INTRODUCTION
Natural waters receive numerous pollutants from a wide variety of sources, nutrients from sewage outlets and fertilizer run off, oil and grease from street and highway run off, chemicals from the fall out of air pollutants, effluents from various industries and pesticides from agricultural operations. Water is regarded as polluted when it is changed in its quality or composition directly or indirectly as a result of human activities. In recent years the industrial countries have been facing a new calamity in the shape of pollution. The pollution havoc in different forms is increasing at an alarming rate.

Man's effective exploitation of the environment especially that of freshwater habitats like rivers, lakes and ponds has resulted in the form of pollution by means of contamination of the ecosystem. Pollution of freshwater ecosystem occurs in many ways like chemical, thermal and radioactive pollution. Many ecologists feel that the role of human population in shaping the world has become increasingly detrimental, and as a result today man is faced with an ecological crisis. Water pollution is also the result of centralised industries. Expensive methods to treat factory effluents have been devised, but in India, the adaptation of these is only a show. Most pollution
is caused by pesticides, pharmaceuticals, Rayon and Pulp industries, Chaliyar is now a dead river because of the effluents discharged from Mavoer (Gwalior) Rayon Factory. A number of cattle died after drinking the poisonous water of the stream flowing below the Harihar factory (Karnataka). In both these factories, there is provision for effluent treatment only to fulfill the legal requirement.

To boost agricultural productivity, developing countries are producing and using pesticides and insecticides and other similar compounds in ever-increasing quantities. The excessive use of these substances results into serious hazards to plants, animals, and man himself. The chemical pollution of different ecosystems has turned to be a major problem, and impact of chemical pollution is more pronounced on non-target organisms of the freshwater ecosystem leading towards the disruption of the ecological balance. The problem of chemical pollution is known to occur in different ways, i.e., organic and inorganic chemical wastes (McKee and Welf, 1963), oil refinery pollution (Dorris et al., 1959), detergents (Nehring, 1962; Cairns et al., 1964), radioactive (Klement and Wallen, 1960) and pesticides (Hiltibran, 1967).
Endogenous factors, respiratory (Conover, 1966) and feeding processes are correlated with the metabolic rate of the aquatic forms. In the environment water can provide the major means of transporting various substances from one source to another. The bulk of pesticide residues are generally confined to the soil and transport through soil by water is limited (Lichtenstein et al., 1967). But in contrast Eyc (1966) and Lichtenstein et al., (1967) reported that water could wash away the soil particles that contain pesticide residues. Since crustaceans happen to be inhabiting aquatic environment, as well as land, they come in contact with aquatic contaminants. Further the uptake of pesticides in crustaceans was reported to be usually through the gills (Presser, 1961).

Pesticides are biological toxicants which are required by man to kill insects and their pests that destroy the crops. As the use of DDT to control crop destroying insects increased, so did the insects resistant to it. This stimulated the search for and synthesis of newer and more toxic chemicals. There are about 1000 synthetic chemicals incorporated into some 45,000 registered pesticides which have been on the market (Berry et al., 1974). The pesticides can be divided into the four major categories according to their use i.e., 1. Insecticides, 2. Herbicides,
3. Fungicides and 4. Other specific pesticides eg., Rodenticides and Molluscicides. Insecticides as the name implies, are intended for the control of insects and the most important categories of the insecticides which are employed often in agricultural and public health operations ultimately result as major environmental contaminants. Depending on chemical structure they are classified broadly into four important categories as follows:

1. Organ-chlorides
2. Organ-phosphates
3. Carbamates and
4. Other minor type such as quinones and phenols etc.

Organochloride insecticides as exemplified by DDT (Dichloro-Diphenyl-trichloroethane), Endrin, Dieldrin and Aldrin etc., are insoluble in water and hence most persistent compounds in the environment and are often referred to as "hard" pesticides. A great deal of work has been done on these insecticides with reference to their uptake and persistence, environmental hazards and toxicological failure due to resistance in fishes (Ferguson, 1967; Culley & Ferguson, 1969; Willford et al., 1969; Cope et al., 1970; Macek et al., 1970; Mayer et al., 1970; Fabacher and
Chambers, 1971; Shepard, 1971). But in many uses carba-
mates like carberyl, dimetilan, aminocarb, sevin, isolan
e tc., and the organophosphates have replaced organo-
chlorides by dint of their rapid biodegradable nature and
relatively less persistence in the environment (Duke and
Dumas, 1974). Since the present investigation is concerned
with the effects of organophosphate insecticide like mala-
thion, some relevant information on organophosphates re-
quires mentioning.

