Seasonal Water Quality Assessment of Ode Lake: A Two-Year Analysis of Physico-Chemical Parameters and Pollution Load

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Abstract: Climate change, population growth, and anthropogenic pollution have intensified water depletion and contamination, making water scarcity a critical global issue. Periodic assessment of freshwater quality is essential for developing protection strategies. In this study, the water quality of Ode Lake, Ahmedabad, Gujarat, was evaluated over two years (Feb 2022 – Oct 2023) using 19 physico-chemical parameters to assess potability and usability. The following water parameters were analyzed in the study to check pollution load on freshwater source – Temp, pH, EC, DO, BOD, COD, Ca, Cl, F, Mg, Na, NH_3, NO_3, SO_4, TA, TDS, TH, TSS, TC. Samples were collected seasonally from February 2022 to October 2023. Laboratory analysis of sample was performed using methods mentioned by IS:3025 and APHA. Results obtained were statistically analyzed to understand characteristics of each parameter of the water body. Pearson correlation matrix was obtained, BISWQI was calculated, and water was classified for each season. Suitability of water for various purposes were determined using CPCB's 'Designated Best Use' guideline. Most of the parameters were within the standard limit set by BIS & WHO. The mean BISWQI of Ode Lake is 90 (SD = 18.9) and Ode Lake water is categorized as 'Good'. Although water quality being 'Good', visible evidence of pollution was found and as per DBU guideline by CPCB, the water is usable for the purpose of irrigation and fisheries. Due to high levels of coliform, BOD and COD, organic pollution in the lake is evident, mainly caused by sewage input and waste disposal. Use of water for drinking purposes without adequate treatment must be avoided due to high coliform levels.

Keywords: Ode lake, Ahmedabad, freshwater, BISWQI, water quality, water body.

I. Introduction

Water plays a critical role in our ecosystem. It is important for the survival of life on earth. Water bodies are such as lakes, rivers, valleys, glaciers contain majority of freshwater on the planet. Freshwater bodies are essential survival thus majority of the human settlements are situated nearby these fresh waterbodies. Large lakes are most often naturally occurring while small lakes are typically semi-natural ecosystems developed by humans in areas suitable for water retention (Maurya RR, 2015). Lakes are widely recognized as some of the most fertile, productive, diverse, and interconnected aquatic ecosystems worldwide. However, the urbanization, increasing population, and changing traditional practices are placing significant stress on the lake's ecosystem. Since past 100 years, global use of freshwater has increased by six-fold and since 1980s has been increasing by 1% every year (Lin et al., 2022). Due to increased water demand, freshwater bodies are overexploited and increasingly getting polluted. Study conducted by Bhatt & Modi (2020) stresses on the overexploitation of water bodies, indicating to the usage of water three fold the capacity of water storage capacity. This leads to unsustainable water usage leading to burden on freshwater sources & pollution. Lakes are being polluted by municipal waste, as well as by agricultural activities due to dissolution of fertilizers and pesticides in runoff water from the neighbouring agricultural land (Zahoor & Mushtaq, 2023). Activities such as bathing, laundry, and dishwashing are also contributing to the lake's pollution due to discharge of domestic wastewater directly to the lakes.

Among various threats to water bodies, water scarcity is a major threat due to climate change & rise in global average temperature. According to the UN World Water Development Report 2024, "One quarter of the world's population, living in 25 countries, face 'extremely high' levels of baseline water stress, withdrawing over 80% of their annual renewable freshwater supply" (UNESCO, 2024). Global warming due to increasing GHG emission worldwide will worsen the water availability due to increase in drought and flood events around the globe (Calvin et al., 2023). Occurrence of pollution in water bodies can cause harmful effect in humans. Numerous studies emphasise on trace metal pollution in lakes and its effects on aquatic as well as human life. These are some of the most persistent pollutants, accumulate in the biota and enter the food chain, posing a risk to human health, particularly concerning cancer when present in high concentrations (Elbaz-Poulichet et al., 2020; Kucukosmanoglu & Filazi, 2020). Various methods such as phytoremediation & bioremediation are being developed recently to reverse the trace metal pollution(E. Patel & Modi, 2018). Active pharmaceutical ingredients (APIs) in the waterbodies are an emerging pollutants along with increase in microplastic pollution in lakes, rivers and oceans (Dusaucy et al., 2021; Shah et al., 2023; Wilkinson et al., 2022).

Thus, under these anthropogenic, environmental & climatic circumstances, it is imperative to maintain our freshwater bodies in pristine condition, providing safe water source for various use cases from drinking, agriculture, industrial to recreational purpose. Periodic water quality assessment and record keeping is necessary to observe changes in water quality and addressal of undesired

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changes. One tool which is useful for the said purpose is incorporation of Water Quality Index (WQI). It is a tool frequently used by researchers to determine the overall water quality at specific locations and times. A WQI is used to condense large & complex water quality dataset to an easy to comprehend digit number, representing the data into categorical classification (Birawat et al., 2021; Deep et al., 2020; Maansi et al., 2022; Maurya RR, 2015; Panikkar et al., 2022; P. S. Patel et al., 2023; Puri et al., 2011; Syeed et al., 2023).

II. Methodology

Study Area:

Ode lake is located in Village: Ode, Sub-district: Daskroi, District: Ahmedabad, State: Gujarat, Country: India. It is situated to the south of the metropolitan city, Ahmedabad. The total geographical area covered by Ode village is 675.77 hectares. There are about 442 houses in Ode village. The Ode village has a population of 2197 of which 1146 are males while 1051 are females as per Population Census 2011 (*Primary Census Abstract*, 2011). The Northwestern bank of Ode Lake is covered with residential buildings and the rest of the banks are surrounded by agricultural land. A temple is situated on the northwest bank of Ode Lake at P1 (Figure 1). Solid waste from the temple i.e., ritual wastes, plastic bags and household waste are openly dumped on periphery of lake at P1 (Figure 1), P2 (Figure 2) and P3 (Figure 3). Thus, deposition of organic waste is evident in the surface water body. Large deposits of plastic waste are quite evident on the west bank of the Lake at P2 (Figure 2). Ode lake is artificially recharged by Narmada canal project. The lake is surrounded by agricultural land. Water is used for irrigation and ritual related purposes.

Table 1 Location of the study area

Parameter	Data
Study area name	Ode lake
Address	Village: Ode, District: Ahmedabad, State: Gujarat, Country: India.
Latitude	22°54'48.25"N
Longitude	72°33'01.41"E
Dimension	215 m long x 413 m wide
Area	62,463 m^2
Perimeter	1056 m

Figure 1 Google earth image of the Ode Lake (October 2022)

Figure 2 Evidence of waste deposition at west bank of Ode Lake at P2 (2022)

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Figure 3 Evidence of pollution due to deposition of waste, plastic, and religious offerings at P3 (October 2023)

Sample Collection

Study was conducted from February 2022 to October 2023 for a total duration of 21 months. Samples of Ode Lake were collected on seasonal basis (Table 3) (Maansi et al., 2022). Samples were collected from the surface of the lake up to depth of 0.5 meter. A composite sample were prepared by mixing samples of four sampling points (P1 to P4) as described in (Figure 1). HDPE plastic container of 2.5 litre capacity was used to store the sample. Collected sample was analysed to observe nineteen physical and chemical parameters of water (Table 2). pH and surface temperature were measured on site with portable pH and temperature meter. For remaining parameters, samples were immediately sent to the laboratory on the same day for further analysis. Sample was analysed using methods mentioned by Bureau of Indian standards (IS:3025) and APHA (APHA, 2017) as mentioned in (Table 2).

