CHAPTER I

GENERAL INTRODUCTION

The quest of man to conquer nature has led to ever increasing degradation of the environment than envisaged. Scientists and environmentalists now appear to be strongly committed to collaborate in finding long term solutions to these vexing environmental and resource problems. The far reaching consequences of the problem can only be solved by making the people environmental conscious, thereby achieving a transition into a sustainable society. Rapid rate of urbanization has imposed great strain on man and ecosystem. Population explosion compounded with pollution from anthropogenic activities has affected aquatic and terrestrial ecosystems, threatening human life and generating massive economic loss. Thus, multifaceted activities like rapid industrialization, expanding population and agricultural activities have severely affected the status of coastal environmental zones (Nirmala *et al.,* 2002).

The Indian sub-continent is blessed with a long stretch of coastal zone that delivers a variety of local and global economic benefits. It supplies a variety of living and non-living resources, which offer opportunities for employment, income, amenities and pleasure to the local people. Biological diversity of coastal ecosystems is economically valuable at the global level too. However, the recent global concerns expressed in various national and international conferences and conventions about the irrational use of coastal resources and biodiversity degradation have completely altered the attitude of policy makers and politicians. More than 200 rivers are seen flowing towards the west coast of India and evolve as estuaries before joining the Arabian Sea. These systems are exposed to the tides from the sea on the west and receive fresh waters of about seventy thousand million cubic meters making the water brackish throughout the year. Backwater systems in Kerala, for instance, have their bed levels at about 1.5 m to 1.8 m below the mean sea level and normally remain separated from the sea by a narrow strip of land of about 0.4 km to 12 km wide. The tropical wetlands and estuaries are known for their biological diversity and are considered to be the most productive yet complex ecosystems of the world that support the livelihood of coastal communities. They provide a diversified portfolio of goods and services and are considered to be of immense value. Being the largest common property ecosystems, estuaries play a dominant role in the economy of Kerala (Remani *et al.*, 1989 a).

1. 1 Wetlands of Kerala: Present Scenario

Wetland systems directly and indirectly support lakhs of people, providing goods and services to them. They help to check floods, prevent coastal erosion and mitigate the effects of natural disasters like cyclones and tidal waves. They store water for long periods. Their capacity during heavy rainfall to retain excess floodwater that would otherwise cause flooding results in maintaining a constant flow regime downstream, preserving water quality and increasing biological productivity for both aquatic life as well as human communities of the region. The importance of wetlands was clearly demonstrated by 2004 Indian Ocean Tsunami.

Wetlands may have provided a green barrier to protect coastlines and the coastal communities that live there. There were localized and anecdotal reports from around the Indian Ocean region of how the damaging impact of Tsunami was reduced behind mangrove stands and coral reefs. Wetlands also provide food and shelter for mammals. They act as natural filters and help to remove a wide range of pollutants from water, including harmful viruses from sewage and heavy metals from industries. Wetlands retain nutrients by storing eutrophic parameters like nitrogen and phosphorus by accumulating them in the sub-soil, thereby decreasing the potential for eutrophication. The importance and usefulness of wetlands was first brought to the notice of the world through a Convention on Wetlands held at the Iranian city of Ramsar, in the year 1971. The Convention was an inter-governmental treaty that provided the framework for national action and international co-operation for the conservation and wise use of wetlands and their resources. As of 9^{th} March, 2007 there are 154 Contracting Parties to the

Convention, with 1650 wetland sites, totaling 149.6 million hectares, designated for inclusion in the Ramsar list of Wetlands of International importance (Kerala State Environment Report, 2007).

According to Ministry of Environment and Forests, Government of India, wetlands are broadly divided into inland wetlands and coastal wetlands and each class is further divided into different types. Geomorphologically, the wetlands in Kerala may be divided among five major systems at the broadest level as marine, estuarine, riverine, lacustrine and palustrine. Due to the unique physical characteristics, Kerala endows like backwater systems and a diverse terrain of high land, midland and low land within a thin strip of landmass of about 38864 sq km. Accordingly, the following major wetland classification system was suggested by Centre for Environment and Development (2003), which is shown in Table 1.

