CHAPTER 1

INTRODUCTION
CHAPTER 1

1.1. INTRODUCTION

Water is one of the important natural resources of the planet earth and essential for the survival of all forms of life. The origin of water on the earth is not so far clear. However, the current presumption is that the primordial earth had no oceans, and perhaps very little atmosphere. It is believed that the volatile constituents bound in the earth’s crust is oozing to the surface through volcanoes, rock movements and hot springs, condensed to form ocean and the atmosphere. By this way, perhaps the remarkable combination of hydrogen and oxygen taken place to form water, which came to existence and eventually became an indispensable component of the earth’s environment.

Water accounts for about 70% of the weight of a human body. Even though 80% of the Earth’s surface is covered by water, 97% of earth’s water is saline and 3% is fresh water. Out of 3% fresh water, 2.14% water is trapped in the giant glaciers and polar ice caps. Thus, not even 1% of total fresh water is available for drinking, agriculture, domestic and industrial consumption (Khadsan and Kadu 2003).

Because of civilization, industrialization and population explosion, the demand for water has increased several folds. But sewage, industrial wastes and varieties of synthetic chemicals polluted considerable part of the limited quantity of water. Thus, the quality and quantity of clean water supply is vital for the welfare of mankind. The rivers, lakes and ponds are the main sources of freshwater for drinking, washing, irrigation, and entertainment purposes. The continued anthropogenic activities in and around the lakes and other freshwater bodies have not only caused water quality deterioration which leads to serious health hazards to the people but also shrinking in the surface area (Zutshi and Khan, 1988, Pandit, 1999).

Water quality can be assessed either monitoring the Physico-Chemical properties of water or by analyzing inhabiting biota. Biota comprises mainly plankton. Plankton are free floating, microscopic organisms, which include tiny
plants (phytoplankton), which are the primary producers and tiny animals (zooplankton) which are the primary consumers or secondary producers of an aquatic ecosystem. The existence of plankton depends upon the quality of water in a given time and space.

Pollution problem in India is worse than some of the Industrialized countries. Localized aquatic pollution is not only dangerous to human health but also damages to the economy. It has been reported that 50 to 70 % pollution loads of the rivers, lakes and ponds is from domestic sewage. Water pollution has adversely affected the aquatic flora and fauna in the lentic and lotic ecosystems.

Urban lakes and ponds are highly degraded due to the direct entry of domestic sewage from the intensively urbanized catchment area. Pollutants like domestic sewage, oxygen demanding wastes, infectious agents, insecticides, herbicides, minerals and other chemical sediments get access to the fresh water bodies, which deplete the water quality severely. Excessive plant nutrients such as nitrates and phosphates, which are present in domestic sewage and agricultural run off, stimulate the growth of microorganisms, which often increase the biological oxygen demand and decrease the amount of dissolved oxygen availability for fishes and other aquatic animals. During recent years, lakes are becoming the victim of the cultural eutrophication.

Now a days all major lakes are facing acute pollution problem and emitting foul odour. Some of the important lakes like Dal and Nagin in Kashmir, Loktak in Manipur and Hussain sagar in Hyderabad have been seriously choked by aquatic weeds due to eutrophication. Silt deposition, eutrophication, excessive algal growth etc., are the usual phenomena of the most lake ecosystem. The seasonal variation of lake water temperature, Physico-Chemical and Biological parameters are conspicuous, which influence the distribution, diversity and abundance of aquatic life in the lakes. Fresh water bodies differ from each other in size, shape, Physico-Chemical nature, degree of pollution and aquatic life. Small fresh water bodies are gaining much significance as the large water bodies are too scattered to fulfill the needs of the present day.
Zooplankton communities of freshwater constitute an extreme assemblage of organisms represented by nearly all the Phyla of invertebrates. They play a vital role in the energy transfer from primary producers to secondary consumers and occupy the second or third trophic level of the aquatic food web. The fish yield, to a greater extent depends on their abundance. The zooplankton of ponds and lakes are dominated by mainly five groups viz., protozoa, rotifera, cladocera, copepoda and ostracoda. Protozoan zooplankton, though important, require specific and elaborate techniques that go beyond the frame work of this study. Metazoan zooplankton can be distinguished into holoplankton, which spend their entire life cycle as plankton (e.g. copepods) and meroplankton, which spend only a part of their lifecycle as plankton (e.g. larvae of insects). The most significant feature of zooplankton is its immense diversity over time and space. Thus similar aquatic systems may have dissimilar assemblage of organisms varying in species composition and biomass. Further, inspite of convergent similarities, zooplankton species have different types of life histories influenced by seasonal variation of abiotic factors, feeding ecology and predation pressure. In an aquatic ecosystem 90% zooplankton species are herbivores, remaining 10% being carnivores. Since secondary predation primarily depends on the biomass of herbivores and non-predatory zooplankters. The diversity of zooplankton is usually studied by enumeration of different taxa or species in a representative sample collected by towing standard plankton net over an adequate distance.

