CHAPTER I

INTRODUCTION AND LITERATURE REVIEW
Water is the most precious element on earth. This indispensable and valuable commodity is not only essential for life, but in a way it can be said that "water is life". Life, according to scientific reportings, first originated in water. Water is both principal, internal as well as external medium of all organisms. Thus it can be said that all life is "aquatic" (Odum, 1971). Water reserves on the earth are immense. However, a major proportion of it is in the form of salt water which is unfit for drinking or irrigation purpose. Although fresh water is also available in sufficient quantity yet its distribution over the globe is uneven. Planet earth consists about 70.8% water. Out of this about 97.3% exists in gigantic oceans, and the remaining 2.7% is trapped in glaciers, as well as in lakes and rivers. Hardly 1% of the global water is in the form of fresh water, which is available for direct use by the infrastructure associated with life. Fresh water lakes hold only about 0.01% of the total inland fresh waters. Out of the 0.01% of the fresh water found in lakes, about 10% is found in Lake Baikal, U.S.S.R. and about 20% is stored in five Laurential lakes of Canada and America. Therefore, only a definite quantity of fresh water is readily available for human consumption. Even this limited quantity of fresh water is now facing the threat of contamination due to rapid urbanization and industrialization processes. According to Tyagi et al. (1989) only one teaspoon-full of sweet water is available per five litres of total water. Since man is not careful in his use of water, he invariably pollutes it. When this polluted water is returned to the open bodies, it contaminates the natural water, contrary to WHO's decision which emphasizes that water delivered to the consumer, should meet the requirement of modern hygiene; and should atleast be free from pathogenic organisms and toxic substances.

Pure water is odourless and tasteless. It appears to be bluish when it occurs in thick layers. Its molecular structure is responsible for many unique properties. Being a polar molecule, it has got hydrogen bonding which is responsible for the
joining of water molecules. It is the best known solvent which dissolves more substances than any other liquid without undergoing any chemical change. It is, therefore, accepted as a universal solvent. Being an inert compound, it can transport various essential substances unchanged in living cells. It freezes at 0°C and boils at 100°C. Since it is feebly ionized to \( \text{H}^+ \) and \( \text{OH}^- \) ions, it is a poor conductor of electricity. Its maximum density is at 4°C, hence ice is formed only at the surface of water body at freezing temperature, leaving warmer and denser water below; which supports aquatic life. The high specific heat of water allows it to resist the seasonal fluctuations in water temperature. Therefore, it is also a poor thermal conductor. A slight variation in temperature results in rapid change in the water density. The viscosity of water is not unique but it plays an important role in determining the shape of most planktonic organisms from minute bacteria and algae to stream lined fishes. Due to high surface tension it helps to support planktonic organisms in it without specialized supportive structures.

Fresh water is mainly of two types:

(i) Lentic or stagnant water — which comprises of many kinds of water bodies such as lakes, ponds, reservoirs, swamps, bogs, etc.

(ii) Lotic or running water — which may comprise of brooks, creeks, rivers, springs, etc.

Natural lakes are inland depressions containing standing enclosed bodies of water; which are strongly influenced by the local climate. Lakes are transitory in nature. They disappear after a course of time due to a change in its nature from oligotrophic to eutrophic. According to Welch (1935) as they age they change. Mainly three zones are found in lakes. These are:

(a) Littoral Zone: It consists of mostly the shallow marginal zone of the lakes where light penetrates up to the bottom. It is covered mainly by rooted aquatic plants and periphytic algae.
(b) Limnetic Zone: This is open water zone where the effective light penetration is up to the depth. This zone may be absent in shallow water bodies. Aquatic macrophytes may be present in this zone.

(c) Profundal Zone: This is the deeper water zone. It may also be absent in shallow water bodies. Macrophytes are totally absent in this zone.

In order to study the nature of our limited fresh water resources, with a view to check further pollution, a new interdisciplinary science known as "Limnology" with multiferous dimensions has emerged. Limnology deals with the study of structural and functional attributes of the lentic and lotic fresh water systems, and problems associated with them. According to Golterman (1975), "Limnology is an interdisciplinary science which combines certain aspects of hydrology, hydrochemistry, hydrophysics and geology. Wetzel (1975) defined limnology in broad terms as "The study of the functional relationship and productivity of fresh water biotic environmental parameters". Now-a-days, limnology is defined as "The scientific study of physical, chemical, biological and meteorological conditions in the fresh waters". The word limnology was derived from Greek word limnos, meaning pool, lake or swamp, and was used in reference to the study of a lake. In 1922, the International Association of Theoretical and Applied Limnology (S.I.L.) included lentic and lotic water systems under the purview of Limnology.

