. Almost 4 million coal miners are monitored for radiation exposure. Fewer people (about a million worldwide) work in mines other than coal mines and in the processing of ores with levels of natural activity appreciably above average. The doses incurred are, nevertheless, monitored routinely.

Radon levels and doses are low in coal mines because the ventilation is usually good. Few if any miners exceed 15 mSv in a year. The state of ventilation in metal and other mines is not always as satisfactory, so the average dose is much higher and a fraction of the workforce does exceed this dose.

About one-fifth of the people considered to be occupationally exposed to enhanced natural radiation work in shops, offices, schools, and other premises in radon-prone areas. Within these areas, the average dose is appreciable. The average dose for such workers is almost 5 mSv per year — higher than for the other groups of occupationally exposed workers. However, it should be remembered that this group is unusual in that its members are identified, precisely because they receive high doses, rather than because they have the same occupation. Radon levels vary markedly from day to day because of the way buildings are heated and ventilated, so short measurements of radon in air may be misleading. The best remedy for high radon levels is the same as in houses, reduced air pressure under the floor.

Doses to aircrew from cosmic rays depend on the routes flown and the amount of flying time. On average, the annual dose is around 3 mSv, but it could be twice as much for long flights continually at high altitudes. By the nature of the radiation and the operations, such doses are unavoidable.

3.3 Average Radiation Exposure to Public and Workers

Generally, public exposure to radiation from natural sources dominates the total exposure. UNSCEAR estimated the average annual effective dose to an individual at about 3 mSv. On average, the annual dose from natural sources is 2.4 mSv and two thirds of it comes from radioactive substances in the air we breathe, the food we eat and the water we drink. The main source of exposure from artificial sources is radiation used in medicine, with an individual average annual effective dose of 0.62 mSv. Medical radiological exposure varies by region, country and health-care system. UNSCEAR has estimated the average annual effective dose from medical applications of radiation in industrialized countries at 1.9 mSv and in non-industrialized countries at 0.32 mSv. However, these values might vary considerably (e.g. in the United States with 3 mSv or in Kenya with only 0.05 mSv).

4.0 Summary

In this unit we have leant that:

i. The average dose overall to occupationally exposed workers from artificial sources is less than 1 mSv in a year.
ii. About one-fifth of the people considered to be occupationally exposed to enhanced natural radiation work in shops, offices, schools, and other premises in radon-prone areas.
iii. Doses in the health professions, medical, dental and veterinary are generally very low, but there are still matters of concern.

5.0 Conclusion

Exposure to ionizing radiation occurs in many occupations. Artificial sources of radiation are commonly used in the manufacturing and service industries etc. Some workers are also exposed to natural sources of radiation in such circumstances that a measure of supervision and protection is required. This is particularly true of exposure to radon in mines and in ordinary premises throughout areas where radon levels are high. Generally, public exposure to radiation from natural sources dominates the total exposure.

6.0 Tutor Marked Assignments

1. Explain how people are artificially exposed to radiation.
2. Relate mining and natural exposure to radiation.

7.0 References and other Resources

International Atomic Energy Agency (2004). Radiation, People and the Environment.

United Nations Environment Programme (2016). Radiation: effects and sources.

United Nations Scientific Committee on the Effects of Atomic Radiation (2000). Report on Sources and Effects of Ionizing Radiation to the General Assembly (2 Volumes), United Nations, Vienna, Austria.

United Nations Scientific Committee on the Effects of Atomic Radiation (2001) Report on Hereditary Effects of Radiation to the General Assembly, United Nations, Vienna, Austria.

UNIT 4: EFFECTS OF RADIOACTIVE MATERIALS

TABLE OF CONTENTS

1.0 Introduction

Hiroshima, Nagasaki, Three Mile Island, Chernobyl and Fukushima-Daiichi: these names have become associated with the public's fear of radiation, either from use of nuclear weapons or accidents at nuclear power plants. In fact, people are much more exposed daily to radiation from many other sources, including the atmosphere and the Earth as well as from applications used in medicine and industry. In 1955, nuclear weapon tests raised public concerns about the effects of atomic radiation on air, water and food. In response, the United Nations General Assembly established the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to collect and evaluate information on the levels and effects of radiation exposure.