Table 1. Classification Scheme for Wetlands of Kerala

Wetland classes	**Wetland type**
Inland Wetland	Fresh water lakes
	Fresh water swamps
	Reservoirs
	Large ponds
Coastal wetlands	Estuaries/ backwaters
	Mangrove Forests
	Kol, Kuttanadu and Pokkali wetland systems
	Coastal swamps
	Mud flat
	Aquaculture ponds
	Islets/Thuruthu

(Source: Centre for Environment and Development, , Project report-2003)

In Kerala, despite its small land area of 38864 km^2, bestowed with 590 km coastal area, vast network of backwaters, lagoons, natural lakes, rivers and canals.

The State has two clearly distinct rainfall seasons i.e., south west monsoon and north east monsoon resulting in near water-logged conditions in almost 20% of the total geographic area of the State. Thus, as much as one fifth of its total landmass is wetlands. Nair *et al.* (1985) reported a total of 217 wetland areas in Kerala (Table 2), of which 157 wetlands are greater than 56.25 ha. with an aerial extend of 127930 ha, in which 64 designated as "inland wetlands" (area 34199.5 ha), whereas 93 are "coastal wetlands (area 93730.5 ha). There are 30 major backwaters/estuaries in Kerala (Table 3).

Table 2. Area under wetlands of Kerala

Wetlands		Area (ha)	% Area	No. of units
Inland wetlands	Natural	2180.00	1.70	11
	Manmade	32019.57	25.03	64
	Total	34199.57	26.73	64
Coastal wetlands	Natural	85671.50	66.97	86
	Manmade	8059.00	73.27	93
	Total	127930.07	100	157

(Source: Centre for Environment and Development, , Project report-2003)

The wetlands of Kerala are treated as sites of exceptional biodiversity in the country and are characterized by several endemic species. The coastal plains have been ravaged since early times of human habitation and most of the land is now used for housing and agriculture. Even these disturbed habitats are potential location for rapid speciation has been amply proved from the long list of new taxa discovered and described from here during the last two decades. Increased trade and commercial activity has brought with it a large number of aquatic and wetland weeds into this area. Moreover, such activities have also resulted in the creation of man-made reservoirs, abandoned granite quarries and clay pits which, in course of time, have provided ideal habitats for aquatic biota.

Table 3. Major Backwaters/Estuaries in Kerala		
No	**Name**	**District**
1	Manieswer	Kasaragode
2	Nileshwar backwater	Kasaragode
3	Chandargiri	Kasaragode
4	Cheruvathoor	Kasaragode Kannur
5	Palakode	Kannur
6	Dharmadam	Kannur
7	Valapattanam	Kannur
8	Mahe	Kozhikode Kannur
9	Korapuzha estuary	Kozhikode
10	Kottapuzha backwater	Kozhikode
11	Payyoli	Kozhikode
12	Beypore estuary	Kozhikode
13	Rorapuzha	Kozhikode
14	Kallayi backwater	Kozhikode
15	Kadalundi estuary	Kozhikode/Malappuram
16	Ponnani backwater	Malappuram
17	Chettuva backwater	Thrissur
18	Azheekode estuary	Thrissur
19	Kodungalloor backwater	Thrissur
20	Vembanad backwater	Ernakulam Kottayam & Alappuzha
21	Cochin estuary	Ernakulam
22	Kayamkulam backwater	Alappuzha kollam
23	Ashtamudi estuary	Kollam
24	Paravoor backwater	Kollam
25	Edava Nadayara backwater	Thiruvananthapuram
26	Anchuthengu backwater	Thiruvananthapuram
27	**Kadinamkulam estuary**	**Thiruvananthapuram**
28	Veli lake	Thiruvananthapuram
29	Poonthura backwater	Thiruvananthapuram
30	Poovar backwater	Thiruvananthapuram

(Source: Thomson, 2003)

An outstanding feature of the Kerala's coastal zone is the presence of a large number of perennial or temporary estuaries popularly known as backwaters. Thirty backwaters occur along the 590 km long coast of Kerala covering an estimated area of around 2, 42,000 ha. An important characteristic of backwaters is their biological diversity, which refers to the diversity of various species of living organisms, plants and animals, the presence of various ecosystem services, and genetic diversity. Such diverse combinations of living organisms and ecological services constitute the natural resource entitlements of the local communities. The wide variety of fish and shellfish resources, aquaculture systems, the brackish water agriculture, mangroves and innumerable forms of microorganisms are directly useful and sustain the economy of local population (Nair and Aziz, 1984).

