CHAPTER I. INTRODUCTION AND REVIEW OF LITERATURE
Water is one of the most vital factor in the
existence of living beings. It is a part of life itself.
Protoplasm of the most living cells contains about 80% of
water, which participates either directly or indirectly in
all metabolic activities. The amount of water on the earth
is about $1.4 \times 10^9 \text{ km}^3$ which covers about 70% of the earth’s
surface with an average depth of about 3000 mts in the form
of Oceanic brine. Out of the total amount of water about
96.42% (13000 geograms) found in Oceans, and 1.78% is in
the form of Ice sheets and rest is as fresh water. Hence
in fresh water it is contributed as about 0.01% (1.8 geograms)
in lakes, about 0.001% (0.13 geograms) in atmosphere
about 0.0001% (0.02 geograms) in rivers about 0.00007% as
biological water.

The quantity of the fresh water on the earth is
estimated to be $29 \times 10^6 \text{ km}^3$ which is about 0.2% of the
global water. Out of this about 10% is lying in Baikal lake
in U.S.S.R. and about 20% in five Laurential lakes of Canada
and America. Thus, there is only a small and definite
quantity of fresh water to meet all the direct and indirect
requirements of the infrastructure associated with out
life and industrial processes.
Water has several unique properties which makes it suitable for the existence of life. Water is called a universal solvent as it dissolves more substance than any other liquid without undergoing any chemical change. Hence being an inert compound, it can transport various essential substance without any chemical changes in living cells.

Water has got the properties of cohesion and adhesion which provides a high surface tension that is advantageous for the existence of many organisms like algae, protozoa and some insects which live on the surface of water. The high specific heat of water enables it to resist the fluctuations in temperature of water bodies rather than land masses.

The study of marine life had been started during the time of Aristotle (384-322 B.C.). However no significant contribution of a strictly limnological nature appeared till early nineteenth century. During later half of nineteenth century and early twentieth century biological work in the field of lake investigations has been conducted. Originally the word 'limnology' was used in reference to the study of lake and is derived from the Greek word 'limnos', meaning 'pool' 'lake' or 'swamp'. It first appeared in the work of F.A. Forel, entitled 'Le Leman, Monographic limnologiques on Lake Geneva, Switzerland.' The first two volumes were published in 1892 and 1895, consisting of the geology, physics and chemistry of the lake while the third volume published
in 1904, deals with the lake's biology. However the concept that the lake is a 'microcosm' (a little world within itself) was developed for the first time in 1887 by Forbes.

The development of techniques in limnology led to well planned and long term researches in different countries. Notable contributions are those of Secchi (1856) who devised Secchi disc to note light penetration in water, Winkler (1888) proposed the technique to measure the dissolved oxygen content of water, Welch (1935) emphasized on the measurement of water temperature and calculation of heat budgets. Gaarder and Gran (1927) introduced the light and dark bottle technique for the measurement of phytoplankton productivity of water. The development of C¹⁴ technique is more useful in measuring narrow changes in productivity (Steemann-Nielsen, 1952). Macrophytic production on the basis of biomass changes during their growth period was suggested by Westlake (1963, 1965).

Hence limnological observations have a long history but it evolved into a distinct science during the last two centuries when inventions such as microscope, the silk plankton net and the thermometer began to provide data which showed that inland water contained microcosms of life with a distinctive structure. According to Colterman (1975) Limnology is an interdisciplinary science, combining aspects of hydrology, hydrochemistry, hydrophysics and geology. However according to Wetzel (1975) 'Limnology is
in broad terms, the study of the functional relationship and productivity of fresh water biotic environmental parameters. At present, Limnology plays a role in the decision making process for problems of dam construction, pollution control and fish and wildlife enhancement.

Earlier studies were mainly restricted to the biological characteristics of the lakes (Fritah and Rich, 1909). However, Thienemann (1925) and Birge and Juday (1926) suggested that only quantitative and qualitative estimation of biota is not enough and stressed the need of simultaneous studies of physico-chemical factors and geomorphology of the lakes. Hutchinson et al. (1932) contributed the hydrobiology of pond and other inland waters of south Africa. Hutchinson (1941) provided the concept of lake ecosystem and Lindeman (1942) has given great emphasis to the production studies of the lakes and introduced for the first time, the concept of energy flow.

