



Physicochemical characterization of Jamnagar district lakes and its correlation with aquatic biodiversity

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Abstract

Lakes within the semi-arid Jamnagar district are vital for regional water security and biodiversity, yet integrated studies linking water quality to biological communities are lacking. This study provides a comprehensive seasonal assessment (April 2024-March 2025) of four lakes subjected to varying anthropogenic pressures. Key physicochemical parameters—including pH, dissolved oxygen, nutrients, turbidity, total dissolved solids (TDS), electrical conductivity (EC), and iron were analysed to compute a Water Quality Index (WQI) and evaluate implications for aquatic biota. Results, benchmarked against WHO and BIS standards, indicate that while most parameters were within acceptable limits, elevated turbidity, TDS, EC, and localized iron contamination were prevalent. One site was notably degraded, with iron concentrations exceeding safe thresholds. Computed WQI values ranged from 63.8 to 81.9, classifying the water as "poor" to "very poor" and ecologically compromised. These conditions pose significant stress: high turbidity and TDS impair photosynthesis and habitat structure, while excess iron introduces toxicological risks. The cumulative impact threatens lacustrine biodiversity across trophic levels. To mitigate further degradation and support ecosystem recovery, urgent implementation of improved wastewater management and the establishment of riparian vegetative buffers is recommended to reduce pollutant influx and enhance natural filtration.

Keywords: Inland lakes, wqi (water quality index), physio-chemical analysis, flora and fauna, ecosystem

Introduction

Water is essential for all life, constituting approximately 70% of the human body and up to 97% of a plant's mass (Bhutiani *et al.*, 2019; Ruhela, 2024) [7, 29]. Nevertheless, freshwater is only accessible in a limited portion of this water (Khan *et al.*, 2014; Ruhela, 2024) [16, 29]. The most significant natural resources are freshwater ecosystems, which include lakes, rivers, and wetlands. These ecosystems offer a range of ecological, social, and economic services in addition to serving as habitats for certain plant, animal, and microbiological life forms (Ahmad Wani *et al.*, 2014; Wakode & Sayyad, 2014) [1, 32]. Because they are less able to self-regulate than lotic systems, lakes are more susceptible to contamination. As a result of urbanization and industry brought about by population growth, there is a significant quantity of groundwater extraction and wastewater production (Bhutiani *et al.*, 2019; Habib *et al.*, 2020; Millier *et al.*, 2010) [7, 14, 22]. True water quality is defined by its precise physical and chemical "recipe" factors like temperature, pH, dissolved oxygen, and nutrient levels. Each aquatic creature is finely tuned to thrive within specific ranges of these conditions. Pollution alters this recipe, causing sensitive species to vanish and tolerant ones to dominate. Therefore, the biological community itself—the presence of a caddisfly larva versus a sludge worm becomes a powerful diagnostic tool, revealing the ecosystem's integrated health and history far beyond a simple chemical test.

Only a tiny portion of this wastewater is treated; the majority is either treated or left untreated to be dumped into freshwater bodies (Bhutiani *et al.*, 2021) [6]. Accelerated nutrient cycling and quicker soil component movement cause the sedimentation rate to increase, which in turn enriches surface water bodies with nutrients and modifies

the composition of aquatic ecosystems (J.C *et al.*, 2008). The abundance of wastes and waste from society in lakes disrupts their hydrology and ecosystem (Das Kangabam *et al.*, 2017; Khan *et al.*, 2014) [11, 16]. Similarly, the dumping of solid and liquid wastes disrupted the geological, biological, chemical, and physical features of Dal and Nigeen Lakes. The variety of human activities in water body catchment areas is typically reflected in the quality of water bodies close to residential areas. Changes in catchment-scale land systems (Rather *et al.*, 2016) [28], untreated sewage discharge (Parvez & Bhat, 2014) [4], urbanization (Ducey *et al.*, 2018; Rashid & Aneaus, 2019b; Wang *et al.*, 2019) [12, 26, 33], acidification (Leach *et al.*, 2019; Moldan *et al.*, 2013) [17, 23], and sediment loading (Rashid & Aneaus, 2019a) [26] are the main causes of the degradation of the water quality (S. A. Bhat & Pandit, 2014) [4] and aquatic biodiversity (S. U. Bhat *et al.*, 2012) [5] of these lakes. As a result, the current study will assess the water quality of Lakhota Lake, which is situated in the centre of Gujarati city of Jamnagar.