Apart from the direct tangible flows of economic benefits, estuaries also provide a variety of indirect services to local communities and to the rest of the world which also enhance the economic significance of these ecosystems manifold. The capacity of estuaries to regulate various gases, climate, water currents and flow, soil erosion and sedimentation, retention and soil formation, nutrient cycling, waste treatment, pollination and thereby control the various biological processes is well recognized. Moreover, estuaries supply various kinds of recreation services and act as the primary pool of genetic resources. In fact, these diverse ecosystem functions along with the direct flow of benefits through the supply of various goods and services make these systems valuable to humanity. These services are enjoyed by human users almost free of cost or at a price much below the cost of acquiring alternate but similar services (Joseph, 2002).

For the last two decades, estuarine resources and environment in India had been intensively used by modern enterprises subject to the development of international markets. Apart from the state and central government enterprises, a number of new firms started modern industrial activities, using estuarine resources and environment indiscriminately. The process was started in Kerala way back in 1939, with the state sponsored drive towards industrialization. Today, there are at least 150 small and large industrial establishments located close to the backwaters (Thomson, 2001).

Although the process of industrialization of different states has been accelerated due to the development of a modern industrial agglomeration around estuaries, it soon started generating external costs to traditional economic activities like fishing, agriculture, aquaculture, coir making, clam fishing, lime shell collection, traditional ferry and transport services etc. Pollutants released into the estuaries by various industries on the banks of the water body have caused severe reduction in the productivity of fishing activities and paddy cultivation. Aquaculture activities were also reduced manifold due to the impact of pollution (Subramanian, 2000).

1.2. Back Waters / Estuaries of Kerala

Backwaters and estuaries are used interchangeable to denote an estuarine space. Kerala coast is strikingly bordered by a string of backwaters, generally running parallel to the shoreline. These water bodies locally known as "Kayals" occupy extensive areas. The size of these water bodies is significantly varied. Out of the thirty backwaters of the Kerala coast, seven are characteristically river mouth estuaries. These backwaters are partially enclosed coastal body of water, which are either permanently, or periodically open to the sea with a measurable variation of salinity due to the mixing of seawater with freshwater (Thomson, 2001).

The backwaters of Kerala provide waterfront for several major and small-scale industries, amongst which coir-retting industry ranks first. This industry provides employment to a large number of people, especially women folk. The raw material for the industry is obtained by immersing the coconut husk in water for eight to none months. Retting of coconut husk presents unique and extremely serious problems along the coastal belt, changing the hydro-ecology of the water body. Traditional and conventional method of retting has adverse impacts on the ecosystem, including fauna, flora and human beings. Lack of dissolved oxygen, very high biological oxygen demand, chloride, hardness, nutrients and low pH, with foul smell of hydrogen sulphide is the characteristic features of the retting yards. Besides, the ecological degradation caused by the liberation of organic wastes during the retting process, the unhygienic conditions prevailing around the area results in health hazard problems to the people engaged in this cottage industry. A vast number of rural populations of coastal Kerala are engaged in retting industry. Irrespective of their age, they find this work as the source of their principle income. The most striking aspect of the retting industry is that the workers in the retting site spent almost the whole day in the unhygienic conditions prevailing in the yard. The areas around the retting yards are inhabited mainly by the community engaged in coir industry. Hence job related diseases are likely to occur among these people. Common diseases likely to occur among the people are filariasis, eye diseases, skin diseases, oedema of lungs and headache due to the inhalation of poisonous gases (Nirmala *et al.,* 2002).

