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Assessment of Water Quality of Tingdil Lake in Aizawl District, Mizoram, North-East India Using Canadian Council of Ministers of the Environment (CCME) Water Quality Index

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Abstract:

Tingdil Lake is an artificial freshwater wetland located in Aizawl District, Mizoram, northeast India (24°19′04″ N, 92°59′18″ E). This study assessed the seasonal water quality of the lake using the Canadian Council of Ministers of the Environment (CCME) Water Quality Index. Water samples were collected from five stations across three seasons - pre-monsoon, monsoon, and post-monsoon, during 2024. Thirteen physicochemical parameters were analysed following standard APHA protocols. Pearson correlation analysis revealed strong positive associations among electrical conductivity, total dissolved solids, and turbidity (r = 0.90-0.93), indicating monsoon-driven runoff as a dominant influence on water quality. CCME WQI scores ranged from 59.89 to 78.38 across stations. Station 1 (Inlet) was classified as "Fair" (WQI = 78.38), while Stations 2-5 were categorised as "Marginal" (WQI = 59.89-61.51). Turbidity was the primary parameter exceeding BIS permissible limits across all seasons. These findings highlight considerable spatial and temporal variability in Tingdil Lake water quality and underscore the need for regular monitoring and targeted management interventions.

Keywords: CCME Water Quality Index, Tingdil Lake, Physicochemical parameters, Mizoram, Freshwater wetland, Water quality assessment

1. **Introduction**:

Lakes are enclosed water bodies with unique physical, chemical, and biological traits, thereby serving as critical systems for investigating ecosystem interactions between land, water, and air (Bhateria & Jain, 2016). Lakes in Mizoram are locally referred to as "Dil," and only a small number of these exist across the region, most of which are small waterbodies or marshy depressions (Lalmuansangi & Lalramnghinglova, 2014). Although Mizoram hosts only a small number of lakes, the only existing scientific document related to water quality are the investigations on Tamdil and Palak Dil, apart from these the Mizoram Pollution Control Board (MPCB) also monitors the water quality of several wetlands, including Rungdil, Rengdil, Tamdil, and Palak Dil, under the National Water Monitoring Programme (NWMP) (MPCB, 2025). Such MCB data, however, is often raw and too technical to be used by non-specialists, stakeholders and policy planners to interpret or to translate into meaningful insights. The use of the Water Quality Index (WQl) methodology provides a useful way to simplify and interpret complex water quality data, and a way to fill gaps in current literature given a lack of water quality research in the lakes.

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The degradation of surface water quality is a large risk to aquatic ecosystems, deteriorates groundwater quality and therefore poses a threat to human health (Wats et al., 2019). Water quality indices (WQIs) are important tools used to provide a synthesis of the many, technical, water quality data in a comprehensible format. These science-based tools enable the reduction of multi-parameter water quality data sets to a single dimensionless number as an overall water quality status (Banda & Kumarasamy, 2020). Different WQI models like the NSF-WQI, CCME-WQI, WAWQI etc., provide flexibility regarding the implementation of water quality assessment models that enable the application of proper methodology based on regional standards, monitoring purposes and parameters available, improving the applicability of water quality assessment models around the world (Chidiac et al., 2023). The application and value of WQIs for evaluating lake water quality has been extensively documented in scientific literature across global contexts (Bati et al., 2022; Ball & Church, 1980; Goher et al., 2014; Kurker & Mutlu, 2019; Trikoilidou et al., 2017; Wang et al., 2019; Wu et al., 2017). Therefore, this study assessed the seasonal water quality of Tingdil Lake using the CCME Water Quality Index to identify spatial and temporal variations in physicochemical conditions.

2. Materials and Methods

2.1 Study Area and Sampling sites:

The study site, Tingdil, comprises an artificial freshwater wetland in Mizoram's Aizawl District. Spatial coordinates identify the location as 24°19′04″ N latitude and 92°59′18″ E longitude, at an elevation of 787 meters above sea level. Covering about 2.52 hectares, Tingdil functions as a relatively small freshwater wetland of notable ecological significance.

