Summary & Conclusion
The present study was undertaken to evaluate the effect of endosulfan on freshwater fish, *Catla catla*, which is widely consumed in the areas of Dharwad, Karnataka (India). Endosulfan is one of the widely used pesticides on variety of crops such as cotton, jowar, wheat, groundnut, sun flower, safflower, bengal gram, maize, sugarcane, paddy, green gram, mango plantation, etc. to control pests like bollworm, whitefly, grey weevil, aphids, red hairy caterpillar, etc. Fish, *Catla catla* apart from its wide availability and commercial importance is also known for its adaptability to laboratory conditions and suitable for toxicity studies. Hence, *Catla catla* was selected for the experiment. Endosulfan on entering the food chain may impose severe health problem to human beings. Therefore, selection of problem is highly relevant.

After undergoing a systematic, meticulous and exhaustive experimentation important conclusion have been arrived at.

1. LC$_{50}$ (96 h) value of Endosulfan was arrived at 3.18 µg/l to fish *Catla catla* following Probit method and Dragstedt- Beheren’s equation. One-tenth of LC$_{50}$ was chosen as sublethal concentration (3.18 µg/l) for sub acute studies (1,5,10,15 days).

2. Different quantity of isomers of endosulfan (α and β) accumulated in functionally different tissues of the fish exposed to both lethal and sublethal concentration of technical
endosulfan. Total endosulfan accumulated in larger quantity during sublethal exposure period compared to lethal exposure condition. Between the two isomers of endosulfan α-endosulfan accumulated in larger quantity than β-endosulfan in all the functional organ tissues. But accumulation of endosulfan sulfate wasn’t detected in any of the tissues during lethal and sublethal exposure periods. The accumulation of pesticide in organ tissues reveals its lipophilic nature.

3. The behavioural pattern of fish exposed to lethal concentration of endosulfan changed, which includes repeated opening and closing of operculum, hyper extension of fins, cock screw swimming, S-jerk, coughing and burst swimming. Whereas in sublethal concentration alteration in behavioural pattern of fish was of lesser degree. Changes in behavioural pattern may be attributed to hypoxic condition, inhibition of enzyme activity, loss of equilibrium and pronounced mucus secretion over the gill and over the body imparted by the toxic effect of pesticide on the fish.

4. The rate of whole animal oxygen consumption altered at both lethal and sublethal concentration of endosulfan. In lethal concentration, rate of oxygen consumption decreased from day 1 to day 4, but in sublethal concentration oxygen consumption rate decreased from day 1 to day 10, which later increased on day 15. The decrement in the rate of oxygen consumption is attributed to
the induction of hypoxic conditions within the animal due to the
in time contact of the respiratory surface with the polluted water
resulting in the alteration of normal respiratory area. Excessive
mucus secretion on the gill due to toxic effect of endosulfan
might have caused demolition of the process of gas exchange.
The alternative reason for the decrease in the oxygen
consumption would be due to the internal action of endosulfan, as
it appears to alter the metabolic cycle at sub-cellular level. The
increment on day 15 under sublethal concentration reveals the
recovery state of the fish or else its adaptation to the low
concentration of endosulfan.

5. Haematological parameters are known to respond quickly to
changes in environmental conditions and hence, constitute an
important diagnostic tool in toxicity studies. Alteration in the
level of WBC, RBC, Hb, MCH, MCHC, PCV and MCV was
noticed in the fish exposed to both median lethal and sublethal
concentration of endosulfan. RBC, Hb and haematocrit values
decreased consecutively under lethal concentration, whereas
WBC increased on later exposure periods. Blood indices like
MCH, MCHC and MCV altered which were dependent on the
variation exhibited by RBC, Hb and PCV values. Under sublethal
concentration the values of blood parameters were found to alter
till day 5 and 10, but on day 15 values observed revealed to be
normal. The effect observed is precise under endosulfan toxicity. Reduction in RBC and Hb might be attributed to the bone marrow depression, reduction in erythropoietin level, decreased intestinal absorption of iron and renal damage owing to endosulfan toxicity. Reduction in PCV could be attributed to low RBC count or haemodilution. Increase in MCV may be because of endosmosis. MCH and MCHC are derived from Hb and RBC and any sort of alteration in the level of Hb and RBC would result in the alteration of MCH and MCHC.