1.3. Retting Process and its Biochemical Aspects

The usual practice of extraction of the fiber commonly employed in India and Sri Lanka is by the natural retting process. The term "retting" designates the process of decomposition of tissues surrounding the vegetable fibers (Nathawal, 1967). This is basically a *"soaking process"* where husks are arranged in bundles in huge coir nets known as *"malis"* and allowed to float freely in the backwater (estuarine) tracts until they get soaked, become heavy and gradually sink to the bottom. Often, the bundles are weighed down by piling on their top with mud and slime collected from the bottom of the backwaters. This method is known as *"net retting".* In some areas the husks are also steeped in pits dug within the reaches of tidal action of back waters. In such situation the process is known as *"pit retting".* When retting is carried out in stakes made out of bamboo splinters it is referred to as *"stake retting".* The period of retting generally varies from 8 to 9 months (Nandan, 2002).

Retting of coconut is basically a biological process involving the release of a variety of biochemical compounds. During the principal biological stage, the anaerobic pectin decomposers dissolve the pectin's in the middle lamella of the parenchymatous tissues and separate the fibre bundles. Markedly offensive odour, resembling those of hydrogen sulphide emanate from the retting pits at this stage. The reason for their development is not fully understood, though it is assumed that they are due to secondary microbiological decomposition processes involving a resolution of the cellulose materials. The odor of methane is particularly noticeable in places where the debris of previous retting has accumulated. Of the various organic compounds like phenol, tannin, lignin, hemi cellulose etc. released during the retting process, pectin decomposition forms the most important function. The breakdown of pectin is affected by three different enzymes in three stages. During the first stage, protopectinase converts insoluble protopectin to pectin, in the next stage demethylation of the pectin is effected by the action of pectase and pectic acid is formed. Pectinase then breaks up the 1-4 linkages of the macromolecule of pectic acid, resulting in the formation of galacturonic acid, arabinose, and galactose. The study also revealed that the pectinolytic enzyme trans-eliminase was detected in the *Bacillus* sp. and certain *Micrococcus* sp. from the retting grounds. The rise in temperature of the ret liquor is believed to be due to the activities of cellulolytic organisms. Cellulose is the major constituent of the secondary cell walls of the husk. Hydrolysis of cellulose ultimately yields glucose, which is an important source for the microorganisms. The enzyme celluloses mediate the breaking down of cellulose. Many microorganisms secrete these enzymes, often splitting up of protein leads to the evolution of foul smelling gases (Jayasankar, 1966).

1.4. Ecology of Retting Zones

The lucrative fishing industry and coir industry of Kerala state have been heavily dependent on the estuarine ecosystems represented by estuaries, lagoons and coastal inlets. Retting activity has caused extensive pollution and mass destruction of flora and fauna in these water tracts. The large scale depletion of the estuarine fisheries has also been attributed to the increasing retting activity. Soaking of large quantities of coconut husks and prolonged periods of retting in the estuarine basins have converted vast areas of the estuaries into virtual cesspools of foul smelling stagnant waters. Retting of jute and allied plant materials has also been found to be a source of pollution in the water bodies of several parts of India and outside. But of all retting activities, coconut husk retting is the most acute form of pollution affecting the aquatic ecosystems and converting sizeable sections of the reproductive water bodies into foul smelling stagnant narrow tracts (Nandan, 2002).

Fish kills have been reported from several areas of Kadinamkulam estuary during premosoon period of every year resulting from the extensive depletion of dissolved oxygen and massive production of hydrogen sulphide. The surface water of the retting area is continuously dimpled and ringed by ripples caused by the rising and bursting at the surface of bubbles of gas. Thus the air covering the area gets charged with hydrogen sulphide gas. Water surface of the retting zones presents a milky appearance during the period from February to June probably on account of bacterial precipitation of the molecular Sulphur from H_2S, when the water comes into contact with oxygen. This milkiness may disappear when the molecular sulphur is converted to sulphate by further bacterial action. The studies conducted by Aziz (1985) and Nandan (1997) on the ecology of the retting grounds have clearly proved beyond doubt that the retting activity in the backwaters has caused grave pollution problems.