ORGANOPHOSPHATE INSECTICIDES:

The organic phosphorous compounds were discovered
during second world war by Gerhard, Schrader, a German
chemist who was engaged primarily in the search for more
powerful agents of chemical warfare (Bowen & Hall, 1952).
From them, through extensive tests came several effective
insecticides. The term organophosphate is generally used
for all toxic compounds which contain a phosphorous atom
(O'Brien, 1967). Majority of toxic organophosphates are
esters of phosphorous, phosphorothioic or phosphoric acids
or of their anhydrides, halides and amides (O'Brien, 1960).
They are used as stomach or contact poisons and fumigants.
They include a variety of insecticides like Malathion,
Parathion, Methyl Parathion, Dimethoate, Phosphomidon, monocrotophos, Dicrotophos, Fonofos, Trichlorofen etc. The suitability of organophosphate insecticides in agriculture for the eradication of pests and insects was first demonstrated by Gerhard and Schrader in Germany during Second World War (O'Brien, 1967). The commonest activation of organophosphates is the conversion of phosphorothionate compound to a phosphate compound. Thus parathion is converted to paraoxen and malathion to Malaoxon. This is often referred to as oxidation, while 'desulfuration' is viewed as a correct term (O'Brien, 1967) whereas, the biodegradation of organophosphates most commonly occurs through the process of hydrolysis by the microsomal enzymes like phosphotases and carboxyesterases are required to convert malathion or malaoxon to non-toxic products like malathion diacid (Knaak and O'Brien, 1960; O'Brien, 1961).

Malathion is especially used to control pest species on paddy, pulses, sugarcane, cotton, oil seeds, vegetables and fruits. So it is a versatile organophosphate insecticide widely used throughout the world to control crop pests, flies and mosquitoes (U.S. Dep. Interior, 1964; Knapp, 1965; Fischer, 1965; Anon, 1966).
The wide applicability of malathion provides many occasions for its entry into the aquatic environment and thereby causing great havoc to fishes, the huge population of the aquatic environment and ultimately resulting in fish kills (Darsie and Corriden, 1950; Mulla, 1961). The field population of fishes after exposure to malathion showed depressed acetylcholine esterase activity in brain tissue (Coppage and Duke, 1971). The studies on the effects of pesticides on fish both marine and freshwater and also on freshwater crabs are extensive (Kalinan et al., 1964; Allison et al., 1964; Bashra Mohideen and Subba Rao, 1982; Parvathi, 1982; Sairath et al., 1981; Ramalingam and Ramalingam, 1982; Sivaprasada Rao and Ramana Rao, 1979; Verma et al., 1980, 1981; Diwan and Nagabhushanam, 1972; Goel et al., 1982; Rita Kumari and Balakrishna Nair, 1978; Kulkarni and Kamath, 1980).

**NON-ENZYMATIC REACTIONS OF ORGANOPHOSPHATE PESTICIDES**

Some non-enzymatic reactions (as distinguished from biochemical reactions) are important to the understanding of organophosphate action. The two vital non-enzymic reactions are hydrolysis and isomerization, since both alter the biological properties in several ways. The hydrolysis of the organophosphate pesticides depends on
the properties of the group attached to the phosphorous. Their susceptibility mostly depends upon the electrophilic character of the group attached to the phosphorous. That is the reason why malathion \( \beta \)-mono acid which has a lesser sensitivity to nucleophilic attack is found to be more stable than the parent malathion (O'Brien, 1971). In general phosphates are more hydrolyzable than their corresponding phosphorothionates. Hence methyl paraxon (phosphate) is more susceptible to hydrolysis than methyl parathion (a phosphorothionate) and the susceptibility increases 22 times (Health, 1956). The other non-enzymatic process of major importance is isomerization. The most common isomerization is the thionothilic type, wherein a sulfur atom changes from the thione \((=S)\) to the thiole \((-S-)\). Parathion is known to isomerize to \(S\)-ethyl parathion (Woodcock and Stringer, 1951) and malathion is known to undergo \(S\)-alkyl isomerization (Fukuto and Stafford, 1957).