Fig 1: Map depicting the study site location

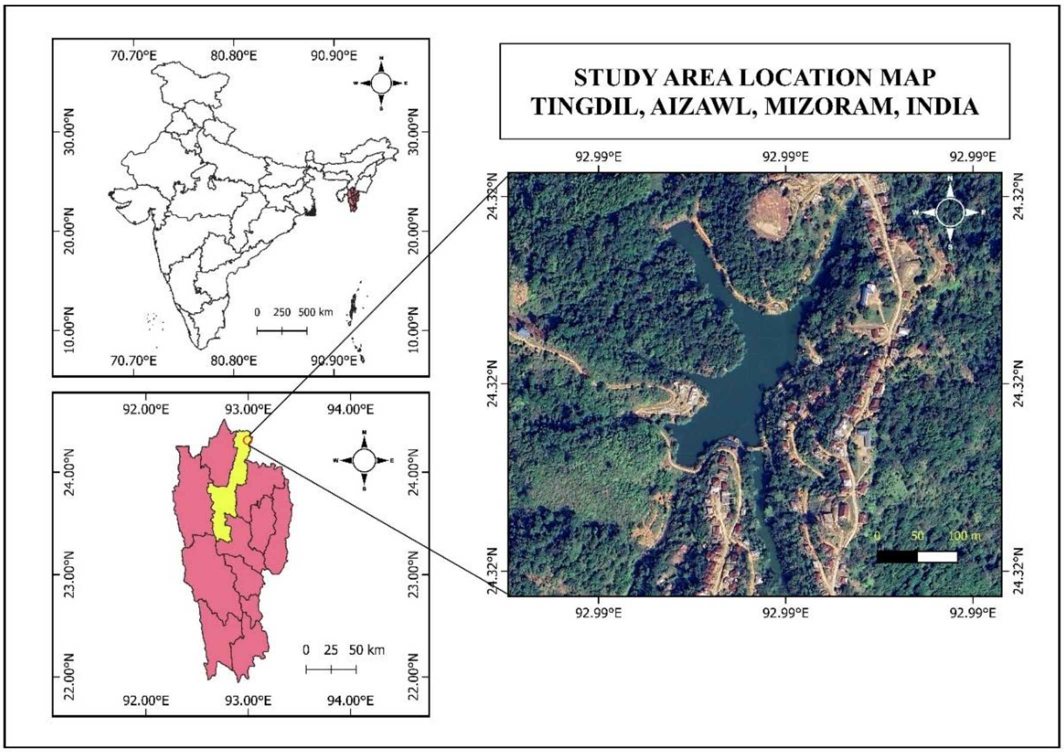


Table 1: Name of sampling sites

Location	Denotation number	Latitude	Longitude

Inlet	S1	24°19'5.71"N	92°59'13.78"E
Outlet	S2	24°19'0.85"N	92°59'16.32"E
Middle	S3	24°19'4.21"N	92°59'18.54"E
Undisturbed	S4	24°19'9.63"N	92°59'16.71"E
Settlement	S5	24°19'1.71"N	92°59'19.15"E

2.2 Methods:

Seasonal monitoring of water quality was undertaken throughout 2024, with samples obtained from five designated locations (as shown in Table 1) during three distinct periods: pre-monsoon, monsoon, and post-monsoon seasons. The study examined 13 physicochemical variables to characterize water quality (Table 1). Field instruments were employed to measure pH, temperature, turbidity at each sampling site. Additional parameters like electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), total hardness (TH), total alkalinity (TAK), total acidity (TA), chloride (Cl^-), total nitrogen (TN) and nitrate (NO_3^-) were quantified through laboratory analysis using established protocols (APHA, 2005; Maiti, 2001, Trivedy & Goel, 1984).

Table 2: Methods for physicochemical analysis of water samples

Parameters	Abbreviation	Units	Methods	BIS Standards
pH	-	-	In-situ measurement	6.5-8.5
Temperature	T	°C	In-situ measurement	-
Electrical Conductivity	EC	µS/cm	EC Meter	300
Turbidity	-	NTU	In-situ measurement	5
Total Dissolved Solids	TDS	mg/L	Gravimetric Method	500
Dissolved Oxygen	DO	mg/L	Winkler Method	5
Biological Oxygen Demand	BOD	mg/L	5-Day BOD Method	5
Chloride	Cl	mg/L	Argentometric method	250
Total Acidity	TA	mg/L	Titrimetric Method	-
Total Alkalinity	TAK	mg/L	Titrimetric Method	200
Total Hardness	TH	mg/L	EDTA Titrimetric Method	200
Total Nitrogen	TN	mg/L	Kjeldahl Method	-
Nitrate	NO^-_3	mg/L	UV Spectrophotometric Method	45

2.3 CCME Water Quality Index:

The CCME Water Quality Index was developed to simplify complex water quality data and present it in an easy-to-understand format for the public. It evaluates the frequency and magnitude of guideline exceedances to provide a clear indicator of overall water quality (Canadian Council of Ministers of the Environment, 2017).

