



Environmental Engineering

Course Code: CIW 333



For Third Year Students-Civil Department

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CHAPTER ONE

The Environment



The Environment

1. Introduction

All the external factors that affect an organism could be defined as **environment**. These factors may be other living organisms or nonliving variables, such as water, soil, climate, light and oxygen.

The environment is never static. Physical forces continuously change the surface of the earth through weather, the action of waves and natural phenomena such as volcanoes. At the same time they introduce gases, vapor and dust into the atmosphere. Living organisms also play a dynamic role through respiration, excretion and ultimately death and decay, recycling their constituent elements through the environment.

Environmental engineering is the application of science and engineering principles to improve the natural environment (air, water and land resources) to provide healthy water, air and land for human habitation (house or home) and for other organisms and to remediate polluted sites. It involves waste water management and air pollution control, recycling, waste disposal, radiation protection, industrial hygiene, environmental sustainability and public health issues as well as knowledge of environmental engineering law. It also includes studies on the environmental impact of proposed construction projects.

Just as the familiar substances of our physical universe are divided into solids, liquids and gases, for convenience our physical environment can be divided into the **atmosphere**, the **geosphere**, the **hydrosphere**, the **biosphere**, the **anthroposphere** and all the **fauna** and **flora**. This is illustrated as follows using the various compartments of the environment as “separate” entities.

1.1. The Atmosphere

The atmosphere is the gaseous envelope that surrounds the solid body of the planet. Although it has a thickness of more than 1100 km about half its mass is concentrated in the lower 5.6 km.

The atmosphere:

- is a protective blanket which nurtures life on the Earth and protects it from the hostile environment of outer space.
- is the source of carbon dioxide for plant photosynthesis and of oxygen for respiration.
- provides the nitrogen that nitrogen-fixing bacteria and ammonia-manufacturing industrial plants use to produce chemically-bound nitrogen, an essential component of life molecules.
- transports water from the oceans to land, thus acting as the condenser in a vast solar powered still.
- serves a vital protective function, absorbing harmful ultraviolet radiation from the sun and stabilizing Earth's temperature.

1.2. The Hydrosphere

The hydrosphere is the layer of water that, in the form of the oceans, covers approximately 70.8 percent of the surface of the earth.

Water :

- covers about 70% of Earth's surface and over 97 % of this water exists in oceans.
- occurs in all spheres of the environment—in the oceans as a vast reservoir of salt water, on land as surface water in lakes and rivers, underground as groundwater, in the atmosphere as water vapor, in the polar ice caps as solid ice and in many segments of the anthrosphere such as in boilers or municipal water distribution systems.
- is an essential part of all living systems and is the medium from which life evolved and in which life exists.

- carries energy and matter are through various spheres of the environment.
- leaches soluble constituents from mineral matter and carries them to the ocean or leaves them as mineral deposits some distance from their sources.
- carries plant nutrients from soil into the bodies of plants by way of plant roots.
- absorbs solar energy in oceans and this energy is carried as latent heat and released in land when it evaporates from oceans. The accompanying release of latent heat provides a large fraction of the energy that is transported from equatorial regions toward Earth's poles and powers massive storms.

1.3. The Geosphere

The **geosphere**, is that part of the Earth upon which humans live and from which they extract most of their food, minerals and fuels. It is divided into layers, which include the solid, iron-rich inner core, molten outer core, and the lithosphere – which consists of the upper mantle and the crust.

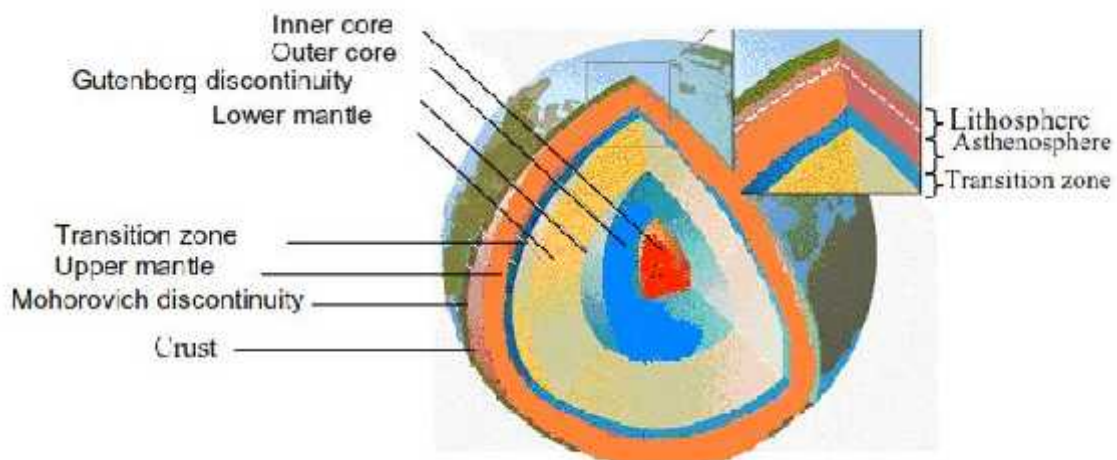


Fig. 1 Inner structure of the earth.

Environmental science is most concerned with the **lithosphere**.

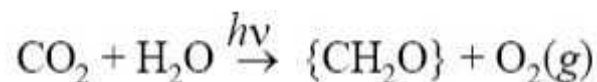
- The **lithosphere**, extends to depths of 100 km and comprises two shells—the **crust** and **upper mantle**.
- The **crust** (the earth's outer skin) is the layer that is accessible to humans and is extremely thin compared to the diameter of the earth, ranging from 5 to 40 km thick.

1.4. The Biosphere

The Biosphere is the earth's relatively thin zone of air, soil and water that is capable of supporting life, ranging from about 10 km into the atmosphere to the deepest ocean floor. Life in this zone depends on the sun's energy and on the circulation of heat and essential nutrients.

The biosphere

- is virtually contained by the geosphere and hydrosphere in the very thin layer where these environmental spheres interface with the atmosphere.
- strongly influences and in turn is strongly influenced by the other parts of the environment.
- strongly influence bodies of water, producing biomass required for life in the water and mediating oxidation-reduction reactions in the water.
- is involved with weathering processes that break down rocks in the geosphere and convert rock matter to soil.
- is based upon plant photosynthesis, which fixes solar energy ($h\nu$) and carbon from atmospheric CO_2 in the form of high-energy biomass, represented as $\{\text{CH}_2\text{O}\}$:



1.5. The Anthroposphere

This is a name given to that part of the environment "made" or modified by humans and used for their activities. Of course, there are some ambiguities associated with this definition. Clearly, a factory building used for manufacturing is part of the anthroposphere, as is an ocean going ship used to ship goods made in the factory. The ocean on which the ship moves belongs to the hydrosphere, but it is clearly used by humans.

The anthroposphere

- is a strongly interconnection to the biosphere.

- has strongly influenced the biosphere and change it drastically. For example, destruction of wild life habitat has resulted in the extinction of vast numbers of species, in some cases even before they are discovered; bioengineering of organisms with recombinant DNA technology and older techniques of selection and hybridization are causing great changes in the characteristics of organisms and promise to result in even more striking alterations in the future.
- It is the responsibility of human kind to make such changes intelligently and to protect and nurture the biosphere.

1.6. The Flora and Fauna

The terms fauna and flora are collective names given to animals and plants respectively. There is a continuous interaction between the various sections of the environment and the flora and fauna. An assembly of mutually interacting organisms and their environment in which materials are interchanged in a largely cyclical manner is known as ecosystem. The environment in which a particular organism lives is called habitat.

We have thus far discussed the different parts of the atmosphere. Although for the convenience of our study we divided the environment into different sections, there exists an unbounded interaction between these parts. All parts of the environment are subjected to drastic change due to human overuse of natural resources.

2. Natural Resources Consumption

In the last two and half century, the industrial revolution has changed the face of the planet by natural resources at an alarming rate, especially fossil fuel. Every year natural resources consumption is rising as the human population increases and standards of living rise.

Following we shall discuss possible environmental consequences accompanying the over consumption of the natural resources: fossil fuel, forest wood, water, land and energy by humans.

2.1. Fossil Fuel

Fossil Fuels, which include petroleum, coal, and natural gas, are energy-rich substances that have formed from long-buried plants and microorganisms. They provide most of the energy that powers modern industrial society. The gasoline that fuels our cars, the coal that powers many electrical plants and the natural gas that heats our homes are all fossil fuels.

Fossil fuels are largely composed of hydrocarbons which are formed from ancient living organisms that were buried under layers of sediment millions of years ago. These fuels are extracted from the earth's crust and refined into suitable fuel products, such as gasoline, heating oil, and kerosene. Some of these hydrocarbons may also be processed into plastics, chemicals, lubricants and other non-fuel products. The most commonly used fossil fuels are petroleum, coal and natural gas.

Once extracted and processed, fossil fuel can be burned for direct uses, such as to power cars or heat homes, or it can be combusted for the generation of electrical power.

What are the consequences?

Within the last century, the amount of carbon dioxide in the atmosphere has increased dramatically, largely because of the practice of burning fossil fuels. This has resulted in an increase in global temperature. The consequences of such an increase in temperature may well be dangerous. Sea levels will rise, completely inundating a number of low-lying island nations and flooding many coastal cities. Many plant and animal species may probably be forced to go into extinction, agricultural regions will be disrupted and the frequency of droughts is likely to increase.

2.2. Forest Wood

Forests are very important for maintaining ecological balance and provide many environmental benefits. In addition to timber and paper products, forests provide wildlife habitat, prevent flooding and soil erosion,

help provide clean air and water, and contain tremendous biodiversity. Forests are also an important defense against global climate change. Forests produce life-giving oxygen and consume carbon dioxide, the compound most responsible for global warming through photosynthesis, thereby reducing the effects of global warming.



Fig. 2. Deforestation causes desertification (A) A conserved forest (B).

Forests provide habitat for a wide variety of plants and animals and perform many other important functions that affect humans. The forest canopy (the treetops) and root systems provide natural filters for the water we use from lakes and rivers. When it rains the forest canopy intercepts and redistributes precipitation that can cause flooding and erosion, the wearing away of topsoil. Some of the precipitation flows down the trunks as stem flow, the rest percolates through the branches and foliage as throughfall. The canopy is also able to capture fog, which it distributes into the vegetation and soil. Forests also increase the ability of the land to store water.

2.3. Soil

Soil, a mixture of mineral, plant and animal materials, is essential for most plant growth and is the basic resource for agricultural production. In the process of developing the land and clearing away the vegetation that holds water and soil in place, erosion has devastated soils worldwide. The rapid deforestation taking place in the tropics is especially damaging because the thin layer of soil that remains is fragile and quickly washes away when

exposed to the heavy tropical rains. Globally, agriculture accounts for 28 percent of the nearly 2 billion hectares of soil that have been degraded by human activities; overgrazing is responsible for 34 percent and deforestation is responsible for 29 percent.

2.4. Water

Clean fresh water resources are essential for drinking, bathing, cooking, irrigation, industry and for plant and animal survival. Due to over use, pollution, and ecosystem degradation the sources of most fresh water supplies—groundwater (water located below the soil surface), reservoirs and rivers—are under severe and increasing environmental stress. Over 95 percent of urban sewage in developing countries is discharged untreated into surface waters such as rivers and harbors.

About 65 percent of the global freshwater supply is used in agriculture and 25 percent is used in industry. Fresh water conservation therefore requires a reduction in wasteful practices like inefficient irrigation, reforms in agriculture, industry and strict pollution controls worldwide.

2.5. Energy

Human being used to produce and use energy throughout history. Humans use energy for industrial production, transportation, heating, cooling, cooking and lighting. The world energy supply depends on different resources. Traditional fuels such as firewood and animal waste for example, are significant energy sources in many developing countries. Fossil fuels account for more than 90 percent of global energy production but their use causes air pollution and are considered to be problematic resources.

One of the most significant factors that aggravated environmental degradation is population growth. The demand for additional food and shelter that accompany population growth will enhance deforestation, cultivation of more land, the use of fertilizers, damming of rivers, and urbanization. These activities will subsequently contribute global ecological imbalance and

environmental pollution. In the following subunit we shall briefly discuss on the impacts of population growth on the environment.

3. Population Increase and the Environment

The world population is increasing at an alarming rate. From 1930 to present it rose from 2 billion to 5.3 billion. And it is expected to rise again to over 8 billion in 2050. The demands of increasing population coupled with the desire of most people for a higher material standard of living are resulting in worldwide pollution on a massive scale.

Environmental problems have led to shortages of food, clean water, materials for shelter and other essential resources. As forests, land, air and water are degraded, people who live directly off these natural resources suffer most from the effects.

Global environmental degradation may result from a variety of factors, including overpopulation and the resulting overuse of land and other resources. Intensive farming, for instance, depletes soil fertility, thus decreasing crop yields. Environmental degradation also results from pollution. Polluting industries include mining, power generation and chemical production. Other major sources of pollution include auto-mobiles and agricultural fertilizers.

In developing countries, deforestation has had particularly devastating environmental effects. Many rural people, particularly in tropical regions, depend on forests as a source of food and other resources, and deforestation damages or eliminates these supplies. Forests also absorb many pollutants and water from extended rains; without forests, pollution increases and massive flooding further decreases the usability of the deforested areas.

Poor land management and increasing population are factors that promote increased irrigation, improper cultivation or overcultivation, and increased numbers of lives- tock. These events alter the land and the soil, diminish the resources, and increase the chances of desertification.

Over the last few years urbanization of rural areas has increased. As agriculture, more traditional local services, and small-scale industry give way to modern industry the urban and related commerce with the city drawing on the resources of an ever-widening area for its own sustenance and goods to be traded or processed into manufactures. Urbanization is among the most significant factors that aggravated environmental degradation. In the following subunit we shall briefly discuss on the impacts of urbanization on the environment.

4. Urbanization and the Environment

Demographically, the term urbanization denotes redistribution of populations from rural to urban settlements. The 20th century has witnessed a rapid urbanization of the world's population. The global proportion of urban population rose dramatically from 13% (220 million) in 1900, to 49% (3.2 billion) in 2005. It is also projected that the figure is likely to rise to 60% (4.9 billion) by 2030.

Urbanization occurs naturally from an effort to improve opportunities for jobs, education, housing and transportation and reduce expenses in commuting and transportation. Living in cities permits individuals and families to take advantage of the opportunities of proximity, diversity and market place competition. With proper planning and long-term vision, dense settlement patterns offer economies of scale that can actually reduce pressures on natural resources from population growth and increase energy efficiency. Since people live close together and need less space in cities, each person requires less critical infrastructure like sewers, electricity, and roads than in decentralized human settlements. However, along with the above social and economic benefits of urbanization comes a number of environmental ills.

In recent decades, valuable farmlands have faced a new threat posed by the urbanization of rural areas. Prime agricultural land has been turned into subdivisions and paved over to create parking lots and streets. Increasing

urban sprawl has led to the need for more highways. In a vicious continuing circle, the availability of new highway systems has enabled even more development. The final result of this pattern of development has been the removal of once productive farm land from agricultural use.

The world's cities account for 75 percent of global energy consumption, 80 percent of greenhouse gas emissions and a disproportionate share of resource use, such as food, timber and steel. Due to this most cities in the world experience the worst urban air pollution as a result of rapid industrialization and increased motorized transport. Worldwide, urban air pollution is estimated to cause one million premature deaths each year.

5. Industrialization and the Environment

The world population is increasing at an alarming rate. From 1930 to present it rose from 2 billion to 5.3 billion. And it is expected to rise again to over 8 billion in 2050. The demands of the increasing population coupled with the desire of most people for a higher material standard of living has intensified industrialization. These industrial activities, aided by modern technologies, provide the food, shelter and goods that humans need for their well-being and survival.

Industrial manufacturing processes may consist of the synthesis of a chemical from raw materials, casting of metal or plastic parts, or any of the other things that is needed to produce a certain product. Each of these processes carries with it the potential to cause significant air and water pollution and production of hazardous wastes. The earlier in the design and development process that environmental considerations are taken into account, the more “environmentally friendly” a manufacturing process will be.

Over the past 30 years, industrial production has been a major source of pollution in urban areas and a significant driver of intensified resource use.

5.1. Environmental Pollutions Resulting from Industrialization

5.1.1. Smog and Acid Precipitation

Most air pollution comes from one human activity: burning fossil fuels—natural gas, coal and oil—to power industrial processes and motor vehicles. This results in the emission of harmful chemical compounds such as carbon dioxide, carbon monoxide, nitrogen oxides, sulfur dioxide, and tiny solid particles—including lead from gasoline additives—called particulates. Various volatile organic chemicals (VOCs), generated from incompletely burned fuels, also enter the air.

Carbon dioxide is one of the green house gases which contribute significantly to global warming. Sulfur dioxide and nitrogen oxide emissions are the principal causes of acid rain in many parts of the world. Sulfur dioxide and nitrogen oxides emitted into the atmosphere, are absorbed by rain to form sulphuric acid and nitric acid. These acids are bad for the lungs and attack anything made of limestone, marble, or metal.

Smog is a type of air pollution produced when sunlight acts upon motor vehicle exhaust gases to form harmful substances such as ozone (O₃), aldehydes and peroxyacetylnitrate (PAN). Before the automobile age, most smog came from burning coal. Burning gasoline in motor vehicles is the main source of smog in most regions today.

Powered by sunlight, oxides of nitrogen and volatile organic compounds react in the atmosphere to produce photochemical smog. Ozone in the lower atmosphere is a poison it damages vegetation, kills trees, irritates lung tissues, and attacks rubber.

Smog spoils views and makes outdoor activity unpleasant. The effects of smog are even worse for the very young and the very old people who suffer from asthma or heart disease. Smog can cause breathing difficulties, headaches and dizziness. In extreme cases, smog can lead to mass illness and death, mainly from carbon monoxide poisoning.

5.1.2. Soil and water pollution

The agriculture and mining industries have profoundly contributed to soil and water pollution. Agriculture has rapidly changed vast forest and grassland areas into cropland.

Mining disturbs groundwater aquifers. Water seeping through mines and mine tailings may become polluted. Pyrite, FeS_2 , is a mineral that is commonly associated with coal. In coal mining, one of the more common and damaging effects on water occurs when this mineral is exposed to air and becomes oxidized to sulphuric acid by bacterial action to produce acid mine water.

While processing mined materials various beneficiation processes are employed to separate the useful fraction of the ore, leaving a residue of tailings which are laden with various chemicals which pollute the soil and water bodies in the surrounding. For example, residues left from the beneficiation of coal are often enriched in pyrite FeS_2 , which is oxidized microbiologically and chemically to produce damaging acidic drainage (acid mine water) which can pollute the soil, surface water and underground water.

5.1.3. Modifications of the Climate

Human activities are reaching a point at which they may be adversely affecting the climate. Global warming, due to the emission of large quantities of carbon dioxide and other greenhouse gases into the atmosphere has resulted in substantial climatic change. Another way is through the release of gases, particularly chlorofluorocarbons (Freons) that may cause destruction of vital stratospheric ozone.

CHAPTER TWO

Atmospheric Chemistry & Air Pollution



Atmospheric Chemistry and Air Pollution

1. Atmospheric Chemistry

Pollution is changing Earth's atmosphere so that it lets in more harmful radiation from the sun. The temperature increase, known as global warming, is predicted to affect world food supply, alter sea level, make weather more extreme and increase the spread of tropical disease.

You are expected to contribute your part to the solution of the current globally burning issue of atmospheric pollution. You should be able to describe the composition of the atmosphere, the major contributors to atmospheric pollution and the way these pollutants are accumulated in the atmosphere. In this unit, we shall discuss the chemistry of the atmosphere and the major pollutants of the atmosphere, describe the way these pollutants are formed and accumulated in the atmosphere and the threat posed by the pollutants.

1.1. Introduction

Atmospheric chemistry: is a branch of atmospheric science in which the chemistry of the earth's atmosphere and that of other planets is studied.

The composition of the atmosphere is of importance for several reasons, but because of the interactions between the atmosphere and living organisms. The composition of the atmosphere has been changed by human activity and some of these changes are harmful to human health, crops and ecosystems. Examples of problems which have been addressed by atmospheric chemistry include acid rain, photochemical smog and global warming. Atmospheric chemistry seeks to understand the causes of these problems and by obtaining a theoretical understanding of them, allow possible solutions to be tested and the effects of changes in government policy evaluated.

1.2. Earth's Atmosphere

Earth's atmosphere is a layer of gases surrounding the planet Earth and retained by the Earth's gravity. It contains roughly 78% nitrogen, 21% oxygen, 0.93% argon, 0.04% carbon dioxide and trace amounts of other gases, in addition to water vapor. This mixture of gases is commonly known as air. The atmosphere protects life on earth by absorbing solar UV radiation and reducing temperature extremes between day and night.

The gases ozone, water vapor and carbon dioxide are only minor components of the atmosphere, but they exert a huge effect on the earth by absorbing radiation. Ozone in the upper atmosphere filters out the ultraviolet light below about 360 nm that is dangerous for living things. In the troposphere ozone is an undesirable pollutant. It is toxic to animals and plants, and it also damages materials.

The atmosphere slowly becomes thinner and fades away into space. Therefore, there is no definite boundary between the atmosphere and outer space. Seventy five percent of the atmosphere's mass is within 11 km of the planetary surface.

1.3. Temperature and the Atmospheric Layers

Although atmospheric pressure decreases in a regular way at higher altitudes the profile of temperature versus altitude is much more complex. The temperature of the earth's atmosphere varies with altitude and the mathematical relationship between temperature and altitude varies between the various atmospheric layers:

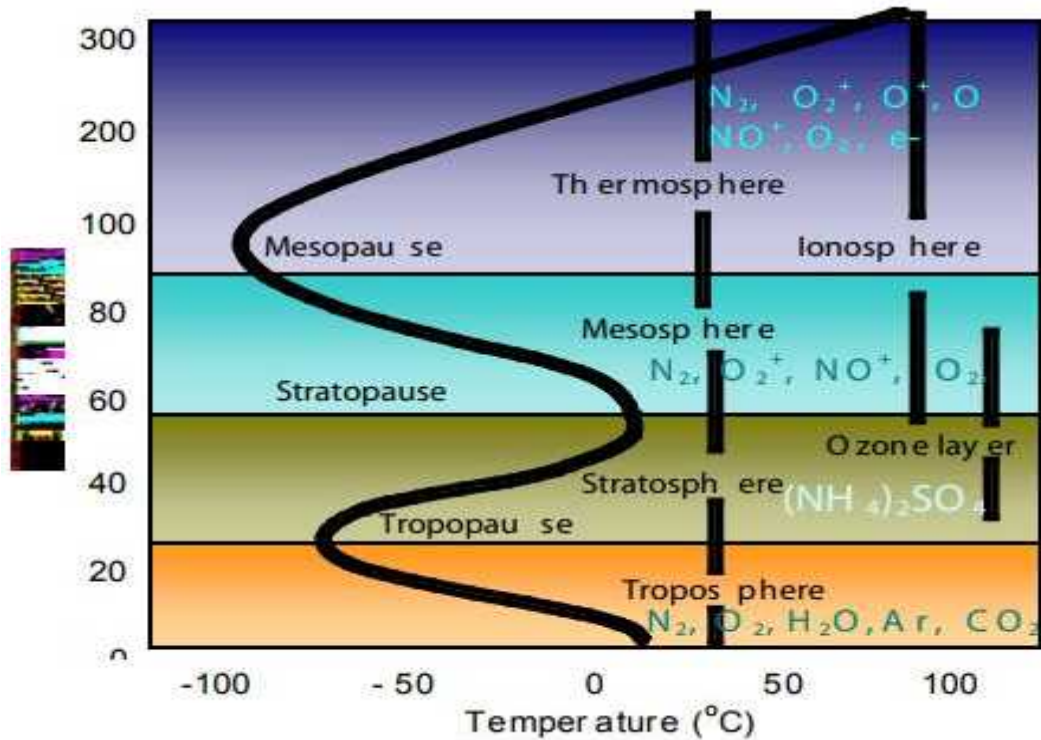


Fig. 3 Variation of average temperature with altitude.

Four regions of the atmosphere: the troposphere, stratosphere, mesosphere and thermosphere, have been defined based on the temperature curve shown in Fig. 3.

The Troposphere is the region nearest the earth's surface. This is the region between the surface of the earth and 7 km altitude at the poles and 17 km at the equator with some variation due to weather factors. Air temperature drops uniformly with altitude at a rate of approximately 6.5° Celsius per 1000 meters. Top is reached at an average temperature of -56.5 °C.

In the **stratosphere**, temperature remains constant with height in the first 9 kilometers (called an isothermal layer) and then goes on increasing.

