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Hydrogeochemical analysis of an urban lake: A case study of Dal Lake, NW Himalaya, India

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Abstract
Urban lakes play a vital role in the ecological and socio-economic fabric of cities, providing numerous benefits to surrounding communities. However, they are often subjected to various anthropogenic pressures, leading to degradation in water quality and ecological health. Dal Lake, situated in the heart of Srinagar city in Jammu and Kashmir, India, is one such urban lake facing numerous challenges due to urbanization, population growth, and tourism activities. This research paper presents a comprehensive hydrogeochemical analysis of Dal Lake to assess its current state in terms of its water quality. Water samples were collected from various locations within the lake and analysed for physicochemical parameters including pH (7.3 to 8.8), EC (120 to 398 µs/cm), TDS (70 to 255 mg/L), Ca^{2+} (22 to 52 mg/L), Mg^{2+} (2.5 to 13 mg/L), TH (67 to 189 mg/L), Na^{+} (0.9 to 6.8 mg/L), K^{+} (0.3 to 3.9 mg/L), HCO_3^{-} (67 to 182 mg/L), Cl^{-} (4 to 28 mg/L), NO_3^{-} (0.2 to 4.6 mg/L), SO_4^{2-} (7 to 32 mg/L) and SiO_2 (0.5 to 6.5 mg/L). The results reveal a complex hydrogeochemical environment within Dal Lake, characterized by spatial and temporal variations in water quality parameters. Furthermore, statistical analysis techniques such as correlation analysis were employed to properly understand the variations in water quality. The concentration of most of the parameters was found higher in Nigeen basin compared to the other three basins which is due to the high residence time of water within Nigeen basin. High levels of nutrients such as nitrogen and phosphorus indicate eutrophication, likely attributed to untreated sewage inflow and agricultural runoff. This research contributes to the understanding of urban lake dynamics and provides valuable insights for policymakers, environmentalists, and stakeholders involved in the conservation and restoration of Dal Lake and similar urban water bodies worldwide.

Keywords: Urban Lake, hydro-geochemistry, water quality, Dal Lake, limnology, pollution, anthropogenic pressures, freshwater

Introduction

Freshwater plays a critical role on Earth, supporting various ecosystems, sustaining life, and serving as a vital resource for human activities (Loucks & van Beek, 2017) [8]. Over the past few decades, the expansion of populations, changes in farming methods and the discharge of sewage from urban regions have significantly multiplied the influx of nutrients compared to their natural levels. This surge has led to a rapid escalation of eutrophication and pollution (Zan *et al*., 2011) [20]. The changing conditions extend to the water resources of Kashmir valley, including its lakes.

A lake can be described as a body of water enclosed by land with no direct connection to the sea (Lehnera and Dolla, 2004) [7]. Urban lakes are vital components of urban ecosystems, serving as reservoirs of biodiversity, recreational areas, and often as sources of drinking water and irrigation. Among these, Dal Lake stands as an emblem of natural beauty intertwined with cultural heritage, nestled in the heart of Srinagar, Kashmir. It holds a pivotal position in shaping the social, cultural, and economic dynamics of the Kashmir Valley (Saleem *et al*., 2015) [12]. The lake used to be among the world's most stunning lakes (Lawrence, 1895). However, today the statement is hardly believable, as the urbanization surrounding Dal Lake has brought forth numerous challenges, altering its hydrogeochemical dynamics and posing threats to its ecological and hydrological integrity (Ganaie & Hashia, 2020) [3]. Human-made influences, such as urbanization, climate shifts, industrial and agricultural pollution, nutrient influxes, sewage release and the invasion of non-native flora and fauna have precipitated swift declines in water quality (Ho & Goethals, 2019) [4].

The impacts are particularly noticeable in developing nations, where swift population expansion, shifts from rural to urban areas and dynamic economic and political changes create significant pressure on land and water resources (Starkl *et al*., 2018; Xu *et al*., 2019) [15, 19].

The hydrogeochemical analysis of Dal Lake holds paramount importance in understanding its current state in terms of its water quality. This research attempts to conduct a comprehensive hydrogeochemical analysis of Dal Lake, delineating the spatial and temporal variations in its water quality parameters. Water quality parameters influenced by human activities include pH, Conductivity, Alkalinity, Nitrate, Silica, Chlorides, Sulphate as well as Calcium, Magnesium, Sodium and Potassium. Exceeding the standards established by the World Health Organization and the Bureau of Indian Standards for most of these parameters could potentially pose health risks (BIS, 1991; McArleton *et al*., 2001; WHO, 2006) [2, 10, 18].

