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Khairun Nissa
Department of Zoology, Government Motilal Vigyan Mahavidyalaya College Bhopal, Madhya Pradesh, India

Rajendra Chouhan
Department of Zoology, Government Motilal Vigyan Mahavidyalaya College Bhopal, Madhya Pradesh, India

Hafsa Haleem
Department of Zoology, Government Motilal Vigyan Mahavidyalaya College Bhopal, Madhya Pradesh, India

Corresponding Author:
Khairun Nissa
Department of Zoology, Government Motilal Vigyan Mahavidyalaya College Bhopal, Madhya Pradesh, India

Evaluation of surface water quality using correlation matrix in Lower Lake, Bhopal, India

Khairun Nissa, Rajendra Chouhan and Hafsa Haleem

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Abstract
The most affordable supply of drinkable water for rural, semi-urban, and metropolitan communities in India is lake water. The ecosystem and lake water supplies are polluted by the numerous sources. The current study attempts to determine the level of surface water pollution in close proximity to Lower Lake in Bhopal, India. For the purpose of collecting samples around Lower Lake's edge, three sampling locations were chosen for the study. Twelve physico-chemical parameters, including air and water temperatures, pH, transparency, electrical conductivity, free CO_2, dissolved oxygen, phosphate, nitrate, chloride, total hardness, and total alkalinity, were examined seasonally for a period of one year (Nov 2020–Oct 2021) in order to evaluate the surface water quality of Lower Lake. Following statistical analysis, it became evident that there were both positive and negative co-relationships between the attributes. It was discovered that the Lower Lake`s surface water is tainted and unfit for direct consumption.

Keywords: Correlation matrix, surface water, water quality, lower lake

Introduction
One of the world's most productive, diverse, and interconnected aquatic ecosystems is the lake. These are significant freshwater Resources that are home to several aquatic species that are threatened or endangered. Numerous factors influence the type of life that can exist in these aqua-Resources, including the quality of the water in such Resources (Qureshimatva *et al*. 2015) [15]. About ha lf of the world's renewable freshwater is provided by lakes, which are also essential for the socioeconomic advancement of human welfare (Johnson *et al*. 2001) [7].
Common sources of surface water contamination include agricultural runoff, weathering of rocks, soil leaching, and mining operations, as well as the discharge of municipal and industrial pollutants (Bhateria and Jain 2016) [2]. In addition to endangering aquatic life, the deterioration of surface water quality also affects the quality of underground water, which has an impact on human health (Wats *et al*. 2019) [30] As a result, it is crucial to regularly monitor the health of these precious natural Resources by assessing the ir physico-chemical and biological properties (Venkatesharaju *et al*. 2010) [25]. Workers throughout the world have devised and accepted a variety of ways and strategies to evaluate the water quality, with the use of water qua lit indices (WQIs) of various types being the most successful method (APHA, 2005) [1].

Materials and methods
Study area
Nawab Chhote Khan built Lower Lake, at coordinates 23°16′0″N and 77°25′0″E, in 1794 to beautify the city. It was made by building an earthen dam, and several earlier wells were incorporated into it. Lower Lake empties into the Halali River, a tiny tributary of the Betwa River, via the Patra drainage system. It has a catchment area of 9.6 km 2 and water spread area of 1.29 km 2. The lake receives drainage from 28 sewage-filled Nullah as well as underground seepage from the Upper Lake.
Many recreational activities are carried out here because it is primarily a recreational location. Many families of washer men profit socioeconomically from the Lower Lake of Bhopal. The lake is under a lot of anthropogenic strain. Locals and visitors use the lake mostly for recreation activities like boating, morning and evening walks, and sight-seeing,

The lake's water quality has been greatly impacted by the adverse effects of population growth in both the city and its bordering states as well as by climatic and seasonal changes. The water body is currently dealing with major problems like siltation, weed infestation, catchment area degradation, reduced rain falls, addition of contaminants, etc., all of which are endangering this lovely ecology. The current study was created to comprehend the seasonal change in the physico- chemical characteristics of surface water in Lower Lake, keeping the necessity and need in mind. Various water quality indices were used to evaluate the water quality.