The index combines three factors: scope, frequency, and amplitude, to produce a single number that represents overall water quality at a glance. The following factors are defined as follows:

Factor 1 (F_1 - Scope): It represents the extent to which measured variables exceed or fall short of their target values, expressed as a percentage. Figure 3 illustrates this graphically, and the mathematical formulation is expressed as:

$$F_1 = \frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables} \times 100$$

Factor 2 (F_2 - Frequency): It denotes the proportion of individual tests exceeding guideline values, expressed as a percentage. Figure 4 provides a graphical representation of this component, while the mathematical formulation is expressed as:

$$F_2 = \frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests} \times 100$$

Factor 3 (F_3 - Amplitude): It measures the extent to which water quality parameters that exceeded guidelines deviate from their target values. The calculation procedure consists of three steps:

Step 1: Excursion calculation forms the first computational step. This metric measures how much each parameter value differs from its respective objective, either exceeding or falling below it. For situations where test values should not exceed objectives, the following formula applies:

$$Excursion = \frac{Failed\ test\ value}{Objective} - 1$$

For the cases in which the test value must not fall below the objective

$$Excursion = \frac{Objective}{Failed\ test\ value} - 1$$

Step 2: To quantify the overall extent of deviation from objectives, all individual excursion values are summed and divided by the total number of tests performed, regardless of whether they met their objectives. This value, designated as the normalized sum of excursions (nse), is computed as:

$$NSE = \frac{\sum_{i=1}^{n} excursion}{Total\ number\ of\ tests}$$

Step 3: The third factor (F_3) is calculated using an asymptotic function that scales nse values to generate a dimensionless value within the 0 to 100 range.

$$F_3 = \frac{nse}{0.01nse + 0.01}$$

After determining the three factors, the final index value is computed by treating them as vectors. The sum of the squared values of each factor equals the square of the index. This method represents the index in three-dimensional space, with each factor positioned along a separate axis. Under this framework, any change in the three factors results in a proportional change in the index value.

The CCME WQI is finally calculated as:

$$CCME\ WQI = 100 - \left[\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}\right]$$

The normalization factor of 1.732 ensures that the final index values fall between 0 and 100, where lower values (approaching 0) correspond to degraded water quality and higher values (approaching 100) correspond to superior water quality.

Table 3: CCME WQI based water quality characterization

CCME WQI	Ranking	Water quality Characteristics
95-100	Excellent	Water quality is safeguarded with negligible threats or impairment; conditions close to natural or undisturbed levels.
80-94	Good	Water quality protection is maintained with limited degree of stress or compromise; environmental conditions rarely stray from natural or optimal states.
65-79	Fair	Water quality is generally safeguarded but periodically threatened or impaired; conditions occasionally deviate from natural or desirable levels.
45-64	Marginal	Water quality is regularly threatened or impaired; conditions frequently deviate from natural or desirable levels.
0-44	Poor	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

Table 4: Computed CCME Water Quality Index for water samples from Tingdil Lake, Mizoram

CCME WQI Elements	Station 1	Station 2	Station 3	Station 4	Station 5
Number of failed variables	3	2	3	2	3
Total number of variables studied	13	13	13	13	13
Total number of tests	39	39	39	39	39
Total number of failed tests	7	6	7	6	7
Excursion	11.92	12.84	17.32	18.04	15.72
Nse	0.3056	0.3292	0.4441	0.4625	0.403
F1	23.07	15.38	23.07	15.38	23.07

F2	17.94	15.38	23.07	15.38	17.94
F3	23.40	24.76	30.75	31.62	28.72
CCME WQI	78.38	61.51	59.89	61.51	59.89
Category	Fair	Marginal	Marginal	Marginal	Marginal

3. **Results**:

3.1 **Seasonal Descriptive Statistics of Physicochemical Parameters**

The physicochemical parameters of Tingdil Lake exhibited distinct seasonal and spatial variations across the three sampling seasons (Table 5). Descriptive statistics including mean, standard deviation, minimum, and maximum values for all 13 parameters across five stations are summarised in Table 5, with seasonal distributions illustrated in Fig. 5.

The descriptive statistics indicated that seasonal differences were most evident in turbidity, dissolved oxygen, and biochemical oxygen demand. Turbidity was highest during the monsoon period, reflecting enhanced surface runoff and sediment input, whereas DO remain above the recommended minimum throughout the study period. BOD was lowest in the monsoon and higher in the pre-monsoon season, suggesting increased organic stress during the dry months.

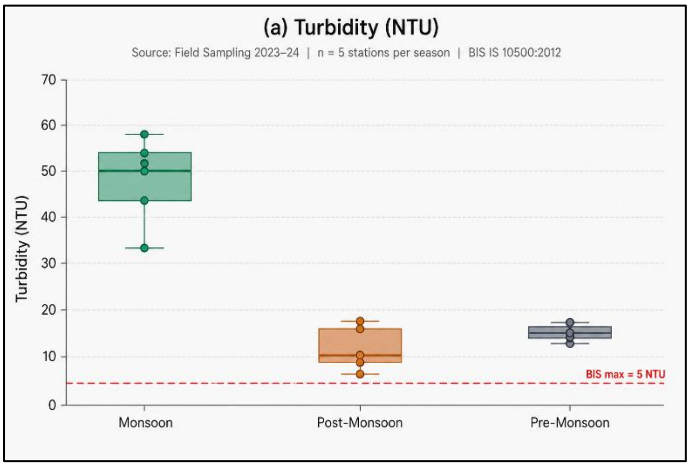
Table 5. Seasonal descriptive statistics (mean, SD, minimum, and maximum) of 13 physicochemical parameters in Tingdil Lake water.