Ultimately, this research endeavours to contribute to the scientific understanding of urban lake ecosystems, with Dal Lake serving as a pertinent case study. We aim to unravel Dal Lake's hydrogeochemical intricacies to inform sustainable management, safeguarding this iconic urban waterbody for future generations.

Study area

Dal Lake, a significant waterbody located in the Kashmir Valley, India. It is a sub-Himalayan, second-largest, freshwater oxbow lake. It has a catchment area of 314 km² and lies between 34°04′ and 34°11′ N to 74°48′ and 74°53′ E at a mean altitude of 1583 m above mean sea level (Fig. 1). The catchment area features rough terrain with significant elevation changes. It comprises multiple drainage basins covering a total area of 23 km², approximately 12 km² of which is dedicated to open water (Trisal, 1987; Jeelani and Shah, 2006; Singh *et al*., 2008) [17, 5, 14].

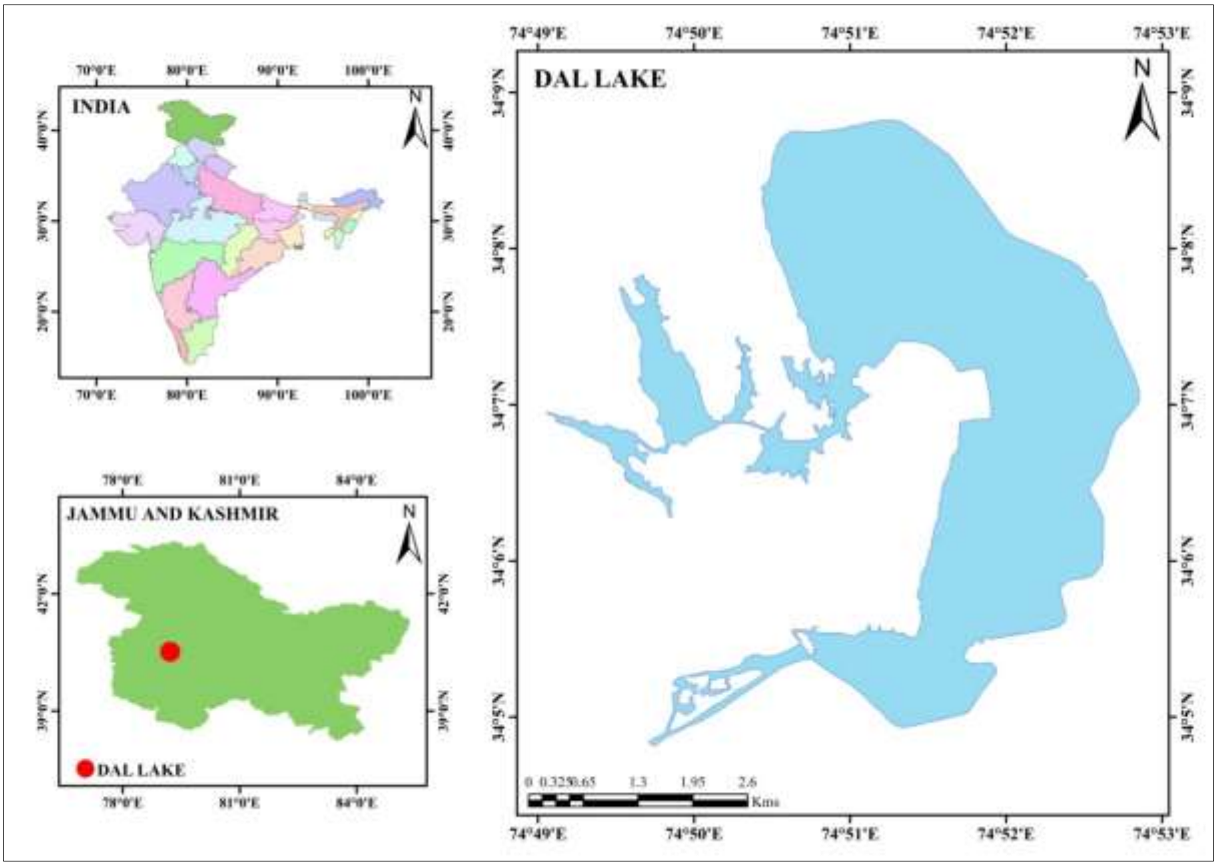
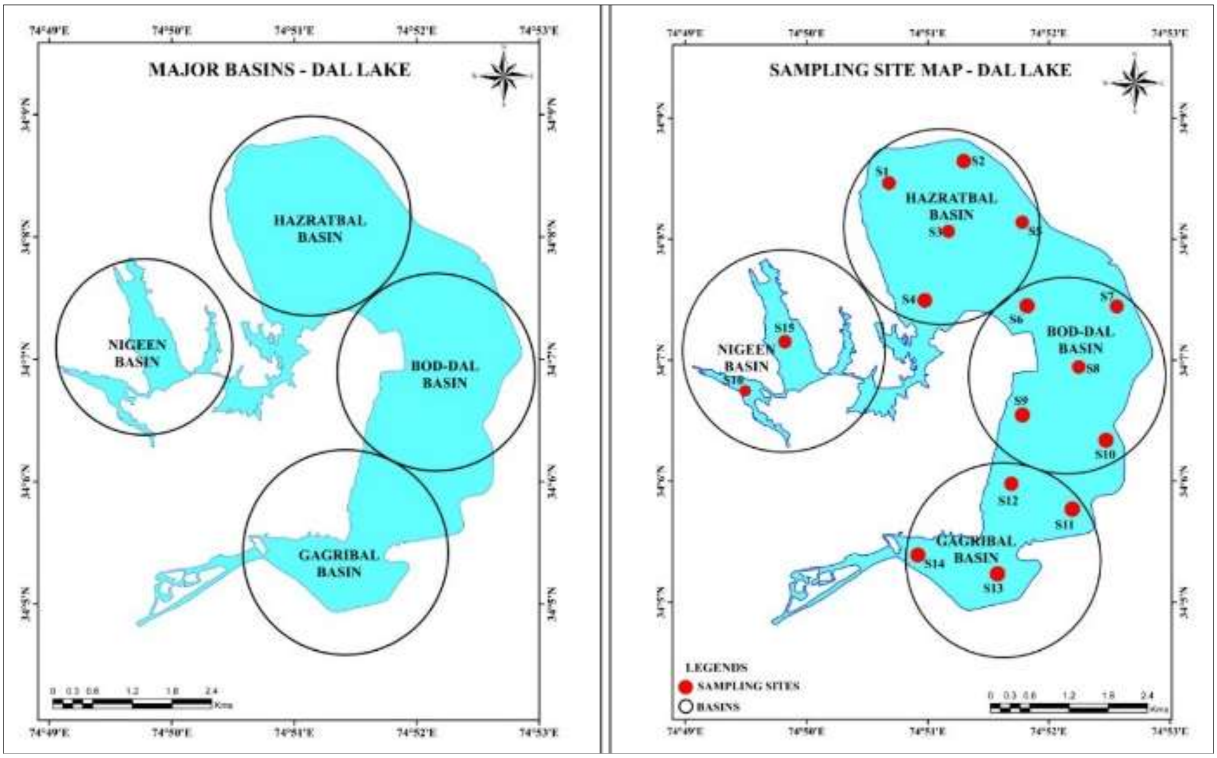