Table 2 Analytical methods of selected physico-chemical parameters

Parameter	Unit	Analytical method
Surface Temperature	°C	Digital Thermometer
pH	pH unit	pH meter
Electrical Conductivity (EC)	µmhos/cm	Electrometry
Dissolved Oxygen (DO)	mg/l	Electrometry
Biological Oxygen Demand (BOD)	mg/l	3 day modified method
Chemical Oxygen Demand (COD)	mg/l	Open Reflux Method
Calcium (Ca)	mg/l	Titrimetric
Chloride (Cl)	mg/l	Titrimetric
Fluoride (F)	mg/l	Spectrophotometry
Magnesium (Mg)	mg/l	Titrimetric
Sodium (Na)	mg/l	Flame photometry
Nitrate (NO3)	mg/l	Spectrophotometry
Sulfate (SO4)	mg/l	Spectrophotometry
Total Alkalinity (TA)	mg/l	Titrimetric
Total Dissolved Solids (TDS)	mg/l	Electrometry
Total Hardness (TH)	mg/l	Titrimetric
Total Suspended Solids (TSS)	mg/l	Thermo-Gravimetry
Total Coliform (TC)	MPN/100 ml	Multiple Tube Fermentation
Ammonia (NH3)	mg/l	Electrometry

Obtained results were statistically analysed to attain in-depth knowledge about the nature of the parameters and status of pollution. WQI was calculated to classify the water using drinking water standards (DWS) of BIS & WHO (*WHO*, 2022; *BIS*, 2012). Seasons of a year were categorized as per (Table 3). Results were compared with various criteria given by CPCB's designated best usage (DBU) guidelines to determine the most suitable use case for the lake water (*CPCB*, 2019).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Table 3 Duration of Seasons in India throughout the year

Season	Month
Monsoon	July – August
Post monsoon	September – October
Winter	November – February
Summer	March - June

Water Quality Index (WQI)

Initial notable development of water quality index was done by Horton for 8 physical and chemical parameters (Horton, 1965). Later, Brown's work advanced the development of WQI (Brown et al., 1972). After year 1998, incorporation of WQI in water studies has been significantly increased, with highest recorded annual publications on the topic reaching to 1316 in year 2022 (Chidiac et al., 2023). Although being a popular method for researchers, many have argued the limitations in the use of WQI and ambiguity associated with it. There is a lack of universally accepted WQI. Often WQI are modified for according to study requirements and country specific water quality standards (Banda & Kumarasamy, 2020; Vasistha & Ganguly, 2020). Often, due to lack of knowledge and incomplete citation of authentic sources leads to incorrect representation of these standards in studies, leading to confusion among the readers (Reddy, 2023).

WQI can be calculated using various methods such as National Sanitation Foundation Water Quality Index (NSFWQI), Bureau of Indian Standards Water Quality Index (BISWQI), Oregon Water Quality Index (OWQI), Canadian Council of Ministers of Environment Water Quality Index (CCMEWQI), World Health Organization Water Quality Index (WHOWQI), British Columbia Water Quality Index (BCWQI), Food and Agriculture Organization Water Quality Index (FAOWQI) and many more (*CCME*, 2017; Chidiac et al., 2023; Fikadu, 2022; Samal et al., 2023; Sikakwe & Ilaumo, 2021). For this study, BISWQI was selected to determine water quality, as study area is in India. It is a WQI which takes into account of drinking water standards IS 10500 (2012) developed by Bureau of Indian Standards (BIS) to calculate WQI (*BIS*, 2012). Number of studies has been completed using the indexing method (Fikadu, 2022; Iwar et al., 2021; Rana et al., 2018; Samal et al., 2023; Vasistha & Ganguly, 2020, 2022). For this study, ten parameters were selected for the calculation of BISWQI. For proper representation of BIS drinking water standards, only parameters listed in the standard were considered for calculation of BISWQI and index was calculated separately using both limits given in the standard. It was calculated in the following steps.

Step 1: Each parameter has been assigned a weight (AW_i) ranging from 1 to 5 based on collective opinions derived from previous WQI studies (Rana et al., 2018; Sharma et al., 2014; Singh et al., 2018; Vasanthavigar et al., 2010; Vasistha & Ganguly, 2020). 1 indicates the least significant parameter while 5 indicates the most significant parameter. Rounded mean of weights was calculated and used AWi for selected parameters, derived from previous studies for the BISWQI calculation (Table 4).

Step 2: The relative weight (RW_i) was calculated using equation:

$$RW_i = \frac{AW_i}{\sum_{i=1}^{n} AW_i}$$

where, RW = the relative weight, AW = the assigned weight of each parameter, n = number of parameters. Assigned weights and calculated relative weights are described in (Table 4).

Table 4 BIS Drinking Water Standards and their respective AW and calculated RW

Parameter	Standard Limits (*BIS*, 2012)		Weight References					Assigned Weight (AW_i)	Relative Weight (RW_i)
	Acceptable Limit (AL)	Permissible Limit (PL) in absence of alternate source	1	2	3	4	5		
Ca (mg/l)	75	200	3	4	2	3	3	3	0.075
Cl (mg/l)	250	1000	5	5	3	5	5	5	0.125
F (mg/l)	1	1.5	-	5	2	5	5	4	0.100
Mg (mg/l)	30	100	3	3	2	3	3	3	0.075
NO_3 (mg/l)	45	No relaxation	5	5	4	5	5	5	0.125
pH	6.5-8.5	No relaxation	4	-	4	4	-	4	0.100
SO_4 (mg/l)	200	400	5	5	4	5	5	5	0.125

TA (mg/l)	200	600	2	4	2	-	-	3	0.075
TDS (mg/l)	500	2000	5	-	4	5	5	5	0.125
TH (mg/l)	200	600	-	4	-	2	-	3	0.075
								$\sum AWi = 40$	$\sum RWi = 1$
Weight References: **1** (Vasistha & Ganguly, 2020); **2** (Rana et al., 2018); **3** (Sharma et al., 2014); **4** (Singh et al., 2018); **5** (Vasanthavigar et al., 2010)									

Step 3: A quality rating scale (Q_i) for all the parameters (except pH) was calculated by using equation:

$$Q_i = \left(\frac{C_i}{S_i}\right) * 100$$

where C_i = observed value of i^{th} parameter, S_i = Standard value of i^{th} parameter.

For pH, the Q_i was calculated by using given equation:

$$Q_i = \left(\frac{C_i - V_i}{S_i - V_i}\right) * 100$$

where V_i = ideal value (considered as 7.0 for pH).

Step 4: For computation of BISWQI, Sub-indices (SI_i) were calculated for each parameter using the following equation:

$$SI_i = RW_i * Q_i$$

Step 5: Finally, BISWQI was calculated using following equation:

$$BISWQI = \sum SI_i$$

The result values of BISWQI were classified into five different categories (Table 5) according to water quality scale referred from previous studies (Das Kangabam et al., 2017; Ramakrishnaiah et al., 2009; Rana et al., 2018; Singh et al., 2018; Vasanthavigar et al., 2010; Vasistha & Ganguly, 2022).

Table 5 Categorical scale to determine quality of the water based on BISWQI

Range	**Water Quality Category**
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very Poor
>300	Unfit for drinking

Sodium Absorption Ratio (SAR)

SAR is an indicator, used to determine suitability of the water for irrigation purpose (Zaman et al., 2018). Ode lake water is used for irrigation purposes. SAR value has been compared with DBU classification given by CPCB (Table 7). Method by Bureau of Indian Standard has been used as reference for the determination of SAR (*IS:11624*, 2001). The following formula is used for the calculation:

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)}}$$

Where, SAR = sodium adsorption ratio $\sqrt{(millimole/litre)}$, Na^+ = sodium ion concentration (meq/l), Ca^{2+} = calcium ion concentration (meq/l), Mg^{2+} = Magnesium ion concentration (meq/l).

Statistical Analysis

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Statistical analysis of the data was performed using SPSS version 25.0. Using SPSS, 'Descriptive statistics' (Table 8) and 'Pearson correlation' (Table 10) were obtained for the 19 parameters. Pearson correlation was used to find linier relation between each parameter at significance level of $P<0.05$ (significant) and $P<0.01$ (highly significant) denoted as '*' and '**'. Pearson correlation value ranges from -1 to +1. +1 indicates positive relation between parameters while -1 indicates negative relation between parameters and 0 indicates no relation between parameters. Results of the Pearson correlation matrix are given in (Table 10).

III. Results and Discussions

Comparison With Drinking Water Standards (DWS) And Designated Best Use (DBU)

As mentioned by Reddy, there is quite discrepancy in the usage of DWS by researchers to assess the water quality of their respected study area (Reddy, 2023). Adequate comprehension of the DWS of is required and must be used adhering to the instructions given by the respective DWS. We have carefully studied DWS to avoid any misinterpretation in our study. Results of the 7 composite samples collected seasonally from the Ode Lake have been compared with WHO (international) and BIS (national) standard to check the compliance rate of our samples.