Jamnagar District in Gujarat provides a vital real-world case study for examining the impact of human activity on water health. This semi-arid region's lakes, ponds, and reservoirs sustain both ecosystems and communities, yet they exist in close contact with major industries and urban expansion. Iconic sites like Lakhota Lake symbolize the cultural importance of these waters while also facing clear urban pressures. However, a systematic understanding of how different freshwater bodies urban, peri-urban, and rural—compare in terms of water quality and aquatic biodiversity is still largely missing. A comprehensive assessment across the district is needed to truly gauge the ecological consequences of Jamnagar's industrial and agricultural landscape.

This study conducts a comparative analysis of aquatic faunal communities and key physio-chemical parameters in selected freshwater bodies across Jamnagar District, Gujarat. Its objectives are to: (1) assess and compare faunal diversity, density, and distribution; (2) analyse spatial and temporal variations in water quality; and (3) establish interrelationships between faunal assemblages and prevailing conditions. The findings will provide a critical baseline dataset to inform the conservation and sustainable management of the district's freshwater resources amid ongoing developmental pressures.

Materials & Methods

1. Sample Collection and Preservation

Water sampling was conducted through random early morning collection in accordance with standard methods (Manual, 1999)^[19]. Triplicate samples were gathered in pre-washed 2-liter plastic containers, with initial pH measurement performed on-site. For laboratory analysis, samples for heavy metal testing were placed in separate bottles, while all samples were transported for the examination of residual parameters.

The study focuses on Ranmal Lake (Lakhota Lake), a 5 lakh square meter feature in central Jamnagar comprising three sections. Located on the northern Kathiawar Peninsula in Gujarat, the Jamnagar area has a hot, semiarid climate and lies approximately 20 meters above sea level along the Gulf of Kutch. To ensure representative sampling, sites were chosen to cover diverse conditions; the primary sites that characterize the lake's water quality are presented in Table 1 and Figure 1.

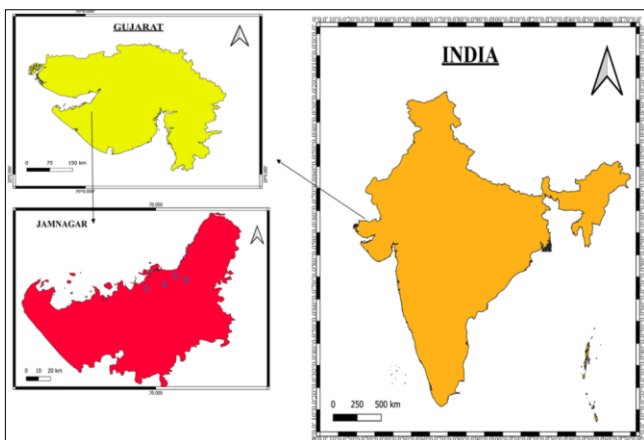


Fig 1: Sampling site's Locations.

Table 1: Sampling sites and its Codes with Latitude and Longitude.

Code	Sample	Latitude	Longitude
Lake- 1	Vibhapar Water	22.4797° N	70.0975° E
Lake-2	Lakhota Water	22.4656° N	70.0645° E
Lake-3	Dhichana Water	22.5772 ° N	69.9986° E
Lake-4	Lakha Baval	22.6559° N	70.3250° E

2. Water sampling and Physio-Chemical Analysis

The water samples were collected in the sampling bottles. Parameters like temperature, conductivity, total dissolved solid, total alkalinity, salinity, pH, dissolved oxygen were analysed on the spot. For other parameters, a water sample was brought to the laboratory for further analysis. Standard methods and protocols were used to analyse water the

Physio-chemical parameters (APHA-AWWA-WPCF, 2012).

3. Water quality index (WQI)

The purpose of the water quality index calculation is to translate complicated data on water quality into information that the general public can use and comprehend. According to Cude (2001) and Brown *et al.* (1970)^[8, 10], the weighted arithmetic index approach was utilized in the present study to construct the water quality index (WQI) (Brown, R.M 1970; Cude, 2001)^[8, 10]. The WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

$$WQI = \frac{\sum QiWi}{\sum Wi}$$

Where; Qi = Quality rating; ■ WI = Relative weight

The WQI is often specified for a particular and intended use of water. The WQI was taken into account in this study for purposes or consumption by humans, and the highest score that could be given to drinking water was 100 (Table 2).