Fig 1: Location Map of the Study Area

Dal Lake, with a water holding capacity of 15.45 million cubic meters (Mm³), has long been regarded as the cradle of civilization in the Kashmir valley, and is affectionately known as the "liquid heart" of Srinagar city (Masoodi & Kundangar, 2018). The lake has been divided into four major sub-basins *viz*., Hazratbal, Bod-Dal, Gagribal and Nigeen basins (Jeelani and Shah, 2006; Saini *et al*., 2008; Saleem *et al*., 2015) [5, 11, 12] (Fig. 2a). The geology of catchment area is dominated by alluvium, agglomerate slates, Triassic limestones and Panjal Traps (Thakur and Rawat, 1992; Jeelani and Shah, 2006) [16, 5]. The lake holds great significance both as a prime tourist spot and as a vital provider of fish, vegetables, and recreation for the local community. Additionally, its waters play a crucial role in supplying water to the city of Srinagar.

Materials and Methods

Surface water samples were collected in one litre prewashed sterile polyethylene plastic bottles from their sampling sites and marked distinctly. A total of 192 water samples were collected from 16 sampling sites within Dal Lake having 5 sites in Hazratbal basin, 5 in Bod Dal basin, 4 in Gagribal basin and 2 in Nigeen basin (Fig. 2b). The sites were selected in such a way so that it will cover the lake entirely. Water samples were collected monthly to conduct the physico-chemical parameters. Following that, samples were promptly transported to analytical laboratory, where subsequent analysis commenced without interruption. The aim of the analysis was to track variations in the chemistry and physical characteristics of Dal Lake water. Physical parameters like pH, Electrical conductivity (EC), and Total dissolved solids (TDS) were measured on field. Parameters for Major ion chemistry like Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-} and SiO_2 were analysed as per the standard methods (APHA 2005). Methods like acid-base titration for alkalinity, EDTA titration for Total Hardness; Mg^{2+} was calculated from total hardness and Ca^{2+}, standard $AgNO_3$ titration for Cl^{-} determination. Flame photometry has been used for Na^{+} and K^{+} determination. SO_4^{2-}, NO_3^{-} and Silica are determined by spectrophotometric method. ArcGIS 10.4.1 software was utilized to create several significant maps.



a) b)

Fig 2a: Showing four major basins of Dal Lake and (2b) showing sampling sites in Dal Lake

Results and Discussion

The analysis and evaluation of water's physico-chemical parameters aimed to comprehend the variations among lake basins. The findings and graphical representation regarding various physico-chemical characteristics of Dal Lake water samples over one year are showcased in (Table 1 / Fig. 3).

pH (Hydrogen ion concentration)

pH represents the concentration of hydrogen ions (H^{+}) in a solution, calculated as the negative logarithm of that concentration in moles per litre (M). In pure water, the molar concentrations of hydrogen and hydroxyl ions are equal. An acidic solution has a pH below 7, while a basic solution has a pH above 7. The pH of lake water tends to be alkaline, typically ranging from 7.3 to 8.8, with an average of 8.1. During November, the pH was observed to be highest in the Bod-Dal basin and lowest in the Nigeen basin in June.

EC (Electrical Conductivity)

The measure of a material's ability to conduct electric charge, known as electrical conductivity, is quantified in Siemens per centimetre (µS/cm). This property serves as a useful indicator for evaluating the trophic status and pollution levels of water bodies (Shastree *et al*., 1991) [13]. In the present investigation, electrical conductivity ranged from 120 to 398 µs cm^{-1}, with an average of 241 µs cm^{-1}. Notably, the highest recorded value was observed in the Nigeen basin during March, while the lowest occurred in the Hazratbal basin in August.

TDS (Total dissolved solids)

TDS represents the collective concentration of inorganic and organic substances within a liquid, encompassing molecular, ionized, or micro-granular (colloidal sol) suspended forms. Predominantly, TDS comprises bicarbonates, sulphates, chlorides, calcium, magnesium, sodium, and silica serving as an important indicator of water quality. Elevated TDS levels can detrimentally impact water's taste, odour and appearance, serving as a potential indicator for the presence of hazardous contaminants or pollutants, thereby posing health risks. In the current investigation, TDS ranged from 70 to 255 mg/L, with an average of 158 mg/L. Notably, the highest TDS value was recorded in the Nigeen basin during March, while the lowest was observed in the Bod-Dal basin in December.

Calcium

Calcium is the fifth most abundant element in the earth's crust. Calcium in nature is primarily derived from the minerals. When referring to "calcium in water," it typically pertains to the concentration of calcium ions (Ca^{2+}) dissolved in the water. The level of water hardness primarily hinges on the presence of calcium within it. In this recent investigation, calcium concentrations fluctuated between 22 and 52 mg/L, with an average of 37 mg/L. The peak calcium content was observed in the Nigeen basin in January, while the lowest was recorded in the Gagribal basin in September.

Magnesium
Magnesium in water refers to the presence and concentration of magnesium ions (Mg^{2+}) dissolved in the water. The concentration of magnesium in water can vary depending on factors such as the geological composition of the area, the presence of magnesium-rich minerals in the soil and rocks, and human activities. Alongside calcium, magnesium is a primary contributor to water hardness. In present study the values ranged between 2.5 to 13 mg/L with an average of 7 mg/L. The highest value was found in Nigeen basin during October and lowest in Bod-Dal basin during the month of March and April.

Total Hardness
Total hardness refers to the concentration of dissolved calcium and magnesium ions present in water. These ions are the primary contributors to water hardness, which is a measure of the water's capacity to precipitate soap and form scale. Hard water can cause scaling in pipes and appliances, decrease the effectiveness of soap and detergents and leave residue on fixtures and dishes. Total hardness is an important parameter in assessing water quality, as it can affect various industrial processes, household activities, and the health of aquatic ecosystems. The values ranged from 67 to 189 mg/L, with an average of 120 mg/L. The highest value was found in Nigeen basin during March and lowest in Hazratbal basin during the month of February.

