CHEMICAL PROPERTIES LIKE DISSOLVED OXYGEN, CARBONDIOXIDE, PH, ALKALINITY, HARDNESS, INORGANIC AND ORGANIC SUBSTANCES, THEIR DISTRIBUTION, DYNAMICS AND INFLUENCE ON AQUATIC ECOSYSTEM

Dissolved Oxygen:-

Most aquatic organisms require oxygen for their metabolic activities. The supply of oxygen in water comes from the exchange with the atmosphere or from photosynthesis in flora and cyanobacteria (blue green algae). Photosynthesis produces organic matter and releases oxygen, whereas aerobic respiration consumes organic matter and uses oxygen. Oxygen production (photosynthesis) predominates in the light whereas oxygen consumption takes place in the dark. Based on these processes lakes can be divided into two zones namely lighted trophogenic zone (where organic matter is synthesised and oxygen generated) and tropholytic zone (leads to decomposition of organic matter and lowering of oxygen level).

The trophogenic zone often corresponds to the epilimnion. The organic matter produced during photosynthesis sinks to the bottom but the oxygen remains in the surface layers (epilimnion). Hence, there is a sharp delineation between oxygen production and consumption. The entire water mass is oxygenated only during periods of circulation, which occur when the surface waters are disturbed by wind. During stagnation periods (absence of wind), only the epilimnion is oxygenated. The oxygen required for the decomposition of organic matter that sinks to the bottom must therefore come from the supply obtained during periods of circulation. Thus the oxygen levels in the hypolimnion are constantly depleted.

The critical determinants of the oxygen balance in a lake are morphometry and productivity. Among the lakes having same productivity, those with greater depth will decompose organic matter with little changes in the dissolved oxygen while shallow lakes lose oxygen completely. The partially decomposed organic matter settles as sediments in the bottom. The layer of water that is in contact with the sediments tends to lose oxygen as decomposition process continues in the sediment. Lower dissolved oxygen in the water overlying the sediments can aggravate water-quality deterioration because lowered DO levels (below 1 mg/L) initiate chemical reactions at the sediment-water interface, releasing phosphorous from the sediments into the water. When the lake mixes due to wind during summer, phosphorous and ammonium that is built up in the sediment triggers algal growth.

The vertical change in oxygen concentration is dependent on the pattern of circulation. In holomictic lakes, water is saturated with oxygen from the top to the bottom. Such oxygen profiles are called as orthrograde curves. In productive lakes where oxygen levels drop to zero in the hypolimnion, the oxygen curve is called as clinograde curve. Aquatic life in lakes has evolved many adaptations for the range of oxygen conditions in the lake. Many organisms have life cycles adapted to the predictable changes in the oxygen conditions such as obligate anaerobic microorganisms, which can live only in regions devoid of oxygen.

Determination of DO concentrations is a fundamental part of water quality assessment since dissolved oxygen is involved in or influences all the chemical and biological reactions in water. Concentrations below 5 mg/L may adversely affect the functioning and survival of biological communities and below 2 mg/L may lead to fish mortality. The measurement of DO can be used to indicate the degree of pollution by organic matter, destruction of organic matter and level of self purification of the water.

Carbon Dioxide :--

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| **Photosynthesis and respiration**  All green plants make their own food by the process known as photosynthesis. They trap energy from sunlight with the aid of chlorophyll and with carbon dioxide and water form sugar. The sugars are stored and used as a source of chemical energy and combine with other molecules to form proteins, oils, fats and carbohydrates. The chemical energy stored as carbohydrates are used for respiration. All plants and animals must respire in order to stay alive, so unlike photosynthesis, it continues even in the dark. During respiration, the oxygen is taken in and combined with cell sugars to release energy. Water and carbon dioxide is released as waste products. |

Carbon atoms link to form complex organic materials, as carbon is the structural basis of all living material on earth. During photosynthesis, energy is used to link carbon compounds forming sugars, starch and cellulose. Plants take up carbon dioxide and fix it in plant material. The amount of carbon dioxide fixed in the plant material is measured as the amount of carbon fixed per volume of the water. The amount of carbon fixed in a given time is an important measure of the productivity of the lake. Plants obtain carbon from the atmosphere in the form of carbon dioxide and animals from plant material. Aquatic plants use carbon dioxide dissolved in the water but the amount depends on the acidity of the water. Above pH 5.0, some of the carbon dioxide molecules form bicarbonate ions and by pH 9 all the molecules are incorporated into bicarbonate plus some carbonate ions. Above pH 9.5 carbonate ions dominate and there is a lack of free carbon dioxide. Majority of living organisms also release carbon dioxide when they respire and this includes many of the bacteria involved in decomposition. These bacteria also release carbon from the bodies of dead plants and animals back into the water for use by living plants.