The research work of F.A. Forel (1841-1912) entitled Le Leman: monographie limnologique on Lake Geneva, Switzerland contained the term "Limnology" which is believed to be used for the first time. Forel in 1892 and 1895 published the first two volumes of his research work which consisted of geology, physics and chemistry of the lake. Later, the third volume was published in 1904, in which the biology of lakes was described. Before this he had already published a paper on the bottom fauna of Lake Geneva entitled Introduction a l'étude de la faune profonde du Lac Leman.
in 1869. In 1901 Forel published the first text book on Limnology entitled "Hand buch der Seenkunde allgemeine Limnologie. Therefore, Forel has long been considered as the father of Limnology.

The study of aquatic flora and fauna which is today known as "Biological Limnology" was undertaken by Leeuwenhoek (1674), who conducted the first microscopic study of filamentous green algae Spirogyra sps. from Lake Berkelse, Netherlands. This report contained the first hand account of the seasonal cycles of algae in lakes, and influence of winds on algal ecology. This report threw light on food-chain dynamics in aquatic ecosystem. It is not known with certainty who described the animal plankton for the first time. It is, however, known that around 1845, Johannes Muller conducted some preliminary studies on animal plankton. Shortly after Muller, Peter Eramus observed microscopic crustacea for the first time in some Swiss lakes. Peter Eramus's work launched a descriptive era for the classification of microorganisms. The word "Plankton" was used for the first time by Hensen in 1887 to describe those suspended microscopic organic materials, which are at the mercy of winds and water currents. Later on Ernst Haechel included both large and small pelagic organisms in the plankton study. Previously, only those organisms which could be retained by a fine silk net were identified, and those which passed through the net were not observed. Later, these unidentified smaller organisms were also discovered and given the name nannoplankton.

Earlier studies on lakes mainly concentrated on the flora and fauna. Thieman (1925) and Birge et al. (1926) realized that only qualitative and quantitative estimation of living organisms is not enough. Gaarder and Gran (1927) had introduced the light and dark bottles technique for the measurement of phytoplankton primary productivity. Hutchinson et al. (1932) contributed towards the hydrology of ponds and other inland waters of South Africa. Later on in 1941, Hutchinson provided the concept of
lake ecosystem. Lindeman (1942) gave due attention to the production studies of the lakes and introduced for the first time the concept of energy. Steemann-Nielsen (1952) described the macrophytic production on the basis of biomass changes, during their growth period. West lake (1963, 1965) provided a description of macrophytes.

The study of physical characteristics of water or physical limnology, began in Switzerland soon after Leeuwnhoek when F. de Duillier in 1730 measured a Seiche (Ossilations of the surface of a lake). Later on during the period between 1779 and 1796, Saussure made temperature observations in deep lakes. The first description about light, heat, temperature and wind was given by Sir John Leslie, who interpreted the findings of James Jardin, who had studied the Scottish Lake between 1812 and 1814. Secchi in 1856 devised the Secchi disc to measure the light penetration in water. Winkler (1888) propounded the technique of analysing the dissolved oxygen content of water. The first extensive measurements of dissolved oxygen were done probably in the estuary of the River Thames, England in 1882. S.A. Forel studied the oxygen content in Lake Geneva, Switzerland in 1885 and modern studies of oxygen distribution began with Birge and Juday (1911). It was Sugawara (1934) who for the first time used the volumetric analysis method for nitrogen estimation, but did not get accurate results because of some technical problems. Welch (1935) emphasized on the measurements of water temperature and calculation of heat budget.

Water pollution studies started around 1860 in river Thames in England. In 1857, a Royal Commission was set up to prevent river water pollution. Later in 1876 and 1890, River Pollution Prevention Acts were enacted in England. In 1898 Royal Commission on sewage disposal was set up. The modern and scientific attitude towards pollution is said to have started with the report of the Royal Commission on sewage disposal. In the meantime limnological study in North America also spread its
roots with the publication of the report on Lake Superior by Agassiz in 1850. In 1887, Stephen A. Forbes started his work on limnology by considering lake as functional ecological systems. He described lake as "microcosm". Historically fresh water systems of India received the scientific attention rather very late, and the pioneering works of some scientists mostly on South Indian Waters are the mile-stones in the Indian Hydrobiology. These pioneer workers were Purthi (1933), Ganapati (1940), Chacko and Krishnamurthi (1954), Prasad (1956), Zafar (1959), Sreenivasan (1964), etc. (In India, upto 1960s, hydrobiological studies did not get much attention from scientific community. During late 1960s, some studies related to the taxonomy of aquatic flora and fauna were conducted.) During early 1970s, Indian limnologists paid attention to systematics of algae and fungi, morphology, life cycle studies mainly of crustaceans, seasonal changes of macrophytes etc. Now-a-days a number of ponds, lakes, reservoirs, tanks and rivers have been investigated mostly with the objectives of applied aspects, such as, fisheries development, productivity assessment, pollution evaluation etc. Even now the situation is not better in India. The workers on production and productivity, energy flow, nutrient dynamics and other biochemical aspects of fresh water bodies of India are still in underdeveloped stage, compared to the strides taken by European and American workers.)