Before going into more detail about the effects of radiation exposure, we should recall the pioneers in radiation science introduced earlier. Soon after Henri Becquerel's discovery, he himself experienced the most troublesome drawback of radiation—the effect it can have on living tissues. A vial of radium that he had put in his pocket damaged his skin. Wilhelm Conrad Roentgen, who discovered X-rays in 1895, died of cancer of the intestine in 1923. Marie Curie, who was also exposed to radiation throughout her working life, died of a blood disease in 1934. It is reported that by the end of the 1950s, at least 359 early radiation workers (mainly doctors and other scientists) had died from their exposure to radiation, unaware of the need for protection.

With the growing awareness of the risks associated with exposure to radiation, the twentieth century witnessed the development of intensive research on the effects of radiation on humans and the environment. The most important evaluation of population groups exposed to radiation is the study of approximately 86 500 survivors of the atomic bombings of Hiroshima and Nagasaki at the end of the Second World War in 1945 (henceforth referred to as the survivors of the atomic bombings). Further, reliable data on the subject comes from experience with irradiated patients, and with workers after accidental exposure (e.g. Chernobyl nuclear power plant accident), and from animal and cell experiments in laboratories.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. effects of radioactive materials on humans;
ii. effects of radioactive materials on animals and
iii. plants.

3.0 Main Content

3.1 Effects of Radioactive Materials on Human Health

Since the discovery of radiation, more than a century of radiation research has yielded extensive information on the biological mechanisms by which radiation can affect health. It is known that radiation can produce effects at the level of cells, causing their death or modification usually because of direct damage to deoxyribonucleic acid (DNA) strands in a chromosome. If the number of damaged or killed cells is large enough, it may result in organ dysfunction and even death. Also, other damage to DNA may occur that does not kill the cell. Such damage is usually repaired completely but if not, the resulting modification known as cell mutation will be reflected in subsequent cell divisions and may ultimately lead to cancer. If the cells modified are those transmitting hereditary information to descendants, genetic disorders may arise.

Information on biological mechanisms and on heritable effects is often gained from laboratory experiments.

On the basis of the observation of their occurrence, health effects following radiation exposure are defined here as either early or delayed health effects. Generally, early health effects are evident through diagnosis of clinical syndromes in individuals, and delayed health effects such as cancer through epidemiological studies by observation of increased occurrence of a pathology in a population. Further, special attention is paid here to effects on children and on embryos/fetuses, and to heritable effects.

3.1.1 Early health effects

Early health effects are caused by extensive cell death/damage. Examples are skin burns, loss of hair and impairment of fertility. These health effects are characterized by a relatively high threshold that must be exceeded over a short period before the effect occurs. The severity of the effect increases with increasing dose after the threshold has been exceeded.

Generally, acute doses higher than 50Gy (Gray, unit of absorbed dose) damage the central nervous system so badly that death occurs within a few days. Even at doses lower than 8Gy, people show symptoms of radiation sickness also known as acute radiation syndrome, which could include nausea, vomiting, diarrhoea, intestinal cramps, salivation, dehydration, fatigue, apathy, listlessness, sweating, fever, headache and low blood pressure. The term acute refers to medical problems that occur directly after exposure rather than ones that develop after a prolonged period. However, victims may survive at first only to die from gastrointestinal damage one to two weeks later. Lower doses may not inflict gastrointestinal injury but still cause death after a few months, mainly from damage to the red bone marrow. Still lower doses will delay the onset of sickness and produce less severe symptoms. About half of those who receive doses of 2Gy suffer from vomiting after about three hours, but this is rare for doses below 1Gy.

Fortunately, if the red bone marrow and the rest of the blood-forming system receive less than 1Gy, they have a remarkable capacity for regeneration and can completely recover—although there will be a higher risk of developing leukaemia in later years. If only part of the body is irradiated, enough bone marrow will normally survive unimpaired to replace what has been damaged. Animal experiments suggest that even if only a tenth of the active bone marrow escapes irradiation, the chances of survival are nearly 100 per cent.

The fact that radiation can directly damage cell DNA is applied to deliberately kill malignant cells with radiation in cancer treatment known as radiotherapy. The total amount of radiation applied in radiotherapy varies depending on the type and stage of cancer being treated. Typical doses for solid tumour treatments range from 20 to 80 Gy to the tumour, which would endanger the patient if delivered as a single dose. Thus, in order to control the treatment, radiation doses are applied in repeated fractions of maximally 2 Gy. This fractionation allows cells of normal tissue to recover, while tumour cells are killed because they are generally less efficient at repairing after radiation exposure.