pH:-

The pH is a measure of the acid-base balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration. The pH scale runs from 0 to 14 (i.e., very acidic to very alkaline) with pH 7 representing a neutral solution. At a given temperature pH indicates the acidic or basic character of the solution and is controlled by chemical and biochemical processes in the solution. Acid-base balance of a waterbody can be affected by inflow of industrial effluents, domestic sewage and atmospheric deposition of acid-forming substances. Diurnal variations in pH can take place due to photosynthesis and respiration cycles of algae in eutrophic waters. Acidity of water is controlled by strong mineral acids, weak acids such as carbonic, humic and fulvic acids, and hydrolysing salts of metals such as iron and aluminium.

Vertical difference in biological activity in the lake may lead to vertical changes in pH. The three main processes that affect lake pH are photosynthesis, respiration and nitrogen assimilation. The effect of photosynthesis and respiration depends on carbonate-bicarbonate-carbon dioxide equilibrium. The simplified formulae for photosynthesis using carbon dioxide or bicarbonate are]

                   6CO2 + 6 H2O         ®                  C6H12O6 + 6O2

                   6 HCO3 + 6 H          ®                  C6H12O6 + 6O2

 From the above equations it is obvious that no protons are used when carbon-di-oxide is taken up during photosynthesis, whereas one proton per carbon atom is used when bicarbonate ions are used for the same. The reverse happens during respiration. When pH is less than 6.3 and only carbon dioxide is present, photosynthesis and respiration have no effect on the pH. At higher pH values, when other forms of inorganic carbon are available, photosynthesis and respiration alter the uptake and release of protons. This affects the alkalinity or acid-neutralising capacity of the water.

HARDNESS :-

Major ions:  These include calcium, magnesium, sodium, potassium, chlorides, sulphates, bicarbonates, etc.

Calcium is present in all surface waters as Ca2+ and is usually dissolved from rocks rich in calcium minerals. The cation is abundant in surface water and along with magnesium is responsible for the hardness in water. It is an important constituent in all organisms and is incorporated into the shells of many invertebrates and bones of vertebrates. Calcium concentration in natural water is <15 mg/L.

Magnesium also contributes to hardness in water. It occurs in many of the organometallic compounds and in organic matter since it is an important element for living organisms. Natural concentrations of magnesium vary from 1 to > 100 mg/L.

The presence of carbonates and bicarbonates influences the hardness and alkalinity of water. Inorganic CO2 arises from atmosphere and biological respiration. The relative amounts of carbonates, bicarbonates and carbonic acid are related to pH. As a result of weathering of rocks combined with the pH range of surface waters (6-8.2), bicarbonate is found as the dominant anion in most surface waters. Carbonate is uncommon in natural surface waters because they rarely exceed pH 9.0.

Most chlorine occurs as chloride in solution. In a clean surface water, chloride concentrations are less than 10 mg/L and sometimes less than 2 mg/L. Higher concentrations can occur due to sewage, industrial effluents and agricultural and road run-off.

**Organic and inorganic compound :-**

 Nutrients:

Nutrients are the basic requirements of plants for their growth along with water and sunlight. Aquatic plants and algae respond to even small changes in the amount of nutrients present in the water. Hence it is necessary to estimate the concentrations of nutrients in the lake water and inflows to the lake. The identification of the watershed areas and land use activities that contribute to these nutrients in the lake water is essential. The two most important nutrients contributing to anthropogenic or cultural eutrophication are nitrogen and phosphorous. Both these nutrients are present in sufficient concentrations in fresh waters to maintain a healthy ecosystem, but anthropogenic activities may alter their concentrations contributing to algal blooms.

 Phosphorous and nitrogen enter the lake not only as inorganic ions but also as inorganic polymers, organic compounds, living micro organisms and detritus. Only a few of these forms are readily available for plant and algal growth. A nutrient-poor lake may have only about 1mg/l of phosphorous or 50 mg/L of nitrogen, while the most fertile lake may have up to a milligram of phosphorous or 20-30 mg/L of nitrogen.

 Nitrogen compounds:

Plants and microorganisms convert inorganic nitrogen to organic nitrogen. The inorganic compounds include nitrite, nitrate, ammonium ions and molecular nitrogen. These undergo biological and non-biological transformations in the environment. The major non-biological transformations include sorption (absorption and adsorption), voltalisation and sedimentation. Biological transformations include: a) assimilation of inorganic ions (ammonia and nitrate) by plants and microorganisms to form organic nitrogen (amino acids); b) reduction of nitrogen gas to organic nitrogen and ammonia by microorganisms; c) oxidation of ammonia to nitrite and nitrate (nitrification); d) conversion of organic compounds to ammonia during the decomposition of organic matter; e) bacterial reduction of nitrate to nitrous oxide and molecular nitrogen under anoxic conditions (denitrification).

