Chapter 1

General Introduction
The mad rat race among the nations over the globe for development has jeopardized the health of man itself. Progress in agriculture and industry has resulted into unlimited exploitation of every bit of natural resource. Such activities of man have adverse effect on all forms of living organisms in the biosphere. Unlimited exploitation of nature by man has disturbed the delicate ecological balance between living and non-living component of the biosphere. The unfavorable conditions created by man himself threaten the survival not only of man himself but also of other living organisms. The number of different animal species likely to become rare is increasing with time. It is very common to find warning at public places reading as "air unfit for breathing", "water unfit for drinking", "do not eat fish caught here" and so on.

The development of industrial civilization over the past six decades in the countries of west as well as those of the developing regions of the world have been largely associated with the expansion and emphasis on more and more of chemical industries and technologies. In fact, chemical technology has now penetrated major areas of human activities and influenced the life style of man. This rapid industrialization and successful green revolution have introduced a large variety of chemicals into our environment. These chemicals entering ecosystem affects man, animal life, plant life and materials and exert serious health and ecological problems. Such chemicals include pesticides for agriculture and health, metals for industries and monomers, plasticizers and stabilizers for plastics which are replacing the traditional materials like wood, glass and metals
in all spheres of life. Many of these chemicals due to their chemical structure and properties remain in the environment for long periods and continue to pose health risks and environmental problems. Several of these are even biomagnified in organisms (biomagnification) and some times biologically transformed (biotransformation) into more toxic chemicals as conversion of mercury into methyl mercury.

The unabated expansion of chemical industries and technologies indeed left a trail of anxiety and global concern. Today, there are more than four million chemicals which are either isolated from natural products or synthesized artificially which tend to alter the entire ecosystem thereby threatening the well being of every living organisms. Human eagerness to perform better and better with respect to the production of food, energy and convenience products in order to ameliorate the way of life has led to a tremendous growth in production of chemicals. In the last three to four decades the production of pesticides only in India increased more than 40 fold, where as the production of dyes, drugs, petrochemicals, fertilizers and metals increased to 30 folds, 5-10 folds, 40 folds, 30 folds and 3 folds respectively. It is evident that such increased production also leads to release of toxic and hazardous wastes into the environment in liquid, solid or gaseous state (Sharma, 1998).

More than sixty thousand chemicals are used in our day-to-day life in the form of fuels, industrial solvents, drugs, pesticides, fertilizers, food additives and consumer products and still many more. Besides these we are adding every year as
many as 500 to 1000 new chemicals to the existing array of chemicals. The species and varieties of environmental chemicals are as many as we can visualize. We may, however, characterize them as: industrial chemicals which include organic and inorganic substances, metals, gases, fumes, solvents and intermediates; agrochemicals, a major input of farming industry, comprising a variety of pesticides, fertilizers and growth promoters; drugs and pharmaceuticals in innumerable number and food additives, plastics, cosmetics, etc. These have caused great dangers and put man and environment at a high risk.

WATER POLLUTION:

More recently, a rapid pace of industrialization, coupled with uncontrolled exploitation of nature, has caused continuous dumping of industrial byproducts, hazardous chemicals and nuclear wastes, resulting in the pollution of river basins, lakes and seas. In this quest of wealth and comforts, man has ignored nature's law and thus disturbed a number of natural cycles. Environment is regarded as "the sum total of all conditions and influences that affect the development and life of organisms". Each living organism from the lowest to the highest has its own environment and this is affected by changes in natural cycle. During the last decade there has been increasing concern at the levels of industrial and agricultural activities contaminating the aquatic environment. Such pollution affects both the human health and the well being of animal population. Since the seas and lakes via rivers and other water sources become the final resting point for pollutants emanating from factory effluents and agricultural applications, it is in
such environment that we might expect to find the first warning of environmental catastrophe.

Water is a unique chemical essential for our survival and its pollution is a major global problem. Our rivers, lakes and seas have limits for observing pollutants and with an increasing world population; there is a subsequent increase in the discharge of sewage, industrial and harbor wastes and dumping of garbage. The contamination of natural waters with man made chemicals has caused serious problem to the aquatic biota (Arillo, et al., 1981; Reber & Brokott, 1983).

