B.Sc 1st year (Semester-II) **Subject: Environment and Water Management**

Unit I Water Pollution

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3.1 Physical and chemical properties of water

Water is a molecule made up of two hydrogen atoms and one oxygen atom. It has the formula H_2O. When oxygen and hydrogen combine (H-O-H) they form a v-shaped triangular molecule. While water molecules are electrically neutral, the oxygen atom holds a small negative charge and the two hydrogen atoms hold small positive charges. Water molecules are attracted to each other, creating hydrogen bonds. These strong bonds determine almost every physical property of water and many of its chemical properties too. Scientists believe this unusual electrical balancing, called polarity, gives water some of its remarkable properties.

Water the Universal Solvent

Scientists often call water the "universal solvent" because water can **dissolve** more substances than any other liquid. Some substances, like common table salt (sodium chloride, NaCl), dissolve in water very easily. When placed in water, sodium chloride molecules fall apart. The positively charged sodium ion (Na^+) binds to oxygen, while the negatively charged chloride ion (Cl^-) attaches to hydrogen. This makes a very stable "salty" water molecule. This property of water allows for the transport of nutrients vital to life in animals and plants. A drop of rainwater falling through the air dissolves atmospheric gases. When rain reaches the earth, it affects the quality of the land, lakes and rivers.

Surface Tension

Water molecules at the surface (next to air) hold closely together, forming an invisible film. Water's surface tension can hold weight that would normally sinkSome aquatic insects such as the water strider or pond skater rely on surface tension to walk on water. Surface tension is essential for the transfer of energy from wind to water to create waves. Waves are necessary for

rapid oxygen diffusion in lakes and seas. Next to mercury, water has the highest surface tension of all commonly occurring liquids.

Water is Sticky

Cohesion

Water molecules stick to each other. This is due to the hydrogen bonds among the molecules. Water molecules at the surface have a much greater attraction for each other than for molecules in the air. This cohesiveness creates a high surface tension at the surface of the water. The water molecules at the surface crowd together, producing a strong layer as they are pulled downward by the attraction of other water molecules beneath them.

Adhesion

Water molecules stick to other substances. You can see this property when water creeps up the inside of a drinking glass. Think of a sponge or a paper towel used to "soak up" spilled water. This is how water makes things wet. Water also clings to living things. Most plants have adapted to take advantage of water's adhesion that helps move water from the roots to the leaves. This is called capillary action. This can also be seen as blood moves through our capillaries, carrying nutrients to each cell within our body.

Thermal Properties

Water absorbs or releases more heat than many substances for each degree of temperature increase or decrease. Because of this, it is widely used for cooling and for transferring heat in thermal and chemical processes. Differences in temperature between lakes and rivers and the surrounding air may have a variety of effects. For example, local fog or mist is likely to occur if a lake cools in the surrounding air enough to cause saturation—small water droplets are suspended in the air. Large bodies of water, such as the oceans or the Great Lakes, have a profound influence on climate. They are the world's great heat reservoirs and heat exchangers and the source of much of the moisture that falls as rain and snow over adjacent landmasses. When water is colder than the air, precipitation is curbed, winds are reduced, and fog banks are formed. These properties of water are crucial in stabilizing temperatures on earth.

Specific Heat

Water has a high specific heat. The amount of energy required to raise the temperature of water by one degree Celsius is quite large. Because so much heat loss or heat input is required to lower or raise the temperature of water, the oceans and other large bodies of water have relatively constant temperatures. Thus, many organisms living in the oceans are provided with a relatively constant environmental temperature. The high water content of plants and animals living on land helps them to maintain a relatively constant internal temperature. The specific heat of water is 5 times greater than of sand. On a hot summer day, beach sand may quickly warm to the point that it is too hot to stand on while ocean water warms only a little. During the evening the temperature of sand will decrease while the temperature of the ocean remains relatively constant.