Sodium
Sodium is one of the most important naturally occurring mineral. Sodium is typically refers to the concentration of sodium ions (Na^+) dissolved in the water. Sodium can enter water sources through the weathering of rocks and minerals, particularly those rich in sodium-containing compounds like halite (rock salt) or soda ash. Sewage and industrial effluents also adds this cation to water sources. Elevated levels of sodium in drinking water can affect its taste and palatability. During current study, the concentration of Na^+ ranged from 0.9 to 6.8 mg/L, with an average of 2.2 mg/L. The highest value was found in Hazratbal basin during February and lowest in Gagribal basin during the month of April and May.

Potassium
Potassium is also an important naturally occurring mineral which is found in low concentrations in natural waters since rocks which contain potassium are more resistant to weathering. In agricultural practices and in industries salts of potassium are widely used which then enters freshwaters directly or indirectly. Throughout our investigation, potassium concentrations varied from 0.3 to 3.9 mg/L, with an average of 1.1 mg/L. The peak concentration occurred in the Hazratbal basin in February, while the lowest was recorded in the Gagribal basin in July.

Bicarbonates
Bicarbonates, also known as hydrogen carbonates, are chemical compounds containing the bicarbonate ion (HCO_3^-). Bicarbonate ions are formed when carbon dioxide (CO_2) dissolves in water, reacting with water to form carbonic acid (H_2CO_3), which then dissociates into bicarbonate ions (HCO_3^-) and hydrogen ions (H^+). It assesses the collective alkalinity within an aquatic environment and is utilized to differentiate between soft and hard water ecosystems. Monitoring bicarbonate levels in surface water is important for assessing water quality and understanding the environmental impacts of human activities such as agriculture, industrial runoff and urbanization, which can affect bicarbonate concentrations and alter the chemistry of waterbody. In the present analysis bicarbonates in Dal lake water ranged from 67 to 182 mg/L, with an average of 99 mg/L. The highest value was found in Nigeen basin during February and lowest in Bod-Dal basin during the month of November.

Chloride
Chlorides in surface water refer to the presence of chloride ions (Cl^-) dissolved in water bodies. Chlorides are naturally occurring ions and are commonly found in water due to the dissolution of salts containing chloride compounds like sodium chloride, potassium chloride, and calcium chloride. It is regarded as an indication of organic load from the catchment area. Monitoring and managing chloride levels in surface water are important for ensuring the health of ecosystems and human populations that rely on these water sources. During current study, it ranged from 4 to 28 mg/L, with an average of 15 mg/L. The highest value was found in Nigeen basin during January and lowest in Gagribal basin during the month of June.

Nitrate
Nitrates are chemical compounds composed of nitrogen and oxygen (NO_3^-) which primarily originate from agricultural runoff, industrial discharges, sewage, and atmospheric deposition. They are often found in surface water as a result of fertilizers, animal waste, and wastewater treatment effluents. Excessive levels of nitrates in surface water can lead to water pollution and pose serious environmental and health risks. When nitrates accumulate beyond certain thresholds, they can contribute to eutrophication of Lake. During current study, the concentration ranged from 0.2 to 4.6 mg/L, with an average of 1.15 mg/L. The highest value was found in Nigeen basin during November and December and lowest in Hazratbal basin during the month of February.

Sulphate: Sulphates in surface water refer to chemical compounds containing the sulphate ion (SO_4^{2-}). These compounds can originate from various natural such as the weathering of rocks containing sulphide minerals, oxidation of organic matter and anthropogenic Sources such as industrial processes, mining, agriculture (especially through the use of fertilizers containing sulphates) and wastewater discharges can introduce sulphates into surface water. Sulphates are water-soluble and can remain dissolved in water for extended periods. However, high concentrations of sulphates in surface water can have environmental implications like Eutrophication, Acidification and Health Concerns particularly gastrointestinal issues. During current study, the concentration of SO_4^{2-} ranged from 7 to 32 mg/L, with an average of 18 mg/L. The highest value was found in Hazratbal basin during December and lowest in Gagribal basin during the month of February.

Silica: Silicon dioxide commonly known as silica represents the presence of dissolved or suspended SiO_2 particles in the water. Silica can be naturally occurring, originating from the weathering of rocks and soils, or it can be introduced into water bodies through various human activities such as industrial processes, agriculture and wastewater discharges. Elevated levels of silica can indicate pollution which can impact water quality and biodiversity. In present study, it ranged from 0.5 to 6.5 mg/L, with an average of 2.21 mg/L. The highest value was found in Nigeen basin during July and September while lowest in Hazratbal basin during the month of December and January.