Fig 1: Lower Lake of Bhopal (Source: - Google Earth)

Methodology

Over the course of a year, seasonal water samples were taken (November 2020-October 2021). With the aid of a digital thermometer, an E-Merck pH meter, and a Secchi disc, respectively, field measurements of variables such surface water temperature, pH, and transparency were taken. To prevent the mixing of air bubbles, the water samples were placed in two distinct polyvinyl propylene bottles (1L and 500 ml) and dipped completely into the water. While the water sample in the second bottle (500 ml) was fixed on the spot using 2 ml MnSO4 and was used for dissolved oxygen analysis, the water sample in the first bottle (1 L bottle) was used for the analysis of parameters like electrical conductivity, total dissolved salts, chloride, total alkalinity, total hardness, carbonate alkalinity, and bicarbonate alkalinity, nitrate and phosphate, whereas the sample in the second bottle (500 ml) was used for dissolved oxygen measurement after being fixed on the spot with 2 ml of MnSO4.

Different techniques were used to analyses chemical parameters. The conductivity and TDS meters from E-Merck were used to measure like electrical conductivity and total dissolved salts, respectively. Total alkalinity by titration technique using 0.02 N standard sulphuric acid as titrant and phenolphthalein/methyl orange as indicators, chloride by titration method using 0.014 N silver nitrate as titrant and potassium chromate as an indicator, and total hardness by EDTA titrimetric method. With the id of a UV-Vis spectrophotometer, nitrate and phosphate were determined using the Brucine method and the stannous chloride method, respectively.

The twelve months of a year were divided into the four distinct seasons:

Winter November – February
Summer March – June
Monsoon July – August
Post Monsoon September – October

Result and Discussion

Physico-chemical analysis of water quality

Air Temperature (°C)

One of the important factors that influence the pH, dissolved oxygen, and alkalinity of water, as well as other factors that determine water quality, is temperature (Khaiwal *et al.* 2003) [8]. Throughout the duration of the investigation, the air temperature in Lower Lake varied from 23.5 to 37 °C. The winter season saw the lowest air temperature recorded, and the summer season saw the highest air temperature. The timing of collection and the impact of the weather, which in the Lakes quite varies during the day and season, could be the cause of spatial variations in air temperature experienced during a particular season (Welch, 1952) [28]. According to Wanganeo (1998) [27] and Khan *et al.* (2015) [10], the Bhoj Wetland's temperature ranged from 22.2 °C to 33.8 °C and 21 °C to 40 °C, respectively.

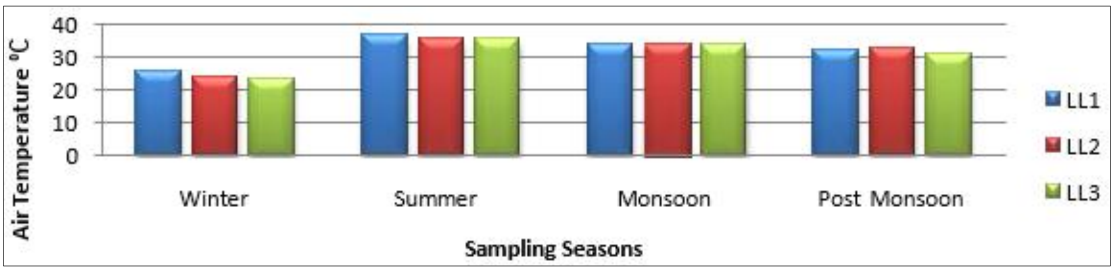

Fig 2: Seasonal variation in air temperature (°C)

Water Temperature

Seasonal and station-specific variations in lake water temperature can be found. The winter season saw the lowest water temperature ever recorded (210 C), while the summer season saw the highest temperature ever recorded (28.50 C). In the current study, the rising water temperature, especially in the summer, can be linked to both the exothermic chemical processes that are prevalent all over the lakes and the general growing trend in atmospheric temperature. Narasimha and Jaya (2001) [1] noted that a rise in temperature can lead to a high rate of evaporation, which can result in a decrease in water level during the summer.

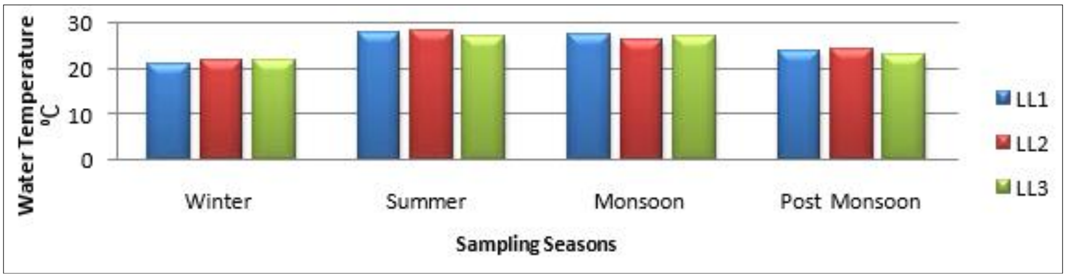

Fig 3: Seasonal variation in Water temperature (°C)