**EFFECTS OF SYNTHETIC ORGANIC INSECTICIDES ON CRUSTACEAN SPECIES:**

Several studies have shown that DDT and related pesticides and PCBs inhibit the activity of Na, K, Mg, ATPases in several animals, (Koch, 1969, 1970; Yap et al.,
1971; Cutkomp et al., 1971a) have shown that the Fiddler crab *Uca pugilator* accumulates PCB and Arochlor 1254 from contaminated sediments. Nimmo and Blackman (1972) have reported that Na⁺, K⁺ and possibly Mg⁺ levels of shrimp *Peneaus aestuarii* and *Peneaus duorarum* are reduced following exposure to sublethal concentration of DDT in sea water. The toxicity levels of Aldrin and Dieldrin have been determined in the freshwater ostracod *Chlamydotheca arcuata* (Kowatski and Schmulbach, 1971). Cantelmo et al., (1978) studied the effects of sodium pentachlorophenolate (Na-PCP) and 2,4-dinitrophenol (DNP) on oxygen consumption of grass shrimp at different stages of the molt cycle. Fox and Ranga Rao (1978) evaluated the effects of Na-PCP and 2,4-DNP in vivo and in vitro on certain hepatopancreatic enzymes like fumarase, malate dehydrogenase and succinate dehydrogenase in the blue crab *Callinectes sapidus*. Matsumura and Narahashi (1971) have observed the inhibition of ATPase activity and electrophysiological changes caused by DDT and related neuroactive agents in Lobster nerve. Caldwell (1974) has examined the resistance to osmotic stress of adult *Cancer magister* and *Hemigrapsus nudus* exposed to the insecticide methoxychlor in sea water. Duke et al., (1970); Nimmo et al., (1971b) and Armstrong et al., (1976) have reported that the sensitivity of adult
crustaceans to toxicants such as Arochlor 1254 and methoxychlor increases during or soon after molting (ecdysis). Nimmo \textit{et al.}, (1979) have studied the effect of diflubenzuron on an estuarine crustacean \textit{Mysidopsis bahia}. Sevin and OP insecticides like patholophos and phosalone have been reported to decrease the activity of oxidative enzymes in \textit{Lepidopteron} insects during intestinal poisoning (Berim and Bykhovets, 1973).

Some pollutants including malathion, have been found to decrease oxygen consumption of the crabs \textit{Paratelphusa jouquemontii} (Kulkarni and Kamath, 1980). Sanders (1971) working with \textit{Gammarus locusta} states that the OP insecticides are more toxic to this animal than chlorinated hydrocarbons. Coppage and Mathews (1974) have used the level of inhibition of AchE activity as an indicator of extent of poisoning in the brain of estuarine fishes and in the nerve cord of pink shrimp \textit{Penaeus duorarum} and have also studied the short term effects of different OP insecticides like malathion, parathion, guthion on AchE activity of pink shrimp. Bradbury (1973) has observed that parathion poisoning in \textit{Carcinus} causes prostration and heavy muscular tetanus followed by death and states that these effects are due to the action of the drug on the central cholinergic interneuronal synapses.
Biochemical Changes following pesticide exposure:

Eisler and Edmunds (1966) reported no consistent changes in the levels of serum chloride, gamma globulin or uric acid, but showed that the concentration of sodium, potassium, calcium and cholesterol were higher after pesticide exposure. In the liver Na, K, Ca, Mg and Zn were consistently lower indicating impaired liver metabolism during pesticide exposure. Inhibition of esterases along with changes in the serum proteins and their electrophoretic mobility patterns were also observed (Eisler, 1967). Sanchez (1967) and Bhatia et al., (1973) reported increased hepatic protein synthesis following dieldrin treatment. Binding of pesticides to serum protein (Skalsky and Gunther, 1975) and phospholipid, lecithin (Haque et al., 1973) were also reported. Pathological changes are known to be associated with biochemical changes (Dikshith et al., 1975).