Water is considered to be polluted when it is altered in composition and is not suitable for domestic usage. This includes changes in the physical, chemical and biological properties of water. Discharge of liquid, gas or solid substance into water is likely to create nuisance or render such water harmful to public health and welfare and to domestic, commercial, industrial, agricultural, recreational and to other legitimate uses for live stock, wild animals and other aquatic biota (WHO, 1972). Poor quality of water caused by the pollutants is today a burning problem of both developed and developing countries (Chung & Chen, 1978; Kinako, 1979; Dakshini & Sen, 1979; Pande & Das, 1980). Still worse pollutants are the chemicals including pesticides and radioactive materials, which are carelessly dumped by industries. There have also been increases in oil pollution due to refinery effluents, off-shore production platform, pipeline and tanker accidents damaging ecological systems and badly affecting aqua fauna. In Feb/Mar, 1952 there was news of an oil slick drifting from Bangladesh towards India, which
affected marine life in the Sunderbans. The slicks are dangerous because these consist of non-biodegradable hydrocarbons, which could damage eggs and larvae of fish and crustaceans.

The rapid industrialization phase of human civilization has lighted the thought of chemical application for human welfare. The problem of anthropogenic or cultural eutrophication which has been greatly augmented by induction of sewage into natural water bodies has been the concern all over the world today (Vollen Weiber, 1968; Cole, 1979). The intrusion of indeterminable amounts and combinations of industrial chemicals into natural waters has caused ecological and biological changes, which is yet to be comprehensively analyzed and evaluated. The drastic effects of water pollution leading to mass fish kills are being reported every year by environmental protection agency (Southwick, 1976). One of such incidents was the fish kills of San Diego harbor (USA) in 1962 where death toll was estimated to be about 3,78,000,00 due to pollution. Another such fish kill was observed in the river Tajo during spring / summer 1991 (Munoz et al., 1994). Fish kill due to industrial effluents were reported on 29th October 1993 in Behlol Nullah, a tributary of river Tavi in Jammu (Dutta et al., 1997). Large number of fish kill due to water pollution in Husain sagar lake, Hyderabad, Andhrapradesh was reported (Deccan Herald, The daily, 8th May, 2000).

Pollution is one of the biggest killer of inland fish and traditional fisher folk are worst affected. Data from the Central Inland Capture Fisheries Research Institute (CICFRI), Barrackpore, shows that the fish catch in most rivers is
declining. The Ganga, for example receives mostly untreated effluents from 29 cities, 70 towns and thousands of villages. Annual inland fish landing of major carp species in Allahabad and Bhagalpur has drastically come down. Moreover, mass fish deaths have been reported in Gomti, a tributary of Ganga, on many occasions. Recently mass mortality of fish and migratory birds were observed at Annehole, Lingambudi and Kukkarahalli lakes near Mysore, Karnataka. (Deccan Herald, The Daily, 24th August, 2001).

It is the same story for every river in India. The Periyar in Kerala has been severely affected due to pesticides, industrial waste and sand mining. Dyeing industries have almost killed the Noyyal in Tamil Nadu. The Yamuna is nothing but a mighty sewage drain with zero aquatic life as it leaves Delhi. The fish catch has come down to 20 percent in the last three decades especially in the downstream of the Hirakud dam on the Mahanadi in Orissa (Down to Earth, 15th February, 2002).

The domestic wastes and the industrial effluents are being indiscriminately discharged into the nearby rivers, reservoirs, lakes and tanks with almost no pretreatment (Jhingran, 1982). In south India also the pollution of the rivers arises due to industrial effluents (Srinivasan & Sunder Raj, 1967). Water pollution is turning India’s famous lakes and tanks into dirty ponds and its major rivers into sewers, threatening the health of millions of people.

In Maharashtra, the coastal water of Mumbai have been polluted so much that the fish caught there, are not edible. Poor sewage disposal facilities in greater
Mumbai and unchecked industrial wastes have polluted the north coast of Colaba district (Statesman, 1979). A most dreadful picture of industrial pollution hazard originating from the state pencil factories of Mandsaur in Madhya Pradesh was reported (Mitra, 1980). Industry emits dense clouds of a fine light dust which the workers constantly inhale and the result is silicosis or pneumoconiosis, a lung disease similar to but much deadlier than tuberculosis. It can kill a person within six weeks with dry cough and suffocation. The figure of deaths due to silicosis is put to be around 2000 during the past five decades.

PEST AND PESTICIDE:

The definition of pest is a living organism, which is not wanted; it usually refers to a whole species or group of organism, present in considerable quantity, and at a time and at a place where the efficiency of some production or activity is threatened. Pests can be a major problem in many crops. They reduce crop yield and quality by feeding on the roots, stems, leaves and fruits of the crop plant.

