REVIEW OF LITERATURE
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Water, being the prime necessity of life, is the soul and hope of the nature. Water is a limited resource which cannot be produced as and when required by the technological means. The requirement of water in all lives, from micro-organism to man, is a serious problem today because all water resources have reached a point of crisis due to unplanned urbanization and industrialization (Singh et al., 2002). 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 (Shiklamanov, 2000). According to Ranjit et al. (2003), 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.

With recent development in industries and sudden population growth, treated and untreated effluents and domestic sewage are constantly being discharged into fresh water bodies (lakes) which change the properties of water and adversely affecting the flora and fauna of that particular water ecosystem. Man has been facing one of the most horrible ecological crisis: the problem of pollution of his environment which sometimes in past was pure, undisturbed, uncontaminated and quite hospitable for him. Pollution is the unfavourable alteration of our environment, largely due to human activities. Freshwater bodies are the most vulnerable habitats, which are changing and are becoming scarce due to anthropogenic activities as e.g., exploitation of water for drinking, irrigation etc., discharge of industrial and domestic effluents, either
partially or untreated into these essential resources. Beaumont et al. (2000) and Almeida et al. (2001) reported that rapid industrialization in India has resulted into a substantial increase in the liquid waste (spent wash or effluent), which is traditionally being discharged into open land or in nearby natural water, causing a number of problems like threat to plant and animal lives, surface water logging, ground water contamination and salinizing of land (Ramona et al., 2001).

Abrupt increase in the human population has greatly contributed towards discharge of large amount of unused/waste chemical/toxic compounds and other similar pollutants into the environment which has converted fresh water bodies like lakes, tanks and rivers to impending contamination sinks giving rise to water pollution problems (Venkatesan 2007; Adhikari et al., 2009). The ecosystem of lakes is complex and fragile. Lokeshwari and Chandrappa (2006) stated that since the rate of discharge of pollutants into the lake is much more than the rate of self cleaning ability they tend to readily accumulate such pollutants. The series of changes in the physicochemical characteristics of water, have been the subject of several investigations (Mahananada et al., 2010).

According to Sarika and Chandramohankumar (2008), the urban aquatic ecosystems are strongly influenced by long term discharge of untreated domestic and industrial wastewaters, storm water runoff, accidental spills and direct solid waste dumping. All these released pollutants have a great ecological impact on the water quality and its surrounding food web (Abhishek
The aquatic environment is extremely variable in their physico-chemical and biological parameters. The water quality depends on the various physico-chemical parameters like pH, TS, TDS, TSS, BOD, COD (Gadi et al., 2003). It also varies due to light, temperature, turbidity, conductivity, nutrients and contaminants and biologically they vary in biomass, growth and aquatic populations. The physico-chemical parameters of water must be monitored regularly, individually or synergistically to keep the aquatic habitat favourable for existence of fish (Mondal et al., 2010). Parashar et al. (2006) analysed parameters like total hardness, total alkalinity and turbidity of the potable water quality of the Upper lake of Bhopal. He considered urbanization and anthropogenic activities and increased human interventions such as disposal of partially treated domestic sewage, urban pollutant and other effluents from agricultural sources to cause eutrophicated condition in the water bodies. The wastes consisting mainly of phosphate-containing detergents and nitrates help in growth of algae and aquatic plants. Nitrates and phosphates are the main components which stimulate the growth of aquatic weeds and blooms causing interference with the dissolved oxygen, BOD, conductivity and turbidity (Parashar et al., 2006). According to Karthi and Divaakar (2008), physico-chemical and biological tests provide important information on the actual state of water, the nature of pollutants, and their origin and on the functions of the self-purification processes. To study the spatial and seasonal variation of water parameters the variation in selected locations in Pillavakkal irrigation system was analysed.
The maintenance of a healthy aquatic ecosystem is dependent on the physico-chemical characteristics of water and also on the biological diversity of water ecosystem.