In view of this documented evidence regarding the availability and versatility of malathion and its deleterious effects on fishes and crabs, malathion is selected as the insecticide to investigate its effects with special reference to crabs.
Such intensive studies on pollution in crabs especially that of organophosphorous pesticides is woefully lacking in crustaceans which not only form one of the major constituents of food chains in the aquatic environment, but also economically important fisheries with great commercial value. Crustaceans lead a remarkable and an efficient life in aquatic environment and they form good evidence of more active systems for ventilation, blood circulation, osmoregulation and excretion. Pesticide in crustacean may be taken through gills and these toxic chemicals make their entry into blood and effect various tissues and organs and ultimately alter the vital physiological processes (Ashley, 1972).

The above literature survey indicates paucity of information on the effects of OP pesticides on aspects of carbohydrate metabolism and respiratory metabolism in crustacea in general and crabs in particular. Hence in the present investigation efforts are made to gain an understanding of some of the important physiological and biochemical changes that occur in the freshwater field crab, *Q. senex senex* exposed to sublethal concentration of malathion, a widely used pesticide in agricultural fields. The following survey of the literature gives an insight of the
impact of insecticides in general, that of organophosphates in particular on various physiological systems affected due to insecticide accumulation in freshwater ecosystems with special reference to crabs.

**Evaluation of Pesticide Toxicity:**

Pollution by spillage and effluents may be an important contributing source of global contamination (Moore, 1970). It should be noted that freshwater organisms are particularly susceptible to damage by pesticides and other pollutants, their habitats are usually confined and it is impossible for them to escape from their polluted habitats. Aquatic animals have to pass large quantities of water over their respiratory surfaces and are subjected to a relatively greater exposure to toxic compounds. Since pollution of most types usually causes deoxygenation, freshwater species are liable to be asphyxiated by pollutants. Thus freshwater habitats are more prone to hazards of pesticide contamination. Various animals exhibit varying degrees of susceptibility to pesticides; also the various physical, chemical and biological components of the environment play an important role in the manifestation of biological response to pesticides.
The toxicity of a particular pesticide depends upon many factors such as animal weight (Pickering et al., 1962), its developmental stage (Kamal Deep and Boer, 1977), time of exposure temperature (Macek et al., 1969), pH, hardness of water (Henderson et al., 1960) and dissolved oxygen content of the medium. It is customary to represent lethality of a chemical to a particular animal species in terms of mortality and time. In aquatic animals the lethality is expressed in terms of lethal concentration (LC) and in the case of terrestrial animals it is expressed in terms of lethal dose (LD). This value represents the amount of poison per unit weight which will kill 50% of the particular populations of the animal species employed for the tests and this, in turn, represents the medium tolerance limit (TLm) measurement (Finney, 1964). If the pesticide is mixed with water, its concentration is generally expressed as mg/l or parts per million (ppm) or parts per billion (ppb) and the lethal dose is expressed as mg/kg weight of the animal. While conducting the toxicological studies, it is essential to evaluate the toxicants by means of responses of the experimental animal after the administration of the toxicants. Different workers adopted different methods for assessing the toxicity of a pesticide. There are different parameters like lethal
concentration, sublethal concentration, median lethal concentration, safe concentration etc., to be computed for evaluating the toxicity of a pesticide. The typical test is the evaluation of the toxicity of an insecticide is to expose the animals in successive batches to different pesticide concentrations for a constant time and after suitable intervals, score the number of animals dead and alive (Finney, 1964). Finney (1964) has proposed a probit method for calculating LC$_{50}$. In this the per cent kill observed for each dose must be calculated and converted to probit by means of a probit table. The probits calculated are then plotted in the graph against the dosage as mentioned by Finney (1964). Most of the investigations of the toxic effects of pesticides on aquatic animals have involved the determination of LC$_{50}$ and the period of exposure is 48 hrs, because the effects may be consistent in this period (Pickering et al., 1962; Keshavan et al., 1982; Sasha Mohideen and Subba Rao, 1982; Basha Mohideen and Parvathi, 1984).