The pace of development was rather gradual in the field of Limnology until 19th century. But during the second half of the twentieth century the development process was rapid. Information related to fresh water systems from all over the world is available now. Today the technological revolution has been closely assimilated and integrated in the study methods and methodology. The use of sattelites, space labs, space shuttles, application of Laser remote sensing, use of third and fourth generation computers especially in making mathematical models etc. are the achievements of the ultra modern limnology. Even radioactive elements are now used in learning the nutrients cycling and metabolic processes in water bodies. Strong et al.
(1974) have described chemical whitening due to calcium carbonate precipitation in Lake Michigan by utilizing the data from the NOVA-2 and EPTS-1 satellites. Strong (1978) studied the phytochlorophyll distribution in the Great Lakes using Landsat. Reid (1978) used Geostationary Operational Environmental Satellite (GOES) system to collect hydrometric, hydrometeorological and water quality data like water temperature, pH, DO, conductivity and turbidity. Smith and Baker (1982) determined the horizontal variation in chlorophyll concentration using sattelite (Nimbus 7 coastal zone colour Scanner). Edward and Melack (1985) used the imagery obtained with multispectral scanner on Landsat for chlorophyll determination.

Researchers throughout the world are now investigating the physico-chemical and biological characteristics of fresh water. There are several physico chemical factors of water which signify the water quality of any fresh water body. These important factors are: temperature, light, conductivity, hydrogen ion concentration, carbon dioxide, alkalinity, hardness, nitrogen, phosphorus, silicate, BOD, COD, chloride etc. Study of these parameters helps in the proper management of a water body, and provides valuable information about its trophic status. Following is a list of researchers in India and abroad, who have made significant contributions in the field of hydrology of lentic water systems:


The most important indicators of water quality are plankton. It has been observed that in oligotrophic waters the plankton community is comparatively less denser than in the eutrophic waters. Several physico-chemical factors of water affect the plankton density and diversity either directly or indirectly. Researchers have identified some pollution tolerant genera of different phyto and zooplankton groups. Kolkwitz and Marson (1908) in their pioneering works reported that there were certain organisms which either preferred polluted or non polluted water bodies. Nygard (1949) and Palmer (1969) prepared a list of those genera and species of different phytoplankton groups which were most pollution tolerant. Several workers have considered plankton especially phytoplankton as the trophic indicators of the lakes. Zooplankton do not indicate a wide range of trophic

It has been observed that as soon as the water quality changes, the productivity of the water body also changes simultaneously. Nitrate and phosphate have been considered as main plant nutrients which control the primary productivity. Temperature and light are the universal factors which limit the phytoplankton productivity. Phytoplankton productivity is due to the photosynthetic pigments - chl. 'a', 'b' and 'c', which are common in almost all plankton algae. Several workers have used both chlorophyll concentration and phytoplankton productivity as the indicators of the trophic status of a water body. Important work in this area is that of: Barrett (1953), Waters and Ball (1957), Rodhe (1958), Stepeneck (1959), Talling (1960,1966,1971), Reid (1961), Prasad and Nair (1963), Findenegg (1965), Sakamoto(1966), Ryther (1967), Ganapati and Sreenivasan (1968,1970,1972), Kalff (1969), Karunakaran et al. (1969), Rao and Prabhakar (1970),

In recent times the presence of aquatic macrophytes has also been considered as an indicator of highly eutrophic nature of a water body. Although macrophytes remove a bulk of nutrients from water, as well as from the sediment, yet after their death and decay, they produce a large quantity of organic matter. Due to the decomposition of the organic matter, the nutrients are released in the overlying water by physico-chemical, mechanical and biological processes, resulting in further eutrophication.


Sediment is a lake product which is derived mainly from allochthonous and autochthonous sources. After the death and decay of aquatic biota, a bulk of sediment is produced. Sediment
is known as the bank or reservoir of a lake, and regulates the water chemistry due to its mixing with water, at high wind velocity and bioturbation. The nutrients are released from sediment into the water, depending on the prevailing physico-chemical factors of the water and sediment. On the basis of sediment analysis several workers have made significant findings. Some important names are:


In the present study, the physico-chemical characteristics of water and sediment have been estimated month wise. Water characteristics have been correlated with the plankton population, chlorophyll contents and primary productivity. The effects of nitrate and phosphate enrichment on phytoplankton productivity have also been taken into consideration. Some nutrients have also been estimated from Hydrilla verticillata (submerged rooted macrophyte) and correlated with water and sediment characteristics. The data gathered from all objectives were subjected to the statistical analysis. Analysis of variance, significant 't' test and co-efficient of correlation techniques have been used for the interpretation of the data.