Zooplankton diversity is one of the most important ecological parameters in water quality assessment. Various indices like richness, diversity, evenness and dominance can be calculated when data on taxonomy of different zooplankter is available. In general, nutrient poor oligotrophic ecosystems possess high diversity and low biomass, while nutrient rich eutrophic systems have low diversity and high biomass of highly pollution resistant species. Biological indicators show the degree of ecological imbalance, while chemical analysis measure the concentration and type of pollutants present. The abundance of zooplankton is more or less governed by the interaction of number of physical, chemical and biological
processes. Fresh water bodies have gained more importance in recent years, mainly because of their multiple uses. There are numerous natural and artificial ponds, reservoirs and lakes in the Indian subcontinent (Rao, 1975). Several workers have attempted to study the hydrobiological profile of varied water bodies and diversity of plankton (Kaushik and Sharma, 1994; Singh, 2000; Patil and Karikal, 2001; Sunkad and Patil, 2003; Sunkad, 2004; Jeelani et al., 2004 & 2005; Manzer et al., 2005 and Sheeba and Ramanujan, 2005).

Water Quality Index was developed for various water uses like domestic water supply, irrigation and recreation using different methods mentioned by many researchers. Water Quality Index (WQI) is a single number (like a grade) that expresses the overall water quality at a certain location based on several water quality parameters. It is defined as “a rating reflecting the composite influence of different water quality parameters, on the overall quality of water” (Tiwari et al., 1986). The water quality index studies were carried out by Harkins (1974), Mohanta and Patra (2000), Bahera et al., (2004), Mohanty (2004), Kesharwani et al., (2004), Padmanabha and Belagali (2005b). WQI is an useful and important tool to assess the overall quality of water and reduce the large amount of water quality data in to a single numerical value.

Various indices, which have been developed for describing structure of both plant and animal communities (Southwood, 1978) are now extensively used in measuring stress on them, cast upon by overexploitation and pollution (Kumar, 1994; Vishalakshi, 1995; Kumar et al., 1998; Ganihar, 1998; Krishna Prasad & Rajagopal, 1998; Raizada et al., 1998; Nautiyal et al., 2000; and Sharma et al., 2005). In the present study, various ecological indices have been applied, to assess the degree of pollution in the lentic ecosystem of Mysore city and also the zooplankton characteristics.

Mysore is one of the famous tourist centers in India and has many small and medium, natural and artificial lakes. The lakes are the source of drinking, washing, irrigation, entertainment etc. From the literature survey, it appears that considerable studies were conducted on the Physico-Chemical factors and

But reports on the zooplankton ecology in the lakes of Mysore are scanty (Padmanabha and Belagali, 2006 a & b). In this direction, the present study is undertaken to know the water quality status, water quality index, zooplankton diversity, zooplankton density, pollution load and to focus more on zooplankton ecology in the lakes of Mysore city. Four lakes were selected for this study viz., Kamana lake, Karanji lake, Kukkarahally lake and Dalvoi lake which are perennial and located at north, east, west and south escorts of Mysore city respectively. The study is carried out from June 2004 to May 2006, with the principal objective of understanding the spatial and temporal distribution, seasonal fluctuations, diversity and abundance of zooplankton, pollution indication, role of some selected heavy metals on the distribution patterns of zooplankton and applicability of suitable ecological indices to evaluate pollution stress in the four lakes of Mysore city.

2. SIGNIFICANCE OF ZOOPLANKTON STUDY

Zooplankton study has not only ecological importance but also economical importance. Zooplankton are:

1. Natural purifiers of polluted water: Some zooplankton play an important role in the natural purification of polluted waters: e.g. the cladocerans have been called "the living filters of bacterium and detritus". Moina dubia, a
cladoceran has been found to contribute to the flocculation of the suspended detritus, bacteria and to certain extent, to the removal of colloidal particles and thus affects a reduction in the turbidity of a pond ecosystem.

2. **Biological indicators of aquatic pollution:** Zooplankton in general, have a number of advantages as indicator organisms in the assessment of aquatic pollution. These are sufficiently large and easy to collect sample, identify and maintain in the laboratory. They have short reproductive cycle and many generations can be studied within short period. They respond more rapidly to environmental changes. Generally calanoid copepods are absent in the polluted water, but cyclopoid copepods are present in the highly polluted water. A number of studies have identified cladoceran and rotiferan species as best indicators of different kinds of aquatic pollution (Mahajan, 1981; Kolkwitz and Marsson, 1902 & 1909).

3. **Live feed in aquaculture:** Due to a number of advantages over artificial feed, many zooplankton species like *Daphnia carinata*, *Brachionus plicatilis* and *Moina species* are preferred as live food for early stages of fish culture. Further, high levels of proteins, free amino acids, fats and carbohydrates are reported in cladoceran species. Zooplankton are the live food in aquaculture, which are very essential to achieve good growth and survival rate of commercially important finfish and shellfish. The mass culture technology is well established for culture of *Brachionus plicatilis*, *Daphnia* and *Moina* species. Recently many attempts are being made to culture copepods, as these have high nutritive value and wide spectrum of size suitability for fish larvae (fingerlings) as live prey (rotifer 0.2 - 0.6 mm, cladocera 0.3 - 0.6 mm, copepoda 0.5 - 5.0 mm).

4. **Ecotoxicological study tools:** Zooplankton are ideal organisms for ecotoxicological studies and environmental monitoring due to their short lifespan, rapid turnover and wide distribution (rotifers have a short lifespan <14 days).
5. **Biological controllers:** Some zooplankton play an important role as biological controllers. For example, cyclooids such as Microcyclops, Mesocyclops and Megacyclops species attack and control mosquito larvae.

6. **The source of industrial products:** Zooplankton are the important source of industrial products such as chitin and its derivatives.

7. **Bioaccumulators and biomagnifiers:** Some zooplankton are believed to absorb nondegradable substances like pesticides, which leads to bioaccumulation and bioamplification.