Pesticides are toxic chemicals by design and as such they represent risks to the users. If the credits of pesticides include enhanced potential in terms of increased production of food and fiber, and amelioration of vector-borne diseases, then their debits have resulted in serious health implications to man and his environment. There is now overwhelming evidence that some of these chemicals do pose potential risk to humans and other life forms and unwanted side effects to the environment (Jeyaratnam, 1985; Igbedioh, 1991; Forget, 1993). No segment of the population is completely protected against exposure to pesticides and the
potentially serious health effects, though a disproportionate burden is shouldered by the people of the developing countries and by high-risk group in each country (WHO, 1990). In developing countries, where users are often illiterate, ill trained and do not possess appropriate protective devices, the risk are magnified (Levine & Doull, 1992).

Different groups and segments of a population are exposed to pesticides in different ways and in different degrees. These are intentional (occupational and homicides) and unintentional exposures (occupational and non-occupational exposures from water, air and food). The occupational hazards in industrial setting and ecological repercussions in the environment could be grouped under as;

1) Operational hazards could be during manufacture and formulation of pesticides in industrial settings and their distributions and use in field conditions.

2) Direct toxic effects on non-target animal life such as pollinators, predators, wild life, etc. during application of pesticides.

3) Post application hazards indirect toxic effects, which involve risk to non-target animals due to toxic residues of pesticides in food or due to pollution of the ecosystem, habit as a whole such as water bodies or soil.

The term pesticides cover a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematocides, plant growth regulators and others. Among these, organochlorine (OC) insecticides used successfully in controlling a number of diseases, such as malaria
and typhus were banned or restricted after the 1960s in most of the technologically advanced countries. The introduction of other synthetic Organophosphate (OP) insecticides in the 1960s, Carbamates in 1970s and the Pyrethroids in the 1980s and the introduction of Herbicides and Fungicides in 1970s-1980s contributed greatly in pest control and agricultural output. Ideally a pesticide must be lethal to the targeted pests, but not to the non-target species including human beings. Unfortunately this is not so, thus controversy of the use and abuse of pesticides has surfaced.

PESTICIDE POLLUTION:

Pesticides are indispensable in modern agriculture to increase the food production by controlling agricultural pests, besides saving the man and his ecological partners from vector borne diseases. There is probably no bigger controversy in the field of environmental toxicology than whether pesticides are responsible for breast cancer in women, the decline of sperm count in male and the congenital malformation in wild animals et al. Americans use some two billion pounds of pesticide each year and it is same with the rest of the world. The worldwide deaths and chronic illnesses due to pesticides poisoning number about 1 million per year (Environnews, 1999). Some pesticides residues stay in food chain for decades.

The rampant use of these chemicals, under the adage, "if little is good, a lot more will be better" has played havoc with humans and other life forms. In India the first report of poisoning due to pesticides was from Kerala in 1958,
where over hundred people died after consuming wheat flour contaminated with parathion (Karunakaran, 1958). Carlson in 1962 warned that OC compounds could pollute the tissues of virtually every life form on the earth, the air, the lakes and the oceans, the fishes that live in them and the birds that feed on the fishes (Carlson, 1962). Later US National Academy of Sciences stated that the DDT metabolite, DDE causes eggshell thinning and the bald eagle population in the United States declined primarily because of exposure to DDT and its metabolite (Liroff, 2000). Certain environmental chemicals including pesticides termed as endocrine disruptors are known to elicit their adverse effects by mimicking or antagonising natural hormones in the body and it has been postulated that their long-term, low-dose exposure are increasingly linked to human health effects such as immunosupression, hormone disruption, diminished intelligence, reproductive abnormalities and cancer (Crisp et al., 1998; Hurley et al., 1998; Brouwer et al., 1999).

A recent study of the World Health Organisation reveals that on an average, one person is poisoned every minute by pesticides in the developing world (Radhakrishna Rao, 1984). Routes of pesticidal entry into the environment are (a) Surface runoff and sediment transport from treated soils, (b) Industrial wastes discharged into factory effluents, (c) Direct application as aerial sprays or granules to control water inhabiting pests, (d) Spray drift from normal agricultural operation, (e) Atmospheric transport, (f) Agricultural wastes and (g) Accidental spills. Surface runoff is generally considered to be the major mode of movement.
of pesticides and other chemicals into the aquatic environment (Edwards et al., 1970, Nicholson and Hill, 1970),

A number of pesticide factories are located near the aquatic ecosystems. Pesticide factories located at Mathura, Faridabad and Agra release their waste products, which require 8000 times dilution to render them free from immediate harmful effects (Agarwal, 1983). Yamuna is quite often referred as open sewer because of great degree of water pollution (Times of India, The Daily, Bombay, 1st June, 1992).