pH

pH, which is calculated as the negative log of the concentration of H + ions, measures the acid/base activity in solution. The lake's productivity increased as the pH increased (Ravi kumar *et al*. 2013; Gopalkrushna, 2011 and Garg *et al*. 2010) [17, 5, 4]. Winter has been recorded to have the lowest pH value, 6.8, while summer and monsoon both have the highest pH va lues, 8.2 and 8.2, respective ly. The high pH leve ls during the summer may be brought on by low water levels and nutrient concentrations in the water, which can cause high levels of free carbon dioxide to be produced as a result of high photosynthesis of micro and macro vegetation (Trivedi, 1989) [2].

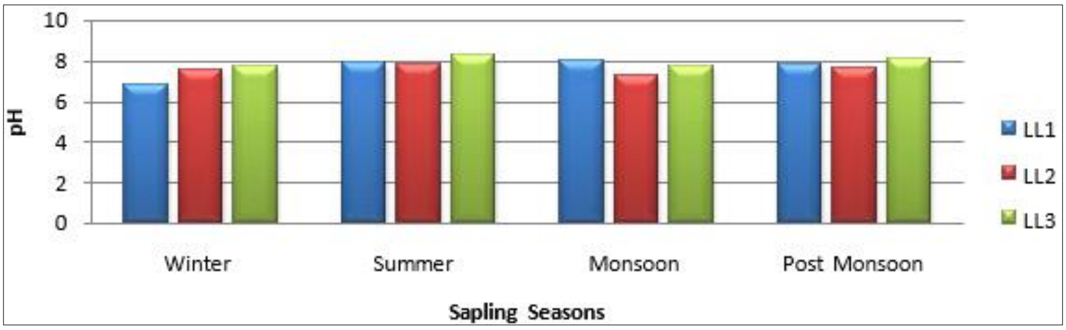

Fig 4: Seasonal variation in pH

Specific Conductivity (µS/cm)

In lake water, the specific conductivity of the water followed a seasonal trend. The lowest specific conductivity value (190.2 Scm-1) and highest specific conductivity value (318.3 Scm-1) were recorded in the winter and summer, respectively. Summertime water evaporation may be the cause of the higher conductivity that was observed during this time. A similar outcome was noted by (Reddy, 2009 and Solanki and Acharya, 2016) [18, 22].

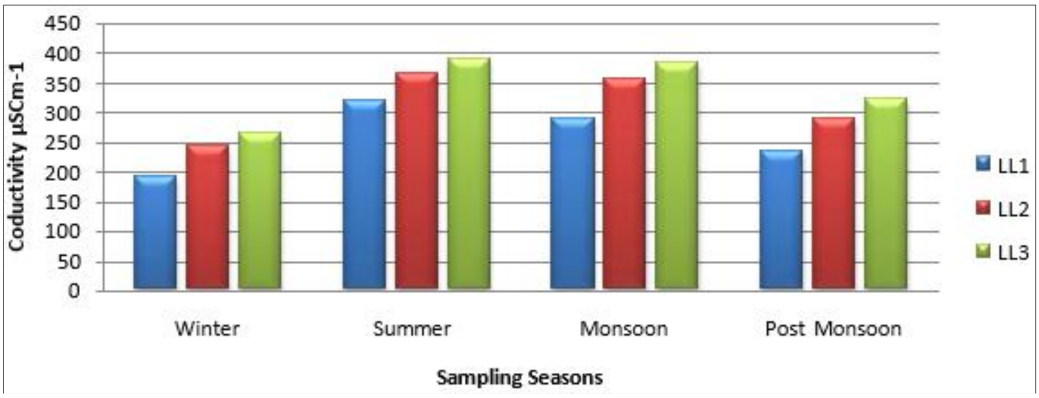

Fig 5: Seasonal variation in Specific Conductivity (µS/cm)

Transparency (Cm)

The presence and amount of suspended organic matter, the amount of silt, the density of the plankton, the latitude, the season, and other variables all affect how transparent or light-permeable the water is (Reid and Wood 1976) [19]. Throughout the whole study period, Lower Lake's transparency varied between 13 and 38 cm. During the monsoon, transparency was measured at its lowest point (13 cm), and at its highest point (38 cm), which was reached in the winter. However, bright skies and strong light penetration may be to blame for high transparency levels in winter.

