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Impact of nutrient enrichment on water quality of a tropical Ramsar Wetland

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Key words: Anthropogenic activities, Non point & Point sources of pollution, Water quality

Abstract

Present study was conducted in Lower Lake of Bhopal which is a part of Bhoj wetland and one of the important resources for the people of Bhopal city. The water body is suffering from severe degree of water quality deterioration due to various anthropogenic activities. Analysis of various physico-chemical parameters of water samples collected from both point and non-point sources indicates that the Lake is moderately polluted and can be used for secondary purposes only after treatment as per standard prescribed by CPCB.

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Introduction

Most of the urban water bodies like lakes, reservoirs, dams, rivers etc in India are facing serious problems of eutrophication due to various anthropogenic activities. Apart from this, the water resources also get contaminated with nutrient enrichment through natural phenomena like to siltation, leaching of autochthonous organic matters etc, thereby accelerating the process of eutrophication. Changes in land use pattern as well as increased use of chemical fertilizers in modern agricultural practices further increased the risk of eutrophication and loss of biodiversity and finally deterioration in water quality (Pani, 2017).

Eutrophication occurs naturally over centuries as lakes through aging process are filled in with sediments (Carpenter 1981). However, human activities accelerate the rate and extent of eutrophication through point and non-point loadings of nutrients, like as nitrogen and phosphorus, resulting dramatic consequences on the water resources used for drinking, fisheries, and recreational purposes (Carpenter *et al.*, 1998), (Chislock, 2013).

Therefore regular water quality assessment of a water body is important to understand the existing status and also to suggest necessary mitigative and conservation measures for abatement of pollution and conservation of the water body.

Keeping this in mind the water quality of Lower Lake which is part of Bhoj Wetland, the only Central Indian Ramsar site was assessed during the period January, 2019 to December, 2020 to understand the present status of water quality with reference to nutrient enrichment from both through the autochthonous and allochthonous sources.

Material and methods

The present study has been designed to assess the cumulative impact of various anthropogenic activities on the water quality of the lake. For this an extensive field survey was conducted in the catchment of the lake including the inflow and out flow channels of the water body. After a meticulous survey, five sampling stations were finalized for collection of water samples so as to have a representation of the existing water quality with respect to various anthropogenic activities being performed in the catchment area of the lake.

Description of Study area

Lower lake is situated in the peaceful and serene surrounding of majestic hills and massive Upper Lake (known as Bhoj Wetland). The lake is a beautiful remnant of the great Mughal Empire.

Locally known as Chota Talab, it is separated from Upper lake by an over bridge. The aesthetic appeal of the lake is enhanced by the magnificent Kamla park garden.

The lake is located to the east of the Upper lake and earthen dam separates the two lakes. It has a water spread area of 1.29 km sq. and a catchment area of 9.6 km sq. The lake still receives subsurface seepage from the Upper lake and untreated domestic sewage from few major inlets (Pani, 2007).

Sampling Stations

Total five sampling stations were selected.

Station -1 (near Banganga (L/1))

Station -2 (Dhobighat (L/2))

Station -3 Centre (Hamidia College (L/3))

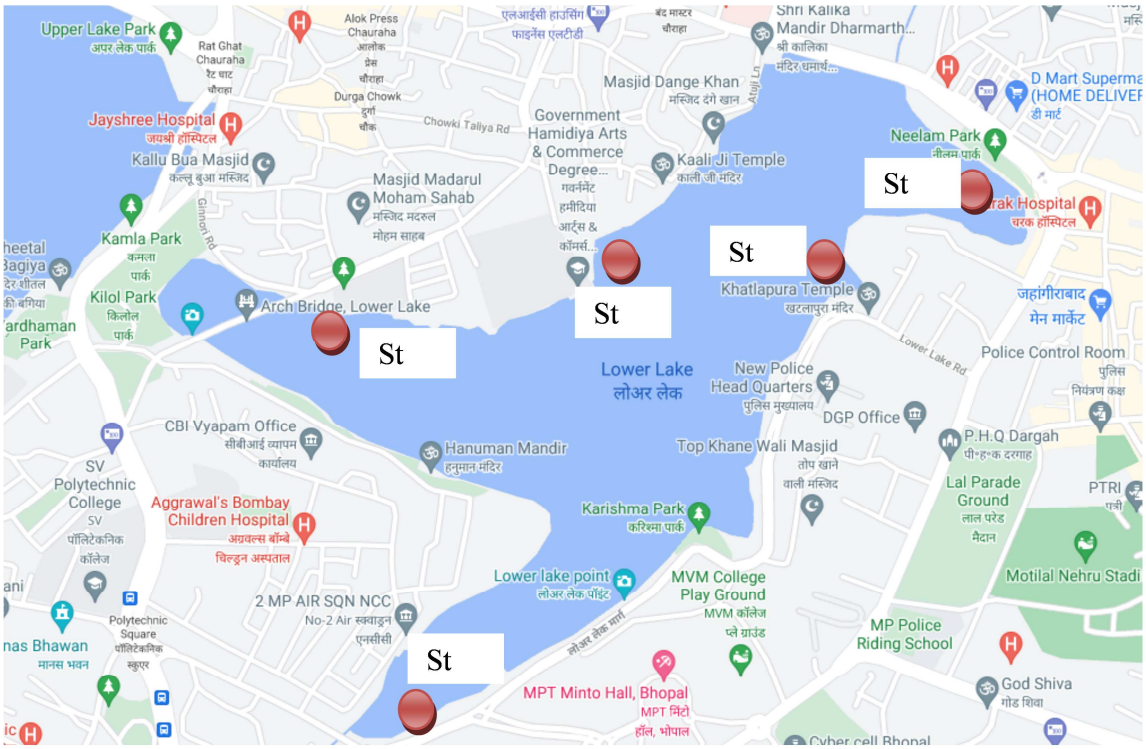
Station -4 Khatlapura (L/4)

Station -5 Jehangirabad (L/5)

Water samples were collected from the identified sampling sites (Map-1) at monthly interval during the period January2019 to December, 2020.

Samples were collected from the surface and bottom layer by using Ruttner water sampler from the five identified sampling stations.

Collection, preservation and analysis of the water samples for various physico- chemical parameters were done following the standard methods described in APHA (2017).



Source: Google map: https://www.google.co.in/maps/@23.2488959,77.4052353,16z

Map 1. Lower Lake with sampling stations.

During the period of investigation following physico-chemical parameters were analyzed as per the procedure mentioned in APHA (2017).

Parameters analyzed

Parameters		
Physical	Chemical	Nutrient
Water Temperature	Total Alkalinity	Nitrate-Nitrogen
Air Temperature	Chloride	Total Phosphorus
pH	Total Hardness	
TDS	BOD	
Turbidity		
DO		

Result and discussion

Result of the analysis of various physico-chemical parameters of the water samples collected from the Lower Lake is summarized in Table 1 with the range values.

Air temperature during the period of investigation ranged from 27.1 to 43.9°C (Fig. 1). The minimum value was recorded at station-4 during December, 2020 while the maximum value was observed at Station-4 during May, 2020(Fig. 1).

Water temperature in surface water ranged from 24.1 – 34.2 °C. The minimum value was recorded at station-5 during, Jan, 2019 while the maximum value was observed at Station-1 during May, 2019 (Fig. 2).

Water temperature in bottom water ranged from 19.8 -31.9 °C. The minimum value was recorded at station-2 during, Feb, 2019 while the maximum value was observed at Station-4 during May, 2019 (Fig. 3).

Temperature is one of the most important ecological features and its measurement is a useful indicator of biochemical and biological activity in a water body. Temperature is known to influence pH, alkalinity and Dissolved Oxygen (DO) concentration in the water (Aggarwal and Arora, 2012). Considering its importance in governing all the ecological processes in an aquatic environment, both air and water temperature at different stations of Lower lake was investigated for the period, January 2019 to December 2020 at monthly intervals.

Water temperature during the period of investigation, was found to have direct relation with atmospheric

temperature; it increased or decreased with the changes in atmospheric temperature. Misra *et al.* (2005) has also found the similar trend in temperature variations. Close relationship between atmospheric temperature and surface water temperature has also been reported by Bhatia *et al.* (1970). The variation in temperature during the period of investigation at some points may also be due to different timings of collection and influence of season as reported in other case study also (Jayram *et al.,* 2003).

Table 1. Range values of various parameters in different seasons at Lower Lake during Jan, 2019-Dec, 2020.