8. **Parasites on aquatic animals:** Many species of zooplankton in general and copepods in particular are parasites on fishes and other animals.

9. **The natural grazers in the aquatic system:** Most common grazing zooplankton are rotifers and daphnids. These have tremendous appetite for the phytoplankton. A healthy population of zooplankton prevents the formation of algal bloom and improves the water quality.

10. **Parasite vectors:** Some of these serve as intermediate hosts to complete cycle of many worms. For example, cyclops is an intermediate host to Dracunculus medenensis or Guinea worm, which is an infection causative worm in humans.

11. **Tools for pathological studies:** Zooplankton are the tools for pathological studies such as abnormal growth, tumors and morphological abnormalities.

12. **Seasonal indicators:** Some of the zooplankton are the indicators of a season. For example, in Daphnia, cyclomorphosis is a significant phenomenon in which body shape changes in a cyclic manner. In winter head is round, helmet like projection develops during spring, which is very well developed during summer, reduced during autumn and becomes round once again during winter.

13. **Food for pearl oysters:** In the pearl industry zooplankton have great value, as they constitute the food of the pearl oysters.

14. **Zooplankton can serve as a different source of food for man:** The chemical analysis of copepods has revealed that they are, as proteinacious as meat and phytoplankton are as nutritious as any of the vegetables. So, it could eventually become a useful supplement to man’s diet and that of domestic animals.
15. **The evildoers:** A sudden zooplanktonic bloom results in the complete deoxygenation of water and in the liberation of certain poisonous chemicals, which may kill other aquatic life. Several examples are known as planktonic blooms that led to the instantaneous and catastrophic deaths of countless fish.

16. **A great nuisance in waterworks:** Zooplankton when sorted out in reservoirs may produce a sudden planktonic bloom that imparts a bitter taste and objectionable smell to the drinking water. It may even block the purifying filters. Thus, a constant watch must be maintained by a competent person to check the development of undesired microorganisms in the reservoirs.

1.3. **SCOPE OF THE STUDY**

The scope of zooplankton ecology is quite vast. The zooplankton ecological principles provide a background for understanding the fundamental relationships between zooplankton and hydrographical parameters. Many concepts of this research may be extended into fishery biology, biological control, public health, ecotoxicology, pollution monitor, pollution control, species conservation and ecological bioindicators. The scope of this study can be also extended/extrapolated for mass culture of zooplankton and use in aqua hatcheries.

1.4. **OBJECTIVES OF THE PRESENT STUDY**

In the present study detailed investigations have been taken up on various aspects of freshwater ecosystem in the four lakes of Mysore city such as:

2. Comparative study of water quality parameters and WQI of four lakes
3. Diversity (qualitative) and density (quantitative) study of zooplankton.
4. Seasonal fluctuations of zooplankton.
5. Interrelation between water quality and zooplankton distribution.
6. Comparative study of zooplankton dynamics in the four lakes.
7. Application of suitable ecological indices to evaluate the pollution level in these lakes.
8. *Effect of some selected heavy metals on the distribution of zooplankton.*
9. Statistical analysis and model building
Fig-1.1: Map of Mysore district with lakes of this study
1.5. STUDY LOCATIONS

The emergence of industrial revolution encouraged the water pollution. The water quality of ponds, lakes, rivers, streams and oceans deteriorated severely due to the influx of atmospheric gases, industrial effluents, municipal sewage, agricultural runoff and decomposed biotic components.

Mysore is a famous tourist center in India and has many small and large lakes. These lakes served as a source of domestic water supply to nearby locality. A survey was conducted to select four lakes namely Kamana lake, Karanji lake, Kukkarahally lake and Dalvoi lake for the study (Fig 1.1) These lakes differ in size, shape, depth, degree of pollution, Physico-Chemical nature, diversity and abundance of biotic components.

1.6. REVIEW OF LITERATURE

It is well known that physical, chemical and biological characteristics of water in any locality influence the composition of flora and fauna. A correct understanding of any biological system could be achieved only if the physical and chemical aspects of the environment are properly understood. Although all the characteristics of freshwater have effect on the biological systems, many of them are subtle and hence not clearly documented. Thus, it is customary approach on the part of researchers to select a few important parameters, which have been proved to have direct influence on freshwater organisms.

A systematic and in-depth study of various hydrographic parameters and zooplankton ecology is found to be most important and inevitable in the assessment of fishery potentiality and human utility of freshwater rivers, ponds and lakes. Several limnologists were and are engaged in studying these ecosystems to understand the various Physico-Chemical processes governing biological production.

1.6.1. HYDROGRAPHY

A review of the previous literature reveals that a good deal of attention has been paid to the Physico-Chemical studies of freshwater in various countries. A number of researchers in the earlier part of the nineteenth century published data on

1.6.2. WATER QUALITY INDEX

Quality of water is of vital concern for the mankind since it is directly linked with human welfare. Growing population, Industrial proliferation, Urbanization, increasing living standards and wide sphere of human activities exert heavy pressure on our vast and limited water resources and its effect must be studied thoroughly. Since water pollution of a growing city is always in the rising trend, the impact has to be studied. Water is said to be polluted, when there is change in its quality and composition, which becomes less suitable or harmful for drinking, domestic and agricultural purposes. Accurate and timely information on the quality of water is necessary to frame a sound policy and to implement the water quality improvement programmes efficiently.