Above the stratosphere in the region from 50 to about 80 km, the temperature again decreases in the **mesosphere**. The atmosphere reaches its coldest temperatures (about -90 °C) at the top layer of the mesosphere (a height of about 80 km).

The upper atmosphere is characterized by the presence of significant levels of electrons and positive ions. Because of the rarefied conditions, these ions may exist in the upper atmosphere for long periods before recombining to form neutral species. At altitudes of approximately 50 km and up, ions are so prevalent that the region is called **the ionosphere**. Ultraviolet light is the primary producer of ions in the ionosphere. In darkness, the positive ions slowly recombine with free electrons. The process is more rapid in the lower regions of the ionosphere where the concentration of species is relatively high.

Atmospheric temperature again increases at the thermosphere. Temperature in this layer can be as high as 1200 °C.

The boundaries between these regions are named the **tropopause**, **stratopause**, **mesopause**, and **thermopause**. The average temperature of the atmosphere at the surface of Earth is 14 °C. Passenger jets normally fly near the top of the troposphere at altitudes of 10 to 12 km, and the world altitude record for aircraft is 37.65 km – roughly in the middle of the stratosphere.

1.4. Characteristics of the Major Regions of the Atmosphere

1.4.1. The Troposphere

This is the region close to the surface of the Earth. Excluding water vapor, the major gaseous components of the atmosphere in this region are N₂ (78.1%), O₂ (21%), Ar (0.9%), CO₂ (0.03%) and variable amounts of CH₄, NO₂, CO, N₂O, H₂, SO₂, Kr, Ne and O₃. About 80 % of the total mass of the atmosphere is contained in this layer of the atmosphere.

In the troposphere, air temperature drops uniformly with altitude at a rate of approximately 6.5° Celsius per 1000 meters. Top is reached at an average temperature of -56.5 °C.

1.4.2. The Stratosphere

The stratosphere contains about 19.9 % of the total mass found in the atmosphere. A thin layer in the upper stratosphere (known as the ozone layer) has a high concentration of ozone.

Ozone absorbs ultraviolet light very strongly in the region 220-330 nm. By doing so, ozone converts the radiation's energy to heat and is responsible for the temperature maximum encountered at the boundary between the stratosphere and the mesosphere at an altitude of approximately 50 km.

The region of maximum ozone concentration is found within the range of 25-30 km high in the stratosphere where it may reach 10 ppm. However, the temperature maximum occurs at a higher altitude. This is due to the fact that ozone is such an effective absorber of UV radiation and most of this radiation is absorbed in the upper stratosphere where it generates heat. Only a small fraction reaches the lower altitudes, where ozone is more concentrated, which remain relatively cool.

This layer is primarily responsible for absorbing the ultraviolet radiation from the sun. The higher temperatures found in the upper region of the stratosphere occurs because of this localized concentration of ozone gas molecules. Ozone molecules absorb UV light creating heat energy that warms the stratosphere.

1.4.3. The Mesosphere

Mesosphere: The layer above the stratosphere is known as the Mesosphere and this layer extends from about 50 to 80 km. It is separated from the thermosphere by a thin layer known as the mesopause.

Temperature goes on decreasing in the mesosphere and the atmosphere reaches its coldest temperatures (about -90 °C) at the end of the mesosphere (at a height of about 80 km).

1.4.4. The Thermosphere

This is part of the atmosphere which is above 80 km altitude. In the outer space of the thermosphere, most particles consist of single atoms, H, He, and O etc. At lower altitude (200 - 100 km), diatomic molecules N₂, O₂, NO etc are present. The high temperature in this layer is generated from the absorption of intense solar radiation by oxygen molecules (O₂).

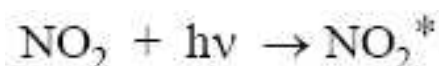
In this region of the atmosphere, while temperature seems extreme, the amount of heat energy involved is very small. Since molecules which can store heat are small in quantity. (Note: that heat stored is directly proportional to quantity of substance).

The air in the thermosphere is extremely thin with large distance between gas molecules. This makes the process of measuring the temperature of the thermosphere with a thermometer very difficult.

1.5. Atmospheric Chemical Reactions

Two constituents of utmost importance in atmospheric chemistry are radiant energy from the sun, predominantly in the ultraviolet region of the spectrum, and the hydroxyl radical, HO•. The former provides a way to pump a high level of energy into a single gas molecule to start a series of atmospheric chemical reactions, and the latter is the most important reactive intermediate of daytime atmospheric chemical phenomena.

Nitrogen dioxide, NO₂, is one of the most photochemically active species found in a polluted atmosphere. A species such as NO₂ may absorb light to produce an electronically excited molecule,



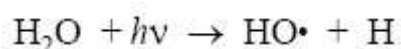
An electronically excited molecule is a molecule which has absorbed energetic electromagnetic radiation in the UV or visible regions of the spectrum.

Electronically excited molecules, free radicals and ions consisting of **electrically charged atoms or molecular fragments** are the three relatively reactive and unstable species that are encountered in the atmosphere. They are strongly involved in atmospheric chemical processes.

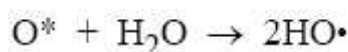
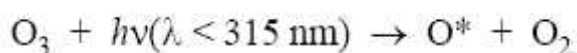
A) Formation of Free Radicals

Free radicals are atoms or groups of atoms with unpaired electrons. Such species may be produced by the action of energetic electromagnetic radiation on neutral atoms or molecules. The strong pairing tendencies of the unpaired electrons make free radicals highly reactive and are involved with most significant atmospheric chemical phenomena.

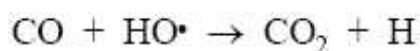
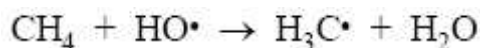
The hydroxyl radical, HO•, is the single most important reactive intermediate species in atmospheric chemical processes. It is formed by several mechanisms. At higher altitudes it is produced by photolysis of water:



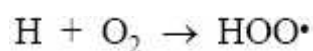
In the relatively unpolluted troposphere, hydroxyl radical is produced as the result of the photolysis of ozone,

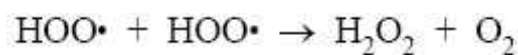
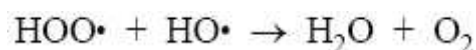


Hydroxyl radical is removed from the troposphere by reaction with methane or carbon monoxide:

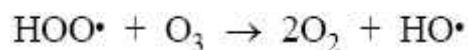
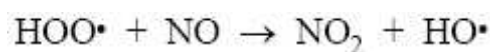


The hydrogen atom produced in the second reaction reacts with O₂ to produce hydroperoxyl radical which in turn may react with another hydroperoxyl or hydroxyl radical



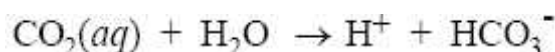
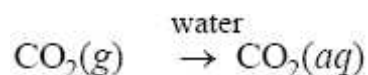


or reactions that regenerate hydroxyl radical



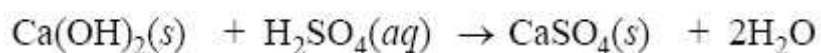
B) Acid – Base Reactions in the Atmosphere

The atmosphere is slightly acidic because of the presence of a low level of carbon dioxide, which dissolves in atmospheric water droplets and dissociates slightly:

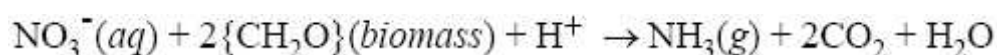


In terms of pollution, however, strongly acidic HNO_3 and H_2SO_4 formed by the atmospheric oxidation of N oxides, SO_2 and H_2S are much more important because they lead to the formation of damaging acid rain.

Basic species are relatively less common in the atmosphere. Particulate calcium oxide, hydroxide and carbonate can get into the atmosphere from ash and ground rock, and can react with acids such as in the following reaction:

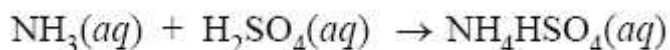
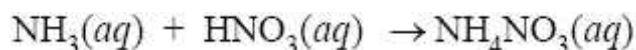


The most important basic species in the atmosphere is gas-phase ammonia, NH_3 . The major source of atmospheric ammonia is the biodegradation of nitrogen containing biological matter and bacterial reduction of nitrate:



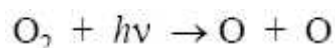
Ammonia is the only water soluble base present at significant levels in the atmosphere. This makes it particularly important as a base in the air.

Dissolved in atmospheric water droplets, it plays a strong role in neutralizing atmospheric acids:



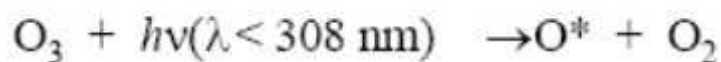
C) Reactions of Atmospheric Oxygen

In addition to O_2 , the upper atmosphere contains oxygen atoms, O ; excited oxygen molecules, O_2^* ; and ozone, O_3 . Atomic oxygen, O , is stable primarily in the thermosphere, where the atmosphere is so rarefied that the three-body collisions necessary for the chemical reaction of atomic oxygen seldom occur. Atomic oxygen is produced by a photochemical reaction:



At altitudes exceeding about 80 km, the average molecular weight of air is lower than 28.97 g/mole observed at sea level because of the high concentration of atomic oxygen. This condition has divided the atmosphere into a lower section with a uniform molecular weight (**homosphere**) and a higher region with a nonuniform molecular weight (**heterosphere**).

Molecular oxygen and excited oxygen atoms (O^*) are produced due to the photolysis of atmospheric ozone



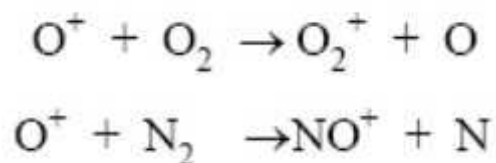
or by highly energetic chemical reactions such as



Oxygen ion, O^+ , which may be produced by ultraviolet radiation acting upon oxygen atoms,



is the predominant positive ion in some regions of the ionosphere. It may react with molecular oxygen or nitrogen to form other positive ions:



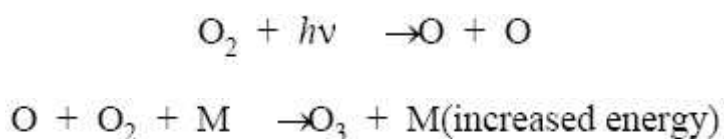
In intermediate regions of the ionosphere, O_2^+ is produced by absorption of ultraviolet radiation at wavelengths of 17-103 nm.



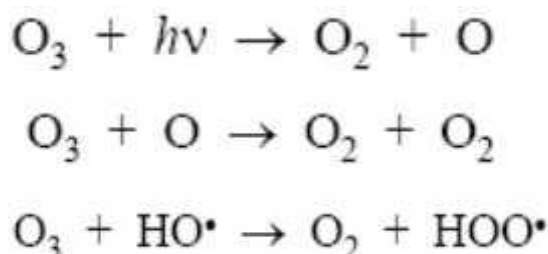
and by the reaction between N_2^+ and O_2



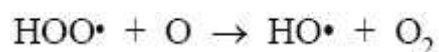
Atmospheric ozone is produced by photochemical dissociation of molecular oxygen followed by a three body reaction



in which M is another species, such as a molecule of N_2 or O_2 , which absorbs the excess energy given off by the reaction and enables the ozone molecule to stay together. In addition to undergoing decomposition by the action of ultraviolet radiation, stratospheric ozone reacts with atomic oxygen, hydroxyl radical, and NO:

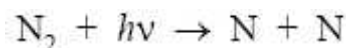


The HO^\bullet radical is regenerated from HOO^\bullet by the reaction,

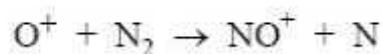
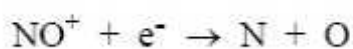


D) Reactions of Atmospheric Nitrogen

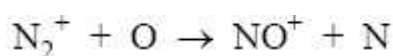
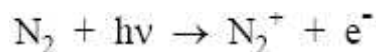
Unlike oxygen, molecular nitrogen is not readily dissociated by ultraviolet radiation. However, at altitudes exceeding approximately 100 km, atomic nitrogen is produced by photochemical reactions:



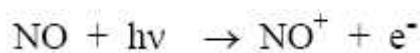
Other reactions which may produce monatomic nitrogen are:



In the region above 105 km of the ionosphere a plausible sequence of reactions by which NO^+ is formed is the following:

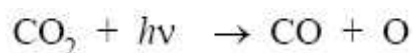


In the lowest region of the ionosphere, which extends from approximately 50 km in altitude to approximately 85 km, NO^+ is produced directly by ionizing radiation:



E) Atmospheric Carbon dioxide

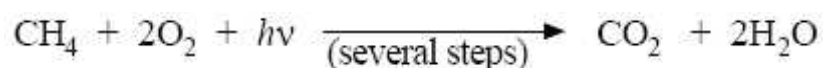
Although only about 0.035% (350 ppm) of air consists of carbon dioxide, it is the atmospheric “nonpollutant” species of most concern. Chemically and photochemically, however, it is a comparatively insignificant species because of its relatively low concentrations and low photochemical reactivity. The one significant photochemical reaction that it undergoes, and a major source of CO at higher altitudes, is the photodissociation of CO_2 by energetic solar UV radiation in the stratosphere:



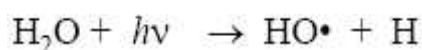
F) Atmospheric Water

The water vapor content of the troposphere is normally within a range of 1–3% by volume with a global average of about 1%. However, air can contain as little as 0.1% or as much as 5% water. The percentage of water in the atmosphere decreases rapidly with increasing altitude.

The cold tropopause serves as a barrier to the movement of water into the stratosphere. Thus, little water is transferred from the troposphere to the stratosphere, and the main source of water in the stratosphere is the photochemical oxidation of methane:



The water thus produced serves as a source of stratospheric hydroxyl radical as shown by the following reaction:



2. Air Pollution

Air Pollution can be defined as the addition of harmful substances to the atmosphere resulting in damage to the environment, human health, and quality of life.

Air pollution causes breathing problems and promotes cancer. It harms plants, animals, and the ecosystems in which they live. Some air pollutants return to Earth in the form of acid rain and snow, which corrode statues and buildings, damage crops and forests, and make lakes and streams unsuitable for fish and other plant and animal life.

Especially the pollutants that result from the use of combustion as a source of energy: oxides of sulfur, oxides of nitrogen, and carbon monoxide.



Fig. 4 A polluted African city air.

2.1. Classification of Air Pollutants

There are a number of ways of classifying air pollutants. Most commonly they are classified on the basis of 1) differences in their physical or chemical characteristics, 2) by their origin, 3) by the nature of the response they elicit, 4) by their legal status.

1) Based on differences in their physical or chemical characteristics

Aerosols:- are tiny particles dispersed in gases and include both liquid and solid particles. Air pollution terminology relating to atmospheric aerosols includes dusts, fog, fumes, hazes, mists, particulate matter, smog, smoke and soot.

Gases and vapors:- are composed of widely separated freely moving molecules which will expand to fill a larger container and exert a pressure in all directions. A substance is a true gas if it is far removed from the liquid state (i.e. the temperature of the substance is above its critical point). A vapor is a substance in the gaseous state which is not far from being a liquid (i.e. it can be condensed to a liquid relatively easily).

2) Based on their origin

Air pollutants are classified in different ways based on their origin. These are:

A) Mobile and Stationary sources

Mobile sources of emissions include automobiles, trains and airplanes while stationary sources include all other sources. Electric power plants, chemical manufacturing industries, air strippers, and soil vapor extraction operations are examples of stationary sources.

B) Direct and Indirect

A direct source emits pollutants directly while indirect sources do not themselves emit pollutants but attract mobile sources (e.g. a shopping mall, athletic stadium).

C) Point source and Area sources

A point source is defined as a stationary source whose emissions significantly impact air quality. Area sources are those that, individually do not have significant impact on air quality but, are significant when viewed together (e.g. dry cleaners, open burning).

3) Based on the way pollutants reach the atmosphere

Air pollutants are classified as primary and secondary pollutants based on the way they reach the atmosphere.

Primary pollutants are those that are emitted directly into the atmosphere from an identifiable source. Examples include carbon monoxide and sulfur dioxide. Secondary pollutants, on the other hand, are those that are produced as a result of chemical reactions in the atmosphere. For example, ozone, which is a major component of urban smog, formed as a result photochemical reactions between oxides of nitrogen, VOCs, and other atmospheric constituents, is a secondary pollutant. In the case of secondary pollutants, the precursors to the pollutant are generally regulated.

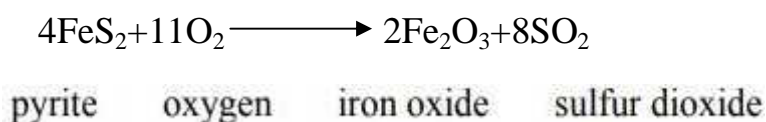
4) Based on their legal status

Based on the way in which they are regulated, or their legal status, six pollutants have been identified by the EPA as criteria pollutants because they are both common and detrimental to human health. These are: particulate matter having diameters of 10 μm or less (10 PM), sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead. For each criteria pollutant, EPA has established a primary and secondary ambient air quality standard. The purpose of the primary standard is to protect public health while the secondary standard is set at a level to protect public welfare from adverse effects. Collectively, these standards are known as the National Ambient Air Quality Standards (or NAAQS).

2.2. Major Sources of Air Pollution

Human activities such as: burning coal and petroleum products (gasoline, kerosene, fuel oil etc; driving a car, and industrial activities, such as manufacturing products or generating electricity are among the major sources of air pollutants. The generation of energy through the combustion of fossil fuels produces plenty of water and carbon dioxide, which contributes to global warming.

When coal, gasoline, and similar fuels are burned, the hydrocarbons and other impurities in them are oxidized. The sulfur of the pyrite that remains in coal, for example, oxidizes to sulfur dioxide, an irritating gas with a harsh, acrid odor. The reaction for the oxidation is



The oxides formed under this condition combine with water vapor in the air to form acids, which return to the ground as acid rain.

Powered by sunlight, oxides of nitrogen and volatile organic compounds react in the atmosphere to produce photochemical smog. Smog contains ozone, a form of oxygen gas made up of molecules with three oxygen atoms rather than the normal two. In the lower atmosphere Ozone is a poison—it damages vegetation, kills trees, irritates lung tissues, and attacks rubber. The severity of smog is determined by measuring the ozone level in the smog. When the ozone level is high, other pollutants, including carbon monoxide, are usually present at high levels as well.

The very young, the very old and people who suffer from asthma or heart disease, are more seriously affected by smog. Smog may cause headaches or dizziness and can cause breathing difficulties. In extreme cases, it can lead to mass illness and death, mainly from carbon monoxide poisoning.

Still another pollutant, a product of the incomplete combustion of carbon or organic compounds, such as the hydrocarbons of gasoline, one that we can't see and that produces no sense of irritation, is carbon monoxide, CO. This gas is known as the silent killer because it is odorless, tasteless, and invisible. Its major symptom is a drowsiness sometimes accompanied by headache, dizziness, and nausea. CO is primarily a pollutant of cities and usually fluctuates with flow of traffic.

Natural Sources

Some of the pollutants resulting from human activities also come from natural sources. For example, Volatile Organic Compounds (VOCs) are emitted into the atmosphere from forest fires or simply by evaporating. The common air pollutant VOCs include

- volatile hydrocarbon components of consumer products such as paint thinners, roof tar, and glazing compounds, which are often listed on ingredients labels as “petroleum distillates.”

- evaporating solvents and propellants of personal care and household products such as nail polish, deodorants, after-shave lotions, hair sprays, and insecticides.
- ethyl acetate and more exotic additives that we exhale when we chew gum and breath fresheners for what advertisers call a “fresh, clean breath.”

Volcanoes spew out sulfur dioxide and large amounts of volcanic ash. Unlike pollutants from human activity, however, naturally occurring pollutants tend to remain in the atmosphere for a short time and do not lead to permanent atmospheric change.

2.3. Air Pollution and Acid-Rain

How natural presence of carbon dioxide in the earth’s atmosphere makes rain acidic with or without air pollution?

Rainwater which was considered to be the purest form of water available in the past, is now known to be often contaminated by pollutants in the air. In the presence of atmospheric moisture, gases such as sulfur dioxide and oxides of nitrogen, resulting from industrial emissions, turn into droplets of pure acid floating in smog, known as **acid rain**.

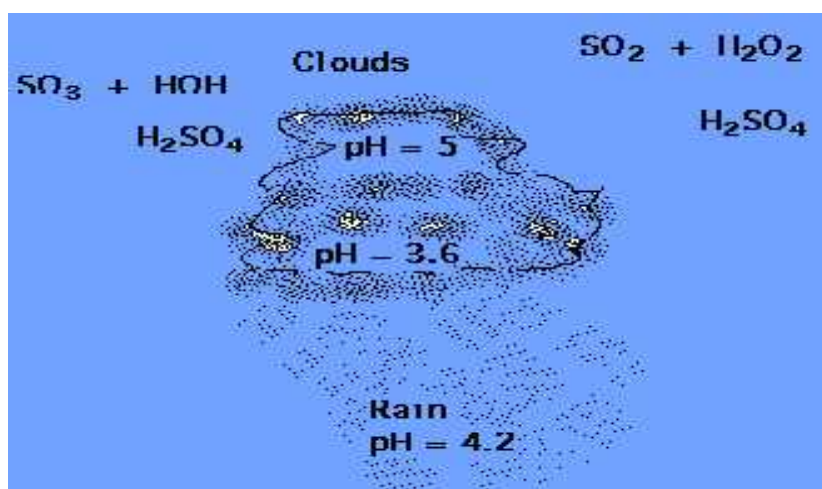


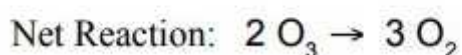
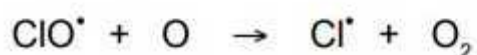
Fig. 5 Acid Rain Formation.

These airborne acids are bad for the lungs and attack anything made of limestone, marble, or metal. Forests and lakes that are far away from industrial activities may be damaged by acid rain resulting from pollutants that may be carried by winds in the troposphere and descend in acid form, usually as rain or snow. Leaves of plants are burned and lakes will be too acidic to support fish and other living things due to acid precipitation.

2.4. Air Pollution and Ozone Depletion

The lower portion of the stratosphere from approximately 15 km to 35 km above Earth's surface contains high concentration, over 90%, of the ozone (O_3) in earth's atmosphere. This part of the Earth's atmosphere is known as the ozone layer. Nearly all, 97-99%, of the sun's high frequency UV-radiation which is potentially damaging to life on Earth is absorbed in this layer.

Several pollutants attack the ozone layer. However, chlorofluorocarbons (CFCs) are known to be chief among them. CFC molecules are stable, virtually indestructible until they reach the stratosphere. Here, the CFC molecules are broken apart by intense ultraviolet radiation and release the chlorine atoms they contain. These chlorine atoms react with ozone and break it down into ordinary oxygen molecules that do not absorb UV-radiation.



The chlorine acts as a catalyst chlorine takes part in several chemical reactions—yet at the end emerges unchanged and able to react again. Therefore, it acts as a catalyst. A single chlorine atom can destroy up to 100,000 ozone molecules in the stratosphere. In addition to CFCs, other pollutants, such as nitrous oxide from fertilizers and the pesticide methyl bromide, also attack atmospheric ozone. Scientists are finding that under this assault the protective ozone layer in the stratosphere is thinning.

2.5. Global Warming

At present, our Earth appears to be facing a rapid warming, which most scientists believe results, at least in part, from human activities. Such an increase in the average temperature of the atmosphere, oceans, and land masses of earth in general is known as Global warming.

What are the reasons?

The energy that lights and warms Earth comes from the Sun. Most of this energy comes as short-wave radiation. Earth's surface, in turn, releases some of this heat as long-wave infrared radiation. Much of the emitted infrared radiation goes back out to space, but a portion remains trapped in Earth's atmosphere. Certain gases in the atmosphere, including water vapor, carbon dioxide, and methane, provide the trap. Absorbing and reflecting infrared waves radiated by Earth, these gases conserve heat as the glass in a greenhouse does and are thus known as greenhouse gases. As the atmosphere becomes richer in these gases, it becomes a better insulator, retaining more of the heat provided to the planet by the Sun. The net result; more heat is received from the sun than is lost back to space, a phenomenon known as **“greenhouse effect”**.

Because of this green house effect, the average surface temperature of the Earth is maintained at a relatively comfortable 15°C. Was this not the case, the surface temperature would average around -18°C. The problem with

global warming is that man is adding to and changing the levels of the greenhouse gases and is therefore enhancing this warming.