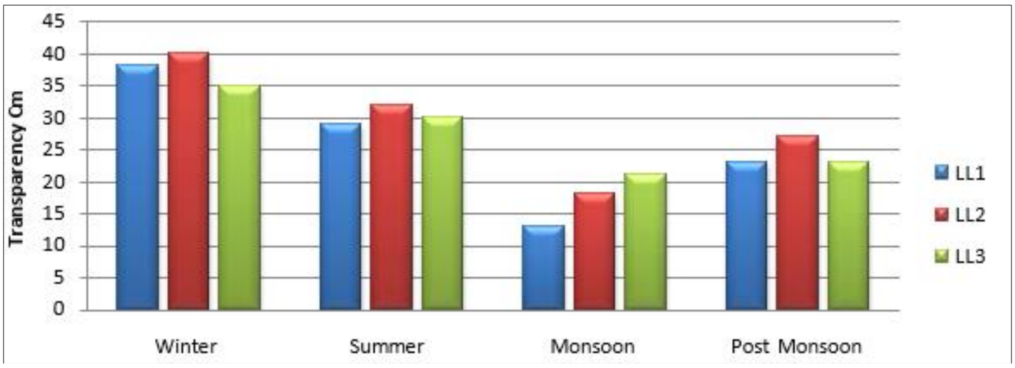

Fig 6: Seasonal variation in Transparency (Cm)

Free Co2 (mg/l)

On a seasonal basis, the highest free carbon dioxide concentration was found to be 20.1 mg/l during the monsoon season, while the lowest concentration was found to be 2.8 mg/l during the winter.

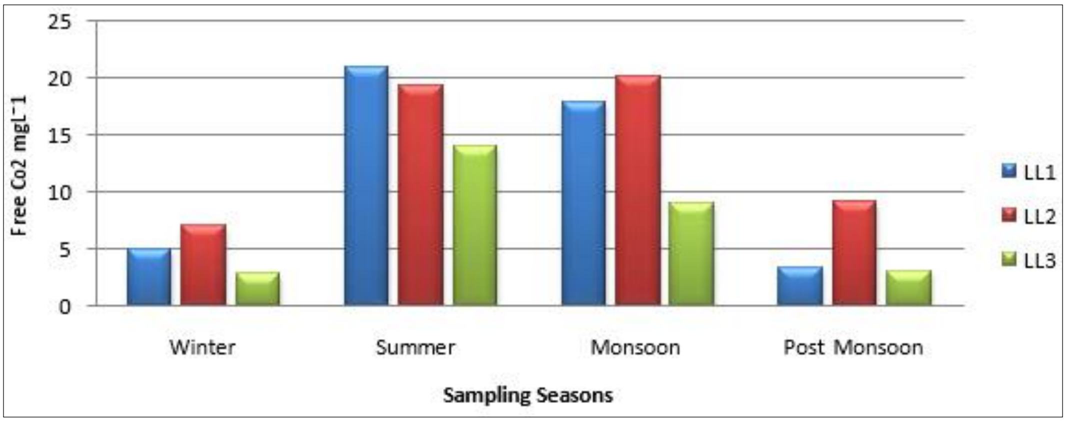

Fig 7: Seasonal variation in Free Co2 (mg/l)

Dissolve d Oxygen (mg/l)

Numerous variables, including temperature, photosynthetic activity, wind direction, life in the water's respiratory system, pollution load, etc., affect a water body's DO. It varies daily, seasonally, and according to temperature changes (Wavde and Arjun 2010) [31]. Seasonal changes affect the dissolved oxygen concentration of the lake over the study period, and it was found that the range of dissolved oxygen was between 2.8 mg/l and 7.9 mg/l. On a seasonal basis, the winter season's maximum dissolved oxygen concentration was 7.9 mg/l, while the summer season's minimum concentration was 2.8 mg/l. Since the summer, the oxygen concentration has been trending downward. According to Tian *et al*. (2012) [23], low oxygen levels during the height of summer may be related to the stratification and temperature rise, which in turn causes an increase in bacterial oxygen consumption.