1.5. Hydrogen sulphide Toxicity

Toxicology is the study of how specific chemicals cause injury to living cells and organisms. It is a study to determine how easily the chemical enters the organisms, what cells are affected by the chemical and what cell functions are impaired (USEPA, 1991). The inherent property of chemicals to cause adverse biological effects is known as toxicity. Toxicity is thus the result of disturbances induced by a chemical that affect the complex and interrelated systems of chemicals, tissues and organs as well as their metabolic processes (Bridges *et al.*, 1990).

Hydrogen sulphide is a potentially lethal gas produced by anaerobic decomposition of protein and other sulfur containing organic matter. It is an irritant gas that produces local inflammation of the moist membranes of the eye and respiratory tract in human beings. Exposure to concentrations (>150 ppm) of hydrogen sulphide may impair the sense of smell, hindering the olfactory detection of high concentrations of the gas. The toxic effects of hydrogen sulphide are based on its property as a chemical asphyxiate. It binds to the mitochondrial enzyme cytochrome oxidase, blocking oxidative phosphorylation and ATP production. This leads to anaerobic metabolism and development of lactic acidosis (Haggard, 1992).

The objective of ecotoxicological studies are to predict, diagnose and prevent the cause of biological/ecological effects as the result of exposure to pollutants in the environment. If an organism has acquired a pollutant load that cannot be tolerated, detoxify or excreted, it can result in the organism's death (Depledge and Fossi, 1994). Chronic stress causes when the organism undergoes either continuous or periodic exposure to low levels of stressors for a period of weeks or years. Because the adverse effects are generally first at the sub-organizational level, sub-lethal or chronic stress is treacherous and is more common than acute stress. Organisms like fish are continuously challenged or stressed by the normal demands of the aquatic environment and may be exposed to sub-lethal levels of contaminants and to unfavorable environmental variables like temperature, water velocities, sediment loads, dissolved oxygen concentration, food availability and other variables. These factors can impose stress on physiological systems (Wepener, 1997).

Because of man's interest in pollution being created on its effects on living organisms, there has been rapid international monitoring over the past two decades.

The understanding and predictions of the reactors and influence of toxicants in and out the environment have become important issue in environmental quality assessment. It is also important in the assessment of the risk or hazard associated with their presence in the environment (Heath and Classon, 1999).

1.6. Oxidative Stress and Fishes

Fishes are exposed to environmental, physical, and biological stressors in nature, as well as under conditions such as aquaculture or angling. In response to such stressors, fish undergo a series of biochemical and physiological changes in an attempt to compensate for the challenge and, thereby cope with the stressor. Physiological responses of fish to environmental stressors have been grouped broadly as primary and secondary. Primary responses, which involve the initial neuro endocrine responses, include the release of catecholamines from chromaffin tissue (Randall and Perry, 1992; Reid *et al.,* 1998) and the stimulation of the hypothalamic-pituitary-inter renal axis culminating in the release of corticosteroid hormones into circulation (Donaldson, 1981; Wendelaar, 1997; Mommsen *et al.,* 1999). Secondary responses include changes in plasma and tissue ion and metabolite levels, hematological features, and stress proteins, all of which relate to physiological adjustments such as in metabolism, respiration, acid-base status, hydro-mineral balance, immune function and cellular responses (Pickering, 1981; Iwama *et al.,* 1997; Mommsen *et al.,* 1999). Additionally tertiary responses occur, which refer to aspects of whole animal performance such as changes in growth, condition, overall resistance to disease, metabolic scope for activity, behavior, and ultimately survival (Wedemeyer and Mc Leay, 1990). This grouping is simplistic, however, as stress, depending on its magnitude and duration, may affect fish at all levels of organization, from molecular and biochemical, to population and community (Adams, 1990).

Thus, chronic exposure to stressors can lead to decreases in features such as growth, disease resistance, and reproductive success. There are differences in the stress responses among species (Vijayan and Moon, 1994). Stressors activate the alarm responses in all physiological compartments and neuro-endocrine mediators are mobilised as a first response. The release of these mediators, mainly hormones generate physiological and metabolic changes that allow organisms to drive energy in order to cope with the stressor, at least at short-term basis. When the stressor is chronic maladaptation may occur and it is known that one the consequences of maladaptation is the depression or suppression of immune mechanisms (George *et al.*, 2004).