Heat of Vaporization

Water has a high heat of vaporization. Water absorbs heat as it changes from a liquid to a gas; the human body can dissipate excess heat by the evaporation of its sweat. A leaf can keep cool in the bright sunlight by evaporating water from its surface. Water's high heat conductivity makes possible the even distribution of heat throughout the body.

Boiling and Freezing

Pure water at sea level boils at 100^{o}C (212^{o}F) and freezes at 0^{o}C(32^{o} F), but extra energy is needed to push water molecules into the air. This is called latent heat—the heat required to change water from one phase to another. At higher elevations (lower atmospheric pressure) water's boiling temperature decreases. This is why it takes longer to boil and egg at higher altitudes. The temperature does not get high enough to cook the egg properly. If a substance is dissolved in water, then the freezing point is lowered. That is why we spread salt on streets in winter to prevent ice formation. Energy is lost when water freezes. A great deal of heat is released into the environment when liquid water changes to ice. It is lost when the high energy phase of liquid water moves to the low energy phase of ice. Nights when ice freezes often feel warmer than nights when ice melts

Water density

Water is most dense at 4^{0}C and then begins to expand again (becoming less dense) as the temperature decreases further. This expansion occurs because its hydrogen bonds become more rigid and ordered. As a result, frozen water (ice floats) upon the denser cold water. The expansion of water takes place even before it actually freezes. This explains why a pond freezes

from the surface down, rather than from the bottom up. As water temperature drops, the colder water (0-4^{0}C) where it is less dense— rises to the pond surface. It freezes to form a lid of ice. This ice insulates the water below from the wintry chill so that it is less likely to freeze. Organisms that inhabit the pond are able to survive the frigid winter below the icy surface.

Solid Expansion

For most substances, solids are denser than liquids. But the special properties of water make it less dense as a solid. Ice floats on water! Strong hydrogen bonds formed at freezing 0^{0}C (32^0 F) lock water molecules away from each other. When ice melts, the structure collapses and molecules move closer together. Liquid water at 4^0 C (39.2^0 F) is about 9% denser than ice. This property plays an important role in lake and ocean ecosystems. Floating ice often insulates and protects animals and plants living in the water below.

pH—

Water molecules have a tendency to ionize. They dissociate into ions (charged particles) hydrogen ions (H^+) and hydroxide ions (OH^-). In pure water a very small number of water molecules form ions in this way. The tendency of water to dissociate is balanced by the tendency of hydrogen ions and hydroxide ions to reunite to form water. A neutral solution contains an equal number of hydroxide ions and hydrogen ions. A solution with a greater concentration of hydrogen ions (H^+) is said to be is said to be acidic. A solution with a greater concentration of hydroxide (OH^-) ions is said to be alkaline or basic.

3.2 Surface and groundwater pollution: sources and types

Water is essential for the existence of all life forms. In addition to household uses, water is vital for agriculture, industry, fishery and tourism etc. Increasing population, urbanization and industrialization has led to the decreased availability of water. The quality of water used is also being deteriorated as it is getting more and more polluted.

About three fourths of our planet earth's surface is covered by water. However, very little of it is available for consumption. Most (about 97%) of the water on earth is present in the seas and oceans. It is too salty to be of any use for drinking, agriculture and industrial purposes. The remaining 3% is fresh water; 75% of which is locked up in the polar ice caps and in glaciers and quite deep under the earth's surface as underground water. The fresh water, which we can use, comes to us from two sources:

i) Surface water

ii) Ground water

(i) Surface Water: Rain and snow are good natural resources of fresh water. It is estimated that of all the precipitation (rain water and snow) that falls on the earth, about one-third is absorbed by the plants and another one-third seeps down into the soil and the remaining one third runs off the surface into streams and rivers. This part of precipitation, which runs off to form streams, rivers and lakes, is called the surface water.