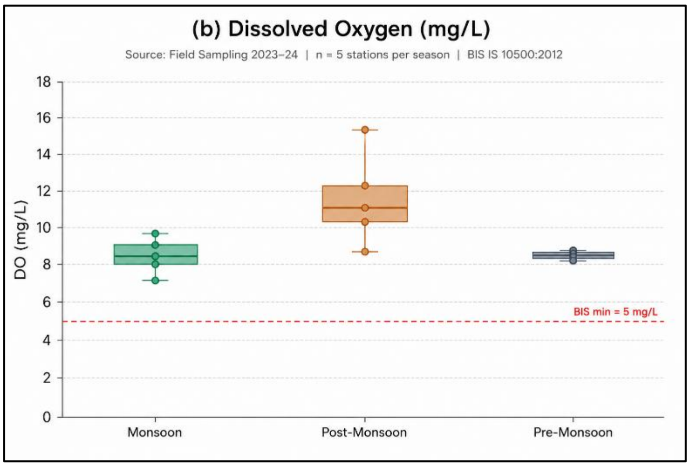
Parameters	Unit	Monsoon				Post monsoon				Pre-monsoon			
		Mean	Min	Max	Std. deviation	Mean	Min	Max	Std. deviation	Mean	Min	Max	Std. deviation
Temp	°C	26.4	26	27	0.548	23	21	25	1.581	34.2	33	37	1.643
Turbidity	NTU	47.4	33	58	9.915	12.6	8	18	4.615	16.4	15	18	1.342
TDS	mg/L	43.8	36	49	5.541	18.2	16	20	1.643	24	22	26	1.581
EC	μS/cm	47	41	52	4.528	27.6	21	36	5.505	34	31	37	2.828
pH		6.52	6.3	6.7	0.179	6.67	6.51	6.87	0.142	6.702	6.64	6.77	0.058
Nitrate	mg/L	5.398	3.9	7	1.145	3.94	3.2	3.5	0.91	3.2	2.8	3.8	0.406
Total nitrogen	mg/L	2.276	1.12	3.36	0.716	3.404	2.8	4.6	0.716	2.66	1.8	3.4	0.623
Total Hardness	mg/L	38.4	24	60	13.37	14	10	18	3.162	18.8	4	28	9.757
Total alkalinity	mg/L	26.8	24	30	2.28	33.6	32	38	2.608	30.4	24	44	7.925
Total acidity	mg/L	19.6	10	32	8.414	20.8	12	36	9.654	20	14	30	6.325
Chloride	mg/L	5	3	7	1.581	14.8	14	17	1.304	14.6	12	17	1.817
BOD	mg/L	1.32	1	2	0.415	3.04	0.8	7.4	2.531	5	4.6	5.4	0.4
DO	mg/L	8.56	7.2	9.8	1.014	11.4	8.8	15.4	2.429	8.84	8.6	9	0.219

Min= Minimum; Max= Maximum; Std. deviation= Standard Deviation

3.2 Boxplot Analysis of Seasonal Variation

The seasonal variation in the key parameters is further illustrated in the boxplots shown in Fig. 2.





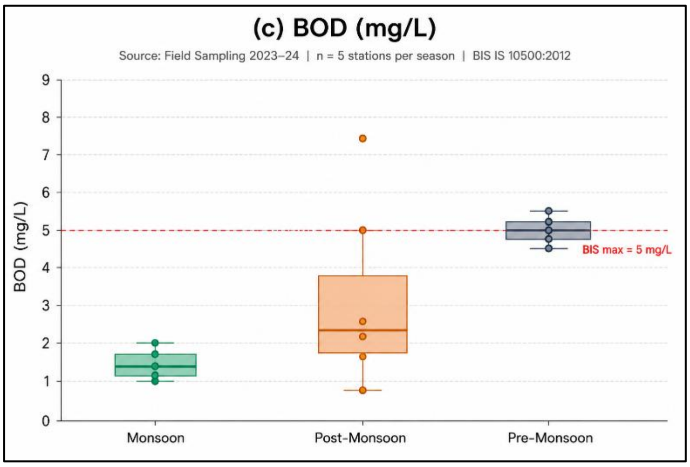


Fig. 2. Seasonal variation of (a) Turbidity, (b) Dissolved Oxygen, and (c) Biochemical Oxygen Demand across five sampling stations in Tingdil Lake (2023-24). Boxes represent the

interquartile range, horizontal line indicates the median, whiskers extend to the full range, and individual points denote station values. Red dashed line indicates the BIS IS 10500:2012 permissible limit.

