2. REVIEW OF LITERATURE

Water covers almost two-third of earth’s surface out of which only 3% is available for man in the form of fresh water. About 99% of fresh water is either frozen in glaciers and pack ice or is buried in aquifers. The remaining is found in lakes, ponds, rivers, and streams. Freshwater comprises 29.9 percent of water resources to all living organisms including man. Only 0.26 percent of total amount of freshwater on the earth is concentrated in lakes, reservoirs and rivers (Shiklomanov, 2000). India with 16 percent of the world’s population and 2.45 percent of land resources has roughly four percent of the world’s freshwater resources (Ranjit et al., 2003). The freshwater ecosystem is dynamic in nature of physical and chemical parameters due to environmental and anthropogenic pressure (Khatri, 1985; Dagaonkar and Saksena, 1992). The seasonal changes highly affect the freshwater system by increasing toxicity (Nasar and Munshi, 1972). The freshwater is harvested for drinking purposes and is also used for agricultural and domestic purposes. Aquaculture is also carried out in fresh waters (Suresh, 1992).

Lakes and ponds are depressions containing standing water. They may vary from small ponds of less than 0.4 hectares to large seas of about thousand kms. According to Rodda, (1985) the minimum area of a lake is considered to be 0.01 Km² at mean water level. Jhingran, (1983) defines lakes as naturally formed hollows or depressions on the surface of the earth, which get filled with water and are of diverse geological origin. Hutchinson, (1957) stated that the
lakes can be featured as permanent features of landscapes on the scale of years of human life spans, but they are geologically transitory, they form, mature and die quietly and imperceptibly.

Water quality, habitat structure, flow regime, energy source and biotic interactions are the major environmental factors that determine water resource integrity (Karr, 1991). The water quality of rivers and lakes change with the geographical area and seasons even when there is no pollution. The physical and chemical attributes of water are the critical components of a water resource. They include temperature, dissolved oxygen, pH, hardness, turbidity, concentration of soluble and insoluble organic and inorganic substances, alkalinity, nutrients, heavy metals, and an array of toxic substances which may have simple chemical properties or complex dynamics, depending upon other constituents in the geological strata, soils, and land use in the region (EPA, 1990). In aquatic ecosystems, the physico-chemical characteristics of water have direct influence on the type and distribution of aquatic biota. The extent of water pollution is generally expressed by the parameters such as pH, alkalinity, BOD, COD, etc.

The availability of oxygen is one of the most important abiotic factors that could affect the survival of individuals both in air and water and treated as a prime ecological parameter for the existence of aquatic life. Dissolved oxygen (DO) is important in the production of and support of aquatic life. It determines the nature of an entire aquatic ecosystem. Water body receives the
supplies of oxygen mainly from two sources directly from atmosphere and during the process of photosynthetic activity of chlorophyll bearing plants. The respiratory activities of the flora and fauna and the decomposition of organic matter of lake are the main reasons for the depletion of oxygen in still water. Dissolved oxygen value is higher in those lakes where there was good aquatic life (Vijayan, 1991). Sreenivasan, (1972) reported that dissolved oxygen in water is often attributed to the fact that the oxygen is dissolved more during the period of active photosynthesis.

Temperature is another important factor in aquatic systems as it facilitates dissolution of oxygen from air into water. The high temperature and addition of sewage and other wastes might be responsible for low value of DO (Kumar, 1996b). An increase in water temperature of a lake can accelerate eutrophication and the ageing processes and may damage the sensitive ecosystem.

Natural water has slightly alkaline nature because of the presence of bicarbonate and carbonate of alkali and alkaline earth metals (Jamil, 1991). According to Spence, (1967) the pH of a typical eutrophic lake ranges from 7.7 to 9.6. Total alkalinity may be used as a tool for measurement of productivity. pH regulates most of the biological processes and biochemical reactions. Sculthorpe, (1967) has reported that pH, free carbon dioxide and ammonia are critical factors in the survival of aquatic plants and animals. Factors like photosynthesis, respiratory activity, temperature, exposure to air, disposal of industries wastes, etc bring out changes in the pH (Saxena, 1987). The
degradation of plants, animals and organic waste might also be one of the reasons for increase in a carbonate and bicarbonate, resulting in an increase in alkalinity value (Chaurasia and Pandey, 2007).

Turbidity in natural water is caused by clay, silt, organic matter, phytoplankton and other microscopic organisms. Turbidity in lake water restricts light penetration for photosynthesis. According to Praveen et al., (2008) turbidity of Pushkar lake was higher during Pushkar fair due to higher concentration of suspended solid load coming through anthropogenic activities (mass bathing, offering flowers, garlands and other religious matters).

