SUMMARY AND CONCLUSION
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Most of the lakes in Bangalore have vanished due to encroachment and construction activity for urban infrastructure expansion. The city once had 262 lakes of which around 7 are untraceable, and more than 7 might have reduced to small cess-pools of water. Unauthorised encroachment of lakes by slums and private parties have risen to roughly 18 in number and almost 14 to 20 have dried up and are leased out by the Government. Till date 28 lakes have been reported to be used by Bangalore Development Authority as sites and extensions for residential areas. The remaining lakes are in fairly advanced state of deterioration.

Although a number of scientists have conducted investigations to assess the water quality of urban water bodies affected by anthropogenic activity in Bangalore city yet a lacuna was observed in the studies on pollution status of lakes such as Vengiah lake (lake A) and Yellamallappa Chetty lake (lake B) with respect to presence of toxic levels of trace metals and other hydrological parameters. These lakes are important for recharging of ground water to compensate the scarcity of water supply in that region. Therefore, a study was conducted to evaluate the extent and type of pollutant load affecting the water quality. Fish reared for commercial purposes in such lakes were taken as target organism to analyse the effect of pollutants on its metabolism during winter, summer and rainy season.

The damage to the water bodies caused by the public due to its diverse activities has attracted an undue amount of interest in recent years. The
hydrological parameters were analysed in the water sampled from lake A and B during three seasons to assess the level of parameters such as temperature, colour, conductivity, turbidity, acidity, total alkalinity, DO, BOD, COD, TDS, TSS, sulphate, nitrate, total phosphorous, etc and trace metals like copper, zinc, iron, aluminium, cadmium, arsenic, lead and mercury.

The study revealed significant variation in physico-chemical parameters including trace metals of water sampled from lake B than lake A when compared to standard BIS and control site. Maximum differences were noted during summer than during rainy season but the values exceeded more in lake B than lake A.

Summer recorded maximum of temperature, conductivity, TDS, acidity, total alkalinity and BOD and minimum levels of TSS, sulphate, nitrate, total phosphorous and DO in lake B which can be attributed to decrease in water level due to evaporation, greater solar radiation and utilization of nutrients for the growth of blooms which resulted in its eutrophicated condition. The colour, turbidity, pH, TSS, sulphates, DO and COD exhibited maximum levels during rainy season due to the influx of excess load of rain water through all the sources adjoining the lake. Nitrates and total phosphorus levels were recorded maximum during winter months since cold temperature caused concentration of nutrients in water. Depletion of DO during summer season might affect the survivability of fishes and other aquatic organisms of the lake in question. Significantly higher levels of aluminium, cadmium, iron, lead and mercury were recorded during winter season from lake B as compared to their
permissible limits. This can be attributed to the fluctuations in the amount of discharge of effluents from adjacent industries into lake B and also to the water conditions during winter season.

The water quality index (WQI) of lake B indicated that its water was unfit for use for irrigation and washing purposes when compared to lake A which in turn exhibited comparatively good WQI during all the seasons. Exposure of human beings either by contact or ingestion especially by the localities that depend on the lake water (B), may cause serious health problems such as skin allergies, itch infection, renal failure, kidney disfunctioning etc.

In the present study, fresh water fish, *Labeo rohita* reared in these water bodies was selected as test fish and muscle and gill tissues were analysed for various biochemical and metabolic changes. Since muscle is an important tissue of nutritive value and gill which is a vital respiratory organ with their extensive surface area directly in contact with water and targeted by pollutants they were selected for further analysis. Biochemical studies including enzymatic activity in muscle and gill tissue along with blood chemistry and genotoxicity studies in fish were assessed during the three seasons.

Biochemical studies *viz.*, protein, glycogen and cholesterol levels were analysed in muscle and gill tissues of fish from lake A, lake B and control site. Protein showed maximum percent change in muscle and gill tissue sampled from lake B during summer season followed by winter and rainy season in comparison to the tissues sampled from control site during respective seasons. Glycogen content exhibited depletion in its levels in both muscle and gill tissue
of *L. rohita* sampled from lakes A and B but a significant reduction in its content was observed in these tissues sampled from lake B during summer and winter season when compared to their respective controls. A marked increase in cholesterol content was observed in the tissues sampled from lake B when compared to those from Lake A and control site during all the three seasons and maximum percent change was recorded in gill followed by muscle tissue.

On the basis of the data analysed, it may be concluded that a significant change in the biochemical constituents in the tissues reflected to the exposure of the fish to the presence of pollutants in water or food consumed. The reduction in the levels of protein and glycogen in the tissues of the fish mainly from lake B (industrially polluted) may be attributed to blocking of protein synthesis which interrupted the amino acid synthesis and may be due to gluconeogenesis and glycogenolysis. Due to hypoxic condition and non-conducive environment of lake B, the fish showed increased carbohydrate metabolism to release energy which resulted in extra expenditure of carbohydrate constituents and non utilisation of cholesterol so as to overcome metabolic stress and for its survival.