It was reported by Basha Mohideen and Subba Rao (1982) that commercial grade malathion is more toxic to C. mrigala than to C. carpio with an intermediate level to L. rohita. The same grade of toxicity was also confirmed
using technical grade malathion (Basha Mohideen and Parvathi, 1984) to major carps. It has been reported that larger crabs *O. senex senex* encountered less *LC₅₀* values of commercial grade malathion than smaller ones (Prasad and Basha Mohideen, 1985). Meenakshi Das *et al.*, (1982) reported *LC₅₀* values for freshwater mussels using the organophosphate insecticides when exposed to methyl parathion, the *LC₅₀* values increased with body size suggesting that larger animals are more tolerant than smaller animals.

According to Dougherty (1951) classification, malathion is moderately toxic to fish populations and rats. Bodkhe and Nagabhushanam (1982) reported 48 hrs *LC₅₀* values of Sevimo in freshwater crab *Barytelphusa cunicularia*. Sanders (1969) reported *LC₅₀* values (ppb) for insecticides to the amphipod crustaceans *Gammarus lacustris*. Malathion is no less toxic than DDT to cladoceran crustacea in the genera *Daphnia* and *Simoccephalus*. Sanders and Cope (1966) and FWPCA (1968), Eisler (1969) gave a static test for 96 hrs *LC₅₀* values in ppb for organophosphate insecticides in decapod crustaceans. Brown (1977) reported that in the New Jersey salt marshes, DDT at 0.25/1/a caused 20% mortality of the blue crab *Callinectes sapidus* and even greater mortality among the smaller specimens of the marsh fiddler crabs *Uca pugnax*. 
Among the organophosphorous insecticides, folidol is the most toxic (Sreenivasan and Swaminathan, 1967). The $T_L_{48}$ hrs to *Tilapia* being as low as 0.6 ppm, whereas phosphomiden is the least toxic to fishes and parathion and malathion represent an intermediate between the two. Malathion and parathion are least hazardous to man (Caplan et al., 1956), livestock (Pasarela et al., 1962), domestic poultry (March et al., 1956; Dougherty, 1962). But in the crustacean populations, malathion and methyl parathion are found to be detrimental (Parker, 1971; Conte and Parker, 1971; Tagatz, 1974; Bookhout, et al., 1977; Bharanikumar et al., 1982). Amongst the crustaceans, crabs are the most susceptible to OP compounds (Brown and Abedi, 1960). Thus the foregoing account on the toxicity of insecticides in crabs indicate the importance of the study of the effects of pesticides on crabs which form protein diet of human food. But little work has been done on the studies involving the evaluation of pesticide toxicity with reference to commercially important crabs.

**Pesticide exposure - Time Course:**

In typical pattern, the animals respond to the environmental stress. Physiological responses to the imposed environmental stress may be pollutional stress by
pesticides, or thermal, osmotic or any other factor.

Environmental stress mainly falls into two categories

namely immediate or short term responses i.e., immediately

following transfer of the animal into the stress medium

and stabilised or long term responses i.e., after pro-

longed exposure of the animal over days or even weeks to

the stress (Grainger, 1958; Kinne, 1958; 1964a; Parva-

theswara Rao, 1968a; Basha Mohideen and Parvatheswara Rao,

1976a; Basha Mohideen and Kunneman, 1979; Basha Mohideen,

1982; 1984). The abrupt rise or fall in the respiratory

activity is due to short response and it is followed by

responses resulting in the gradual stabilisation of res-

piratory rate and at the (natural) aquatic habitat medium.

This is due to complete adaptation of the animal to the

stress medium. It is possible because of long term chronic

responses. This is indicative of recoverable change.