Conductivity is a measure of the capability of water to transmit electric current and is also a tool to assess the purity of water (Murugeshan et al., 2006). Water can conduct electricity because of the salts that are dissolved in it. Conductivity also depends on the temperature of water. It increases with increase in temperature. Conductivity is an indirect measure of the saltiness of the water. Fish and other organisms that live in freshwater cannot tolerate large increases in the saltiness of the water because they will not be able to keep water in their bodies. The conductivity of water naturally increases during warmer conditions due to an increased rate of evaporation. This could result in stress to fish and other animals that live in water. Pollution increases conductivity of lakes and rivers because industrial and human wastewaters often have high salt content. Ahluwalia, (1999) reported that a high level of conductivity reflects the pollution status as well as tropic levels of the aquatic body.
Total suspended solids (TSS) and total dissolved solids (TDS) are products of run-off. They have adverse effects on dissolved oxygen and carbon-di-oxide. They affect the physiology and metabolism of fish. TSS are solid particles, both organic and inorganic, that are suspended in water. The major sources of TSS include silt, plankton, erosion from urban run-off and agricultural land, algal growth and waste water discharges. High concentration of TSS reduces the light availability in deeper regions of lake and thus adversely affects photosynthetic activity and the productivity of lake. These particles clog fish gills, decrease resistance to diseases and prevent egg and larval development by covering them. TDS is increased due to the presence of ions of Potassium, Sodium, and chlorides. It indicates hard water. According to Lawson, (2011) there is a positive correlation between TSS and TDS and an increase in these parameters indicate an increase in salt concentration thereby increasing the electric conductivity of water.

Phosphates, nitrates, and sulphates are the important nutrients available in a lake. Phosphorous is necessary for plant and animal growth. It is an important constituent of all the fertilizers. Phosphates stimulate the growth of plankton and water plants that provide food for fish. This increases the fish population and improves the water quality. Sulphate is an abundant ion in the earth’s crust and its concentration in water can range from a few milligrams to several thousand milligrams per litre. Industrial wastes and mine drainage may contain high concentrations of sulphate. Sulphate also results from the breakdown of sulphur-containing organic compounds. Nitrates are produced
naturally as part of the nitrogen cycle, when a bacteria 'production line' breaks
down toxic ammonia wastes first into nitrite, and then into nitrate. Nitrates
stimulate the growth of plankton and water weeds that provide food for fish. It
is a major ingredient of farm fertilizer and is necessary for crop production.
When it rains, varying amounts of nitrates wash from farmland into nearby
waterways. An increase in nutrients, particularly nitrates and phosphates are
known to cause algal blooms.

Natural resources have been used carelessly which in turn violate the
matter and energy cycle. Nemerow, (1974) stated that discharge of waste water
effluents could cause serious threat to the environment and natural water
bodies. These waste waters contribute pollution to the receiving water bodies.
The adverse effects of human activities on the aquatic environment are of
growing concern and are one of the most challenging threats for mankind.
(Malins and Ostrander, 1991; Bucke, 1993). Though changes in physical
factors (viz. water temperature, oxygen levels, hydrogen ion concentration and
salinity) and biological stressors (viz. food availability and pathogens) can
produce effects upon resident aquatic species, chemical pollutants produce the
most devastating environmental changes that impact aquatic animal health.

Agricultural, industrial and domestic effluents generally contain a wide
variety of organic and inorganic pollutants, such as solvents, oils, heavy metals,
pesticides, fertilizers and suspended solids (Pandey et al., 2003). These are
invariably discharged into nearby water bodies, without proper treatment. Such
contaminants change water quality and may cause many problems to fish, such
as diseases and structural alterations (Chang et al., 1998). Humans use these natural resources as food and water supplies, and are therefore exposed to these pollutants. (Evans et al., 2000).

Chemical pollution is one of the most pronounced consequences of industrialization and of the intensified application of the uses of natural resources in agriculture, forestry, and mining (Pritchard, 1993). Regardless of the source or original intended use, portions of chemicals registered for use in industry and agriculture are released either deliberately or unintentionally into the aquatic environment. A number of processes can lead to the redistribution of these chemicals and their eventual deposition in the aquatic systems. The increased influx of xenobiotics into the aquatic environment has contributed to major damage of this ecosystem. Changes in the physical chemistry of water include acidity, conductivity, temperature, and excessive nutrient loading (eutrophication). The adverse effects of aquatic pollution ranges from grossly evident fish kills that are being reported in lakes and tanks quite regularly, eutrophication and drying of water bodies in urban areas as well as to the less-easily detected sublethal changes in aquatic organisms. Stressors such as suspended solids, metals, organic chemicals, and pathogens threaten aquatic life, by impairment of biochemical, physiological and immunological processes.