Precipitation (rain or snow) that runs-off into stream, rivers and lakes is called surface water. The hydrological cycle involves evaporation of water from oceans, rivers and other sources to form clouds. The clouds on saturation with water vapours cause precipitation falling back on earth's surface. On surface, the water runs off to rivers and finally to oceans. The water again evaporates and the cycle continues. Surface water has a natural tendency to clean itself as it contains certain organisms that break down pollutants into harmless substances.

(ii) Ground Water:

The part of precipitation that seeps into the ground as a result of gravity and fills the pores between soil particles and rocks under it is called ground **water**. The water bearing layers of soil and rocks are called **aquifers**. Ground water is very important for agricultural and industrial purposes. Ground water in the form of wells and springs is often the only source of water supply especially in villages and small towns. In spite of a good number of water resources, we have shortage of usable water. This is due to increasing population, urbanization and industrialization. There is a need to optimize use of water and also conserve surface run off of water by means of rainwater harvesting, groundwater conservation, making use of recycling methods etc.

Water Pollution

A large amount of water is discharged back after domestic and industrial usage. This is contaminated with domestic waste and industrial effluents. When this contamination reaches beyond certain allowed concentrations, it is called pollution and the contaminants are called the pollutants. Water pollution may be defined as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. If the concentration of substances naturally present in water increases then also the water is said to be polluted.

Water pollution may be defined as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. Industrialisation and population explosion are two important factors for water pollution.

Water may be called polluted when the following parameters stated below reach beyond a specified concentration in water.

i) Physical parameters. Colour, odour, turbidity, taste, temperature and electrical conductivity constitute the physical parameters and are good indicators of contamination. For instance, colour and turbidity are visible evidences of polluted water while an offensive odour or a bitter and difference than normal taste also makes water unfit for drinking.

ii) Chemical parameters: These include the amount of carbonates, sulphates, chlorides, fluorides, nitrates, and metal ions. These chemicals form the total dissolved solids, present in water.

iii) Biological parameters: The biological parameters include matter like algae, fungi, viruses, protozoa and bacteria. The life forms present in water are affected to a good extent by the presence of pollutants. The pollutants in water may cause a reduction in the population of both lower and higher plant and animal lives. Thus, the biological parameters give an indirect indication of the amount of pollution in water.

Surface Water Pollution

When pollutants enter a stream, river or lake these gives rise to surface water pollution. The surface water pollution has a number of sources. These can categorised as:

- Point and Non-point Sources
- Natural and Anthropogenic Sources

(i) Point and Non-point Sources

The well-defined sources that emits pollutants or effluents directly into different water bodies of fresh water are called point sources. Domestic and industrial waste are examples of this type. The point sources of pollution can be effectively checked. On the other hand, the non-point sources of water pollution are scattered or spread over large areas. This type of sources deliver pollutants indirectly through environmental changes and account for majority of the contaminants in streams and lakes. For example, the contaminated water that runs off from agriculture farms, construction sites, abandoned mines, enters streams and lakes. It is quite difficult to control non-point sources.

(ii) Natural and Anthropogenic Sources

An increase in the concentration of naturally occurring substances is also termed pollution. The sources of such an increase are called natural sources. Siltation (which includes soil, sand and mineral particles) is one such natural source. It is a common natural phenomenon, which occurs in most water bodies. Indiscriminate deforestation makes soil loose and flood waters bring silt from mountains into streams, rivers and lakes.

On the other hand, the human activities that result into the pollution of water are called anthropogenic or manmade sources of water pollution**.** For example, domestic (sewage and waste water), industrial and agricultural wastes that goes into the rivers, lakes, streams and seas are anthropogenic sources. Certain materials that are leached from the land by run-off water and enter the various water bodies also belong to this category.

Ground Water Pollution

When the polluted water seeps into the ground and enters an aquifer it results into ground water pollution. The most of our villages and many townships, ground water is the only source of drinking water. Therefore, pollution of groundwater is a matter of serious concern. Groundwater gets polluted in a number of ways. The dumping of raw sewage on soil, seepage pits and septic tanks cause pollution of groundwater. The porous layers of soil hold back solid particles while the liquid is allowed to pass through. The soluble pollutants are able to mix with the groundwater. In addition to these, the excessive use of nitrogenous fertilizers and unchecked release of toxic wastes and even carcinogenic substances by industrial units many result in slow trickling down through the earth's surface and mixing with the groundwater. This problem is very serious especially in areas where water table is high (i.e., where water is available near surface of earth).