3.1.2 Delayed health effects

Delayed health effects occur a long time after exposure. In general, most delayed health effects are also stochastic effects, i.e. for which the probability of occurrence depends on the radiation dose received. These health effects are believed to be caused by modifications in the genetic material of a cell following radiation exposure. Examples of delayed effects are solid tumours and leukaemia occurring in exposed persons and genetic disorders occurring in the offspring of persons who were exposed to radiation. The frequency of occurrence—but not the severity— of these effects in a population appears to increase with larger doses. Epidemiological studies are of great importance in understanding delayed health effects after radiation exposure. Such studies use statistical methods to compare the occurrence of a health effect (e.g. cancer) in an exposed population with that in an unexposed population. If a considerable increase is found in the exposed population, it may be that it is associated with the radiation exposure for the population as a whole. The most important long-term evaluation of populations exposed to radiation is the epidemiological study of the survivors of the atomic bombings. This is the most comprehensive study ever conducted becauseof the large number of people, essentially representative of the general population, receiving a wide variety of doses spread fairly evenly over the body. Estimates of the doses received by this group are also relatively well known. So far, the study has revealed a few hundred more cancer cases than would be expected in this group if they had not been exposed to radiation. Because many of the survivors of the atomic bombings are still alive, studies are continuing in order to complete the evaluation.

3.1.3 Cancer

Cancer is responsible for about 20 per cent of all fatalities and is the most common cause of death in industrialized countries after cardiovascular disease. About four out of ten persons in the general population are expected to develop cancer during their lifetime even in the absence of radiation exposure. In recent years, the most common cancers among men have been lung, prostate, colorectum, stomach, and liver cancer and among women they have been breast, colorectum, lung, cervix, and stomach cancer.

The development of a cancer is a complex process, consisting of a number of stages. An initiating phenomenon, most probably affecting a single cell, appears to start the process, but a series of other events seem to be necessary before the cell becomes malignant and the tumour develops. Cancer becomes evident only long after the first damage is done, following a period of latency. The probability of cancer occurring following radiation exposure is a major concern and could be calculated for a group if it were exposed to a sufficiently high level of radiation to cause an increased occurrence of cancer that would overcome the statistical and other uncertainties. However, the real contribution of radiation as a cause of cancer remains unknown.

Leukaemia, thyroid cancer and bone cancer first appear within a few years of exposure to radiation, while most other cancers are not expressed until at least 10 years, often several decades, after exposure. However, no single type of cancer is uniquely caused by exposure to radiation so it is impossible to distinguish radiation-induced tumours from those arising from many other causes. Nevertheless, it is important to estimate the probability of getting cancer after certain doses of radiation in order to provide a sound scientific basis for setting exposure limits.

3.1.4 Other health effects

High radiation doses to the heart increase the probability of cardiovascular diseases (e.g. heart attacks). Such exposure may happen during radiotherapy, although treatment techniques nowadays result in lower cardiac doses. However, there is no existing scientific evidence to conclude that exposure to low doses of radiation causes cardiovascular diseases.

UNSCEAR recognized that there was an increased occurrence of cataracts among Chernobyl emergency workers, possibly associated with high doses of radiation. Further, UNSCEAR has also studied the effects of radiation on the human immune system in survivors of the atomic bombings, in emergency workers at the Chernobyl nuclear power plant and in patients undergoing radiotherapy treatment. The effects of radiation on the immune system are assessed by estimating changes in cell numbers or by using a variety of functional analyses. High doses of radiation suppress the immune system mainly because of damage to lymphocytes. Their reduction is currently used as an early indicator to determine the radiation dose after acute exposure.

3.1.5 Effects on offspring

If radiation damage occurs in reproductive cells, the sperm or ovum, it can lead to heritable effects in descendants. Moreover, radiation can directly damage an embryo or fetus already developing within the womb. It is important to distinguish between radiation exposure of adults, children and embryos/fetuses. UNSCEAR has conducted comprehensive reviews of health effects, including heritable effects, in these groups.