Table 6 Compliance rate of samples when compared with drinking water standard

Parameter	BIS Standard (*BIS*, 2012)				WHO Standard (*WHO*, 2022)	
	AL	PL	% compliance to AL	% compliance to PL	GV	% compliance to GV
Temp °C	-	-	-	-	-	-
pH[1]	6.5-8.5	No relaxation	43%	43%	6.5-8.5[2]	43%
EC[1] (μmhos cm^{-1})	-	-	-	-	-	-
DO	-	-	-	-	-	-
BOD	-	-	-	-	-	-
COD	-	-	-	-	-	-
Ca	75	200	100%	100%	-	-
Cl	250	1000	86%	100%	250[2]	86%
F	1	1.5	100%	100%	1.5	100%
Mg	30	100	86%	100%	-	-
Na	-	-	-	-	200[2]	86%
NH_3	0.5	No relaxation	86%	86%	-	-
NO_3	45	No relaxation	86%	86%	50	100%
SO_4	200	400	100%	100%	250[2]	100%
TA	200	600	57%	100%	-	-
TDS	500	2000	43%	100%	1000[2]	71%
TH	200	600	100%	100%	200[2]	100%
TSS	-	-	-	-	-	-

AL - Requirement (Acceptable Limit); PL – Permissible Limit; GV – Health Based Guideline Value

[1] All parameters expect pH and EC are in mg/l

[2] Taste threshold values (not health-based guideline value)

Note: For BIS drinking water standard, values exceeding those under 'Acceptable Limit' render the water not suitable, but still may be tolerated in absence of alternate water source but up to limits indicated under 'Permissible Limit'

As per the comparison with DWS, all 4 out of 10 parameters of all the samples (Ca, F, SO_4 and TH) fully comply with both limits acceptable limit (AL) & permissible limit (PL) provided by BIS standard. While other 6 parameters (pH, Cl, Mg, NO_3, TA, TDS) failed to fully comply with BIS standards. All samples were in 100% compliance to permissible limit (PL), except pH and NO_3. Overview of BIS compliance gives an idea of overall water quality being usable but only after application of adequate water

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

treatment. Looking at the WHO health-based guideline values (GV), no violation are found, rendering the water suitable for drinking water. Although due to parameters crossing the of taste threshold values given by WHO, will render the water unacceptable for the drinking purpose by end users. Thus, treatment before usage as drinking water is recommended.

Table 7 Designated best use of Ode Lake water

Designated Best Use	Class	Criteria	Winter	Summer	Monsoon	Post-monsoon	Overall
Drinking water sources without conventional treatment but after disinfection	A	TC ≤ 50 MPN/100ml					
		pH = 6.5 to 8.5		✔	✔		
		DO ≥ 6 mg/l			✔		
		BOD ≤ 2mg/l					
Outdoor bathing (Organized)	B	TC ≤ 500 MPN/100ml					
		pH = 6.5 to 8.5		✔	✔		
		DO ≥ 5mg/l			✔		
		BOD ≤ 3mg/l					
Drinking water source after conventional treatment and disinfection	C	TC ≤ 5000 MPN/100ml	✔				
		pH = 6 to 9		✔	✔	✔	
		DO ≥ 4 mg/l			✔	✔	
		BOD ≤ 3 mg/l					
Propagation of wildlife and fisheries	D	pH = 6.5 to 8.5		✔	✔		✔
		DO ≥ 4mg/l			✔	✔	
		NH_3 (as N) ≤ 1.2 mg/l	✔	✔	✔		
Irrigation, Industrial Cooling, Controlled Waste Disposal	E	pH = 6.0 to 8.5		✔	✔		✔
		EC < 2250	✔	✔	✔	✔	
		SAR < 26	✔	✔	✔	✔	
		Boron < 2mg/l	NA	NA	NA	NA	

As per the designated best use (DBU) water criteria given by CPCB, results were compared with the suggested limits (Table 7). Results failed to be fulfilled majority of criteria under class A, B and C. Thus, suggesting that water cannot be used for drinking water and outdoor bathing. While partial fulfilment of class D suggests that water can be used for the propagation of wildlife and fisheries. Although in this study, Boron levels have not been analyzed, majority of the samples fulfil the criteria of E class, rendering water usable for irrigational purpose.

Physico-chemical Results of Water

Samples were collected on a seasonal basis. During the year 2022, samples were collected in the months of February (winter), May (summer) and September (post-monsoon) and during the year 2023 in months of January (winter), April (summer), July (monsoon) and October (post-monsoon). Descriptive statistics of both years combined for all the parameters are summarized in (Table 8) as minimum, maximum, mean, standard error and standard deviation.

Table 8 Descriptive statistics of water parameters

Parameter	Descriptive Statistics				
	Min	Max	Mean	SE	SD
Temp (°C)	25.7	36	32.17	1.54	4.08

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

pH	8.1	9.5	8.66	0.22	0.57
EC (µmhos cm^{-1})	658	2722	1219.14	281.04	743.56
DO	3.1	6.4	4.23	0.40	1.07
BOD	53	320	202.57	33.27	88.02
COD	135	850	496.43	84.81	224.38
Ca	20	40	28.57	3.22	8.52
Cl	88	304	155.43	27.70	73.30
F	0	0.4	0.13	0.05	0.13
Mg	15	36	24.43	2.89	7.63
NO_3	1.9	49.6	12.07	6.61	17.48
NH_3	0.05	2.4	0.48	0.32	0.85
Na	76	282	131.47	26.96	71.33
SO_4	13	192	62.34	22.38	59.20
TA	183	235	205.00	7.77	20.57
TC (MPN/100ml)	1960	11300	5968.00	1280.33	3387.42
TDS	396	1444	705.71	149.97	396.79
TH	125	200	173.21	10.71	28.35
TSS	10	62	28.57	7.92	20.95
Note: Unit(s) of every parameter, except pH, EC and TC are mg/l					

Surface temperature is an important parameter, affecting the water chemistry by increasing and decreasing the rate of reaction between various water parameters. Other than climatic conditions, the area and depth of the waterbody, as well as volume of the water of the concerned waterbody affects the fluctuations in the surface temperature of the waterbodies throughout the day and year. The average surface temperature of Ode Lake was 32.17 °C (*SD* = 4.08) with the highest temperature observed was 36 °C during summer of 2022 and lowest was 25.7 °C during the winter of 2022. Similar observation has been made in Malav Lake (Solanki et al., 2011), Kankaria Lake (P. U. Verma et al., 2011) and Chandola Lake (P. Verma et al., 2012). In the years 2022 and 2023, values ranged between 25.7 – 36 °C and 28 – 35.6 °C, respectively.

pH is the negative log of concentration of H^+. It measures concentration of H^+ on a scale of 0 to 14. It is helpful to understand dominance of acidic or basic activity in a waterbody and determine productivity of lake (Bhateria & Jain, 2016). Higher pH value is correlated with increase in productivity of the lake (Garg et al., 2010; Maansi et al., 2022). Lower pH leads to corrosion in pipelines and higher pH affects skin and eyes (Ravikumar et al., 2013). Water with pH value between 6.5 to 8.5 is acceptable for drinking purpose (*WHO*, 2022; *BIS*, 2012). In this study, the average pH value of Ode Lake was 8.66 (*SD* = 0.57) with the highest pH observed was 9.5 (winter 2022) and lowest was 8.1 (monsoon and post-monsoon 2023). The water of Ode Lake was found to be slightly alkaline throughout all seasons.