The ground water can move over large distances by virtue of the large empty space available below the earth's surface. This way if some impurities seep into the ground water at one point, they may be observed at a different point far removed from the point of source. In such a case it is difficult to estimate the source of water pollution. However, suspended impurities and bacterial contaminants are removed in the process of seepage by the soil acting as an absorbent and filter, and water acting as a solvent. Since the movement of groundwater through the porous rock is very slow, pollutants which get mixed with the groundwater are not readily diluted. Furthermore, groundwater does not have access to air (in

contrast to surface water) therefore, oxidation of pollutants into harmless products in groundwater does not occur.

Water Pollutants

The various sources from where pollutants enter the water bodies. These can be broadly put under the following types.

(i) Sewage Pollutants (Domestic and Municipal Waste)

(ii) Industrial Pollutants

(iii) Agricultural Pollutants

(iv) Radioactive and Thermal Pollutants

(i) Domestic and Municipal Pollutants : The sewage contains garbage, soaps, detergents, waste food and human excreta and is the single largest sources of water pollution. Pathogenic (disease causing) microorganisms (bacteria, fungi, protozoa, algae) enter the water system through sewage making it infected. Typhoid, cholera, gastroenteritis and dysentery are commonly caused by drinking infected water. Water polluted by sewage may carry certain other bacteria and viruses cannot grow by themselves, but reproduce in the cells of host organisms. They cause a number of diseases, such as, polio, viral hepatitis and may be cancer which are resistant to like the organic matter are oxygen demanding substances. They are responsible for deoxygenation of water-bodies which is harmful for aquatic life. Other ingedients which enter the various water bodies are the plant nutrients, i.e., nitrates and phosphates. They support growth of algae, commonly called algal bloom (blue-green species). This process is called eutrophication.

(ii) Industrial Pollutants : Many industries are located near rivers or fresh water streams. These are responsible for discharging their untreated effluents into rivers like highly toxic heavy metals such as chromium, arsenic, lead, mercury, etc. along with hazardous organic and inorganic wastes (e.g., acids, alkalies, cyanides, chlorides, etc.). River Ganges receives wastes from textile, sugar, paper and pulp mills, tanneries, rubber and pesticide industries. Most of these pollutants are resistant to breakdown by microorganisms (called nonbiodegradable), therefore damage the growth of crops and the polluted water is unsafe for drinking purposes. Factories manufacturing plastic, caustic soda and some fungicides and pesticides release mercury (a heavy metal) along with other effluents in nearby water body.

Mercury enters the food chain through bacteria, algae, fish and finally into the human

body. The toxicity of mercury became evident by the Minamata Bay tragedy in Japan during the period 1953-60. Fish died due to mercury consumption and those who ate fish were affected by mercury poisoning and quite a few died. The milder symptoms of mercury poisoning are depression and irritability but acute toxic effects can cause paralysis, blindness, insanity, birth defects and even death. The high concentration of mercury in water and in fish tissues results from formation of soluble monomethylmercury ion, (CH_3, Hg^+) and volatile dimethylmercuty [$(CH_3)^2$ Hg] by anaerobic bacteria in sediments.