3.1.6 Effects on children

Health effects in humans depend upon a number of physical factors. Because of their anatomical and physiological differences, the impacts of radiation exposure on children and on adults are different. Further, because children have smaller bodies and are less shielded by overlying tissues, the dose to their internal organs will be higher than that for adults for a given external exposure. Also, children are shorter than adults, so they may receive higher doses from radionuclides deposited on the ground. Regarding internal exposure, because of the smaller size of children, and because their organs are, thus, closer together, radionuclides concentrated in one organ irradiate other organs more than would be the case for adults. There are also many other age-related factors involving metabolism and physiology that make a substantial difference in dose at different ages. Several radionuclides are of particular concern regarding internal exposure of children. Accidents involving releases of radioactive iodine-131 can be significant sources of exposure of the thyroid. For a given intake, the dose to the thyroid for infants is about nine times higher than that for adults. Studies of the Chernobyl nuclear power plant accident have confirmed the link between thyroid cancer and iodine-131, which concentrates mainly in this organ.

Epidemiological studies have shown that young people under 20 years of age appear to be about twice as likely as adults to develop leukaemia following the same radiation exposure. Further, children under 10 years are particularly susceptible; some other studies suggest that they are three to four times more likely to die of leukaemia than adults. Other studies have also shown that girls exposed at under 20 years of age are about twice as likely to develop breast cancer as adult women. Children are more likely than adults to develop cancer after radiation exposure, but it may not emerge until later in life when they reach an age at which the cancer normally becomes evident.

3.1.7 Effects on the unborn child

An embryo or fetus can be exposed through radioactive material transferred by the mother via food and drink (internal exposure) or directly through external exposure. Because a fetus is protected in the uterus, its radiation dose tends to be lower than the dose to its mother for most radiation exposure events. However, the embryo and fetus are particularly sensitive to radiation, and the health consequences of exposure can be severe, even at radiation doses lower than those that immediately affect the mother. Such consequences can include growth retardation, malformations, impaired brain function and cancer.

3.2 Effects on Animals and Plants

Effects of radiation exposure on animals and plants are receiving more attention than previously. In past decades, the prevailing view was that if human life were adequately protected, both plants and animals would be similarly protected. UNSCEAR evaluated the effects of radiation exposure on plants and animals and found that a theoretical dose range of 1–10 Gy was unlikely to result in effects on animal and plant populations and that individual responses to radiation exposure varied (mammals are the most sensitive of all animals). Those effects that are likely to be significant at the population level concern fertility, mortality and the induction of mutations. Reproductive changes, such as in the numbers of offspring, are a more sensitive indicator of radiation effects than mortality.

Lethal doses represent doses at which 50 per cent of the exposed subjects would die. For plants exposed in a relatively short time (acute), these have been noted to range from less than 10 to about 1000 Gy. In general, larger plants are more radiosensitive than smaller ones. Lethal doses range from 6 to 10 Gy for small mammals and are about 2.5 Gy for larger ones. Some insects, bacteria and viruses can tolerate doses of over 1000 Gy.

4.0 Summary

In this unit we have leant that:

i. Epidemiological studies have shown that young people under 20 years of age appear to be about twice as likely as adults to develop leukaemia following the same radiation exposure.

ii. Leukaemia, thyroid cancer and bone cancer first appear within a few years of exposure to radiation, while most other cancers are not expressed until at least 10 years, often several decades.

iii. High radiation doses to the heart increase the probability of cardiovascular diseases (e.g. heart attacks).

5.0 Conclusion

Since the discovery of radiation, more than a century of radiation research has yielded extensive information on the biological mechanisms by which radiation can affect health.
If radiation damage occurs in reproductive cells, the sperm or ovum, it can lead to heritable effects in descendants.

6.0 Tutor Marked Assignments

1. Discuss the health implication of radioactive material on the unborn child.
2. Discuss early health effects of radiation on humans.

7.0 References and other Resources

United Nations Environment Programme (2016). Radiation: effects and sources.

UNIT 5: CONTROL AND PREVENTION OF RADIOACTIVE POLLUTION

TABLE OF CONTENTS

1.0 Introduction

Areas in various parts of the world have become contaminated with radionuclides as a result of various human activities. In cases where the level of contamination is high, measures might be needed to ensure that the area is safe for people to live or use for other purposes. For small areas, it might be possible to do this by removing contaminated soil and other materials, but for large areas the amount of material would be too large.