Lakes in the city and industrial belts under the stress of increasing input of various toxic metals and toxic level of essential elements in water bodies have undergone eutrophication. Input of runoff material from fertilizer fields, organic matter, rich sewage load, washing of clothes and use of soaps are principal source of nutrient enrichment. Sewage and effluents are common in the water bodies located in and around the cities adversely affecting the aquatic bodies. Municipal and industrial waste water discharge constitutes a constant polluting source, whereas surface runoff is a seasonal essential phenomenon, largely affected by climate within the basin. Hence, the chemical composition of the water is function of hydro-geochemical processes acting within the catchment (Mahapatra and Mishra, 2005).

Metabolic activities of aquatic organisms are dependent on the pH of water (Wang et al., 2002). According to Murdoch et al. (2001), the optimal range of pH for sustainable aquatic life is 6.5 – 8.2. Reduction in the pH level in lakes during summer might be due to the presence of organic acids resulting from decaying vegetation (Pidgeon and Cains, 1987). Das and Shrivastva (2003) reported that clay, slit, organic matter, phytoplankton and other microscopic organisms cause turbidity in lake water. According to Dagaonkar and Saksena (1992); Mariappan and Vasudevan (2002); and Garg et al. (2006), high turbidity showed presence of large amount of suspended solids due to the
silt clay and other particles mostly during rainy season. High turbidity reduces the light available for the aquatic plants thereby affecting photosynthesis and lowering the rate of primary productivity (Verma et al., 1979). Electric conductivity is a measure of water capability to transmit electric current and to assess the purity of water (Murugeshan et al., 2006). Ahluwalia (1999) suggested that a high level of conductivity reflected the pollution status as well as tropic levels of the aquatic body. Seasonal variations in the conductivity were observed in Sursagar Lake of Baroda (Solanki, 2001) and in Chandola Lake in Ahmadabad (Verma et al., 2012).

According to Lawson (2011), a positive correlation exists between TSS and TDS and an increase in these parameters indicate an increase in salt concentration thereby increasing the electric conductivity of water. Variation in BOD is an indication of dynamism in the aquatic life present in a lake. An increase in BOD indicated an increase in the amount of organic matter in water (Garg et al. (2010). According to Boyd (1981), COD of water increased with increasing concentration of organic matter and it was a reliable parameter for judging the extent of pollution in water (Amirkolaie, 2008).

Adeyemo (2008) reported high DO during rainy season which could be due to increased aeration because of rainfall. Total alkalinity is a measure of the capacity of water to neutralize acids to a designated pH (Edokpayi and Osimen, 2001). In water it is due to salts of weak acids and bicarbonates of highly alkaline water (Kataria et al., 2006). Alkalinity between 30 and 500 mg/l is generally acceptable to fish production (Abowei and George, 2009).
et al., (2001) reported that high levels of both phosphates and nitrates lead to eutrophication, which increased algal growth and ultimately reduced dissolved oxygen in the water. The pollutants altered the natural condition of aquatic medium that caused behavioural changes as well as morphological imbalance of aquatic organisms (Yadav et al., 2005).

High level of variation in physical and chemical parameters was observed in Chandola lake of Ahmadabad by Pradeep et al. (2012) and that of two lakes Lodra and Nardipur (Gujarat) by Patel and Patel (2012). Influence of seasons on water quality, abundance of fish and plankton species of Ikwori Lake, South-Eastern Nigeria was studied by Offem et al. (2011). He recorded highest values of water temperature and bicarbonate ions during the dry season and lowest values during wet season. Lawson (2011) worked on mangrove swamps of Lagos Lagoon, Nigeria and stated that water was not potable because of the presence of heavy metal. Water characteristics at downstream of station-B along river Tunga at Shivamogga, Karnataka studied by Goudar et al. (2012) showed variation indicating polluted status of that station.