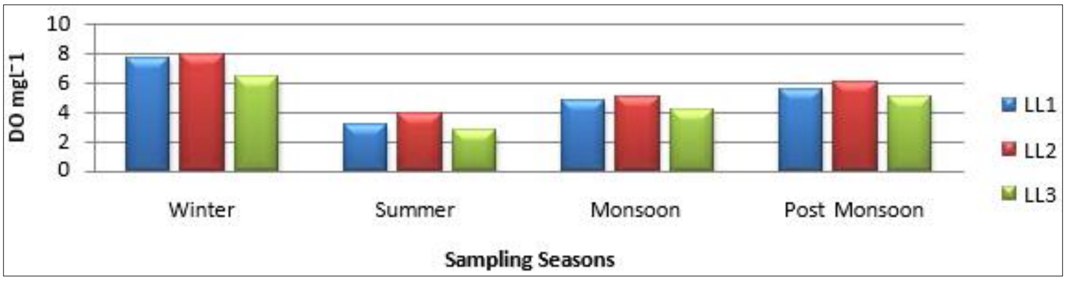

Fig 8: Seasonal variation in DO (mg/l)

Phosphate (mg/l)

It is one of the variables that restrict any water body's capacity to produce (Hutchinson 1957) [6]. Phosphorus can be found in lakes from a variety of sources, including rock deposits and catchment area runoff. Agricultural runoff carrying fertilizers and home wastewater are the main sources of phosphate entering the lake ecology (Gopalkrushna 2011) [5]. The lowest level of phosphate was recorded during the winter (0.32 mgl-1) while the highest level was recorded during the monsoon (2.13 mgl-1). However, Verma *et al*. (2012) [26] showed that the summertime has greater phosphate concentrations.

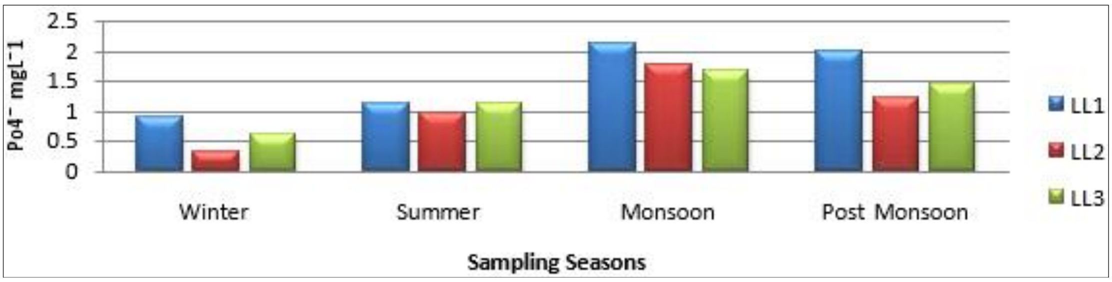

Fig 9: Seasonal variation in Po4⁼ (mg/l)

Nitrate (mg/l)

The most prevalent type of nitrogen in natural waters is inorganic. It is the primary nutrient that promotes the rapid growth of aquatic algae and hydrophytes (Lodh *et al*. 2014) [11]. In freshwater bodies, nitrate is present in relatively low concentrations but is thought to be a crucial source of nitrogen for protein synthesis. In the current study, higher nitrate concentrations (4.1 mg-1) and lower nitrate concentrations (2.09 mgl-1) were found during the monsoon and winter, respectively. The same was discovered in the current study: influx of nitrate-rich food water from the catchment area carries along substantial amounts of contaminations such sewerage that accelerate nitrate levels in the monsoon season.

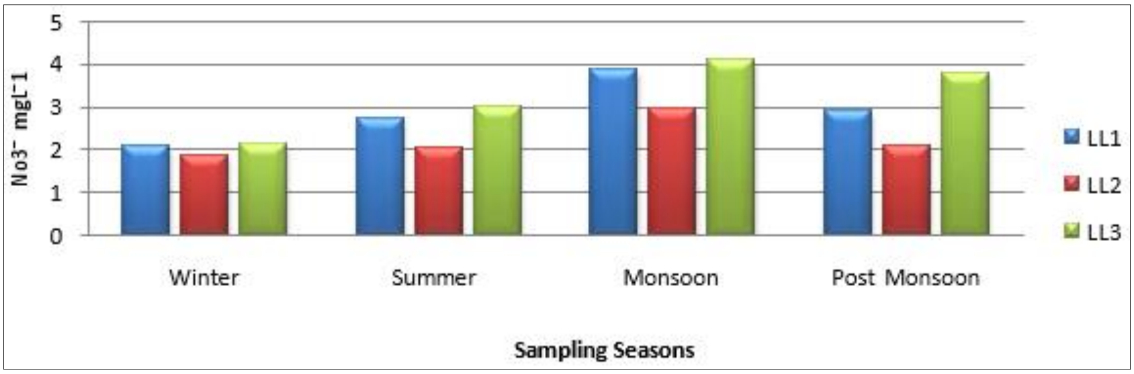

Fig 10: Seasonal variation in No3 (mg/l)