Electrical conductivity (EC) is a parameter which depicts the ability of water to conduct a current of electricity. Deterministic factors which affect EC are concentration of cation and anion, their mobility and temperature during measurements (APHA, 2017; Maansi et al., 2022). EC is majorly dependent on geology of area (Bhateria & Jain, 2016). Other reasons for high EC could be input of domestic wastewater, particularly carbonate and bicarbonate from detergents. In this study, average value of EC was found to be 1219 µmhos cm^{-1} (*SD* = 743.56) with values ranged between 658 – 2722 µmhos cm^{-1}. Year 2022 and 2023 recorded values ranged between 710 – 2722 µmhos cm^{-1} and 658 – 1640 µmhos cm^{-1}, respectively. Both summer (2022 & 2023) showed highest recorded value of 2722 and 1640 µmhos cm^{-1}, respectively. Evaporation of water can be associated with higher levels during the summer. While in post-monsoon season, EC levels were much lower, 710 (2022) & 658 (2023) µmhos cm^{-1} caused by dilution of lake water due to monsoon precipitation. Similar seasonal variations were observed in Sukhna Lake, Kankaria Lake, Chandola Lake, Nikol Lake and Ramsagar reservoir (Garg et al., 2010; Maansi et al., 2022; P. Verma et al., 2012; P. U. Verma et al., 2011, 2013)

Dissolved oxygen (DO) is an important indicator determining the trophic status of surface water bodies. Levels of DO can vary with fluctuations in temperature, respiration by aquatic life and decomposition due to pollution load (APHA, 2017; Maansi et al., 2022). Higher DO levels helps in proliferation of aquatic fauna, while lower levels affect the survivability (Kotadiya et al., 2013). Pollution in waterbodies can deplete DO levels, with levels below 5 mg/l causing stress to aquatic life forms (Ravikumar et al., 2013). Average DO concentration was found to be 4.23 mg/l (*SD* = 743.56) with values ranging from 3.1 to 6.4 mg/l. In the years

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

2022 and 2023, values ranged between 3.1 – 4.1 mg/l and 3.5 – 6.4 mg/l, respectively. The highest recorded value was 6.4 mg/l (monsoon 2023), caused due to mixing of O_2 in water due to wind action and precipitation and the lowest recorded value was 3.1 mg/l (summer 2022), due to elevated temperature of summer causing decrease in overall DO levels. Similar seasonal variation has been observed in Ghuma Lake (Kotadiya et al., 2013), Malav Lake (Solanki et al., 2011), Kankaria Lake (P. U. Verma et al., 2011), Chandola Lake (P. Verma et al., 2012) and Nikol Lake (P. U. Verma et al., 2013).

Biochemical oxygen demand (BOD) is an important indicator of biological activity in water, representing the oxygen consumed by bacteria and microorganisms. These organisms thrive in water due to assimilation of organic matter present in water bodies under aerobic conditions (Garg et al., 2010). It is commonly used as an indicator of organic pollution. Higher levels of BOD indicate higher content of organic matter in water bodies. Oxygen is consumed by biological activities i.e., (breathing by fishes) and concentrations of dissolved oxygen in water is decreased by this action (Kotadiya et al., 2013; Maansi et al., 2022). During study of the Ode Lake, average concentration of BOD was found at 202.6 mg/l (*SD* = 88.02) and values of BOD of every season were within range of 150 mg/l to 320 mg/l. In the years 2022 & 2023, values ranged between 150 – 235 mg/l and 53 – 320 mg/l, respectively. In both seasons, the highest values were observed in summer season, while the lowest values were 150 mg/l (winter 2022) and 53 mg/l (post-monsoon 2023). Similar seasonal observations has been made by researchers (Garg et al., 2010; Kotadiya et al., 2013; Solanki et al., 2011; P. U. Verma et al., 2011). BOD levels are quite high when compared to suggested levels (30 mg/l) by government of India for effluent meant to be discharged into inland surface water bodies (*The Environment (Protection) Rules, 1986*, n.d.). BOD values are much higher compared to COD values of Ode Lake. This suggests that Ode Lake water, dominantly occupied by microorganism & plankton, has high organic content. This might be due to disposal of municipal wastewater and religious waste in the water body (Figure 3).

Chemical oxygen demand (COD) of water shows the presence of oxidizable organic matter in waterbody when a strong chemical oxidant is present (Garg et al., 2010). It is an important indicator of pollution commonly used in pollution studies. High COD levels indicate high organic pollution in waterbodies. Usually, COD levels are higher compared to BOD levels (Sawyer et al., 2003). Average concentration of COD within Ode Lake was found to be 496.4 mg/l (*SD* = 224.38) ranging between 135 – 850 mg/l. In the years 2022 & 2023, COD levels ranged between 390 – 495 mg/l and 135 – 850 mg/l, respectively. In both years, summer showed the highest COD levels and post monsoon showed the lowest levels. While there is no standard value of COD in DWS, government of India suggests 250 mg/l for industrial effluent discharge into inland surface water bodies (*The Environment (Protection) Rules, 1986*, n.d.). COD values in most of the samples were found to be higher than the suggested COD levels and which indicates the presence of pollution in Ode Lake.

Calcium (Ca) and magnesium (Mg) are associated with the hardness of water. They do not pose risk to health but often makes water undesirable by the end used for the purpose of drinking and household usage (APHA, 2017). In urban waterworks infrastructure, water with high Ca and Mg levels can lead to scaling of the pipelines. They also induce difficulty in washing clothes, leading to higher usage of detergent. In natural waters, these are important nutrients for the aquatic organism (P. U. Verma et al., 2013). Average concentration of calcium and magnesium was observed to be 28.6 mg/l (*SD* = 8.52) and 24.4 mg/l (*SD* = 7.63), respectively. Ca value with values ranged between 20 – 40 mg/l and Mg values ranged between 15 – 36 mg/l. Both ions are below standard limits suggested of BIS, 75 mg/l for Ca and 30 mg/l for Mg (Table 6).

Chloride (Cl) parameter is used an indicator of sewage and industrial pollution by researchers (Maansi et al., 2022). Human excreta and urine contain high concentration of chloride, thus deposition of sewage water increases chloride levels (P. Verma et al., 2012). Salts of Na, K, Mg and Ca contributes to increase in Cl levels and usually exists in water in form of $CaCl_2$, $MgCl_2$, NaCl and KCL (Garg et al., 2010; P. U. Verma et al., 2011). Although of no health concern, high Cl in water indicates organic pollution, gives salty taste and contributes to unacceptability of water by end users (*WHO*, 2022; Solanki et al., 2011). Average concentration of Cl was observed to be 155.4 mg/l (*SD* = 73.30), with values ranging from 88 to 304 mg/l. In the year 2022 & 2023, values ranged between 96 – 160 mg/l and 88 – 304 mg/l, respectively. Chloride concentrations were highest in summer and lowest in the post monsoon season for both the years. Similar seasonal variations were observed in Sukhna Lake, Ghuma Lake, Malav Lake, Nikol Lake and Ramsagar Lake (Garg et al., 2010; Kotadiya et al., 2013; Maansi et al., 2022; Solanki et al., 2011; P. U. Verma et al., 2013). Higher values can be explained by the high evaporation rate of water in summers, resulting in a decrease in volume of water in the Ode Lake and increase in Cl levels. The post-monsoon season of both years has shown a decrease in concentration of chloride, 96 & 88 mg/l respectively. Samples from all seasons except summer 2023 (304 mg/l) were below standard limit (250 mg/l) given by BIS & WHO (Table 6).

Fluoride (F) is an important parameter for human health. Trace amounts of fluorine are present in waterbodies all around the globe, depending upon geological structure of the area of concern. WHO has provided health-based guideline value of 1.5 mg/l for drinking water. Long term consumption of water with higher levels of fluoride causes dental fluorosis and skeletal fluorosis in human body (*WHO*, 2022). Ode Lake water contains an average fluoride concentration of 0.13 mg/l (*SD* = 0.127), with values ranging from 0 to 0.4 mg/l. In the year 2022 & 2023, values ranged between 0.08 – 0.11 mg/l and 0 – 0.4 mg/l, respectively. Like chloride, fluoride concentrations were highest in summer of 2022 (0.11 mg/l) and lowest in monsoon of 2023 (0 mg/l). Post monsoon season of both years showed lowest concentration of fluoride, 0.08 mg/l (2022) & 0 mg/l (2023). Fluoride levels were found to be below standard limits given by BIS & WHO (Table 6) throughout all seasons. Thus, Ode Lake water can be deemed safe from fluoride induced diseases. Studies of Loktak Lake and Mallathalli Lake also found safe fluoride levels throughout all seasons (Das Kangabam et al., 2017; Ravikumar et al., 2013).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Sodium (Na) is a naturally occurring element in waterbodies. According to WHO, it is not of health concern in potable water, although affects likability of the water (*WHO*, 2022). High sodium levels often correspond to contamination of sewage into waterbodies. In Ode Lake, the mean concentration of sodium was determined to be 131.5 mg/l (*SD* = 71.33), with values ranging between 80 – 126 mg/l in the year 2022 and 76 – 282 mg/l in year 2023. Highest values were recorded in the summer season and lowest were recorded in post monsoon season of their respective years. Similar seasonal variation was found in Ramsagar lake (Garg et al., 2010). BIS did not provide standard limits for sodium, while WHO provides only taste threshold limit of 200 mg/l with no health-based guideline limits. Majority of the samples fulfill the taste threshold limits of WHO (Table 6).