Significant differences in turbidity, dissolved oxygen and biochemical oxygen demand were found between seasons in boxplots. The turbidity was found to be maximum during monsoon season and was found to be more than BIS limit during monsoon as well as during other seasons of the study period, dose of oxygen is found to be more than the BIS limit throughout the study period. BOD exhibited low monsoon values and showed an increasing trend towards pre-monsoon while one high value was observed over the post monsoon season, suggesting station level variation. In general, the box plots show that the water quality of Tingdil Lake was significantly affected by the seasonal variations.

3.3 Pearson Correlation Analysis

To further examine the interrelationships among the physicochemical parameters of Tingdil Lake, Pearson correlation analysis was performed at a significance level of 0.05, and the results are presented in Fig 3.

There were strong relationships between various physicochemical parameters of Tingdil Lake, as indicated by pearson correlation analysis. The strengths of the relationship among the three variables were high (0.90–0.93) indicating a common effect of the runoff induced dissolved and suspended materials. TH was also found to have positive correlation with EC, TDS and turbidity with good to high negative correlation with these parameters. The correlation of the DO with most of the parameters was weak to moderate and was positively correlated with pH and chloride concentration while BOD was positively correlated with pH concentration. The heatmap indicates that these three factors (seasonal runoff, mineralization, and organic inputs) are all important to the water quality of the lake.

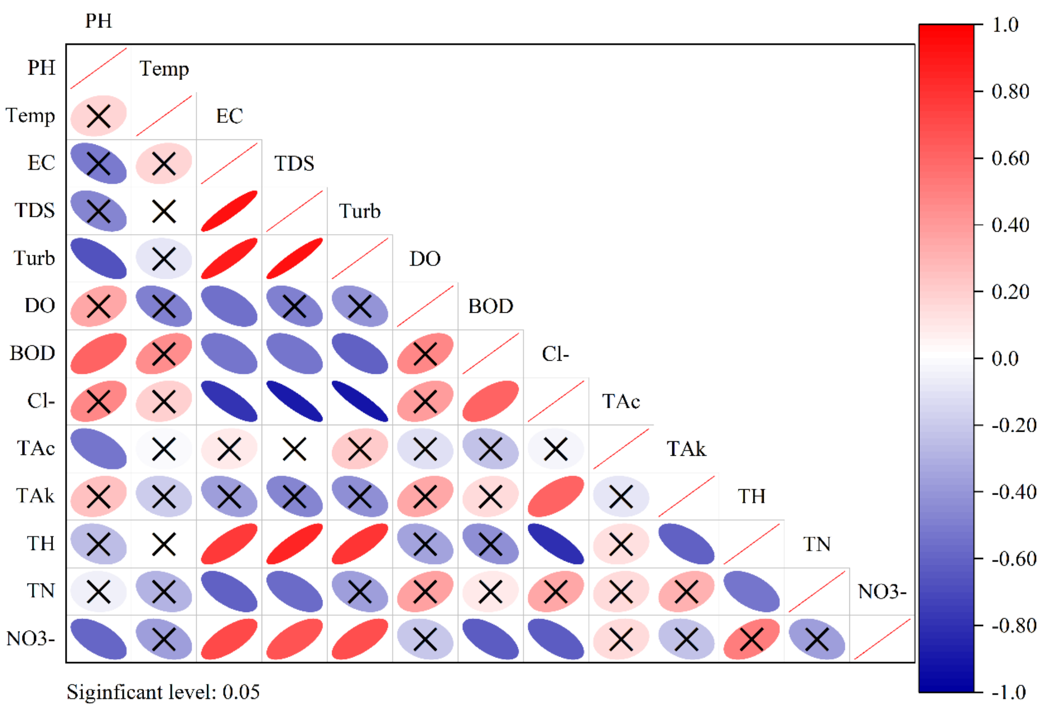


Fig 3: Pearson correlation matrix of physicochemical parameters of Tingdil Lake water samples. Values represent Pearson’s correlation coefficients (r); red indicates positive

correlations and blue indicates negative correlations. X denotes non-significant correlations ($p > 0.05$). Significance level: 0.05.

3.4 Parameter-wise Discussion of Water Quality

pH: All the pH measured five stations were spatially and temporally varied in the range of 5.35 to 6.77. The pH was lower in all the seasons of Station 1 (Inlet) ranging from 5.35 to 6.87, which suggests slightly acid condition, while in Station 2 (Outlet), the pH was comparatively higher (6.4-6.77) during the post-monsoon and monsoon seasons respectively. The pH values at Station 3 (Middle) and Station 5 (Settlement) were found to be in the near neutral range of 6.4-6.7. The recorded pH levels were within the BIS acceptable range of 6.5-8.5, however some of the stations indicated slightly acidic pH trends especially in pre-monsoon season. The spatial variation in pH may be a reflection of the various local inputs and catchment influences at the sampling stations.