Chloride (mg/l)

Inorganic salts like Na Cl and K Cl, which are mostly derived from soil, anima l waste, and urban and industrial wastes, are the principal sources of chloride in water (Gopalkrushna 2011) [5]. It is also regarded as a crucial sign of water pollution (Podhade *et al*. 2020) [14]. Chloride levels in Lower Lake ranged from 26.14 mgl-1 to 61.21mgl-1. Chloride levels were higher during the monsoon seasonmgl-1) and lower throughout the winter (26.14 mgl-1). The increased chloride content in water may be caused by anthropogenic pollution and sewage disposal, as shown by (Chatterjee *et al*. 2010) [3].

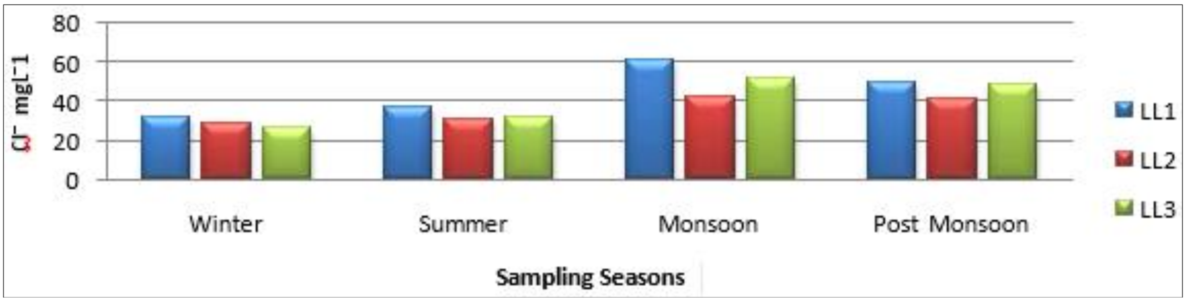

Fig 11: Seasonal variation in C1-(mg/1)

Total Hardness (mg/l)

The presence of cations like calcium and magnesium in water is primarily responsible for this. The total hardness of water samples in Lower Lake varies from (141 mg/l) to (273 mg/l). The Monsoon had the highest hardness values (273 mg/l), while the winter had the lowest hardness values (141 mg/l). The presence of magnesium suggested that sewage inflows and minerals produced as a result of soil erosion and siltation had contaminated the area (Verma *et al*. 2012) [26]. The decline and disintegration in submerged macrophytes may be responsible for the high concentration of total hardness seen during monsoon.

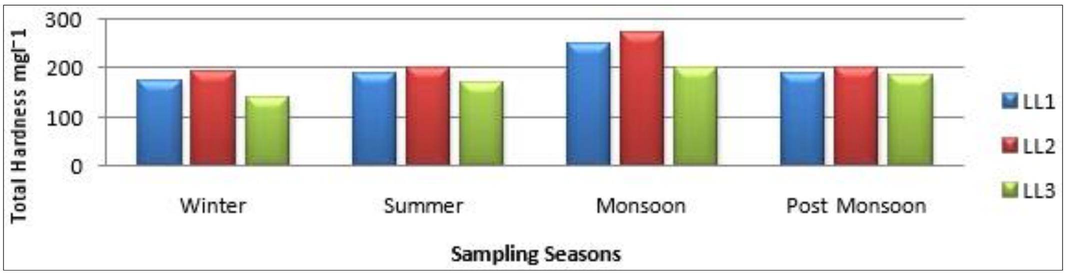

Fig 12: Seasonal variation in Total Hardness (mg/l)

Total Alkalinity (mg/l)

Total alkalinity demonstrates the water's ability to act as a buffer, preserving its pH (Lodh *et al*. 2014) [11].The ability of water to neutralize acids is measured by its alkalinity. It is not typically regarded as a contaminant (Sharma and Kumar, 2017) [2]. The variance in total alkalinity over the study period varies significantly between the different seasons. The readings vary from 141 mgl-1 to 273 mgl-1, it was reported. Winter saw the lowest level of total alkalinity (141 mgl-1) while monsoon season saw the highest level of total alkalinity. The desired level of total alkalinity for drinking water, according to Bureau of Indian Standards, is below 200 mgl-1, and the allowable level, in the absence of an alternative source, is 600 mgl-1 (BIS, 1992).