Studies on heavy metals in rivers, lakes, fish and sediments have been a major environmental focus especially during the last decade (Pote et al., 2008; Praveena et al., 2008). Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bioaccumulation in aquatic ecosystems (Miller et al., 2002). The degree of toxicity produced by the pollutants is dose independent upon environmental conditions such as temperature, pH, oxygen content and presence of residue
molecules (Singh and Mishra, 2009). The presence of toxic metals in environmental matrices is one of the major concerns of pollution control and environmental agencies in most parts of the world (Tay et al., 2009) and are widely distributed in the environment with sources mainly from the weathering of minerals and soils (Merian, 1991).

Ohe et al. (2004) explained that surface waters, such as lakes, rivers, and seas contain complex mixtures of pollutants as a result of anthropogenic action, including genotoxic compounds which cause adverse effects on public health and aquatic ecosystems. Aquatic environment serves as convenient repositories for man’s biological and technological wastes and current awareness of the potential hazards of pollutants in the aquatic environment. This stimulated much interest in the use of fish as indicators due to their position in the trophic chain, their sensitivity to low concentrations of genotoxic substances and their ability to metabolize xenobiotics and accumulate pollutants (Grisolia and Corderio, 2000; Vander Oost et al., 2003).

Industrial discharge containing toxic and hazardous substances, including heavy metals (Woodling et al., 2001) harm the aquatic ecosystem tremendously. Heavy metals are among the most persistent pollutants in aquatic ecosystem because of their resistance to decomposition in natural conditions (Khan, 2011). High concentration of these metals can be released into the aquatic environment as a result of leaching from bed rocks, atmospheric decomposition, water drainage, run off from river banks and discharge of urban and industrial waste waters (Rabee et al., 2011). Due to the
bioaccumulating properties of metals in aquatic ecosystems, they are of great concern (Censi et al., 2006). Therefore, it has public interest (Gibbs, 1972; Niemi et al., 1990). Hajeb et al. (2009) stated that the heavy metals may reach a toxic concentration level that can potentially destroy the ecological environment. The rate at which this effect is pronounced greatly depends on the industrialization level and the use of mechanized agricultural activities as well as on uncontrolled urbanization along the coastal areas (Zheng et al., 2008). Subsequently, these anthropogenic activities have increased the release of harmful heavy metals into the aquatic environment (Hajeb et al., 2009).

Attention on water contamination and its management has become a need of the hour of far reaching impact on human health (Mahapatra and Mishra, 2005). Water quality data are essential for the implementation of responsible water quality regulations for characterizing and remediating contamination and for the protection of the health of the human and aquatic organisms (Shrestha and Kazama, 2006). Status of lakes in Bangalore is a direct measure of status management of anthropogenic activities causing adverse effects and loss of wetlands (Kiran and Ramachandra, 1999). The impact of urbanization on Bellandur lake, Bangalore was studied by Chandrasekhar et al. (2003). He reported high values of alkalinity, BOD and COD and low levels of dissolved oxygen indicating polluted nature of the lake.

Fish are the best and popular test organisms for monitoring aquatic toxicity and have large mobility which allows them to assess large scale regional effect (Kime et al., 1996). Any change in the natural conditions of
aquatic medium caused several physiological adjustments in fish (Black, 1955).

As fish fauna serves as a food source, it is essential to know the impact of water pollution on them (Ellis, 1944). Staniskiene et al. (2006) reported that in order to maintain the quality and nutritive properties of fish, it is important to regularly monitor and evaluate the pollution levels in water reservoirs.

Fish are important part of the majority of human diet (Domingo et al., 2007) due to high content of omega-3 fatty acids, vitamins, minerals and low levels of saturated fats (Mahaffey, 2004). American heart association recommended their consumption at least two times a week (AHA, 2010). There is evidence of beneficial relation between fish consumption and lower risk of prostate cancer (Augustsson et al., 2003), renal cell cancer (Wolk et al., 2006) and coronary heart disease (Mozaffarian and Rimm, 2006). In contrast to beneficial effects, fish can also contribute significant dietary exposure to the chemical contaminants such as persistent organic pollutants and metals. Fish is used in a variety of diets since it is a good source of digestible protein, vitamins, minerals, and polyunsaturated fatty acids (Carvalho et al., 2005) which support healthy living (Ikem and Egiebor, 2005).

