Chapter 1

GENERAL INTRODUCTION AND OBJECTIVES

1.1 General Introduction

1.1.1 Water: the tincture of life
1.1.2 Rivers: the arteries of the earth
1.1.3 Periyar: Carter for booming of Cochin City
1.1.4 Pollution in Periyar: river in the verge of destruction.
1.1.5 Heavy metal pollution in river and its effects on aquatic organisms

1.2 Objectives
1.1 General Introduction

1.1.1 Water: the tincture of life

    Earth, Water, Fire, Air and Sky are the “Panchabhootha”, the five elements that make a living body. The balance between these five elements keeps the body alive and healthy. Water is our second most important resource. It is impossible to substitute for most of its uses, difficult to depollute, expensive to transport, and it is truly a unique gift to mankind from nature(Alphonsa 2013). Water is essential at all levels of life, cellular to ecosystem. It is essential to circulation of body fluids in plants and animals, and it stands as the key substance for the existence and continuity of life through reproduction and different cyclic process in nature; it plays the central role in mediating global scale ecosystem processes, linking atmosphere, lithosphere, and biosphere, by moving substances among them, and enabling chemical reactions to occur(Jithesh 2008).

    There are more than 326 million trillion gallons of water on Earth. Only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of this freshwater, less than 1% is located in surface water resources like lakes, rivers and swamps are important because they supply water for the population in the whole year. The fresh water habitats are considered worthwhile not only as a supply resource but as a living system by which the global ecosystem is balanced (Jithesh 2008).

    India has vast aquatic resources comprising 2.02 million km² Exclusive Economic Zone, 8129 km coast line, 1.3 million ha of beels, jheels and swamps, 45,000 km rivers, 3.10 million ha of reservoirs, 0.12 million km of canals, 0.92 million ha brackishwater and 2.25 million ha of ponds and tanks(Pandey & Gopal 2003). Rivers are the major source of water in India. The riverine resources of India containing 113 major and minor rivers along with principal tributaries have a combined length of 45,000 km. Rainwater is the main
source of water in rivers. India receives more rainfall per unit area than elsewhere in the world. Rainfall in India is dependent on southwest and northeast monsoons. According to (Bose 2003), the average annual precipitation of the country is estimated to be 4000 billion m$^3$ but only 1000 billion m$^3$ per year is available as usable surface water and ground water.

Kerala is rightly called as the land of waterbodies. It has 44 rivers, all of which originate in the Western Ghats. All these rivers are rain-fed (unlike rivers in North India that originate in the glaciers), rivers of Kerala is heavily dependent on the monsoon. Fortunately, Kerala receives two monsoons-one from the southwest and the other from the northeast distributed between June and December. Two-third of the rainfall occurs during the southwest monsoon from June to September. However, the water availability per capita ratio in Kerala is one of the lowest in the country and has been declining over time. Per capita annual availability of utilizable water (m$^3$) in Kerala was 1248 (Lathika 2010).

Utility of water as a resource is difficult to measure. The water bodies constitute a very important part of the earth’s life-support module, since they provide water and function as air purifiers, temperature moderators and waste assimilators (CESS, 1984). All the vital activities of organisms, such as thermoregulation, circulation, respiration, excretion and reproduction are based on water in one way or the other (Lohner et al. 2001). Freshwater environment generally exhibits a great diversity in physical, chemical and biological conditions from season to season and region to region. The steady flow of clean, fresh water is an essential element for every elements of an ecosystem. Globally, 3240 km$^3$ of fresh water is drawn, and used annually; 69% of this is used for agriculture, 23% for industry, and 8% for domestic purposes (WRI, 1994).