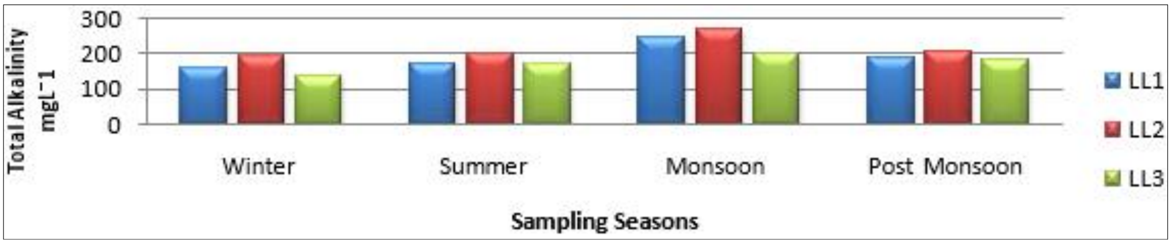

Fig 13: Seasonal variation in Total alkalinity (mg/1)

Correlation analyses for different surface water quality parameters

Correlation analysis is a bivariate method used to evaluate the degree of interrelation and association between two variables. A correlation of –1 indicates that one variable changes inversely with relation to the other whereas a correlation of + 1 indicates a perfect positive relationship between two variables. A correlation of zero indicates that there is no relationship between the two variables at a significant level of ≤ 0.5. More precisely it can be said that parameters showing r ≥ 0. 7 are considered to be strongly correlated where as "r" between 0.5 and 0.7 shows moderate correlations. In this study the correlation matrix demonstrated that most traits have positive correlations with one another. There have also been instances of negative correlation. In all the four seasons, there is a very strong positive association between total alkalinity and total hardness.

Table 1: Pearson Correlation Matrix for winter

	AT	WT	pH	Cond	TP	Free CO_2	DO	PO4-	NO3-	Cl-	TH	TA
AT	1											
WT	-0.9819	1										
pH	-0.99973	0.97735	1									
Cond	-0.99500	0.95821	0.99704	1								
TP	0.30037	-0.11470	-0.32231	-0.39408	1							
FreeCo2	0.21589	-0.02748	-0.23838	-0.31228	0.99617	1						
DO	0.55688	-0.38988	-0.57591	-0.6370	0.95950	0.9312	1					
PO4-	0.74925	-0.86091	-0.73376	-0.67940	-0.40663	-0.48489	-0.13282	1				
NO3-	0.17636	-0.3592	-0.15359	-0.07723	-0.88589	-0.92303	-0.71935	0.7840	1			
Cl-	0.94491	-0.86602	-0.95221	-0.97286	0.59603	0.52361	0.79808	0.49120	-0.15554	1		
TH	0.36463	-0.18209	-0.38603	-0.45575	0.99767	0.98791	0.97646	-0.34347	-0.85224	0.64933	1	
TA	0.07080	0.11897	-0.09381	-0.17002	0.97269	0.98925	0.8679	-0.6075	-0.96936	0.39341	0.95463	1

Table 2: Pearson Correlation Matrix for summer

	AT	WT	pH	Cond	TP	Free CO_2	DO	PO4-	NO3-	Cl-	TH	TA
AT	1											
WT	0.18898	1										
pH	-0.2773	-0.9958	1									
Cond	-0.93998	-0.5127	0.58853	1								
TP	-0.75592	0.5	-0.41931	0.48718	1							
Free Co2	0.68788	0.84274	-0.88813	-0.89426	-0.04482	1						
DO	-0.15554	0.94063	-0.90593	-0.19085	0.76426	0.60999	1					
PO4-	0.39735	-0.82603	0.77145	-0.06038	-0.90112	-0.39272	-0.9683	1				
NO3-	0.22728	-0.91332	0.87258	0.1186	-0.80933	-0.55047	-0.99732	0.98396	1			

Cl-	0.993	0.07550	-0.16571	-0.89482	-0.82580	0.6004	-0.26743	0.49964	0.33710	1		
TH	0.03846	0.98852	-0.97072	-0.37711	0.62509	0.75174	0.98111	-0.9017	-0.96436	-0.0760	1	
TA	-0.41931	0.81223	-0.75592	0.08437	0.91129	0.37049	0.96201	-0.99971	-0.97938	-0.5203	0.89104	1

