The adoption of new technology in agricultural crop production and protection has increased the use of various pesticides among which endosulfan, an organochlorine pesticide is one. Although it is phased out in many western countries, still it is being used in tropical and sub-tropical regions (EFSA, 2005). The endosulfan used in agricultural fields enters the aquatic environment, generally as a consequence of runoff from the fields and/or accidental discharge and get dispersed widely throughout the water system. In addition, elevated residue levels of endosulfan in plant ingredients have also been reported (Lorenzatti et al., 2004). The increasing use of these plant ingredients in aqua-feeds in order to develop a more sustainable aquaculture has led to an increased exposure of endosulfan in fish. This compound has been found to be moderately persistent in the environment and has a tendency to bioaccumulate in various aquatic organisms (Naqvi et al., 1993). It is also reported to have a strong acute toxic effect on fish/shellfish (Naqvi et al., 1993; Petri et al., 2006) and cause a drastic decline of their population in the aquatic environment.

Malathion[O,O-dimethyl-S-(1,2-dicarbethoxyethyl) phosphorodithioate] is one of the most widely used organophosphate pesticides for agriculture crops against several pests and public health programs, this insecticide is also considered as a low toxic for domestic use (Lasram et al., 2008). Toxic effects of malathion have been studied extensively in experimental animals and in exposed workers (Ahmed et al., 2009). Malathion is known to inhibit
acetylcholinesterase activity in target tissues (Ahmed et al., 2009; Jensen et al.,
2010; Rezg et al., 2008) and has been linked to the dysfunction of several organ
systems, including the liver (Kalender et al., 2010), testis (Uzun et al., 2009),
pancreas (Vasough-Ghanbari et al., 2007), brain (Silva et al., 2006) and
erthrocytes (Durak et al., 2009). In recent years, studies have indicated that
OP compounds, especially malathion, are able to induce oxidative stress by
changing the status of oxidant-antioxidant balance of body (Azadbar et al.,
2009). Some authors can demonstrate that malathion exposure causes toxic
effects in animals and humans (Acker et al., 2009; Parron et al., 1996). The
lipophilicity of organophosphate insecticides favors their incorporation in
membranes. Therefore, insecticides may result from physicochemical changes
at the level of membrane lipid structure and organization (Videira et al., 2001;
Ogutcu et al., 2008). Several studies show that malathion caused hepatotoxicity
(Kalender et al., 2010), testicular toxicity (Uzun et al., 2009), hematotoxicity
(Durak et al., 2009), genotoxicity (Giri et al., 2002). Finally, hematological
alterations may be used for diagnosis in the field to assess pollution related
pathophysiological alterations in fish.