Acid and alkaline phosphatase activity were analysed in muscle and gill tissue of fish from control, lake A and lake B. Decrease in ACP activity was recorded in both the tissues from lake A and B when compared to respective controls but percent change in ACP activity was more in tissues sampled from lake B. A reduction in the activity of ALP was recorded in tissues sampled from lake A and B when compared to those of control site. A marked decrease
in the activity of phosphatases in the tissues was recorded from lake B followed by lake A and control ones during all the three seasons. Such alteration in acid and alkaline phosphastase activities might be to maintain physiological equilibrium of fish exposed to toxicants present in lake A and B which may in turn disrupt the biochemical processes.

SDH, MDH and LDH activities were analysed in muscle and gill tissue of fish from control site, lake A and B during winter, summer and rainy season. Dehydrogenase activities can be considered as marker of mitochondrial abundance indicating state of fish health and its physiological condition. A decrease in SDH activity was recorded in muscle tissues sampled from lake A and B during three seasons. Similar trend was recorded in gill tissue but decrease in percent change was more in gill tissue when compared to muscle tissue during summer season. MDH activity also showed a decrease in both the tissues sampled from lake A as well as from B when compared to control site during all the three seasons. An increased activity of LDH in the muscle and gill tissues sampled from lake A and B was recorded when compared to those from control site. Maximum percent change in LDH activity was recorded in muscle and gill tissue sampled from lake B during summer season. The above results indicated that the respiratory activity of fish under stress due to adverse environmental conditions and followed an anaerobic metabolism to combat the toxic effects.

Variations in biochemical constituents including enzymatic activities reflect the metabolic response of tissues towards anaerobic (stressful)
conditions of lake B caused by the long term exposure to pollutants present in the water bodies with variation in their physico-chemical parameters and presence or absence of trace metals.

In the present investigation, muscle and gill tissue of fish from lake A and B were analysed for accumulation of trace metals such as Cu, Zn, Fe, Cd, Al, Pb, As and Hg. The study revealed higher accumulation of trace metals such as Cu, Zn and Fe in the muscle tissue when compared to gill tissue of fish from both lake A and B. Maximum accumulation of these metals was observed in muscle tissue of fish from lake B than those of lake A and control site during summer season and a minimum during rainy season. Muscle and gill tissue of fish from lake B showed accumulation of heavy metals such as Cd, Al and Pb. These metals were not detected in tissues of fish from lake A and control site. Maximum accumulation of Al and Pb was recorded in gill tissue and that of Cd in muscle tissue from fish of lake B during summer season. Although the levels of these trace metals are not high, a potential danger may emerge in the future depending on pollution sources and continuous consumption of fishes with accumulation of heavy metals from lake B.

The correlation between water parameters, biomolecule constituents, dehydrogenases activity as well as bioaccumulation of metals reveal that the survivability of fish in stressful hypoxic condition become difficult and is at stake due to depletion of DO, high levels of BOD & COD and variation in the nutrient level along with presence of Cd, Al and Pb in tissue of fish from lake B.
The serum protein pattern of blood of fish from control site, lake A and B by SDS-PAGE was studied visually and compared with the pre-stained Novex protein ladder. The banding pattern of serum proteins of blood varied from each other in fishes from lake A and B but deterioration of such bands was more in blood sampled from fish of lake B.

Change in the general structure of erythrocytes / deformed and erythrocyte swelling along with nuclear abnormalities was observed in the blood samples of fish from lake B when compared to lake A. Micronuclei were not detected in any of the blood samples. The variation in the frequency of nuclear abnormalities from summer to winter and rainy might be due to the differences in concentration of pollutants in water.

To conclude our study on fresh water fish, *L. rohita* sampled from control site, lake and B, it can be said that variation in levels of physico-chemical parameters including trace metals which act as mutagenic/genotoxic compounds, interfered with xenobiotic metabolic pathways affecting glycolysis, the Krebs cycle, oxidative-phosphorylation, protein and amino acid metabolism as well as carbohydrate and lipid metabolism. Muscle of fish provides an excellent source of nutrition for human diet but due to its exposure to various pollutants, the nutritive value of the fish in question may be reduced which if consumed on regular basis would cause health problems in man.
RECOMMENDATIONS

- Regular monitoring of lakes.
- Increase in green cover & natural edge conditions of the lake to be preserved around the lake.
- Strict enforcement of laws and offenders to pay the penalty.
- Sewage, sullage and toxic wastes to be avoided to flow in the lake.
- Lakes to be protected from anthropogenic activities such as water sports and washing of animal, clothes, etc.
- Upgradation of storm water drainage system and aligning the drain network, checking blockage and overflowing of storm water drains.
- Depth of the lake to be increased by desilting every three years.
- STPs and ETPs to be installed with required capacity.
- Periodic rejuvenation of lakes, artificial aeration, dredging and dilution of lake water with flushing in water with low nutrients.
- Bioremediation to be carried out for oxygenating and purification of lake.
- Health of fishes to be monitored periodically.
- Integrated water management to be used rather than single process.

The results and findings of the present work along with recommendations and suggestions will be forwarded to the concerned authorities of lakes for the management and conservation of lakes.