Table 3: Pearson Correlation Matrix for monsoon

AT		**WT**	**pH**	**Cond**	**TP**	**Free CO_2**	**DO**	**PO4-**	**NO3-**	**Cl-**	**TH**	**TA**
AT	1											
WT	-0.86602	1										
pH	-0.92857	0.98974	1									
Cond	0.21938	-0.67781	-0.56582	1								
TP	0.14285	-0.61858	-0.5	0.99697	1							
Free Co2	0.65324	-0.18715	-0.32557	-0.59538	-0.65605	1						
DO	0.75592	-0.32732	-0.45895	-0.47286	-0.53994	0.98947	1					
PO4-	-0.31480	0.74720	0.64460	-0.99509	-0.98439	0.513	0.38339	1				
NO3-	-0.98561	0.76905	0.85247	-0.05132	0.02648	-0.77182	-0.85570	0.14984	1			
Cl-	-0.88368	0.99933	0.99429	-0.65054	-0.58952	-0.22286	-0.36157	0.72247	0.79185	1		
TH	0.73545	-0.29813	-0.43143	-0.49972	-0.56556	0.99345	0.99952	0.4116	-0.83939	-0.3327	1	
TA	0.73545	-0.29813	-0.43143	-0.49972	-0.56556	0.99345	0.99952	0.4116	-0.83939	-0.3327	1	1

Table 4: Pearson Correlation Matrix for post-monsoon.

AT		WT	pH	Cond	TP	Free CO2	DO	PO4-	NO3-	Cl-	TH	TA
AT	1											
WT	0.99587	1										
pH	-0.98624	-0.99717	1									
Cond	-0.60739	-0.53276	0.46770	1								
TP	0.69337	0.75592	-0.80295	0.15127	1							
Free Co2	0.72466	0.78423	-0.82860	0.1072	0.99901	1						
DO	0.96076	0.98198	-0.99339	-0.36323	0.86602	0.88735	1					
PO4-	-0.02844	-0.11907	0.19330	-0.77680	-0.74001	-0.7094	-0.30457	1				
NO3-	-0.96874	-0.98726	0.99642	0.39136	-0.85043	-0.87294	-0.99953	0.2755	1			
Cl-	-0.62340	-0.69181	0.74408	-0.24249	-0.99567	-0.9905	-0.81580	0.79931	0.79786	1		
TH	0.88032	0.91975	-0.94663	-0.15785	0.95221	0.96482	0.97735	-0.49922	-0.97047	-0.9197	1	
TA	0.82199	0.87030	-0.90482	-0.04686	0.98031	0.98811	0.94769	-0.59264	-0.93756	-0.9577	0.99377	1

AT: Air Temperature, WT: water Temperature, Cond: Specific Conductance, TP: Transparency, CO_2: Carbon Dioxide, PO_4: Phosphate, TA: Total Alkalinity, TH: Total Hardness, Cl: Chloride, NO_3: Nitrate, DO: Dissolved Oxygen

Conclusion

The current study provided a summary of the Lower Lake's water quality situation. The following are some of the study's key findings:

- Over the course of a year, there are many seasonal fluctuations in the lake's water quality
- The current study showed that different physicochemical factors, including temperature, pH, dissolved oxygen, and nutrients, have an impact on biological systems. By carefully examining these parameters, it can be deduced that the flip-flop pattern is followed by the values found during the current inquiry. Increased lake water hardness and alkalinity were identified as deciding factors that altered the water quality. It was discovered that dissolved oxygen was a factor that had a favorable effect on water quality. Analka Line Lake was discovered.
- The use of multiple water quality indicators to evaluate seasonal changes in the quality of Lower Lake's surface water clearly demonstrated that the majority of the physicochemical properties are over the allowable limits. The results of many indices showed that the lake's current condition ranged from marginal to fa ir, which is not very attractive. As a result, Lower Lake symbolizes a disturbed ecological situation and declining water quality.
- In addition to normal siltation from its catchment areas, the input of untreated sewage from the nearby human habitats via different Nullah and chaos is the main cause of pollution in Lower Lake.
- •Lower Lake Bhopal's water quality is getting worse, and its nutrient level is concerning. Regular monitoring and preventative measures are needed to keep the lake free from eutrophication. The prohibition of activities that cause pollution is one of the suggested measures to enhance water quality. To preserve the lake's visual value and prevent further deterioration, it is advised that frequent lake monitoring, de-weeding, and desilting be done.

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