There are many different types of contaminants present in the environment. These range from synthetic chemicals to trace metals that are required for life. Concerns about these contaminants range from possible harmful effects on the ecosystem possible harm to humans consuming such contaminated organisms (Melancon, 1995). Stress has many consequences to the overall quality of health and longevity of fish. It causes biochemical, physiological and behavioral changes. Stress factors induce the mobilization and reallocation of energy (Barton *et al.*, 1988), increase oxygen uptake and transfer, and suppression of immune function (Maule *et al.*, 1989; Mock and Peters, 1990).

The sub-lethal levels of pollutants usually cause biochemical or physiological effects at the basic level of organisation, the sub cellular level in an organism. Data on sub-lethal level would help in identifying the toxicant causes the effects before dramatic changes (e.g. mass mortality) occur in the natural population in the aquatic ecosystem. Before death of the organism can occurs normal physiological process are effected and death being too proper criteria for determining whether a substance is harmful or not, it is important to find bio-indicators/biomarkers of health and sub-lethal toxicant effects (Van Vuren *et al.*, 1999).

Experimental studies using live, intact creatures have played, and continue to play, an essential role in developing new knowledge and better understanding of life processes, life forms, and the environment in which these forms and processes occur. The enormous evolutionary radiation of fishes comprises at least 25,000 species. Fishes exist in myriad forms and have developed many unique physiological, behavioral, and ecological specializations. Fishes occupy a variety of niches in virtually every kind of aquatic habitat. Understanding their biology simply cannot be accomplished in the absence of experimentation with live, intact animals (Bruce, 2002).

The environment that surrounds an organism plays a critical role in the growth, development and well being of that organism. A clear cause-effect relationship upon exposure of a given organism or a cell to a particular environmental factor or stressor has been demonstrated. Some kind of sensing mechanism(s) must be present to alert the cells to imminent danger, and to trigger the orderly sequence of events that will mitigate the danger. Organism from the simplest to the most complex had developed methods to cope with stressful stimuli. Consequently most living cells have the ability to cope with a wide array of environmental challenges, including natural and synthetic toxins, extreme temperatures, oxidative challenge, high metal levels and radiation (Scandalios, 1992). The cellular biomarker responses provide the greatest potential for identifying when conditions have exceeded compensatory mechanisms, and the individuals and populations are experiencing chronic stress, which if unmitigated may progress to severe effects at the ecosystem level. They are routinely used as diagnostic tools in biomedical applications, as early warning signals of early disease conditions, for prognosis, and evaluating the effectiveness of remedies. These kinds of frame work can be applied to estuarine organisms as a means of characterizing habitat quality. To do this effectively, it requires a sound basis for interpreting cellular data, including expected values and an appreciation of the potential variation. According to Van der Oost *et al.* (2003) fishes are generally considered as the most feasible organisms for pollution monitoring in aquatic systems.

According to Selye (1973) 'stress' is ''the nonspecific response of the body to any demand made upon it''. The response to stress is considered an adaptive mechanism that allows the fish to cope with real or perceived stressors in order to maintain its normal or homeostatic state. Stress can be considered as a state of threatened homeostasis that is re-established by a complex suite of adaptive responses (Chrousos, 1998). If the intensity of the stressor is overly severe or long lasting, physiological response mechanisms may be compromised and can become detrimental to the fish's health and well-being, or maladaptive, a state associated with the term ''distress'' (Selye, 1974; Barton and Iwama, 1991).