Other ways of protecting people include restrictions on access to or use of areas, for example, preventing house building on areas affected by mining wastes that could produce high radon levels. Chemical treatments can also be used to reduce the amount of activity that gets from soil into food. Examples of this include giving 'Prussian blue', a chemical that increases the rate at which caesium is excreted by the cow so that it does not get into milk and meat to cows grazing on contaminated grass in the Chernobyl area and treating the soil on Bikini Island with potassium to stop the trees absorbing caesium.

2.0 Objectives

By the end of this unit, student should be able to understand:

i. proper radioactive waste management;
ii. decommissioning and
iii. other radioactive/control measures.

3.0 Main Content

3.1 Radioactive Pollution Control/Preventive Measures

Some of the measures which can be used to control or prevent radioactive pollution are listed below:

3.1.1 Establishment of restricted areas

In the case of accidents where there has been significant local contamination, the local doses can be significantly greater than the dose constraint. Where appropriate, measures are taken to minimize doses to people, such as the establishment of restricted areas in the vicinity of Chernobyl. Following the nuclear accident at Chernobyl, over 100 000 people were moved from their homes in what are now Belarus, Ukraine and the Russian Federation, and various areas became "restricted" because of the levels of fallout on the ground. A vast clean-up operation was mounted at the Chernobyl reactor site itself involving over 750 000 people. Such measures can reduce both the individual and collective doses substantially.

3.1.2 Proper radioactive waste management

The aims of waste management are to process the wastes in such a way as to make them suitable for storage and disposal, and to store or dispose of them so that there are no unacceptable risks to present and future generations. Here disposal implies simply that there is no intention to retrieve them, rather than that it would be impossible to do so.

In many countries, short lived waste is disposed of in near surface repositories, which are normally either lined trenches several metres deep or concrete ‘vaults’ constructed on or just below the ground surface. The disposed waste is covered with a few metres of earth, and often a clay cap to keep water out. A similar disposal method is used in some countries for the disposal of large amounts of NORM (Naturally Occurring Radioactive Material) waste, such as tailings from the mining and milling of uranium. For example, Sweden operates a repository under the bed of the Baltic Sea at Forsmark for its more active (but mostly short lived) low/intermediate level waste.

Many low/intermediate level wastes do not occur in a form that is immediately suitable for disposal; they have to be mixed into an inert material such as concrete, bitumen or resin. In the past, some countries disposed of these wastes into the ocean, but since that has been prohibited by the London Convention, these wastes are normally stored awaiting decisions on the method of disposal. Among the most likely options is a repository deep underground in good geological conditions. Although many countries have plans for geological repositories of this type, only the USA is currently operating one, the Waste Isolation Pilot Plant (WIPP) in New Mexico, for wastes containing actinides. Where the intention is to dispose of spent nuclear fuel directly rather than reprocess it, the spent fuel is stored, either at reactor sites or in special central facilities. This is partly to allow the fuel to cool, but clearly it must continue until a disposal facility is available. High level liquid waste from reprocessing operations is normally kept in special cooled tanks, but facilities to solidify it by incorporation in vitreous material are being built. The glass blocks will be stored for several decades to allow them to cool before eventual disposal, probably deep underground.

3.1.3 Decommissioning

Decommissioning is the process that takes place at the end of the working life of a nuclear facility (or part of a facility), or any other place where radioactive materials were used, to bring about a safe long term solution. This might include decontaminating equipment or buildings, dismantling facilities or structures, and removing or immobilizing remaining radioactive materials. In many cases, the ultimate objective is to clear the site of all significant radioactive residues, but this is not always possible or necessary.

Till date, relatively few full scale commercial nuclear facilities have been completely decommissioned. However a great deal of experience has been gained from the decommissioning of a wide variety of facilities, including a few nuclear power plants, several prototype and research reactors, and many laboratories, workshops, etc. The fact that many nuclear reactors around the world are approaching the end of useful life has focused attention on the issues associated with decommissioning.

Decommissioning requires strict control of operations to optimize the protection of workers and the public. For dealing with the most radioactive parts of facilities, particularly reactor cores, remote handling techniques have been developed. Dismantling of large facilities also generates large volumes of ‘waste’. Some of this will be low/intermediate level radioactive waste and needs to be managed accordingly. However, there may also be large amounts of structural materials such as steel and concrete that are not significantly radioactive. Special procedures may be needed to 'clear' such materials as exempt, meaning that they do not have to be treated as radioactive waste.