One of the most effective ways to communicate the information on water quality trends is by making use of water quality index (WQI). Physico-Chemical analysis of water will give us a complete picture of its physical and chemical constituents and certain numerical values but estimating exact quality of water, an indexing system has been developed, known as “Water Quality Index”, which gives us an idea of quality of water of a whole system. Water quality index was developed for various water uses like domestic water supply, irrigation and recreation, using different methods by many researchers. In the formulation of water quality index, the importance of various water quality parameters depend on the intended use of water. In the present study, the water quality parameters are studied from the point of human consumption. There are three steps in the development of an index system. They are

1. Selecting water quality characteristics. 2. Establishing a rating scale for each parameter. 3. Giving weightage to each parameter.
1. **Selecting water quality characteristics**: Water quality characteristics are found by measuring the water quality standards such as physical, chemical and biological water characteristics. Some of these parameters may be important for a particular purpose of use. It is not necessary that the parameter is equally important for another use. For domestic water supply pH, dissolved oxygen, total dissolved oxygen, total hardness, alkalinity, biological oxygen demand, chloride, calcium and magnesium are considered as important water quality parameters to formulate water quality index.

2. **Establishing a rating scale for each parameter**: Rating scale has been developed based on expert’s opinion in such a way that, each characteristic can be assigned a value depending on its water quality conditions. The rating 100 indicates the best water condition and zero shows the worst condition.

3. **Giving weightage to each parameter**: Relative importance of weightage of different parameters is developed based on Delphi method. The weightages of parameters are assigned by providing a numerical value between one and ten. One represents the important parameter and ten shows the lowest importance. Based on the opinion survey, nine parameters are identified as important parameters for domestic use of water (Harkins, 1974; Tiwari et al., 1986; Tiwari and Ali, 1988; Mohanta and Patra, 2000 and Venkatasubramani et al., 2005).

Mohanta and Patra (2000) conducted studies on the water quality index of river Sanamachhakandana at Keonjargarh of Orissa in India. In this study, the quality of water was assessed by testing various Physico-Chemical parameters such as pH, total alkalinity, total hardness, chloride, calcium, magnesium, total solids, dissolved oxygen and biochemical oxygen demand contents. The mean value of water quality parameters was considered for the computation of water quality index. The recorded results showed that during summer the river water was more affected than winter and rainy seasons. So water quality index provided information about the pollution load. Pradhan et al. (2001) investigated the water quality index for the ground water around phosphate fertilizer plant. Chatterjee et al., (2002) determined the water quality index of a degraded river in Asanol industrial area in West Bengal. Mandoli et al., (2002) evaluated the water quality index of Ganga sagar pond in Jabalpur (M.P).

Sinha et al., (2004) published a research paper on water quality index of Ram Ganga river water at Moradabad and the study revealed that the river water was found to be severely polluted not only in the down stream but also upstream from Moradabad due to the mixing of industrial effluent. Kesharwani et al., (2004) investigated water quality index of Amkhera pond in Jabalpur city in Madhya Pradesh. In this study nine Physico-Chemical parameters such as pH, total alkalinity, chloride, nitrate, phosphate, dissolved oxygen, total solids, biochemical oxygen demand and chemical oxygen demand were monitored and considered for the computation of water quality index. The results revealed that pond water was polluted and not safe for human use. Mariappan et al., (2004) studied the water quality index of ground water in and around Sivakasi town and the results indicated unsuitability of the ground water bodies for human consumption. Bahera et al., (2004) investigated seasonal variations in the water quality index for Vani Vihar lake in Bhubaneshwar. From the results, it appears that water quality of lake was not suitable for designated use and seasonal variation indicated that the quality of water was highly polluted during summer and least during winter season. Mohanty (2004) published a paper on water quality index of four religious
ponds in the temple city of Bhubaneshwar. The study revealed that all these ponds became most polluted in the month of July and least in the month of April. The water quality of these ponds was deteriorated severely and the water was unfit for drinking purpose. Venkatasubramani et al., (2005) studied the ground water quality index for Coimbatore east zone. Mariappan et al., (2005) reported about water quality index and Physico-Chemical characteristics of ground water in and around Thanjavur town. Padmanabha and Belagali (2005b) published a research paper on the comparative study of water quality index in the four lakes of Mysore. According to this study, Dalvoi lake recorded highest Water Quality Index followed by Kukkarahally lake, Karanji lake and Kamana lake recorded lowest WQI.

1.6.3. ZOOPLANKTON

Zooplankton constitute important microscopic organisms occurring abundantly in all types of aquatic habitats. They play a vital role in the energy transfer of aquatic ecosystem. Due to their food value for many fishes and shrimps, these organisms are actively investigated worldwide. There are many detailed reports on the taxonomy and distribution of zooplankton of a particular type of aquatic system such as freshwater, estuarine or marine. Some times, these groups are reported with regard to specific habitats such as ponds, lakes, and rivers or in relation to seasonality or physico-chemical factors. Knowledge of their abundance, composition and seasonal variation, therefore is an essential prerequisite for any successful aquaculture programme.

Zooplankton are good indicators of changes in water quality because these are strongly affected by environmental conditions and responds quickly to changes in environmental quality. Among zooplankton, rotifers and cladocerans are apparently most sensitive indicators of the water quality. Following the changes in the environment, well marked changes occur in the plankton populations in different seasons. Individuals of the same species may develop different structures, e.g. spines and processes, in different seasons to cope with the changed environment. For example, in Brachionus (a rotifer) five different forms were
reported from the Punjab waters during different seasons (Battish, 1968). The helmet of Daphnia species is a very well known example of this kind. Such seasonal changes occurring in the body form of a zooplankter is called ‘Cyclomorphosis’.