Nitrate (NO_3) is a nutrient of great importance for the growth of hydrophytes and aquatic algae. It is found in low concentration in surface water bodies (Maansi et al., 2022). High concentration of nitrate in water indicates sewage contamination, promoting algal growth. Ammonia produced by sewage water under aerobic environment converts into nitrite (NO_2) and then nitrate (NO_3) (Solanki et al., 2011). Nitrate levels more than 5 mg/l indicate pollution from anthropogenic source, either by sewage or industrial waste input or by input of agricultural runoff from surroundings (P. U. Verma et al., 2011). The concentration of nitrate in Ode Lake ranged between 1.9 – 49.3 mg/l, with mean concentration being 12.07 mg/l (*SD* = 17.48). The highest nitrate levels were 18.1 mg/l (summer 2022) and 49.6 mg/l (monsoon 2023). While the lowest observed values were 1.9 mg/l (post-monsoon 2022) and 2.6 mg/l (summer 2023). Most of the samples fulfill the standard limit given by WHO (50 mg/l). While only one nitrate result (49.6 mg/l) of monsoon season (2023) exceeds the BIS limit of 45 mg/l (Table 6).

Ammonia (NH_3) in the environment exists due to metabolic processes, agricultural runoff, and industrial discharge. In natural surface water as well as ground water, concentrations are usually below 2 mg/l. It is an indicator of microbial growth, sewage input and animal waste input in water (*WHO*, 2022). High ammonia is harmful for fish. High pH causes ammonia to remain in gaseous state in water, causing toxicity (Garg et al., 2010). In Ode Lake, the mean concentration of NH_3 was found to be 0.48 mg/l (*SD* = 0.85) with values ranging between 0.04 – 2.4 mg/l. In the year 2022 & 2023, values ranged between 0.10 – 2.40 mg/l and 0.05 – 0.25 mg/l, respectively. Highest ammonia values were observed in post-monsoon of year 2022 and summer of year 2023. While the lowest values were observed in winter of year 2022 and post-monsoon of year 2023. Majority of the samples satisfy the acceptable limit given by BIS (Table 6).

Sulphate (SO_4) in high concentration has a laxative effect on the human body. Sulphate in natural waters is largely dependent on sulfur cycle, usually present due to bacterial activity (Kotadiya et al., 2013). In Ode Lake, average concentration of sulphate (SO_4) was found to be 62.34 mg/l (*SD* = 59.2) with values ranged between 13 – 28.8 mg/l and 41.8 – 192 mg/l, in the year 2022 and 2023 respectively. For both years, summer showed the highest sulphate levels due to an increase in concentration caused by evaporation of lake water (Garg et al., 2010). Low levels were due to dilution from rainwater. Sulphate levels in all samples were fully in compliance with the acceptable limit (200 mg/l) given by BIS and taste threshold value given by WHO (250 mg/l) (Table 6).

Total alkalinity (TA) is the buffering capacity of the water to neutralize acid input and maintain pH levels (Maansi et al., 2022). Carbonate, bicarbonate and CO_2 in water dictates alkalinity in water (Solanki et al., 2011; P. U. Verma et al., 2011). Detergent in sewage and respiration by living organisms, increases alkalinity in water (P. U. Verma et al., 2013). High alkalinity gives bitter taste to the water and damages soil if used for irrigation purpose, in turn reducing the crop output (Ravikumar et al., 2013). Average value of total alkalinity (TA) in Ode Lake was observed to be 205 mg/l (*SD* = 20.57), with values ranging between 183 – 200 mg/l in year 2022 and 195 – 235 mg/l in year 2023. For both years, the highest value was observed in the summer season due to a high decomposition rate, leading to liberation of CO_2. While the lowest values were observed in winter of year 2022 and post-monsoon of year 2023. Similar seasonal variations were observed in Sukhna Lake, Chandola Lake and Ramsagar Lake (Garg et al., 2010; Maansi et al., 2022; P. Verma et al., 2012). WHO does not provide any standard limits for total alkalinity, while BIS provides acceptable limits of 200 mg/l and permissible limit of 600 mg/l. Only samples of winter (2022) and post-monsoon samples (2022 & 2023) were able to fulfill the acceptable limits (Table 6).

Total coliform is a bacteriological parameter. In drinking water, there should be no detectable coliforms (*WHO*, 2022). In the study, total coliform (TC) levels ranged between 1960 – 11300 MPN/100ml, with average value being 5968 (*SD* = 3387.42). In the year 2022, the highest value found was 9500 MPN/100ml (summer), while in year 2023 the highest value was 11,300 (post-monsoon). The lowest values in the year 2022 & 2023 were 1960 (post-monsoon) and 3330 (summer), respectively. Similar to this, Fateh Sagar Lake also observed high coliform levels in monsoon season (Rawal et al., 2018). Total coliform shows abnormally high deviation when compared with other parameters and huge spike in post monsoon of 2023, might be due to error during laboratory analysis. It is to note that as per drinking water specifications by BIS, coliform should not be detected, and this condition is applicable only for water distribution systems (*BIS*, 2012).

Total dissolved solids (TDS) principally indicate dissolved inorganic salts of Ca, Mg, K, Na, HCO_3, Cl and SO_4 in water. These can be present naturally due to geology or due to various anthropogenic sources such as sewage, solid waste, runoff water and industrial wastewater (*WHO*, 2022). Organic matter in water affects TDS levels (Maansi et al., 2022). High TDS reduces acceptability of the water by the end users (Solanki et al., 2011). TDS values of Ode Lake ranged between 396 – 1444 mg/l, with an average concentration being 705.7 mg/l (*SD* = 396.79). In the years 2022 & 2023, values ranged between 412 – 1444 mg/l and 359 – 1050 mg/l, subsequently. In both years, TDS levels were the highest in summer season, while the lowest values were observed in post-monsoon season. Sukhna Lake, Kankaria Lake, Chandola Lake and Ramsagar Lake experienced similar seasonal variation (Garg et al., 2010; Maansi et al., 2022; P. Verma et al., 2012; P. U. Verma et al., 2011). All samples were able to fulfill the permissible

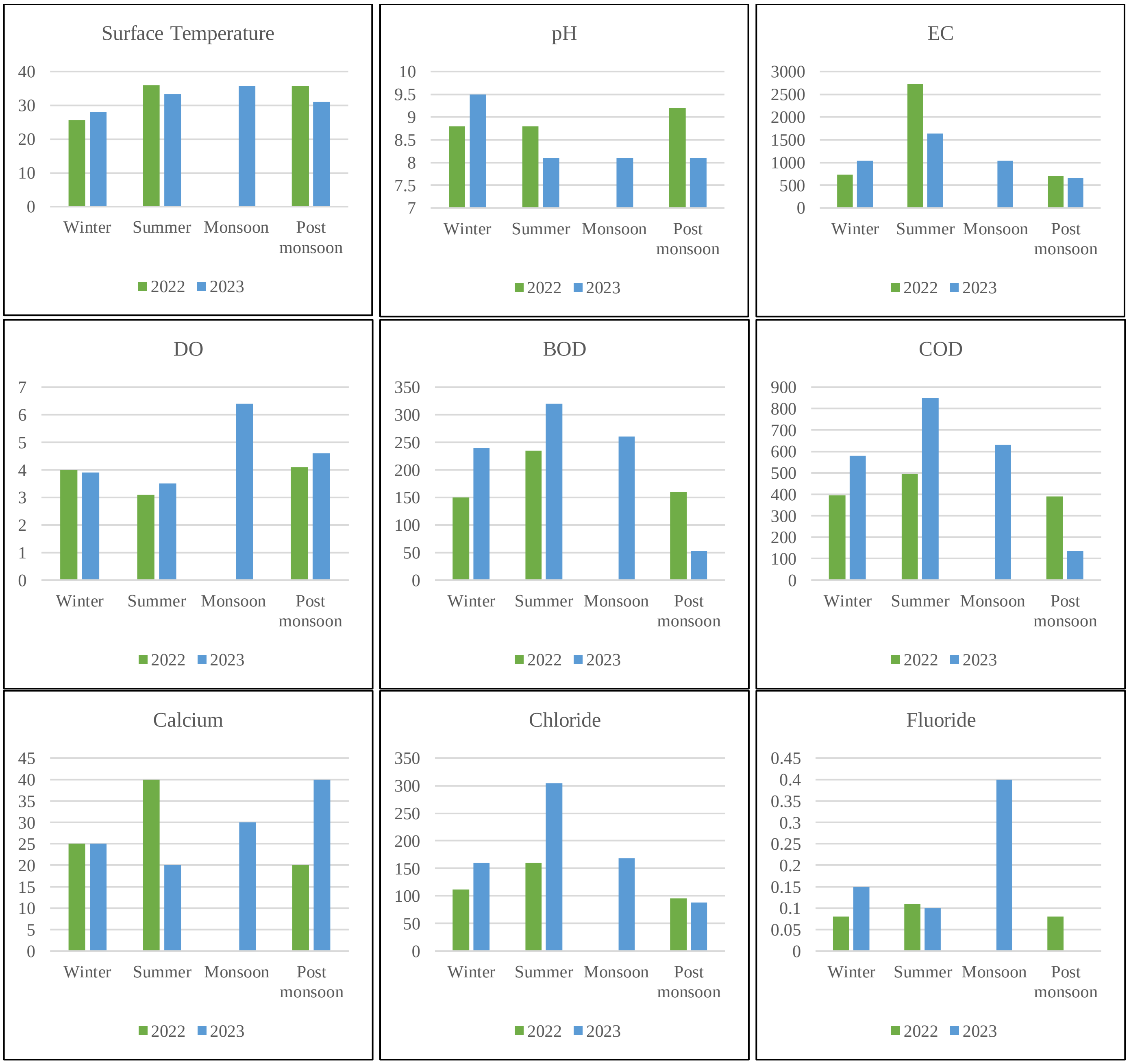
ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