1.1.2 Rivers: the arteries of the earth

River, a large natural stream of water flowing in a channel to the sea, a lake, or another river. A river may have its source in a spring, lake, from damp, boggy places where the soil is waterlogged, from glacial melt water, or simply from rain flowing off
impermeable rock or man-made surfaces. Almost all rivers are joined by other rivers and streams, termed "tributaries", the highest of which are known as headwaters. Water may also be recruited to a river from ground-water sources. Ten important rivers of the world are played an important and life-sustaining role in human societies for thousands of years, which is why many of the world's great cities sit on the bank of a great river.

Rivers in India are given religious importance, are considered to be holy and sacred. Hindu Mythology considers these rivers as Gods. The river systems provide irrigation, potable water, cheap transportation, electricity, as well as provide livelihoods for a large number of people all over the country. Seven major rivers (Indus, Brahmaputra, Narmada, Tapti, Godavari, Krishna and Mahanadi) along with their numerous tributaries make up the river system of India. Kerala has 44 rivers, of which 41 originate from the Western Ghats and flow towards west into the Arabian Sea. The important rivers from north to south are Valapattanam (110 kms.), Chaliar (69 kms.), Kadalundipuzha (130 kms.), Bharathapuzha (209 kms.), Chalakudy (130 kms.), Periyar (244 kms), Pamba (176 kms), Achancoil (128 kms.) and Kalladayar (121 kms.). Other than these, there are 35 more small rivers and rivulets flowing down from the Ghats.

1.1.3 Periyar: Carter for booming of Cochin City

Kerala’s coastal zone is unique with the presence of a large number of perennial or temporary backwaters (Kayals), endowed with rich biological and genetic diversity (Ouseph 1992). Six rivers (Achenkovil, Pampa, Manimala, Meenachil and Muvattupuzha in the south and a branch of Periyar in the north) are discharging about $2 \times 10^{10} \text{m}^3/\text{y}$ of fresh water, 60% of which is during summer monsoon (June - Sep). Among six, Periyar and Muvattupuzha are the major rivers emptying to the system (Anu et al. 2014).

The river Periyar, the longest river of the state (PWD 1974); (CESS 1984) with a length of 244 Km and stretching from Western Ghats to Lakshadweep Sea is considered to be the life line of Central Kerala. It originates from the Sivagiri peaks (1800m MSL) of Sundaramala in Tamil Nadu. The total length is about 300Kms (244Kms in Kerala;
General Introduction and Objectives

However, recorded as 229Km in (NEERI 1992) with a catchment area of 5396Sq Kms (5284 Sq. Kms in Kerala). Maximum width is recorded as 405m (Joy, 1992). Total drainage area is 5398 Sq Km, out of this 5284 in Kerala and 114 in the Western slope of the Anamalai hills in Tamilnadu(KSPCB 1981); (KSPCB 1985); (PWD 1986). The total annual flow is estimated to be 11607cubic meters.

Originating from ‘Sivagiri’ group of hills in ‘SundaraMalai’ and after about 48Km, Periyar River receives the Mullayar and then turns west to flow into the Periyarlake at Thekkady. From there it flows on and passes Vandiperiyar and after receiving River Perumthurai and River Kattappana, reaches the Idukki catchment. Afterwards, Idamalayar joins Periyar near Neriamangalam. After Neriamangalam the river flows into the Periyar Barrage and then on to the Bhoothathankettu dam. The river then meanders through Malayattoor, Kalady and Alwaye. At Alwaye, the river bifurcates into the Mangalapuzha branch and the Marthanadavarma branch. The former joins river Chalakudy and finally drains into the Lakshadweep Sea and the latter bisects the industrial belt at Eloor before discharging into the backwaters adjoining the Arabian Sea (KSPCB 1981). During its journey to Arabian Sea at Cochin the river is enriched with water of minor tributaries like Muthayar, Perunthuraiar, Chinnar, Cheruthony, Kattappanayar and Edamalayar at different junctures.