Most of the lentic members of the zooplankton, e.g. rotifers, notostracans and cladocerans develop special types of eggs known as ‘resting eggs’ which can tide over the unfavorable conditions. Besides, for the efficient utilization of their environment, to fully cope with it and to escape predation, zooplankton have evolved very interesting phenomena, such as diurnal migration, seasonal population fluctuation, cyclomorphosis and reproductive strategies. These aspects were discussed in detail by Welch (1952) and Edmondson (1959). Rotifers were first used as indicators of aquatic pollution by Kolkwitz and Marsson (1902, 1909). Sladecek (1983) published detailed account of rotifers as indicators of water quality. It deals with various methods and indices used for such purposes. These indices developed in one part of the world are not directly applicable elsewhere. Even within the European continent the same species occurring in different countries show different environmental indication (Pejler, 1957, 1965 & 1981). The fact is that the distributional data of a species heavily depend on precise taxonomic information. Unfortunately the taxonomic problems of this zooplanktonic group were not clearly resolved within several genera and species. What is emerging recently is that, among cladocera and rotifers, there are infact species groups and such species will ultimately be divided into smaller units. Viewed in this context, what we find as differences in bioindication of same species is actually a taxonomic difference. It is likely that at times, even conspecific populations from different geographical regions may have genetic differences.

Anderson (1889) explained in detail on Indian rotifers. Ahlstrom (1940) reported about the rotiferan genera Brachionus and Platyas from California. Sewell (1947) explained about the free-swimming copepoda. Berzins (1949) classified the tropic status of the water bodies according to the type of rotifers present. Das and
Srivastava (1956 (a) & (b)) conducted quantitative studies on freshwater plankton of fish tank in Lucknow. Pejler (1957) characterized the rotifers according to the tropic status of the water bodies. Edmondson (1957 & 1959) explained in detail on zooplankton. Beach (1960) studied the planktonic rotifers of the Oquenoc river system in the Presque isle country in Michigan. George (1961 & 1966) made ecological observation on the Physico-Chemical nature of water and rotifers of certain shallow ponds of Delhi.

and Asthana (1986) studied water quality and phytoplankton population in small polluted aquatic systems. Shinde and Samant (1986) monitored change in the plankton diversity as an indicator of water quality in the Panchaganga river system. This study revealed that slight anthropogenic impact was responsible for the change in the diversity of plankton organisms and more diversity at the lower reaches of the river system. Srivastava et al., (1986) studied rotifers as bioindicators and their seasonal distribution in river Ganga. This study revealed the presence of a large number of pollution tolerant species and proved that rotifers are the best bioindicators in consideration of good quality of water or aquatic environment. Day et al., (1987) discussed the ecological role of zooplankton. Hawkins (1987) reported fifty species (35 species of rotifers, 13 species of cladocerans and 2 species of copepoda) of zooplankton from the Solomon dam. Balkhi et al., (1987) analyzed hydrology and zooplankton of Anchar lake in Kashmir. Michael and Sharma (1988) reported on new records of fresh water Cladocerans from Indian waters. This study recorded 25 new species from India. Srivastava et al., (1990) conducted zooplankton studies of Ganga river between Kalakanker (Pratapgarh) and Phaphamau (Allahabad) in U.P. From the study it was concluded that the water quality of river was responsible for qualitative and quantitative variation in zooplankton fluctuations. Huys and Boxshell (1991) published on copepod evolution. Pace et al., (1992) conducted comparative analysis of zooplankton in deactive enviroment of Hudson river. Battish (1992) reported the fresh water zooplankton from India. Role of some environmental factors on the fluctuation of plankton in a lentic pond at Calcutta was reported by Sarkar and Choudhary (1992). Subbamma (1993) conducted studies on plankton of a fishpond in Kolleru lake area of Andhra Pradesh. Kumar (1994) studied periodicity and abundance of rotifers in relation to certain Physico-Chemical characteristics of two ecologically different ponds of Santnal Parganas in Bihar. Dussart and Dufaye (1995) prepared a guide to identify copepoda and other microinvertebrates of the continental waters. Takamura et al. (1995) published about the effect of fish grazing on the zooplankton periodicity. Staggs
(1996) published the role and effects of factors on zooplankton community. Lavens and Sorgeloos (1996) prepared a manual on the production and use of zooplankton as live food for aquaculture. Basu and Dick (1996) studied the factors regulating phytoplankton and zooplankton development in temperate rivers. Marneff et al., (1996) studied the diversity of zooplankton in the lower Meuse river of Belgium. Fourriot et al., (1997) reported on the origin and development of river zooplankton. Dube and Reddy (1998) prepared a training manual on culture of zooplankton as live food organisms for aquahatcheries. Chandrasekhar (1998) studied the diversity of cladocera in the Baroni pond of West Bengal. Bath and Kaur (1998) studied the seasonal distribution and population dynamics of rotifers in Harike reservoir of Punjab. Dhanapathi (2000) published taxonomic notes on Rotifers from India. Dutta and Sharma (2000) studied the ecology of zooplankton of sewage fed Farooq Nagar pond in Jammu. Mrithunjaya and Hosmani (2002) published comparative account of Physico-Chemical parameters, enzymatic activity and plankton population in three water bodies of Mysore city. Das and Ghosh (2002) published a research paper on mathematical modeling approach for pollutant transport in lakes, reservoirs and river. Chandrashekhar and Chaterjee (2002) reported fifteen species of cladocera, which belong to eleven genera and four families from Malda district in West Bengal. Eswari and Bai (2003) reported on zooplankton diversity in Tamiraparani river basin. As per this study, rotifers were the dominant group represented by 16 species followed by copepoda with 11 species but cladocerans and ostracods recorded poorly throughout the river basin. Chandrasekhar (2004) studied the cladoceran composition of Adra lake in West Bengal. During the study period, the cladocerans were dominant over other zooplankton groups. Out of 13 cladoceran species reported, Diaphanosoma excisum and Macrothrix spinosa were dominant followed by Moina brachiata and Bosmina longistri. Kumar and Prasad (2004) studied the resting egg diversity and zooplankton emergence patterns from soil egg bank of dried water bodies. As per this study, the zooplankton abundance in ephemeral pools was higher than the permanent ponds. The number of species recorded in the egg bank was more than
those present in the water columns of the temporary pools. Sunkad (2004) reported on diversity of zooplankton in Rakasakoppa reservoir of Belgaum in Karnataka. This study recorded total 27 species of zooplankton. Rotifers were the dominant group with 15 species followed by 7 species of cladocera, 4 species of copepoda and 1 species of ostracoda. A statistical analysis of data revealed that zooplanktonic groups were positively or negatively correlated with some physical, chemical and biological parameters. Babu et al. (2004) reported on cladocera of Periyar lake and adjacent sites of Thekkady in Kerala. According to this study, 23 species of cladocerans were documented. Berde and Pai (2004) reported on the seasonal fluctuations in the rotifera community of Someshwar temple tank of Pannhalgarh hillport, Kolhapur district in Maharastra. Shukla et al., (2004) mentioned that phytoplankton, zooplankton, fish and various other flora and fauna were used as ideal tools for pollution studies and for biological monitoring. Chavan et al., (2004) published the abundance of rotifers in Manjara project water reservoir. The study revealed that rotifer population showed significant correlation with different Physico-Chemical parameters like water temperature, pH, dissolved oxygen, alkalinity, hardness etc. Altaff (2004) prepared a manual on the taxonomy and culture of zooplankton. Sheeba and Ramanujan (2005) reported the quantitative and qualitative study of zooplankton in Ithikkara river of Kerala. In this study, they reported 13 species of rotifers, 14 species of crustaceans (especially cladocera, copepoda and ostracods) and 5 species of meroplankton. According to this study, copepods were the dominant group followed by rotifers. Jeelani et al. (2004 & 2005) studied species diversity and seasonal distribution of rotifers in the Anchar lake and Dal lake of Kashmir. They reported 26 species of rotifers and also studied the role of abiotic factors on the distribution of rotifers. Biochemical composition of some marine copepods was estimated by Prabu et al., (2005). Manzer et al., (2005) reported on a comparative study of population kinetics and seasonal fluctuations of zooplankton in two diverse ponds of north Bihar. According to this study, rotifers were found to be dominant over the other groups throughout the year. Abundance of zooplanktonic fauna was recorded
higher during summer than winter and rainy seasons. Padmanabha and Belagali (2006, b) reported the comparative study on population dynamics of rotifers and the role of water quality index on the rotiferan periodicity in the lakes of Mysore. Indra and Ramanibai (2006) reported on the zooplankton diversity in the Chennai coast of Tamilnadu.