The growing interest of scientists in limnological studies led to well planned and long term researches in different countries. Notable among these are: Chestum et al. (1942), Chandler (1944), Pennak (1949, 1955), Colebrook (1960), Biswas (1969 a, b, 1972, 1973, 1977), Berman et al. (1972), Jerry (1973), Cenf and Viner (1973), Hicke (1973), Moriarty et al. (1973), Lewis (1973, 1974), Berman and Pellingher (1974), Manf and Blazka (1974), Pellingher and


Recent studies in limnology using advanced space technology and laser fluorescence system have been done by a few workers in America and Canada. Strong et al. (1974), have described 'chemical whitening' due to calcium carbonate precipitation in Lake Michigan by utilizing the data from the NOAA-2 and EPTS-1 Satellites. Strong (1978) has studied the 'chemical whitening' and chlorophyll distribution in the Great Lakes as viewed by Landsat. Reid (1978) used 'Geostationary operational environmental satellite' (GOES) system to collect hydrometric, hydrometeorological and water quality data like water temperature, pH, dissolved oxygen, conductivity and turbidity.

The progress made in the field of limnological studies has enhanced our knowledge of physico-chemical characteristics of water and the dependence of all life process on these factors makes it desirable to consider water as an environment. The most important physical and chemical parameters of the water are the temperature, transparency, alkalinity, ion-compositions, oxygen, carbon-dioxide, BOD, COD, nitrate, ammonia, phosphorus, silica and some other major and minor nutrients.
It is very essential to have a thorough knowledge of the chemistry of water in order to understand the biological phenomenon completely. An adequate knowledge of the chemistry of water helps to understand the metabolism of the ecosystem and also the general hydrobiological interrelationship.

Hutchinson (1957) remarked that a skillful limnologist can probably learn more about the nature of a lake from a series of oxygen determinations than from any other kind of chemical data. According to Goldman and Horne (1983) the short and long term variations in dissolved oxygen of lakes and rivers is a good measure of their trophic state. They further reported that oligotrophic water shows little variation in saturation of oxygen, while eutrophic ones may range from virtual anoxia to 250% saturation. The first extensive measurements of dissolved oxygen were done probably in the estuary of the river Thames, England, in 1882. S.A. Forel studied oxygen in lake Geneva Switzerland in 1885 and modern studies of oxygen distribution began with Birge and Juday in 1911.

Carbon dioxide is a by product of respiration in both plants and animals and is utilised during photosynthesis. Carbon dioxide has an inverse relationship with oxygen (Odum, 1971). Although carbon dioxide is only a minor component of the air, it is quite abundant in water because its solubility
is about 20 times more than oxygen in water. The distribution of oxygen and carbon dioxide in natural waters provides a convenient measure of organic production and decomposition and forms the basis of most methods of measuring primary production.

The hydrogen ion concentration controls the chemical state of many lake nutrients including carbon dioxide (Goldman and Horne, 1963). Changes in pH influence other important plant nutrients such as phosphate, ammonia, iron and trace elements. According to Talling (1976) the rate limiting step for photosynthetic carbon uptake is the dehydration of carbonic acid. Environmental carbon dioxide also gets dissolved in the water of lakes when strong wind blows across its surface. Even during short periods of intensive photosynthesis, this source (mixing by wind) may be insufficient to meet the maximum carbon dioxide requirements of plants.

After carbon, hydrogen and oxygen the element which is found in abundance in living cells is nitrogen, which is essential for most biochemical reactions. The quantity of nitrogen accumulated by each animal or plant varies from the 1 to 10% of dry weight and to some extent reflects the availability of nitrogen in the adjacent environment (Cerloff and Hoog 1954, Fitzgerald, 1962). It was Sugawara (1939) who for the first time used the volumetric analysis method used by him did not provide accurate results because
of technical problems such as collecting and keeping water at its original temperature and pressure until the gases are analysed. Benson and Parker (1961) used mass spectrometry and gas chromatography for measurement of dissolved nitrogen gas. Strickland and Parsons (1972), Solorzano (1969), Jenkins (1975) used chemical method for estimation of nitrate, ammonia and organic nitrogen. In aquatic ecosystems the major forms of nitrogen which are available to bacteria, fungi and plants are nitrate and ammonia. The ammonium ion is rapidly uptaken by phytoplankton and other aquatic plants (Toetz, 1971). The actual amount of ammonia present at any time in a water body depends on the balance among animal excretory rates, plant uptake and bacterial oxidation. Ammonia if present in high concentration in water becomes toxic to animals and plants especially at elevated pH levels when ammonium hydroxide is formed.