More than 50% of India's economy is dependent upon agriculture and India's agriculture has to go a long way to reach the yield of the advanced countries. Pesticides constitute an important component in agriculture development and protection of public health in India, since the tropical climate is very conductive for insect breeding. There are about twenty major diseases, which have been brought under control by the use of pesticides. The major among them are malaria, filariasis, dengue, Japanese encephalitis, cholera and louse-borne typhus. Worldwide concern in scientific, industrial and government communities over traces of toxic chemicals in foodstuffs and in both, abiotic and biotic environments has justified the present triumvirate of specialized works in this field. The use of organic natural or man-made chemicals however imposes a continuous change in the chemical environmental quality with in a short time period. Continuous exposure to pesticides shows that naturally resistant individuals will dominate pest population. This situation necessitates frequent
change of pesticides or to a large application of the same pesticide in order to affect lethality (Laws, 1981).

In India the residues of pesticides in food, raw agricultural commodities and component of the environment have not so far been studied extensively. Still a few reports show the presence of pesticide residues in essential commodities. Research in Tarai area of Uttar Pradesh shows an average DDT content of 0.35 to 0.46 ppm in vegetables (Visweswaraiah et al., 1975). BHC levels in some vegetables in Mysore (India) varied from 10.5 to 20 ppm (Visweswaraiah & Jayaram, 1972). BHC level in Hassan (India) varies from 3.68 to 15.5 ppm (Majumder & Krishnamurthy, 1963). Research in Tarai area showed an average DDT content of 0.51 to 0.845 ppm in dairy concentrates; 0.028 to 0.39 ppm in poultry egg, 0.58 to 0.64 ppm in hays and other feeds and 0.0032 to 0.002 ppm in milk (Viswesaraiah et al., 1975). Joia et al. (1979) reported contamination of BHC and HCH ranging from 1 to 5 ppm in wheat flour in Punjab.

The incident of pesticide poisoning in agricultural workers of Hadigodu came to light in December 1977. They were reported to have suffered from painful swelling and immobilization of hip and knee joints ultimately leading to washing away of lower limbs, due to the long term consumption of pesticide exposed crabs and fishes (NIN, 1977). The death of 150 persons in Kerala due to the consumption of malathion mixed wheat has also been reported (The Hindu, 1985). Reddy (1985) reported that in twin cities of Andhra Pradesh, many women suffered with abortions and children showed chromosomal damage due to the
consumption of pesticide containing grapes. David (1985) has cited two epidemics of epilepsy in Sitapur of Uttar Pradesh due to BHC poisoning.

A rapid survey conducted by the Central Fisheries Extension Centre, Hyderabad revealed the mortality of large variety of fish during 1973 due to pesticides (Hingorani et al., 1973). According to a report of Central Bureau of Investigation (CBI), Government of India, as many as 4,536 persons died in 1965 alone on account of carelessness in handling poisonous substances (Visweswaraiah et al., 1975).

In the year 1958, organophosphorus pesticides in Kerala state caused 104 deaths. This catastrophe was created by consumption of food products contaminated by the compound, which was leaked from the containers in a ship (Shinde, 1979).

Fatal poisoning due to toxicity of methyl-parathion had occurred in formulating and packing unit of a factory in Bombay in the year 1962, due to skin absorption and inhalation (Shinde, 1979). In 1964, 100 persons suffered from toxic effects of endrin of which one died due to consumption of contaminated rice. On consumption of food on banana leaves contaminated by copper sulphate, 160 persons suffered from itching and vomiting in Kerala state (Shinde, 1979). In July, 1976, an out break of epilepsy among over 150 people in Sitapur, Lakshmipur, Kheri and Hardoi districts of Uttar Pradesh was found to be due to consumption of wheat mixed with BHC (The Hindu, 1976).
There is extensive information on pesticide residues in fish from different parts of the globe. The highest quantity of DDT (1.3 gm/kg) has been recorded in fin fish and Atlantic Croakers in the estuary near Pensacola (Hansen & Wilson et al., 1970), which ultimately led to the banning of DDT by the Environmental Protection Agency (E.P.A.) in the US (Anon, 1972). However the presence of other pesticides along with DDT in fishes in alarming concentrations has been recorded from other parts of the world. Environment of Pesticides and Organic Pollutants is reported in the top 100 to 150 m layer of the sea in Narragonsett Bay in USA (Duce et al., 1972), high levels of OP residues in the water of Holland Marsh in Southern Ontario and high levels of Malathion in the waters of Texas (Coppage et al., 1975). Residue levels of DDT up to 250 mg/kg and 235 mg/Kg of DDT in eggs of *Salmon gairdneri* was reported by Sodergren et al. (1978). These are only few to mention.