Saravanan et al. (2011) reported that endosulfan caused significant
lower value of red blood corpuscles (RBC), hemoglobin, plasma glucose, and
protein levels when compared to the control groups (p < 0.05). However, white
blood corpuscles (WBC) increased throughout the study period. The results
indicate that a low amount of endosulfan alters the hematological and
biochemical parameters of fish, which can be useful in diagnosing the
structural and functional status of fish exposed to toxicants. Mukhopadhyay and Dehadrai (1980) studied that juveniles of *Clarias batrachus* were exposed for 40 days to malathion (purity 98.16%) at a concentration of 500 µg/litre. Incorporation of 1-lysine-U-14C into the protein of the liver was significantly reduced under this subacute exposure to malathion and could not be recoupled even at higher dietary protein. Increased total and differential leucocyte count, decreased erythrocytes, haemoglobin and haematocrit values, with no change in the erythrocyte sedimentation rate, were observed. Malathion exposure of the fish caused little alteration in its hepatic protein and nucleic acids but a marked decrease in liver glycogen and a significant increase in serum glucose and free amino acid level. The effect of malathion on liver and gill esterase activities has been correlated with toxicity. Verma *et al.* (1982b) measure the activity of three phosphatase in liver, brain and gills of *Saccobranchus fossilis* after 30 days exposure to endosulfan (0.63 µg/l). The depression in the activity of these enzymes was increased by the addition of ascorbic acid to the food of the fish. Rao and Rao (1984) studied the activity levels of aspartate amino-transferase, alanine aminotransferase and total adenosine triphosphatase in muscle, gills, liver and brain after exposure to *Tilapia mossambica* to methyl parathion. The activities of both the aminotransferases deviated in all the tissues inferring the diversion of a-amino acids into TCA cycle as keto acids to augment energy production during stress. An increase in the activities of glutamate-pyruvate transaminase and glutamate-oxalacetate transaminase was observed by Sadhu *et al.* (1985) in *Channa punctatus* exposed to malathion and phosphamidon for 10 days. Asatalos (1987) reported four fold increase in LDH activity after exposure of *Cyprinus carpio*. Hypothalamichthys molitrix and
*Silurus ganis* to copper sulphate and paraquat. Ghosh (1987) reported that aerobic oxidation through Krebs cycle was adversely affected in *Oreochromis mossambicus* exposed to Ekalux, Nuvan and Suguin as revealed by the unequivocal inhibition in the activity of SDH in liver, gill, brain and muscle and the elevation of LDH activity. Effect of Hildet and Hibech on alkaline phosphatase in stomach, intestine, pyloric caeca, liver and kidney of *Ophiocephalus punctatus* has been studied by Garg and Sangeeta Rani (1987). In stomach and kidney there was a gradual decrease in enzyme activity while in pyloric caeca it increased with lapse of time. Intestine and liver revealed decrease in activity at 96 hr stage but it was increased in 15 and 30 days treatment stages. Vasanthi and Ramaswamy (1987) have reported inhibition of succinic dehydrogenase levels in liver, muscle and heart of endosulfan exposed *Sarotherodon mossambicus*. Ghosh (1987) reported that aerobic oxidation through Krebs cycle was adversely affected in Indian Catfish *Oreochromis mossambicus* exposed to organophosphates and Ekalux, Nuvan and Suguin as revealed by the unequivocal inhibition in the activity of LDH activity. Bhaskaran (1998) studied the *in vitro* influence of DDT and methyl parathion (MP) on the respiratory control of liver mitochondria of the fish *Channa striatus* using polarographic technique. They reported a RC ratio of 2.6 for the mitochondria by using succinate as the substrate. The ratio decreased to 1.0 or 1.78 at the highest concentration (10\(^{-3}\) m) of DDT or methyl parathion. The effect of exposure to LC\(_{50}\) for 96 hr and to a sublethal concentration to Sevin for 120 days on *Channa punctatus* has been studied by Sastry *et al.* (1988). The
activity of hexokinase increased in kidney, intestine, liver and muscles but decreased in the gills and brain. The activity of LDH decreased in kidney and intestine, liver and muscles but decreased in the gills and brain. The activity of PDH decreased in all the six tissues. Rani et al. (1989) examined the effect of trichlorofon and methyl parathion on carbohydrate metabolism of *Clarias batrachus*. The specific activities of LDH, ICDH, SDH and MDH were inhibited in exposed fish indicating that organophosphorus compounds interfere with the aerobic oxidation of carbohydrates. Rajeshwari et al. (1989) have reported decrease in the activity of SDH in liver and muscle of the fish *Tilapia mossambica* exposed to thiodon for 24, 72 and 96 hours. Impact of endosulfan on MDH and LDH activities of a fresh water catfish *Clarias batrachus* has been studied by Tripathi and Shukla (1990). The activity of cytoplasmic and mitochondrial MDH and LDH in liver and muscle was inhibited. Gill et al. (1990) in their studies on *in vivo* and *in vitro* effect of sublethal concentration of aldicarb, phosphamidon and endosulfan in *Puntius conchonius* have reported alterations in enzyme activities in brain, gill, liver, muscle, kidney, gut and ovaries.

Agarwal (1992) observed relative decrease in blood glucose level and increase in blood urea and serum cholesterol level in *Channa punctatus* exposed to mercuric chloride for 28 days. The effect of exposure to sublethal concentration of lead nitrate on *Heteropneustes fossilis* has been studied by Singhal (1994). Blood glucose and muscle glycogen levels remained below normal level after 60 days. After 120 days of treatment, blood glucose, liver
and muscle glycogen level were elevated while lactic acid level decreased in blood, liver and muscle.