Carbon dioxide (CO_2) is the gas most significantly enhancing the greenhouse effect. Plant respiration and decomposition of organic material release more than 10 times the CO_2 than released by human activities, but these have generally been in balance before the industrial revolution. Since the industrial revolution amounts have increased drastically due to combustion of fossil fuel (oil, natural gas and coal) by heavy industry and other human activities, such as transport and deforestation.



Fig. 6 Gases from industrial emission.

What are the effects?

i) The world is expected to have a more extreme weather, with more rain during wet periods, longer droughts, and more powerful storms.

ii) Melting of the polar ice caps, leading to a rise in sea level. Such a rise would flood coastal cities, force people to abandon low-lying islands, and completely inundate coastal wetlands. Diseases like malaria may become more common in the regions of the globe between the tropics and the polar regions, called the temperate zones.

iii) Climate change may bring extinction for many of the world's plant species, and for animal species that are not easily able to shift their territories as their habitat grows warmer.

2.6. Solving the problem of air pollution

What can be done about acid rain and other forms of air pollution? Several options are available, including

- the use of alternative energy sources.
- removal of pollutants from the products of combustion.
- improvement in the efficiency of the combustion process itself.
- energy conservation.

We will look briefly at the first two, which make use of chemicals and chemical processes.

There are several alternative energy sources for motor vehicles. Of these, natural gas is particularly appealing because of its small potential for air pollution. This fuel contains few sulfur impurities; it burns cleanly with little formation of sulfur or nitrogen oxides. While electric cars powered by batteries might seem to be a completely pollution-free alternative, their use might only shift environmental concerns from one source or location to another. After all, if we switched from the internal combustion engine to electric batteries as a source of power, the total quantity of energy now provided by gasoline, diesel fuel, and similar refinery products would have to be replaced by an equivalent quantity of electricity, which would be needed to recharge the newly introduced transportation batteries. The burden of producing this additional quantity of electricity would have to be taken up by existing or new electric power generators, which would in itself introduce new environmental concerns.

Cars and other vehicles account for less than half of the total emissions of SO_x and NO_x (but most of the CO) in the United States. Electric utilities

and other stationary facilities produce the majority of these pollutants. While these plants might be designed to use alternative energy sources, perhaps including nuclear power, more practical or more immediate approaches include improving the efficiency of the combustion process itself and removing pollutants from exhaust gases before they reach the atmosphere.

Several different approaches are used to reduce pollutants in industrial exhausts, including electrostatic precipitation, filtration, and scrubbing. Electrostatic precipitation removes particulates and aerosols, which are small particles of liquids and solids dispersed in smoke. (Smaller particles, less than 10⁻³ mm in diameter, make up the aerosols; the larger particles are the particulates). Exhaust gases pass between two charged vertical plates or electrodes. The particles pick up electrons supplied by the negative electrode and move to the more positive one. There the liquid particles accumulate and flow the bottom of the collector; with agitation the solid particles drop off.

CHAPTER THREE

Hydrology & Natural Cycles



Hydrology and Natural Cycles

1. Introduction

Hydrology is the study of the movement, distribution, and quality of water on Earth and other planets, including the hydrologic cycle, water resources and environmental watershed sustainability. A practitioner of hydrology is a hydrologist, working within the fields of earth or environmental science, physical geography, geology or civil and environmental engineering.

Domains of hydrology include hydrometeorology, surface hydrology, hydrogeology, drainage basin management and water quality, where water plays the central role. Oceanography and meteorology are not included because water is only one of many important aspects within those fields.

2. The Hydrological cycle

The global system that supplies and removes water from earth's surface is known as the hydrologic cycle (Fig. 7). Water is transferred to earth's atmosphere through two processes (1) evaporation and (2) transpiration as moist air rises it cools.

Eventually enough moisture accumulates and the mass cools sufficiently to nucleate (from small crystals) on microscopic particles. Sufficient growth causes the droplets or snowflakes to become heavy enough to fall as precipitation.

As they fall on the earth's surface, the droplets either run over the ground into streams and rivers or percolate into the ground to form groundwater.

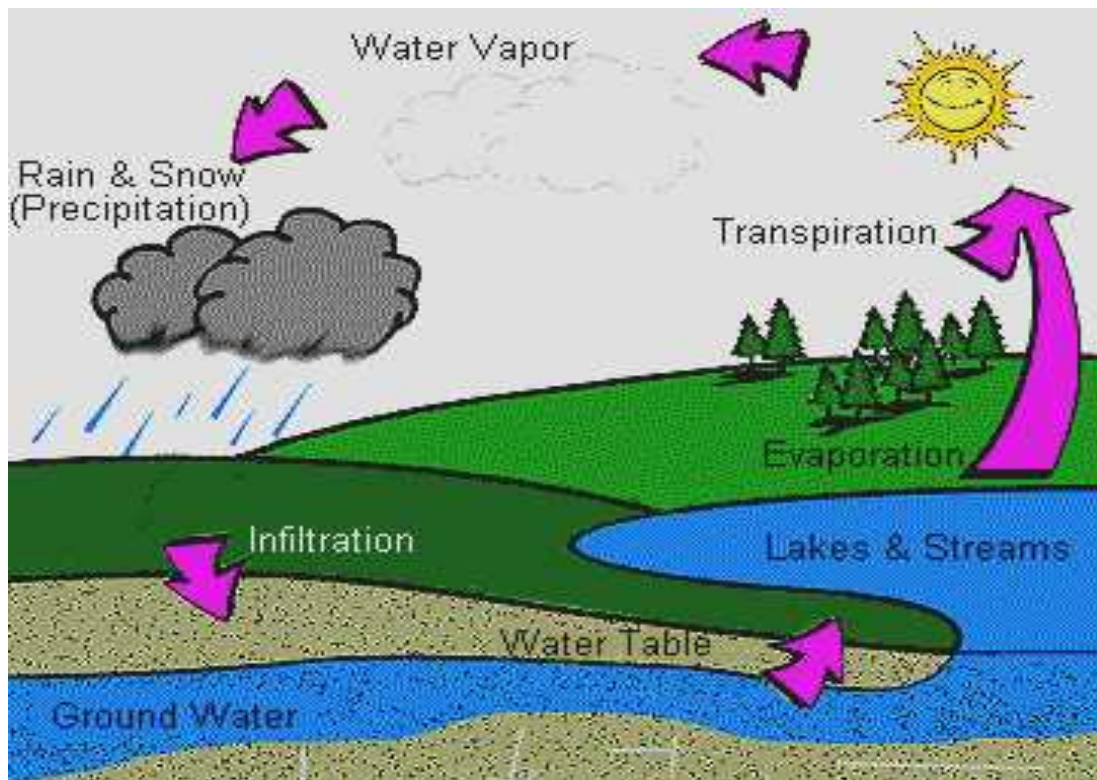
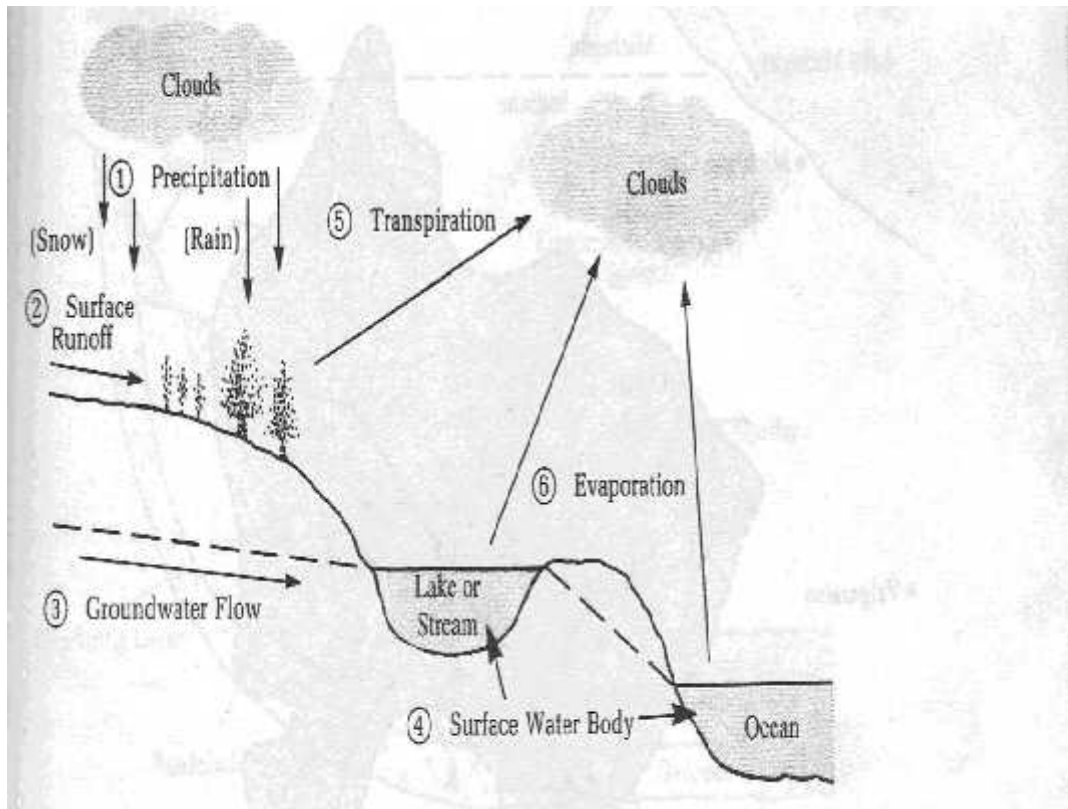
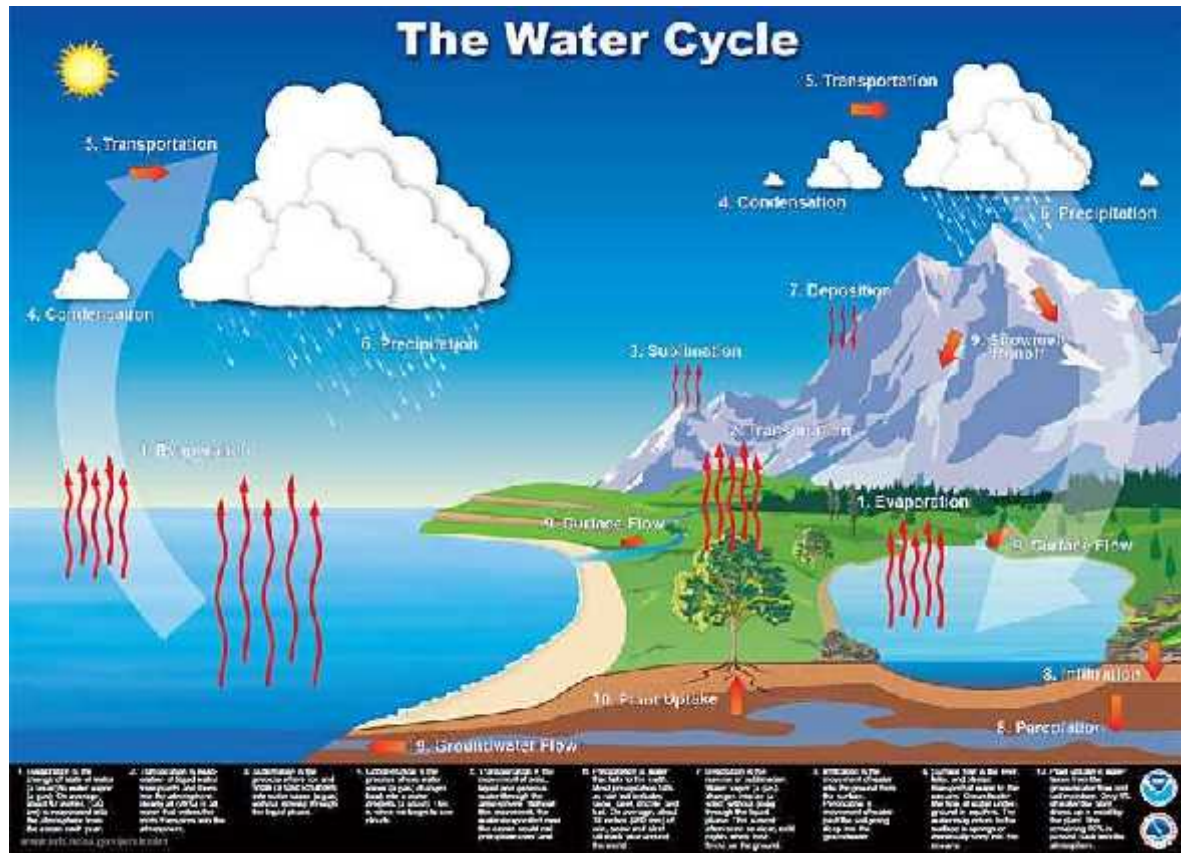


Fig. 7 Hydrological cycle

تتكون كلمة هيدرولوجى اليونانية الأصل من مقطعين الأول (هيدرو) وتعنى ماء والثانية () .
الكلمة إصطلاحا على أنها العلم الذى يدرس توزيع المياه ودورها فى الطبيعة .
بالإضافة لخصائصها الفيزيائية والكيميائية والبيولوجية كما يسمى توزيع الماء ما بين اليابسة والمحيطات والبحار والغلاف الغازى بالموازنة المائية.

دورة المياه فى الطبيعة:

دورة المياه تكون متكاملة بمعنى أنه لا تضيع المياه بل تتحول من صورة إلى أخرى.
الطبيعة يوجد على هيئة بخار فى الهواء أو ماء سائل على هيئة أمطار وأنهار وبحار ومحيطات أو مجمد فى القطب الشمالى أو مخزون فى التربة والنباتات والمحيطات.
97% من المخزون الرئيسى للمياه على سطح الكرة الأرضية ومنها تبدأ دورة المياه عندما يتبخر الماء ويتحول إلى سحب الذى يكون أقل كثافة من الهواء فيحمله إلى طبقات الجو العليا وعندما تبرد هذه الطبقات تتكثف السحب وتحول إلى مياه تتساقط على شكل أمطار على الأرض ، هذه الأمطار يذهب جزء منها إلى التربة للمزروعات وجزء آخر يكون الخزانات الجوفية فى باطن الأرض كما يصل جزء من هذه الأمطار إلى الأنهار والترع والبحيرات.



3. Surface water hydrology

Precipitation: Surface water hydrology begins before the precipitate hits the ground. The form precipitate takes (rain, sleet, hail, or snow) is important.

For example, it takes about 10 mm of snow to make the equivalent of 1 mm of rain. Other factors of importance are the size of the area over which the precipitation falls, the intensity of the precipitation, and its duration.

Once the precipitation hits the ground, a number of things can happen. It can evaporate promptly. This is especially true if the surface is hot and impervious.

If the soil is dry and/or porous, the precipitate may infiltrate into the ground or it may only wet the surface. This process and the process of wetting leaves and blades of grass are called interception. The precipitate may be trapped in small depressions or puddles.

It may remain there until it evaporates or until the depressions fill and overflow. And last but not least, it may run off directly to the nearest stream or lake to become surface water. The four factors (evaporation, infiltration, interception, and trapping) that reduce the amount of direct runoff are called abstractions.

Stream flow: The water that makes up our streams and rivers is derived from two sources: direct runoff and groundwater ex-filtration, or base flow, as it is more commonly called. Direct runoff is a consequence of precipitation. Base flow is the dry weather flow that results from the seepage of groundwater out of stream banks.

4. Groundwater hydrology

Water table (unconfined) aquifer: As we mentioned earlier, part of the precipitation that falls on the soil may infiltrate. This water replenishes the

soil moisture or is used by growing plants and returned to the atmosphere by transpiration. Water that drains downward below the root zone finally reaches a level at which all of the openings or voids in the earth's materials are filled with water. This zone is known as zone of saturation. Water in the zone of saturation is referred to as groundwater. The geologic formation that bears the water is called an aquifer. The upper surface of the zone of saturation, if not confined by impermeable material, is called the water table (Fig. 8). The aquifer is called a water table aquifer or unconfined aquifer. Water will rise to the level of the water table in an un pumped water table well.

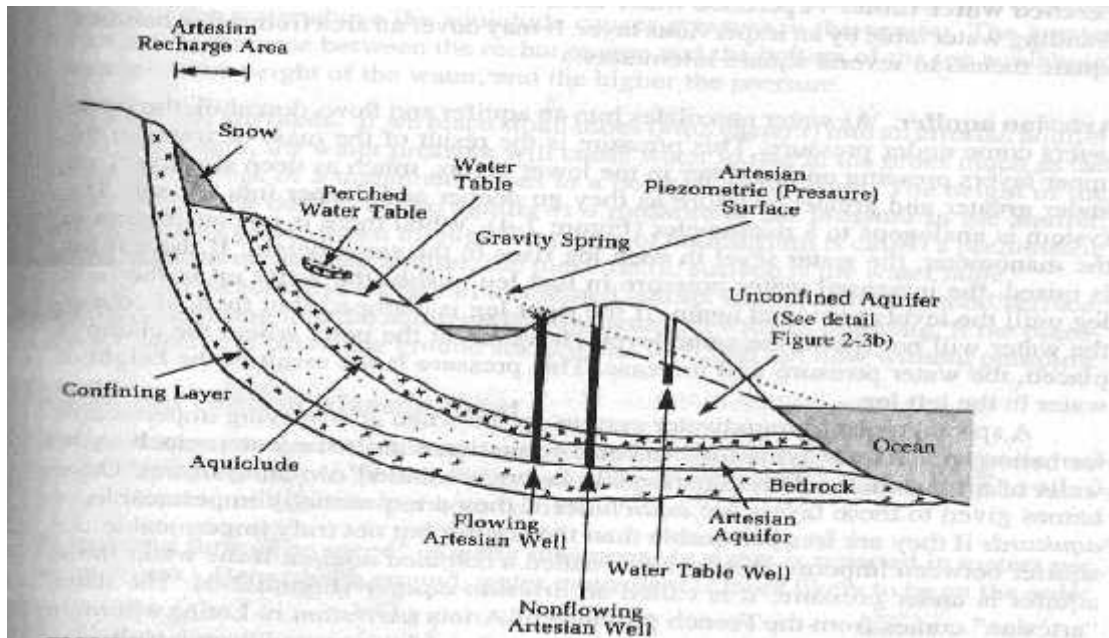


Fig. 8 Schematic of groundwater aquifers.

The smaller void spaces in the porous material just above the water table may contain water as a result of capillarity. This one is referred to as the capillary fringe (Fig. 9). It is not a source of supply since the water held will not drain freely by gravity. The region from the saturated zone to the surface is also called the vamoose zone.

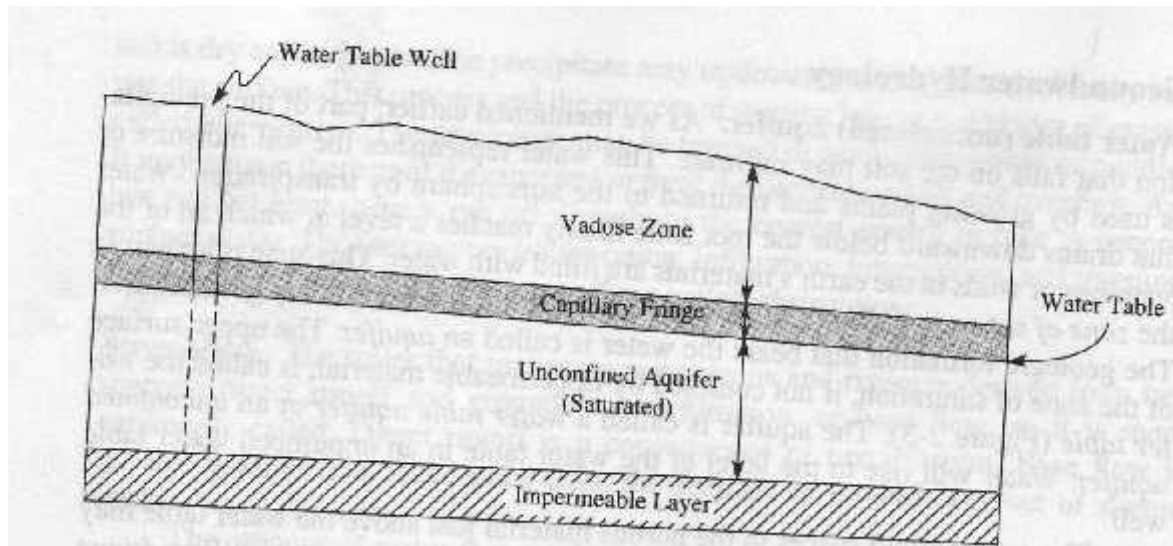


Fig. 9 Detail of the unconfined aquifer.

Springs: Because of the irregularities in underground deposits and in surface topography, the water table occasionally intersects the surface of the ground or the bed of stream, lake, or ocean. At these points intersection, groundwater moves out of the aquifer. The place where the water table breaks the ground surface is called a gravity or seepage spring (Fig. 8).

Perched water table: A perched water table is a lens of water held above the surrounding water table by an impervious layer. It may cover an area from a few hundred square meters to several square kilometers.

Artesian aquifer: As water percolates into an aquifer and flows downhill, the lower layers come under pressure. This pressure is the result of the mass water in the upper layers pressing on the water in the lower layers, much as deep sea divers are under greater and greater pressure as they go deeper and deeper into the sea. The system is analogous to a manometer, the water level in each leg rises to the same height. If the left leg is raised, the increased water pressure in that leg pushes the water up in the right leg until the levels are equal again. If the right leg is clamped shut then, of course, the water will not rise to the same level. However, at the point where the clamp is placed, the water pressure will increase. This pressure is the result of the

height of water in the left leg.

Piezometric surfaces: If we place small tubes (piezometers) into an artesian aquifer along its length, the water pressure will cause water to rise in the tubes as the water in the legs of a manometer rises to a point of equilibrium is called a piezometric surface. In an unconfined aquifer, the piezometric surface is the water table.

If the piezometric surface of a confined aquifer lies above the ground surface, a well penetrating into the aquifer will flow naturally without pumping. If the piezometric surface is below the ground surface, the well will not flow without pumping.

Infiltration: Of the numerous equations developed to describe infiltration, Horton's equation is useful to examine because it characterizes phenomena of interest. Horton expressed the infiltration rate as:

$$F = f_c + (f_o - f_c) e^{-kt}$$

Where F = infiltration rate, mm/h

f_c = equilibrium or final infiltration rate, mm/h

f_o = initial infiltration rate, mm/h

k = empirical constant, h^{-1}

t = time, h

Infiltration rate is a function of the properties of the soil; thus, the values for f_o , f_c , and k are, as you might expect, a function of the soil type.

Evaporation: The loss of water from the surface of a lake or other body is a function of solar radiation, air and water temperature, wind speed, and the difference in vapor pressures at the water surface and in the overlying air. As with estimates of infiltration rate, there are numerous methods for estimating evaporation.

Dalton first expressed the fundamental relationship in the form:

$$E = (e_s - e_a)(a + b.u)$$

Where E = evaporation rate, mm/day

e_s = saturation vapor pressure, mm(Hg)

e_a = vapor pressure in overlying air, mm(Hg)

a , b = empirical constants (from 0.5 to 0.8)

u = wind speed, Km/hr

Example: Calculate the evaporation rate above the surface of a lake if the wind speed is 15 km/hr causes vapor pressure over lying air 7 mm(Hg) at a point where saturation vapor pressure is 12 mm(Hg)- Given constants (a, b) (0.7, 0.8)?

Evapo-transpiration: Water loss from plants (transpiration) is difficult to separate from losses from the soil surface or the root zone. For mass-balance calculations, these are often lumped together under the term evapotranspiration. The rate of evapo-transpiration is a function of soil moisture, soil type, plant type, wind speed, and temperature. Plant types may affect evapotranspiration rates dramatically.

هيدروليكا الآبار:

دائرة السحب:

هي محيط الدائرة الذي يعود عنده منسوب المياه الجوفية إلى وضعه الأصلي بعد تشكله إلى الشكل لسحب المياه من البئر.

وفيما يلي سنقوم بتوضيح كيفية حساب التصرف الخارج من الآبار بأنواعها الضحلة أو العميقة.