Periyar has been performing a pivotal role in shaping the economic prospects of Kerala, as it helps in power generation, domestic water supply, irrigation, tourism, industrial production, collection of various inorganic resources and fisheries. However, as in the case of many other inland water bodies, river Periyar is gradually undergoing eco-degradation throughout its course of flow due to various anthropogenic stresses, which include indiscriminate deforestation, domestic- agricultural- industrial water pollution, excessive exploitation of resources, large scale sand mining, various interferences in the flow of water, etc(Joseph 1984).
1.1.4 Pollution in Periyar: river in the verge of destruction.

The river Periyar is rightly considered as the ‘Dakshina Ganga’. There are eight townships (Vandiperiyar, Upputhara, Cheruthoni, Munnar, Kalady, Perumbavoor, Alwaye, Paravur), which pollute the river with urban sewage. Numerous large and small industries which utilized the river for development directly and indirectly crippled the physico-chemical and biological characteristics of the river. Eloor - Edayar industrial area is the major source of this illegal and inhuman activity. More than 247 chemical industries manufacturing petrochemical products, pesticides, rare-earth elements, rubber processing chemicals, fertilizers, zinc/chrome products, leather products etc located here. These industries discharge 173.5 million liters of highly polluted effluents per day into the river Periyar. This leads to the large-scale mortality of aquatic life in the river and agricultural lands besides threatening the air and soil qualities. After conducting surveys in 1999 and 2002, Green Peace, the international environmental group, had declared Eloor a ‘toxic hotspot of global proportions’. Of the 105 compounds isolated from this sample including two isomers of DDT, twelve DDT metabolites, four isomers of hexachlorocyclohexane (HCH), including the gamma-isomer, better known as the insecticide lindane, hexachlorobutadiene (HCBD), mono- and dichlorobiphenyls and various chlorinated benzenes and toluenes. Hexachlorobutadiene, also found in all samples from this site and low chlorinated PCB congeners (mono- and dichlorinated), detected and are also believed to arise as by-products of the manufacture of other chlorinated chemicals (Stringer et al. 2003). Isomers of the chlorinated pesticide endosulfan and its metabolite endosulfan ether, which were detected in the sediment samples during 1999 but further downstream in 2002. Many heavy metals were also reported from the river. Concentrations of almost all metals were higher in the downstream samples than in the upstream samples. Merchem manufactures various chemicals including zinc compounds and may be a source of zinc to the creek; IRE processes the mineral monazite, manufacturing compounds of rare earth elements and may discharge effluents containing metals such as lead and zinc. FACT manufactures a range of fertilizer products including phosphate-based fertilizers derived from phosphoric acid (Stringer et al. 2003). Fertilizers of this type are derived from
phosphate ores (Kroschwitz & Howe-Grant 1995a). The production of fertilizers using phosphate ore has been associated with the formation of waste streams contaminated with a range of heavy metals (EFMA 2000). Many governmental and non-governmental organizations (NGO’s) were consistently opposed for the large-scale, illegal dumping of wastes into the river Periyar from numerous industries in the Eloor - Edayar industrial area (Alphonsa 2013), but still the problem is worsening the situation.

1.1.5 Heavy metal pollution in river and its effects on aquatic organisms

At first glance, it would appear to be a rather simple matter to define a “heavy metal” – it is a metal that is “heavy”. There seems to be a consensus in the literature that the term “heavy metal” is badly defined and is best avoided (Duffus 2002); (Nieboer & Richardson 1980). Its definition should certainly not be based on the density of the metal in elemental whether the defined lower limit on the density of a heavy metal is 3.5 or 7 g cm\(^{-3}\). The term “heavy metal” should be defined in relation to the position of the element form in the period table, because this position is related to the chemical properties of compounds that include the element. So that three groups from the periodic table should be considered heavy metals: (1) transition elements, all of which are metals, even though some of them form slightly amphoteric oxides (i.e. Ti, Zr, Hf, Rf, V, Nb, Ta, Cr, Mo, W, Mn, Tc, Re, Fe, Ru, Os and Zn); (2) rare earth elements, which are subdivided into the lanthanide series (including La itself) and the actinide series (including Ac); (3) some elements from the p-group that are either metals (Al, Ga, In, Tl, Sn, Pb, Sb, Bi and Po) or metalloids/borderline elements; then lead group elements like Ge, As and Te (Appenroth 2010).