Temperature: The temperature of water at the five stations of Tingdil lake were 21°C to 37°C. The lowest temperature (21-25°C) was observed in post-monsoon season and the highest temperature (33-37°C) was observed in pre-monsoon season. Highest temperature was recorded at Station-5 (Settlement) during pre-monsoon, which may be attributed to less depth of water and higher exposure to solar radiation. During the monsoon season the temperature was moderate at 26-27°C at all the stations. Within each season, the difference in temperature between stations was small (less than 4°C) suggesting uniform thermal conditions in the lake.

Electrical Conductivity: The electrical conductivity values for all the sampling points and seasons ranged from 5 to 52 µS/cm, well below the BIS limit of 300 µS/cm with Station 4 (Undisturbed) and Station 5 (Settlement) showing significantly higher EC (52 and 51 respectively) in the monsoon season with possible runoff and anthropogenic influence producing ions. The lowest EC values were recorded at the station (Inlet) in pre-monsoon (24 µS/cm) and monsoon (45 µS/cm) periods indicating dilution effect from the inflow of freshwater streams. Higher EC values were observed during monsoon season at most stations as compared to other seasons. Low EC values are representative of low mineralization and is indicative of the lake water quality being acceptable with respect to ionic load.

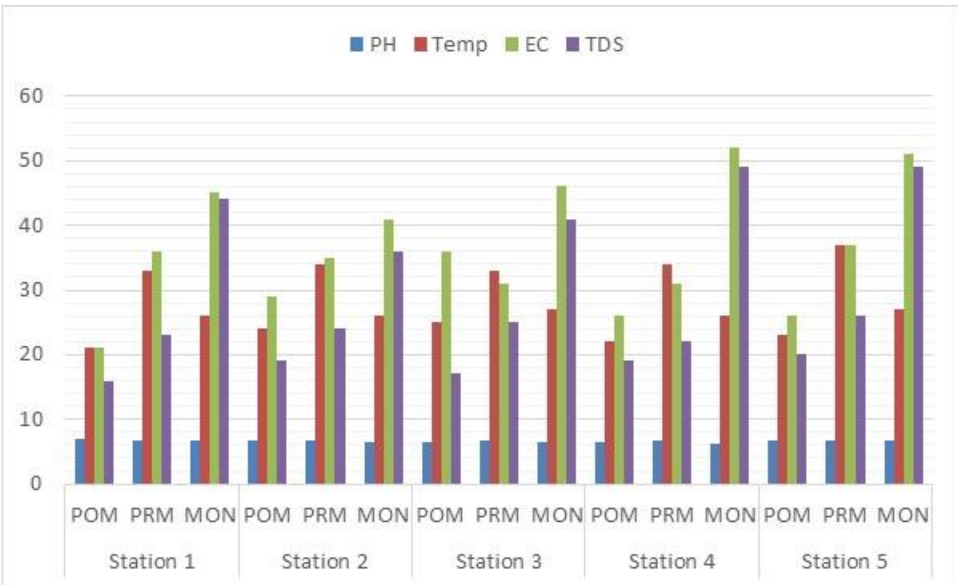


Fig 4: Distribution of physicochemical parameters in water samples [values expressed in mg/L except pH and turbidity (NTU)]

Total Dissolved Solids: TDS values in Tingdil Lake were very low, ranging from 3 to 52 mg/L at all five stations, which is far below the BIS limit of 500 mg/L. At Station 4 (Undisturbed) and Station 5 (Settlement), the TDS was highest during monsoon with values of approximately 49–51 mg/L and may be attributed to the effect of pollutants. Station 1 (Inlet) and Station 3 (Middle) generally showed lower TDS values, indicating relatively dilute water. Low TDS values are overall, suggesting that the water is very dilute with low dissolved mineral content.

Turbidity: At all sites in Tingdil Lake, the turbidity was highly variable ranging from 5–58 NTU with many stations above the BIS standard of 5 NTU. The turbidity was maximum at Station 4 (Undisturbed) at 58 NTU followed by Station 3 (Middle) at 53 NTU for the monsoon season, which suggests high concentrations of suspended ma7er due to rainfall and runoff. The post monsoon season recorded low turbidity (8-18 NTU) at all the stations due to sedimentation of suspended materials. Moderate turbidity levels (9 – 42 NTU) were observed at Station 1 (Inlet) and Station 2 (Outlet). The large increase in turbidity in the monsoon period is probably attributable to sediment input and resuspension by run-off particles.