Some information is available on the effects of pesticides on enzymological parameters in fish. The effect of exposure to a sublethal concentration of eldrin for 30 days on the activities of alkaline phosphatase and glucose-6-phosphatase in the liver and kidney of *Channa punctatus* has been studied by Sastry and Sharma (1979). In the liver, the two enzymes showed inhibition in the activities while in kidney, increase in the activities of both the enzymes was noted. Gaafar et al. (2010) studied the pathologic and clinicopathologic findings due to chronic exposure to the organophosphate fungicide edifenphos on Nile tilapia *Oreochromis niloticus*. Eight weeks exposure to 1/10 96 hours LC50 (0.1 ppm) led to adverse effect on some serum parameters. The *in vivo* effect of monocrotophos, individually and in combination with endrin and sevin on *Heteropneustes fossilis* was reported by Thomas and Murthy (2006). Alkaline phosphatase activity showed an increase in liver, kidney and intestine. Koundinya and Ramamurthi (1978) found that sumithion and sevin inhibited enzymes like acetylcholinesterase (AChE), succicit dehydrogenase (SDH) but increased the acetylcholine (ACh) content and lactate dehydrogenase (LDH) activity in *Tilapia mossambica*. Sastry and Sharma (1981) also noted alterations in brain enzymes activities of *Channa punctatus* exposed to sublethal concentrations (0.4 mg/l and 0.2 mg/l) of diazinon for 15 and 30 days. The effect of acute and chronic exposure to diazinon has been studied in the liver, stomach, intestine and pyloric caeca of a
freshwater telost fish *Channa punctatus* by Sastry and Malik (1982). In acute exposure SDH activity was elevated in intestine and pyloric caeca. No alteration was noted in LDH activity but PDH was inhibited in pyloric caeca. Chronic exposure resulted in inhibition of the activities of the three dehydrogenases in all the four parts at both intervals. Sastry and Siddiqui (1982) studied the effect of exposure to a sublethal concentration of sevin in *Channa punctatus*. In liver, muscle, brain and gills the LDH activity was higher in pesticide exposed fish in comparison to control fish, but the same enzyme activity was inhibited in kidney and intestine. Decrease in PDH activity occurred in all the six tissues. Succinate dehydrogenase activity decreased in muscle at the three time periods and after 30 and 60 days in liver and brain.

Pandi (1991) studied the effect of pesticide fenvalerate on some biochemical parameters in some fresh water fishes such as *Oreochromis mossambicus*, *Mystus vittatus* and *Channa striatus*. They reported a decrease in SDH activity and increase in protease activity in muscle and liver of fenvalerate exposed fish. The impact of different concentrations of pesticide dimethoate on acid and alkaline phosphatase activities in different tissues of *Lepidocephalichthys thermalis* was investigated by Sheela and Muniandy (1992). They reported an increase in the activities of acid and alkaline phosphatase in muscle and liver with increasing concentrations of dimethoate. Effect of pesticides on various biochemical aspects of fishes has also been investigated by different workers. Increase in the levels of glycogen, cholesterol, protein, glucose and total amino acids in *Salmo gairdneri* on
exposure to eldrin has been reported by Grant and Mehrle (1973).

Shakori et al. (1976) found an increase in serum proteins following organophosphate intoxication in the muscle, gill and liver of malathion exposed *Tilapia mossambicus*. Occurrence of hyperglycemia and decrease in the levels of glycogen in liver and muscle on exposure of *Sarotherodon mossambicus* to sumithion has been reported by Koundinya and Ramamurthi (1979). Decrease was reported in the levels of total free amino acids and total protein. Singh and Singh (1980a, b) observed the effect of malathion and eldrin on the total lipids and cholesterol contents of ovary, liver and blood serum during different phases of annual reproductive cycle in the fresh water teleost, *Heteropneustes fossilis*. The pesticide induced a significant decrease in lipid concentration during preparatory and late post-spawning phases only and an increase in ovarian cholesterol occurred in pre and post-spawning phases. Singh and Srivastava (1981) studied the effect of endosulfan on carbohydrate metabolism in Indian catfish *Heteropneustes fossilis*. Muscle and liver glycogen decreased whereas blood glucose was increased. Initial decrease in protein content in liver and kidney of *Heteropneustes fossilis* was reported by Dubale and Awasthi (1982) during first week of exposure to sublethal concentration of dimethoate. However, a temporary recovery was observed between second and third weeks of exposure. Joshi (1982) reported accumulation of glycogen in liver and muscle of monocrotophos exposed *Tilapia mossambica*. Singh and Srivastava (1982) have reported depletion of muscle glycogen and increase in blood lactate and pyruvate on exposure of *Heteropneustes fossilis* to IOA ppm of
formation for 3, 6, 12, 48 and 96 hours.