	Parameter		Min.	Station	Month	Year	Max.	Station	Month	Year
1	Air Temperature (°C)	S	27.1	4	Dec	2020	43.9	4	May	2020
2	Water Temperature (°C)	S	24.1	5	Jan	2019	34.2	1	May	2019
		B	19.8	2	Feb	2019	31.9	4	May	2019
3	pH	S	6.4	1	April	2019	8.4	3 &4	March,19 & May,20	2019, 2020
		B	6.1	1,2,5	Mar, April, Oct, Nov	2019	9.2	3	Feb, March	2019
4	TDS (mg/l)	S	162.3	4	Oct	2020	492.8	2	July	2020
		B	154.2	4	Oct	2020	479.3	5&1	Sept, July	2019, 2020
5	Turbidity (JTU)	S	6.0	2	April.	2020	97	5	Aug	2019
		B	6.0	3	Dec.	2020	89.0	1	Aug	2019
6	DO (mg/l)	S	Nil	1	July	2020	9.6	4	May	2020
		B	0.0	1	May	2020	12.4	4	April	2019
7	Chloride (mg/l)	S	25	4	Sept.	2020	63	1	July	2019
		B	21	3	Dec	2019	90	5	May	2019
8	Total Alkalinity (mg/l)	S	104	5	March	2020	240	1	July	2020
		B	100	5	March	2020	220	1	Aug	2020
9	Total Hardness (mg/l)	S	110	3	Jan	2020	230	1	July	2019
		B	104	5	Jan	2020	214	1	July	2019
10	BOD (mg/l)	S	1.2	3,4	Dec	2020	32	1	June	2019
		B	0.8	2	Dec	2020	22	1,2,5	March	2020
11	Nitrate (mg/l)	S	0.44	1	Oct	2020	5.71	2	July	2020
		B	0.41	1	Oct	2020	5.31	1	July	2020
12	Total Phosphorus	S	1.17	5	Dec	2019	5.40	4	Aug	2020
		B	1.19	3,4,5	Dec	2019	4.91	5	July	2019
	S: Surface		B: Bottom							

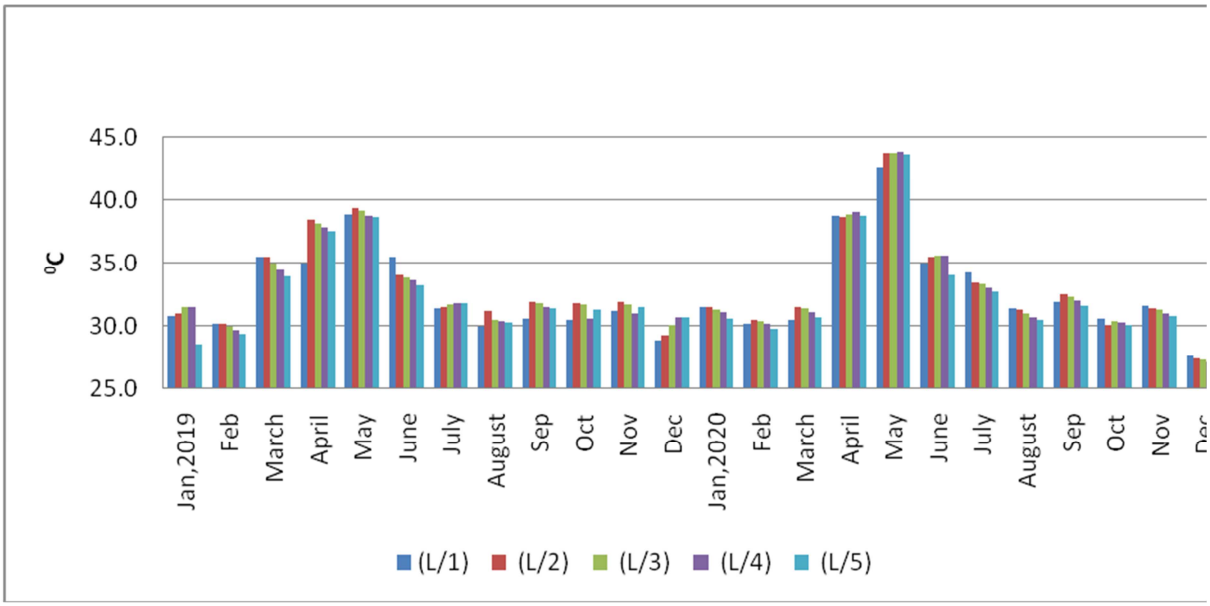


Fig. 1. Variation in Air Temperature (°C) at different stations of Lower Lake during Jan-Dec, 2019-2020.

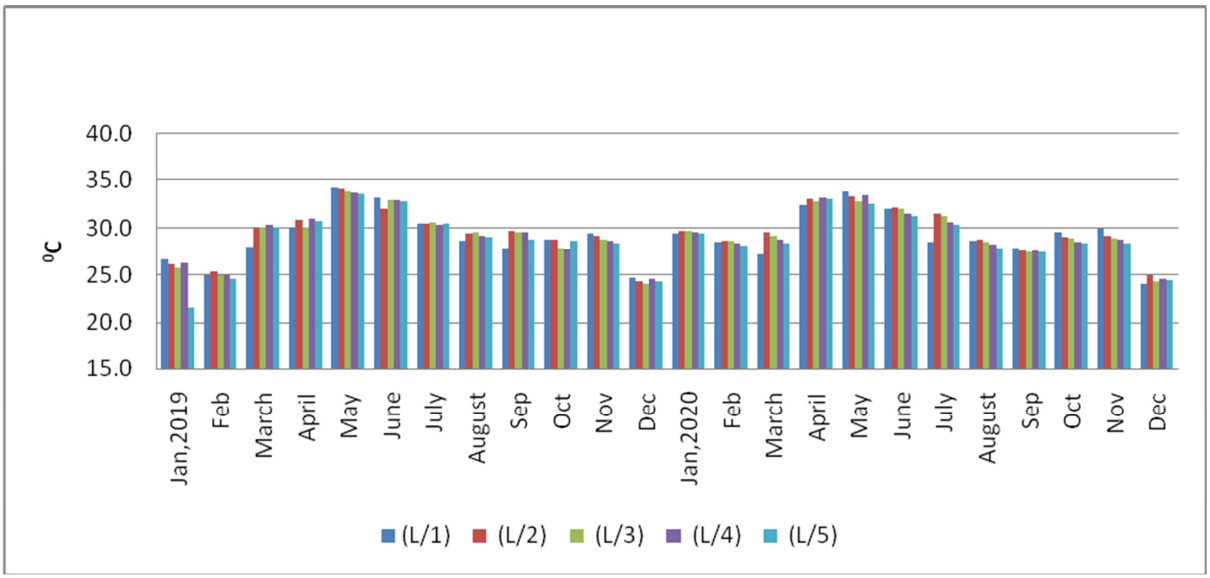


Fig. 2. Variation in Water Temperature (°C) in Surface water at different stations of Lower Lake during Jan-Dec, 19-20.

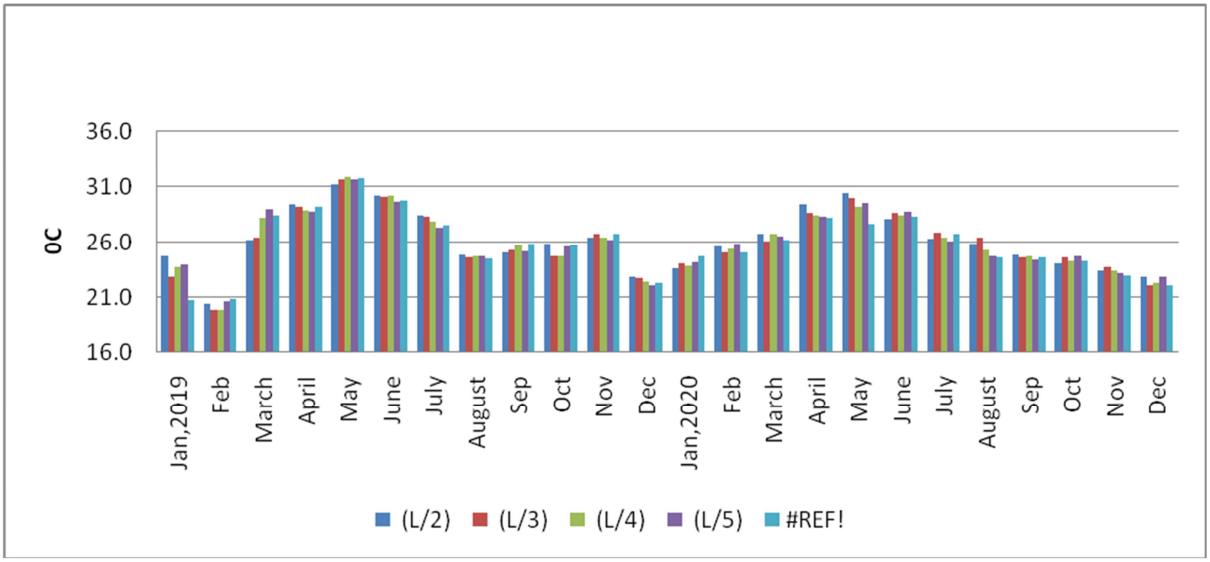


Fig. 3. Variation in Water Temperature (°C) in Bottom water at different stations of Lower Lake during Jan-Dec, 19-20.