 In lakes where the concentration of nitrogen compounds is extremely low, plants can take up additional inorganic nitrogen immediately. The discharge of sewage into the water body causes large growth of algae (if discharged directly into the lake or river). Raw sewage normally contains complex organic compounds of nitrogen that is decomposed by bacteria before they are used by plants. Eventually bacteria use up all oxygen present in the water, which leads to the death of aquatic plants and animals. Along with sewage, sometimes, fertilisers are washed off from the surrounding agricultural land, which adds to eutrophication (the process of enrichment of lakes due to addition of nutrients).

 Ammonia:

Ammonia occurs naturally in water due to the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of nitrogen gas in water by micro-organisms and gas-exchange in the atmosphere. At certain pH levels, high concentrations of ammonia are toxic to aquatic life and are detrimental to the ecological balance of water bodies. In aqueous solution, un-ionised ammonia exists in equilibrium with ammonium ion. Total ammonia is the sum of these two forms, also forming complexes with several metal ions, and may be adsorbed into colloidal particles, and suspended and settled sediments. The concentrations of un-ionised ammonia depend on pH, temperature and total ammonia concentration. Unpolluted waters may contain small amounts of ammonia and ammonia compounds (less than 0.1mg/L as nitrogen), but may reach 2-3 mg/L N. Higher concentrations are an indication of organic pollution due to sewage, industrial waste and fertiliser run-off. Natural seasonal fluctuations also occur as a result of death and decay of aquatic organisms, particularly phytoplankton and bacteria in nutritionally rich waters.

 Nitrate and nitrite:

Nitrate ions are commonly found in natural waters. It may be reduced to nitrite by denitrification process (usually under anaerobic conditions). The nitrite ions rapidly oxidise to nitrate, which is an essential constituent of aquatic plants, although seasonal fluctuations can occur due to plant growth and decay. The natural concentration of 0.3 mg/L of nitrate may be enhanced by fertilisers in the runoff, and industrial and municipal wastewaters (to 5 mg/L). In lakes, concentration of nitrate in excess of 0.2 mg/L of nitrate nitrogen stimulates algal growth leading to eutrophication. Nitrite concentrations in freshwaters are usually low (0.001 mg/L). High nitrite concentrations in water are indicative of poor microbiological quality of water. Determination of nitrite and nitrate in surface waters gives a general indication of the nutrient status and level of organic pollution. As the determination of nitrate is difficult due to interferences from other substances in the water, the precise choice of method may vary according to the expected concentration of nitrogen as nitrate.

 Organic nitrogen:

Organic nitrogen consists of protein substances and the product of their transformations. It is subject to seasonal fluctuations of the biological community, formed in water by phytoplankton and bacteria, and recycled within the food chain.

 Phosphorous:

Phosphorous is an essential nutrient for living organisms and exists in water bodies as dissolved and particulate matter. In natural waters, it occurs mostly as dissolved orthophosphates and polyphosphates and organically bound phosphates. Changes between these forms occur continuously due to the degradation and synthesis of organically bound forms and oxidised inorganic forms. Phosphorous is rarely found in high concentrations in freshwaters and ranges from 0.005 to 0.020 mg/L. High concentrations of phosphates can indicate the presence of pollution and are responsible for eutrophic conditions. Carbon and nitrogen are abundant in natural waters and additionally available from gases in the atmosphere. In majority of lakes, availability of phosphorous is the limiting factor, which controls the rate at which plants grow and therefore the productivity of the whole plant community. Phosphorous is much more readily lost from an ecosystem than nitrogen and carbon as it reacts with mud and chemicals in water in ways that make it unavailable for plants. Plants can absorb phosphorous only as dissolved inorganic phosphorous, which is rapidly taken up by algae and macrophytes.

Bacteria in the sediments at the bottom of the lake break down organic content of dead plants and animals and phosphate is released into the water in the spaces between the sediment particles. This process is rapid in sediments devoid of oxygen. In a lake with oxygenated water, even a thin layer of sediment having oxygen will act as a barrier and prevent the release of phosphate from the sediments below (which is deoxygenated). If water becomes deoxygenated (as in summer), phosphate is slowly released from the sediments. In a shallow lake, however, the phosphate may stay locked in the deep layers, but due to the lack of depth the wind mixes the water and releases the phosphate from the sediment. Aquatic plants and algae absorb the released phosphate in the water and their population’s increase. This enhances the death and decomposition of more phosphate containing materials in the water, which in turn reduces the oxygen levels and speeds up the release of more phosphate. This is a cyclical process and explains why shallow lakes are productive.