Fish are also good indicators of heavy metal contamination in aquatic systems because they occupy different trophic levels and are of different sizes and ages (Burger et al., 2002). High levels of accumulated metals in fish could become a significant metal exposure pathway and a consequent health risk for fish consuming human population (Turyk et al., 2012). The heavy metal intakes by fish in a polluted aquatic environment varied depending on ecological
requirements, metabolisms, and other physico-chemical factors, such as salinity, water pollution level, food, and sediments. Fish accumulated metals in its tissues through absorption, and humans can be exposed to these metals via the food web. The consumption of contaminated fish caused acute and chronic effects to humans (Nord et al., 2004).

Fish an indirect target is an extremely reliable component of an aquatic monitoring system because they integrate the effect of detrimental environmental change as consumers and occupies a relatively high position in the aquatic food chain. Fish when exposed to pollutants, pathogens and xenobiotic substances present in water bodies caused stress which in turn affected their metabolism and biochemical profiles. These altered physiological adaptations are however variable and flexible in response to water quality of a large variety of aquatic habitats. Among the various pollutants, heavy metals, in particular, are widespread contaminants released into aquatic systems from numerous factories and industries (Sreekala and Zutshi, 2012).

Any biological response to an environmental pollutant measured in an organism is described as a biomarker, comprising a broad range of parameters such as hematological, immunological, reproductive, endocrine, genotoxic, neuromuscular, physiological, histological and morphological (Vander Oost et al., 2003). Biochemical and physiological indicators such as enzymes, can be used (as biomarkers) to identify possible environmental contaminations before the health of aquatic organisms is seriously affected (Bamhoom, 1996) and to measure water quality indices (Mekkawy et al., 2010a). Disturbances in
biochemical composition of biomolecules such as proteins, carbohydrates and lipids due to the variation in the water parameters resulted into changes in the metabolic rate in the tissues of the aquatic organism thereby playing a major role as precursors in fish under stress conditions. Protein content in brain, liver and muscle tissue of *Clarias batrachus* (Tripathi and Verma, 2004) and in *Nemacheilus botia* (Dhapate *et al.*, 2007) showed variation due to the endosulfan-induced impairment of metabolism. Sobha *et al.* (2007) reported alteration in glycogen content in the tissues of freshwater fish, *Catla catla* exposed to the heavy metal toxicant cadmium chloride. Vutukuru and Kalpana (2013) studied the acute effects of mercuric chloride on vital biochemical constituents viz., protein and glycogen of Zebra fish, *Danio rerio*. Freshwater fish *Cirrhinus mrigala* exposed to lethal and sub lethal concentrations of Cypermethrin (10% E.C) a synthetic pyrethroid insecticide showed biochemical changes in total glycogen, proteins and nucleic acids (Veeraiah *et al*., 2013). Cholesterol is required to build and maintain membranes. Biochemical changes in liver tissue of fresh water fish *Tor tor* exposed to Butachlor revealed significant increase in cholesterol content (Rajput *et al*., 2014). The effect of chronic exposure to λ-cyhalothrin on some biochemical parameters like protein, glycogen and cholesterol in the freshwater catfish *Clarias gariepinus* was evaluated by Oluah and Chineke (2014). The industrial effluents from tannery, electroplating and textile mills caused marked depletion in biochemical composition (glycogen, protein and lipid) in tissues such as gill, liver, muscle and kidney of the fish, *Labeo rohita* (Muley *et al*.,
Such changes in the metabolic processes may be produced by influencing the enzyme system.