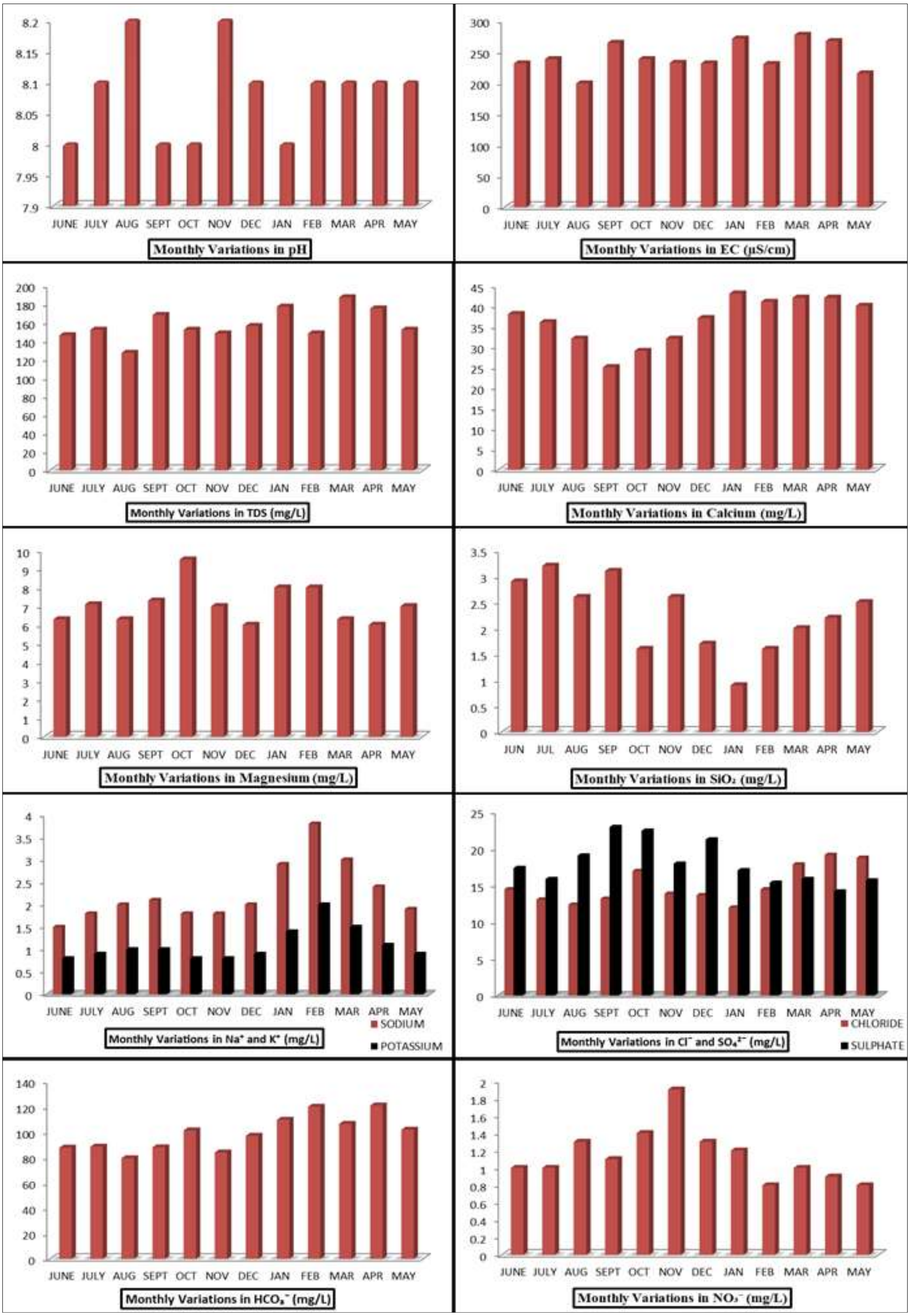


Fig 3: Showing monthly variations in different physico-chemical parameters in Dal Lake

Table 1: The minimum and maximum values of Physico-chemical parameters of Dal Lake