1- الآبار الضحلة:

According to Darcy's Law:

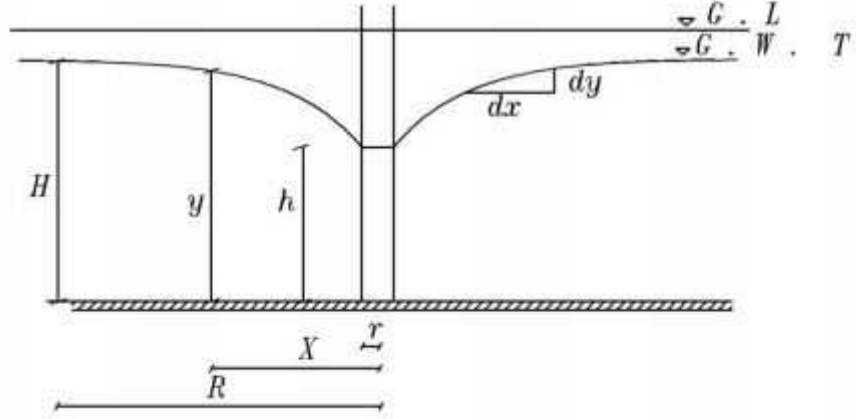
$$V = K.i$$

Where, V is the velocity of ground water,

K is the coefficient of permeability,

And i is the hydraulic gradient $= \frac{dy}{dx}$

The equation of the discharge can be written as,



$$Q = A.V$$

Thus,

$$Q = 2 \cdot \pi \cdot x \cdot y \cdot K \cdot \frac{dy}{dx}$$

$$\frac{Q}{x} dx = 2 \cdot \pi \cdot y \cdot K \cdot dy$$

$$Q \cdot \int_1^R \frac{dx}{x} = 2 \cdot \pi \cdot K \cdot \int_h^H y \cdot dy \quad Q \cdot (\ln x) \Big|_r^R = 2 \cdot \pi \cdot K \cdot \left(\frac{y^2}{2} \right) \Big|_h^H$$

$$\therefore Q = \frac{\pi \cdot K \cdot (H^2 - h^2)}{\ln R/r}$$

العوامل التي تؤثر على التصريف هي:

- معامل النفاذية: يتناسب طرديا مع التصريف.
- إرتفاع سطح المياه عن السطح الغير منفذ:
- إرتفاع المياه في ماسورة السحب عن الطبقة غير المنفذة: تتناسب عكسيا كلما قلت
- نصف قطر دائرة التأثير:
- نصف قطر ماسورة السحب كلما زادت زاد معها التصريف.

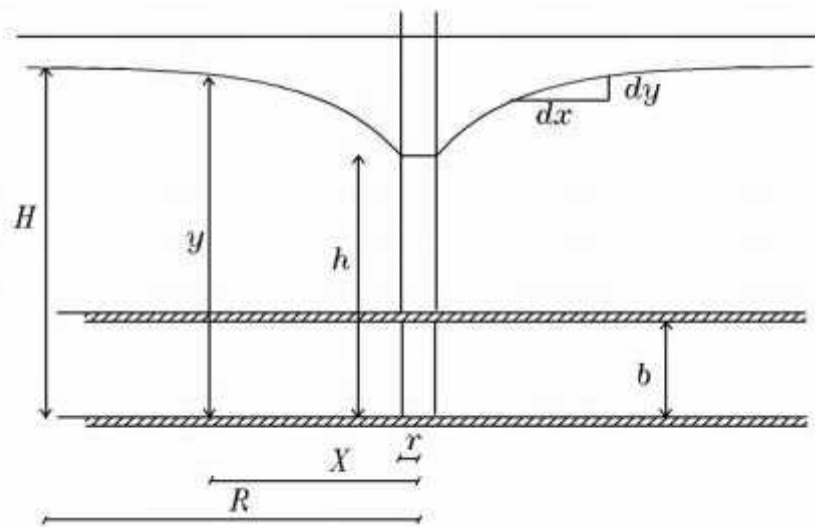
According to Darcy's Law,

$$V=K.i$$

The equation of the discharge can be written as,

$$Q=A.V$$

$$\text{Thus, } Q = 2.\pi.x.b.K.\frac{dy}{dx}$$



$$\frac{Q}{x}.dx = 2.\pi.b.K.dy$$

$$Q.\int_r^R \frac{dx}{x} = 2.\pi.b.K.\int_h^H dy \quad Q.(\ln x)\Big|_r^R = 2.\pi.b.K.(y)\Big|_h^H$$

$$\therefore Q = \frac{2.\pi.b.K.(H - h)}{\ln R/r}$$

Examples:

1) A surface well is 12 inches in diameter and discharges 2000 gallons per minute. If the water height in the wells is 100 feet before drawing, the water height during withdrawal is 90 feet. Find the discharge when the water in the well is 50 feet?

2) A surface well with a diameter of 24 inches gives a discharge of 100 liters per second when the well level is five meters below the original level of the groundwater and the original depth of the well is 30 meters and the radius of the impact circle is 300 meters.

Calculate: 1- coefficient of permeability in cubic meters per day?

2- The inclination of the groundwater surface?

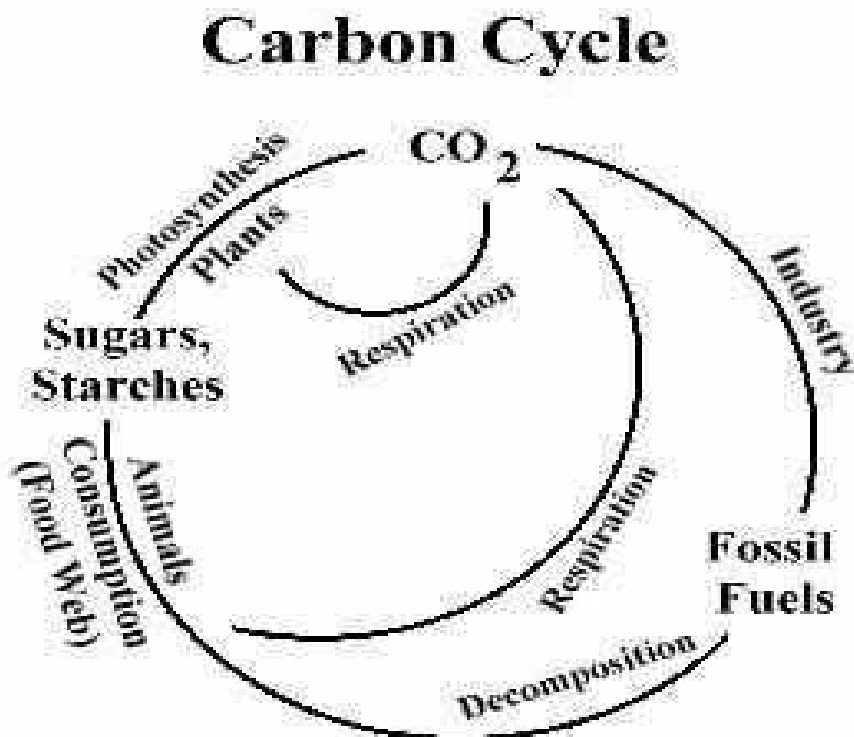
3) If you know that the depth of water in a surface well is 15 meters in the event of non-disposal and its diameter is 30 cm, and the decrease in the well level from the original level of groundwater is three meters, and the permeability factor is 11.4 cubic meters per square meter per day. Find the resulting discharge if you know that the radius of the circle of influence is 300 meters?

5. Natural Cycles

Carbon Cycle

All living things are made of carbon. Carbon is also a part of the ocean, air, and even rocks. Because the Earth is a dynamic place, carbon does not stay still. In the atmosphere, carbon is attached to some oxygen in a gas called carbon dioxide. Plants use carbon dioxide and sunlight to make their own food and grow. The carbon becomes part of the plant.

Plants that die and are buried may turn into fossil fuels made of carbon like coal and oil over millions of years. When humans burn fossil fuels, most of the carbon quickly enters the atmosphere as carbon dioxide. Carbon dioxide is a greenhouse gas and traps heat in the atmosphere. Without it and other greenhouse gases, Earth would be a frozen world. But humans have burned so much fuel that there is about 30% more carbon dioxide in the air today than there was about 150 years ago, and Earth is becoming a warmer place.



دورة الكربون

_____:

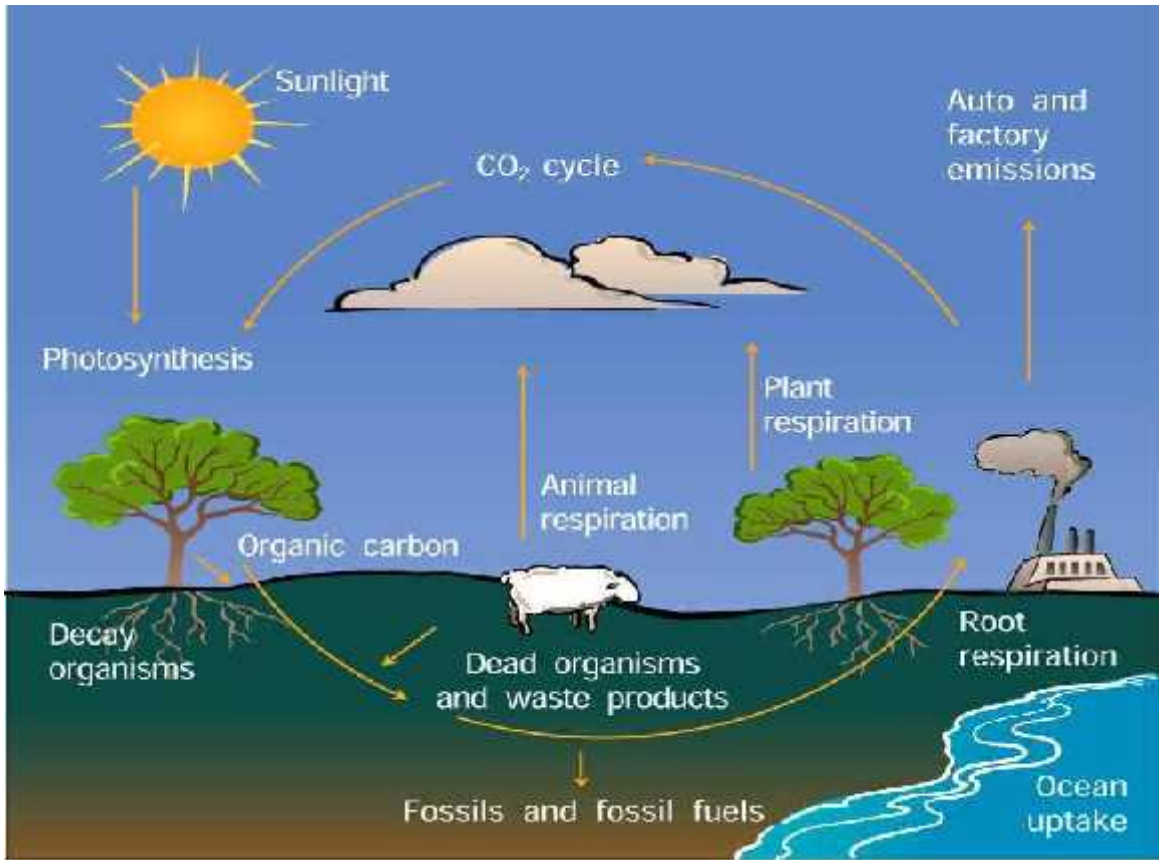
يوجد الكربون على هيئة غاز ثانى أكسيد الكربون فى الهواء الجوى أو مذابا فى مياه البحار والمحيطات.

مسارات الكربون البسيطة:

- 1- إطلاق غاز ثانى أكسيد الكربون خلال عملية التنفس وانتشاره فى الهواء.
- 2- إستخدامه من قبل النبات فى عملية البناء الضوئى لصنع الغذاء.

_____:

- 1- يدخل الكربون فى تركيب الغذاء الذى يصنعه النبات.
- 2- تتغذى الحيوانات على هذا الغذاء وربما تنتقل من حيوان إلى آخر.
- 3- تحلل المخلوقات الحية الدقيقة جثث الحيوانات بعد موتها وتعيد الكربون مرة أخرى إلى التربة أو فى الهواء على شكل ثانى أكسيد الكربون.
- 4- يستخدم النبات الكربون مرة أخرى فى صنع الغ . مصير الكربون المختزن فى باطن الأرض يتحول بعد زمن طويل بتأثير الضغط والحرارة إلى فحم وبتترول.



دورة الفسفور The Phosphorus Cycle

أولاً: يوجد الفسفور في الطبيعة في صخور الفوسفات الموجودة علي سطح الأرض
ثانياً: تنقسم دورة الفسفور الي جزئين كلا يكمل الآخر احدهما

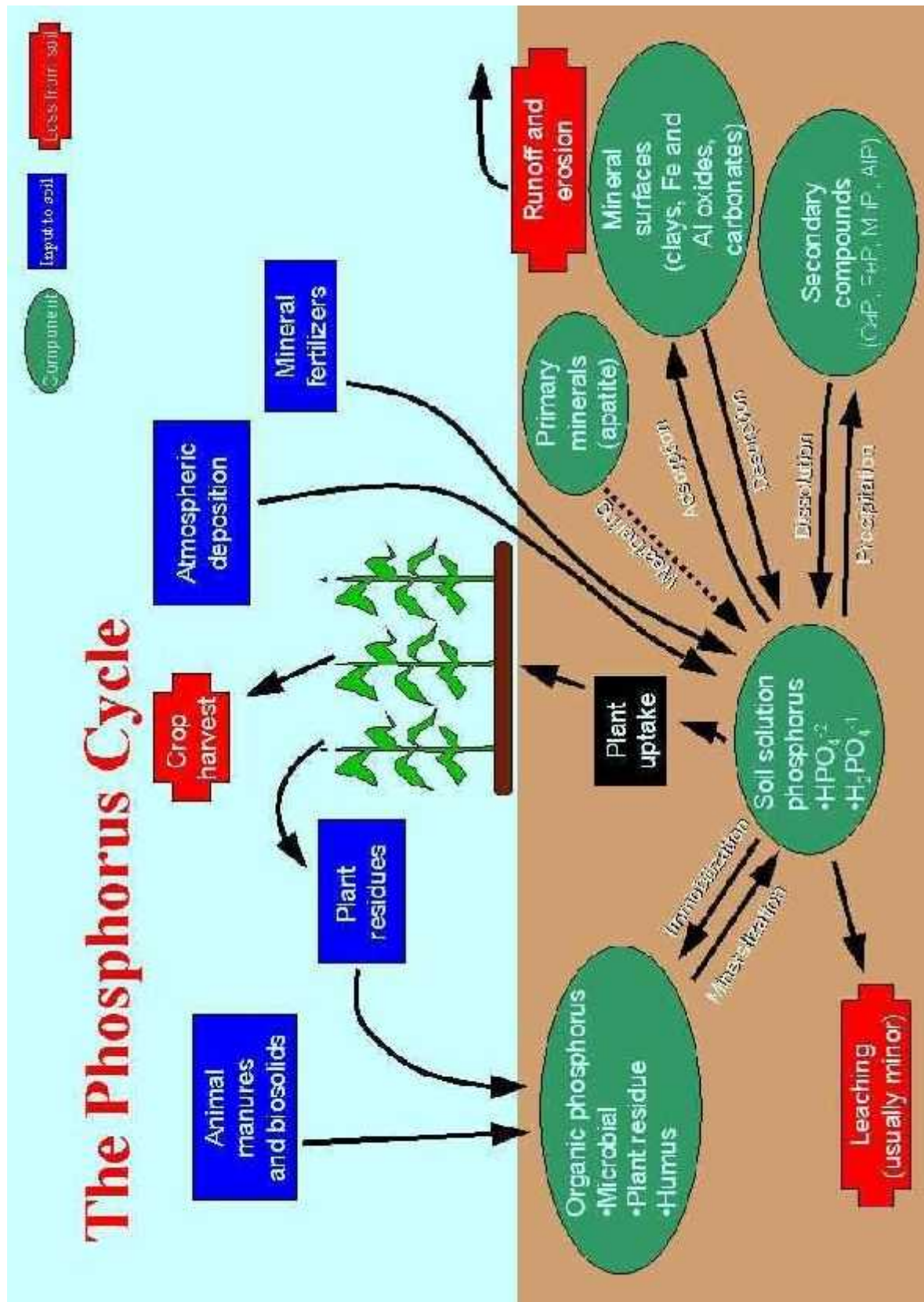
(١) يبدأ علي اليابسة حيث تتفتت صخور الفوسفات التي توجد علي اليابس بفعل الماء
(الامطار و الانهار) و الرياح و اشعه الشمس و جنور النباتات ثم تذوب في ماء التربة
و تكون املاح يمتصها النبات بواسطة الجذور.

(٢) ينتقل الفسفور المذاب بعد ذلك من كائن لآخر في سلاسل الغذاء و عندما تموت
الكائنات التي بها فسفور تتحلل اجسامها فيعود الفسفور مرة ثانية للتربة بواسطة الكائنات
المحللة

ثالثاً: جزء اخر من رواسب الفوسفات المفتتة يذوب في المسطحات المائية
مثل الانهار التي تصب في البحار حيث يترسب الفسفور عبر ملايين السنين في البحار
مكونا صخور رسوبية تصبح مورد رئيسي لاملاح الفسفور

رابعاً: تحمل تيارات الماء الصاعده بعض املاح الفسفور الموجوده في اعماق
البحار و المحيطات الي السطح حيث تصل اولا الي الكائنات البحرية النباتية و
عندما تتغذي عليها الكائنات البحرية الحيوانية في سلسلة الغذاء البحري تصل اليها
من خلال العلاقات الغذائية (الاسماك - الطيور البحرية)

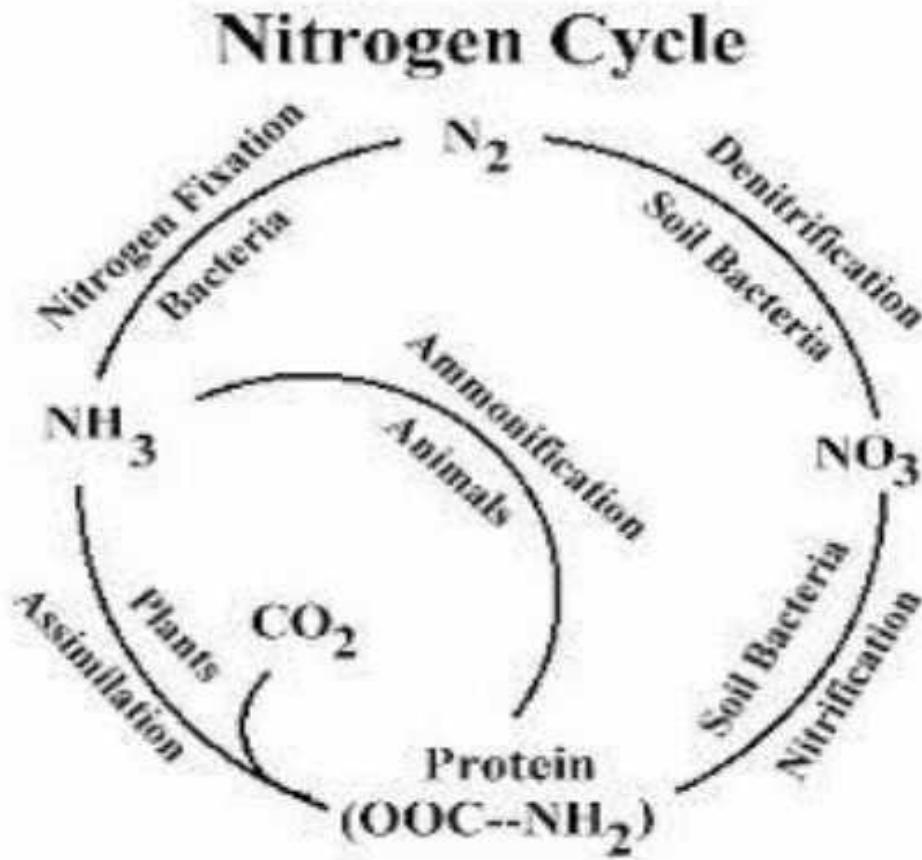
خامساً: يعود بعض الفسفور مره اخري الي الارض عن طريق الاسماك التي يتغذي
عليها الانسان او عن طريق فضلات و بقايا الطيور و الحيوانات التي تتغذي علي
الاسماك (مخلفات الطيور البحرية مثل النورس و العقاب و البطريق) والتي تعتبر
من اغنى المخلفات بالفسفور لذا يمكن استخدامها في صناعة السماد.



The Nitrogen Cycle

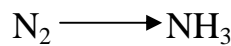
عنصر النيتروجين مهم جدا لبناء البروتينات والحوامض النووية

بالرغم من ان نسبة النيتروجين في الهواء الحوي 78%
الا ان معظم الكائنات لا تستطيع ان تنتجها في عملية انتاج البروتينات والمواد الاخرى.
لذلك لكي تستطيع النباتات انتاج البروتينات يجب ان تحصل على النيتروجين في شكل مواد غير عضوية.



تقسم دورة النيتروجين إلى أربعة مراحل:

1- تثبيت النيتروجين: تحويل النيتروجين الجوى إلى مركبات غير عضوية (أمونيا).



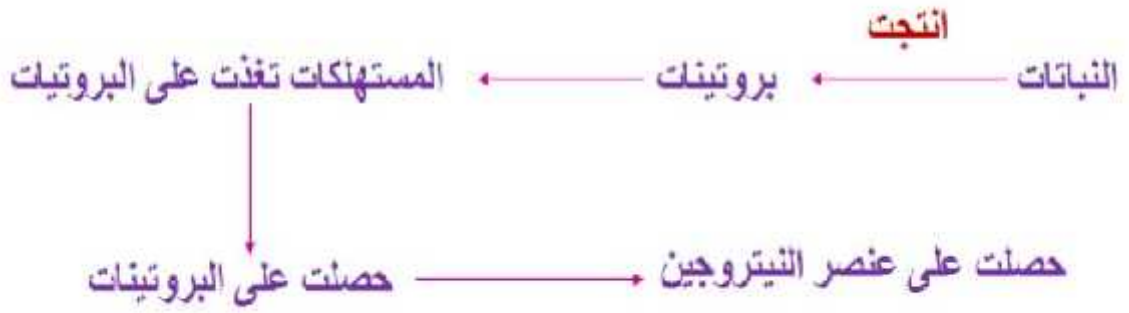
تقوم بهذه العملية بكتيريا تعيش فى جذور النباتات البقولية.

2- النيترة: تحويل الأمونيا إلى نترات.