Degree of responses to toxicant exposure and a link between external and internal structure of aquatic organisms can be assessed by enzymatic assays (Gabriel and Akinrotimi, 2011). Enzyme determinants of fish can be applied as an indicator of chemical intoxication (Cengiz and Vnlu, 2006) and heavy metal intoxication because of their sensitivity to metal pollution (Mora et al., 2004). According to Bols et al. (2001), enzyme systems also play a significant role in food utilization and metabolic activity. But since this system may get altered under the stress of pollutants it can be considered as one of the major biomarker indicating the level of changes, consequent of pollutants in the tissues, organs and body fluid of the fish that can be recognized and associated with established health impairment process (Akinrotimi et al., 2009; Magar and Afsar, 2013). Enzyme analysis of organs such as muscles, kidney, liver, heart and gills in fish can provide important information about the internal environment of the organism (Boeger et al., 2003). Variation in the metabolic enzyme activities in fish is directly proportional to the concentration of the toxicant (Pesce et al., 2009). Evaluation of enzyme activities in the tissue and organs of aquatic organisms in the diagnosis of the effects of pollutants is one of the emerging areas in toxicological monitoring and remediation programmes (Oluah et al., 2005).

Physiological conditions can be assessed by analysing activities of phosphatases in fishes (Kågedal et al., 2001; Sreenivasan et al., 2011).
Phosphatase is a hydrolytic enzyme, leading to the release of ortho-phosphate from phosphorus compound and is based on the optimum pH of action environment. It can be classified into acid phosphatase (ACP, EC 3.1.3.2, optimum pH≤6.0) and alkaline phosphatase (ALP, EC 3.1.3.1, optimum pH≥8.0) (Jansson et al., 1988). Both enzymes (ACP and ALP) are metalloenzyme, involved in various metabolic processes, such as permeability, growth and cell differentiation, protein synthesis, absorption and transport of nutrients, and gonadal maturation (Ram and Sathayanesan, 1985). In fisheries sciences, changes in phosphatase activities have been regarded as indices of growth, illness and spawning of fish (Matusiewicz and Dabrowski, 1996). The phosphatases (ACP and ALP) are important biomarkers because they are involved in adaptive cellular response to the potential cytotoxicity and genotoxicity of pollutants (Velisek et al., 2006). Alterations in ACP and ALP activities in tissues and serum were reported in fish *Clarias batrachus* exposed to pesticides by Jyothi and Narayan (2000). According to Sivaperumal and Sankar (2013), changes in activity of phosphatases were observed in liver of *L. rohita* exposed to methylparathion which inturn affected its intermediary metabolism.

Kong et al. (2012) while exposing gold fish *Carassius auratus* to mercury during embryonic development reported increase in ACP and ALP activities. According to Sreenivasan et al. (2011), changes in activity of phosphatases in the hepatopancreas and muscle of the fresh water female field crab, *Spiralothelphusa hydrodroma* (Herbst) were recorded when treated with
Cypermethrin. Rajalakshmi and Mohandas (2005) suggested ACP as a reliable marker tool for the biological assessment of metal pollution. Das et al. (2004) also observed that acid phosphatases were involved in the immune defense of the oysters. Various concentrations of copper and mercury at varying length of exposure were found to influence ACP enzyme activity in *Lamellidens corrianus* (Rajalakshmi and Mohandas 2005, 2008).


Dehydrogenases are the redox enzymes. Succinic dehydrogenase (SDH) is a primary enzyme in the oxidative catabolism of sugars. Malate dehydrogenase (MDH) an enzyme in citric acid cycle that helps in the conversion of malate into oxaloacetate (using NAD+) as a catalyst and vice versa where as lactate dehydrogenase (LDH) converts pyruvate to lactate in absence or in short supply of oxygen .LDH is widely used as a biomarker of lesions in organ and tissue in toxicology. Koenig and Sole (2014) reported changes in the activity of LDH in deep sea fish, *Alepocephalus rostratus, Lepidion lepidion, Coelorinchus mediterraneus* and *Bathypterois*