Parameters		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
pH	Min	7.3	7.5	7.6	7.8	7.9	7.9	7.6	7.5	7.7	7.9	7.8	7.6
	Max	8.4	8.5	8.5	8.3	8.3	8.8	8.6	8.4	8.4	8.4	8.3	8.5
	Avg	8.0	8.0	8.1	8.0	8.0	8.2	8.1	7.9	8.1	8.1	8.1	8.1
	SD	0.3	0.3	0.3	0.2	0.1	0.2	0.3	0.2	0.2	0.1	0.2	0.2
EC µS/cm	Min	175	166	120	178	155	140	132	189	144	187	180	139
	Max	309	288	290	350	335	310	360	366	310	398	361	309
	Avg	231	238	199	264	238	232	231	272	230	278	267	216
	SD	40	39	56	69	60	62	69	62	52	55	59	50
TDS mg/L	Min	116	106	77	114	99	83	70	121	92	113	115	77
	Max	198	184	186	224	214	198	237	234	198	255	241	224
	Avg	147	152	128	169	153	148	157	177	148	188	175	153
	SD	23	25	36	44	38	40	57	40	34	48	41	47
Ca^{2+} mg/L	Min	30	27	24	22	23	26	30	35	36	36	37	35
	Max	45	48	47	32	37	36	46	52	50	50	51	48
	Avg	38.2	36.8	32.9	25.9	29.1	32.1	37.2	43.2	41.6	42.9	42.4	40.6
	SD	5.2	6.9	7.6	3.1	3.9	3.2	4.9	4.7	4.1	3.7	4.2	3.1
Mg^{2+} mg/L	Min	4.0	4.5	4.0	4.8	6.0	4.0	3.0	4.5	5.0	2.5	2.5	4.2
	Max	8.8	9.3	8.0	12.0	13.0	9.0	8.5	12.2	14.0	10.8	10.0	10.1
	Avg	6.3	7.2	6.3	7.3	9.5	6.9	5.9	7.6	7.6	6.4	6.0	7.1
	SD	1.5	1.5	1.1	2.2	2.2	1.5	1.7	2.4	2.6	2.8	2.4	1.8
TH mg/L	Min	98	96	84	82	82	81	87	76	67	82	103	102
	Max	147	149	150	109	126	127	150	180	179	189	167	158
	Avg	121.4	121.2	107.9	95.0	111.7	108.1	117.1	135.1	130.3	130.2	130.5	130.3
	SD	14.4	19.1	21.2	7.5	13.8	10.7	17.1	25.5	24.7	25.2	18.6	14.8
Na^{+} mg/L	Min	1.0	10	1.5	1.6	1.3	1.2	1.0	1.3	1.9	1.4	0.9	0.9
	Max	2.2	2.6	2.6	2.7	2.5	3.0	4.1	5.3	6.8	5.6	4.0	2.8
	Avg	1.5	1.7	2.1	2.1	1.7	1.7	1.9	2.8	3.7	3.0	2.4	1.8
	SD	0.4	0.5	0.3	0.3	0.3	0.5	0.9	1.1	1.4	1.8	0.9	0.6
K^{+} mg/L	Min	0.5	0.3	0.4	0.5	0.5	0.4	0.4	0.8	1.0	0.6	0.4	0.4
	Max	1.2	1.4	1.4	1.5	1.3	1.6	2.1	3.2	3.9	3.3	2.0	1.4
	Avg	0.8	0.9	0.9	1.0	0.8	0.7	0.9	1.4	1.9	1.6	1.1	0.9
	SD	0.2	0.3	0.3	0.3	0.2	0.4	0.5	0.6	0.8	0.8	0.5	0.3
HCO_3^- mg/L	Min	80	72	70	80	86	67	79	94	98	92	103	91.7
	Max	110	115	100	120	151	132	145	160	182	156	173	135
	Avg	87.6	88.5	79.4	88.0	101.4	83.8	97.1	109.6	120.0	106.6	121.0	101.8
	SD	8.2	11.7	8.8	11.8	20.1	19.6	19.5	21.3	25.8	19.3	21.7	12.7
Cl^- mg/L	Min	4	5	8	9	10	11	8	7	10	14	15	11
	Max	22	18	17	16	23	18	25	28	26	25	27	26
	Avg	14.5	13.1	12.4	13.2	17.1	13.8	13.7	12.0	14.5	17.8	19.	18.7
	SD	5.4	3.5	2.8	1.9	3.7	2.2	4.5	5.8	4.1	2.9	2.8	4.2
NO_3^- mg/L	Min	0.7	0.6	0.8	0.9	1.0	1.0	0.5	0.5	0.2	0.4	0.5	0.7
	Max	1.3	1.5	2.2	2.7	3.5	4.6	4.6	3.4	2.2	1.6	1.2	1.1
	Avg	0.9	1.0	1.3	1.2	1.5	1.8	1.4	1.3	0.8	0.9	0.8	0.8
	SD	0.17	0.26	0.36	0.57	0.76	1.10	1.28	0.84	0.57	0.33	0.22	0.11
SO_4^{2-} mg/L	Min	10	9	11	18	16	12	13	10.5	7	9.3	8	10
	Max	25	22	26	31	30	25	32	24.5	24	21	19	21
	Avg	17.43	15.81	19.18	23	22.5	17.92	21.33	17.13	15.4	15.89	14.23	15.66
	SD	4.81	4.44	4.43	4.24	4.51	4.29	6.22	4.80	5.46	3.82	3.43	3.99
SiO_2 mg/L	Min	2	1.9	1.5	1.5	0.6	1.3	0.5	0.5	0.8	1.2	1.5	1.5
	Max	5.5	6.5	6	6.5	3.7	5.9	3	2.5	3.8	4.2	4	4.8
	Avg	2.90	3.21	2.59	3.12	1.58	2.62	1.16	0.90	1.6	2.05	2.25	2.53
	SD	1.11	1.49	1.34	1.47	0.94	1.44	0.79	0.64	0.91	0.91	0.75	1.02