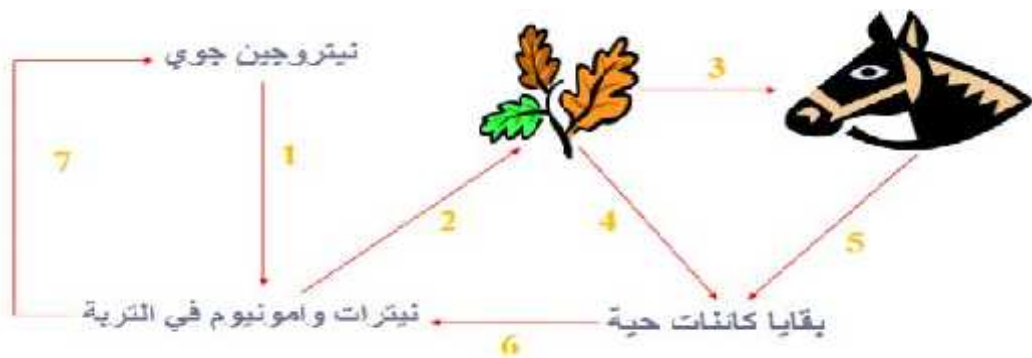
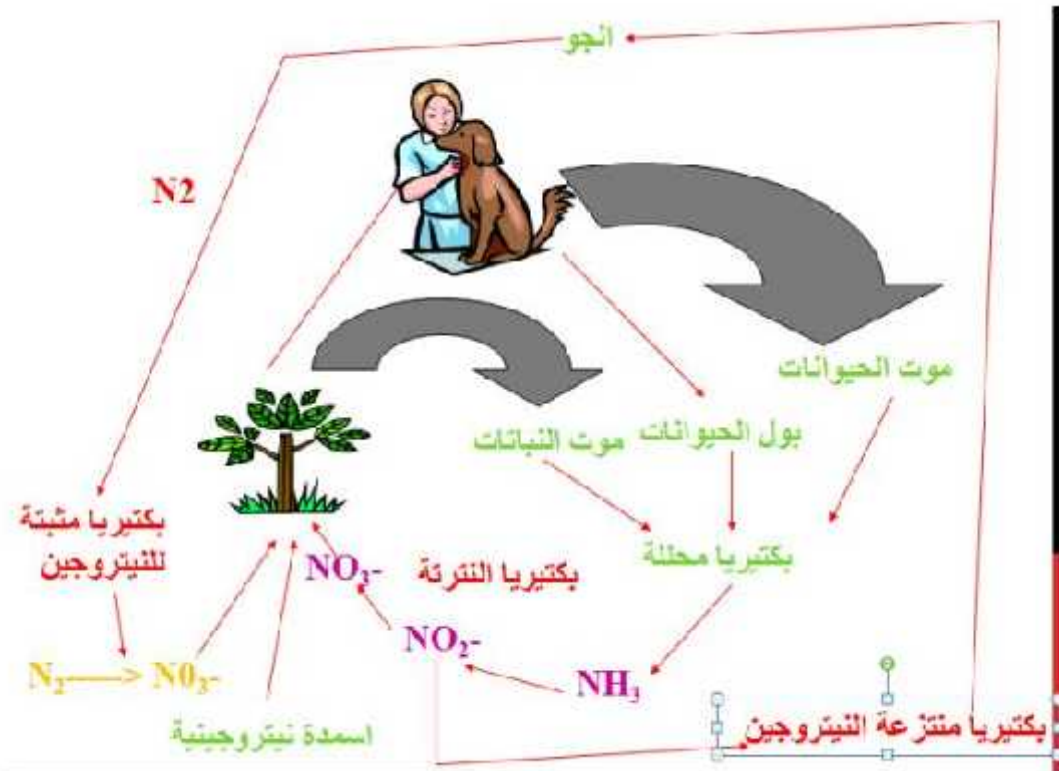


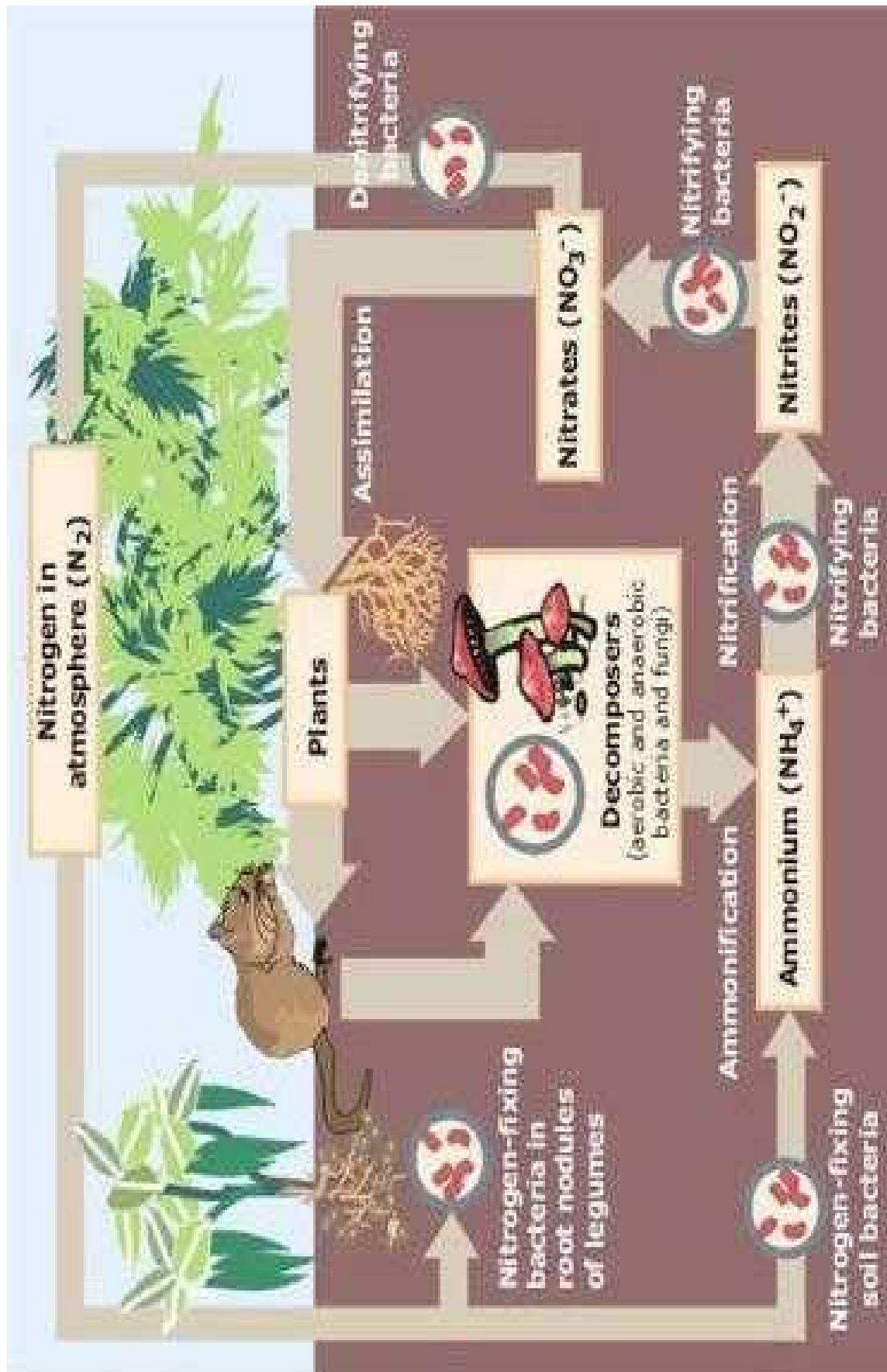
تقوم بهذه العملية بكتيريا تدعى بكتيريا النيترة.

3- إنتقال النيتروجين فى الشبكات الغذائية:



4 - النيتروجين: تحويل النترات إلى نيتروجين جوى.
تقوم بهذه العملية بكتريا تعيش فى التربة.





CHAPTER FOUR

Aquatic Chemistry & Water Pollution



Aquatic Chemistry and Water Pollution

1. Aquatic Chemistry

1.1. Properties of Water

Water is a vitally important substance in all parts of the environment. It covers about 70% of Earth's surface and occurs in all spheres of the environment. It is an essential part of all living systems. Water carries energy and matter through various spheres of the environment. It carries plant nutrients from soil into the bodies of plants by way of plant roots.

The properties of water would best be understood by considering the structure and bonding of the water molecule

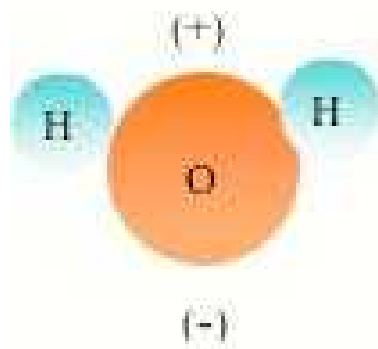


Fig. 10 A dipolar water molecule.

A single water molecule we have two hydrogen atoms bonded covalently to an oxygen atom. The three atoms are arranged in a V-shape structure with an angle of 105° . Because of its bent structure and the fact that the oxygen atom attracts electrons more strongly than hydrogen atoms, a water molecule behaves like a dipole having opposite electrical charges at either end. The water dipole may be attracted to either positively or negatively charged ions like with Na^+ and Cl^- during the dissolution of NaCl .

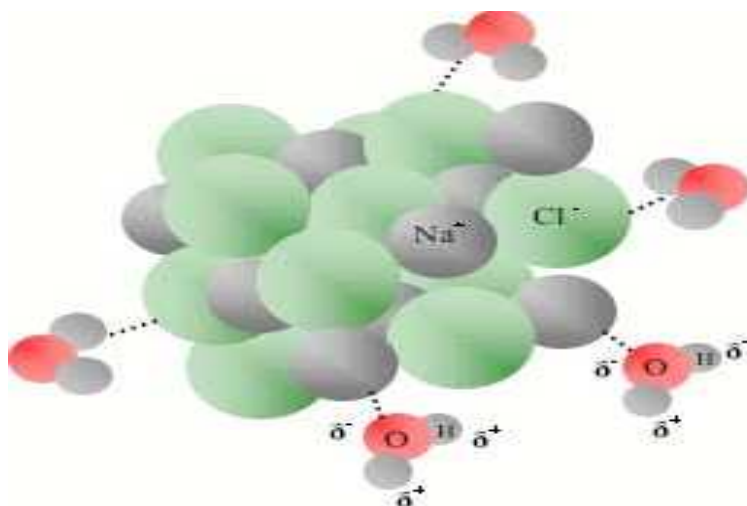


Fig. 11 Dissolution of sodium chloride crystals in water.

Water has the ability to form hydrogen bonds. Hydrogen bond is a special type of bond that can form between the partially positively charged hydrogen atoms in one water molecule and the partially negatively charged oxygen atoms in another water molecule. Hydrogen bond holds water molecules together with strong and also help to hold some solute molecules or ions in solutions.

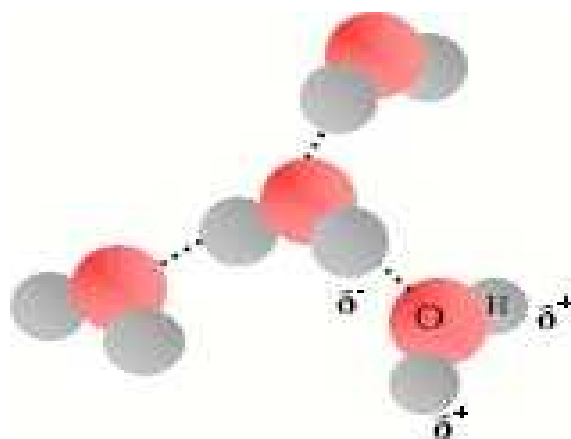


Fig. 12 Hydrogen bonding between the negative and positive poles of water molecules.

To have a clear understanding of water pollution you should be able to describe the chemical interactions taking place in the large water bodies. In the following section of the module, Chemical Reactions in Water bodies, the solubility of atmospheric gases in open water bodies, chemical reactions that

are responsible for the acid–base characteristics of water, complexation reactions and their equilibria, calculations of stability constants and concentrations of species in equilibrium are described. Water pollution and the physical and chemical parameters used to describe pollution, the sources of water pollution and water pollution control are also discussed in brief.

1.2. Chemical Reactions in Water bodies

Chemical interactions in natural water system are very complex and many variables should be taken into account to describe their chemistry. They are open dynamic systems and have variable inputs and outputs of energy and mass. Therefore, it is difficult to obtain a true equilibrium condition in these kind of systems. Because of this, such systems are frequently described by simplified models. Such models can give us useful generalizations and insights of the nature of aquatic chemical processes, and provide guidelines for the description and measurement of natural water systems. Fig. 13 is one such model that illustrates the main categories of aquatic chemical phenomena.

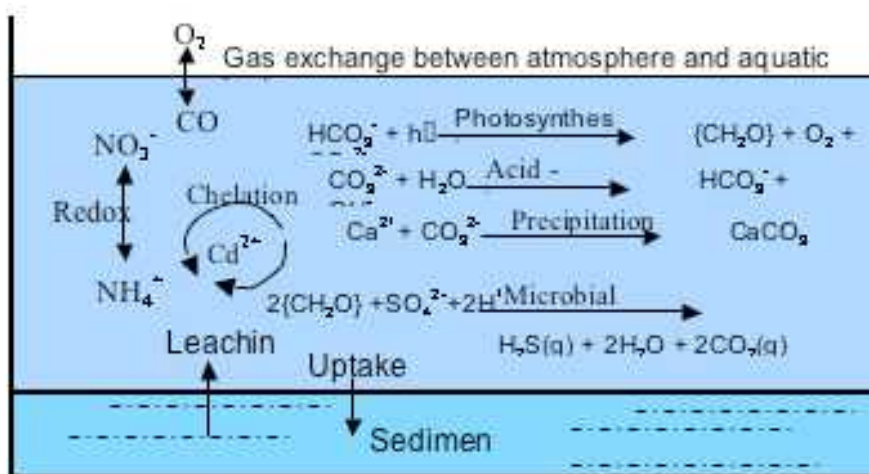


Fig. 13 Major Aquatic chemical processes.

1.2.1. Dissolved Gases in Water

Natural water systems contain a number of gases dissolved in them. Among these gases O_2 and CO_2 are vital for aquatic animals and plants. For

example O_2 is essential for fish and CO_2 for photosynthetic algae. Some gases in water can also cause problems, such as the death of fish from bubbles of nitrogen formed in the blood.

A) Oxygen in Water

Most of the elemental oxygen that we find dissolved in water comes from the atmosphere and also from the photosynthetic action of algae. As many kinds of aquatic organisms require oxygen for their existence, water bodies should contain appreciable level of dissolved oxygen.

Dissolved oxygen can decrease due to different reasons. Part of the oxygen coming from algal photosynthesis during the day for example is used up by the algae itself as part of their metabolic processes. Because of this, dissolved oxygen contribution through algal photosynthesis is not that efficient. The degradation of biomass coming from dead algae and other organic matter also consume dissolved oxygen. Therefore, the ability of a body of water to reoxygenate itself by contact with the atmosphere is an important characteristic.

B) Carbon Dioxide in Water

Carbon dioxide is present in virtually all natural waters and waste waters and is the most important weak acid in water. The CO_2 in water comes from the dissolution of atmospheric CO_2 and from microbial decay of organic matter. Carbon dioxide and its ionization products have extremely important influence upon the chemistry of water. Many minerals are deposited as salts of the carbonate ion.

Although dissolved CO_2 is often represented as H_2CO_3 just a small fraction of the dissolved CO_2 is actually present as H_2CO_3 . Therefore, to make a distinction, nonionized carbon dioxide in water is designated simply as CO_2 .

The equilibrium for dissolution of CO_2 in water is represented by the following equations:

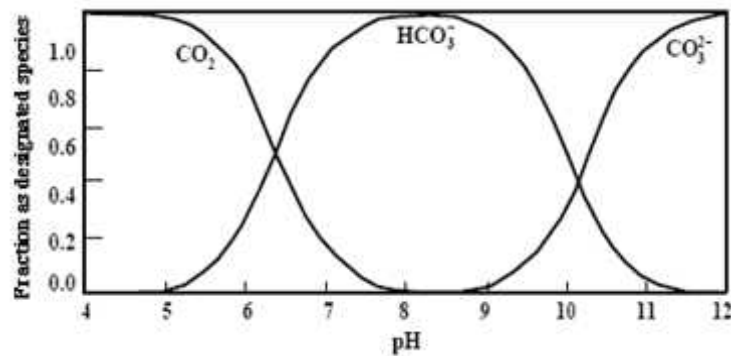


$$K_{a1} = \frac{[\text{HCO}_3^-][\text{H}^+]}{[\text{CO}_2]} = 4.45 \times 10^{-7} \quad \text{p}K_{a1} = 6.35 \quad (3.2)$$



$$K_{a2} = \frac{[\text{CO}_3^{2-}][\text{H}^+]}{[\text{HCO}_3^-]} = 4.69 \times 10^{-11} \quad \text{p}K_{a2} = 10.33 \quad (3.5)$$

Therefore, dissolved CO_2 at equilibrium contains: CO_2 , bicarbonate ion (HCO_3^-), and carbonate ion (CO_3^{2-}). The predominant species formed by CO_2 dissolved in water depends upon pH. This is best shown by a distribution of species diagram with pH as a master variable as illustrated in Fig. 14.



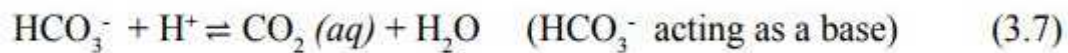
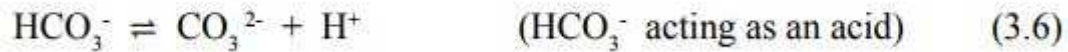
From Fig. 14 we can see that hydrogen carbonate (bicarbonate) ion (HCO_3^-) is the predominant species in the pH range found in most waters, with CO_2 predominating in more acidic waters.

1.3. Acid-base phenomena in water

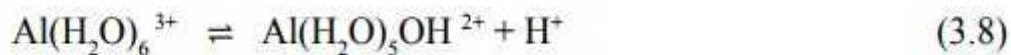
In your general chemistry courses you have studied the various definitions of acids and bases given by different scientists. In this section, we use the definition given by Bronsted and Lowry. According to the Bronsted - Lowry definition, acids are described as those chemical species that lose H^+

ion in a reaction and bases as those chemical species that accept the H^+ ion lost by acids.

The bicarbonate ion, HCO_3^- , is an important species in the acid-base chemistry of water. In water, it may act as either an acid or a base:



Acidity as applied to natural water and wastewater is the capacity of the water to neutralize OH^- and alkalinity is the capacity to neutralize H^+ . Although virtually all water has some alkalinity acidic water is not frequently encountered, except in cases of severe pollution. Existence of weak acids, particularly CO_2 , and sometimes $H_2PO_4^-$, H_2S , proteins, and fatty acids is in general the reason for water acidity. Acidic metal ions, such as Fe^{3+} , may also contribute to water acidity. The acidic character of some hydrated metal ions such as $Al(H_2O)_6^{3+}$ may also contribute to water acidity:



Alkalinity is important in water treatment and in the chemistry and biology of natural waters. In water treatment, we frequently need to know the alkalinity of water to calculate the quantities of chemicals to be added. Water which is highly alkaline often has a high pH and generally contains elevated levels of dissolved solids which make it unsuitable to be used in boilers, food processing, and municipal water systems.

Alkalinity serves as a pH buffer and reservoir for inorganic carbon, thus helping to determine the ability of water to support algal growth and other aquatic life, so it can be used as a measure of water fertility. In general, bicarbonate ion, carbonate ion, and hydroxide ion are the basic species responsible for water alkalinity (See the reactions below).



Alkalinity may be expressed as either phenolphthalein (bicarbonate) alkalinity or total alkalinity. Phenolphthalein alkalinity, is determined by titrating the water with acid to the pH at which HCO_3^- is the predominant carbonate species (pH 8.3), while total alkalinity, is determined by titrating with acid to the methylorange endpoint (pH 4.3), where both bicarbonate and carbonate species will be converted to CO_2 . In total alkalinity calculation for water below pH 7, the H^+ concentration in the water must be subtracted since its concentration will be significantly high. In a medium where the only contributors to alkalinity are HCO_3^- , CO_3^{2-} , and OH^- , alkalinity is calculated by using the following equation.

$$[\text{alk}] = [\text{HCO}_3^-] + 2[\text{CO}_3^{2-}] + [\text{OH}^-] - [\text{H}^+] \quad (3.12)$$

The concentration of CO_3^{2-} is multiplied by 2 because each CO_3^{2-} ion can neutralize 2 H^+ ions.

Alkalinity is given as Mol H^+ /L or Equivalents/L or mg/L of CaCO_3 , based upon the acid-neutralizing reaction: $\text{CaCO}_3 + 2\text{H}^+ \rightleftharpoons \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$.

Natural water typically has an alkalinity, designated here as “[alk]” of 1.00×10^{-3} equivalents per liter (eq/L), meaning that the alkaline solutes in 1 liter of the water will neutralize 1.00×10^{-3} moles of acid.

Example: The alkalinity of a river was determined to be 5×10^{-3} mol H^+/l , and its pH is 8.0. Calculate the concentrations of CO_3^{2-} and HCO_3^- and in the river.

Solution: $[alk] = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]$

Using the given pH value we can calculate $[H^+]$ and $[OH^-]$

$$pH = -\log [H^+]$$

$$8 = -\log [H^+] \Rightarrow [H^+] = 10^{-8}$$

$$K_w = [H^+][OH^-] = 10^{-14} \Rightarrow [OH^-] = \frac{10^{-14}}{10^{-8}} = 10^{-6}$$

Replacing the values of the concentrations of H^+ and OH^- in the alkalinity equation we will have

$$[alk] = [HCO_3^-] + 2[CO_3^{2-}] + 10^{-6} - 10^{-8}$$

From the equation for the second dissociation constant of H_2CO_3 we can calculate the concentration of HCO_3^- in terms of that of CO_3^{2-}



$$K_{a_2} = \frac{[CO_3^{2-}][H^+]}{[HCO_3^-]} = 4.69 \times 10^{-11}$$

$$\Rightarrow [HCO_3^-] = \frac{[CO_3^{2-}] \times 10^{-8}}{4.69 \times 10^{-11}}$$

$$\Rightarrow [HCO_3^-] = 213.22 [CO_3^{2-}]$$

Replacing $213.22 [CO_3^{2-}]$ in place of $[HCO_3^-]$ we have

$$[alk] = 213.22 [CO_3^{2-}] + 2[CO_3^{2-}] + 10^{-6} - 10^{-8}$$

$$\Rightarrow 5 \times 10^{-3} = 213.22 [CO_3^{2-}] + 2[CO_3^{2-}] + 10^{-6} - 10^{-8}$$

$$215.22 [CO_3^{2-}] = 5 \times 10^{-3}$$

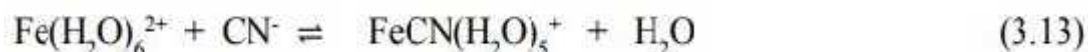
$$[CO_3^{2-}] = \frac{5 \times 10^{-3}}{215.22} = 2.3 \times 10^{-5}$$

$$[HCO_3^-] = 213.22 [CO_3^{2-}] = 213.22 \times 2.3 \times 10^{-5} = 4.95 \times 10^{-3}$$

1.4. Complexation reactions in water

Water contains different kinds of metal ions that exist in numerous forms. Unpolluted waters and biological systems contain the metal ions: Mg^{2+} , Ca^{2+} , Mn^{2+} , Fe^{2+} , Fe^{3+} , Cu^{2+} , Zn^{2+} , VO^{2+} and metal ions such as Co^{2+} , Ni^{2+} , Sr^{2+} , Cd^{2+} , and Ba^{2+} exist in contaminated water.

All metal ions in water exist bonded, or coordinated to other species such as water or other stronger bases that might be present in the water. Metals may also exist in water reversibly bound to inorganic anions or to organic compounds as metal complexes. For example, a cyanide ion can bond to dissolved iron(II) by donating a pair of electrons:



One of the water molecules in $\text{Fe}(\text{H}_2\text{O})_6^{2+}$ is replaced by a cyanide ion to form $\text{FeCN}(\text{H}_2\text{O})_5^+$. Additional cyanide ions may replace the remaining water molecules to form $\text{Fe}(\text{CN})_2(\text{H}_2\text{O})_4$, $\text{Fe}(\text{CN})_3(\text{H}_2\text{O})_3^-$, $\text{Fe}(\text{CN})_4(\text{H}_2\text{O})_2^{2-}$, $\text{Fe}(\text{CN})_5(\text{H}_2\text{O})_3^{3-}$, and $\text{Fe}(\text{CN})_6^{4-}$. The kind of reaction that has taken place between the CN^- ions and hydrated Fe^{2+} is called complexation. The product of the reaction, $\text{FeCN}(\text{H}_2\text{O})_5^+$ in the above equation, is known as a **complex**, **complex ion**, or **coordination compound**. The species that donates the pair of electrons to the central metal ion, CN^- in the example above, is called a ligand. In the example above, the cyanide ion donates a single pair of electrons or it possesses only one site that bonds to a metal ion, and is known as a unidentate ligand. There are ligands that possess more than one site (more than one atom) to form a bond with a metal ion. Such ligands form ring structured complexes and are known as chelating agents. The species formed are known as chelates. Chelating agents are common potential water pollutants. They occur in sewage effluent and industrial wastewater such as metal plating wastewater.

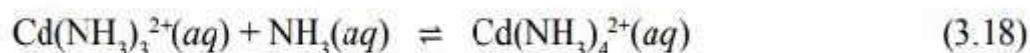
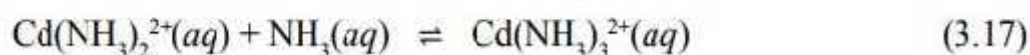
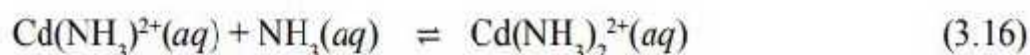
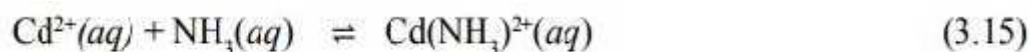
Complexation may have a number of effects in water. It may cause changes in the oxidation state of a metal ion and may result in the formation of a more soluble form of the metal from an insoluble compound. Insoluble complex compounds remove metal ions from solution. Because of their ability to solubilize heavy metals from plumbing, and from deposits containing heavy metals complexing agents are of primary concern in wastewater. Complexation may increase the leaching of heavy metals from waste disposal sites and reduce the efficiency with which heavy metals are removed with sludge in conventional biological waste treatment.