Table 2: Water quality index (WQI) and its status according to Chatterjee and Raziuddin (2002)

Water quality Index Level	Water Quality Status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for Drinking purpose

Results and Discussion

1. Sampling

The geographic coordinates of the four lakes, situated within a ~35 km radius in western India, reveal a spatial pattern that critically informs their starkly divergent water chemistries. The close proximity and similar moderate ionic profiles of Lakes-1 (Vibhapar) and -2 (Lakhota) indicate shared geology and anthropogenic influences within a common sub-catchment near Jamnagar. In contrast, the distinct northwest location of Lake-3 (Dhichana) aligns with its hyper-saline, brackish character, suggesting a separate hydrological basin influenced by saline groundwater, evaporative concentration, or intense local salinization. Similarly, the isolated north-eastern position of Lake-4 (Lakha Baval) correlates with its uniquely severe chemical oxygen demand, implicating a distinct watershed subject to point-source industrial or municipal pollution. This spatial analysis confirms that the extreme impairments in Lakes-3 and -4 are not regional anomalies but are driven by highly localized watershed-specific factors be they geological or anthropogenic necessitating targeted, site-specific remediation strategies rather than a uniform regional management approach.

2. Results of Physio-Chemical Analysis of Water Samples

The mean value of the physio-chemical parameters (Table 3) of samples were compared with BIS standard (IS10500:2012)^[2] parameters for drinking water quality. The result revealed that the domestic waste and sewage were the main source of water pollution. The water of these

ponds was used for washing clothes, drinking of cattle, bathing purpose. The result revealed that this was not suitable for bathing and drinking but in most of the ponds the production is good and several species inhabit this region. The results also revealed that most of the physio-chemical parameters were good for fish culture but the value of physio-chemical parameters indicated that this water is not suitable for drinking purpose. The physio-chemical parameters and their range value of these ponds was as follows:

2.1 pH

The pH across all four lakes was consistently circumneutral, ranging from 7.35 in Lake-1 to 7.75 in Lake-3, with Lakes-2 and -4 displaying intermediate values. All measurements fall within the optimal range (pH 6.5-9.0) for freshwater biota, indicating well-buffered systems as illustrated in Figure 2(I). The minor but systematic variation likely stems from localized differences in biogeochemical processes like primary productivity or groundwater inputs. The absence of extreme pH conditions points to stable, resilient aquatic habitats with a low risk of pH-related ecological stress.

2.2 TDS

Electrical conductivity (EC) measurements delineated two distinct hydro-chemical regimes among the studied lacustrine systems. As per illustrated Figure 2(III) Lakes L-1 (Vibhapar), L-2 (Lakhota), and L-4 (Lakha Baval) formed a homogeneous cluster with moderate EC values ranging from 1033 to 1180 $\mu\text{S}/\text{cm}$, characteristic of typical freshwater environments. In pronounced contrast, Lake L-3 (Dhichana) exhibited a substantially elevated EC of 7520 $\mu\text{S}/\text{cm}$, exceeding the other systems by a factor of approximately 6 to 7. This order-of-magnitude difference classifies L-3 as a high-salinity or brackish system, indicating a fundamentally distinct ionic composition. Given the circumneutral pH observed across all sites, the pronounced ionic strength in L-3 is likely attributable to elevated concentrations of neutral salts, such as sodium chloride or sulphates, rather than contributions from strong acids or bases. This hydro-chemical disparity suggests a divergent hydrological or geogenic origin, potentially driven by saline groundwater intrusion, intense evaporative concentration, or historical anthropogenic salinization.

Corresponding total dissolved solids (TDS) concentrations provide a direct measure of mineralization. In alignment with EC trends, TDS values at all sampling locations exceeded the Bureau of Indian Standards (BIS) permissible limit of 500 mg/L for drinking water. The recorded values are also notably higher than ranges previously reported for freshwater systems in other regions (e.g., 514.0-549.3 mg/L in the NCR). As established, EC serves as a robust proxy for dissolved ionic content, directly reflecting a water body's mineralization state (Mayanglambam & Neelam, 2022) [20]. Consequently, the exceptionally high EC and TDS in L-3 confirm its severely degraded condition, rendering it unsuitable for potable use as per WHO (2011) aesthetic guidelines, which classify water with TDS > 1000 mg/L as unpalatable.

2.3 Total Hardness

Based on the total hardness data, the suitability of the lakes for aquaculture diverges sharply. Lakes-1, -2, and -4 exhibit moderate hardness (190-350 mg/L). While these levels

exceed the optimum for fish culture (75-150 mg/L) and approach stressful thresholds, they still constitute a sub-optimal yet viable environment for hardy species. In stark contrast, Lake-3 demonstrates extreme hardness (~2097 mg/L), an order of magnitude higher than the others as illustrated in Figure 2(II). This concentration far surpasses lethal limits for most freshwater fish, creating an uninhabitable environment due to ionic stress. This finding, combined with its previously noted exceptional conductivity, confirms Lake-3's classification as a saline, mineral-rich system with a fundamentally different geology. It is categorically unsuitable for conventional freshwater aquaculture. All sampled waters remain unfit for human consumption due to prior indications of sanitary contamination.