6. The ion concentration and the ATPase activity altered in fish exposed to lethal and sublethal concentration of endosulfan. Na\(^+\), K\(^+\) and Ca\(^{2+}\) ion in gill, muscle and liver decreased to a significant level because of pesticide concentration. Na\(^+\) - K\(^+\), Mg\(^{2+}\) and Ca\(^{2+}\) ATPase activity decreased corresponding to the ionic change at different exposure periods. Ion transport across the cell membrane is critical biological function. Altered activities of ATPase due to endosulfan interference may cause altered cellular proliferation and movements.

7. Protein metabolism demolished in all tissues (Gill, muscle and liver) of fish under lethal and sublethal endosulfan stress. Under lethal concentration soluble, structural and total protein level decreased significantly. Under sublethal concentration decrease was noted up to day 10, which later on day 15 decreased to
normalcy. In correspondence to decrease in free amino acid and protease activity were noticed in all the tissues. Prevalence of pathological condition in the organ system of an animal may decrease protein synthesis potential, which in turn increase the amino acid content might be due to non-selective blocking of phosphorylation process in the central nervous system and tissue. Greater activity levels of Aspartate aminotransferase (AAT), Alanine aminotransferrase (AIAT) and Glutamine dehydrogenase (GDH) observed in all the tissue of fish exposed to lethal concentration. At sublethal concentration the enhancement was initial, which recovered back to normalcy with increased exposure period. The results reveal the interference of endosulfan in transamination process. Increase in AAT, AIAT and GDH could also be due to stepwise induction of these enzymes by greater association of their oligomers, which would further favour the structural reorganization of proteins and incorporation of keto acids in to the TCA cycle to favour gluconeogenesis or energy production. Urea and glutamine levels increased with the decrease in the level of ammonia under lethal concentration, but under sublethal concentration decrease in ammonia and increase in urea and glutamine was observed up to day 10, which with the
increase in exposure levels reveal the adaptation of fish to the ambient medium. Suppression of ammonia level with the significant elevation of glutamine and urea level indicates that higher concentration of ammonia is toxic and mobilization towards the formation of less toxic compounds might have taken place. The diminished ammonia level suggests decreased ammonia fixation through keto acids to glutamate formation by the action of NADPH dependent GDH. The formation of urea, glutamate and glutamine by the respective enzymes seems to be as alternative pathway for the detoxification of ammonia.

From the above observation relevant to physiological, behavioural and biochemical response of freshwater fish, *Catla catla* to endosulfan the conclusion could be drawn that the changes arrived at are dependent on concentration of pesticide and the duration of exposure. Irreparable damage was caused to the physiological, biochemical and behavioural activities of the fish at higher concentration. The damage increased and prevailed over time of exposure. Under low concentration, i.e., sublethal concentration stress observed was only for short period (1 to 10 days) and on later days of exposure the stress appeared to be lesser and the fish seemed to adapt the toxic environment. The recovery tendency shown by the fish, perhaps could be due to physiological resistance developed by the
animal, which also be reasoned as possible enhancement of detoxification mechanism and endosulfan elimination process. Therefore, the above statement suggests that the fish can adapt to low concentration of endosulfan toxicity during long-term exposure periods.

It is hoped that the study will give valuable scientific data useful in determining the same concentration of endosulfan to ensure protection of worthy fishery resource and provide base line information for monitoring pesticides in the aquatic environment. There are vivid and considerable amount of data available on non-target effect of organochloride especially endosulfan and effects are evident. Therefore, the study makes the comparisons between laboratories more meaningful with due emphasis on the standardization of pesticide bioassay.

The study made is preliminary and a small segment of vast subject of pesticide toxicology. Limitation in the availability of laboratory facilities and time for completion of this work prevented the researcher from penetrating in to the core of this investigation. Nevertheless the researcher is hopeful of pursuing this work further.