1.4.1. Stability of Complexes

The formation of a metal–ligand complex is described by a formation constant, K_f . The value of the formation constant expresses the stability of the complex. The formation constant for the complexation reaction between Cd^{2+} and NH_3 , for example, is given by

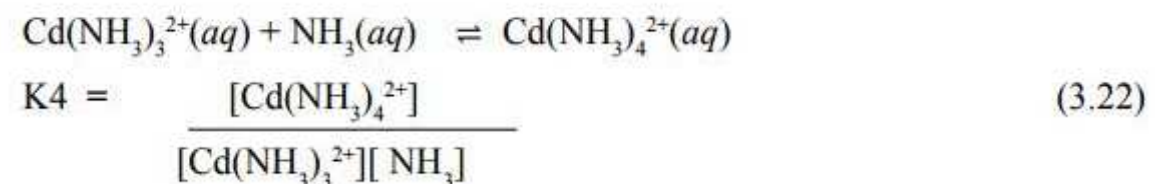
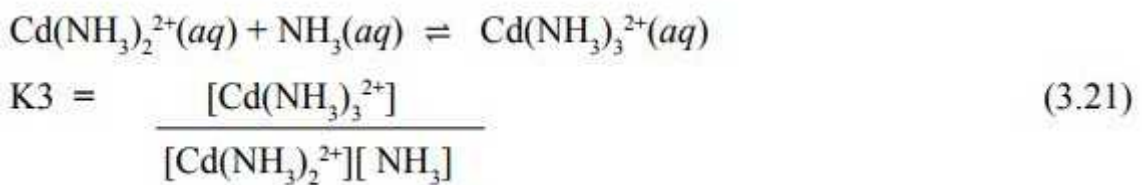
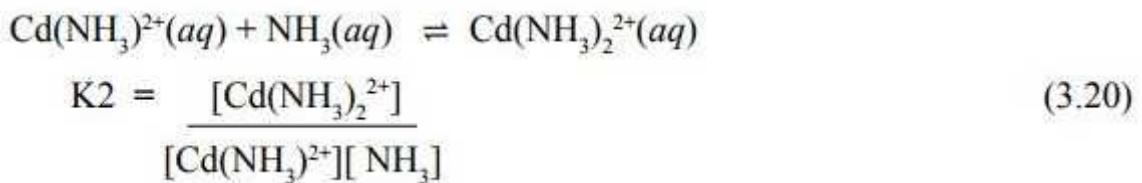
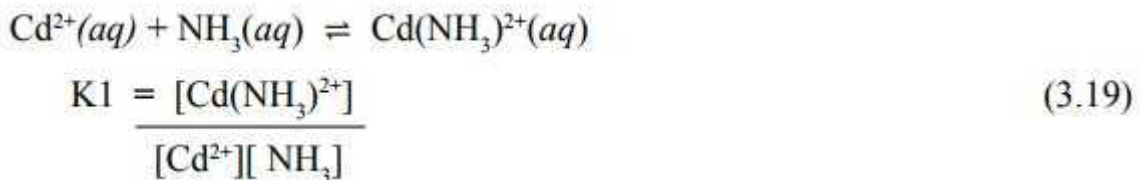
$$K_f = \frac{[\text{Cd}(\text{NH}_3)_4^{2+}]}{[\text{Cd}^{2+}][\text{NH}_3]^4} = 5.5 \times 10^7 \quad (3.14)$$

The complexation reaction between Cd^{2+} and NH_3 including many others occur in a stepwise fashion. For example, the reaction between Cd^{2+} and NH_3 involves four successive reactions which are shown by the equations given below.



Since it is not clear what reaction is described by a formation constant the above successive reactions create a problem. To avoid this, formation constants are divided into stepwise formation constants and cumulative or overall formation constants.

Stepwise formation constants, designated as K_i for the i^{th} step, describe the successive addition of a ligand to the metal–ligand complex formed in the previous step and overall, or **cumulative formation constants**, which are designated as β_i , describe the addition of i ligands to the free metal ion. Thus, the equilibrium constants for reactions 3.15 - 3.18 are, respectively, K_1 , K_2 , K_3 , and K_4 . The formation constant expressions for each of the steps are given by equations 3.19 – 3.22.



The equilibrium constant expression given in equation 3.14, therefore, is correctly identified as β_4 , where

$$\beta_4 = K_1 \times K_2 \times K_3 \times K_4$$

$$\text{In general } \beta_i = K_1 \times K_2 \times K_3 \times \dots \times K_i$$

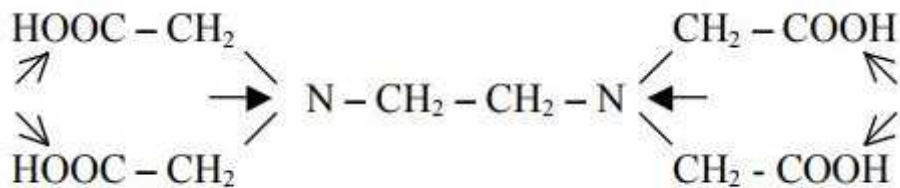
The formation constant given in 3.14, for example, is given by

$$\beta_4 = \frac{[\text{Cd}(\text{NH}_3)_4^{2+}]}{[\text{Cd}^{2+}][\text{NH}_3]^4} = 5.5 \times 10^7 \quad (3.23)$$

At pH values of 11 or above, EDTA is essentially all in the completely ionized tetra negative form, Y^{4-} , illustrated below:

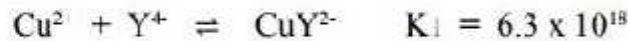
Of the several complexing agents found in water is ethylene diamine tetraacetic acid (EDTA). Most metals are known to form chelates with EDTA.

It has the structure given below



EDTA contains four replaceable hydrogen atoms and depending on the pH it contains H_4Y , H_3Y^- , H_2Y^{2-} , HY^{3-} , and Y^{4-} in different proportions. In water, metal ions and hydrogen ions compete for Y^{4-} . At lower pH values, the protonated forms of EDTA dominate the unprotonated forms while as pH increases, the fraction of free Y^{4-} that can be complexed to metal ions increases. At pH values of 11 or above, EDTA is essentially all in the completely ionized tetranegative form, Y^{4-} .

Example: Copper reacts with EDTA to form CuY^{2-} according to the reaction



A wastewater was analyzed to determine the relative amount of EDTA-complexed copper and free uncomplexed copper and the following results were obtained:

$$\text{pH} = 11$$

$$\text{Total Cu(II)} = 5.0 \text{ mg/L}$$

Excess free EDTA = 200 mg/L (expressed as the disodium salt, $\text{Na}_2\text{H}_2\text{C}_{10}\text{H}_{12}\text{O}_8\text{N}_2 \cdot 2\text{H}_2\text{O}$, formula weight 372)

Will most of the copper be present as the EDTA complex or in the uncomplexed form? Calculate the equilibrium concentration of the hydrated copper(II) ion, Cu^{2+} ?

Solution

At pH 11, uncomplexed EDTA exists as Y^{4-} . Its molar concentration, $[\text{Y}^{4-}]$ is given by

$$[\text{Y}^{4-}] = \frac{0.2 \text{ g L}^{-1}}{372 \text{ g mol}^{-1}} = 5.4 \times 10^{-4}$$

The formation constant for the reaction, $\text{Cu}^{2+} + \text{Y}^{4-} \rightleftharpoons \text{CuY}^{2-}$, is given by

$$K_1 = \frac{[\text{CuY}^{2-}]}{[\text{Y}^{4-}][\text{Cu}^{2+}]} = 6.3 \times 10^{18}$$

From this equation, the ratio of complexed copper to the uncomplexed will be

$$\frac{[\text{CuY}^{2-}]}{[\text{Cu}^{2+}]} = 6.3 \times 10^{18} \times [\text{Y}^{4-}]$$

Replacing 5.4×10^{-4} for $[\text{Y}^{4-}]$ we have,

$$\frac{[\text{CuY}^{2-}]}{[\text{Cu}^{2+}]} = 6.3 \times 10^{18} \times 5.4 \times 10^{-4} = 3.4 \times 10^{15}$$

This result indicates that, copper existing as the complex ion is extremely larger than the uncomplexed copper or essentially all of the copper is present as the complex ion.

2. Water Pollution

Of all the resources that we have on our planet water is undoubtedly the most precious. Without it, life on Earth would be non-existent: it is essential for everything on our planet to grow and prosper. Although we recognize this fact, we disregard it by polluting our rivers, lakes, and oceans. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. In addition to innocent organisms dying off, our drinking water has become greatly affected by pollution. In order to combat water pollution, we must understand the problems and become part of the solution.

2.1. Water Quality

The quality of water that we use for different purposes in life can be evaluated by using physical and chemical parameters. Quality indicators under both the physical and chemical parameters are described in the following sub-units.



“The quality of water is evaluated depending on its intended use!”

2.1.1. Physical Water Quality Parameters

Physical parameters define those characteristics of water that respond to the sense of sight, touch, taste or smell. Suspended solids, turbidity, color, taste and odor, and temperature fall in this category.

A) Suspended solids - Sources and impacts

Solids can be dispersed in water in both suspended and dissolved forms. Although some dissolved solids may be perceived by the physical sense, they fall more approximately under the category of chemical parameters.

Solids suspended in water may consist of inorganic substances such as clay and silt or organic particles such as plant fibers, algal and bacterial remains. Because of the filtering capacity of the soil, suspended material is seldom a constituent of ground water.

Other suspended material may also result from

- human use of the water.
- Industrial use

Domestic wastewater usually contains large quantities of suspended solids that are mostly organic in nature.

Suspended materials in water make the water aesthetically unpleasant and provide adsorption sites for chemical and biological agents. Biological degradation of suspended organic solids results in objectionable by-products. Biologically active (live) suspended solids may include disease causing organisms as well as organisms such as toxin-producing strains of algae. Suspended solids could be divided into filterable residues and non-filterable residues.

Suspended solids, where such material is likely to be organic and /or biological in nature, are important parameter of wastewater. The suspended-solids parameter is used to measure the quality of the wastewater affluent, to monitor several treatment processes, and to measure the quality of the effluent. EPA has set a maximum suspended solids standard of 30 mg/L for most treated wastewater discharges.

B) Turbidity: Sources and impacts

Turbidity is the measure of the extent to which light is either absorbed or scattered by suspended particles in water. Absorption and scattering are known to be influenced by both the size and surface characteristics of the suspended material. Therefore, turbidity can not be a direct quantitative measure of suspended solids. For example, a small pebble in a glass of water would not produce any turbidity. However, if this pebble were crushed into small particles of colloidal size it produces a measurable amount of turbidity although the mass of the pebble will not change.

Turbidity in surface waters results from soil erosion. Household and industrial waste waters such as soaps, detergents and emulsifying agents produce stable colloids that result in turbidity.

Impacts

Turbidity makes drinking water aesthetically displeasing and the colloidal materials associated with turbidity provide adsorption sites for chemicals that may be harmful or cause undesirable tastes and odors and for biological organisms that may be harmful to health.

C) Color and its sources

Pure water has no color. However, due to foreign materials natural water is often colored. The tannins, humic acid, and humates taken up by water from filterable suspended organic debris such as leaves, weeds, or wood, impart yellowish-brown color to water. Non-filterable substances such as iron oxides cause reddish water. Industrial wastes from textile and dyeing operations, pulp and paper production, food processing, chemical production, and mining, refining, and slaughterhouse operations may add substantial coloration to water in receiving streams. In general part of the water coloration coming from filterable suspended matter is said to be **apparent color** and that contributed by dissolved solids, which remain after removal of

filterable suspended matter, is known as **true color**.

Impacts

Similar to turbid water, colored water is aesthetically unacceptable to the general public. Highly colored water is unsuitable for laundering, dyeing, papermaking, beverage manufacturing, and dairy production. Therefore, colored water is less marketable both for domestic and industrial use.

D) Taste and odor

The taste of water is the flavor that water gives us when we put it into our mouth, and the quality of water that we perceive by our sense of smell is its odor. Consumers may attribute a wide variety of tastes and odors to water. Substances that produce odor in water will almost invariably impart a taste as well. However, the converse is not true, as there are many mineral substances that produce taste but not odor. Organic materials or, their biological decomposition, are known to produce both taste and odor problems in water. Principal among these are the reduced products of sulfur that imparts a “rotten egg” odor and taste. Also, certain species of algae secrete an oily substance that may result in both taste and odor. The combination of two or more substances neither of which would produce taste or odor by itself may sometimes result in taste or odor problems. Alkaline mineral imparts a bitter taste to water, while metallic salts may give a salty or bitter taste.

Impacts

Taste and odor make water aesthetically displeasing to consumers. Some of the substances that impart bad taste and odor may be carcinogenic.

E) Temperature and its sources

Temperature is not used as a parameter to evaluate potable water or waste water directly. It is however, one of the most important parameters in natural surface water systems. The temperature of surface waters governs to a

large extent the biological species present and their rates of activity. It also influences most chemical reactions that occur in natural water system the solubility of gases in water.

Generally, shallow bodies of water are more affected by ambient temperatures (temperature of the surrounding atmosphere) than are deeper bodies. Water used for the dissipation of waste heat in industry and the subsequent discharge of the heated water may result in an increasing in the temperature of receiving streams, though perhaps localized. Removal of forest canopies and irrigation return flows can also result in increased stream temperature.

Impacts

Lower temperatures favor slower rate of biological activity. Provided that essential nutrients are available, biological activity is doubled by an increase of approximately 10 °C. With an increase in metabolic rates, organisms that are efficient at food utilization and reproduction flourish, while other species decline and are perhaps eliminated altogether. Algal growth is often accelerated in warm water and can become a problem when cells cluster into algae mats. Natural secretion of oils by the algae in the mats and the decay products of dead algae cells can result in taste and odor problems. Higher order species, such as fish, are affected dramatically by temperature and by dissolved oxygen levels, which are a function of temperature. Game fish generally require cooler temperatures and higher dissolved-oxygen levels.

Temperature changes affect the reaction rates and solubility levels of chemicals. Most chemical reactions involving dissolution of solids are accelerated by an increase in temperature. The solubility of gases, on the other hand, decreases at elevated temperatures. Thus, with an increase in temperature the level of dissolved oxygen will decrease. This is undesirable

situation since biological oxidation of organics in streams is dependent on adequate supply dissolved oxygen.

2.1.2. Chemical water quality parameters

Water has been called the universal solvent, and chemical parameters are related to the solvent capabilities of water. Total dissolved solids, alkalinity hardness, fluorides, metals, organics and nutrients are chemical parameters of concern in water quality management.

3. Thermal Pollution

If you look at Figure 15, you might assume that a toxic chemical caused the massive fish kill in the photo. But the fish were not killed by a chemical spill—they died because of thermal pollution. When the temperature of a body of water, such as a lake or stream increases, that can lead to thermal pollution. Thermal pollution can occur when power plants and other industries use water in their cooling systems and then discharge the warm water into a lake or river. Thermal pollution can cause large fish kills if the discharged water is too warm for the fish to survive. But most thermal pollution is more subtle. If the temperature of a body of water rises even few degrees, the amount of oxygen the water can hold decreases significantly. As oxygen levels drop, aquatic organisms may suffocate and die. If the flow of warm water into a lake or stream is constant, it may cause the total disruption of an aquatic ecosystem.



Fig. 15 Fish kills, ex. this one in Brazil, result from thermal pollution.

4. Groundwater Pollution

Pollutants usually enter groundwater when polluted surface water percolates down from the Earth's surface. Any pollution of the surface water in an area can affect the groundwater. Pesticides, herbicides, chemical fertilizers, and petroleum products are common groundwater pollutants. Leaking underground storage tanks are another major source of groundwater pollution. Most of the tanks—located beneath gas stations, farms, and homes—hold petroleum products, such as gasoline and heating fuel.

As underground storage tanks age, they may develop leaks, which allow pollutants to seep into the groundwater. The location of aging underground storage tanks is not always known, so the tanks often cannot be repaired or replaced until after they have leaked enough pollutants to be located. Modern underground storage tanks are contained in concrete and have many features to prevent leaks. Other sources of ground water pollution include septic tanks, unlined landfills, and industrial wastewater lagoons, as shown in Fig. 16.

4.1. Cleaning Up Groundwater Pollution

Groundwater pollution is one of the most challenging environmental problems that the world faces. Even if groundwater pollution could be stopped tomorrow, some groundwater would remain polluted for generations to come. As you have learned, groundwater recharges very slowly. The process for some aquifers to recycle water and purge contaminants can take hundreds or thousands of years. Groundwater is also difficult to decontaminate because the water is dispersed throughout large areas of rock and sand.

Pollution can cling to the materials that make up an aquifer, so even if all of the water in an aquifer were pumped out and replaced with clean water, the ground water could still become polluted.

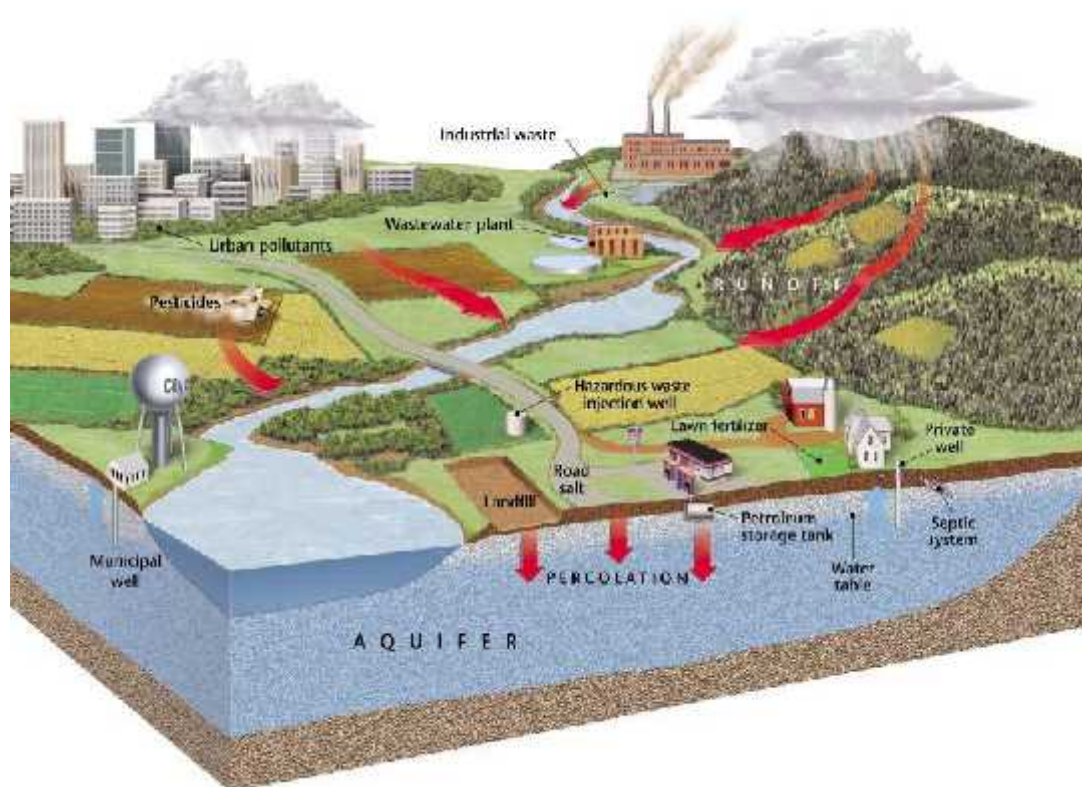


Fig. 16 Some of the major sources of groundwater pollution. Runoff and percolation transport contaminants to the groundwater.

5. Ocean Pollution

Although oceans are the largest bodies of water on Earth, they are still vulnerable to pollution. Pollutants are often dumped directly into the oceans. For example, ships can legally dump wastewater and garbage overboard in some parts of the ocean. But at least 85 percent of ocean pollution—including pollutants such as oil, toxic wastes, and medical wastes—comes from activities on land. If polluted runoff enters rivers, for example, the rivers may carry the polluted water to the ocean. Most activities that pollute oceans occur near the coasts, where much of the world's human population lives. As you might imagine, sensitive coastal ecosystems, such as coral reefs, estuaries, and coastal marshes, are the most affected by pollution.

Oil Spills Ocean water is also polluted by accidental oil spills. Disasters such as the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, make front-page news around the world. In 2001, a fuel-oil spill off the coast

of the Galápagos Islands captured public attention. Each year, approximately 37 million gallons of oil from tanker accidents are spilled into the oceans. Such oil spills have dramatic effects, but they are responsible for only about 5 percent of oil pollution in the oceans. Most of the oil that pollutes the oceans comes from cities and towns. Every year, as many as 200 million to 300 million gallons of oil enter the ocean from nonpoint sources on land. That's almost 10 times the amount of oil spilled by tankers. In fact, in one year, the road runoff from a coastal city of 5 million people could contain as much oil as a tanker spill does. Limiting these non point sources of oil pollution would go a long way toward keeping the oceans clean.

The United States Environmental Protection Agency (EPA) divides water pollution into the following six categories

1) Biodegradable waste consists mainly of human and animal waste. When biodegradable waste enters a water supply, the waste provides an energy source (organic carbon) for bacteria. Organic carbon is converted to carbon dioxide and water, which can cause atmospheric pollution and acid rain; this form of pollution is far more widespread and problematic than other forms of pollutants, such as radioactive waste. If there is a large supply of organic matter in the water, oxygen-consuming (aerobic) bacteria multiply quickly, consume all available oxygen, and kill all aquatic life.

2) Plant nutrients, such as phosphates and nitrates, enter the water through sewage, and livestock and fertilizer runoff. Phosphates and nitrates are also found in industrial wastes. Though these chemicals are natural, 80 percent of nitrates and 75 percent of phosphates in water are human-added. When there is too much nitrogen or phosphorus in a water supply (0.3 parts per million for nitrogen and 0.01 parts per million for phosphorus), algae begin to develop. When algae blooms, the water can turn green and cloudy, feel slimy, and smell bad. Weeds start to grow and bacteria spread. Decomposing plants

use up the oxygen in the water, disrupting the aquatic life, reducing biodiversity, and even killing aquatic life. This process, called eutrophication, is a natural process, but generally occurs over thousands of years. Eutrophication allows a lake to age and become more nutrient-rich; without nutrient pollution, this may take 10,000 years, but pollution can make the process occur 100 to 1,000 times faster.

3) Heat can be a source of pollution in water. As the water temperature increases, the amount of dissolved oxygen decreases. Thermal pollution can be natural, in the case of hot springs and shallow ponds in the summertime, or human-made, through the discharge of water that has been used to cool power plants or other industrial equipment. Fish and plants require certain temperatures and oxygen levels to survive, so thermal pollution often reduces the aquatic life diversity in the water.

4) Sediment is one of the most common sources of water pollution. Sediment consists of mineral or organic solid matter that is washed or blown from land into water sources. Sediment pollution is difficult to identify, because it comes from non-point sources, such as construction, agricultural and livestock operations, logging, flooding, and city runoff. Each year, water sources in the United States are polluted by over one billion tons of sediment! Sediment can cause large problems, as it can clog municipal water systems, smother aquatic life, and cause water to become increasingly turbid. And, turbid water can cause thermal pollution, because cloudy water absorbs more solar radiation.

5) Hazardous and toxic chemicals are usually human-made materials that are not used or disposed of properly. Point sources of chemical pollution include industrial discharges and oil spills. The Oil Pollution fact sheet includes more detailed information about oil spills, as well as other sources of oil pollution. Non-point sources of chemical pollution include

runoff from paved roads and pesticide runoff. Many people think industries produce the greatest amount of chemical pollution. But domestic and personal use of chemicals can significantly contribute to chemical pollution. Household cleaners, dyes, paints and solvents are also toxic, and can accumulate when poured down drains or flushed down the toilet. In fact, one drop of used motor oil can pollute 25 liters of water! And, people who use pesticides on their gardens and lawns tend to use ten times more pesticide per acre than a farmer would!

How can we prevent water pollution?

When we throw something in the garbage, or flush the toilet, we tend to forget about it. Because individuals are responsible for many non-point sources of pollution, we do not always realize how much we are contributing to water pollution. It seems easier to point the finger at agricultural, industrial, and mining operations. However, here are a few tips:

- Conserve water; the less water you use, the less will be running down the drains and into gutters, carrying pollutants with it.
- Keep pet litter and debris out of street gutters.
- Use pesticides sparingly; in general, people tend to use 10 to 50 times more fertilizer on their lawns and gardens than is necessary for good plant health.
- Or, use compost to fertilize your garden.
- Keep your vehicles running properly. If you have an oil leak, fix it immediately, and if you change your own oil, dispose of the used oil properly.
- Use natural cleaners, such as baking soda, vinegar and borax.
- Use detergents with less phosphate; sewage plants can only remove about 30 percent of the phosphates from waste.
- Toxic products like paints, automobile oil, polishes, and cleaning

products should be stored and disposed of properly.

- Refrain from throwing litter into streams, lakes, rivers, or seas.

How can a society do to prevent water pollution?

- Knowledge on ways of preventing water pollution and its effects on human health should be spread more widely.
- Tighter laws should be legislated and existing laws amended to curb illegal dumping of trash and poisonous chemical wastes into water sources.
- Waste materials must be disposed of properly.
- Daily household rubbish can be buried or thrown away neatly in plastic bags, to be sent to special rubbish collecting areas.
- Industrial wastes should be treated before disposal, to make sure the substances are harmless.
- Stuff like glass, paper, plastic and metal can be recycled.
- Excess use of insecticides and chemical fertilizers should be avoided as far as possible.