Dissolved Oxygen: Dissolved oxygen levels were consistently high across all stations, ranging from 7.2 to 11.2 mg/L, well above the BIS minimum of 5 mg/L. At Station 1 (Inlet) the highest DO of 11.2 mg/L was recorded during pre-monsoon, whereas lowest DO was recorded at Station 5 (Settlement) during the same period with the value of 8.6 mg/L. High DO is indicative of well-oxygenated waters and good conditions for aquatic life in the entire lake.

Biological Oxygen Demand: Highest BOD value at both the Station 3 (Middle) and Station 5 (Settlement) was 5.4 in pre-monsoon period which indicates that there is high concentration of organic matter and microbial activity during this period. The lowest BOD concentration recorded was at Station 4 (Undisturbed) with 0.8mg/l indicating low organic load and good water quality at this station in post-monsoon. The overall low values of BOD indicate that there is little organic load in the lake and the Tingdil Lake is relatively natural with minimal anthropogenic organic wastes input.

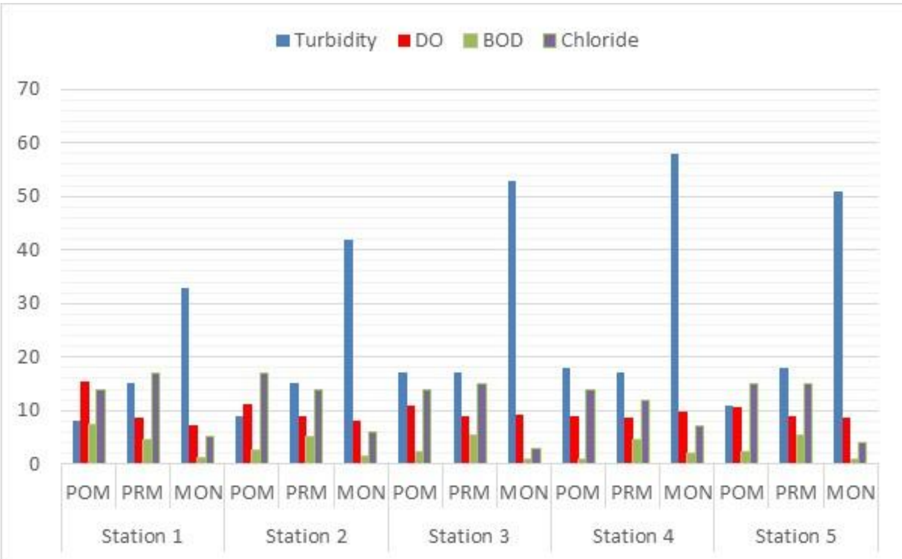


Fig 5: Distribution of physicochemical parameters in water samples expressed in mg/L

Chloride: The chloride concentration at the stations ranged from 3 to 17 mg/L in all seasons, significantly lower than BIS guideline (250 mg/L), while the Station 1 (Inlet) and Station 2 (Outlet) had relatively high concentrations ranging between 14 to 17 mg/L with maximum concentration recorded during Post-monsoon and Pre-monsoon seasons. Pre-monsoon season station 3 (Middle) had the lowest chloride concentration of 3mg/l, thus having the least contamination from anthropogenic activities at this site. The spatial variability was moderate, with moderate chloride concentration (4-15 mg/L) recorded through the different seasons at Station 4 (Undisturbed) and Station 5 (Settlement). The low chloride levels experienced overall indicate little impact of domestic wastewater or agricultural input with little salinization.

Total Acidity: All stations had total acidity between 10 and 36 mg/L. The maximum acidity at Station 1 (Inlet) was 36 mg/L during post monsoons, whereas lower acidity values (14-22 mg/L) were observed at Station 5 (Settlement). Post-monsoon months can be correlated with the increased acidity, which could be due to the decomposition of organic matter. The moderate acidity is in line with the slightly acidic lake pH values that have been found.

Total Alkalinity: Total alkalinity values ranged from 24 to 44 mg/L, well within the BIS limit of 200 mg/L. Station 1 (Inlet) showed the highest alkalinity of 44 mg/L during pre-monsoon, while Station 2 (Outlet) had the lowest at 24 mg/L. The moderate alkalinity levels indicate the lake has some capacity to resist pH changes, though values are relatively low compared to many freshwater systems.

Total Hardness: Total hardness ranged from 4 to 34 mg/L, far below the BIS limit of 200 mg/L, indicating soft water. Station 1 (Inlet) had the highest hardness of 34 mg/L during pre-monsoon, while other stations showed lower values (4-24 mg/L).

Total Nitrogen: Total nitrogen concentrations varied from 1.12 to 4.6 mg/L across all stations. Station 5 (Settlement) recorded the highest value of 4.6 mg/L during post-monsoon, suggesting nutrient inputs from nearby human activities. Other stations maintained moderate levels (2.24-3.56 mg/L). The elevated nitrogen at the settlement area indicates localized nutrient enrichment that should be monitored.