2.4 Turbidity

The comparative analysis of turbidity across the four lakes revealed a strong positive correlation ($r \approx 0.96$) between two measurement methods, confirming they consistently tracked the same underlying water clarity gradient illustrated in Figure 2(IV). This gradient increased progressively from Lake-1 to Lake-4, likely reflecting a rise in sediment loading or algal productivity. Near-perfect agreement between methods was found for Lakes-1 and -4, indicating high consistency at the spectrum's extremes. However, a notable deviation occurred in Lake-2, where one method recorded a higher turbidity. This site-specific anomaly suggests a potential influence from localized factors, such as differences in particle composition (e.g., organic matter) or brief sediment resuspension during one sampling event. While the strong correlation supports the general reliability of the monitoring methods, the discrepancy in Lake-2 underscores that accurate inter-site comparisons require careful consideration of particle characteristics, instrument calibration, and exact sampling conditions. Menberu *et al.* (2021) [21] noted that Hawassa Lake's turbidity levels ranged from 4.0 to 16.0 NTU (Menberu *et al.*, 2021) [21].

2.5 Chloride

Chloride (Cl^-) functions as an essential micronutrient and catalytic cofactor in photosynthesis. It is critically involved in the water-splitting reaction of Photosystem II and supports osmotic and electrochemical balance in autotrophic organisms. Based on the chloride concentration data, a definitive environmental contrast is established. Lake-3 exhibits exceptionally high chloride levels (~1645-1676 mg/L), nearly an order of magnitude greater than the other lakes. This extreme concentration is a clear indicator of major anthropogenic salinization, likely from prolonged road salt application or industrial discharge, categorizing it as a salinity-impaired system with severe ecological implications. In contrast, Lakes-1, -2, and -4 form a distinct group with significantly lower chloride concentrations, ranging from approximately 166 to 189 mg/L in Lake-4 as illustrated in Figure 2(V). While a very strong correlation ($r \approx 0.999$) between measurement methods confirms the overall spatial pattern, proportional discrepancies for these lower-concentration lakes highlight the need for rigorous quality control. Variations may arise from analytical precision differences, sample matrix effects, or real temporal changes, such as dilution from runoff. Therefore, accurate trend assessment for monitoring programs in these waterbodies requires careful checks for matrix interference and verification of temporal stability.

2.6 Total Alkalinity

Of the four lakes, alkalinity measurements reveal a stark contrast in buffering capacity and geological influence. As per Figure 2(VI) Lake-1 possesses by far the greatest alkalinity (~426.5 mg/L CaCO₃), indicating a watershed dominated by carbonate-rich bedrock, such as limestone, which provides a high resistance to acidification and pH fluctuations. In contrast, Lakes-2, -3, and -4 exhibit moderately low to low alkalinity, with Lake-3 being the lowest at ~97.6 mg/L CaCO₃. This suggests catchments with igneous or silicate-based geology, making these systems more sensitive to acidification from atmospheric deposition or organic acids. The extremely strong correlation ($r \approx 0.999$) between measurements confirms this spatial pattern is robust, with minor discrepancies attributable to typical methodological variance. The gradient from high to low alkalinity has direct ecological implications: Lake-1 is a well-buffered, stable habitat, while the lower-alkalinity lakes are more vulnerable to episodic acidification, which can stress aquatic biota and alter nutrient chemistry. This analysis underscores watershed geology as the primary control on lake chemistry and highlights alkalinity as a key indicator of a lake's susceptibility to acidification.

2.7 Bicarbonate

Analysis of bicarbonate concentrations reveals a pronounced chemical gradient driven by watershed geology. Lake-1 exhibits exceptionally high levels (~422.5-426.5 mg/L HCO₃⁻), indicating a catchment dominated by carbonate rock weathering (e.g., limestone), which provides a strong, inherent buffering capacity against acidification. In contrast, Lakes 2, 3, and 4 have significantly lower bicarbonate concentrations (94.95-159.6 mg/L) illustrated in Figure 2(VII), suggesting watersheds with silicate-based geology or greater influence from organic acids. This results in a much lower acid-neutralizing capacity. The very strong correlation ($r \approx 0.97$) between measurements confirms the robustness of this spatial pattern. The ecological implication is clear: Lake-1 is highly resistant to pH fluctuations from acid deposition, while the other lakes are more vulnerable. This acidification sensitivity can stress aquatic life by altering nutrient availability and increasing metal toxicity. The data underscores that catchment geology is the primary control on a lake's carbonate chemistry and its resilience to anthropogenic disturbance.