**HISTORY AND DEVELOPMENT OF PYRETHROIDS:**

Since the discovery of insecticidal property of DDT in 1943 many organochlorine, organophosphate and carbamate insecticides were developed without any great increase in the level of insecticidal activity. Subsequent search for new effective insecticides led to the discovery of synthetic pyrethroids. Earlier natural pyrethrins were used in pest control but they were too expensive and unstable, as a result they could not be used in agricultural pest control in large scale. The newly developed synthetic pyrethroids offer a class of insecticide with a wide range of ideal properties viz; quick action, high insecticidal efficiency, low
mammalian toxicity, less persistence and amenability to synergistic action. Their
great potency against insect pest and smaller dosages required for their control
with less risk of environmental contamination has opened a new chapter in insect-
pest control.

The pyrethroids are synthetic analogs and derivatives of the original
pyrethrins and represent a diverse group of over 1,000 powerful insecticides.
Pyrethrum is the natural extract that occurs in the flowers of *Chrysanthemum
cinerariaefolium* and *Chrysanthemum cinum*. In the early 18th century the
caucasian tribes have used pyrethrum flowers to control body lice. The insecticidal
properties of pyrethrum flowers (*Genus* chrysanthemum, most commonly
*C. cinerariaefolium*) has been recognized in the middle of the last century. In the
19th century it was introduced in Europe, United States (1828), Africa and South
America (1876). Today Kenya stands first in its production followed by Tanzania,
Uganda, Congo, Ecuador and Japan. Pyrethrum has long been recognised as
possessing insecticidal properties. Over the years, first the chemical extracts of
pyrethrum and then more recently, the specific synthrum has been used as
insecticide for many hundreds of years, possibly since the first century A.D (Hill,
1989) in Asia to kill various insects such as fleas, mosquito, and ticks, and later
during the 19th century it was exploited as an effective insecticide. Large areas of
pyrethrum are cultivated in high altitude regions of Kenya, Tanzania and Ecuador,
for commercial extraction of natural insecticide.
Pyrethroids are about equally toxic whether applied topically or injected, except for relatively inactive compounds. There are many pyrethroid compounds that have been used as pesticides. Some major pyrethroids are listed below:

1) Allethrin  
2) Bioaltherin  
3) Bioresmethrin  
4) Barthrin  
5) Cyclethrin  
6) Cyflurthrin  
7) Cismethrin  
8) Cyhalothrin  
9) Deltamethrin  
10) Decamethrin  
11) Fenvalerate  
12) Phenothrin  
13) Permethrin  
14) Resmethrin  
15) Tetramethrin  

The first synthetic pyrethriods, allethrin and cyclethrin, were produced around 1950 (Schechter *et al.*, 1949), but lacked adequate photostability and are less effective than the pyrethrins against many insects (Wouters & Van den Bercken, 1978). Tetramethrin was introduced in 1964 (*Kato et al.*, 1964) and is an excellent knock down agent, but it too, has inferior insecticidal activity. By 1968
the first pyrethroids with greater activity than pyrethrins were produced. These include Resmethrin (Elliott, 1976) and Cismethrin (Lhoste et al., 1971). Photostable pyrethroids followed by the mid 1970's and included phonothrin (Fujimoto et al., 1973), permethrins (Elliott et al., 1973), deltamethrin (Decamethrin; Elliott et al., 1974) and Fenvalerate (Ohno et al., 1974). Due to the great potential for structural variation in the pyrethroids (Elliott, 1980), new compounds are constantly being synthesized.

Synthetic pyrethroids have been evaluated since 1976 in India and in the beginning they were tested on cotton and rice fields etc. The uses of these products have been increasing at an extremely fast rate in many countries of the world including India. At present permethrin, cypremethrin, decamethrien and fenvalerate are the main synthetic pyrethroids being developed commercially.

CHEMISTRY OF PYRETHROIDS:

Pyrethrum comprises of six active insecticidal compounds called pyrethrins. The six individual pyrethrins are Pyrethrin I, Pyrethrin II, Cinerin I, Cinerin II, Jasmolin I, Jasmolin II (Smith et al., 1986). The constitution of these natural esters was established by a succession of organic chemists, challenged by the complexity of their structures and fascinated by their biological activity of these synthetic compounds (Elliott, 1989). Two different types of pyrethroids are recognized, based on difference in basic structure (the presence or absence of a cyano group) and the symptoms of poisoning in laboratory rodents (Coats, 1990). Type I pyrethroids do not include a cyano group, and clinical signs of type - I
pyrethroids induced toxicity include whole body tremors. The type-II pyrethroids include a cyano group and are characterized by their elicitation of salivation and sinons writhing (choreoathetosis).