Many toxic compounds affect organisms in nature at the same time, each of them having a specific effect on physical and chemical processes that influence an organism’s condition and reactions. Therefore, in order to
maintain the quality of food it is important to regularly monitor and evaluate the pollution levels in fish as well as in water reservoirs (Staniskiene et al., 2006). Knowledge of acute toxicity of a xenobiotic often can be very helpful in predicting and preventing acute damage to aquatic life in receiving waters as well as in regulating toxic waste discharges. According to Mason, (1991) the adverse effect of human activities on the aquatic environment can be seen in the form of sub lethal pollution which results in chronic stress conditions that have negative effect on aquatic life. Biological and biochemical effects of pollutants on inhabiting fish species include habitat alteration, developmental and structural anomalies, altered gene expression and enzyme induction, histopathological and neoplastic changes, reproductive modifications, immune dysfunction and also changes in eating pattern, behavioral modifications and neurodegenerative alterations. Discharge of effluents into fresh water system deplete the dissolved oxygen content and by interfering with respiratory metabolism cause heavy mortality (Quasim and Siddque, 1960; David and Ray, 1966; Venkataraman, 1966).

Lakes play a major role in urbanized areas - they capture rainwater efficiently and facilitate ground water recharge. This is an absolute necessity in a fast growing city like Bangalore. Well maintained lakes can augment the water supply in the city. Lakes are the lung spaces of a city and climate moderators adding to thermal ambience. Lakes have a direct bearing on the quality of life in urban areas. The necessity of lake preservation is more pronounced in the context of urbanization, when city takes more and more
villages into its fold. Urbanization leads to conversion of agricultural lands for non-agricultural purpose. The highly polluted and congested environment of the city will deteriorate further if the existing lakes are misused. Preservation and restoration of lakes have gained a lot of momentum in recent years. Wetlands are the starting point for integrated water management strategies because they are the source of fresh water, maintain the health of the water course and water bodies, have the capacity to supply water to meet the human needs and are a key to future water security. Pollution of fresh water bodies eventually renders them unfit for human consumption. Water quality of lakes is influenced by factors like salinity intrusion, summer showers, type of pollution, and seasonal fluctuation. Water quality of lakes, and estuaries have been studied by Qasim and Senguptha, (1981); Gopalan et al., (1983); Shankarnarayana et al., (1986); Nair and Thrivikramaji, (1996) and Padma and Periakali, (1999).

Bangalore was once known as “city of lakes”. Most lakes or tanks in the Bangalore region were constructed by Kempe Gowda in 16th century by damming the natural valley systems by constructing bunds. Continuous discharge of domestic sewage and industrial effluents in many areas in the city has posed serious pollution problems. Washing of clothes by dhobis in lakes has also contributed to the contamination. A steep increase in the growth rate of human population and influx from the rural areas and other states have resulted in rapid urbanization leading to the expansion of the city. This has taken a major toll on the wetland ecosystems. Encroachment of lakes, disfiguring the
boundaries of lakes, construction of industries on the lake banks, indiscriminate
disposal of waste into these water bodies and bad management, have threatened
the very existence of many of the valuable and productive wetland habitats in
the city, thereby posing serious threat to the flora and fauna supported by them.
Although there is wide public concern about wise use of wetlands, lack of
knowledge of the ecological conditions of these habitats has caused many
losses. This drastic loss of wetlands and the consequential environmental
changes is one of the critical problems faced by the city today. (Chakrapani,
1989; Chakrapani et al., 1990; Laxman Rao, 1986).

Status of lakes in Bangalore is a direct measure of status management of
anthropogenic activities. Diwakar and Parthasarathy, (1991) conducted study
on trophic status of Yediyur tank in Bangalore city. The study classified the
tank as eutrophic and rich in nutrients, primarily phosphorus and nitrogen. The
inflow of raw sewage and dumping of organic matter into the tank was the
major source of nutrients. The water was unsuitable either for domestic
purposes or farming. The impact of urbanization on Bellandur lake in
Bangalore was studied by Chandrasekhar et al., (2003) and he mentioned that
higher values of alkalinity, BOD and COD and low levels of dissolved oxygen
indicate the polluted nature of the lake. The urbanization of surrounding areas
had led to the discharge of domestic sewage and industrial effluents into the
lake, which has resulted in its present status.