Metals are present in very low concentrations in natural aquatic ecosystems (Nussey 1998) usually less than a few mg/L, due to various processes such as weathering and erosion (Viljoen 1999). As a natural resource heavy metal also possess some biological importance. Some of these metals are essential to living organisms in trace amounts (Cu, Co, Mn, Mo, Se and Zn to both plants and animals). Essential trace elements have a narrow optimal
concentration range for growth and reproduction say less than 0.01 per cent (Joseph 2002) and both excess and shortage can be detrimental to organisms (Pelgrom et al. 1994), with unusually high concentrations i.e., level exceeds these required for correct nutritional response becoming toxic to aquatic organisms. Other metals (Cd, Hg, Pb and Metalloids like As, Sb, and Se) have unknown biological function (Seymore 1994) although some essential physiological roles have been inferred for As, Cd and Pb recently (Dara 1993). Cadmium is major contaminants of aquatic environments (Munger et al. 1999) that are toxic towards aquatic organisms (Witeska et al. 1995) even at concentrations found in natural waters (Pelgrom et al. 1994). The most important heavy metals in water pollution are zinc, copper, lead, cadmium, mercury, nickel and chromium (Seymore 1994); (Viljoen 1999).

High natural concentration of metals in food and water could have led to the first exposure. Heavy metal contamination in sediment is one of the largest threats to environmental quality and human health. Generally, as metals enter a coastal environment, they are transferred to the sediments by various processes, that is, adsorption on to particle surfaces and co-precipitation with solid phases (Karickhoff 1984); (Daskalakis & O’Connor 1995); (Lee et al. 1998). These sediments become an important reservoir for metals and provide input records of metals to the ecosystem (Salamons & Forstner 1984); (Zwolsman et al. 1996). Some of the sediment-bound metals may remobilize and be released back to waters with a change of environmental conditions, and impose adverse effects on living organisms (Joseph 2002).

Metal uptake by aquatic organisms is a two-phased process, firstly involving rapid adsorption or surface binding, followed by a slower transport into the cell interior. Transport of metals into the intracellular section may be aided by either diffusion of the metal ion across the cell membrane or by active transport by a carrier protein (Brezonik et al. 1991); (Wepener et al. 2001). Toxicity by heavy metals is induced by delivery of meals to the cell and the specific action of the metal determines the ultimate severity of the toxic action, which not only cause cytotoxicity but also enter into the food chain causing hazardous impacts on human health and animals (Joseph 2002).
Heavy metals have been recognized as strong biological poisons because of their persistent nature, toxicity, tendency to accumulate in organisms and undergo food chain amplification (Morehead et al. 2000). They also damage the aquatic fauna including fish. The fishes were affected, either directly through uptake from the water, or indirectly through their diet, vegetation, invertebrates or smaller fish (Schreck 2000). Metals released into aquatic ecosystems, are responsible for the physiological irregularities of fishes (Lauwerys et al. 1995). All of these effects of heavy metals usually affect fishes negatively leading to stress and eventually, in most cases, death (Barbosa & Ribas 2000).