Great deal of work has been done on this mode of stress

with reference to temperature acclimation in crustaceans

(Earl Prentice, 1980; Hanumante et al., 1981). But very

little work has been done with reference to pollution stress

(Sreenivasulu Reddy et al., 1982; Fingerman et al., 1981;

Prasad and Basha Mohideen, 1985).
A conceptions! model of possible effects of pesticides and other toxic substances was proposed by John Couch (Duke and Dumas, 1974). In this model the possible impact of a stress on a biological system is described from factors that a biological system changes from the (1) a normal steady state to compensate state, (2) from the compensate state to death. It is revealed by this model that an adverse effect of a pesticide may be temporarily or permanently modified to render the homeostatic mechanism incapable of maintaining an acceptable altered steady state. An acute dose of a pesticide could cause a biological system to oscillate outside its normal range of variations, yet with time could return to the normal state without suffering lasting effects. Such a compensation state was reported by Coppage and Duke (1972), that when malathion was sprayed aerially to control mosquito vectors the AchE activity of the fish brain returned to normal within 40 days. Mukhopadhysay and Dehadri (1978) reported that the detoxifying of the microsomes from liver and gills in the air breathing cat fish Clarius batrachus were enhanced, under sublethal exposure of malathion after 30 days. Recently, Basha Mohideen and Subba Rao (1984) and Basha Mohideen and Parvathi (1984) are reported that the oxygen consumption in the major carps was recovered after 30 days of exposure to malathion.
It is customary to study the sublethal effects on a time-scale to extrapolate the action of pollutant or toxicant affecting the physiological processes and behaviour of animal life. Some work has been turned out in these lines in marine organisms including fishes (Vernberg and Vernberg, Vernberg et al., 1978). Recently this has been reported by Sujatha and Basha Mohideen (1985) in the crab, Obilesu and Basha Mohideen (1985) on Tilapia subjected to sublethal exposure of malathion and methyl parathion. But however the work on these lines with special reference to commercially important crustacean species like crabs is scanty. Hence time course studies of sublethal exposure are useful to evaluate the compensatory mechanisms on pollutinal stress.

Pesticide Toxicity - Oxygen consumption:

The rate of oxygen consumption serves as an indicator of pollutional stress and changes in oxygen consumption reflects the alterations in environment. The rate of oxygen uptake is considered as a good index for all physiological activity and such an index is easy to obtain both in laboratory and in the field. Depression of $O_2$ consumption with pollutional stress is often associated with morphological gill damage (Bayne et al., 1980; Basha Mohideen and Parvathi, 1984).
Thus variations in respiratory activity has been used as sensitive indicators of stress in aquatic animals exposed to pollutants. Generally the insecticides gain their entry through the gills of crustaceans (Keshavan, 1982) and therefore the first physiological function to be affected is oxygen consumption. Organophosphates are reported to inhibit whole animal as well as tissue respiration (Hunter et al., 1967; Basha Mohideen and Subba Rao, 1982; Basha Mohideen and Parvathi, 1984). Koundinya and Ramamurthy (1978) reported that pesticides like Sevin and Sumithion suppressed tissue respiration in *Tilapia mossambica*. Recently Shahnawaz and Basha Mohideen (1986) have shown that malathion exposure at different temperatures suppressed oxygen consumption in *Labeo rohita* and the malathion toxicity increases in ambient temperature. It is well known from the previous study that the organophosphate insecticides results in the suppression of oxygen consumption, therefore depressed respiration of the whole animal (Bhagyalakshmi et al., 1982; Lee, 1969; Subba Rao, 1980; Parvathi, 1984) is brought about during pollution stress. Diwan and Nagabhushanam (1982) reported the decreased level of oxygen consumption in *Barytelphusa cunicularia* exposed to toxic substances.
A significant decrease in oxygen consumption, when exposed to malathion showed in *Paratelphusa jacquemontii* (Kulkarni and Kamath, 1980). But studies involving oxygen consumption of whole animal with reference to sublethal effects of organophosphate pesticides in crustaceans are scanty and no attempt has been made on commercially important crabs.