The natural pyrethrins have excellent insecticidal properties and low mammalian toxicity, but are of limited use because of their low photo stability and high biodegradability (Wouters & Van den Bereken, 1978). However, the new synthetic pyrethriods are relatively stable, have a high toxicity to a wide spectrum of insects (Elliott, 1976), and have tremendous agricultural potential (Harris, 1969). Moreover, pyrethroids are much less persistant than the organochlorine insecticides, such as DDT and dieldrin and apparently do not accumulate in the environment. In many ways, the mixed active constituennts of pyrethrum, the natural pyrethrins, are ideal insecticides (Potter, 1973) because they act rapidly against wide range of insect species and have no action on mammals under normal conditions (Casida, 1980) and being quickly re-arranged or decomposed in air or light to inactive products (Chen & Casida, 1969; Bullivant & Pattenden, 1973), do not leave harmful residues.

MODE OF ACTION OF PYRETHROIDS:

Pyrethriods, like other major class of insecticides (organophosphates, carbamates and organochlorines) interfere with the function of the nervous system. Initial symptoms of pyrethriods poisoning include incoordination and locomotor instability (knockdown), followed by hyper excitation, tremors and convulsions (Wouters & Van den Bereken, 1978). The precise mode of action of
these insecticides probably involves an interaction with the sodium channel in the nerve membranes (Vijverberg et al., 1982). Their principal effect is to induce a continuous series of nerve impulses, referred to as repetitive activity, which completely upsets the proper functioning of the entire nervous system and eventually results in death (Wouters & Van den Bercken, 1978; Vijverberg et al., 1982 & 1985). Based on symptomology of pyrethroid toxicity, the poisoning is broadly classified into two types. Type I poisoning syndrome produced by the pyrethroids without cyano substituent is characterised by restlessness, incoordination, prostration and paralysis in the cockroach (Gammon et al., 1981) and whole body tremors in rat (Verschoule & Aldridge, 1980). The type II poisoning syndrome symptoms include convulsions, intensive hyperactivity, burrowing behaviour, coarse tremors, clonic seizures and salivation in rats (Gammon et al., 1982; Gray et al., 1989; Eldefrawi et al., 1985).

The mode of action has been extensively studied both in vertebrates (Jacques et al., 1980) and invertebrates (Vijverberg et al., 1982). Generally it is believed that all pyrethroids have essentially the same basic mode of action (Van den Bereken & Vijverberg, 1988). In particular, both type I and type II agents are known to cause prolongation of the sodium current associated with nerve membrane depolarization (Vijverberg & Weillae, 1985). The neural sodium channel being the primary molecular target (Narahashi, 1985, Vijverberg et al., 1982). However, there is evidence suggesting that type II pyrethroids can also interact with GABA receptors, inhibition of both (3S)- or (3R)-bicyclo
phosphorothionate (TBPS) binding at the GABA-A-receptor-ionophore complex (Lawrence & Casida, 1983) and GABA-induced chloride fluxes (Abalis et al., 1986) has been reported in studies on CNS preparation. Recent studies on cultured neurons of rat dorsal root ganglia, found that the type II pyrethroid deltamethrin was ineffective on GABA induced inward chloride currents at a concentration (10 μM) which drastically prolonged the voltage activated sodium channel current (Ogata et al., 1988)

Type I pyrethroid effects are generated largely by the action on the central nervous system (CNS) as shown by the good correlation between brain levels of cismethrin and tremor (Wright et al., 1988) and the induction of tremor by small quantities of cismethrin directly injected into the CNS (Gray and Rickard, 1989; Staatz et al., 1982). Poisoning is associated with marked increases in both spinal (Carlton, 1977; Staatz-Benson & Hosko, 1986) and brain stem excitability (Forshow & Ray, 1986), although not with marked effects on the higher centers.