Nickel reaches the hydrosphere by fall-out from the atmosphere by surface run-off by discharge of industrial and municipal waste and also following natural erosion of soils and rocks. The major source of discharge of nickel is urban wastewater followed by smelting and refining of non-ferrous metals (Nriagu & Pacyna 1988). The maximum permissible limit of Ni is 0.1mg/L set by WHO (1993). Nickel is essential at trace levels for human health (Moore & Ramamoorthy 1984), aquatic ecotoxicity testing has shown that NiSO₄·6H₂O and NiCl₂·6H₂O fall into the "harmful" classification where their abnormally high concentrations can become toxic and disturb the homeostasis of an animal (Farkas et al. 2002); (Javed 2003). Nickel can enter body via inhalation, ingestion and dermal absorption. According to (Nebeker et al. 1985) nickel has been shown as moderately toxic to fish and aquatic invertebrates when compared to other metals. Acute toxicity arises from competitive interaction with five essential elements calcium, cobalt, iron, copper and zinc. Nickel can replace essential metals in the metallo-enzymes and may leads to the disruption of metabolic pathways. Ni can accumulate in aquatic life, but its magnification along in food chain is not confirmed (Lokhande et al. 2011). Nickel is known to be a calcium channel blocker (Zamponi et al. 1996) thus the decrease in transport of Ca(II) to intracellular space is compensated by increase of free Ca(II) from intracellular stores. These changes of intracellular concentrations of Ca(II) have been shown to signal gene expression changes associated with cell growth, differentiation and apoptosis (Rosen et al. 1995). Nickel is not a cumulative metal; it is excreted well via urine and feces. Following absorption, the kidney
is the primary route of elimination. Excretion of nickel also occurs in the saliva and sweat, which may contribute significantly to the elimination of nickel in hot environments (Valko et al. 2005).

Zinc is a relatively abundant metal, which is found at varying concentrations in nearly all uncontaminated aquatic and terrestrial ecosystems from geological rock weathering. Metalliferous mining activities, ore-dressing and processing, agricultural use of sewage sludge and composted materials, and the pesticides are the main pollutant source of Zinc in the environment and it is one of the most common heavy metal pollutants. In the aquatic environment it will predominantly bind to suspended material before finally accumulating in the sediment (ATSDR 2000); (Bryan & Langston 1992). Re-solubilisation back into an aqueous, more bioavailable phase, is possible under certain physical-chemical conditions, e.g. the presence of soluble anions, the absence of organic matter, clay minerals and hydrous oxides of iron and manganese, low pH and increased salinity (ATSDR 2000). The permissible limit of Zn 5.5 mg/L as per USPH standard (Lokhande et al. 2011).

Zinc belongs to a class of microelements which are essential for proper functioning of the body (Hilmy et al. 1987) (Kotze et al. 1999). Zn deficiency can cause an increase in membrane permeability (Cakmak 2000). Fish take it up directly from water, especially by mucous and gills (Skidmore 1964). Zinc is an activator of numerous enzymes present in the liver as recorded by (Yacoub 2007) and (Cogun et al. 2005). High quantities of zinc in the aquatic environment can have a direct disrupting effect on the external cell membranes or cell walls of organisms, resulting in rapid mortality. The rare toxicity of zinc arises from its synergistic/antagonistic interaction with other heavy metals particularly its homologue cadmium. Authors like (Annune et al. 1994b) reported that zinc could cause sub-acute effects that change fish behaviors. Such observed behaviors include lack of balance since most fins are motionless in the affected fish, agitated swimming, air gulping, periods of quiescence and death (Kori-Siakpere & Ubogu 2008a); (Kawade & Khillare 2012) suggested excessive intake of zinc causes digestive problems and causes kidney damage.
Cadmium (Cd) is a heavy metal with no known biological function and is a highly toxic metal. The average concentration in natural waters is 0.4µg/l. It is introduced into the aquatic environment primarily by human activities like mining, fertilizer application and industrial discharges (James & Little 2003); (Ezemonye & Enuneku 2005) by the use of cadmium in electroplating, in photographic industry and in the manufacture of storage batteries, pigments, glass ceramics and plastic stabilizers, phosphate fertilizers using cadmium containing rock phosphate as the raw material (Forstner & Wittman 1979). In drinking waters the maximum permissible concentration set by World Health Organisation recommended guideline concentration of 0.005 mg/L (WHO, 2008). Although its concentration in the aqueous environment, both in water and sediment are low, several fold enrichment is observed in the aquatic biota. It is bioaccumulative and persistent in the environment with a residence half-life of 10-30 years (ATSDR 2000). Cd (II) has moderate covalency in bonds and high affinity for sulfhydryl groups, leading to increased lipid solubility, bioaccumulation and toxicity. Cadmium accumulates in liver and kidney through its strong binding with cysteine residues of metallothionein.