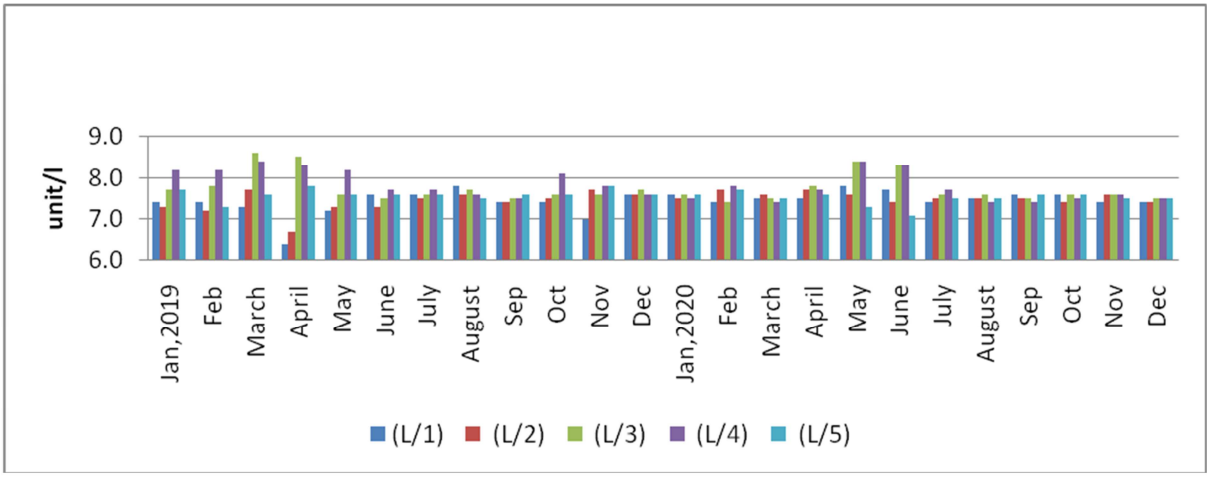


Fig. 4. Variation in pH in Surface water at different stations of Lower Lake during Jan-Dec, 2019-2020.

The variation in temperature during the period of investigation has affected the pH values of the Lake.

pH in surface water ranged from 6.4- 8.4. The minimum value was recorded at station-1 during, April, 2019 while the maximum value was observed at Station-3&4 during March, 2019 and May 2020(Fig.4).

pH in bottom water ranged from 6.1-9.2. The minimum value was recorded at station-1, 2, 5 during, March, April, Oct, & Nov 2019 .While the maximum value was observed at Station-3 during Feb & March, 2019 (Fig.5).

Hydrogen ion concentration or pH is the most important and commonly studied property of natural water and wastewater. The measurement of pH is of great importance because chemical and biochemical reaction in an aquatic body takes place at a particular pH and plays an important role in productivity of water body. In Lower Lake, Bhopal the pH values in most of the places were observed to be slightly alkaline in surface waters while in bottom waters of few point sources (viz. near Kilol Park, Ginnori & Banganga inlet) pH values were recorded slightly acidic in bottom waters.

During the period of investigation a close look of the seasonal variation also depicted slightly higher values of pH during the summer months compared to monsoon and winter months. In Lower Lake, the pH in general was slightly alkaline at surface water while it was observed slightly acidic especially in bottom water samples collected from inlets.

Hydrogen ion activities in a water body also related to Total Dissolved Solids (TDS). Total dissolved solids information is used to determine the overall ionic effect in a water source. Total dissolved solids in natural water mainly composed of a large variety of salts and inorganic minerals i.e., dissolved solids such as chlorides, carbonates, bicarbonates, nitrate, phosphate etc. which impart particular taste to water at higher concentration. TDS when present in excess in the water may create an imbalance for aquatic life. Certain physiological effects on plants and animals are often affected by the number of available ions in the water.

Total Dissolved Solids in surface water during the period of investigation ranged from 162.3 – 492.8mg/l. The minimum value was recorded at station-3 during, Oct, 2020, while the maximum value was observed at Station-2 during July, 2020 (Fig. 6).

Total Dissolved Solids in bottom water ranged from 154.2-483.9mg/l. The minimum value was recorded at station-4 during, Oct, 2020 .while the maximum value was observed at Station-5&1 during Sep 2019 & July, 2020 respectively. (Fig. 7).

During period of investigation, higher values of TDS in Lower Lake were recorded at some stations which may be because of agitation of water and local impacts.

Turbidity in surface water ranged from 6.0 -97 JTU. The minimum value was recorded at station-2 during, Aril, 2020, while the maximum value was observed at Station-5 during June, 2019 (Fig. 8).

Turbidity in bottom water ranged from 6-89 JTU. The minimum value was recorded at station-3 during, Dec, 2020, while the maximum value was observed at Station-1 during Aug, 2019 (Fig. 9).

Dissolved Oxygen (DO) is an important parameter to understand the trophic status of a water body. Dissolved Oxygen in surface water during the period of investigation ranged from Nil to 9.6mg/l. The minimum value was recorded at station-1 during, July, 2020, while the maximum value was observed at Station-4 during May, 2020 (Fig. 10).

DO in bottom water ranged from 0.0 – 12.4mg/l. The minimum value was recorded at station-1 during, May, 2020, while the maximum value was observed at Station-4 during April, 2019 (Fig. 11).

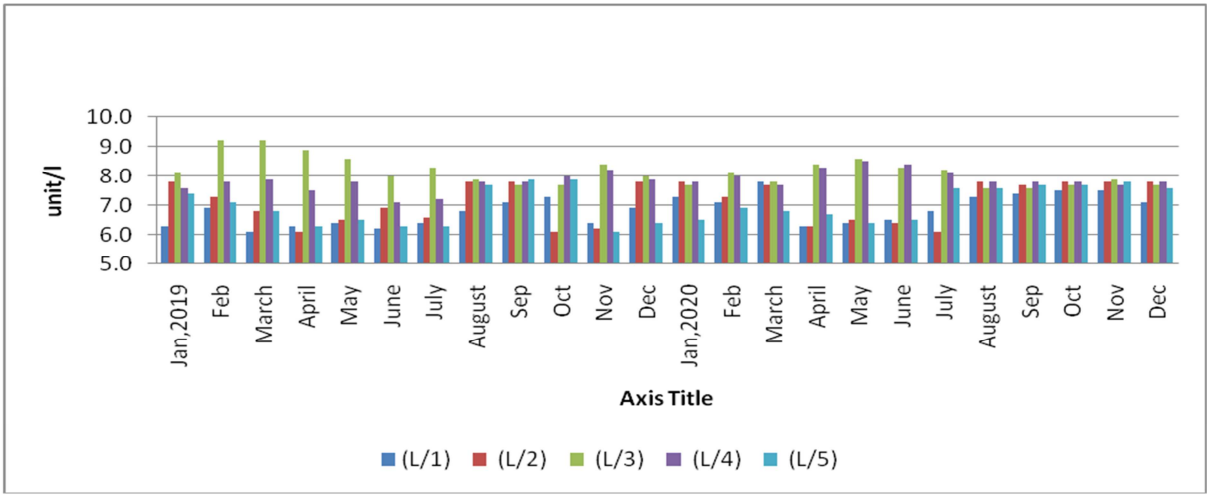


Fig. 5. Variation in pH in Bottom water at different stations of Lower Lake during Jan-Dec, 2019-2020

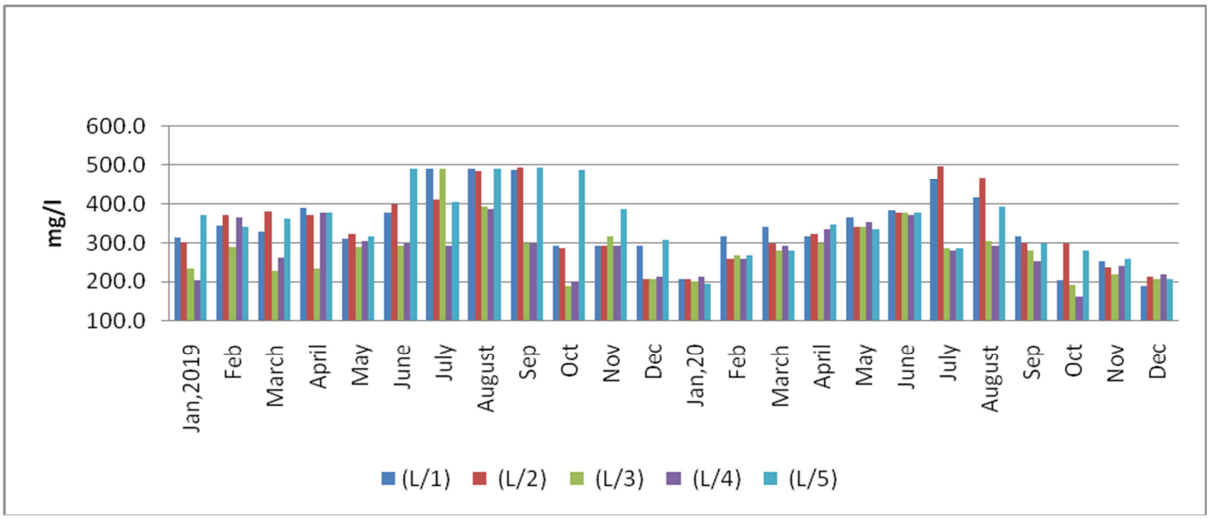


Fig. 6. Variation in TDS in surface waters at different stations of Lower Lake during Jan-Dec, 2019-2020