Decrease in protein content in the brain of *Tilapia mossambica* was observed by Joshi and Desai (1983) after exposure to monocrotophos. Sastry and Siddiqui (1984) observed marked alterations in the level of plasma proteins, glucose and lactic acid in the blood, glycogen and lactic acid content of liver and white skeletal muscle on exposure of *Channa punctatus* to quinalphos. Rao and Rao (1984) studied the effect of methyl parathion on the tissue lipid profiles of *Oreochromis mossambicus*. They reported decrease in the level of total lipids and phospholipids and increase in the level of free fatty acids and cholesterol. Lal *et al.* (1986) reported changes in the levels of glucose and free fatty acids of plasma, red blood corpuscle and hemoglobin after exposure of *Heteropneustes fossilis* to malathion for 15 days.

Reddy (1987 a, b) observed decrease in total, structural and soluble proteins and increase in free amino acids in kidney, intestine and gills of *Cyprinus carpio* exposed to malathion. Ghosh (1987) observed depletion in glycogen content of liver and muscle whereas blood glucose level was elevated on exposure of *Clarias batrachus* to three organophosphate pesticides. Exposure of fish to sublethal concentration of lindane and carbofuran in submerged condition on exposure to air caused unequivocal reduction in the lactic acid content of liver, muscle, heart and blood of the fish *Anabas testudineus* Bakthavathsalam (1988). Technical endosulfan at sublethal concentrations produced marked alterations in protein, glycogen and total lipids
of kidney, liver and muscle on exposure of Catla catla to endosulfan (Rao, 1989). Effects of endosulfan, malathion and sevin on Puntius stigma was studied by Khillare and Wagh (1989). Free amino acids in muscle, protein content and glycogen were reduced but ascorbic acid was increased liver and muscle tissue.

Ghosh and Chatterjee (1989) studied the effect of Nuvan on the organic reserves of fresh water telost Channa punctatus after exposure for 48 hours, 5,10,15,20 and 30 days. Significant depletion in lipid content was observed in liver, brain, testis and ovary and significant elevation of cholesterol was observed in liver, testis and ovary of Nuvan exposed fish. Hypoglycemia and hypolactemia after 96 hours and 15 days of exposure to monocrotophos in Channa punctatus has been reported by Samuel and Sastry (1989). Thakur and Choudhary (1990) noted significant depletion in protein content in liver of Amphipnous cuchis after exposure to sublethal concentration (10, 20 ppm) of dimethoate for 40 days. Effect of nuvan on the nutritive value of Channa punctatus was studied by Sastry and Dasgupta (1991) after exposure to sublethal concentration (1 ppm) for 15, 30 and 60 days. They reported decrease in total protein and total carbohydrate in liver and muscle. Sheela and Muniandy (1992) studied the impact of different sublethal concentrations of the pesticide dimethoate on protein, carbohydrate and lipid content of muscle and liver in Lepid ocephalichthys thermalis. Protein, carbonohydrate and lipid levels of muscle and liver decreased with increasing concentration of dimethoate. Singh and Srivastava (1992) studied the effect on biochemical
parameters of *Heteropneustes fossilis* after exposure to subacute and sublethal concentrations of aldrin for four to seven days respectively. Hyperglycemia and glycogenolysis in the fish throughout the exposure period was reported. DNA and RNA content in liver decreased significantly in the group exposed to subacute concentration of aldrin, whereas only liver RNA content decreased significantly in fish exposed to sublethal concentration.

Gupta *et al.* (1989) studied the effect of LAS on some enzymes in liver and gills of the teleost *Channa punctatus*. They observed inhibition in the activity of ACP, ALP, GPT and GOT in liver and gills at 20, 40 and 100 mg/l of LAS whereas 5-nucleotidase was inhibited at 40 and 100 mg/l in both the organs. Roy (1989) studied the detergent (SDS) induced changes in certain enzymes in various cell types of *Rita rita*. Twenty-four hours of detergent treatment induced decrease in acid phosphatase, alkaline phosphatase, and 5-nucleotidase activities while no reaction for these enzymes after 203 days could be observed in epithelial cells. The peripheral areas of the goblet mucus cells in the opercular epidermis exhibited strong reaction for acid phosphatase and non specific estarases. The cytoplasmic contents of the club cells showed moderate reaction for glucose-6-phosphatase, glucose-6-ogisogate dehydrogenase and alkaline phosphatase. Significant decrease in erythrocyte count and other haematologic parameters was reported in *Anabas testudineus* by Banerjee and Kumari (1988) on exposure to LC$_{so}$ concentration of Zn, Hg and Cd for 24 hours. Hematological parameters were examined in five Gangetic fishes with special reference to sex and pollution harbouring between Kalakankar and
Phaphaman by Shrivastava et al. (1991). In their study they observed higher total erythrocyte count and packed cell volume and lower mean cell hemoglobin in males than in females. Lower total erythrocyte count, hemoglobin content and higher mean cell hemoglobin values were observed in these Gangetic species than in fishes of other freshwater bodies. Thallium nitrate induced anemia and decrease in RBC count, Hemoglobin and PCV and increase in the MCHC, WBC count and MCH values have been reported by Garg et al. (1991). Ahmad and Datta Munshi (1992) have observed that red blood cell morphology of *Catla catla* exposed to 96 hours showed shrinkage and crenation in their configuration alongwith slight erythronisocytosis and degeneration of cell membrane. Ravindra Kumar and Agarwal (1993) have reported significant decrease in RBC, Hb, ESR and MCHC and increase in WBC count after 15 and 30 days of exposure to sublethal concentration of mercuric chloride in *Clarias batrachus*.

