CONCLUSION
Changes in the chemical composition of natural aquatic ecosystems can distress the non-target organisms, predominantly fish. Fish have been largely used to evaluate the quality of aquatic systems as bioindicators for environmental pollutants. In polluted areas, exposure of fish to xenobiotics leads to interactions between these chemicals and biological systems, which give rise to biochemical disturbances. Despite the fact that tropical ecosystems are threatened by degradation due to ill planned development, little research has been done on the impact of contaminants on tropical ecosystems and tropical fish species. Monocrotophos (MCP) is one of several organophosphorus insecticides (OPs) developed to replace organochlorines. Fish can be exposed to monocrotophos either accidentally or under treatment conditions. Being one of the most extensively used OP insecticide in crop protection programmes, monocrotophos can reach the aquatic systems by land run off or leaching. In fish culture, the treatment with OPs is a common method employed to control larval stages of predator insects that threaten fish larvae. Furthermore, OPs are also used to treat skin and gill infections caused by external parasites.

Observed increase in the frequency of surfacing movements of *H. fossilis* subjected to monocrotophos intoxication, indicates respiratory stress.

Energy and metabolic status of the fish demonstrates that monocrotophos has induced biochemical alterations and caused significant metabolic and the physiological consequences. Reduction in the protein content of fish can be due to the rapid utilization of protein due to pesticide induced stress. The observed decrement in total carbohydrate and glycogen content of the fish and subsequent rise in the blood glucose levels indicates that the carbohydrates were used up to meet energy demand of the body, under stress.
It is an issue of concern that in test fish, the concentrations of major biochemical constituents of organs, particularly the total protein, carbohydrate, lipid and glycogen content, were much lower than in controls, which in turn reflects a loss of nutritive value and poses a grave threat to its prospective use as a foodstuff.

The biochemical changes induced by monocrotophos stress is due to disturbed metabolism manifested as inhibition of enzymes, retardation of growth, damage and dysfunction of the tissues. OPs have their own target sites of action, and most of them are metabolic depressors.

The increase of biomarker enzymes in plasma might be due to the necrosis of liver. The assayed enzymes can work as swift and sensitive biomarkers, for monitoring the impact of organophosphorus pesticides on aquatic biota and eventually entire ecosystem.

The present study reveals that monocrotophos has profound effect on the haematological parameters of stinging catfish *Heteropneustes fossilis*. Exposure to low concentrations of monocrotophos resulted in significant haematological alterations in stinging catfish, *H. fossilis*.

Decline in WBC, RBC and Hb values and increase in PCV of the monocrotophos treated fish raises a serious apprehension a propos the immunity status of the fish. These alterations may be disruptive to the survival capacity of the catfish in their natural environment.

Monocrotophos is a potent acetyl cholinesterase inhibitor that blocks the cholinergic activity of the central ganglion of pest invertebrates. The present study underlines the significance of acetyl cholinesterase as the most reliable marker enzyme in monitoring organophosphorus pollution of freshwater environments. Monocrotophos treated fish exhibited behavioural
signs such as erratic swimming, loss of balance, hyperactivity and convulsions which are common in fish intoxicated with anticholinesterase insecticides.

Exposure to monocrotophos significantly inhibited Mg$^{2+}$- and Na$^+$, K$^+$ - ATPase activities in gill tissues of *H. fossilis*. Inhibition of these activities indicates interruption in its cellular and ionic regulation and salt uptake. The present study further validates that ATPase activity can be taken as a significant index of cellular activity and forms a practical toxicological tool. The ATPase system in the freshwater fish *H. fossilis* (Bloch) seems to be a sensitive enzymatic biomarker of exposure to monocrotophos.

Basically, lysosomal functional integrity is a good diagnostic biomarker of exposure to toxicants. From the present study it can be observed that lysosomal membranes were destabilized and hydrolytic enzymes were released from the cell due to leakage of the membrane. A leaking membrane can perform as open doorway to substances into the cell, which in normal conditions not allowed. Disturbed lysosomal stability, to a great extent add to, the impaired proficiency of immune system and to loss of body tissues due to autophagy.

Antioxidants such as superoxide dismutase, catalase, glutathione-S-transferase, glutathione peroxidase, and total reduced glutathione were significantly altered indicating the possibility of direct action of monocrotophos with the enzyme synthesis. Due to the complexity of interactions between pro-oxidant factors and antioxidants, it appears that single responses cannot provide a general marker of oxidative stress. Individual antioxidants can be sensitive and specific but difficult to predict. They are useful as "response biomarkers" indicating a varied pro-oxidant challenge and potentially important early warning signals. Variations of individual
antioxidants are useful for understanding the mode of action of a chemical stressor and the possible molecular interaction with specific responses. However, their value is more limited for understanding the biological effect in terms of health condition of the organisms. However, the adverse effects of oxidative stress on these parameters cannot be overlooked. From an eco-physiological point of view it is apparent that, the use of monocrotophos in agriculture and storage facilities must be carefully evaluated.

Histopathological evaluation points out that exposure to sub lethal concentrations of monocrotophos caused destructive effect in the gill, brain and liver tissues of *H. fossilis*. Liver of the monocrotophos treated animals exhibited various histopathological features such as vacuolated hepatocytes, cell necrosis, pyknotic nuclei, cytoplasmic degeneration and necrosis leading to disintegration of hepatocytes. Brain of the treated animals displayed histopathological features such as glee cell proliferation, encephalomalacia, total damage to neurons, neuronophagia and loss of neurons. Gill of the treated fishes were showing pathological features like hyperplasia, lifting of secondary epithelium, squamous metaplasia, fusion of secondary lamellae, break down of pillar system and hyperaemia of cells.

Such tissue level alterations can reduce the nutritional value of fish as an important edible commodity which in turn might negatively affect its market demand. It is concluded that the findings of the present histological investigations reveal a direct relationship between pesticide exposure and histopathological disorders observed in several tissues. The current study reinforces the relevance of histopathology as a potent tool for monitoring contamination in aquatic environments.

Studies on bioaccumulation of monocrotophos in muscle, by whole body analysis using gas chromatography proved that monocrotophos
Conclusion

accumulates in the edible part of fish. This can be harmful to consumers in next ecological level, including humans, and can be potent for biomagnification. Levels of bioconcentration were low at all the three sub lethal treatment groups, but it resulted in serious deleterious effects on the metabolic machinery of the fish which could be inferred from studies on various aspects described in this investigation. Possible measures should be taken to make certain that monocrotophos do not contaminate natural water resources, fisheries and aquaculture farms.

Crop protection measures play an important role in agricultural management, particularly in developing countries having high poverty levels. However, there are alternative chemicals other than monocrotophos available. In the light of these findings, it is important that national and international agencies with crop management and environmental conservation expertise should work with pesticide manufacturers, national and local stakeholders in order to find out means of reducing the environmental impacts of such toxic chemicals.

The freshwater fishes constitute one of the major sources of nutritious food for humans. Indiscriminate use of pesticides in agricultural operations can have every possibility to reach aquatic systems and cause deleterious effects to aquatic fauna and flora. Monocrotophos is the most extensively used OPs in India, especially for paddy, cotton and sugar cane. Fresh water fishes are major non-target species for the pesticide action. *H. fossilis*, a fresh water fish, inhabiting in paddy fields and adjacent streams are at risk of population depletion, categorizing them as vulnerable in conservation status (IUCN 1993; CAMP 1998). In this scenario the study conducted on the stress responses of *H. fossilis* to OP insecticide monocrotophos is significant as a source of basic data, for future ecotoxicological studies.