There is no known mechanism for controlling cadmium levels in humans, together with relatively longer half-life in biological systems makes cadmium one of the most toxic metals (Craig 1986). Cadmium has been shown to stimulate free radical production, deplete antioxidant levels resulting in oxidative deterioration of lipids, proteins and DNA and initiating various pathological conditions in animals and humans (Shaikh et al. 1999). Cadmium can also replace essential metals such as copper and zinc in several metalloproteins, altering the protein conformation and affecting their activity because this element interacts ubiquitously with sulphydryl groups of amino acids, proteins and enzymes (Serafim & Bebianno 2007). Thus, the toxic effects of cadmium are related to changes in natural physiological and biochemical processes in organisms (Ezemonye & Enuneku 2011). The kidney is the main target organ of cadmium toxicity in humans, following extended exposure (ATSDR 2000). It is equally toxic to invertebrates and fishes (Moore & Ramamoorthy 1984).
Lead is a naturally occurring metallic element that is present in the environment in low levels, principally in ionic forms. The average concentrations of lead in river and ocean waters are 0.1 and 0.003 µg/l respectively (Martin & Whitfield 1983) although rivers flowing adjacent to industrialized centers may contain up to 100 µg/l. The permissible limit for lead in drinking water is <0.05mg/L (WHO, 2008). Sources of lead contamination to the environment include fairly localized impacts such as disposal of lead-acid batteries, lead based paint wastes in landfills, fillings from the processing of lead minerals etc. Atmospheric fallout is usually the most important source of lead in the freshwaters (Moore & Ramamoorthy 1984). Although the amount of lead remaining in solution in surface waters is often low, with the major fraction bound to suspended or bottom sediment particles (ATSDR 2000). Re-entry to surface waters can occur as a result of erosion of lead-containing soil particulates, or through formation of relatively soluble lead sulphate at the soil / sediment surface (ATSDR 2000).

Lead does not have detectable biological roles. Lead can enter the human body through uptake of food (65%), Water (20%) and air (15%) and cause several unwanted effects, such as: Disruption the biosynthesis of haemoglobin and anaemia a rise in blood pressure, Kidney damage and Miscarriages and subtle abortions, disruption of nervous systems, brain damage, declined fertility of men through sperm damage and diminished learning abilities of children and behavioural disruptions of children, as aggression impulsive behavior. Lead has a tendency to accumulate in tissue and organs of exposed fish resulting in hepatic and renal dysfunction with growth retardation (Haneef et al. 1998). Lead has been reported to enter mitochondria, induce swelling and distortion of mitochondrial cristae, uncouple energy metabolism, inhibit cellular respiration and alter calcium kinetics. Lead induces apoptosis in a number of experimental systems (Iavoccoli et al. 2001); (Gulati et al. 2010).

Arsenic is widely distributed in soils, sediments, water, air and living organisms. Arsenic concentrations found in natural waters range from less than 0.5 mg/l to more than 5000 mg/l. Extreme concentrations are rare but are most frequently found in
groundwater (Smedley & Kinniburgh 2002). Arsenic, despite its poisonous reputation, may be a necessary ultra trace element for humans, red algae, chickens, rats, goats, and pigs. A deficiency results in inhibited growth. Arsenic has its source from ground water enriched with arsenic, arsenic containing pesticides, mining operations and agriculture run off (Chakraborty et al. 1998).