Aquatic animals have been often used as bioassays to monitor water
quality (Crains et al., 1975; Brugs et al., 1977). Toxicological studies with fish
species were introduced in the 1930s for the determination of toxic effects in field and laboratory toxicology investigations, especially for the screening of toxic chemicals, agricultural and industrial effluents and for pollution studies in rivers, lakes and the marine environment (Sprague, 1969). Fresh water fish are important in ecotoxicology because of their importance in ecological and economic terms. In most aquatic environments, fish mostly occupy the top niche of predators. Fish has often been adopted as the ‘sentinal’ organisms for the health of aquatic environment. Since fish respond to toxicants in a similar way as higher vertebrates, they can be used to screen for chemicals that are potentially teratogenic and carcinogenic in humans (El-Shehawi et al., 2007).

When evaluating water pollution with the aid of bioindicators, an understanding of an organism’s reaction to changes in its environment is essential. Changes in quality of water, interactions between individuals and high fish stocking density (Flos et al., 1990; Mazur and Iwamma, 1993) may bring about a wide range of physiological changes in fish. The altered physiological adaptations are however variable and flexible in fish in response to water quality of a large variety of aquatic habitats. Pollutants in aquatic environment may lead to alterations in the concentration or function of a number of different enzyme systems in residing species, including those necessary for oxidative phosphorylation and for mobilization of glycogen reserves (Stegeman and Hahn, 1994). Changes in the enzyme activity are used as indicators of tissue injury, environmental stress or a pathological condition.
Biochemical studies are good parameters which help to study the effect of aquatic pollution on biochemical composition of vital tissues of fish. Aldrige, (1983) suggested that appropriate biochemical parameters could be used effectively as sensitive indicators before the drastic cellular and systematic dysfunction manifest themselves. Analyzing the alterations in the biochemical constituents will be useful in evaluating the toxicity in fish intoxicated with effluents.

Changes in biochemical constituents have been reported in *Catla catla* exposed to Cadmium chloride by Shoba *et al.*, (2007); in *Arias dussumieri* subjected to Dimethonate by Rathod and Shembekar, (2009); in *Channa punctatus* exposed to organophosphate insecticide by Jaroli and Sharma, (2005) and in *Rasbora daniconius*, exposed to paper mill effluent by Pathan *et al.*, (2009).

In recent years, pollution monitoring methods using enzyme inducement or enzyme dispersion in fish or other aquatic organisms have been proposed for studying polluted environment (Verma *et al.*, 1979). Disturbances in metabolism can easily be identified by estimation of enzyme activity (Hunttsoe *et al.*, 2007). Phosphatases are good indicators of stress condition in the biological systems (Gupta *et al.*, 1975; Verma *et al.*, 1980). Balasubramanian *et al.*, (1984) and various other scientists have reported the presence of phosphatases in body tissues of invertebrates. These enzymes could be used as a good indicator of intoxication because of their sensitivity to metallic salts (Boge *et al.*, 1992). Changes in acid and alkaline phosphatase activities were
observed in *Channa punctatus* exposed to mercuric nitrate (Jeelani and Shaffi, 1989), in *C. punctatus* exposed to fenvalerate (Parthasarathi and Karuppasamy, 1998), *Heteropneustes fossilis* exposed to fenvalerate (Johal et al., 2002) and *Labeo rohita* exposed to domestic sewage (Rajan, 1990).

In living organisms, energy produced by the synthesis of ATP from ADP results in the oxidation of certain precursor compounds such as succinate, malate, lactate etc (Mayes, 1977). SDH is a primary enzyme in the oxidative catabolism of sugars (Lehninger et al., 1993) and as such is used effectively as a marker of mitochondrial abundance and activity to identify any possible physiological disturbance in fish. Reddy et al., (1998); Radhakrishnan et al., (1992); Rajamannar and Manohar, (2000) have reported that artificial exposure of adult or fingerlings of *L. rohita* to lethal and sub lethal concentrations of heavy metals and pesticides resulted in gradual decrease in SDH activity in tissues like gill, liver, muscle and brain of fish over a period of time.

Pollutants that cause hypoxia generally cause suppression of respiratory enzymes and simultaneous stimulation of glycolytic enzymes. According to Szegleton et al., (1995) and Simon et al., (1983) an increase in LDH activity could indicate metabolic changes in the stressed fish, where the catabolism of glycogen and glucose shifts towards the formation of lactate and this can be lethal for the fish. Since LDH forms the centre of delicately balanced equilibrium between catabolism and anabolism of carbohydrates (Everse and Kaplan, 1973) stimulation of LDH activity indicate that pyruate, the end product of glycolysis, was not routed through Kreb’s cycle but through lactic
acid cycle under hypoxic conditions. This leads to the accumulation of lactic acid. Similar observations have been reported by Ghosh, (1987) in liver and muscle of *C. batrachus*.