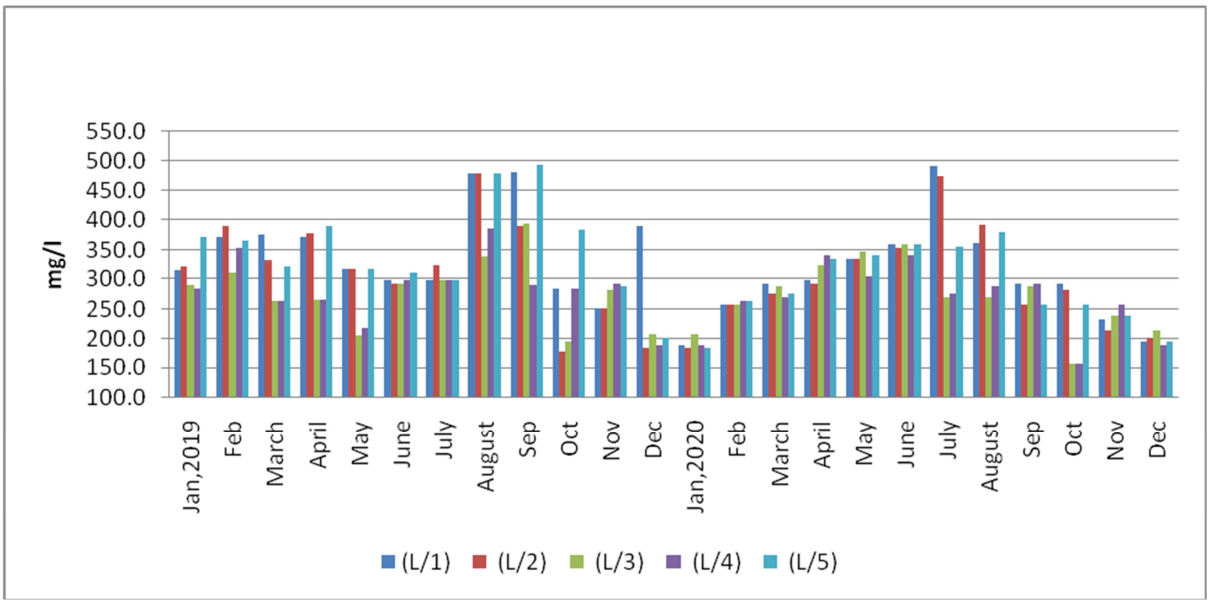


Fig. 7. Variation in TDS in bottom waters at different stations of Lower Lake during Jan-Dec, 2019-2020

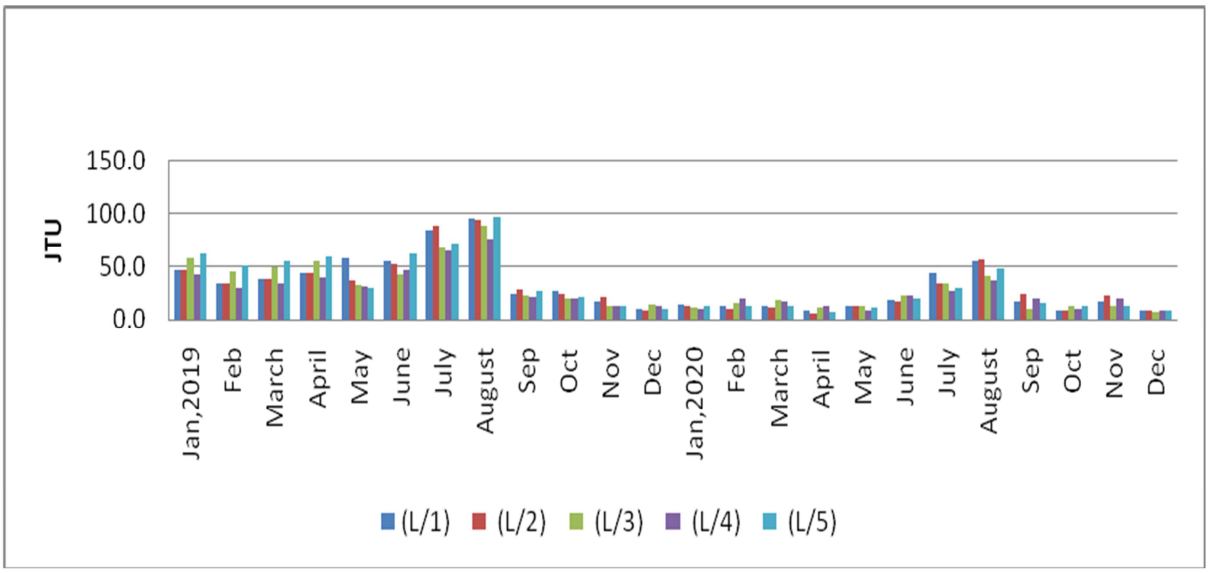


Fig. 8. Variation in Turbidity (JTU) in surface water at different stations of Lower Lake during Jan-Dec, 2019-2020

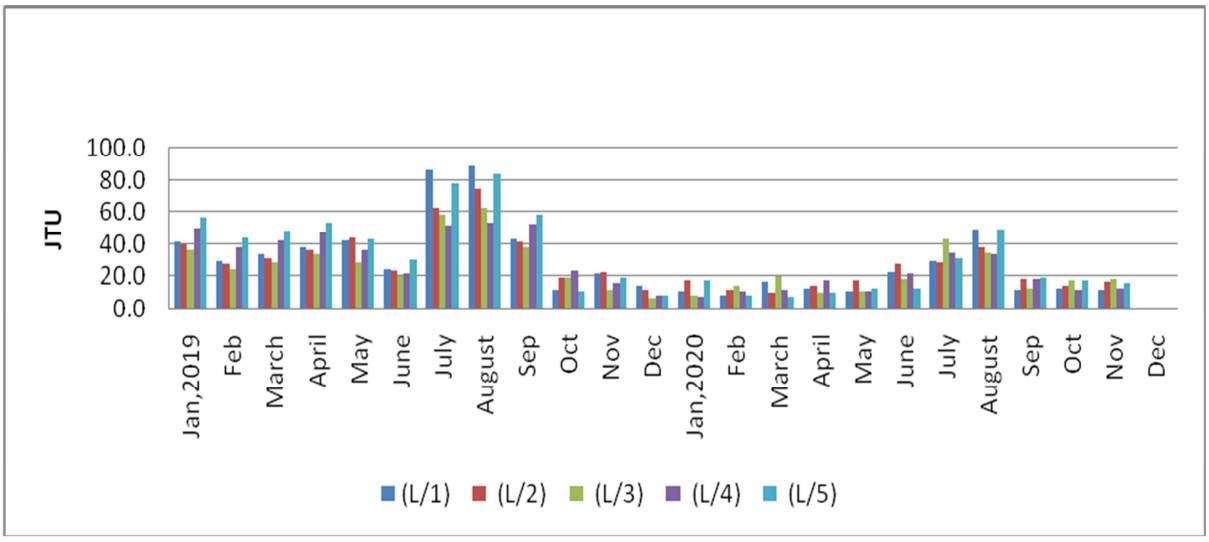


Fig. 9. Variation in Turbidity (JTU) in bottom water at different stations of Lower Lake during Jan-Dec, 2019-2020

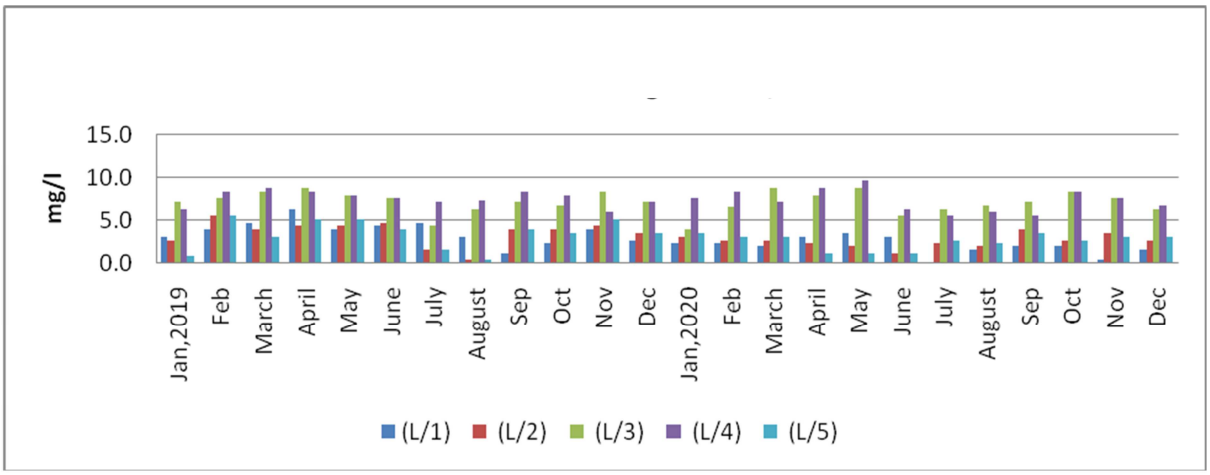


Fig. 10. Variation in Dissolved Oxygen (mg/l) in surface water at different stations of Lower Lake during Jan-Dec, 2019-2020