Statistical analysis

Pearson Correlation coefficients were calculated to obtain relations between the variables (Table 2). The SiO_2 showed positively significant correlation with NO_3^- (r=0.972), TDS (r=0.991) and negatively significant correlation with pH (r=-0.970). NO_3^- was found positively significant correlated with TDS (r=0.995) and EC (r=0.995). HCO_3^- is positively significant correlated with Total Hardness (r=0.969) and K^+ shows a strong positively significant correlation with Na^+ (r=0.999). Total Hardness showed positively significant correlation with Mg^{2+} (r=0.982) and Ca^{2+} (r=0.959). Mg^{2+} is found negatively significant correlated with pH (r=-0.958) and TDS is found positively significant correlated with EC (r=0.981).

Table 2: Matrix showing Pearson Correlation coefficients among observed variables across sixteen sampling locations within Dal Lake

	SiO_2	SO_4^{2-}	NO_3^-	Cl^-	HCO_3^-	K^+	Na^+	TH	Mg^{2+}	Ca^{2+}	TDS	EC	pH
SiO_2	1												
SO_4^{2-}	-.073	1											
NO_3^-	.972*	.030	1										
Cl^-	.720	.608	.811	1									
HCO_3^-	.914	.336	.939	.935	1								
K^+	-.641	.796	-.580	.004	-.289	1							
Na^+	-.617	.821	-.546	.046	-.255	.999**	1						
TH	.854	.423	.841	.900	.969*	-.152	-.125	1					
Mg^{2+}	.891	.277	.838	.807	.939	-.267	-.247	.982*	1				
Ca^{2+}	.678	.663	.695	.926	.900	.129	.159	.959*	.900	1			
TDS	.991**	-.025	.995**	.771	.931	-.619	-.589	.847	.863	.685	1		
EC	.947	.025	.995**	.808	.918	-.584	-.547	.799	.785	.657	.981*	1	
pH	-.970*	.000	-.902	-.698	-.905	.532	.515	-.906	-.958*	-.749	-.937	-.855	1

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

Conclusion

Based on the present findings, it is determined that the primary causes behind the decline in water quality in Dal Lake include heightened nutrient levels stemming from excessive use of fertilizers and pesticides in the catchment area, unplanned urban development, and encroachment in the vicinity of Dal Lake. Hydrogeochemical analysis indicates that the water of Dal Lake typically exhibits alkaline nature with moderate electrical conductivity. The concentration of most of the parameters like EC, TDS, TH, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, NO_3^- and SiO_2 was found higher in Nigeen basin compared to the other three basins which is due to the high residence time of water within that basin. The presence of domestic, agricultural, and other commercial activities around Dal Lake, such as houseboats and hotels, directly impacts its water quality. Consequently, chemical parameters tend to register higher levels near sewage treatment plants (STPs), sewage pipelines, and drains from houseboats and hotels. The higher values of nutrients particularly NO_3^- obtained in the study indicates nutrient enrichment leading to eutrophication of lake, which is due to anthropogenic activities, untreated sewage and solid disposal of wastes from its catchment areas which has led to the degradation of water quality. It is recommended to periodically monitor the water quality of lake and installation of more STP's so that waste water will get discharged into the lake after its proper treatment.

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