**Pesticide Toxicity - Carbohydrate Metabolism:**

Carbohydrates play not only a structural role in the cells but may serve as reservoirs of chemical energy to be increased or decreased according to organismal needs. The major function of carbohydrates in the metabolism is to serve as a fuel and provide energy for other metabolic processes of the animal. Carbohydrates in the blood serve as immediate source of energy and in the liver tissue (Hepatopancreas in the invertebrates) serve as important energy reserves of the animals.

Impairment of carbohydrate metabolism has been observed in a variety of physiological disorders and pathological conditions (Latner, 1975; Harper et al., 1978). Investigations have been conducted earlier on carbohydrate
metabolism during pathological conditions in different animals following exposure to some kinds of pesticides. But very little is known about the effects of OP insecticides on carbohydrate metabolism. It has been reported that chronic and acute poisoning of sheep and chicken with OP insecticides like thiophos, chlorophos and methyl nitrophos is accompanied by profound changes in carbohydrate metabolism. Kabeer Ahmed Saheb (1979) has studied the effect of OP pesticide malathion on the carbohydrate metabolism of the fish *Tilapia mossambica*.

Extensive as well as intensive work has been carried out on blood glucose, liver and muscle glycogen in fishes with reference to exercise effects as well as temperature and salinity stresses (Heath and Pritchard, 1965; Dean and Goodnight, 1964; Umminger, 1971a, b; Basha Mohideen and Parvatheswara Rao, 1971, 1972) and a beginning is made on pollution stress (malathion) in major carps (Basha Mohideen and Parvathi, 1984). Organophosphate insecticides are reported to decrease liver glycogen and increase blood glucose in animals. Exposure to OP compounds like malathion, dipterex and DDVP in the fish *Cyprinus carpio* at 5 ppm increase blood glucose levels, while DDVP even at 1 ppm concentration decreased liver glycogen content.
Pesticides may be ingested by aquatic crustaceans along with food or taken up from the surrounding medium via the gut or gills. The accumulation of the compounds by crustaceans in the organs was regarded as passive (Bryan, 1971; Wright, 1978). Many studies were carried out on the accumulation of toxic substances by crustaceans (Wright, 1976; 1977a; 1978; Wharf and Van den Brock, 1977). These crustaceans show a significant increase in haemolymph sugar level and a suppression in the total carbohydrates of hepatopancreas in sublethal and lethal periods when exposed to organophosphate insecticides (Bhagyalakshmi et al., 1983) whereas Sreenivasulu Reddy et al., (1983) observed hyperglycemia in the freshwater crab exposed to benzene hexachloride.

Glycogen, commonly called the animal starch, is the main storage of polysaccharide and a great source of blood sugar. A good deal of work has been done on carbohydrate metabolism with reference to metal toxicity in aquatic animals, especially in fishes (Gayyam and Shafi, 1977; Shafi, 1978; Sastry and Sunita, 1982; Srivastava, 1982; Natarajan, 1982). From the reports of Koundinya and Ramamurthy (1979), it has been found that the organophosphate pesticide sumithion in Sarotherodon mossambicus at lethal (LC₅₀/48 hrs) increased the blood glucose levels, but it reduced the liver glycogen.
Studies involving carbohydrate energy sources with reference to organophosphorous pesticides are few in number (Basha Mohideen and Parvathi, 1984) and are highly lacking in freshwater crustaceans, especially on crabs, having a great commercial value. Therefore an attempt is made in this investigation to explore the effects of pesticide like malathion on haemolymph sugars and hepato-pancreatic glycogen in the freshwater field crab *O. senex senex* which has a great commercial value.

**Pesticide exposure - Enzyme studies:**

Long term exposure of poikilotherms to pesticide toxicity is often followed by specific change in the rates of various physiological or behavioral processes and such physiological adjustments are generally considered to be homeostatic and are of adaptive significance. Coincidental to these adjustments in the physiological activities are parallel adjustments in respiratory rates indicating that energy metabolism has compensated in response to the varied energy demands during exposure to pesticides.

The general outline of crustacean metabolism is very similar to that of mammals. Glycolysis, pentose shunt pathway and citric acid cycle contributes towards energy
metabolism of crustacean (Munday and Poet, 1971). However not much information is available in crustaceans regarding the nature of metabolic pathways that might have been altered as a result of exposure to sublethal concentration of pesticide. It is suggested that contributions of these pathways to the total metabolism may vary with change in environment (Munday and Poet, 1971). Only a few studies are made in crustaceans on these lines.