Arsenic is a protoplastic poison due to its effect on sulphydryl group of cells interfering with cells enzymes, cell respiration and mitosis (Gordon & Quastel 1948) and leads to cancer and terratogenic effects. Arsenic enters the human body through ingestion, inhalation, or skin absorption. Most ingested and inhaled arsenic is well absorbed through the gastrointestinal tract and lung into the blood stream, 95 to 99 % of the arsenic is located in erythrocytes, bound to the globin of hemoglobin and is then transported to the other parts of the body. It is distributed in a large number of organs including the lungs, liver, kidney, and skin (Hunter et al. 1942). Most arsenic absorbed into the body is converted by the liver to less toxic methylated form that is efficiently excreted in the urine. Acute arsenic exposure may promote immediate gastrointestinal tract infection whereas chronic effects may exert degenerative, inflammatory and neoplastic changes of respiratory, haematopoietic, cardiovascular and nervous system (Neiger & Osweiler 1989).

As far as living organisms are concerned, the overall health status depends on the physiological wellness of individual organs ultimately the proper structure and function of the tissues. Metal ions are considered as the dangerous and harmful ones among various pollutants which are organic or inorganic in nature due to their tissue degenerative nature. Heavy metals become toxic when they are not metabolized by the body and they are accumulated in the soft tissues. Among the tissues affected by heavy metal toxicity, blood is one of the primary targets due to its immediate exposure after absorption. Blood plays a decisive role in the regulation of life processes to make them function properly. An organism must be able to keep its blood composition relatively constant under normal conditions and must also have the ability to change it under extreme conditions such as stress situations. Changes occurring in the hematological characters of fishes provide a
sensitive measure to assess the health of fish fauna. So the fish blood is a valuable
diagnostic tool for the investigation of diseases and physiological or metabolic
alterations(Soundararajan & Veeraiyan 2014). The heavy metals accumulate in the
hemopoietic tissues and by their suppression(Kumada et al. 1980), the defect in iron
metabolism caused by deficiency in intestinal absorption (McKie et al. 2001), entry of
heavy metals into the RBC and the oxidation or denaturation of Hb by inhibiting the
glycolysis or metabolism of the hexose monophosphate shunt (HMPS)(Kumada et al.
1980), etc may induce anaemia. Arsenic, lead, copper, like heavy metals, toxins chlorates,
and a variety of other chemicals can cause severe red cell destruction, and hemolytic
anemia is a part of the clinical syndrome associated with intoxication by these substances.
Arsenic may cause hemolysis by interacting with sulphydryl groups. Lead inhibits a variety
of red cell enzymes, including several enzymes of porphyrin metabolism and pyrimidine-5’-
nucleotidase. The anemia that it produces is usually not primarily hemolytic in nature.

Next to blood, Liver is one of the secondary targets of pollutants like heavy metals.
It is the most multifaceted and active organs in higher animals. In a vertebrate body, the
liver is the most important target organ as it is the chief metabolic and detoxification center
(Abbasi & Krishnan 1993). It is the site for numerous and varied metabolic activities,
including synthesis of bile which contains bile salts, bile pigments, cholesterol and lecithin.
The chemical once absorbed is transported by the blood to either a storage point, such as
bone or to the liver for transportation. In the liver it may be stored there, excreted in bile, or
passed back into the blood for possible excretion by kidney or gills or stored in extra
hepatic tissues such as fat (Javed & Usmani 2011). The liver may accumulate in the liver to
toxic levels and cause pathological alterations (Khangarot 1992). Fish liver also plays an
important role in vital functions and is the major organ for accumulation, biotransformation,
and excretion of contaminants in fish(Triebskorn et al. 1994); (Triebskorn et al. 1997).The
liver tissues in fish are more often recommended as an environmental indicator of water
pollution than any other organs.
General Introduction and Objectives