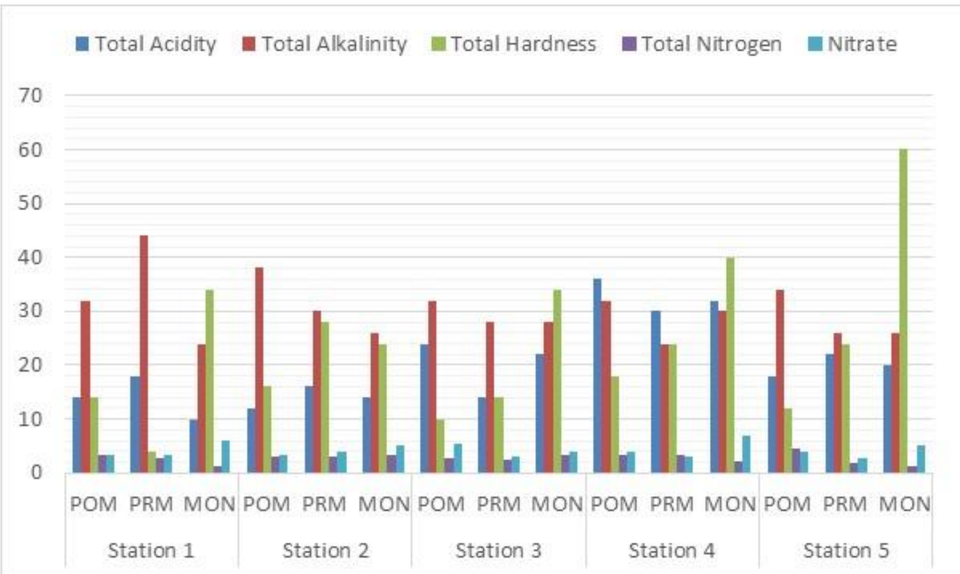


Fig 6: Distribution of physicochemical parameters in water samples expressed in mg/L

Nitrate: Nitrate levels ranged from 2.8 to 7 mg/L, well below the BIS limit of 45 mg/L. Station 4 (Undisturbed) and Station 2 (Outlet) showed the highest values (7 and 6 mg/L) during monsoon, likely from leaching of nitrogen from surrounding soils. Station 3 (Middle) had consistently lower nitrate (2.9-5.5 mg/L). The moderate nitrate levels suggest controlled nutrient loading in the lake.

3.5 CCME WQI Assessment: The study showed that 13 water quality parameters were tested at all sampling locations. A total of 39 tests were done during the monitoring period. The number of parameters that failed to meet required standards at Stations 1, 2, 3, 4, and 5 were 3, 2, 3, 2, and 3, respectively, showing some differences in water quality across the study area. Stations 3 and 5 had the most failed parameters. The number of failed tests varied across stations; Stations 1, 3, and 5 recorded 7 failures each, while Stations 2 and 4 recorded 6 failures each. This pattern shows that water quality problems were not the same at all locations. The nse values, which measure how far the water quality went beyond acceptable limits, ranged from 0.3056 to 0.4625. Station 4 had the highest value (0.4625), followed by Station 3 (0.4441), showing that these locations had the worst deviations from safe water quality standards. The calculated CCME WQI factors (F1, F2, and F3) showed different patterns across stations, with F3 values following this order: Station 4 (31.62) > Station 3 (30.75) > Station 5 (28.72) > Station 2 (24.76) > Station 1 (23.40), indicating that water quality was more affected at some stations than others.

4. Conclusion:

Based on the CCME Water Quality Index results, the assessment of Tingdil Lake reveals considerable spatial variability in water quality across the five monitoring stations. Station 1 demonstrated the highest water quality with a CCME WQI score of 78.38, placing it in the "Fair" category, indicating that water quality is usually protected but occasionally threatened, with conditions sometimes departing from natural or desirable levels. In contrast, Stations 2, 3, 4, and 5 exhibited significantly lower WQI scores ranging from 59.89 to 61.51, indicating regular deterioration with conditions frequently departing from natural levels. The excursion values, which measure the extent by which failed test values deviate from objectives, were notably higher at Stations 4 (18.04) and 3 (17.32) compared to Station 1 (11.92), indicating greater magnitude of pollution at these locations. All stations recorded 2 to 3 failed variables out of 13 parameters tested across 39 total measurements, with the F1 component (scope - percentage of variables that failed to meet objectives) ranging from 15.38% to 23.07%, while F2 (frequency of failed tests) and F3 (amplitude of excursion) values collectively contributed to the lower WQI scores at marginal stations. These findings indicate that while Tingdil Lake generally maintains acceptable physicochemical conditions, recurring exceedances at Stations 2–5 highlight the need for sustained monitoring and targeted management interventions.

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