Several attempts have been made to study the effect of a number of pesticides on different parameters of the blood of fishes. Andrews et al. (1966) observed an increase in haematocrit value of bluegills exposed to 0.05 mg/L of heptachlor for 4 h. Mount and Putnicki (1996) while investigating a fish kill due to eldrin noted that the hematocrit values were lowered to half of the normal. Eisler (1967) found that both methoxychlor and methyl parathion reduced haematocrit values in northern puffers. Verma et al. (1979) showed an increase in Hb, RBC, WBC and PCV but decrease in ESR and CT in *Sacco branch us fossilis* after an intervals of 15, 30, 45 and 60 days of clorodance.
exposure. They also showed significant reduction of MCH and MCV but no significant variation was observed in MCHC. Sevin and sumithion, lowered RBC counts, hemoglobin and haematocrit in *Tilapia mossambica* (Koundiya and Ramamurthi, 1979). Bansal *et al.* (1979) reported that exposure to different concentrations of pesticides (chlorinated hydrocarbons) for varying periods bring about increase in TEC, TLC, Hb and packed cell volume. The effect of aldrin on RBC count, hemoglobin content and haematocrit value and white blood cells were studied by Mahajan and Juneja (1979). Pesticide exposure to *Clarias batrachus* has been reported to cause lymphopenia by Dalela *et al.* (1980).

Malathion is reported to cause erythropenia and other changes in the blood of *Clarias batrachus* (Linn.) by Mukhopadyhay and Dehadrai (1980). Goel *et al.* (1982) have reported anemia in *Heteropneustus fossilis* after malathion exposure with decreased RBC, hemoglobin and haematocrit value. Srivastava and Mishra (1983) have found thrombocytopenia in different piscine species exposed to organophosphate pesticides. Occurrence of erythrocytic necrosis resulting in hypochromic microcytic anemia has been reported in *Tilapia mossambica* exposed to thiodon by Srinivasan (1983). Lindane is reported to cause increase in TEC, Hb, PCV, TLC in *Heteropeustes fossilis* by Srivastava and Mishra (1985). Significant decrease in RBC, Hemoglobin and PCV associated with a decrease in MCHC has been observed by Goel and Maya (1986) in *Clarias batrachus* exposed to Ragor. Variations in blood parameters of the fish *Channa punctatus* exposed to organophosphorus
pesticides have been studied by Chakrabarty and Banerjee (1988). The effect of exposing *Channa punctatus* to endosulfan for 30 days caused decrease in TEC, TLC, Hb and PCV as reported by Abidi and Srivastava (1988). Munni Kumari *et al.* (1989) reported decrease in clotting time in *Clarias batrachus* after treatment with cythion, metacid, DDT and lindane.

Kumar and Banerjee (1990) noted decrease in Hemoglobin and PCV and increase in ESR in the blood of *Clarias batrachus* exposed to sevin. Exposure to sevin caused hypochromasia, crenation of erythrocyte membrane, decrease in TEC, Hb, MCH, MCHC, TLC and in small lymphocytes count in *Clarias batrachus* (Birendra and Banerjee, 1991). DDT induced polycythemia in an Indian cat fish *Clarias batrachus* with increase in TEC, Hb and PCV has been reported by Munni Kumar and Yadav (1992). Exposure of the carp, *Cyprinus carpio* to malathion caused decrease in Hb and RBC and increase in leucocyte count (Ramesh *et al.* 1992). The effect of sublethal concentrations of Alachlor and Rogor on *Heteropneustus fossilis* was studied after 5 to 30 days by Chaturvedi and Agarwal (1993). The results indicated a significant decrease in Hemoglobin, PCV, MCHC and clotting time whereas MCV and MCH were elevated.