limit of (2000 mg/l) BIS standard, but about half of the samples failed to fulfill acceptable limit (500 mg/l) of BIS. Samples collected in summer season of both the years failed to fulfill the taste threshold limit of WHO (1000 mg/l) (Table 6).

Total hardness (TH) measures the capacity of water to react with soap. Hard water requires much more detergent to wash clothes. Hardness of the water is principally contributed by calcium and magnesium ions (*WHO*, 2022; Solanki et al., 2011). In the study of Ode Lake, mean total hardness was 173.2 mg/l with values ranged between 125 – 200 mg/l. In the years 2022 & 2023, values ranged between 125 – 187.5 mg/l and 162.5 – 200 mg/l, subsequently. Highest levels of TH were observed in summer season due to higher evaporation rate, while lowest were observed in post-monsoon season due to dilution by rainwater. All samples were able to fulfill the standard limits set by BIS and WHO (Table 6). Similar seasonal trends were observed in Kankaria Lake and Nikol Lake (P. U. Verma et al., 2011, 2013)

Total suspended solids (TSS) measures suspended filterable solids in the water sample. Although parameter itself is not of much importance and no standard has values provided in DWS, it does contribute to reduced light penetration in the lake, affecting photosynthesis process. of Ode Lake ranged between 10 – 62 mg/l, with an average value being 28.57 mg/l (*SD* = 20.95). In the years 2022 & 2023, values ranged between 15 – 62 mg/l and 10 – 55 mg/l, subsequently. In both years, TSS levels were the highest in winter season, while the lowest values were observed in summer of 2022 and monsoon of 2023.

Figure 4 Plot of physico-chemical parameters



ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Pearson Correlation Matrix

The Pearson correlation matrix was derived and presented in (Table 10). The study has found 16 significant correlations at significance level P<0.05 and 12 highly significant correlations at significance level P<0.01 between among parameters. Among

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

these only one significant correlation was found to be negative between surface temperature and total suspended solids. Temperature was found to be negatively correlated with TSS ($P<0.05$). EC is highly significantly correlated with TDS as reported by (Das Kangabam et al., 2017; Maansi et al., 2022). BOD was found to be significantly correlated with COD, Cl, Mg, Na. For COD, significant correlation was found with Cl, Mg, Na, SO_4 and TA. Calcium is significantly correlated with total coliform. Chloride is correlated with Mg, Na, SO_4 and total alkalinity. Fluoride is correlated with nitrate. Magnesium is correlated with Na, SO_4, TA and TH. Sodium is correlated with sulphate and total alkalinity. Total alkalinity is correlated with total hardness. BISWQI calculated using acceptable limit is correlated with EC, BOD, COD, TDS. It is to note that correlations found do not always mean cause and effect relation between parameters. Thus, it should not be used for linier predictions and cause or effect assumption.

Water Quality Index (WQI)

For the calculation of water quality index, we have considered both 'acceptable limit' (AL) and 'permissible limit' (PL) provided in drinking water standards by Bureau of Indian Standards (*BIS*, 2012). WQI results were categorized on a seasonal and yearly basis based on categorical scale (Table 5). Throughout the study period, BISWQI values ranged between 61 – 113 when considered 'acceptable limit' and 35 – 68 when considered 'permissible limit' of BIS drinking water specifications. Overall water quality of lake was categorized as 'Good' for both years. Water of summer season was categorized as 'Poor' quality for both years. It is to note that the "Acceptable Limit" is to be considered to determine the potability of water for drinking purposes. No sample was categorized as 'Unfit' (Table 9). Thus, making the water of Ode Lake Potable for the duration of the study period.

Table 9 Categorical classification of water using BISWQI

Year	Season	BISWQI[1]		BISWQI[2]	
		Value	Category	Value	Category
2022	Winter	76	Good	49	Excellent
	Summer	113	Poor	62	Good
	Post-monsoon	79	Good	55	Good
	Overall	90	Good	56	Good
2023	Winter	105	Poor	68	Good
	Summer	104	Poor	49	Excellent
	Monsoon	93	Good	55	Good
	Post-monsoon	61	Good	35	Excellent
	Overall	91	Good	52	Good

[1] WQI based on 'Acceptable Limit' of BIS standard

[2] WQI based on 'Permissible Limit' of BIS standard

Table 10 Pearson correlation matrix

TA	TDS	TH	TSS	TC	WQI[1]	WQI[2]
1						
0.39	1					
.779*	0.59	1				
0.06	-0.29	-0.14	1			
-0.30	0.18	0.15	-0.37	1		
0.65	**.81***	0.68	0.06	-0.26	1	
0.34	0.39	0.27	0.34	-0.44	**.79***	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).
1 WQI based on AL of BIS drinking water standard 2 WQI based on PL of BIS drinking standard

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Parameter	Temp	pH	EC	DO	BOD	COD	Ca	Cl	F	Mg	Na	NO_3	SO_4
Temp	1												
pH	-0.28	1											
EC	0.46	-0.04	1										
DO	0.16	-0.42	-0.50	1									
BOD	0.31	-0.03	0.54	-0.09	1								
COD	0.22	-0.09	0.41	-0.06	**.98****	1							
Ca	0.16	-0.30	0.36	0.07	-0.41	-0.52	1						
Cl	0.20	-0.34	0.48	-0.20	**.86***	**.91****	-0.35	1					
F	0.33	-0.19	0.05	0.73	0.54	0.50	-0.08	0.23	1				
Mg	0.04	-0.16	0.23	0.08	**.90****	**.95****	-0.49	**.88****	0.53	1			
Na	0.21	-0.38	0.42	-0.19	**.82***	**.88****	-0.38	**.99****	0.18	**.86***	1		
NO3	0.47	-0.36	0.18	0.75	0.35	0.27	0.27	0.09	**.92****	0.28	0.04	1	
SO4	0.14	-0.48	0.36	-0.23	0.68	**.74***	-0.30	**.96****	0.03	**.76***	**.98****	-0.08	1
TA	0.01	-0.08	0.29	-0.12	0.73	**.76***	-0.25	**.82***	0.23	**.86***	**.81***	0.04	**.77***
TDS	0.46	-0.11	**.99****	-0.50	0.61	0.51	0.28	0.59	0.05	0.34	0.54	0.15	0.49
TH	0.17	-0.40	0.53	0.14	0.71	0.67	0.20	0.73	0.53	**.755***	0.68	0.52	0.64
TSS	**-.86***	0.58	-0.29	-0.24	0.05	0.10	-0.45	-0.07	-0.10	0.18	-0.11	-0.34	-0.14
TC	0.00	-0.43	0.24	0.05	-0.51	-0.58	**.96****	-0.34	-0.21	-0.51	-0.35	0.15	-0.22
WQI^1	0.30	0.23	**.79***	-0.34	**.87***	**.78***	-0.10	0.67	0.37	0.67	0.60	0.26	0.45
WQI^2	0.11	0.70	0.42	-0.21	0.59	0.48	-0.23	0.17	0.40	0.39	0.09	0.23	-0.10