Mukherjee and Jana (2007) observed activity of SDH in gill, liver and muscle tissue of *Catla catla*, *Labeo rohita* and *Oreochromis mossambicus* raised in ponds of a sewage-fed fish farm. Xiaorong *et al.* (2014) reported variations in SDH activity in sperm of Chinese fish *Nibea albiflora* after cryopreservation. More *et al.* (2005) observed decrease in the level of SDH activity in *Lamellidens marginalis* exposed to copper sulphate. Antonopoulou *et al.* (2014) studied characterization of cellular and metabolic responses including MDH activity and examined the antioxidant defence in the liver of meagre (*Argyrosomus regius*) in relation to dietary lipid consumed. Li *et al.* (2015) evaluated the effect of linseed oil (LO) replacing different levels of fish oil (FO) on growth, muscle fatty acid composition and metabolism of tilapia (*Oreochromis niloticus*) along with MDH activity. Narra *et al.* (2015) reported enhancement of malate dehydrogenase activity in brain, blood and liver tissues of *Clarias batrachus* by exploring the modulatory effects of chlorpyrifos and protective role of vitamin C. According to Thirumavalavan (2010), the level of succinic acid dehydrogenase decreased and lactate dehydrogenase increased in
brain, gill, liver and kidney tissue of *Catla catla* exposed to sublethal concentration of copper sulphate. Bashir and Zuhair (2002) reported that alteration in SDH and LDH activity due to lead intoxication may cause injured mitochondrial function and reduction in carbohydrate oxidation.

Contamination of fresh water fish with heavy metals is a recognized environmental problem (Staniskiene *et al.*, 2006). Metals can be taken up by aquatic organisms through skin, gills and gastrointestinal tracts. Once entered, metals are not distributed equally in the body of organism, but accumulate in particular organs (Izabela *et al.*, 2008). Some metals are known to be toxic even at low concentrations, including arsenic, cadmium, mercury and lead (Lee *et al.*, 2009) and others such as copper and cobalt, are known to be essential elements and play important roles in biological metabolism at very low concentrations (Lee *et al.*, 2009).

The presence of heavy metals in fishes from the Coastal waters of Kapar and Mersing, Malaysia water was reported by Bashir *et al.* (2013). Heavy metals are dangerous even at low concentrations in fish and water having a particular significance in ecotoxicology and their toxic effects have been widely published for a number of water bodies (Ekeanyanwu *et al.*, 2011). The indestructible nature and long term toxic effects of heavy metals including lead (Pb), nickel (Ni), manganese (Mn), zinc (Zn), cadmium (Cd) and chromium (Cr) to man as a result of consumption of organisms obtained from polluted rivers has raised scientific and environmental concerns (Kumar *et al.*, 2012). Like in other organisms, heavy metals do not get destroyed in humans. Instead,
they tend to accumulate in the body and were stored in soft and hard tissues such as liver, muscles and bone threatening the health of humans (Castro-Gonzeza and Méndez-Armentab, 2008). The heavy metals are among those pollutants, which received attention in various countries and were considered the most dangerous category of pollutants in the sea (Hassaan et al., 2007). Subathra and Karuppasamy (2008) and Samir and Ibrahim (2008) reported bioaccumulation of metals like copper and iron in fishes Mystus *vittatus* and *Oreochromis niloticus* respectively.

Hematological study is important in toxicological research because hematological alteration is good method for rapid evaluation of the chronic toxicities of a compound. Haematological parameters of fish are closely related to their response to environmental and biological factors (Fernandes and Mazon, 2003). According to Osman et al. (2010b), blood parameters are useful for the measurement of physiological disturbances in stressed fish and thus provide information about the level of damage in the fish. A thin epithelial membrane separates fish blood from the water and any unfavorable change in the water body is reflected in the blood (Kori-Siakpere and Uboga Ewoma, 2008). The study of blood characteristics may corroborate important subsidies of diagnoses and prognoses of morbid conditions in fish populations and therefore, contribute to better comprehending comparative physiology, phylogenetic relations, feeding conditions and other ecological parameters (Osman et al., 2010b). The determination of protein content in blood plasma is a good indicator to detect intra-specific and inter-specific variation among
species, identify populations, and for investigation of ecological stress, physiological homeostasis and aquatic pollution (Sharaf-Eldeen and Abdel-Hamid, 2002).