Calcium and magnesium bicarbonate were the main contributors to the hardness, as shown by their strong positive associations. Since the kind of rock has a major influence on the calcium and magnesium contents (Azis Aziz *et al.*, 2019)^[3], the schist rocks in the catchment serve as the main source of calcium in the springs. When assessing the suitability of groundwater for residential, commercial, and agricultural uses, total hardness is a crucial criterion to consider (Lu *et al.*, 2024).

2.8 Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand (BOD) data reveals a stark contrast in organic pollution among the lakes. As per Figure 2(VIII) Lake-3 exhibits exceptionally high BOD (65.2-67.75 mg/L), indicating a severe load of biodegradable organic matter from sources like wastewater or agricultural runoff. This poses a major threat to dissolved oxygen and aquatic life, risking hypoxic conditions. In contrast, Lake-4 shows negligible BOD, consistent with

oligotrophic, unpolluted conditions. Lakes 1 and 2 display moderate, variable BOD levels (0-16.8 mg/L), suggesting localized or periodic organic inputs requiring monitoring to prevent deterioration. The analysis identifies Lake-3 as critically impacted, necessitating urgent source identification and mitigation to address its high oxygen demand and prevent ecosystem degradation. The other lakes represent a range from stable, low-nutrient conditions to systems warranting vigilant oversight. Dissolved oxygen levels in the aquatic environment between 5.0 and 8.0 mg/l have been shown to be sufficient for the survival and growth of flora and animals (Garg *et al.*, 2010)^[13]. The BOD test is used to determine whether water contains organic materials. To put it simply, it is the oxygen that aquatic microbes require to decompose the organic matter in the water body that is biodegradable (Santos *et al.*, 2008; Sharma, 2013)^[30, 31].

2.9 Chemical Oxygen Demand (COD):

The amount of organic matter in water that is both biodegradable and non-biodegradable is measured by the COD (Khan *et al.*, 2014)^[16]. Since COD is a quicker test than BOD, it is recommended over BOD (Sharma, 2013)^[31]. As per illustrated in Figure 2(IX) of the four lakes, Chemical Oxygen Demand (COD) analysis identifies Lake-4 as critically distinct, exhibiting an exceptionally high oxidizable material load (205.06-207.6 mg/L). This value is approximately five times greater than the moderate and uniform levels found in Lakes 1-3 (38.55-47.95 mg/L). The extreme elevation in Lake-4 signals a major, chronic anthropogenic input, likely from sources such as untreated wastewater, intensive aquaculture effluent, or polluted urban/agricultural runoff. The ecological implication is severe, as the oxidation of this substantial load can rapidly deplete dissolved oxygen, create anoxic conditions, and release harmful substances, fundamentally degrading ecosystem health and biodiversity. In contrast, the COD in Lakes 1-3 suggests comparable baseline levels of natural organic matter with minimal acute pollution influence. The excellent analytical precision, confirmed by near-identical duplicate measurements across all sites, validates this stark disparity as a real feature of the lakes' chemistry. The findings necessitate immediate investigation and remediation of pollution sources in Lake-4, while management for Lakes 1-3 should focus on protective measures to prevent a similar trajectory of degradation.

The decomposition of plant matter and agricultural runoff have an impact on the nitrogen concentration of surface water bodies. Nitrate is a biomarker of organic pollution that may be found in fertilizers, atmospheric precipitation, agricultural residues, decaying organic waste, and septic tanks (Khan *et al.*, 2014; Ramakrishnaiah *et al.*, 2009)^[16, 25].

3. Water Quality Assessment Based on the Water Quality Index (WQI):

The Water Quality Index (WQI) is a widely applied analytical tool for evaluating the suitability of groundwater for human consumption. In this study, the integrated water quality was quantified using eight physicochemical parameters: pH, Total Dissolved Solids (TDS), Total Hardness (TH), Chloride (Cl⁻), Sulfate (SO₄²⁻), Nitrate (NO₃⁻), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). The permissible limits prescribed by the Bureau of Indian