(iii) Agricultural Waste: Manure, fertilizers, pesticides, wastes form farms, slaughterhouse, poultry farms, salts and silt are drained as run-off from agricultural lands. The water body receiving large quantities of fertilizers (phosphates and nitrates or manures becomes rich in nutrients which leads to eutrophication and consequent depletion of dissolved oxygen. Consumption of water rich in nitrates is bad for human health especially for small children. Pesticides (DDT, dieldrin, aldrin, malathion, carbaryl etc.) are used to kill insect and rodent pests. Toxic pesticide residues enter the human body through drinking water or through food chain (biomagnification). These compounds have low solubility in water but are highly soluble in fats. For example, the concentration of DDT in river water may be very low but some fish over a period of time accumulate so much of DDT that they become unfit for human consumption. The use of pesticides in our country is increasing very rapidly. Some of these chemicals which are highly toxic become metabolised by animals that graze on fields. Therefore, these poisonous chemicals have been often observed in the human food chain. The presence of these chemicals in humans even in minute amounts can cause hormonal imbalance and may lead to cancer.

(iv) Physical Pollutants: Physical pollutants can be of different types. Some of them are discussed below :

(a) Radioactive Wastes: Radionuclide's found in water are radium and potassium-40. These isotopes originate from natural sources due to leaching from minerals. Water bodies are also polluted by accidental leakage of waste material from uranium and thorium mines, nuclear power plants and industries, research laboratories and hospitals which use radioisotopes. Radioactive materials enter human body through water and food, and may be accumulated in blood and certain vital organs. They cause tumors and cancer.

(b) **Thermal Sources**: Various industries, nuclear power plants and thermal plants require water for cooling and the resultant hot water is often discharged into rivers or lakes.

This results in thermal pollution and leads to the imbalance in the ecology of the water body. Higher temperature lowers the dissolved oxygen level (which is very essential for marine life) by decreasing the solubility of oxygen in water. Fish and other aquatic organism can get affected by a sudden change in water temperatures.

(c) **Sediments** : Soil particles carried to streams, lakes or oceans form the sediments. The sediment become polluting due to their large amount. Soil erosion defined as the soil carried by flood water from crop land, is responsible for sedimentation. The sediments may damage the water body by introducing a large amount of nutrient matter.

(v) Petroleum Products: Petroleum products are widely used for fuel, lubrication, plastics manufacturing, etc. and happen to be poisonous in nature. Crude oil and other related products generally get into water by accidental spillage from ships, tankers, pipelines etc. Besides these accidental spills, oil refineries, oil exploration sites and automobile service centers pollute different water bodies. Oil slick which floats on the water surface causes death of marine life and severely affects the ecosystem of the ocean.

3.3 Thermal and marine pollution

Thermal Pollution

An increase in the optimum water temperature by industrial process (steel factories, electric power houses and atomic power plants) may be called as "Thermal Pollution." Many industries generate their own power and use water to cool their generator. This hot water is released into the system from where it was drawn, causing a warming trend of surface water. If the system is poorly flushed, a permanent increase in the temperature may result. However, if the water is released into the well flushed system, permanent increase in temperature does not occur.

Effects

Many organisms are killed instantly by the hot water resulting into a high mortality. It may bring other disturbance in the ecosystem. The egg of fish may hatch early or fail to hatch at all. It may change the diurnal and seasonal behaviour and metabolic responses of organisms. It may lead to unplanned migration of aquatic animals.

Macrophytic population may also be changed. As temperature is an important limiting factor, serious changes may be brought about even by a slight increase in temperature in a

population. For minimizing thermal pollution, hot water should be cooled before release from factories and removal of forest canopies and irrigation return flows should be prohibited.

Causes or Sources of Thermal Pollution:

(1) Coal-fired Power Plants:

Some thermal power plants use coal as fuel. Coal-fired power plants constitute the major source of the thermal pollution.

(2) Industrial Effluents:

Industries generating electricity require large amount of Cooling water for heat removal. Other industries like textile, paper, and pulp and sugar industry also re lease heat in water, but to a lesser extent.

(3) Nuclear Power Plants:

Nuclear power plants emit a large amount of unutilized heat and traces of toxic radio nuclear into nearby water streams. Emissions from nuclear reactors and processing installations are also responsible for increasing the temperature of water bodies.

(4) Hydro Electric Power:

Generation of hydro-electric power also results in negative thermal loading of water bodies.