Oxidative stress or oxystress can be defined as an elevation in the steady state concentration of reactive oxygen species, which occur when the balance between the mechanisms triggering oxidative conditions and cellular antioxidant is impaired. Oxidative stress may ensue when the ability to buffer against reactive oxygen species (ROS) is exceeded either by excessive production of ROS or by depletion of antioxidant. This can alter cellular redox-poise and initiate a variety of responses via intracellular pathways (Sun and Oberley, 1996). Oxygen toxicity is defined as injurious effects due to cytotoxic ROS, also referred to as reactive oxygen intermediates (ROI), oxygen free radicals or oxyradicals (Di Giuloi *et al., 1989*; Halliwell and Gutteridge 1999; Winzer, 2001). These reduction products of molecular oxygen (O_2) are the superoxide anion radical ($O_2^{\bullet -}$), hydrogen peroxide and the hydroxyl radical ($^{\bullet}OH$), an extremely potent oxidant capable of reacting with critical cellular macromolecules, possibly leading to enzyme inactivation, lipid peroxidation (LPOX), DNA damage and, ultimately, cell death (Winston and Di Giulio, 1991). Defence systems that tend to inhibit oxyradical formations include the antioxidant enzymes superoxide dismutase, catalase, glutathione peroxidase (GPx) and reduced glutathione (GSH). SOD, CAT and GPx are critically important in the detoxification of radicals to non-reactive molecules (Stegeman *et al., 1992*; Lopez *et al., 1993*). Oxidative stress typifies the toxicity induced by xenobiotics (Lemaire and Livingstone, 1993). The enzymatic antioxidant system comprises of the superoxide dismutase (SOD), catalase (CAT) and peroxidase (POP). The biochemical antioxidants include glutathione, vitamin C, vitamin E, vitamin A, beta-carotene, bioflavonoid, ubiquinone etc. The enzymatic and biochemical antioxidant defense mechanisms work together to counter oxidative stress.

Lipid peroxidation leads to destruction of membrane lipids and production of lipid peroxides and their by-products such as aldehydes. Malondialdehyde is formed from the breakdown of polyunsaturated fatty acids (PUFA) and it serves as a convenient index for determining the extent of lipid peroxidation (Jamil, 2001). It is a biomarker of effect representing the state of membrane lipid peroxidation. Among the cellular molecules, lipids that contain unsaturated fatty acids with more than one double bond are partially susceptible to action of free radicals. The resulting reaction known as lipid peroxidation (LP) disrupts biological membranes affecting their structure and function. During lipid peroxidation a large number of toxic by-products are formed that have effects at sites away from the area of their generation. Hence, they behave as toxic second messengers. MDA is one of them which have major toxicological importance. Lipid peroxidation appears to have considerable potential as a biomarker for environmental risk assessment (Stegeman *et al.,* 1992; Hai *et al.,* 1995), although it can occur as a consequence of cellular damage due to a variety of insults other than exposure to xenobiotics causing oxidative stress (Kappus, 1987).

1.7. Relevance of the Study

The aquatic environment is the ultimate sink of toxic chemicals generated by man's industrial, agricultural and domestic activities. Pollutants discharged into streams and rivers are transported over long distances affecting ecosystems miles from the point of discharge. However the importance of monitoring and preserving the aquatic environment cannot be overemphasized, because water provides the life support system for aquatic life and all life forms. Fishes are important aquatic animals and are sensitive to wide variety of toxicants. As fish fauna serves as food source for humans, it is essential to know the impact of water pollution on fishes. *Oreochromis mossambicus* (Tilapia) is one of the most abundant species in the Kadinamkulam estuary and this estuary is polluted mainly by coir retting activities. There fore the present study is conducted to assess the impact of water pollution produced by coir retting especially the H_2S contamination on fishes in the estuary.

To determine the physico-biochemical changes with special reference to lipid peroxidative changes in fishes due to H_2S contamination both the field experiments and aquarium studies are also conducted.

1.8. Objectives of the Study

- To determine the hydrochemical characteristics of Kadinamkulam estuary with special reference to coir retting areas.

- To find out the sediment characteristics of the selected stations of the estuary

- To assess the fish diversity in the retting and non retting zones of Kadinamkulam estuary.

- To find out the morphological, biochemical, haematological and histopathological changes in *Oreochromis mossambicus* (Peters) one of the abundant species in the coir retting areas.

- To determine the morphological, biochemical, haematological and histological changes in *Oreochromis mossambicus* (Peters) exposed to hydrogen sulphide in aquarium conditions.

- To suggest the management measures for the conservation of Kadinamkulam estuary and its biota.