IV. Conclusion

The present study attempted to give a detailed perspective of water quality status of Ode Lake. Highlights of the study are as following:

- Seasonal variation was observed for the duration of two years. Slight variation was found in most parameters was found. Levels of parameters seemed to increase over time with significant increase in COD, BOD, magnesium, sulphate, total alkalinity, and total hardness from 2022 to 2023. Similar conclusion has been made by (Maansi et al., 2022).
- Most parameters are found within standard limits set be BIS and WHO but fulfil drinking water criteria of DBU for drinking water when compared with best use criteria by CPCB. Coliform and DO being the most deterministic parameters for this conclusion. While water did fulfil the DBU criteria for fisheries and irrigation use.
- Water quality index (BISWQI) was found between range of 61 – 113. Water quality was found to be lowest during summer season and improved during the monsoon and post-monsoon season. Overall water quality index was 90 (SD = 18.9) and water is categorised as ‘Good’. Although being good quality, water is not recommended for drinking purpose before adequate treatment, due to high coliform levels 5968 MPN/100ml (SD = 3387.42). Along with high BOD levels, suggests the organic pollution load in the water of Ode Lake. Main source of pollution in lake seems to be deposition of sewage water and ritualistic waste.
- Regular cleaning of surroundings and fencing of lake periphery is recommended to prevent waste disposal. Water must be treated adequately prior to consumption as drinking water.

References

1. APHA (Ed.). (2017). Standard methods for the examination of water and wastewater (23rd edition). American Public Health Association.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

2. Banda, T. D., & Kumarasamy, M. V. (2020). Development of Water Quality Indices (WQIs):A Review. Polish Journal of Environmental Studies, 29(3), 2011–2021. https://doi.org/10.15244/pjoes/110526
3. Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water: A review. Sustainable Water Resources Management, 2(2), 161–173. https://doi.org/10.1007/s40899-015-0014-7
4. Bhatt, P., & Modi, N. R. (2020). Assessment of Impact of Agriculture on Water Resource Through Water Budgeting. International Journal of Research Culture Society, 4(7), 180–183.
5. Birawat, K. K., T, H., C.Nachiyar, M., N.A, M., & C.V, S. (2021). Impact of urbanisation on lakes—A study of Bengaluru lakes through water quality index (WQI) and overall index of pollution (OIP). Environmental Monitoring and Assessment, 193(7), 408. https://doi.org/10.1007/s10661-021-09131-w
6. Brown, R. M., McClelland, N. I., Deininger, R. A., & O'Connor, M. F. (1972). A water quality index—Crashing the psychological barrier. Indicators of Environmental Quality: Proceedings of a Symposium Held during the AAAS Meeting in Philadelphia, Pennsylvania, December 26–31, 1971, 173–182.
7. Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., Romero, J., Aldunce, P., Barrett, K., Blanco, G., Cheung, W. W. L., Connors, S., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., … Péan, C. (2023). IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. (First, p. 186). Intergovernmental Panel on Climate Change (IPCC). https://doi.org/10.59327/IPCC/AR6-9789291691647
8. Canadian Water Quality Guidelines for the Protection of Aquatic Life. (2017). Canadian Council of Ministers of the Environment. https://ccme.ca/en/res/wqimanualen.pdf
9. Chidiac, S., El Najjar, P., Ouaini, N., El Rayess, Y., & El Azzi, D. (2023). A comprehensive review of water quality indices (WQIs): History, models, attempts and perspectives. Reviews in Environmental Science and Bio/Technology, 22(2), 349–395. https://doi.org/10.1007/s11157-023-09650-7
10. Das Kangabam, R., Bhoominathan, S. D., Kanagaraj, S., & Govindaraju, M. (2017). Development of a water quality index (WQI) for the Loktak Lake in India. Applied Water Science, 7(6), 2907–2918. https://doi.org/10.1007/s13201-017-0579-4
11. Deep, A., Gupta, V., Bisht, L., & Kumar, R. (2020). Application of WQI for water quality assessment of high-altitude snow-fed sacred Lake Hemkund, Garhwal Himalaya. Sustainable Water Resources Management, 6(5), 89. https://doi.org/10.1007/s40899-020-00449-w
12. Designated Best Use Water Quality Criteria. (2019). Central Pollution Control Board. https://cpcb.nic.in/wqm/Designated_Best_Use_Water_Quality_Criteria.pdf
13. Dusaucy, J., Gateuille, D., Perrette, Y., & Naffrechoux, E. (2021). Microplastic pollution of worldwide lakes. Environmental Pollution, 284, 117075. https://doi.org/10.1016/j.envpol.2021.117075
14. Elbaz-Poulichet, F., Guédron, S., Anne-Lise, D., Freydier, R., Perrot, V., Rossi, M., Piot, C., Delpoux, S., & Sabatier, P. (2020). A 10,000-year record of trace metal and metalloid (Cu, Hg, Sb, Pb) deposition in a western Alpine lake (Lake Robert, France): Deciphering local and regional mining contamination. Quaternary Science Reviews, 228, 106076. https://doi.org/10.1016/j.quascirev.2019.106076
15. Fikadu, G. (2022). Determination of Selected physicochemical water quality parameters of the upper stream of Amerti watershed of Western Ethiopia. Environmental Challenges, 8, 100558. https://doi.org/10.1016/j.envc.2022.100558
16. Garg, R. K., Rao, R. J., Uchchariya, D., Shukla, G., & Saksena, D. N. (2010). Seasonal variations in water quality and major threats to Ramsagar reservoir, India. African Journal of Environmental Science and Technology, 4(2). https://www.ajol.info/index.php/ajest/article/view/56323
17. General Standards for Discharge of Environmental Pollutants (Part-A: Effluents). (n.d.). Government of India. Retrieved 30 August 2024, from https://cpcb.nic.in/displaypdf.php?id=R2VuZXJhbFN0YW5kYXJkcy5wZGY=
18. Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda. (2022). World Health Organization. https://www.who.int/publications/i/item/9789240045064
19. Horton, R. K. (1965). An index number system for rating water quality. J Water Pollut Control Fed, 37(3), 300–306.
20. Indian Standard—Drinking Water Specification (Second Revision). (2012, May). Buereu of Indian Standards. https://cpcb.nic.in/wqm/BIS_Drinking_Water_Specification.pdf
21. IS:11624 (1986): Guidelines for the quality of irrigation water. (2001). Buereu of Indian Standards. https://law.resource.org/pub/in/bis/S06/is.11624.1986.pdf
22. Iwar, R. T., Utsev, J. T., & Hassan, M. (2021). Assessment of heavy metal and physico-chemical pollution loadings of River Benue water at Makurdi using water quality index (WQI) and multivariate statistics. Applied Water Science, 11(7), 124. https://doi.org/10.1007/s13201-021-01456-8
23. Kotadiya, N. G., Acharya, C. A., Radadia, B. B., & Solanki, H. A. (2013). Determination Of Water Quality Index and Suitability of a Rural Freshwater Body in Ghuma Village, District Ahmedabad, Gujarat. Life Sciences Leaflets, 36, 68–75.
24. Kucukosmanoglu, A. G., & Filazi, A. (2020). Investigation of the Metal Pollution Sources in Lake Mogan, Ankara, Turkey *. Biological Trace Element Research, 198(1), 269–282. https://doi.org/10.1007/s12011-020-02031-z
25. Lin, L., Yang, H., & Xu, X. (2022). Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review. Frontiers in Environmental Science, 10, 880246. https://doi.org/10.3389/fenvs.2022.880246