CHAPTER FIVE

Water Treatment



Water Treatment

1. Introduction

Water can be contaminated by the following agents:

- Pathogens – disease-causing organisms that include bacteria, amoebas and viruses, as well as the eggs and larvae of parasitic worms.
- Harmful chemicals from human activities (industrial wastes, pesticides, fertilizers).
- Chemicals and minerals from the natural environment, such as arsenic, common salt and fluorides. Some non-harmful contaminants may influence the taste, smell, color or temperature of water, and make it unacceptable to the community.

Water from surface sources is often contaminated by microbes; whereas groundwater is normally safer, but even groundwater can be contaminated by harmful chemicals from human activities or from the natural environment.

Rainwater captured by a rooftop harvesting system or with small catchment dams is relatively safe, provided that the first water is allowed to flow to waste when the rainy season starts.

The amount of water to be treated should also be assessed. This can be estimated by assuming that each person will need a minimum of 20–50 liters of water a day for drinking, cooking, laundry and personal hygiene.

A community should be consulted when choosing a water-treatment system and should be made aware of the costs associated with the technology. In particular, community members should be made aware of the behavioral and/or cultural changes needed to make the system effective over the long-term and thus be acceptable to them. Communities may also need to be educated about protecting water sources from animal or human contamination, and mobilized. It should be emphasized that all the positive effects of a water-treatment system could be jeopardized if the water is not

drawn, stored and transported carefully and hygienically.

2. Drinking Water Treatment Process:

Now that you are familiar with drinking water treatment, let's examine modern methods in greater detail. In general, the treatment of drinking water by municipal water systems involves a few key steps:

Aeration:

The water is mixed to liberate dissolved gases and to suspended particles in the water column.

Flocculation:

The materials and particles present in drinking water (clay, organic material, metals, microorganisms) are often quite small and so will not settle out from the water column without assistance. To help the settling process along, "coagulating" compounds are added to the water, and suspended particles "stick" to these compounds and create large and heavy clumps of material.

Sedimentation:

The water is left undisturbed to allow the heavy clumps of particles and coagulants to settle out.

Filtration:

The water is run through a series of filters which trap and remove particles still remaining in the water column. Typically, beds of sand or charcoal are used to accomplish this task.

Disinfection:

The water, now largely free of particles and microorganisms, is treated to destroy any remaining disease-causing pathogens. This is commonly done with chlorination (the same process used to eliminate pathogens in swimming pools), ozone, or ultraviolet radiation. The water is now safe to drink and is sent to pumping stations for distribution to homes and businesses.

The Fact Sheets in this section deal with both community and household methods for treating water. Some household treatment methods and their effectiveness are summarized in Table 1, whereas the following household and community water-treatment technologies are described in greater detail:

Household water-treatment systems

- boiling.
- Household slow sand filter.
- Domestic chlorination.

Community water-treatment systems

- Storage and sedimentation.
- up-flow roughing filter.
- slow sand filtration.
- Chlorination in piped water-supply systems.

TABLE 1 HOUSEHOLD WATER-TREATMENT SYSTEMS AND THEIR EFFECTIVENESS¹

Treatment system	Effectiveness over factors that affect water quality									
	Bacteria, amoebas	Guinea-worm	Cercaria	Fe, Mn	Fluoride	Arsenic	Salts	Odour, taste	Organic matter	Turbidity
Straining through fine cloth Consists in pouring raw water through a piece of fine, clean, cotton cloth to remove some of the suspended solids.	—	☺☺☺	—	—	—	—	—	—	☺	☺
Aeration Oxidizes iron (Fe) and manganese (Mn). Good aeration of the water is also important for slow, sand filtration to be effective, especially if there is not enough oxygen in the surface water. Water can easily be aerated by shaking it in a vessel, or by allowing it to trickle through perforated trays containing small stones.	—	—	—	☺☺☺	—	—	—	☺☺	☺	—
Storage/pre-settlement Storing water for only one day can eliminate some bacteria, but it should be stored for 48 hours to eliminate cercaria (snail larvae). The longer the water is stored, the more the suspended solids and pathogens will settle to the bottom of the container. The top water can then be used after sedimentation.	☺	—	☺☺☺	☺	—	—	—	☺	☺	☺☺
Coagulation, flocculation and settlement In coagulation, a liquid coagulant, such as aluminium sulfate, is added to the water to attract suspended particles. The water is then gently stirred to allow the particles to come together and form larger particles (flocculation), which can then be removed by sedimentation, settlement or filtration. The amount of coagulant needed will depend on the nature of the contaminating chemical compounds and solids.	☺	—	☺	☺	☺☺☺	☺☺☺	—	☺	☺	☺☺
Slow sand filtration Water passes slowly downwards through a bed of fine sand at a steady rate. The water should not be too turbid, otherwise the filter will get clogged. Pathogens are naturally removed in the top layer where a biological film builds up. A potential problem is that some households do not use this technology effectively and the water can remain contaminated.	☺☺☺	☺☺☺	☺☺☺	☺☺	—	☺☺	—	☺☺	☺	☺☺☺

The treatments were categorized as being: of no effect, or of unknown effectiveness (—); of little effect (☹); moderately effective (☺); highly effective (😊).

TABLE 1 CONTINUED										
Treatment system	Effectiveness over factors that affect water quality									
	Bacteria, amoebas	Guinea-worm	Cercaria	Fe, Mn	Fluoride	Arsenic	Salts	Odour, taste	Organic matter	Turbidity
<p>Rapid sand filtration The sand used is coarser than in slow sand filtration and the flow rate is higher. The method is used to remove suspended solids and is effective after the water has been cleared with coagulation/flocculation. There is no build-up of biological film, hence the water will still need to be disinfected. It is easier to remove trapped debris from upflow sand filters, compared to filters in which the water flows downwards.</p>	☺	😊😊	☺	😊😊	—	—	—	☺	😊	😊😊
<p>Charcoal filter Granular charcoal (or granulated activated carbon) can be used in filtration and is effective in improving the taste, odour and colour of the water. However, it should be replaced regularly, because bacteria can breed in it.</p>	—	😊😊	😊😊	☺	—	—	—	😊😊😊	—	☺
<p>Ceramic filter The filter is a porous, unglazed ceramic cylinder and impurities are deposited on its surface. Filters with very small pores can remove most pathogens. Open, porous ceramic jars can also be used. The ceramic filter method can only be used with fairly clear water.</p>	😊😊😊	😊😊😊	😊😊😊	—	—	—	—	😊😊	😊😊	😊😊😊
<p>Solar disinfection Ultraviolet radiation from the sun will destroy most pathogens, and increasing the temperature of the water enhances the effectiveness of the radiation. In tropical areas, most pathogens can be killed by exposing the contaminated water to sun for five hours, centred around midday. An easy way to do this, is to expose (half-blackened) clear glass/plastic bottles of water to the sun. Shaking the bottle before irradiation increases the effectiveness of the treatment. The water must be clear for this treatment to be effective.</p>	😊😊😊	😊😊	😊😊	—	—	—	—	—	—	—

TABLE 1 CONTINUED

Treatment system	Effectiveness over factors that affect water quality									
	Bacteria, amoebas	Guinea-worm	Cercaria	Fe, Mn	Fluoride	Arsenic	Salts	Odour, taste	Organic matter	Turbidity
<p>Chemical disinfection Chlorination is the most widely used method of disinfecting drinking-water. Liquids (such as bleach), powders (such as bleaching powder), and purpose-made tablets can be used. Iodine can also be used as a chemical disinfectant. Deciding on the right amount of chlorine to use can be difficult, because the effectiveness of chlorination depends on the quality of the untreated water, which may vary according to the season.</p>	☺☺☺	—	☺☺☺	—	—	—	—	☺	☺☺☺	—
<p>Boiling Bringing the water to a rolling boil will kill most pathogens, and many are killed at lower temperatures (e.g. 70 °C). This approach can be expensive, however, because fuel/charcoal is needed to boil the water.</p>	☺☺☺	☺☺☺	☺☺☺	—	—	—	—	☺	☺	—
<p>Desalination/evaporation Desalination by distillation produces water without chemical salts and the method can be used at household level. The method can be expensive because of the capital investment needed and because fuel/charcoal is used to heat the water. The volume of water produced is also low.</p>	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺

Should water be chlorinated?

The water-treatment methods described above can reduce the number of pathogens in water, but do not always eliminate them completely. And although boiling and solar disinfection are effective, the methods are impractical with large volumes of water. In contrast, chemical disinfection inactivates pathogenic organisms and the method can be used with large

volumes of water.

Chlorine compounds usually destroy pathogens after 30 minutes of contact time, and free residual chlorine (0.2–0.5 mg per liter of treated water) can be maintained in the water supply to provide ongoing disinfection. Several chlorine compounds, such as sodium hypochlorite and calcium hypochlorite, can be used domestically, but the active chlorine concentrations of such sources can be different and this should be taken into account when calculating the amount of chlorine to add to the water.

The amount of chlorine that will be needed to kill the pathogens will be affected by the quality of the untreated water and by the strength of the chlorine compound used. If the water is excessively turbid, it should be filtered or allowed to settle before chlorinating it.

3. Reducing the concentration of chemicals in water

- Iron and manganese

Water collected from boreholes can have a high concentration of iron (greater than 0.3mg/l, the WHO guideline value). This can be the result of naturally high iron content in the soil, or the result of corrosion (from iron pipes, borehole casings and screens).

The iron gives the water an unpleasant metallic taste and odor, stains laundry and white enamel on sinks and bowls, and discolors food. Although such levels of iron are not known to be harmful, the undesirable properties can cause communities to accept contaminated water that has no taste, instead of safe water that has a metallic taste. Most of the iron can be removed simply, by aerating the water and filtering it through sand and gravel. The sand and gravel used in the filters will need to be cleaned periodically.

Similar problems arise when water has excessive manganese concentrations (above 0.1 mg/l, the WHO guideline value), but again the water can be treated by aeration, followed by filtration and settlement.

- Fluoride

High concentrations of fluoride (above 1.5 mg/l, the WHO guideline value) can damage bones and teeth. Low-cost treatment methods include the Nalgonda system (which uses lime to soften the water), and using alum as a coagulant. With either treatment, the water is then left to settle at the same time it is being chlorinated.

- Arsenic

Arsenic is widely distributed throughout the Earth's crust and enters water as dissolved minerals. It can also enter water bodies in industrial effluents or by deposition from the atmosphere. Arsenic concentrations greater than the WHO guideline value of 0.01 mg/l are toxic. Simple treatment methods include adding lime to soften the water, or adding alum as a coagulant, followed by settlement.

When arsenic (or fluoride) is to be removed at household level, the implementation should always be carefully planned and supported by the community.

4. Solar disinfection

The principle underlying solar disinfection is that microorganisms are vulnerable to light and heat. One easy and simple way to treat water is to use the SODIS system (Solar Disinfection), which has been tested both in the laboratory and in the field. A transparent container is filled with water and exposed to full sunlight for several hours.

As soon as the water temperature reaches 50 °C, the inactivation process is accelerated and usually leads to complete bacteriological disinfection.

5. Household water-treatment systems

5.1. Boiling

The technology:

Heating water is an effective way to kill the microorganisms in it. WHO recommends that the water be brought to a vigorous boil. This will kill, or inactivate, most organisms that cause diarrhea. High turbidity does not affect disinfection by boiling, but if the water is to be filtered, this must be done before boiling. For household use, water is mostly boiled in a pot on a stove. If it is not to be stored in the same pot in which it was boiled, the water should be poured into a clean storage container immediately after boiling, so that the heat of the boiled water will kill most of the bacteria in the storage container. Fuel costs and the time involved in boiling and cooling the water, limit the usefulness of this method.



Fig. 17 Boiling of water.

Potential problems

- The water becomes decontaminated after boiling.

- Fuel for boiling the water is scarce and consequently, expensive.
- Boiled water tastes flat this may be corrected by adding herbs to the water during boiling and not drinking it for six hours after it has been boiled.

5.2. Household slow sand filter

The technology

The technology with a household slow sand filter, water is passed slowly downwards through a bed of sand, where it is treated by a combination of biological, physical and chemical processes. Fine particles in the water are filtered out by the sand, while microorganisms grow on top of the sand filter and feed on bacteria, viruses and organic matter in the water. The filter can be made of clean 200-liter steel barrels connected by hoses.

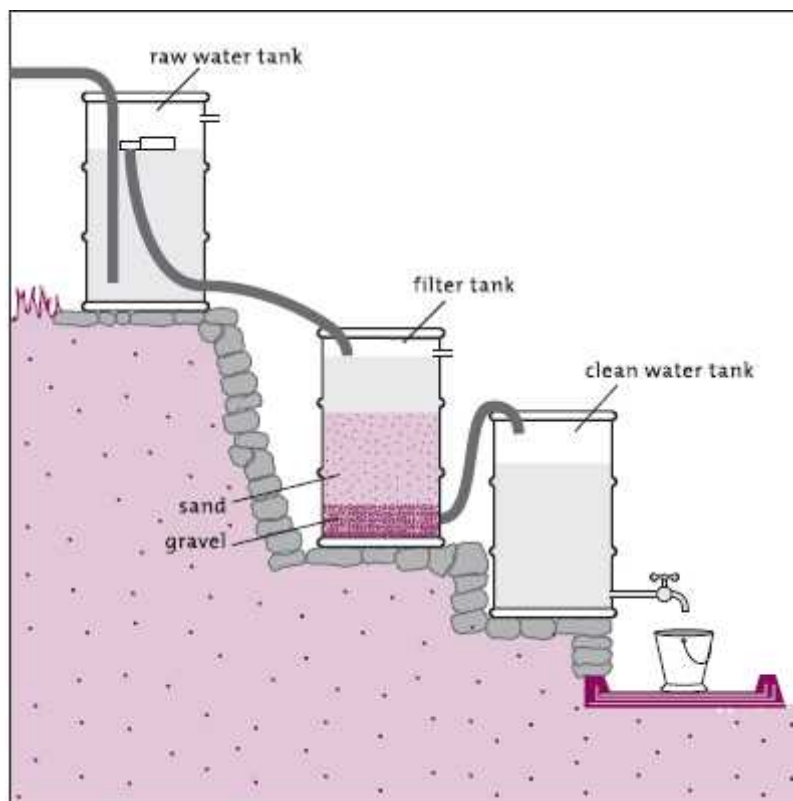


Fig. 18 Household flows and filter.

The system consists of a raw-water supply tank, a filter tank and a clean water tank. A floating weir (that can be made of a bowl, two small tubes and a hose) in the supply tank maintains a constant flow of water to the top of the

filter tank, where it is purified by passing down wards through a 45–60-cm bed of washed sand and a 5-cm layer of fine gravel. The water flows through the sand at about 0.1 m/hour ($1 \text{ m}^3 \text{ m}^{-2} \text{ h}^{-1}$). Water drains from the bottom layer of the filter tank via a perforated tube and is led to a clean water-storage tank. To prevent oxidation of the steel barrels, they must be treated with cement mortar, or any safe protective paint.

Instead of steel barrels, tanks of Ferro cement and other material scan also be used. All tanks should be protected with lids. With good operation and maintenance, a household slow sand filter produces water virtually free from disease-causing organisms.

Initial cost: This depends on the local cost of used metal drums and other parts.

Yield: 380 liters per day for a tank 0.45 m in diameter.

Area of use: In places where drinking-water is unsafe and needs to be purified at household level.

Manufacturers: Local artisans can make a household slow sand filter.

Potential problems

- Water quality drops if the flow rate through the filter is too high.
- If the water flow is interrupted for more than a few hours, or if the surface of the filter runs dry, beneficial microorganisms in the filter may die and the effectiveness of the filter may be impaired.
- Excessive turbidity ($>30 \text{ NTU}$) in the raw water can cause the filter to clog rapidly, in which case a pre-filter may be needed.
- When water quality is very poor, harmful and bad-tasting products like ammonia may be formed in the lower layers of the filter.
- Smooth vertical surfaces in the filter tank may cause short circuits in the water flow, producing badly-filtered water.
- In some regions, sand is expensive or difficult to get – as an

alternative, other materials such as burnt rice husks can be used.

5.3. Water chlorination at household level

The technology

Chlorination of water at household level can be used as an emergency measure or as part of everyday life. When water quality cannot be trusted, a carefully measured amount of concentrated chlorine solution is added to a container with a known amount of clear water. The mixture is stirred and left for at least 30 minutes to let the chlorine react and oxidize any organic matter in the water. After this, the water is safe to drink. The amount of chlorine needed depends mainly on the concentration of organic matter in the water and has to be determined for each situation. After 30 minutes, the residual concentration of active chlorine in the water should be between 0.2–0.5 mg/l, which can be determined using a special test kit. The concentrated chlorine solution can be made of clear water and chlorine-producing chemicals, such as bleaching powder, sodium hypochlorite, or organic chlorine tablets.



Fig. 19 Domestic chlorination using a chlorine tablet.

It can be prepared at household level, but also in larger quantities and distributed among the households. A concentrated chlorine solution should be

used within a relatively short time (defined according to the compound used) before it loses its strength.

In some cases, chlorine-producing chemicals are added directly added to the water, without prior dilution. Some chlorine products come in combination with a flocculent to help settle suspended material in the water.

Initial cost: The costs depend on the type of chlorine compound used, the quality of the untreated water, etc.

Yield: About 150–1400 m³ treated water per kg of dry chemical, depending on the water quality and the strength of the concentrated chemical.

Area of use: Wherever drinking-water needs to be disinfected at household level and chlorine is available.

Potential problems

- If the water quality varies over time, the required dose of chlorine has to be recalculated.
- If they are not stored properly, chlorine-producing chemicals lose their strength quickly – even when stored under the best conditions, bleaching powder loses half of its strength in about a year.
- Chlorine-producing chemicals and test media are often not readily available.

6. Community water-treatment systems

6.1 Storage and sedimentation

The technology

The quality of raw water can be improved considerably by storage. During storage, non-colloidal, suspended particles slowly settle to the bottom of a storage tank, and solar radiation will kill some of the harmful organisms in the water. Schistsomalarvae, for example, will die after storage for at least 48 hours. In contrast, colloidal particles remain in suspension.

The smaller the suspended particles, the longer the water needs to be

retained in the reservoir. If the suspended matter precipitates very slowly, chemicals can be added to induce coagulation and flocculation.

The reservoir can be constructed in several ways:

- Below ground level, with a lining of plastic sheeting to separate the stored water from the ground.
- With a lining of loam, clay or concrete.
- Entirely from brick or concrete.

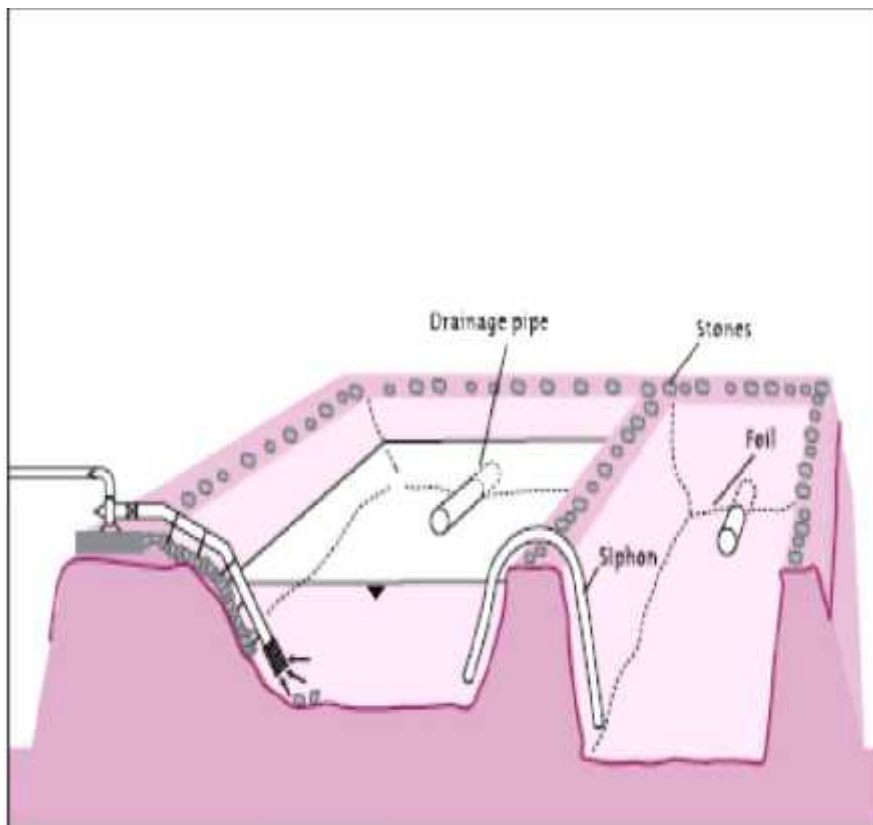


Fig. 20 Domestic chlorination using a chlorine tablet.

Reservoirs for sedimentation usually have two separate sections.

While one is in use, the other can be cleaned. They have an intake on one side of the reservoir (or at the bottom), an outlet on the opposite side just beneath the water level, and a bottom outlet to flush the deposited material. When the water quantity or quality at the source is temporarily low, a large storage reservoir can also provide an alternative temporary source of water.

Initial cost: Depends on the type of construction.

Range of depth: Usually, 0.7–2.0 m.

Treatment time: A few hours to several days.

Area of use: Wherever raw water contains high concentrations of suspended solids, or where the quality or quantity of the water at the source varies considerably.

Potential problems

- leaks, which should be repaired immediately;
- If the solids in the water do not settle quickly enough, coagulation and flocculation may be needed.

6.2. Upflow roughing filter

The technology

Roughing filters are often used to pretreat water by removing suspended solids from the water that could rapidly clog a slow sand filter. Roughing filters can also considerably reduce the number of pathogens in the water, as well as the amount of iron and manganese.

There are many types of roughing filters with different flow directions (downflow, upflow and horizontal flow filters), and with different types of filter medium (e.g. sand, gravel, coconut husk fiber).

Upflow roughing filters are relatively cheap and easier to clean than downflow or horizontal flow filters.

An upflow filter box can be made of bricks, concrete or ferro-cement. It can have a round or rectangular shape, with vertical or partially inclined walls, and it is usually about 1.5 m deep. Water flows in through an under drain system on the bottom, usually a perforated PVC pipe, which also permits rapid abstraction during cleaning when the flow direction is reversed (backwashing).

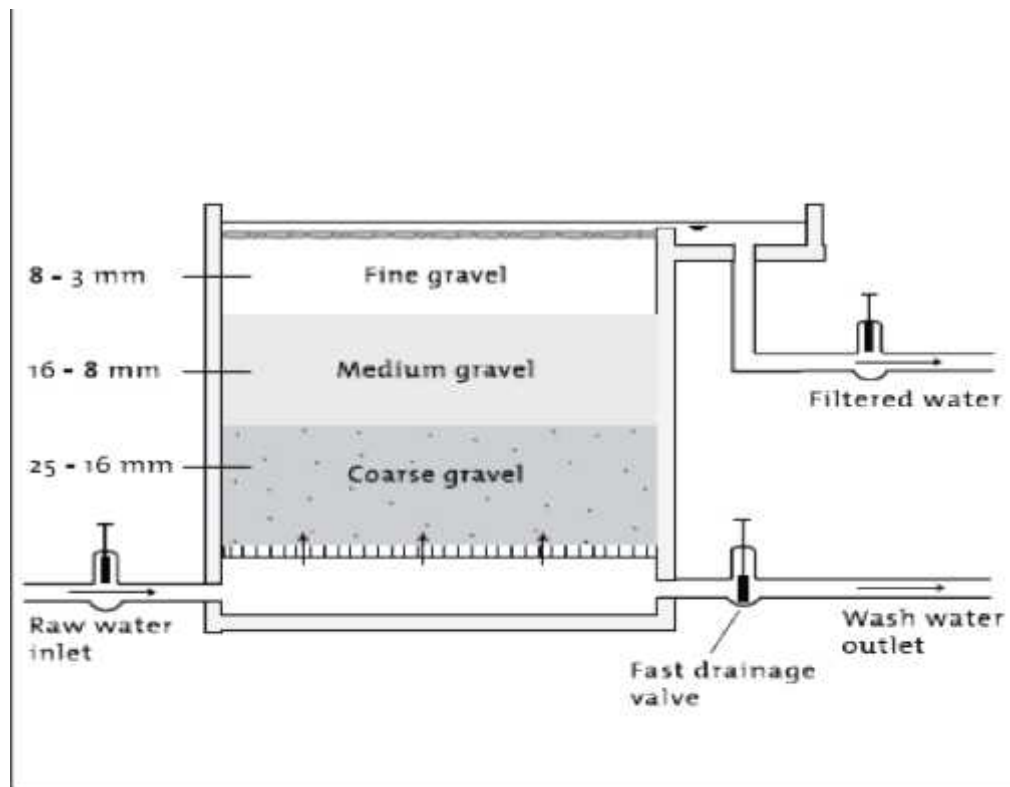


Fig. 21 Upflow roughing filter.