(5) Domestic Sewage:

Domestic sewage is often discharged into rivers, lakes, canals or streams without waste treatment. The municipal water sewage normally has a higher temperature than receiving water. With the increase in temperature of the receiving water the dissolved oxygen content (DO) decreases and the demand of oxy gen increases and anaerobic conditions occur.

Control of Thermal Pollution:

(1) Cooling Ponds:

Cooling ponds or reservoirs constitute the simplest method of controlling thermal discharges. Heated effluents on the surface of water in cooling ponds maximize dissipation of heat to the atmosphere and minimize the water area and volume. This is the simplest and cheapest method which cools the water to a considerable low temperature. However, the technique alone is less desirable and inefficient in terms of air-water contact.

(2) Cooling Towers:

Using water from water sources for cooling purposes, with subsequent return to the water body after passing through the condenser is termed as cooling process. In order to make the cooling process more effective, cooling towers are designed to control the temperature of water. In-fact, cooling towers are used to dissipate the recovered waste heat so as to eliminate the problems of thermal pollution.

(3) Artificial Lake:

Artificial lakes are man-made bodies of water which offer possible alternative to once through cooling. The heated effluents may be discharged into the lake at one end and the water for cooling purposes may be withdrawn from the other end. The heat is eventually dissipated through evaporation. These lakes have to be rejuvenated continuously. A number of methods have been suggested and developed for converting the thermal effluents from power plants into useful heat resources for maximing the benefits.

i. Industrial and space heating.

ii. Biological applications such as soil warming.

iii. Fish culture, livestock shelters and for heating greenhouses.

Most of these potential physical applications are of colder regions or locations.

Marine Pollution

Marine pollution is defined as the introduction of substances to the marine environment directly or indirectly by man resulting in adverse effects such as hazardous to human health, obstruction of marine activities and lowering the quality of sea water.

Causes of Marine Pollution:

(a) Oil:

It is a sea-based pollutant which is probably worst of the pollutants of the marine environment. Oil in the marine environment come from a variety of sources. These include natural submarine seepage, natural decay of marine plant and animal life, shore based industries and transport

activities, off-shore drilling wrecked oil tankers and other ships, and discharges from ships which pump out cargo and ballast tanks with sea water.

Of the two natural sources sub-marine seeps may be controllable but plants and animal decay is not. The oil discharges on the oceans first forms slicks which float on the surface. If the oil becomes absorbed on solid particles it may sink. The floating and suspended oil is absorbed by billions of tiny phytoplankton, organisms which act as a biological blotter. Since these organisms are the building blocks of the food chain the other higher forms of marine life feed upon them and successively pass the oil pollutants on to still higher organisms.

(b) Wastes Disposal:

Wastes are often divided into two major categories, i.e. domestic and industrial wastes Domestic wastes include domestic sewage, wastes from food processing detergents and run of from agricultural areas. Industrial wastes include heavy metals, radioactive nuclides, inorganic chemicals and heated water. The extent and variety of wastes spewed out by industry is tremendous. To take the American example, every year the US discards 7 million automobiles, 20 million tonnes of paper, 48 billion cans, 26 billion bottles and jars. Much of this material is made of aluminum and plastic. The mining industry discards more than 3 billion tonnes of waste rock and mill tailing. According to an official estimate every year, the American lakes, rivers and estuaries receive some 50 trillion gallons of hot water used for cooling by the power industry, and un known millions of tonnes of organic and chemical pollutants from cities, plants and industrial plants. Chlorinated hydrocarbons are another land based pollutants which have drawn the attention of international community. The chlorinated hydrocarbon pesticides — including DDT, dieldrin and endrin are known to be important pollutants in the marine environment.

These pesticides, used extensively for agricultural pest control, enter the marine environment through water runoff from agricultural areas from the atmosphere. It is estimated that nearly half of the pesticides sprayed over agricultural land is carried off by winds into the atmosphere. DDT and its residues have been found in penguin in the Antarctic and in petrels in Bermuda.