Serum proteins are very complex and are involved in a wide range of physiological functions in both healthy and diseased state, therefore they play a role of great importance for zoologists, enzymologists, immunologists and toxicologists. In the last decade a wealth of literature is accumulated on blood plasma protein fraction in different animals, including fish (Yilmaz et al., 2007). Saleem et al. (2013) collected blood samples for protein analysis from chicken of pure (boiler and layer) and local breeds for genotyping through sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). Singh and Sharma (1998) reported changes in serum proteins of *Clarias batrachus* exposed to sub lethal concentrations of Carbofuran. Toxic effect of Phorate on the serum biochemical parameters in snake headed fish, *Channa punctatus* was reported by Singh et al. (2010). According to Arockia et al. (2007), the fishes (*O. mossambicus*) exposed to various concentrations of the carbamate pesticide, Methomyl for different durations revealed variation in protein fractions. Although many reports on electrophoresis studies of serum fractions from healthy fish have been published (Hongkun et al., 2008), but little is known about use of protein electrophoresis in fish for monitoring of different aquatic habitats (Osman et al., 2010).

Among the currently available procedures, micronuclei and nuclear abnormalities assays are the most widely applied methods due to its proven
suitability for fish species (Cavas & Ergene-Gozukara, 2003; Kirschbaum et al., 2009). Nuclear abnormalities (NAs), such as micronuclei and other nuclear malformations, are considered good indicators of cytotoxicity and genotoxicity, respectively (Kirschbaum et al., 2009). It was suggested that in genotoxicity studies with fish, both alterations in nuclear morphology and micronuclei number should be considered when using the micronuclei test (Kirschbaum et al., 2009). These structures are easy to visualize in erythrocytes and are therefore often used as a measure of chromosomal aberrations (Hartwell et al., 2000). For the determination of genotoxic effect in fish, the micronucleus test and the study of the abnormal shape of nuclei are suitable measures with which the presence or absence of genotoxins can be detected in water. The detection of MN and NAs in fish helps us to assess the status of water quality as well as the health of a particular species and any potential risk it might have after consumption (Talapatra and Banerjee, 2007).

Micronucleus test (MNT) is a widely used cytogenetic technique for assessment of chromosomal damage induced by various genotoxicants. Schroder (1966) for the first time studied the formation of micronuclei in mammalian bone marrow cells; subsequently this assay was developed by Schmid (1975) in mammalian systems. The MN are also known as Howell-jolly bodies in mammals. Like mammalian species, MNT has also been adopted to study genotoxicity in fishes. The formation of morphological nuclear abnormalities such as notched, lobed, and blebbed nuclei were first described in fish erythrocytes by Carrasco et al. (1990). Such NAs were used
by several authors as possible indicators of genotoxicity (Da Silva Souz and Fontanetti, 2006). Micronucleus bioassay offers several types of unique information as a bioindicator for chromosomal aberrations not available from other methods: (1) the integrated effect of a variety of environmental stresses on the health of an organism and population, community and ecosystem; (2) early warning of potential harm to human health based on the responses of wildlife to pollution; and (3) the effectiveness of remediation efforts in decontaminating waterways (Villela et al., 2006). Furthermore, Furnus et al. (2014) found two types of NA in various native fishes of Argentina. Micro nuclei test is recommended to be conducted as part of the monitoring protocols in aquatic toxicological assessment programs (Ohe et al., 2004; Udroiu, 2006). Some of the advantages of the micronucleus test are its simplicity, reliability and sensitivity (Ayllon and Garcia-Vazquez, 2000). The in vivo micronuclei frequency assay has been widely used as a technique for genotoxicity monitoring of polluted aquatic media and in the screening for the presence of toxic compounds suspected to be genotoxic (Ossana et al., 2010; Wirz et al., 2005). Walia et al. (2013) stated that heavy metals induced such changes in fishes which cannot be reversed and caused cytotoxic damage resulting in death of fishes. Exposure to sublethal concentration of cadmium in air breathing fish, Channa punctatus increased abnormalities in erythrocytes as was reported by Karuppasamy et al. (2005).