1.6.4. HEAVY METALS ANALYSIS IN AQUATIC ECOSYSTEMS

Ecology is concerned with the quantitative interactions in complex systems and resources, which can be evaluated in species, population and community level interactions of various Physico-Chemical components of an ecosystem. But increasing human population produces a strain on these resources and the availability of energy as well as materials thus depletes the diversity and abundance of smallest protozoan to the largest blue whale. It has been noted that heavy metal concentration has correlation with various ecological parameters of microbial, meso faunal and meiofaunal communities (Ellis et al., 2001). Heavy metals constitute a heterogenous group of elements widely varied in their chemical properties and biological functions. Heavy metals are kept under environmental pollutant category due to their toxic effects on plants, animals and human beings. Heavy metals occur in soil and aquatic ecosystems and relatively smaller proportion in atmosphere as particulate or vapour. Heavy metal toxicity to plants and animals vary with the species, specific metal concentration and chemical speciation. Many heavy metals are essential trace nutrients of animals and human being (Wintz et al., 2002). Heavy metals like copper and zinc serve either as cofactors and activators of enzyme reactions. Some of the heavy metals such as cadmium, mercury, arsenic etc., are strongly poisonous to metal sensitive enzymes, resulting in the growth inhibition and death of organisms. An alternative classification of metals based on their coordination chemistry, categorizes heavy metals as class B metals that come under non-essential trace elements such as mercury, silver, lead and nickel (Nieboer and Richardson, 1980), which are highly toxic agents. These heavy metals are persistent and bioaccumulative and do not readily breakdown in the environment or not easily metabolized. Such metals
accumulate in ecological food chain through uptake at primary producer level and then through consumption at consumer levels, finally leading to biomagnification. Heavy metals are also potent carcinogens. Cadmium intake leads to itai-itai disease and mercury intake leads to minimata disease. Other metals such as arsenic, cause poisoning if contamination in drinking water. Excessive levels of ionic metals in surface water have detrimental health risks to humans and pose environmental stress.