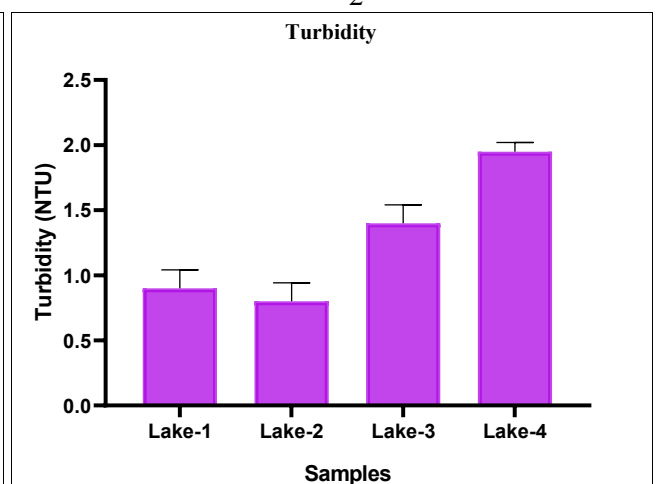
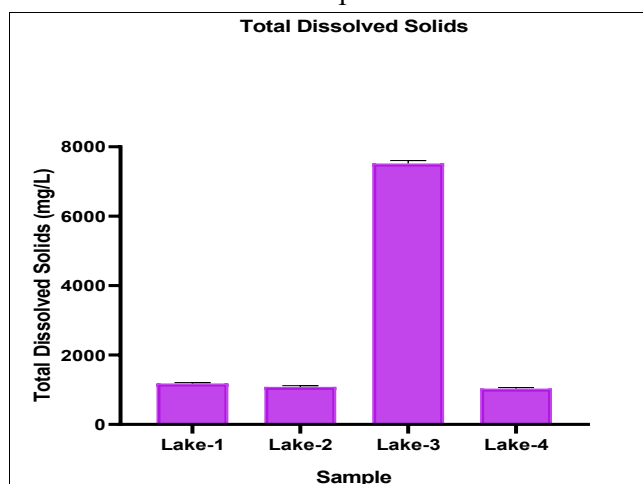
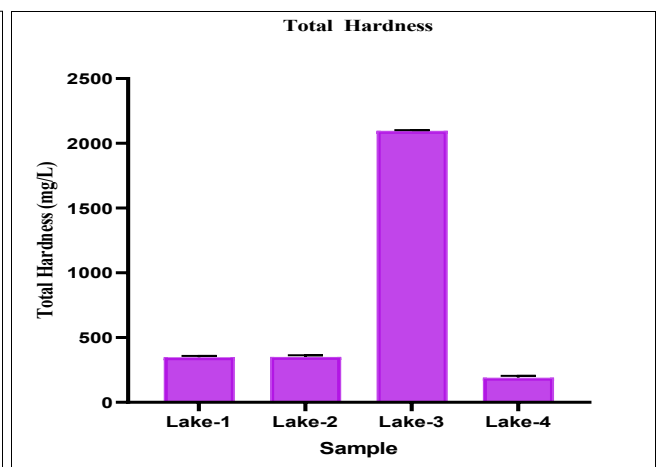
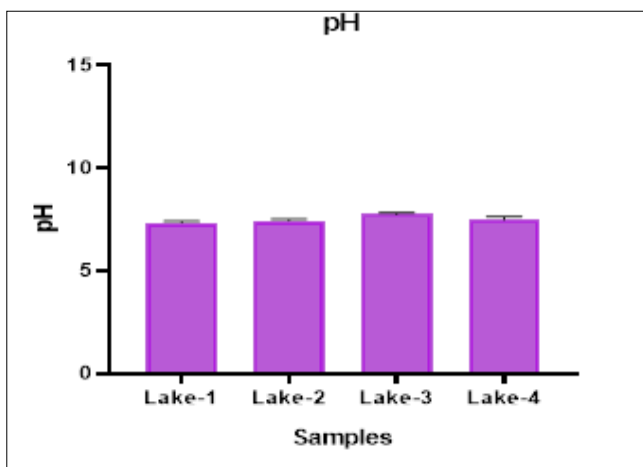
Standards (BIS) for drinking water were adopted as the reference values for index calculation. The WQI was computed using the weighted arithmetic index method (Brown *et al.*, 1972). Among all measured parameters, pH exhibited the highest quality rating (Qi) and was consequently treated as a criterion pollutant across all sampling locations. Based on the classification scheme proposed by Chatterjee and Raziuddin (2002), the groundwater quality was categorized into five distinct classes: (I) excellent (WQI 0-25), (II) good (WQI 26-50), (III) poor (WQI 51-75), (IV) very poor (WQI 76-100), and (V) unsuitable for drinking purpose (WQI > 100). The calculated indices and corresponding classifications for each