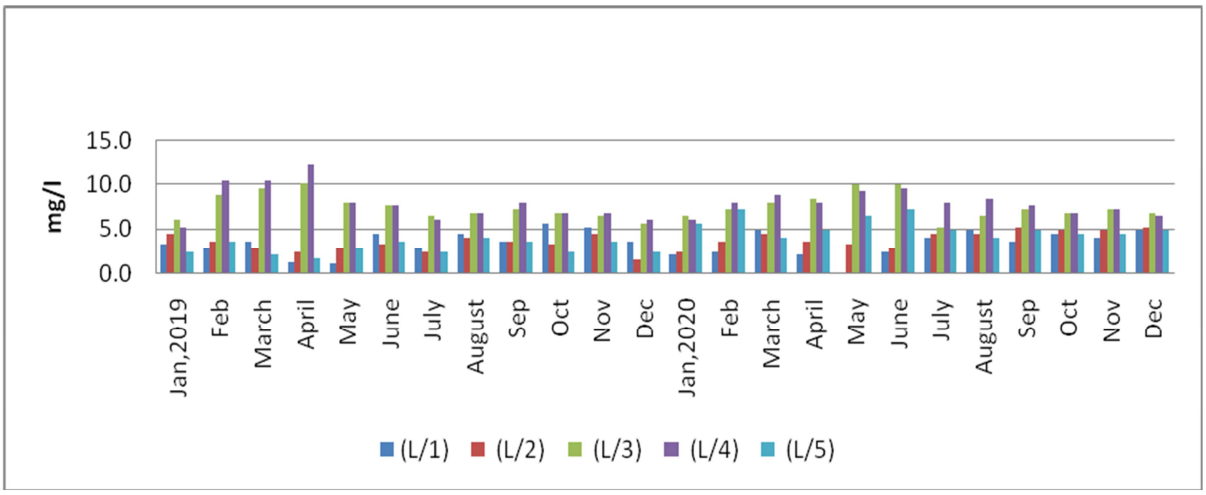


Fig. 11. Variation in Dissolved Oxygen (mg/l) in Bottom water at different stations of Lower Lake during Jan-Dec, 2019-2020

High dissolved oxygen concentration during summer months could be on account of high photosynthetic activity by the standing phytoplankton crop and macrophytic vegetation in presence of optimum light. In Lower lake comparatively higher values of Dissolved Oxygen were observed in water samples collected from Station 3 and Station-4 during most of the period of investigation while values were low in waters samples collected from Banganga, Dhobighat and Jahangirabad inlet points. Surface water in general during the period of investigation depicted higher values of DO.

Chloride occurs in all natural water in widely varying concentration. As the mineral content increases chloride content also increases. Chloride in surface water during the period of investigation ranged from 25-63mg/l. The minimum value was recorded at station-4 during, Sept, 2020, while the maximum value was also observed at Station-1 during July, 2019 (Fig.12).

Chloride in bottom water ranged from 21.90-51.95mg/l. The minimum value was recorded at station-3 during, Dec, 2019 while the maximum value was observed at Station-5 during May, 2019 (Fig.13).

High chloride content in general indicates pollution in the water body. High chloride content may also be attributed to quantity of domestic sewage. Pani and Misra (2005), reported that a high value of chloride gives indication of pollution due to sewage. In Lower lake higher range of chloride values depicted contamination of the lake water due to inflow of sewage from the three major inlets (Banganga, Dhobighat and Jahagirabad).

Alkalinity is an important parameter for fish and aquatic life because it protects or buffers against pH changes and makes water less vulnerable to acid rain. The main sources of natural alkalinity are rocks, which contain mainly carbonate and bicarbonate compounds. Borates, silicates, and phosphates may also contribute to alkalinity.

In Lower Lake, Total Alkalinity in surface water ranged from 104-240mg/l. The minimum value was recorded at station-5 during, March 2020, while the maximum value was observed at Station-1 during July, 2020 (Fig.14).

Total Alkalinity in bottom water ranged from 100-220mg/l. The minimum value was recorded at station-5 during, March, 2020, while the maximum value was observed at Station-1 during Aug, 2020 (Fig.15).

Total hardness in water is the sum of the concentrations of alkaline earth metal (e.g. Ca^{++},mg^{++}). In most fresh water nearly all the hardness is imparted by the calcium and magnesium ions which are in combination with bicarbonates and carbonates (temporary hardness) apart from sulphates, chlorides and nitrates.

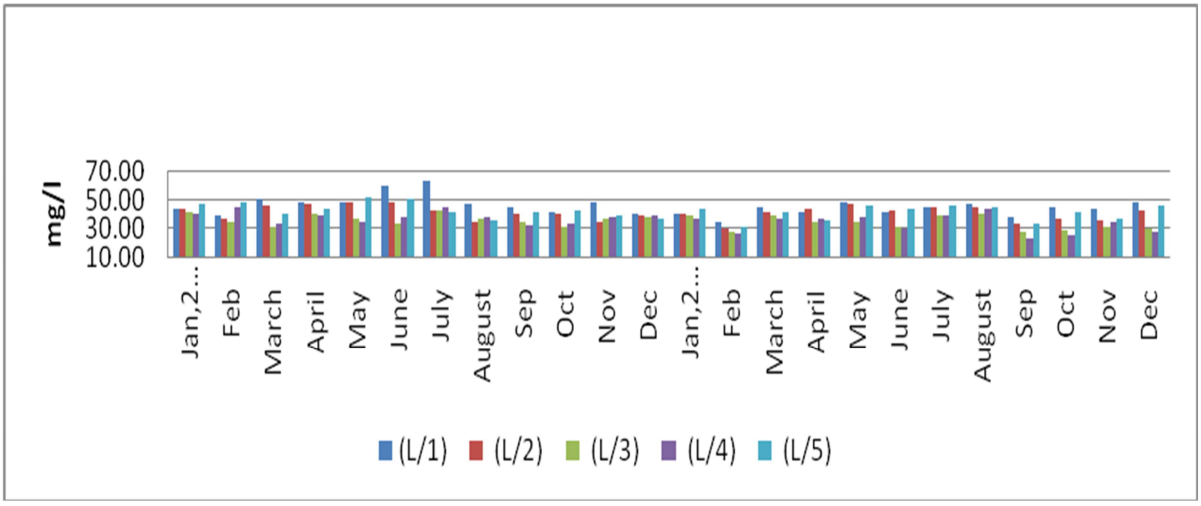


Fig. 12. Variation in Chloride (mg/l) in Surface waters at different stations of Lower Lake during Jan-Dec, 2019-2020

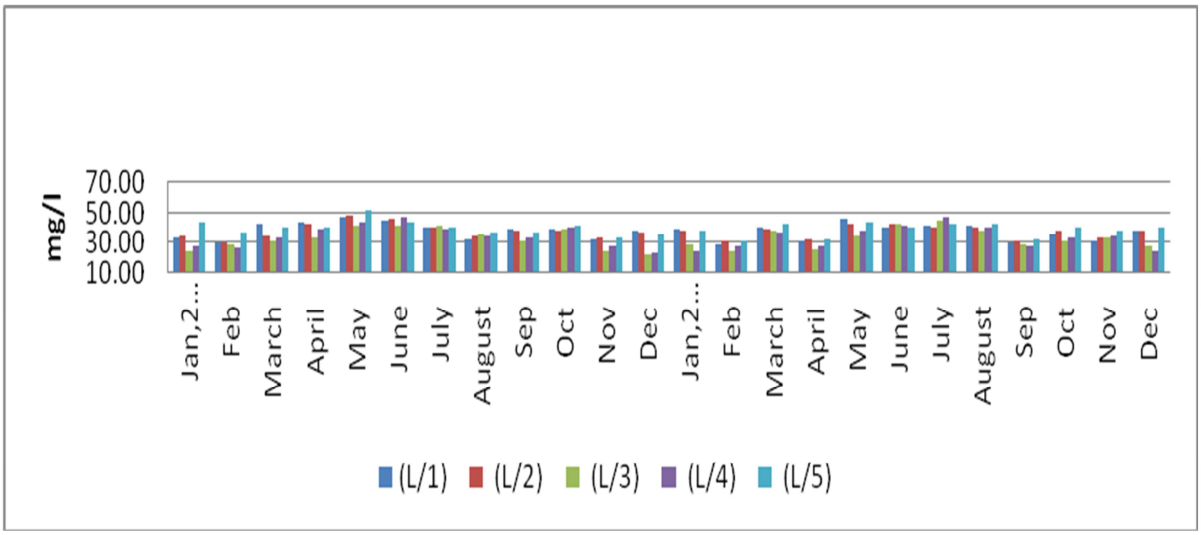


Fig. 13. Variation in Chloride (mg/l) in Bottom waters at different stations of Lower Lake during Jan-Dec, 2019-2020

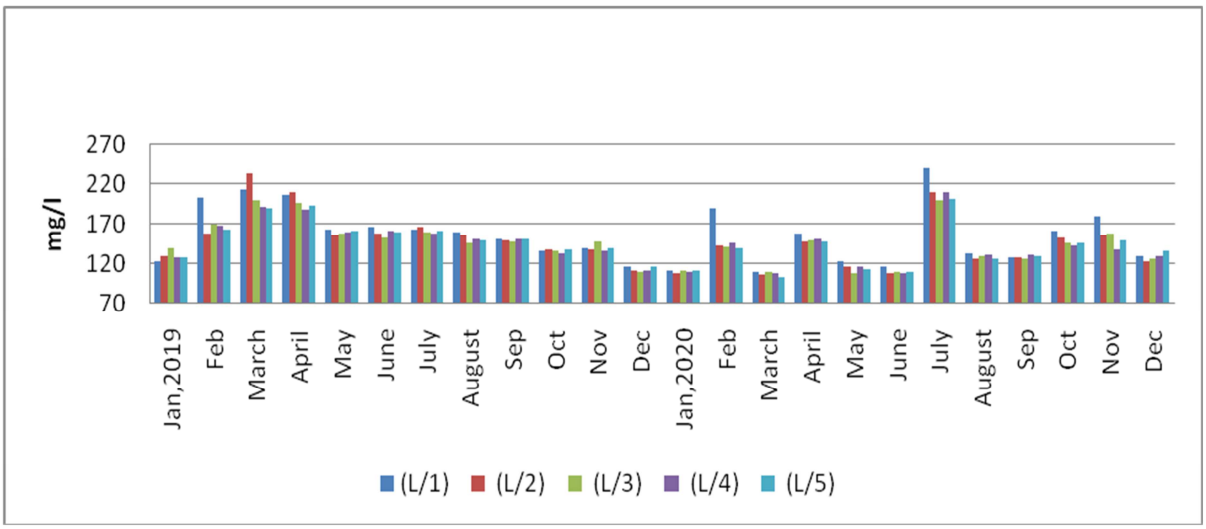


Fig. 14. Variation in Total Alkalinity (mg/l) in Surface waters at different stations of Lower Lake during Jan-Dec, 2019-2020.