3.1.4 Proper labeling

It is necessary for any material with radioactive content to be labeled, and the necessary precautions advised on the content of the label. The reason for this is because radiation can enter the body by a mere touch of radioactive material. Containers with such elements should be well labeled in order to make one use protective gear when handling them.

3.1.5 Alternative energy sources

The evolution and use of nuclear power was not a bad thing initially. However, considering the damage and threats it has on the environment, it is high time for its use to be discontinued and for the world to perhaps focus on alternative and environmentally friendly energy sources like renewable sources of energy namely solar, hydro-electric and wind power. The use of radioactivity to generate energy in nuclear power plants, for example, leads to the production of more radiation to the atmosphere considering the waste released from the various processes and combustion.

3.1.6 Proper storage

It is mandatory for containers carrying radioactive material to be stored properly. For starters, such substances should be stored in radiation proof containers to ensure no seeping or leakage during handling. Proper storage means no harm and can minimize cases of accidental leakage.

3.1.7 Efficient transport of radioactive materials

Radioactive materials are routinely transported all around the world by air, sea, road and rail. These materials include those associated with the nuclear fuel cycle from uranium ores to spent fuel and radioactive waste but also radionuclides for nuclear medicine and research, and radioactive sources for industry and radiotherapy. Although the safety record of these transports is excellent, they sometimes cause concern in the areas through which they pass. For example, a number of countries have expressed particular concern about ships carrying radioactive waste passing through or close to their territorial waters.
Regulations are, therefore, needed not just to ensure that the chances of an accident, which could result in radioactive material being dispersed in the environment, are kept to a minimum, but also to ensure that the workers involved in transport including those loading and unloading shipments as well as drivers/pilots are protected.

The IAEA (International Atomic Energy Agency) Regulations for the Safe Transport of Radioactive Material were first published in 1961 and have been revised periodically since. The Regulations govern the necessary packaging, shielding, labelling and other precautions that must be taken when transporting various types of radioactive material, including tests that packages must undergo to prove that they can withstand possible accidents. The requirements are graded according to the level of activity of the materials to be transported. In general, more hazardous radioactive materials need more extensive and more robust packaging and stricter quality and administrative controls. The IAEA's Transport Regulations are widely accepted as the global standard for the transport of radioactive materials. In some cases, the Agency's Regulations are incorporated into national laws or regulations. Other countries write their own regulations governing transport of radioactive materials, but make them consistent with the IAEA Regulations. Another way in which the Agency's Regulations are applied is through international regulations on the transport of hazardous goods. The regulations for the different modes of transport are issued by different organizations, particularly the International Civil Aviation Organization (ICAO) for air transport, the International Maritime Organization (IMO) for transport by sea, and regional organizations such as the Inland Transport Committee of the UN Economic Commission for Europe for transport by land and inland waterways. These organizations' regulations cover all types of hazardous material, and the parts that deal with radioactive materials are based on the IAEA Transport Regulations.

4.0 Summary

In this unit we have leant that:

i. It is necessary for any material with radioactive content to be labeled, and the necessary precautions advised on the content of the label.
ii. Decommissioning is the process that takes place at the end of the working life of a nuclear facility (or part of a facility).
iii. It is mandatory for containers carrying radioactive material to be stored properly. Proper storage means no harm and can minimize cases of accidental leakage.

5.0 Conclusion

In areas contaminated with radioactive materials, measures might be needed to ensure that the area is safe for people to live or use for other purposes. In the case of accidents where there has been significant local contamination, the local doses can be significantly greater than the dose constraint. Where appropriate, measures are taken to minimize doses to people, such as the establishment of restricted areas in the vicinity of Chernobyl.

6.0 Tutor Marked Assignments

1. Identify and explain five ways of preventing radioactive pollution.
2. Explain how decommissioning is carried out.

7.0 References and other Resources

International Atomic Energy Agency (2004). Radiation, People and the Environment.

Radioactive Pollution: Causes, Effects and Solutions to Nuclear Radiation. https://www.conserve-energy-future.com/radioactive-pollution-causes-effects-solutions.php. Accessed 21.07.2020.

General Observations

The inputs to this section is insignificant, it is basically minor syntax and readjustment of the summary before conclusion, this is due to a indepth search and wide consultations made into the preparation of the write-up