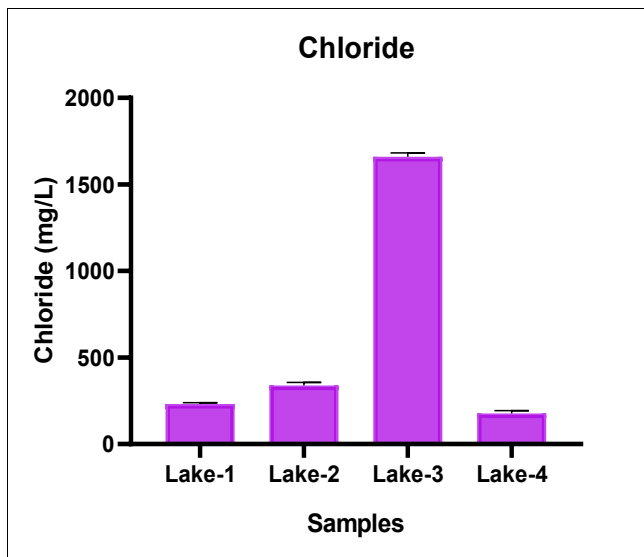
Sampling site are presented in Table 4 and illustrated spatially in Figure 3. The calculated Water Quality Index (WQI) values across the investigated sites ranged from 42 to 115. According to the established classification (Chatterjee & Raziuddin, 2007)^[9], this range indicates that the water quality at most sites falls within the poor category (WQI 51-75). An exception was observed at Lake 3, where the recorded WQI of 115 categorizes the groundwater as Unsuitable for Drinking Purpose (WQI >100). Consequently, the Inland water across the study area is unsuitable for direct human consumption without prior treatment.

Table 3: Physiochemical Analysis of Water samples.

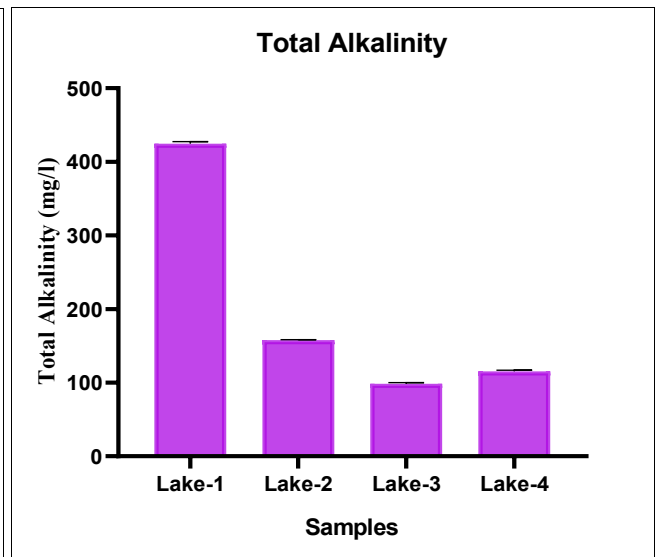
Sr. No.	Parameters	Units	Samples			
			Lake-1	Lake-2	Lake-3	Lake-4
1	pH	----	7.3	7.3	7.5	8.3
2	Total Dissolved Solids (TDS)	mg/L	1160	1060	7580	660
3	Total Hardness	mg/L	340.79	340.80	2094.11	180.71
4	Turbidity	NTU	0.8	0.7	1.3	2.0
5	Odour	----	Agreeable	Agreeable	Agreeable	Agreeable
6	Electric Conductivity	mS/cm ³	2.43	2.35	15.79	1.24
7	Chloride	mg/L	226.52	327.20	1676.00	166.11
8	Total Alkalinity	mg/L	422.0	158.25	94.95	116.05
9	Nitrate	mg/L	ND	ND	ND	ND
10	Bicarbonate	mg/L	422.0	158.25	94.95	116.05
11	Acidity	mg/L	0.00	0.00	0.00	0.00
12	Chemical Oxygen demand (COD)	mg/L	45.23	41.12	205.60	16.48
13	Biochemical Oxygen Demand (BOD)	mg/L	14.86	13.90	67.78	BDL