Heavy metals enter the human body either through inhalation or ingestion. However urbanization, traffic, industrial, agricultural, waste incineration and mining activities have significantly contributed to the entry of heavy metals through inhalation into human body. Through food and water also these metal ions are ingested into human body. Heavy metal pollution can originate from both natural and anthropogenic sources. Activities such as mining, smelting operations and agriculture have contaminated water bodies with heavy metals such as Cadmium, Copper and Zinc (Herawati et al., 2000). Heavy metals originate within the Earth’s crust; hence their natural occurrence in soil is simply a product of weathering product. In aquatic system, whole plants and animals are exposed to the heavy metals. Heavy metals are readily mobile in environment and accumulate in flora and fauna (Bergren, 1992; Edwards et al., 1992, Eriksson, 1989, 1990a, 1990b; Leita and Nobili, 1991; Lindberg and Turner, 1988; Sanka and Dobzal, 1992; Severson et al., 1992; Neilsen et al., 1991; Obbard and Jones, 1993). Phytoplankton are the primary producers in the aquatic ecosystem and heavy metals accumulated in these primary producers. Zooplankton are the primary consumers, which graze on phytoplankton. Zooplankton become live food to fishes, human beings consume fishes. So, heavy metals from aquatic system get access to the human body wherein biomagnification takes place, which leads to several detrimental effects on human health.

**Zinc (Zn^{2+})**: The recommended daily dietary allowed intake of Zinc is 15 mg for adults and 20-25 mg for pregnant and lactating woman (NRC-NAS, 1980). Acute Zinc toxicity in human beings leads to vomiting, dehydration, drowsiness,
lethargy, electrolyte imbalance, abdominal pain, nausea, lack of muscular coordination and renal failure (Prasad and Oberlas, 1976). Chronic dose of Zinc increases the risk of developing anaemia, damage to the pancreas, lowers the HDL cholesterol level and raises LDL cholesterol level and possibly enhances the symptoms of Alzheimer’s disease (Athar and Vohora, 1995)

**Lead (Pb$$^{2+}$$):** Children are particularly susceptible to lead exposure due to high gastrointestinal uptake and permeable to blood brain barrier leading to neurotoxic effects even at low levels of exposure (Jarup, 2003). The major exposure pathway of inorganic lead is via ingestion and absorption through the gastrointestinal tract, respiratory tract and inhalation. Kidney and liver are considered to be potential targets of lead toxicity before storage in bones (Athar and Vohora, 1995). Lead has the potential to cause variety of biological effects such as decreased haemoglobin synthesis, impairment of neurobehavioural and psychological functions, peripheral neuropathy, indirect effect on heart, renal tubular damage and reproductive problems (Brown and Kadama, 1986).

**Nickel (Ni$$^{2+}$$):** Daily intake of nickel through food is approximately 300 µg (WHO 1987). Nickel induces embryo toxicity (Teratogenic effect), nephrotoxic effects, allergic reactions and contact dermatitis (EPA, 2002). Nickel is a potential carcinogen for lung and may cause skin allergies, lung fibrosis and cancer of respiratory tract in occupationally exposed populations (Kasprazak et al., 2003).

**Cobalt (Co$$^{2+}$$):** Cobalt is most widely distributed heavy metal in aquatic environment. According to Gillies (1978), highest permissible level of Cobalt in drinking water is 1.0 ppm. He also stated that, Cobalt could be beneficial or nontoxic in concentration upto 7 µg/ day. In excess, it can cause polycythaemia, respiratory ailment, cardiomyopathy and thyroid abnormalities.

Boudouin and Scopa (1974) reported the acute toxicity of various metals to fresh water zooplankton. Heavy metal pollution in some natural water bodies of Jharkand was reported by Singh et al., (2003). Impact of sewage containing domestic wastes and heavy metals on the quality of Varuna river water was studied by Agarwal et al., (2004). Hoo et al., (2004) studied the level of
selected heavy metals at residential area nearby Labu river in Malaysia. Sinha and Chatterjee (2004) studied the effect of some heavy metals (Zinc, Cobalt, Nickel and Lead) on the diversity and dominance of moss dwelling testacids. Pandey et al., (2004) reported the distribution of heavy metals in the wastewater of river Pandu at Kanpur. This study revealed that, the enrichment of the heavy metals caused bioaccumulation and biomagnification in the edible components produced in the wastewater. Sinha (2004) evaluated some heavy metals in waters of Sai river at Rae Bareli during pre monsoon and monsoon period. Heavy metal toxicity and bioaccumulation in flora and fauna affects the metabolic processes which was reported by Patnaik et al., (2004). Bhatkar et al., (2004) published the work on heavy metal induced biochemical alterations in the fresh water fish Labeo rohita. Effects of chlorides of Chromium, Nickel and Zinc on melanophores was reported by Bhatkar (2004). Piska et al., (2004) reported on ground water quality of Jeedimetla IDA in Hyderabad. Accumulation of heavy metals in some species of Lichens in south Tamilnadu was reported by Uijily and Kumaraguru (2004). In this study, the accumulation of heavy metals was used as bioindicators in pollution monitoring. Hoo et al., (2004) evaluated the level of selected heavy metals at residential area nearby Labu river system of Malaysia. Sinha and Chatterjee (2004) studied the effect of some heavy metals on the diversity and dominance of moss dwelling testacids using some community parameters. Sharma and Agarwal (2005) reported the biochemical effects of heavy metals on human health. Toxicity of various concentrations of heavy metals such as Zinc, Cadmium, Cobalt, Manganese, Nickel, Chromium and Iron on microorganisms was studied by Agarwal et al., (2005). This study suggested that, microorganisms could be used for bioremediation of heavy metal pollution environments. Samanta et al., (2005) published the work on heavy metals in water of Hooghly and Haldi river and their impact on fish. From the study, it appeared that sub lethal pollution of heavy metals was responsible for histopathological lesion. Even though it did not cause death, but was detrimental to fish health. The heavy metal concentrations also created stress on other aquatic organisms. Gupta and Ray (2005) reported that
bioaccumulation of Cd$^{2+}$, Zn$^{2+}$, Cu$^{2+}$ and Cr$^{3+}$ in plants reduces chlorophyll content. Padmanabha and Belagali (2006 a) reported on the effects of heavy metals on rotifers and statistical models for the rotifers in the lakes of Mysore city.