Type II pyrethroids produce more complex poisoning syndrome and act on a wider range of tissues. They give sodium tail currents with relatively long time constants (Wright et al., 1988). It was first noted by Bernes & Verschoyle (1974) that type II poisoning in rats involves progressive development of nosing and exaggerated jaw opening similar to that seen in response to an irritant placed on the tongue, salivation which may be profuse, increasing extensor tone in the hind limbs causing a rolling gait, in coordination progressing to a very coarse tremor, choreoform movements of the limbs and tail often precipitated by sensory stimuli,
generalized chrepoathelosis (Withing spasms), ionic seizures, apnea and death (Ray, 1982). At lower doses subtle repetitive behaviour is seen (Brode & Aldridge, 1982). In dogs similar symptoms are seen (Thebault et al., 1985). Type II pyrethroids generally decrease rather than increase the startle response to sound (Crofton & Reiter, 1984), although this is a complex response and at low doses, type II pyrethroids give an increased startle (Hijzen & Slangen, 1988). The cerebral cortical response to sound is also depressed (Ray, 1980).

Repetitive discharges from various parts of the nervous system like giant axons of cockroach *Periplaneta americana* (Narahashi, 1962) and squid (Starkus & Narahashi, 1978) mortar neurons of housefly, *Musca domestica* (Adams & Miller, 1980), neurosecretory cells of stick insect, *Crausius morosus* (Orchard & Osborne, 1979), CNS of leech, *Hirudo medicinalis* (Leake, 1977) and cotton leaf worm larvae (Gammon & Holden, 1982), peripheral nervous system of the desert locust, *Schistocerca gregaria* (Clements & May, 1977) and voltage clamp studies of squid axons (Narahashi & Anderson, 1967) were reported. These reveal the increased transient sodium conductance due to pyrethroid poisoning and also the shift in sodium activation curve in the direction of depolarization (Narahashi & Anderson, 1967). Sodium inactivation curve in the direction of hyper polarization has been reported (Wang et al., 1972) for the same cause.

Besides causing repetitive firing in peripheral nerves of vertebrates (Wouters and Bercken, 1978), allethrin was reported to show negative co-efficient for repetitive firing in nerves of clawed frog (Bercken et al., 1973). Fenvalerate
intoxication in birds like bobwhite quail, *Colinus virginianus*, (Bradbury & Coats, 1982) and cypermethrin poisoning in Japanese quail, *Coturnix coturnix* (Edwards *et al.*, 1986) have shown to be associated with hyperactivity, ataxia, and toxic discharges. Similar symptoms have been identified in fishes such as rainbow trout, *Salmo gairdneri* due to permethrin (Glickman *et al.*, 1981; Holcombe *et al.*, 1982) and cypermethrin (Edwards *et al.*, 1986) intoxication.

In mammals, the symptoms of pyrethroid poisoning results from interaction of these insecticides with Central Nervous System (CNS) (Ray & Cremer, 1979; Staatz *et al.*, 1982). Carlton (1977) has reported the repetitive firing in rabbit sensory nerve due to cismethrin. Jacques *et al.*, (1980) observed slow depolarizing waves of up to 30 mv in inexcusable tissue cultured nerve cells from rat brain under deltamethrin stress.

**USE OF PYRETHROIDS**:

Pyrethroids are used primarily in the control of household and agricultural insect pests, as well as in industrial, stored products and veterinary applications and are also used as large-scale forest spray insecticides. In particular, they are a promising group of compounds for spruce bud worm control. 1982 onwards the world market of pyrethroid insecticide is ever been increasing. Associated with an increased popularity of these compounds is an increased concern over possible ecological ramifications caused by their usage. Ecological toxicity testing of pyrethroids has been undertaken since the late 1970’s when permethrin started to
become a popular insecticide, and a considerable amount of information has been accumulated.

**PYRETHROID PERSISTANCE IN THE ENVIRONMENT**:

The environment fate and degradation of pyrethroid insecticides have been reviewed by many researches (Leahey, 1979; Roberts, 1981). Pyrethroids compounds are all esters and hence, are rapidly degraded, both by macroscopic and microscopic organisms. Permethrin, one of the most widely used agricultural pyrethroids; has a half life of one to three weeks in various silt and clay soils, and up to fifteen weeks in organic soils (Kanfman et al., 1977; Kaneko et al., 1978; Belanger and Hamilton 1979; Williams & Brown 1979; Chapman & Harris, 1981; Chapman et al., 1981). Cypermethrin, fenpropathrin and fenvalerate have half-lives of approximately two to four weeks in mineral and organic soils (Chapman & Harris 1981; Chapman et al., 1981). Dethamethrin is more persistent, with a half-life of less than two months in soil (Chapman et al., 1981).