Gill tissue is an organ having a large surface and separates blood from water in fish and is very susceptible to changes in concentrations of the variables (heavy metals, temperature, pH etc.) in the environment. These variables affect the structural integrity of the gill and cause morphological changes. For this reason gills are good indicators of water pollution (Bhagwant & Elahee 2002); (Koca et al. 2005). The gill is an important site for the entry of heavy metals that provokes lesions and gill damage (Bols et al. 2001); (Lock & Van Overbeeke 1981). Because the gills are intimately associated with ionic regulation it is predictable that heavy metals will influence aspects of osmotic and ionic regulation in fish (Alphonsa 2013). The direct exposure of gills in the water medium has been dominantly accepted as they are the main site to water contamination and toxicity (Karan et al. 1998).

Muscle tissue forms a major part of the body weight of fish when compared to other vertebrates (Fabbri et al. 1998) and is also economically valuable (Javed & Usmani 2011). An investigator listed hyperproteinaemia, hyperlipaemia, induction or inhibition in enzyme activities, dystrophy, etc in response to various aquatic pollutants including heavy metals in various organs like muscle (Yousafzai & Shakoori 2007).

The thesis on “Pollution stress responses in fishes of Periyar River at Ernakulam district in field and experimental conditions” presents a comprehensive study on the concentration of Pb, Ni, Zn, Cd and As in selected stations of Periyar River, its bioaccumulation as well as its effects on the histological, haematological, biochemical changes in the fish, Anabas testudineus by suitable bioassay methods. The work also carried out a detailed analysis of recovery of these characteristics by transferring fish from polluted water to pollution-free water in the laboratory conditions.

Anabas testudineus (Perciformes: Anabantidae) (Bloch 1792) was selected for the study as it forms a good candidate species for bioassay studies due to its hardy nature, presence of accessory respiratory organs, ability to live out of water for long time, economic importance as table fish, ornamental fish, its ecological importance, availability etc. It is fresh water, euryhaline and eurythermal teleost. These fishes are well known for
their air breathing ability, and they can survive out of water in moist air for six days. Slender fish with large scales, spines on gill cover, Scales on the head rigidly attached to the skull bone, strongly ctenoid, Grey brown to silver colour, with a dark spot on the base of caudal fin. Omnivorous feeds on macrophyte vegetation, different invertebrates, and small fish. No parental care. No sexual dimorphism, the fish will spawn in the evening between plants, and the egg hatch in 24-36 hours. This fish is extremely adaptable, and can be kept in any water, soft, hard, alkaline and acidic, even in brackish water. They are nick-named as ‘Climbing perch’ since them ascent banks and even lower branches of trees. These fish are cultured in ponds and they have a very good commercial value, because of their nutritive value and taste. The fish *Anabas testudineus* has been selected as the test animal because of its euryhaline and eurythermal nature, and unique position in food chain. They are quite sturdy and ideally suited for experimentation in laboratory for longer periods (Afsar et al. 2012). This fish was selected because they qualified most of the criteria for a standard fish as suggested by (Adelman & Smith 1976). Besides there was another reason behind its selection as a material for the present study that it was one among the few fishes that can be uniformly obtained from the selected stations.
General Introduction and Objectives

1.2 Objectives

The thesis is divided into seven chapters to pursue the following objectives:

- Concentration of selected heavy metals like Lead, Nickel, Zinc, Arsenic and Cadmium in water, sediment and biomass of contaminated regions of Periyar River at Ernakulum district.
- Is there any significant seasonal variation in the concentration of these metals in water, sediment and biomass collected from selected stations and the relationship if any, exist between them.
- Influence of the pollution on the haematological, histological, biochemical and antioxidant parameters in selected organs of fish (*Anabas testudineus*) collected from the site.
- Correlation between various haematological, biochemical and antioxidant parameters in *Anabas testudineus*.
- Amelioration of the heavy metal pollution induced alterations in haematological, histological, biochemical and antioxidant parameters in *Anabas testudineus* by the treatment in controlled laboratory conditions for 30 days.