1.6.5. BIODIVERSITY BASED INDICES OF WATER QUALITY

In pollution stressed aquatic environment, changes in the community structure are reflected in the diversity pattern of the component species. These changes can be quantified numerically to arrive at diversity indices, which are useful in water quality monitoring. More number of species are present in the unpolluted or clean water bodies whereas less number of species are able to tolerate pollution load in the polluted aquatic environment. Changes in the biotic community can be best described through a ‘diversity index’, which is used to describe the community in terms of both density and the number of different types of organisms.

Range of diversity index in benthic macroinvertebrates population was reported by Wilhm (1970). Copeland and Chil (1971) published a research paper on species diversity and water quality in Glovestone Bay, Texas. Various indices, which have been developed for describing structure of both plant and animal communities (Southwood 1978) are now extensively used in measuring stress on them, cast upon by overexploitation and pollution (Kumar, 1994; Vishalakshi, 1995; Kumar et al., 1998; Ganihar, 1998; Prasad and Rajagopal, 1998; Raizada et al., 1998 and Nautiyal et al., 2000). Siddiqui et al., (1986) calculated species diversity, species evenness and species richness for biomonitoring the fresh water ponds at Darbhanga in north Bihar of India. Chaurasia and Agarwal (2004) applied biodiversity indices to evaluate water quality and suggested that polluted water always supports low diversified flora and fauna while clean water supports high community diversity. Sharma et al., (2005) published about the diversity indices for a comparative assessment of pollution degree in lentic and lotic ecosystems.

In the present study, we have examined the applicability of diversity indices with a view to select the most appropriate ones to assess the degree of pollution in the lakes of Mysore city.
1.7. SEQUENCE OF THE THESIS

The thesis is conveniently divided into 10 Chapters.

Chapter I: INTRODUCTION – This involves significance of zooplankton study, scope and objectives of the present work, brief details of the study locations and literature survey.

Chapter II: ENVIRONMENTAL SCENARIO - deals with the general topography & climate of Mysore district and Mysore city

Chapter III: MATERIALS AND METHODS - consists of analytical methods, sampling and preservation of water samples, the instruments used for the study, collection and preservation of zooplankton, methods of data interpretation etc.,

Chapter IV: RESULTS AND DISCUSSION ON HYDROGRAPHY - deals on the Physico-Chemical nature of lakes water. Seasonal, annual and biannual fluctuations, comparative study of hydrography and hydrogeochemistry in the four lakes of Mysore city.

Chapter V: WATER QUALITY INDEX – involves the computation, results, discussion and comparison of Water Quality Index.

Chapter VI: PERIODICITY OF ZOOPLANKTON – involves distribution, abundance and diversity of zooplankton in the lakes of Mysore city.

Chapter VII: DIVERSITY INDICES TO ASSESS AQUATIC POLLUTION - In this Chapter, ecological indices for the assessment of aquatic pollution are applied to know the suitability.

Chapter VIII: HEAVY METALS -vs- ZOOPLANKTON – deals about an impact of heavy metals on the population dynamics of zooplankton – a model approach.

Chapter IX: STATISTICAL ANALYSIS - comprises Statistical Tools - Cluster analysis and correlation analysis.

Chapter X: SUMMARY AND CONCLUSION – summarises and concludes about the study “Comparative account of zooplankton ecology in the lakes of Mysore”.

29
Summary

1. Water is one of the important natural resources and essential for the existence of life.
2. The pollution of lakes in the developing cities is always in the rising trend due to anthropogenic activities.
3. Water quality can be assessed either monitoring hydrographical profile or inhabiting biota.
4. Mysore city is one of the famous tourist centers in south India and it has several small and medium lakes.
5. For this study, four lakes namely Kamana lake, Karanji lake, Kukkarahally and Dalvoi lake were selected in the Mysore city, to evaluate hydrographical profile and it’s role on the zooplankton (rotifera, cladocera, copepoda and ostracoda) periodicity.
6. The scope of this study is vast and significant. The principles of this investigation may be extrapolated to fishery biology, ecotoxicology, pollution monitor and public health etc.
7. The Principal objective of the study
   a. Comparative study of water quality parameters and water quality index of four lakes
   b. Diversity (qualitative) and density (quantitative) study of zooplankton.
   c. Seasonal fluctuations of zooplankton.
   d. Interrelation between water quality and zooplankton distribution.
   e. Comparative study of zooplankton periodicity in the four lakes of Mysore city.
   f. Application of suitable ecological indices to evaluate the pollution level in these lakes.
   g. Effect of some selected heavy metals on the distribution of zooplankton.
   h. Statistical analysis and model building.
8. Previous literature review was carried out on following aspects.
   a. Hydrographical parameters.
   b. Zooplankton.
   c. Water quality index.
   d. Heavy metals in aquatic ecosystems.
   e. Biodiversity indices.