For backwashing, a special drainage valve is installed which can be opened quickly. The under drains are covered with a layer of coarse gravel, on top of which lie several layers of finer gravel and coarse sand. The filter layers are covered with a 0.1 m-deep layer of boulders, to avoid exposing the outflow directly to sunlight; this helps to prevent algal growth. The outflow is stored in an outlet structure. In some cases, the outflow of one roughing filter is fed to another roughing filter with finer material for further cleaning.

Initial cost: Reported construction costs are US\$ 20–40 per m³ of water per day, for a structure designed to be in operation for 24 hours a day. (data from Colombia, 1986; Wolters & Visscher, 1989).

Filtration rate: Approximately 0.6 m/h. **Performance:** If raw water with turbidity below 50 NTU is used as the source for a roughing sand filter, the outflow has turbidity below 12 NTU. Approximately 84–98% of suspended solids are removed. Better results are obtained with two or three filters in series.

Use: As a pre-treatment stage prior to slow sand filtering or other purification processes.

Potential problems

- High loads of organic and other suspended material in the raw water clog the filter and reduce the hydraulic cleaning capacity.
- Roughing filters only remove some of the solids and pathogens in the water, and additional treatment is needed.

6.3. Slow sand filtration

The technology

The treatment of water by slow sand filtration combines biological, chemical and physical processes when the water slowly passes downwards through a bed of sand. Fine particles are filtered out, and in the sand and on top of the filter bed a population of microorganisms develops that feed on bacteria, viruses and organic matter in the water. The filter reservoirs have drains on the bottom covered with gravel and sand. Raw water slowly enters the filter through an inlet, and an outlet leads the clean water from the drains to the clean-water mains.

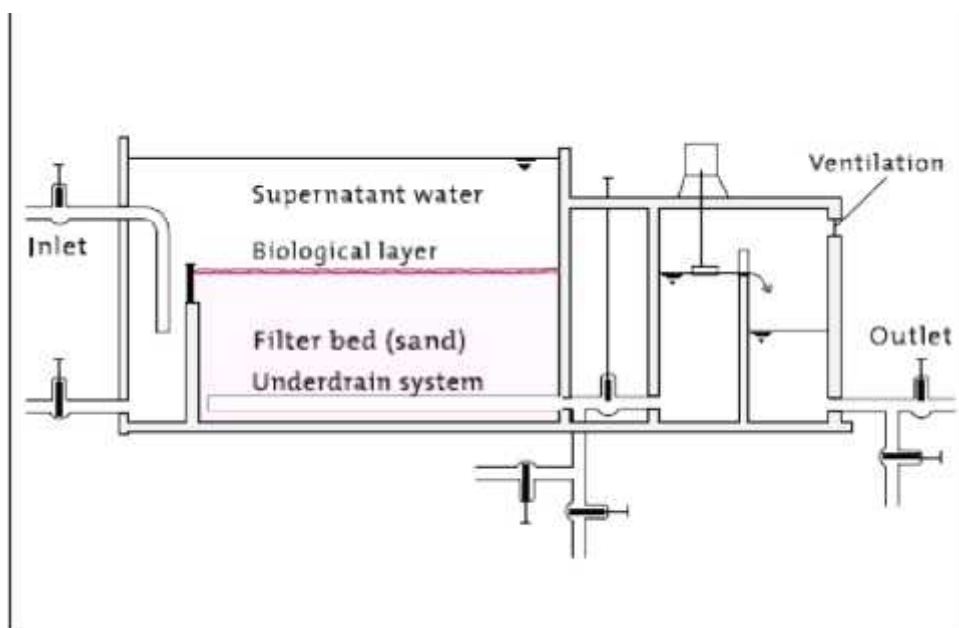


Fig. 22 Slow sand filters

During operation, the sand filter is covered with a water layer of 0.3–1.0 m. For the filter to work well, water must flow continuously at a rate of 0.1–0.3 m/hour. For community use, filter reservoirs can be made of concrete, bricks, ferro-cement, etc. At least two filters are needed if clean water is to be provided continuously.

When the quality of the raw water is poor, it is recommended that pretreatment steps be added (e.g. upflow roughing filter). Sometimes, the water is chlorinated after filtration to prevent recontamination.

Initial cost: Data from rural India in 1983 indicate an initial cost of US\$ 60–130 per m² of filter area. In Colombia, the cost was US\$ 105–215 per m² in 1987.

Yield: 0.1–0.3 m³ m⁻² hour⁻¹.

Area of use: All over the world.

Potential problems

- If the flow rates through the filter are too high, water quality drops.
- Excessive turbidity (>30 NTU) in the raw water can cause the filter to clog rapidly, in which case a pre-filtration step may be needed.
- When the water quality is very poor, harmful and bad-tasting products such as ammonia may be formed in the filter.
- It may take some time for people to believe that a green and slimy filter can produce safe water.
- If the water flow is interrupted for more than a few hours, beneficial microorganisms in the filter may die and the filter action will become impaired.
- Smooth vertical surfaces in the filter can cause short circuits in the water flow and result in poor-quality water.

- In some regions, sand is expensive or difficult to get.
- It takes a few days for a filter to “ripen” after re-sanding and in this period the water quality is lower.

6.4 Chlorination in piped systems

The technology

Chlorination is a chemical method for disinfecting water. The chlorine inactivates pathogens in the water and provides a barrier against recontamination. It is normally applied at the last stage of a drinking-water treatment process. The most frequently used low-cost technology methods are batch chlorination and flow chlorination. For batch chlorination, a concentrated chlorine solution is added to the water in a reservoir, with both inlets and outlets closed.

The water is stirred and the chlorine is left to react for at least 30 minutes. After that, the outlets can be opened. When the reservoir is empty, the outlets are closed and the reservoir is refilled with a new batch of water to be disinfected.

Flow chlorinators continuously feed small quantities of a weak chlorine solution to a flow of fresh water, often at the inlet of a clear-water reservoir. Usually, a small reservoir containing the chlorine solution is placed on top of the water reservoir and the solution is administered close to the point where fresh water comes in, and turbulence guarantees good mixing. A special device, such as the floating bowl chlorinator, enables precise dosage.

Sometimes a special electric pump is used for this purpose. Electrical devices that convert a solution of kitchen salt to active chlorine can be purchased for on-site chlorine production. Small test kits are also available for monitoring and for adjusting chlorine doses to the water quality and quantity. Chlorine-producing compounds must always be stored and prepared with care.

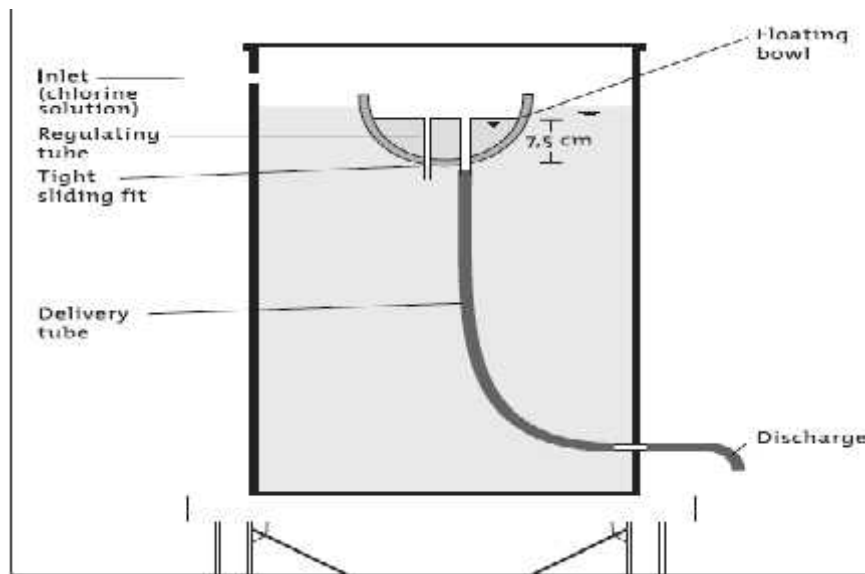


Fig. 23 floating bowl chlorinator.

Initial cost: A chlorinator and hoses can cost as little as 15 US\$, but there will be additional costs for the tank, for the concentrated chlorine solution, and for the construction costs of a protective shelter.

Yield: Generally, 350–1400 m³ of treated water per kg of a 70% chlorine compound.

Area of use: Wherever drinking-water needs to be disinfected and chlorine is available.

Potential problems

1) Chlorination is less effective in alkaline water (pH above 8.0). 2) When the water contains excessive organic matter or suspended material, it will need to be pretreated. 3) The cost and availability of chlorine compounds can be serious limitations. 4) Chlorination affects the taste of water and for this reason the water may be rejected by consumers who have not been informed. 5) On the other hand, users may believe a chlorine taste indicates that the water has been disinfected, but water can still taste of chlorine even when not enough has been added to purify it.

Despite these limitations, disinfecting drinking-water by chlorination is one of the most effective and least-expensive technologies available and should be encouraged.

CHAPTER SIX

Solid Waste Engineering



Solid Waste Engineering

1. Definition of Waste

- No universally accepted definition exists.
- A useful definition: “Waste is a left-over, a discarded product or material of no or marginal value for the owner and which the owner wants to get rid of”.
- The definition suggests that waste depends on time (e.g. new products war/shortage) location (e.g. rural/small town vs. urban, climatic differences), culture (e.g. foodwise), social conditions (e.g. poor vs. rich) as well as political regulations (e.g. fees on disposable items: bag, packaging etc.).
- Solid waste: “The third pollution”. Water and air pollution are the two first ones. The waste is transported by a media (aqueous fluid, gaseous fluid) and the main measures are cleaning of the transport media.
- Solid waste has no “transport media” to be cleaned, but must be managed to allow safe recycling of materials and disposal in the environment.
- Waste can be a solid, sludge, and a liquid.

2. Waste as natural phenomenon

- Generation of waste is a natural and inevitable part of life.
- The nature provides effective means to handle waste.
- If there are no abrupt changes, a natural balance is preserved and the (ecological) system continues to function at a steady cyclic (seasonal) pace.
- However, tremendous socio-economic development which has taken place in the last centuries has constituted such an abrupt change.

3. Distortion of the balance

- Concentration of population in cities (benefits of civilisation, problem of public health).
- Industrial revolution (mass production of goods incorporating various toxic metals).
- Furthermore, previously nonexistent, thus xenobiotic, compounds were created and produced in large amounts (xenobiotic – Greek: foreign to life).

4. Impacts of solid waste generation

Throwing wastes into the unpaved streets, and roadways led to the breeding of rats, flies, mosquitoes and insects. Solid waste generation can lead to many problems such as

- Degradation of the public health because of the spread of diseases.
- Ecological phenomena such as water and air pollution.
- Liquid from dumps and poorly engineered landfills has contaminated surface waters and underground water. (Liquid leached from waste dumps may contain toxic elements, such as copper and uranium).
- The burning or incineration of the solid waste into the air led to air pollution. Good example of this case is the air pollution in Cairo and Giza due to the burning of rice straw which is caused the so called the black clouds.

5. Importance of Solid Waste Management

Solid Waste Management is closely related to other major issues of global importance:

- Protection of the environment.
- Urbanisation.
- Access to clean drinking water.
- Depletion of natural resources.

- Trends in international waste trade.

Sustainability cannot be discussed without addressing the waste issue!

6. Functional Elements of a Waste Management System

1. Waste Generation.
2. Collection.
3. Transfer and Transport.
4. Separation, Processing, and Transformation of Solid Waste.
5. Disposal.

6.1. Waste Generation

is closely related to consumption:

- Americans are world largest consumers and world largest waste producers – they comprise 6% of the world population and produce half of all the waste.
- Americans (USA) produce on average over 2 kg of household waste per person per day.
- Europeans (EU) produce on average 1.5 kg of household waste per person per day waste per person per day.

Careless behaviour is the other reason for the huge amounts of waste:

- In spite of all recycling programmes, in most EU member states waste generation increases faster than the economy grows.
- Average American throws 65 kg food a year.
- Americans throw in 3 months enough aluminium cans to build their entire civil aircraft fleet again.

What are the sources of waste?

Agriculture, Mining, Construction, Industry, Households, Offices, Other sources, In the Netherlands also: dredging soil.

Table 2 Sources of solid waste within a community.

No	Source	Typical facilities, activities generated	Types of solid waste
1	Residential	Single family and multifamily detached dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, and other metals.
2	Commercial	Stores, restaurants, markets, etc.	Paper, cardboard, plastics, food wastes, metals, glass, etc.
3	Treatment plant sites	industrial treatment processes, Water, and wastewater	Treatment plant wastes, and residual sludge
4	Industrial	Construction, fabrication, light and heavy manufacturing, etc.	Industrial process wastes. Non industrial wastes including food wastes, rubbish, hazard wastes, etc.
5	Agriculture	Field and raw crops, farms, etc.	Spoiled food wastes, agricultural wastes, hazard wastes.

Table 3 Typical distribution of components in Solid Waste for developing and developed countries (percent by weight).

المحتوى	الدول النامية	الدول المتقدمة
Organic		
Food wastes	40-85	6-30
Paper	1-10	20-45
Plastics	1-5	2-8
Yard waste	1-5	10-20
Rubber	1-5	0-2
Inorganic		
Glass	1-10	4-12
Aluminum	1-3	0-1
Other metal	1-5	0-10

6.2. Waste collection

The term collection includes not only the gathering or picking up of solid wastes from the various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied.

- Manual methods used for the collection of residential wastes include the direct lifting and carrying of loaded containers to the collection vehicle for emptying.

- It is very important to calculate the traveling period between the collection areas to the final disposal area.

- Separation of the wastes may be handled in the collection phase by specialized different containers by specialized different containers for different types of solid waste for different types of solid waste.

Wide varieties of systems and equipment have been used for the collection of solid waste. These systems may be classified from several points of view, such as the mode of operation, equipment used, and types of wastes collected.



Fig. 24 Solid waste collection.

6.3. Transfer and Transport

Transfer and transport refers to the means, facilities, and appurtenances used to effect the transfer of wastes from one location to another.

Small collection vehicles are transferred to larger vehicles that are used to transport the waste over extended distances to disposal sites.

It is very important to calculate the traveling period between the collection areas to the final disposal area.

Types of transfer stations:

- Direct load:** the waste in the collection vehicles are emptied directly into the vehicle to be used to transport them to a place of final disposal area. Used normally in the small communities.

- Storage load:** the wastes are collected to storage area. Then will be transfer to the final disposal sites. It is useful for the large communities.

- Combined of storage and direct load:** it is combined between the above to systems.

Health, safety, and environmental requirements are needed in the transportation of solid waste.



Fig. 25 Solid waste transfer and transport.

6.4. Separation, Processing, and Transformation of Solid Waste

- Separation of solid waste could be at the source or at the final stage before disposal of the solid waste.

- It is very important to separate the recyclable materials to reduce the volume of the waste disposal.

- Types of separation depend on the types of solid waste. Such as:
Density separation: air classification is the unit operation used to separate light materials such as paper and plastic from the heavier materials such as ferrous metal, based on the weight difference of the material in an air stream.

- **Magnetic separation:** magnetic separation is a unit operation whereby ferrous metals are separated from other waste materials by utilizing their magnetic properties.

Consideration involved in the implementation of waste separation :

- Selection of the materials to be separated.
- Identification of the material specifications.
- Development of separation process flow diagrams.
- Layout and design of the physical facilities.
- Selection the equipments and facilities that will be used.
- Environmental control.
- Safety and healthy impact.

6.5. Disposal

The solid waste can be disposed of by various methods such as:

- By filling it in low lying areas and depressions.
- By burning or incineration.
- By barging it out into the sea.
- By composting, i.e. by digesting by bacterial agency.

6.5.1. Principles of Biological decomposition of solid waste

- Biological process is consider the most important process in decomposing of the solid waste.
- Biological decomposition occurs with naturally present bacteria. It is complex process within landfill sites, consisting of various biologically mediated sequential and parallel pathways by which solid waste is decomposed to various end products.
- Biological decomposition takes place in three stages, each of which has its own environmental and substrate requirements that result in characteristic end products.
- Aerobic decomposition.- Anaerobic decomposition.

Forms of decomposition	Primary byproducts
Aerobic decomposition	CO ₂ , H ₂ O, NITRATE AND NITRITE
Anaerobic decomposition	CH ₄ , CO ₂ , H ₂ O, ORGANIC ACIDS, NITROGEN, AMMONIA, FERROUS AND MANGANOUS SALTS.

7. Integrated Solid Waste Management

1. Source reduction
2. Recycling
3. Waste Transformation
4. Landfilling

7.1. Source reduction

- The highest rank of integrated solid waste management.
- Reducing the amount and toxicity of the wastes that are now generated.
- Reducing the cost of the Transportation of solid waste.

7.2. Recycling

- The second rank of ISWM
- Separation and collection of waste materials.
- Preparation of these materials for reuse, reprocessing, and

remanufacturing.

- It is very important factor to reduce the amount of waste to be disposed of.

7.3. Waste Transformation

- The third rank of ISWM.
- Could be through the physical, chemical, and biological transformation.
- Used to improve the efficiency of solid waste management operation and systems.
- To recover conversion products and energy in the form of gases or heating.

7.4. Landfilling

- It is the method to dispose solid waste that can not be recycled and are of no further use.
- It is a complete process in itself.
- The land could be used in agriculture.

8. Planning for Integrated Waste Management

- Proper Mix of Alternatives and Technologies.
- Flexibility in Meeting Future Changes.
- Monitoring and Evaluation.

9. Future Challenges and Opportunities

- Changing Consumption Habits in Society.
- Reducing the Volume of Waste at the Source.
- Making Disposal Safer.
- Development of New Technologies.

CHAPTER SEVEN

Soil Pollution



Soil Pollution

1. Introduction

Unhealthy soil management methods have seriously degraded soil quality, caused soil pollution, and enhanced erosion. In addition to other human practices, the use of chemical fertilizers, pesticides, and fungicides has disrupted the natural processes occurring within the soil resulting in soil pollution. Soil pollution is a buildup of toxic chemical compounds, salts, pathogens, or radioactive materials that can affect plant and animal life. The concern over soil contamination stems primarily from health risks, both of direct contact and from secondary contamination of water supplies.

All kinds of soil pollutants originate from a source. The source is particularly important because it is generally the logical place to eliminate pollution. After a pollutant is released from a source, it may act upon a receptor. The receptor is anything that is affected by the pollutant. The following subunit describes some of the most common sources of soil pollution.

2. Sources of Soil Pollution

The most common toxic soil pollutants include metals and their compounds, organic chemicals, oils and tars, pesticides, explosive and toxic gases, radioactive materials, biologically active materials, combustible materials, asbestos and other hazardous materials. These substances commonly arise from the rupture of underground storage tanks; application of chemical fertilizers, pesticides, and fungicides; percolation of contaminated surface water to subsurface strata; leaching of wastes from landfills or direct discharge of industrial wastes to the soil etc.

2.1. Pollution by Heavy metals

Heavy metal soil contaminants such as cadmium, lead, chromium, copper, zinc, mercury and arsenic are a matter of great concern. Naturally all soils contain heavy metals. However, their levels are increased by:

- Industry (non-ferrous industries, power plants, iron, steel and chemical industries).
- Agriculture (irrigation with polluted water, use of mineral fertilizers).
- Waste incineration.
- Combustion of fossil fuels.
- Road traffic.

2.2. Pollution by Pesticides and organic contaminants

Pesticides that are used in agricultural practices pollute the soil directly by affecting the organisms that reside in it. Organic pollutants enter the soil via atmospheric deposition, direct spreading onto land, contamination by wastewater and waste disposal.

Organic contaminants include pesticides and many other components, such as oils, tars, chlorinated hydrocarbons, PCBs and dioxins.

The use of pesticides may lead to:

- destruction of the soil's micro-flora and fauna, leading to both physical and- chemical deterioration.
- severe yield reduction in crops
- leaching of toxic chemicals into groundwater and potentially threatening drinking water resources.

3. Effects of Soil Pollution

Existence of the ecosystems requires existence of plants. Humans and animals can not survive without plants. Soil is not only a source of nutrition but also a place for plants to stand. Pollution of agricultural soils by heavy metals is known to reduce agricultural yield and increase levels of these toxic heavy metals in agricultural prod- ucts, and thus to their introduction into the

food chain. Vegetables and crop plants grown in such soils take up these toxic elements and pose health risk to humans and animals feeding on these plants.

The major concern about soil pollution is that there are many sensitive land uses where people are in direct contact with soils such as residences, parks, schools and playgrounds. Other contact mechanisms include contamination of drinking water or inhalation of soil contaminants which have vaporized. There is a very large set of health consequences from exposure to soil contamination depending on pollutant type, pathway of attack and vulnerability of the exposed population.



Fig. 26 Animals ingest what ever the plant they are grazing on has taken up from the soil.

Organic pollutants which are directly applied into soils or deposited from the atmosphere may be taken up by plants or leached into water bodies. Ultimately they affect human and animal health when taken up through the food they eat and the water they drink. More recently research has revealed that many chemical pollutants, such as DDT and PCBs, mimic sex hormones and interfere with the human body's reproductive and developmental functions. These substances are known as endocrine disrupters. Another interesting example is the contamination of milk that occurred in Hawaii in early 1982. It was found that milk from several sources on Oahu contained very high levels of heptachlor. This is a pesticide that causes cancer and liver disorders in mice and is suspected to be human carcinogen. The source of the

heptachlor was traced to be chopped-up pineapple leaves fed to cattle.

Soils might be affected less by pollution compared to water or air. However, cleaning polluted soils is more difficult, complex and expensive than water and air. Soil reclamation is a too costly activity.

In addition to its effects on the economy, health, and natural resources, pollution has social implications. Research has shown that low-income populations do not receive the same protection from environmental contamination as do higher-income communities. Toxic waste incinerators, chemical plants, and solid waste dumps are often located in low-income communities because of a lack of organized, informed community involvement in municipal decision-making processes.

4. Control of Soil Pollution

Soil pollution prevention requires proper land use planning and provision of environmental infrastructures. For example, industries that can cause accidental discharge of pollutants and toxic chemicals will not be allowed to be sited within water catchments.

Once preventive measures are established, controls are stringently enforced to ensure that pollution control equipment are properly maintained and operated, and effluents discharged meet emission standard. The quality of the environment is monitored regularly to ensure that these pollution control measures are adequate. Biological way controlling pests and diseases in agriculture that relies on natural predation rather than chemicals is another method of controlling soil pollution.

Glossary

- **Environment:** All the external factors that affect an organism.
- **Atmosphere:** The mixture of gases surrounding any celestial object that has a gravitational field strong enough to prevent the gases from escaping; especially the gaseous envelope of Earth.
- **Ecosystem:** organisms living in a particular environment, and the physical parts of the environment that affect them.
- **Geosphere:** The solid earth, including soil, which supports most plant life.
- **Hydrosphere:** Earth's water.
- **Biosphere:** All living things on Earth.
- **Anthroposphere:** That part of the environment made or modified by humans and used for their activities.
- **Fauna and Flora:** Animals and Plants collectively.
- **Ozone layer:** a thin layer in the upper atmosphere that is rich in O₃ molecules and serves to shield Earth from the Sun's harmful ultraviolet rays.
- **Fossil fuel:** The organic matter of wood, or the hydrocarbons of natural gas, coal, petroleum etc. that have been formed from the partially decayed animals and vegetable matter of living things that inhabited the Earth in eras long past.
- **Pollution:** The presence of an excess of a substance generated by human activity in the wrong environmental location.
- **Acid rain :** Rain having abnormally high acidity as a result of interactions with atmospheric pollutants.
- **Photochemical smog:** Air pollution produced when sunlight causes hydrocarbons and nitrogen oxides from automotive exhaust to combine.

- **Greenhouse Effect:** the warming of the Earth by solar heat trapped through the insulating effect of atmospheric gases.
- **Global Warming:** Increase in the average temperature of the atmosphere.
- **Water Pollution:** Water Pollution, contamination of streams, lakes, underground water, bays, or oceans by substances harmful to living things.
- **Air Pollution:** addition of harmful substances to the atmosphere resulting in damage to the environment, human health, and quality of life.
- **Waste:** is a left-over, a discarded product or material of no or marginal value for the owner and which the owner wants to get rid of’.

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