Organophosphorous pesticides are most toxic compound and are known to inhibit cholinesterase activity in almost all tissues of freshwater fishes (Goodman et al., 1979; Jash et al., 1982). Apart from the inhibition of above enzyme OP compounds seen to interfere with other enzymes. These pesticides are reported to cause respiratory failures (O'Brien, 1967). These pesticides also inhibit a number of physiological and biochemical parameters at enzyme levels (Fest and Schmidt, 1975; Corbett, 1974; Rainsford, 1978).

The nervous system is found to have profound influence on the functional activity of enzymes (Bajusz, 1965). Since altered physiological or pathological conditions in tissues are known to influence marked changes in the activity of several enzymes (Knox and Greengrad, 1965)
an attempt was made to assay two selected enzymes of the carbohydrate metabolism in HUE crabs to understand the possible impact of malathion on these enzymes concerned with the energy yielding processes. Hence (SDH) succinate dehydrogenase was selected as representative of the oxidative metabolism and (LDH) lactate dehydrogenase was selected to represent the glycolytic segment of the carbohydrate metabolism.

Since the freshwater crab *O. senex senex* is capable of adjusting to pesticide exposure, it is natural to expect that variation in energy metabolism will occur. Attention was hence focussed on energy metabolism and activity of enzymes like SDH and LDH are studied in the crabs subjected to exposure of sublethal concentration of malathion.

(a) **Succinate Dehydrogenase**

Succinate dehydrogenase being the key enzyme in TCA cycle, its activity reflects the metabolic energy production. This fact has been established in different tissues (Hiltibran and Johnson, 1968; Gumbran and Tappel, 1962). Inhibition in succinate oxidase and pyruvate oxidase systems has been noticed in rat liver on malathion exposure by O'Brien (1959). The oral administration of
malathion to rats decreased the hepatic succinate dehydrogenase (Miroslow et al., 1973). Vasielas et al., (1976) reported the ultrastructural modification in mitochondria and endoplasmic reticulum and depression in TCA cycle enzymes in organophosphate insecticides exposed animals. Kabeer Ahmed et al., reported suppression of SDH activity in Lamellidens marginalis on exposure to malathion. All these studies indicate that inhibition of TCA cycle enzymes blocks the energy releasing system during pesticide exposure in animals.

However, very limited reports were available on the oxidative metabolism during pesticide exposure on crabs and also at sublethal levels. Hence an attempt is made to study the activity of an important oxidative enzyme like SDH during malathion exposure in the case of O. senex senex.

(b) Lactate dehydrogenase:

It represents one of the key enzymes of anaerobic glycolytic pathway in animals. LDH activity is known to elevate during conditions favouring anaerobic respiration to meet the energy demands and when aerobic oxidation is lowered (Harper, 1977) under pathological conditions. Inhibition in glycolysis and accumulation of lactic acid in
blood of rats was reported by Prokliina and Kaminskaya (1969) in subjecting the rats to continuous oral dose of carbonates like sevin, tillam and thiram. Further from the studies of Kabeer Ahmed (1979); Sivaprasad Rao and Ramana Rao (1979), it is clear that on sublethal exposure to malathion and methyl parathion in *I. mosambica* there are changes in LDH activity in muscle, gill and liver. These variations suggested the accumulation of lactic acid in the tissues of pesticide exposed fish. Sumithion elevated the LDH activity in different tissues like muscle and brain, but more significant elevations are noted in liver, gill, intestine and kidney. There is great deal of work existing on the physiological and biochemical responses of poikilothersms.

Very little information is available on the anaerobic metabolism in relation to pesticide exposure in animals and as such the extent of involvement of glycolytic enzymes, hence energy expenditure of glycolytic metabolism especially in economically important food crabs exposed to pesticides needs to be substantiated. In fact studies on such glycolytic involvement during sublethal exposure of pesticides are conspicuous by their absence in crabs which have a great commercial value.