BDL= Below Detection Limit

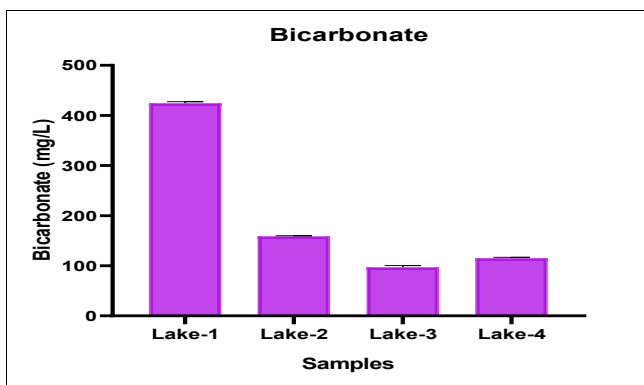




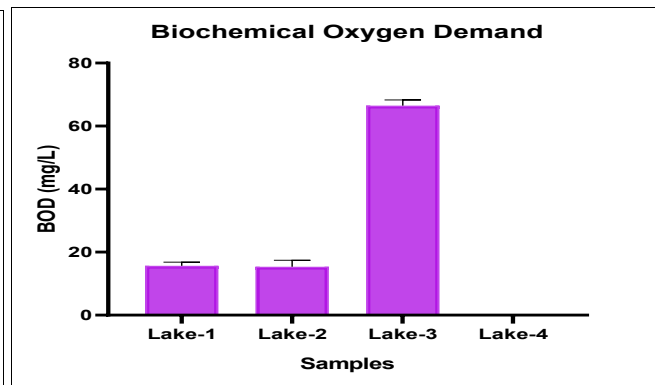
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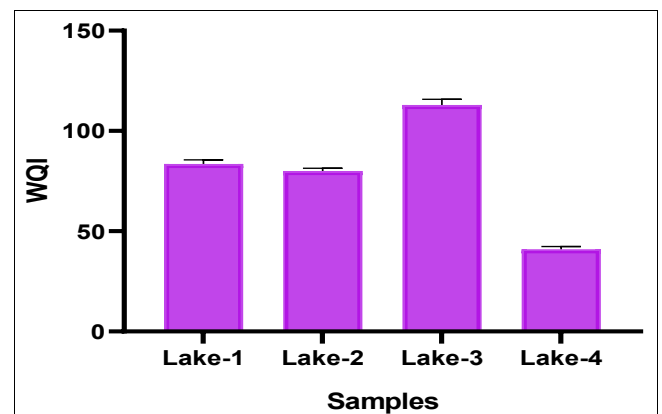
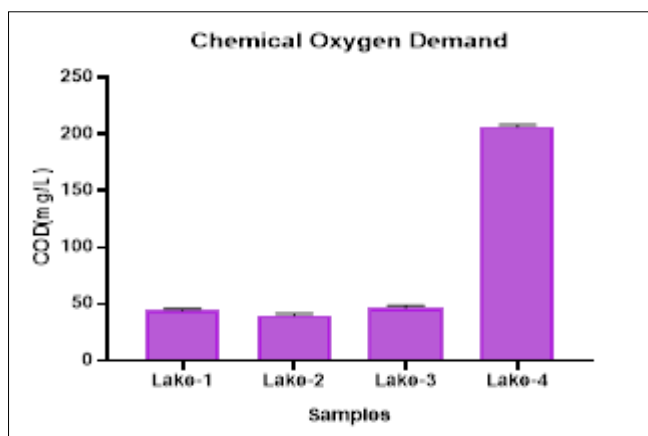


Fig 3: Water Quality Assessment Based on the Water Quality Index

Fig 2: Various Parameters of Physio-chemical analysis of Inland water samples of Jamnagar districts. (I) pH, (II) Total Hardness, (III) TDS, (IV) Turbidity, (V) Chloride, (VI) Total Alkalinity, (VII) Bicarbonate, (VIII) BOD & (IX) COD.

Table 4: Water Quality Assessment Based on the Water Quality Index (WQI):

Sample Code	Samples	WQI	Quality Status
Lake- 1	Vibhapar Water	82	Very Poor
Lake-2	Lakhota Water	79	Very Poor
Lake-3	Dhichana Water	115	Unsuitable for Drinking Purpose
Lake-4	Lakha Baval	42	Good

Conclusion

This investigation provides a comprehensive physicochemical assessment of four inland lakes within the Jamnagar District, delineating their current limnological status and implications for ecosystem health. While a circumneutral pH is maintained across the systems, supporting basic biotic functions, significant water quality degradation driven by anthropogenic pressures is evident. Marked spatial variability reflects divergent watershed characteristics and pollution sources. Vibhapar Lake and Lakhota Lake exhibit moderate eutrophication and mineralization, with elevated TDS, hardness, chloride, and

BOD rendering the water non-potable without treatment. Dhichana Lake emerges as a critically impaired, hypereutrophic system, characterized by extreme salinity, conductivity, and organic loading, classifying it as unsuitable for human consumption or conventional aquaculture. In contrast, Lakha Baval Lake demonstrates comparatively better conditions, achieving a "good" Water Quality Index (WQI) rating, though an elevated COD signals persistent, localized oxidative contamination requiring continued monitoring. The computed WQI values (range: 42-115) categorize most lakes as "poor" to "very poor," with one deemed "unsuitable for drinking." This quantifies the substantial stress from untreated sewage, domestic waste, agricultural runoff, and industrial discharges. Resultant physicochemical alterations including habitat degradation, hypoxic conditions, and ionic stress pose a clear threat to aquatic biodiversity. These findings underscore the urgent need for targeted, lake-specific management over uniform approaches. Critical interventions must prioritize catchment-scale pollution control, enhanced wastewater treatment, riparian buffer restoration, and institutionalized monitoring using integrated indices like the WQI. The generated baseline data constitute a vital scientific foundation for policymakers and environmental managers in developing sustainable conservation and restoration frameworks for the region's freshwater resources.

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