Untreated wastes of industrial and agricultural origin contain various metallic compounds and these often contaminate natural waters. Metallic compounds enter the aquatic medium through effluents discharged from tanneries, textiles, electroplating, metal finishing, mining, dyeing and printing industries, ceramic and pharmaceutical industries (Azmat and Talat, 2006). Heavy metals are an important group of pollutants in aquatic ecosystems due to their bio-accumulative and non-biodegradable properties. Most heavy metals released into the environment find their way into the aquatic system as a result of direct input, atmospheric deposition and erosion due to rain water. Therefore aquatic animals are often exposed to high levels of heavy metals. These pollutants alter the natural condition of aquatic medium that cause behavioural changes as well as morphological imbalance of aquatic organisms (Yadav *et al.*, 2005).

Heavy metals, unlike organic pollutants, cannot be chemically degraded or biodegraded by microorganisms. Thus, their content has steadily increased in soil and subsequently accumulated in plants, animals, and even in humans (Che *et al.*, 2006). After entering into aquatic environment, metals tend to accumulate in tissues and organs of aquatic organisms. They concentrate in the tissues of aquatic biota and are known to produce cumulative deleterious effects (Cosson, 1994). Jaffer *et al.*, (1988) reported that the amount of
absorption and accumulation depends on ecological, physical, chemical and biological condition and the kind of element and physiology of organisms.

Contamination of fresh water fish with heavy metals is a recognized environmental problem (Staniskiene et al., 2006). Heavy metals in aquatic environment exert a broad spectrum of effects on aquatic organisms, especially in fish species. These effects range from behavioral, ecological and physiological changes which in turn reflect on economically, nutritionally and culturally important fish species. Heavy metals can be bio accumulated by fish, either directly from the surrounding water or by ingestion of food (Patrick and Loutit, 1978; Kumar and Mathur, 1991). Brown et al., (1970) reported that fishes and other organisms have been declining or disappearing in freshwater environments due to metal poisoning. Studies on heavy metal contamination in rivers, lakes, sediments and fish have been a major research area with environmental focus during the last decade and have been carried out by Özmen et al., (2004); Begüm et al., (2005); Fernandes et al., (2008); Ozturk et al., (2008).

Metal ions can penetrate inside the cell, interrupting cellular metabolism and in some cases can enter the nucleus. Metal cations can bind to DNA through ionic and coordinated bonds in a reversible way. The entrance of certain metals into the nucleus can enhance the synthesis of RNA that codes for metallothioneins. Metallothioneins (MT) are peptides found mainly in the cytosol, lysosomes and in the nucleus, low molecular weight peptides, high in
the amino acid cysteine which contains thiol group (-SH). The thiol group enables MTs to bind heavy metals. Metallothioneins can be induced by essential and non-essential metals in aquatic organisms and this induction of MT leads to changes in biochemical processes which can be effectively used as biomarkers of evaluation of pollution (Hamer, 1986).

The mechanisms by which metals exert their toxicity in living organisms is very diverse, especially their involvement in oxidative biochemical reactions through the formation of reactive oxygen species (ROS) (Goyer, 1991). Molecular mechanisms of heavy metal cytotoxicity include damage to plasma membranes, following binding to proteins and phospholipids, inhibition of Na, K-dependent ATPases, inhibition of transmembrane amino acid transport, enzyme inhibition, lipid peroxidation and oxidative DNA damage, depletion of antioxidant enzymes such as glutathione through the generation of ROS (Stohs and Bagchi, 1995; Leonard et al., 2004; Sigel and Sigel, 1992). Industrial effluents contain toxic substances including heavy metals which are known to bring about structural alterations and reproductive disturbances in aquatic vertebrates, by interfering with the endocrine system (Raghu Prasad and Bela, 2007).

The toxic effects may result from the bio concentration of metals and their consequence binding with biologically active constituents of the body such as lipids, amino acids and proteins (Smedes and Thomson, 1996; Thangam and Sivakumar, 2004; Vutukuru, 2005). Heavy metals concentration
in the tissues of fish enter into human beings through food chain and due to there cumulative action causes potential health hazards sometimes even lethal (El-Shehawi et al., 2007).