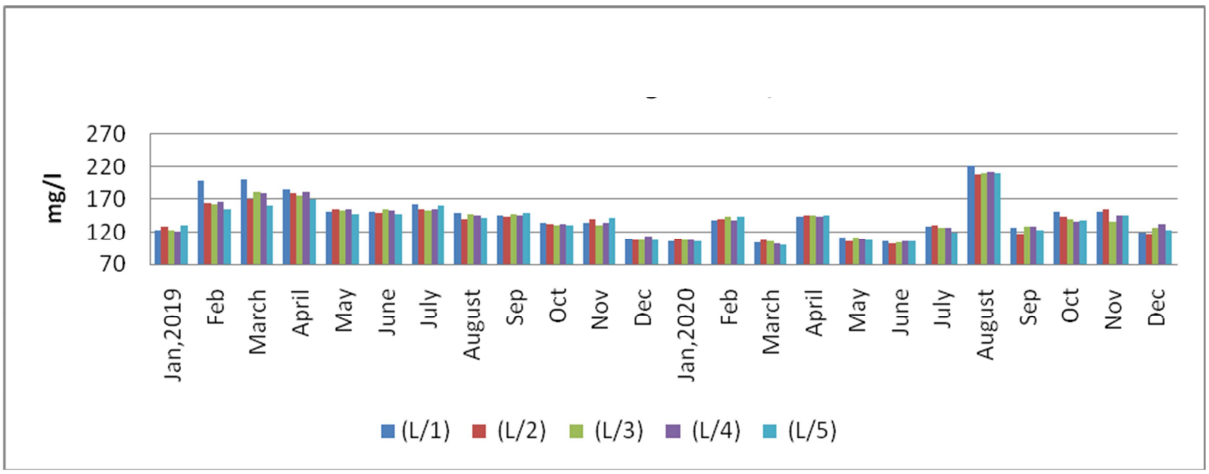


Fig. 15. Variation in Total Alkalinity (mg/l) in Bottom waters at different stations of Lower Lake during Jan-Dec, 2019-2020

Total Hardness of Lower Lake in surface water ranged from 110-230mg/l. The minimum value was recorded at station-3 during, Jan, 2020, while the maximum value was observed at Station-1 during July, 2019 (Fig. 16).

Total Hardness in bottom water ranged from 104 - 214mg/l. The minimum value was recorded at station-5 during, Jan, 2020, while the maximum value was observed at Station-1 during July, 2019 (Fig. 17).

Hirekhan and Patil (2003) stated that in the hardness of water, $CaCO_3$ is an important measure of pollution and its increase pertains to the excess presence of Ca,mg and Fe.

Bio-chemical Oxygen Demand in surface water ranged from 1.2-32mg/l. The minimum value was recorded at station-3&4 during, Dec, 2020 while the maximum value was observed at Station-1 during June, 2019 (Fig. 18).

Bio-chemical Oxygen Demand in bottom water ranged from 0.8 -22mg/l. The minimum value was recorded at station-2 during, Dec, 2020, while the maximum value was observed at Station-1, 2&5 during March, 2020 (Fig. 19).

Nitrates derived from agriculture sources. The introduction of large quantity of nutrients, mainly nitrogen and phosphorus to lake water can cause eutrophication problems (Kouimtzis et. al., 1994). Nutrient pollution especially not only with phosphorus but also with nitrogen coming from urban runoff and sanitary sewer systems can lead to eutrophication of the receiving water bodies, Stevens, (2005).

Nitrate – Nitrogen (NO_3-N) in surface water ranged from 0.44-5.71mg/l. The minimum value was recorded at station-1 during, Oct, 2020, while the maximum value was observed at Station-2 during July, 2020 (Fig.20).

Nitrate – Nitrogen in bottom water ranged from 0.41-5.31mg/l. The minimum value was also recorded at station-1 during, Oct, 2020, while the maximum value was observed at Station-1 during July, 2020 (Fig.21).

Like Nitrate – Nitrogen, Phosphorus is also an important parameter in understanding the trophic status of a water body. Total phosphorus in surface water during the period of investigation ranged from 1.17 -5.62mg/l. The minimum value was recorded at station-5 during, Dec, 2019, while the maximum value was observed at Station-4 during Aug, 2020 (Fig.22).

Total phosphorus in bottom water ranged from 1.19-8.42mg/l. The minimum value was recorded at station-3, 4, and 5 during, Dec, 2019, while the maximum value was observed at Station-5 during July, 2019 (Fig.23).

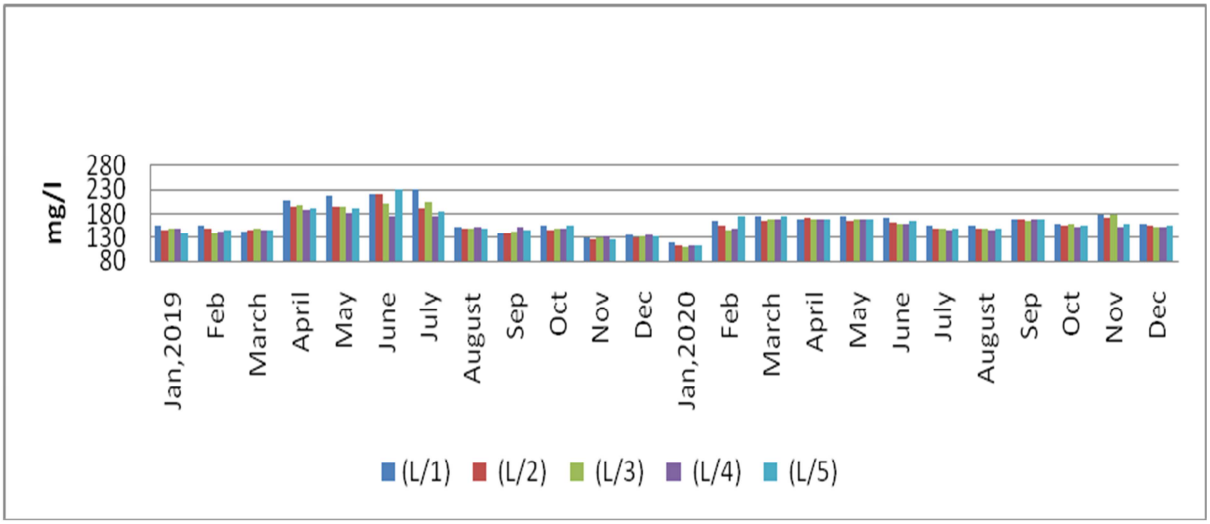


Fig. 16. Variation in Total Hardness (mg/l) in Surface waters at different stations of Lower Lake during Jan-Dec, 19-20.

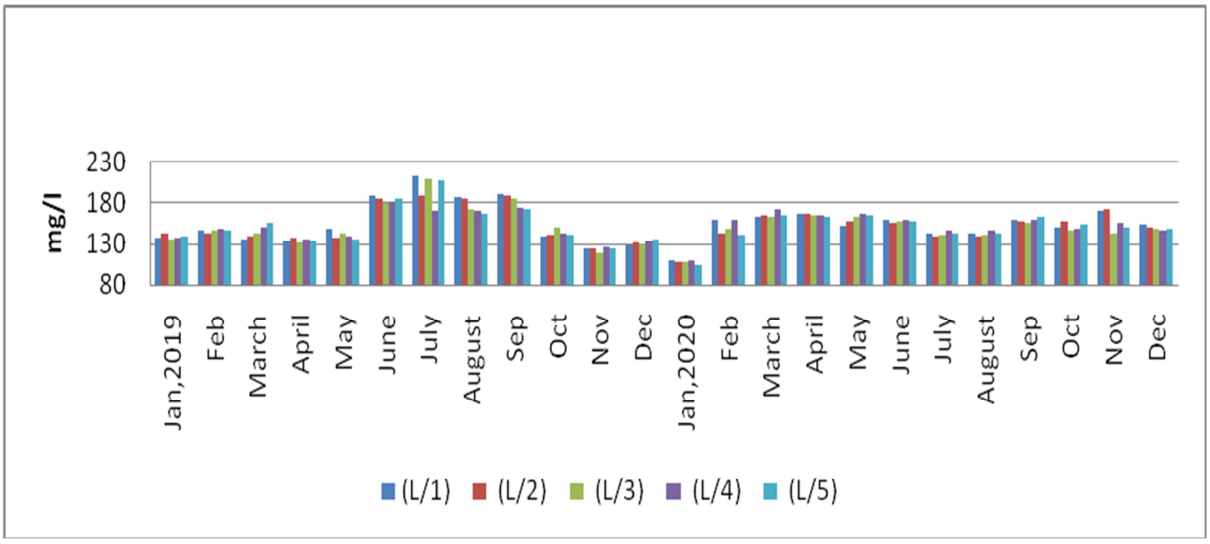


Fig. 17. Variation in Total Hardness (mg/l) in Bottom waters at different stations of Lower Lake during Jan-Dec, 19-20.