26. Maansi, Jindal, R., & Wats, M. (2022). Evaluation of surface water quality using water quality indices (WQIs) in Lake Sukhna, Chandigarh, India. Applied Water Science, 12(1), Article 1. https://doi.org/10.1007/s13201-021-01534-x
27. Maurya RR, Q. U. (2015). Determination of Physico-Chemical Parameters and Water Quality Index (Wqi) of Chandlodia Lake, Ahmedabad, Gujarat, India. Journal of Environmental & Analytical Toxicology, 05(04), Article 04. https://doi.org/10.4172/2161-0525.1000288
28. Panikkar, P., Saha, A., Prusty, A. K., Sarkar, U. K., & Das, B. K. (2022). Assessing hydrogeochemistry, water quality index (WQI), and seasonal pattern of plankton community in different small and medium reservoirs of Karnataka, India. Arabian Journal of Geosciences, 15(1), 82. https://doi.org/10.1007/s12517-021-09291-6
29. Patel, E., & Modi, N. (2018). A review of phytoremediation. Journal of Pharmacognosy and Phytochemistry, 7(4), 1485–1489.
30. Patel, P. S., Pandya, D. M., & Shah, M. (2023). A systematic and comparative study of Water Quality Index (WQI) for groundwater quality analysis and assessment. Environmental Science and Pollution Research, 30(19), 54303–54323. https://doi.org/10.1007/s11356-023-25936-3
31. Population finder | Government of India. (2011). [Government website]. Office of the Registrar General & Census Commissioner, India Ministry of Home Affairs. https://censusindia.gov.in/census.website/data/population-finder
32. Puri, P. J., Yenkie, M. K. N., Sangal, S. P., Gandhare, N. V., Sarote, G. B., & Dhanorkar, D. B. (2011). Surface water (lakes) quality assessment in Nagpur city (India) based on water quality index (WQI). Rasayan Journal of Chemistry, 4(1), 43–48.
33. Ramakrishnaiah, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India. Journal of Chemistry, 6(2), 523–530. https://doi.org/10.1155/2009/757424
34. Rana, R., Ganguly, R., & Gupta, A. K. (2018). Indexing method for assessment of pollution potential of leachate from non-engineered landfill sites and its effect on ground water quality. Environmental Monitoring and Assessment, 190(1), 46. https://doi.org/10.1007/s10661-017-6417-1
35. Ravikumar, P., Aneesul Mehmood, M., & Somashekar, R. K. (2013). Water quality index to determine the surface water quality of Sankey tank and Mallathahalli lake, Bangalore urban district, Karnataka, India. Applied Water Science, 3(1), 247–261. https://doi.org/10.1007/s13201-013-0077-2
36. Rawal, I., Joshi, H., & Chaudhary, B. L. (2018). Water Quality Assessment Using Physicochemical and Bacteriological Parameters of Fateh Sagar Lake, Udaipur, India. Water Resources, 45(3), 427–435. https://doi.org/10.1134/S0097807818030120
37. Reddy, A. G. S. (2023). A review on violation of drinking water specifications in water supply and research publications. Environment, Development and Sustainability, 25(2), 1084–1100. https://doi.org/10.1007/s10668-021-02038-z
38. Samal, P., Mohanty, A. K., Khaoash, S., & Mishra, P. (2023). Hydrogeochemical characteristics and spatial analysis of groundwater quality in a semi-arid region of Western Odisha, India. Arabian Journal of Geosciences, 16(1), 72. https://doi.org/10.1007/s12517-022-11127-w
39. Sawyer, C. N., McCarty, P. L., & Parkin, G. F. (2003). Chemistry for environmental engineering and science. McGraw-Hill. https://dspace.agu.edu.vn/handle/agu_library/4151
40. Shah, A., Arjunan, A., Baroutaji, A., & Zakharova, J. (2023). A review of physicochemical and biological contaminants in drinking water and their impacts on human health. Water Science and Engineering, 16(4), 333–344. https://doi.org/10.1016/j.wse.2023.04.003
41. Sharma, P., Meher, P. K., Kumar, A., Gautam, Y. P., & Mishra, K. P. (2014). Changes in water quality index of Ganges river at different locations in Allahabad. Sustainability of Water Quality and Ecology, 3–4, 67–76. https://doi.org/10.1016/j.swaqe.2014.10.002
42. Sikakwe, G. U., & Ilaumo, B. U. (2021). Contamination of water sources by potentially toxic elements around agricultural and quarry land uses of Oban Massif and environs southeastern Nigeria. Arabian Journal of Geosciences, 14(14), 1325. https://doi.org/10.1007/s12517-021-07647-6
43. Singh, P. K., Panigrahy, B. P., Verma, P., & Kumar, B. (2018). Evaluation of the Surface Water Quality Index of Jharia Coal Mining Region and Its Management of Surface Water Resources. In V. P. Singh, S. Yadav, & R. N. Yadava (Eds.), Environmental Pollution (Vol. 77, pp. 429–437). Springer Singapore. https://doi.org/10.1007/978-981-10-5792-2_34
44. Solanki, H. A., Verma, P. U., & Chandawat, D. K. (2011). Evaluating the Water Quality of Malav Lake by Mean of Physico-Chemical Analysis. Life Sciences Leaflets, 20, 944–945.
45. Syeed, M. M. M., Hossain, M. S., Karim, M. R., Uddin, M. F., Hasan, M., & Khan, R. H. (2023). Surface water quality profiling using the water quality index, pollution index and statistical methods: A critical review. Environmental and Sustainability Indicators, 18, 100247. https://doi.org/10.1016/j.indic.2023.100247
46. UNESCO. (2024). The United Nations World Water Development Report 2024: Water for prosperity and peace. UNESCO World Water Assessment Programme; NS/258/15. https://unesdoc.unesco.org/ark:/48223/pf0000388948.locale=en
47. Vasanthavigar, M., Srinivasamoorthy, K., Vijayaragavan, K., Rajiv Ganthi, R., Chidambaram, S., Anandhan, P., Manivannan, R., & Vasudevan, S. (2010). Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India. Environmental Monitoring and Assessment, 171(1–4), 595–609. https://doi.org/10.1007/s10661-009-1302-1
48. Vasistha, P., & Ganguly, R. (2020). Assessment of spatio-temporal variations in lake water body using indexing method. Environmental Science and Pollution Research, 27(33), 41856–41875. https://doi.org/10.1007/s11356-020-10109-3

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

49. Vasistha, P., & Ganguly, R. (2022). Water quality assessment in two lakes of Panchkula, Haryana, using GIS: Case study on seasonal and depth wise variations. Environmental Science and Pollution Research, 29(28), 43212–43236. https://doi.org/10.1007/s11356-022-18635-y
50. Verma, P., Chandawat, D., Gupta, U., & Solanki, H. (2012). Water Quality Analysis of an Organically Polluted Lake by Investigating Different Physical and Chemical Parameters. International Journal of Research in Chemistry and Environment, 2(1), 105–111.
51. Verma, P. U., Chandawat, D. K., & Solanki, H. A. (2011). Seasonal Variation in Physico-Chemical and Phytoplankton Analysis of Kankaria Lake. Life Sciences Leaflets, 19, 842–854.
52. Verma, P. U., Chandawat, D. K., & Solanki, H. A. (2013). Pollution Status of Nikol Lake Located in Eastern Ahmedabad, Gujarat- India. International Journal of Innovative Research in Science, Engineering and Technology, 2(8), 8.
53. Wilkinson, J. L., Boxall, A. B. A., Kolpin, D. W., Leung, K. M. Y., Lai, R. W. S., Galbán-Malagón, C., Adell, A. D., Mondon, J., Metian, M., Marchant, R. A., Bouzas-Monroy, A., Cuni-Sanchez, A., Coors, A., Carriquiriborde, P., Rojo, M., Gordon, C., Cara, M., Moermond, M., Luarte, T., … Teta, C. (2022). Pharmaceutical pollution of the world's rivers. Proceedings of the National Academy of Sciences, 119(8), e2113947119. https://doi.org/10.1073/pnas.2113947119
54. Zahoor, I., & Mushtaq, A. (2023). Water Pollution from Agricultural Activities: A Critical Global Review. International Journal of Chemical and Biochemical Sciences, 23(1), 164–176.
55. Zaman, M., Shahid, S. A., & Heng, L. (2018). Irrigation Water Quality. In M. Zaman, S. A. Shahid, & L. Heng, Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques (pp. 113–131). Springer International Publishing. https://doi.org/10.1007/978-3-319-96190-3_5