Phosphorus is not needed by phytoplanktons in large quantities for growth as compared to carbon, oxygen, hydrogen and nitrogen, but it is one of the most common limiting factor in fresh water. There are three main reasons behind this: (1) phosphorus containing minerals are some times geochemically scarce and thus the normal nutrient supply derived from rock breakdown is poor in phosphorus content. (2) there is no gaseous phase in the phosphorus cycle hence there is no equivalent nitrogen fixation (3) phosphorus is sufficiently reactive to be tightly bound to a variety of soils (Goldman and Horne, 1983)
Silicon, calcium, magnesium, sodium, potassium, sulphur, chlorine, iron and the minor elements constitute most of the plant and animal nutrients. Diatoms require large quantities of silica for the formation of their cell walls. Calcium is the main skeletal component of many animals and some plants, but it is also important in buffering lake waters. Magnesium, which has a similar water chemistry to calcium, is vital for energy transfer in any cell because it acts as catalyst in the change that taken place from ATP to ADP. Plants require magnesium to form an active center to their major pigment chlorophyll 'a'. Unlike terrestrial plants, water algae do not need potassium in large quantities. Both potassium and sodium are usually present in excess of biological requirements.


The studies we now know as biological limnology originated in 1674 with the first microscopic description of the filamentous green algae, Spirogyra from Berkelse lake Netherlands, by Leeuwenhoek. Although Leeuwenhoek considered himself as a microbiologist, his report contains the first account of the seasonal cycles of algae in lakes, hints about food-chain dynamics and the influence of winds on algal ecology.

The discovery of animal plankton was another important milestone in the development of aquatic biology. Although it is not known for certain who was the first person to describe plankton, credit can be given to Johannes Muller for conducting some of the earliest studies around 1845. A short time later another Muller, Peter Erasmus observed microscopic crustaceae for the first time in some Swiss lakes.

The word 'plankton' which means 'wandering' was first used by Hensen in 1887 to describe the suspended
microscopic material at the mercy of the winds, currents and tide. The meaning of the word 'plankton' was later expanded by the German biologist Ernst Haeckel to include both large and small pelagic organisms.

The number and type of plankton in water varies with the depth, site of collection, time and the season. They also differ according to the source of water, its organic and inorganic content and with geological, biological and climatic factors. All plants and animals that inhabit large sheet of water, are less subject to violent temperature changes and maintain an equilibrium in its constitution and seasonal periodicity, when compared to terrestrial environment. Diversion of ecological changes at times, results in a slow eutrophication, which varies in its degree from lake to lake. This results in the variation of plankton and other aquatic organisms.

Phytoplankton in temperate regions usually grow in a series of pulses or blooms. The first blooms are initiated in spring due to an increased in sun light and autumn growth is terminated because light decreases in winter. In tropical regions growth may be nearly continuous when sufficient nutrients are available. In polar regions where sunlight and ice-free periods are brief, there is only a single short period for growth.

The life cycle of each species is further modified by the availability of nutrients, the degree of thermal stratification, algal movements relative to the water, zooplankton grazing, interalgal competition and parasitism by protozoans, fungi, bacteria or viruses.


The green algae is one of the large group of phytoplankton, in terms of number of species. It is almost a widely distributed and well adapted as diatoms are among the phytoplankton most commonly encountered and easily recognized of the microscopic. The diatom phytoplankton are distinct on account of their golden brown, unicellular or colonial organisms as well as the siliceous cell wall which is variously decorated with rows of pores, slits thickenings, internal partitions and various knobs or spines. Patrick (1948) studied the distribution of diatoms and effecting factors, Verduin (1951) examined the comparision of spring diatom. Ray and Rao (1969) reported the density of diatoms in relation to physico-chemical conditions, Williams and Clesceri (1971) studied the changes in diatom population in lake George New York.