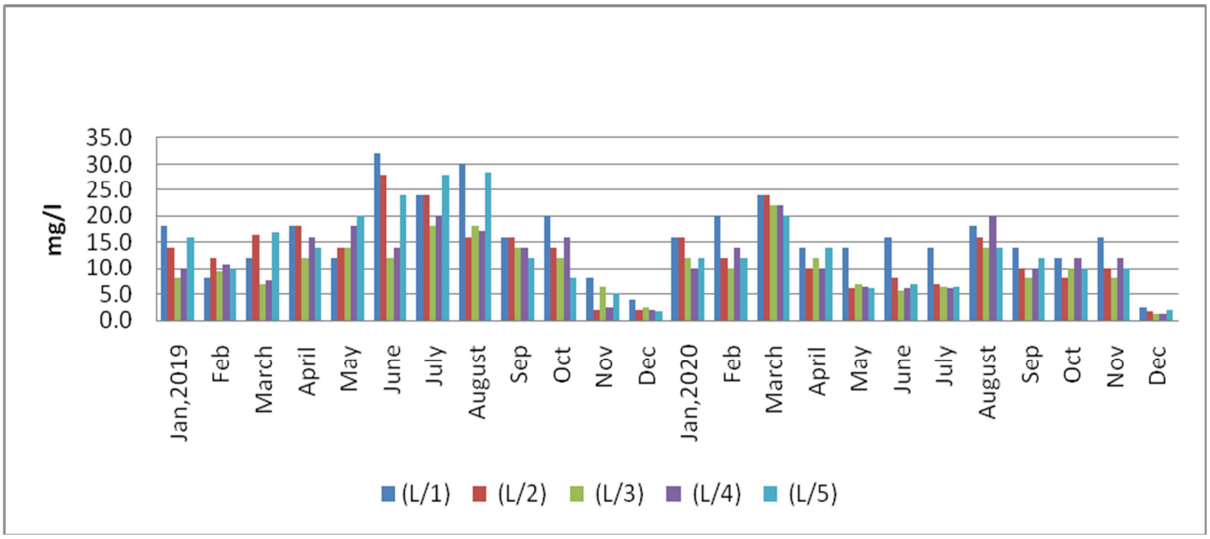


Fig. 18. Variation in BOD (mg/l) in Surface waters at different stations of Lower Lake during Jan-Dec, 19-20.

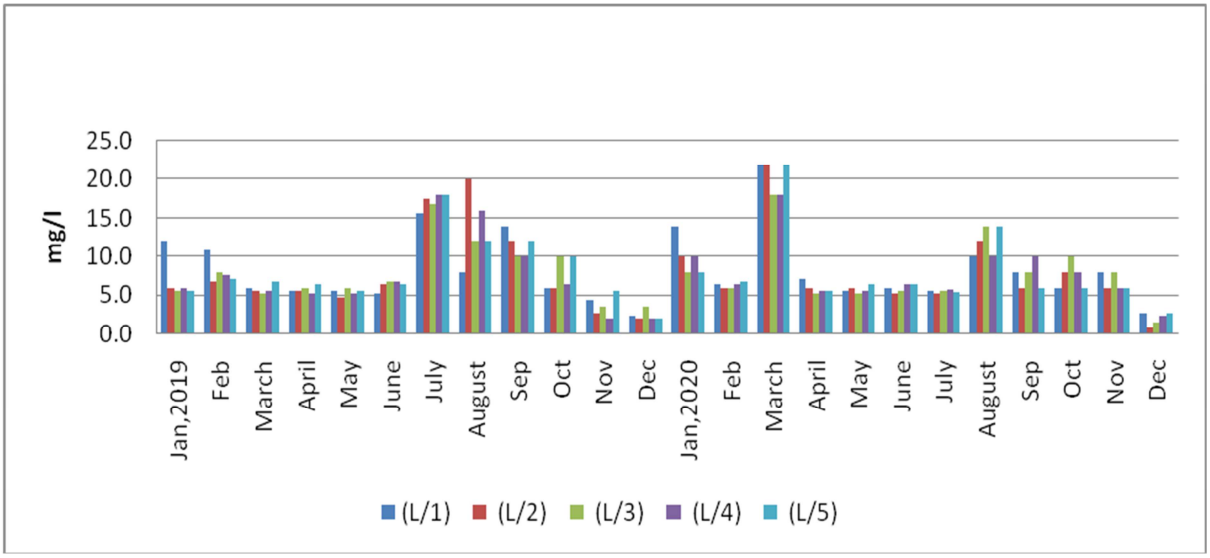


Fig. 19. Variation in BOD (mg/l) in Bottom waters at different stations of Lower Lake during Jan-Dec, 19-20.

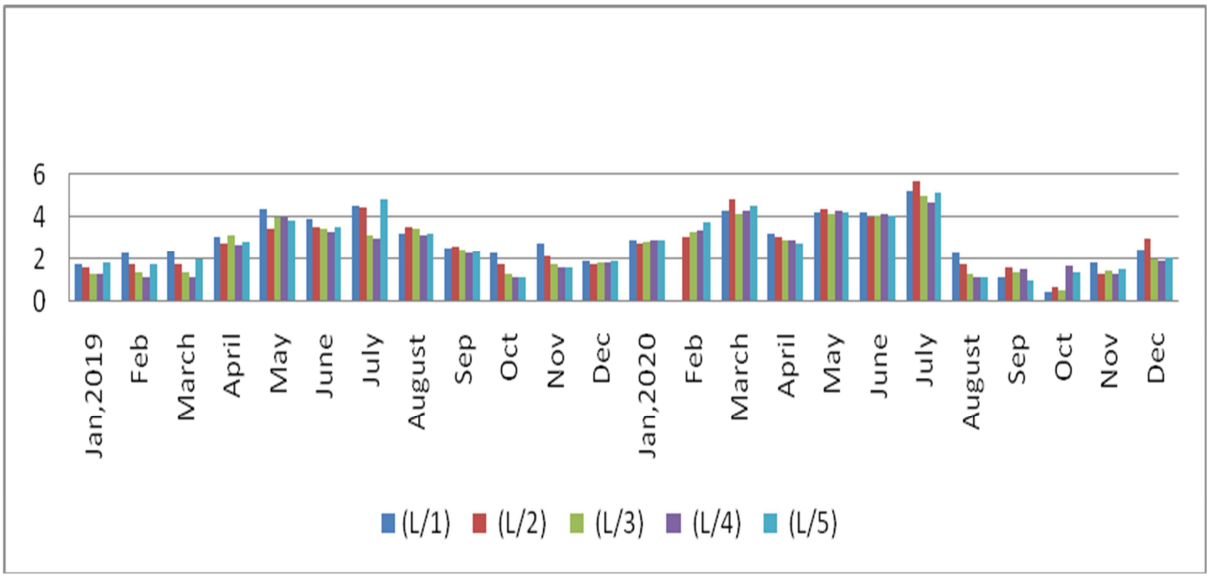


Fig. 20. Variation in Nitrate (mg/l) in Surface water at different stations of Lower Lake during Jan-Dec, 19-20.

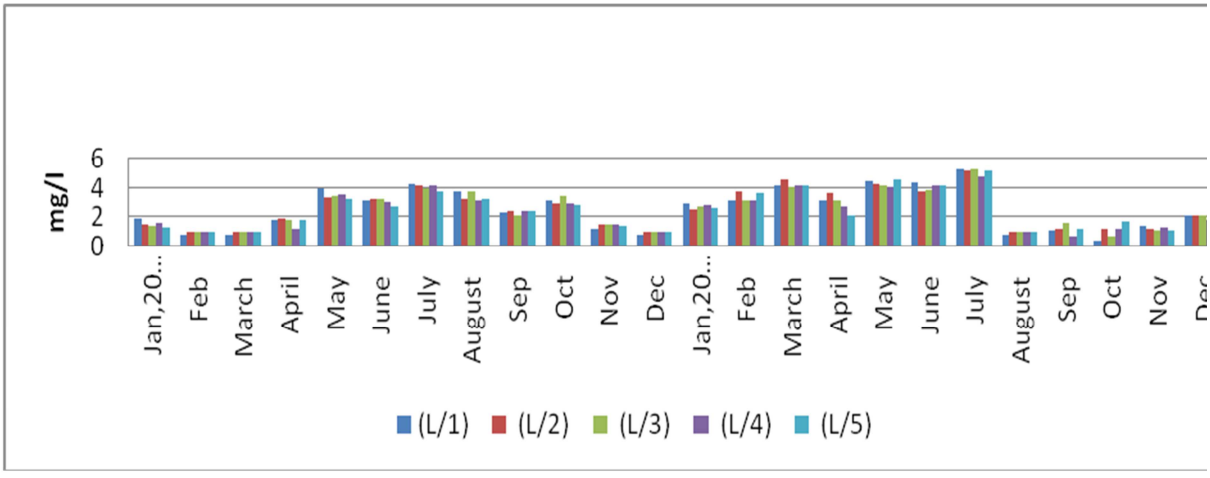


Fig. 21. Variation in Nitrate (mg/l) in Bottom water at different stations of Lower Lake during Jan-Dec, 19-20.