The half-life of permethrin in pond water is more than one day but immobilized residues may be found in the hydrosoil for considerably longer periods (Rawn et al., 1982). In the esturine environment fenvalerate and permethrin evidence half-lives of 27 to 34 days and more than 2 to 5 days respectively (Schimmel et al., 1983), while the former is degraded by up to 50% in less than nine days in tidal marsh sediments (Caplan et al., 1984). Consequently, pyrethroid insecticides do not persist in the environment for long periods of time and apparently do not accumulate in the biosphere, (Smith et al., 1986).
SCOPE FOR THE PRESENT STUDY:

The freshwater ponds offer scope for fish culture. There are about 48 major ponds and 232 minor ponds with water spread area of 1287.06 hectares and 635.5 hectares respectively in and around Dharwad (Dharwad taluk), Karnataka, India, which appear quite suitable for pisciculture purpose. Fish culture is already in practice in these ponds. The yield of the fish from these freshwater ponds is about 2236.889 metric tons/year (Assistant Director of Fisheries, Department of Fisheries, Government of Karnataka, Dharwad, Karnataka, 2001-2002).

The agricultural lands of Dharwad taluk comprises about 80,924 hectares. Array of pesticides are used by the farmers for controlling agricultural pests and diseases. The main crop of the region are cotton, jowar, wheat, groundnut, sunflower, bengal gram, maize, sugar cane, safflower, paddy, green gram, mango plantation, etc and a variety of vegetables. Whose protection against pest is done by using a different pesticides like parathion, malathion, diazinon, dimethoate, quinolphos, dimecron, phenthoate (OP); DDT, BHC, endosulphan, aldrin, dieldrin, endrin, heptachlor, toxaphene, chiordane (OC); carbaryl, carbofuran, aldicarb (Carbamate); fenvalerate, decamethrin, cypermethrin, permethrin (Pyrethroid), etc.

One among the Indian major carps, *Cirrhinus mrigala* inhabiting the freshwater sources, is widely cultured in ponds and lakes of this region. This fish is largely preferred for table purpose as a low cost protein and vitamin source. Hence this fish has a good commercial value and also forms an important
component of the freshwater ecosystem. This fish is considered for culture in fish farm and for composite fish culture; as such it is prone to pesticide intoxication resulting from industries, agriculture practices, household application, forest spraying, etc. Owing to its high productivity, easy availability and wide consumption by the natives, the species *Cirrhinus mrigala* was considered as a suitable experimental animal for the study of pesticide toxicity. Fenvalerate is a commonly used pyrethroid insecticide in this region to protect the crops. The survey of literature reflects that fenvalerate, a broad-spectrum pyrethroid insecticide, affects a wide range of non-target organisms such as fishes and other aquatic living forms.

In view of the forgoing account the present investigation was projected to understand the impact of median lethal concentration and sublethal concentration of fenvalerate on the fish, *Cirrhinus mrigala* with the following objectives.

1) **Toxicity Evaluation**:

   The lethal concentration (LC) studies were conducted and median lethal concentration (LC$_{50}$) was determined.

2) **Accumulation of Fenvalerate (Residue Analysis)**:

   Fish tend to accumulate the pesticide from the surrounding medium into different tissues through various modes. The quantity of fenvalerate accumulated in the tissues (gill, muscle and liver) was quantified by employing gas chromatography (GC) technique
3) Behavioural Toxicology:

Some observations on physical, morphological and behavioural changes were made in the fish exposed to fenvalerate.

4) Whole Animal Oxygen Consumption:

Since stress is known to influence the rate or respiration, whole animal respiratory rates were determined in control and experimental fish.

5) Ach and AchE:

Since acetylcholinesterase (AchE) is the target enzyme for the pyrethroid, fenvalerate, this aspect was also investigated in the control and in pesticide exposed fish tissues (gill, muscle, liver and brain). Acetylcholine (Ach) content was also determined in the tissues under the same experimental conditions.

6) Carbohydrate Metabolism:

Studies on changes in carbohydrate metabolism include estimation of blood glucose, glycogen, lactate, pyruvate and activity measurement of enzymes LDH, SDH, glycogen phosphorylase, G-6-Phosphatase in the control and experimental fish tissues (gill, muscle and liver).

7) Hematology:

Some hematological parameters like RBC and WBC count, Haemoglobin (Hb), concentration, blood glucose and certain
hematological values such as MCV, MCHC, PCV, MCH were attempted and determined in the blood of control and experimental fish.

8) Ions and associated ATPase:

Concentration of Na\(^{2+}\)-K and Ca\(^{2+}\) ions and the activities of associated ATPase as Na\(^{2+}\)-K ATPase, Ca\(^{2+}\) ATPase and Mg\(^{2+}\) ATPase were estimated in control and experimental fish tissues (gill, muscle and liver).