The blue green algae are the only group of algae which possess the prokaryotic type of cellular organization and are accordingly called cyanobacteria. The body of blue-green algae is limited to unicells, colonies, branched and unbranched filaments. The important contributions on blue green algae are those of Allen (1952), Reynolds (1971), Shapiro (1973), Murphy et al. (1976), Schmitt and Olive (1980), Lampert (1981 a, b, 1982), Konopka (1981), Lovstad (1983, 1984b).
The dinoflagellates as a group are also rather animal like in a number of respects viz. most species which have been cultured require one or more vitamins for growth, heterotrophic forms are known to be both free living and parasitic. They are golden brown, unicellular or colonial. Few species exhibit amoeboïd, coccoid or filamentous body forms. Pollinger and Berman (1975), Pollinger and Serruya (1976), and Pollinger and Zemel (1981) have studied the dinoflagellates blooms.

Lake zooplankton is ubiquitous. Its main components are protozoans, rotifers and crustaceans including cladocerans, ostracodes and copepodes. Inadequate knowledge of the zooplankton and its components is a major setback to a better understanding of the factors influencing biological productivity of the fresh water bodies. Golterman (1975) also felt that the "Studies of zooplankton are still at the pioneer stage". Important work in this field are those of Deevey (1948), Welch (1952), Pennak (1953), Tees and Armitage (1960), Beeton (1960), Arsen (1964), Dumont (1968), Saunders (1969), Joseph (1970), Stout (1970), Edmondson and Winber (1971), Chapman (1972), Zaret and Suffern (1976), Gliwicz (1977), Burns and Mitchell (1980), Gulati et al. (1982), Dussart et al. (1984).

Some important studies related to these aspects in India have been done by Alikunhi et al. (1955), Cheeko and Krishnamurthy (1954), Das and Shrivastava (1955, 1957),

However, Indian freshwater biologists have not studied protozoa exhaustively and extensively as compared to the efforts made in other countries. Studied on Rotifera (in India) have been done by George (1961), Jyoti and Sehgal (1979), Sharma (1983), Dutta and Bandyopadhyaya (1984), Saksena (1984), Chourasia (1985), Tiwari et al. (1988).

All the crustaceans without exceptions are aquatic. They have a hard shield covering their body to which are attached body muscles. There are 30,000 marine species in the world. The exact number of Indian freshwater species is not known. Das and Akhtar (1970) has been reported the cladocera from Dal lake Kashmir and Jain and Rao (1989) reported the cladocera from Ujjain area. However, Borecky (1956), Wells (1960), Hall (1964), Green (1967, 1976), Allan (1977), Nanazota and Yasuno (1985), De Mott (1984), Diner et al. (1986), and George (1986) have been reported the population dynamic from other countries.

The measurements of photosynthesis as a form of phytoplankton primary productivity of any ecosystem are essential in food chain studies. The daily and seasonal
carbon flow in the system forms the basis of annual food pyramid and it can be used to estimate the maximum production at higher trophic levels. In addition to long term effects changes in photosynthetic rates may show almost instantaneous effects of a nutrient toxicant or physical change in the environment. The advantage of primary productivity assays is that it directly measures the effects before they are marked by adoption or dilution in the food chain. Photosynthesis converts light energy into chemical energy which is stored in the form of organic compounds such as carbohydrates, proteins and lipids. The amount of new organic compounds produced by autotrophs is called primary production whereas the amount produced per unit time is called primary productivity (Marshall, 1983).


Considering the work done by earlier workers and the papers they have left, it was thought worthwhile to study the monthly variations in physico-chemical parameters of limnological significance in order to understand the basic structure and functional relationship of different environmental factors and biotic component of aquatic ecosystems. Three water bodies in Sagar, differing widely in age, productional status, water quality, surrounding geologic, biological conditions and water use patterns were considered for investigation. In these water bodies practically no limnological work had been done so far.

In the present investigation an attempt has been made to study the physico-chemical and biological aspects of the water bodies. The brief points of the study are as follows:

1. The general survey of the water bodies was made in regard to history, geology, geographical situation and local climatic condition.
2. Monthly periodical studies were carried out at two zones from each water bodies, for thirteen months. The depth wise data were also collected for physico-chemical and biological characteristics.

3. Study of temporal and spatial variation of various physico-chemical properties of water at different water bodies.

4. Study of temporal and spatial variation of plankton populations.

5. Study of temporal and spatial variation of phyto-plankton primary productivity.

6. To work out the possible relationship among abiotic and biotic factors and productivity.

7. To evaluate the trophic status of the water bodies due to eutrophication.