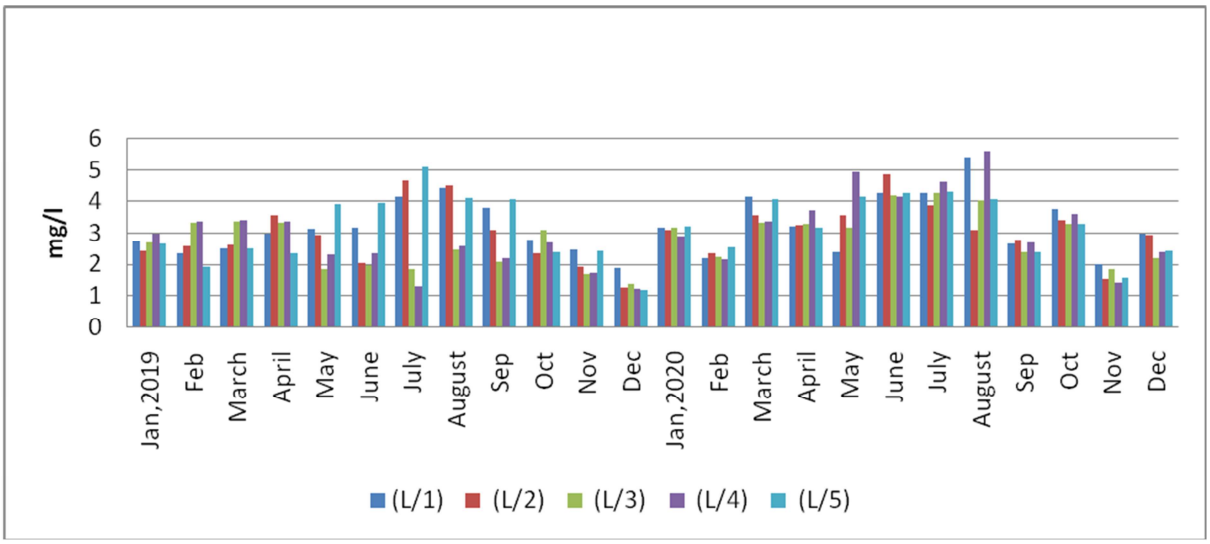


Fig. 22. Variation in Total Phosphorus (mg/l) in Surface waters at different stations of Lower Lake during Jan-Dec, 2019-2020.

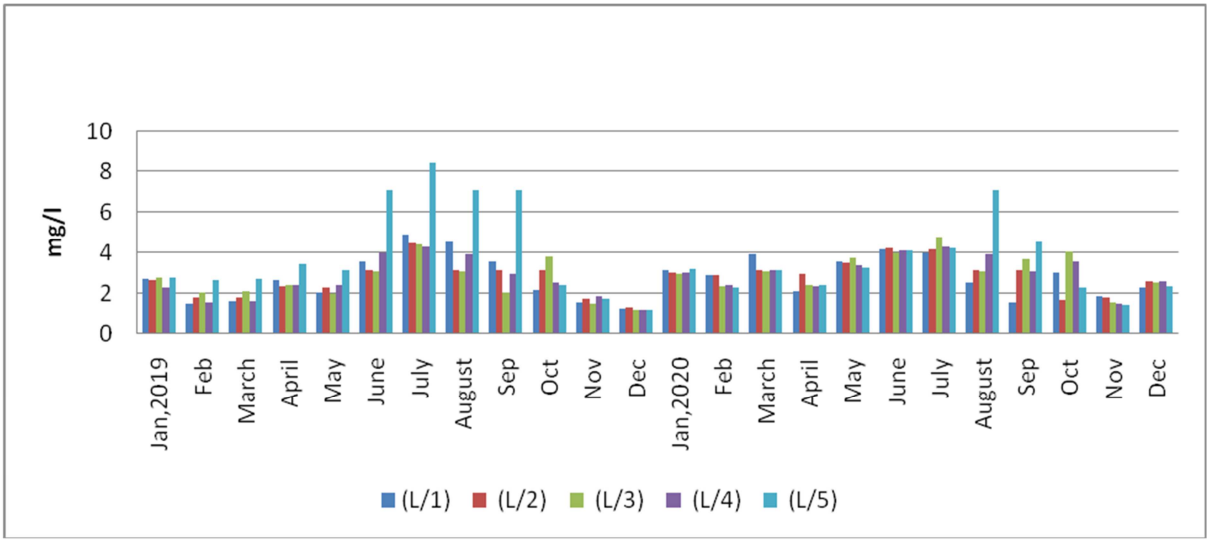


Fig. 23. Variation in Total Phosphorus (mg/l) in Bottom waters at different stations of Lower Lake during Jan-Dec, 2019-2020.

Phosphates enter waterways from human and animal wastes. The element phosphorus is necessary for plant and animal growth. Nearly all fertilizers contain phosphates (chemical compounds containing the element, phosphorous). When it rains, varying amounts of phosphates wash from farm soils into nearby waterways.

There has been a greater evidence of progressive deterioration of the water quality not only in India but also all over the world (Pani and Misra, 2005). While the natural factors like dust, storm, runoffs and weathering of minerals are slow process in causing eutrophication but modern civilization, industrialization and increase in pollution have lead to fast degradation of our fresh resources (Pandey *et al.*, 2010). With the increase in human population and their activities the self- purification power of water resources has diminished, leading to severe problems. In urban areas the situation is still worse where the water body is subject to much greater human pressure including direct discharge of sewage and industrial waste, which often contains heavy metals (Pani, and Mishra, 2000).

Water quality can be assessed by various parameters such as BOD, temperature, electrical conductivity, nitrate, phosphorus, potassium, dissolved oxygen, etc. along with heavy metals such as Pb, Cr, Fe, Hg, etc. which are of special concern because they produce water or chronic poisoning in aquatic animals. Harmful algal blooms are becoming increasingly common in freshwater ecosystems globally. Pollution by plastic debris is an increasing environmental concern in water bodies, where it affects open-water, shoreline and benthic environments (Bhateria and Jain, 2016).

In India River and lake pollution is very severe and critical problem due to huge amount of pollutants discharged by urban activities. Thus, water pollution needs serious immediate action and continuous monitoring of pollution level in order to prevent the water because of its importance in maintaining the human health, plants and agriculture. Without fresh water sustainable development will not be possible.

Water quality assessment is very important, as the majority of the water used in urban cities comes from surface water. It is the measure of how suitable the water is from a biological, chemical and physical perspective. Water quality can be impacted negatively by both natural and human causes. Physico-chemical parameters like pH. Dissolve oxygen, hardness, nitrates phosphates have direct impact on water quality of any aquatic system. The changes in different parameters have a relationship with the external influence, anthropogenic activities, nutrient loading etc. These physico-chemical parameters have deep and strong relationship with biological parameters as well as the biodiversity of aquatic system. Thus the assessment of water quality through physico-chemical and biological analysis for understanding the changes in constituents of water is very important as it can reflect directly on the biotic community of the aquatic system.

The effects of pollution stress manifest themselves in several ways in the lake biota viz. change in the pattern of distribution, elimination of scientific strategy, dominance of tolerant species, change in diversity and morphological and physiological changes (Dixit *et al.*, 2014).

Nutrients are essential for plant growth and development. Many nutrients are found in wastewater and fertilisers, and these can cause excess weed and algae growth if large concentrations end up in water. This can contaminate drinking water and clog filters. Nutrient over-enrichment can cause a range of economic and non-economic impacts, including eutrophication and associated anoxia and hypoxia, loss of sea grass beds and corals, loss of fishery resources, changes in ecological structure, loss of biotic diversity, and impairment of aesthetic enjoyment.

Eutrophication is nutrient enrichment; it drives excess primary productivity in waterways. It can be either natural or caused by human impact. Eutrophication sets off a chain reaction in the ecosystem, starting with an overabundance of algae and plants. The excess algae and plant matter eventually decompose, producing large amounts of carbon dioxide. This lowers the pH of lake water.

The aim of this study was to evaluate the existing quality of lower lake of Bhopal with respect to inflow of nutrients through sewage especially from various major inlets of the lake. The present investigation concludes that the water quality of the Lower Lake is being deteriorated at several places due to various factors. The concentration of BOD (0.8mg/l to 32mg/l), Total Phosphorus, Nitrate-nitrogen and Chloride reveal high degree of organic pollution from the major inlets at some intervals. Similarly high concentrations of inorganic constituents like total hardness (104mg/l to 230mg/l), total alkalinity (100mg/l to 290mg/l), etc also indicate deteriorating water quality of the lake. All the water samples contain significant amount of nitrate and phosphate that provides nutrition for the growth and multiplication of microorganisms. Thus, by detailed analysis of the data obtained during the study period Jan, 2019-Dec, 2020 it can be concluded that the quality of water of Lower lake in general observed to be of alarming level and mostly falls within class – C

of Central Pollution Control Board (CPCB, New Delhi) under designated best uses of water for irrigation and drinking water after conventional treatment.

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