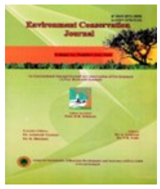
Environment Conservation Journal 25 (2):604-610, 2024

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Water quality assessment of Lakhota Lake, Jamnagar, Gujarat, India, with special reference to the water quality index (WQI)

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ARTICLE INFO

Received : 10 February 2024
Revised : 02 April 2024
Accepted : 20 April 2024

Available online: 05 May 2024

Key Words:
Contamination
Heavy metals
Lakhota Lake
Organic matter
Wastewater
WQI

ABSTRACT

The present study was carried out to assess the water quality of Lakhota Lake. Objective water samples from five different sites were collected and analyzed from January 2023 to December 2024. Furthermore, the data obtained were processed to calculate the water quality index (WQI). The values obtained were compared with the guidelines for drinking purposes suggested by the World Health Organization and Bureau of Indian Standard. The results revealed that all the studied parameters were within the permissible limits except turbidity, TDS and EC, which exceeded the permissible limits. Among all the sites, site 5 was more heavily polluted than all the other sites. Among the heavy metals, iron was found above the permissible limits at Site 3, Site 4 and Site 5. Eight water quality parameters were used in the WQI approach to estimate the integrated groundwater quality. The WQI values ranged from 63.8 to 81.9, indicating that the Lakhota Lake water is not suitable for drinking water, including water from both humans and animals. At sites 1-4, the WQI falls in the poor category, while at site 5, it falls under the very poor category. There is a need for proper wastewater management in and around Lakhota Lake to protect the water quality and aesthetic properties of the lake. It is finally suggested that vegetation should also be planted at the boundaries of the lake, which will work as a natural purifier for the water of the lake.

Introduction

Water makes up 70% of the body weight of humans and 97% of the body weight of plants, and as such, it is necessary for all living things to survive (Bhutiani *et al.*, 2019). Nevertheless, freshwater is only accessible in a limited portion of this water (Khan *et al.*, 2014). 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 (Wani *et al.*, 2014; Wakode and Sayyad, 2016). 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 (Miller *et al.*, 2010; Bhutiani and Ahamad, 2018; Habib *et al.*, 2020). 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.*, 2017). 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 (Akan *et al.*, 2008). The abun-

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Doi:https://doi.org/10.36953/ECJ.27782024

dance of wastes and waste from society in lakes disrupts their hydrology and ecosystem (Khan *et al.*, 2014; Das *et al.*, 2017). 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), untreated sewage discharge (Parvez and Bhat, 2014), urbanization (Rashid *et al.*, 2017; Ducey *et al.*, 2018; Wang *et al.*, 2019), acidification (Moldan *et al.*, 2013; Leach *et al.*, 2019), and sediment loading (Rashid and Aneaus, 2019) are the main causes of the degradation of the water quality (Bhat and Pandit, 2014) and aquatic biodiversity (Bhat *et al.*, 2012) of these lakes. As a result, the current study will assess the water quality of Lakhota Lake, which is situated in the center of Gujarati city of Jamnagar.

Materials and methods

Three sections make up the 5 lakh square meter Ranmal Lake (also known as Lakhota Lake), which is located in the center of Jamnagar. At an elevation of approximately 20 m above mean sea level, the district of Jamnagar is situated in Gujarat, on the northern Kathiawar Peninsula in western India, along the Gulf of Kutch coast. The climate in Jamnagar is hot and semiarid. The present sampling sites were selected to cover a wide range of variables, and key sites that represent the water quality of the lake sample collection sites are shown in Table 1 and Figure 1.

Table 1: Selected sites for water quality assessment of Lakhota Lake, Jamnagar, Gujarat, India

SN	Sampling site	Code given	Coordinates
1	Siddhivinayak Plaza, Government Colony	Site-1	Lat-22.466754, Long-70.060446
2	Near Jamnagar Municipal Park, Summair Club Road	Site-2	Lat-22.464223, Long-70.062112
3	Government Colony	Site-3	Lat-22.465742, Long-70.066487
4	Shri Kalindi Coal Company, Bedeshwar	Site-4	Lat-22.466192, Long-70.06673
5	Shankar Tekri Main Road, Vallabh Nagar	Site-5	Lat-22.468979, Long-70.058541

Figure 1: Map showing sampling locations of the study area

Sample collection and preservation

Triplicate water samples were collected early in the morning by random sampling. Throughout the course of the investigation, samples were collected in 2-liter prewashed plastic containers. At this location, the pH was measured. Subsequently, the specimens were moved to the laboratory to examine the residual parameters. Samples were collected in different bottles for the investigation of heavy metals. In accordance with accepted practices, the parameters were examined (APHA 2018).

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), the weighted arithmetic index approach was utilized in the present study to construct the water quality index (WQI). The WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

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

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 Chaterjee 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

Results and Discussion

Inland ecosystems are important because they supply drinking water, recharge the groundwater system, maintain water quality by trapping sediments, retain and recycle nutrients and remove toxins. The analysis of the physical and chemical parameters of the lake water provided considerable insight into the water quality of Lakhota Lake, and the present study identified the parameters responsible for degrading the water quality. The average values of the physicochemical parameters obtained during the course of the study of Lakhota Lake are presented in Table 3.

The suspended particles in the water are the cause of turbidity. Surface water bodies became murkier due to runoff from unclean roads, soil erosion, and the disposal of household and industrial wastewater. Site -1 had the lowest turbidity (9.8 NTU±2.3) during the research period, while Site-5 had the highest turbidity (15.4 NTU±2.7). The average turbidity in the lake was 11.8 NTU±2.2. The increased turbidity levels in surface water bodies are also a result of the active breakdown of organic materials. High turbidity values hinder light from penetrating the lake. Menberu *et al.* (2021) noted that Hawassa Lake's turbidity levels ranged from 4.0 to 16.0 NTU. The total dissolved ionic concentration is known as the total dissolved solids (TDS). The presence of ions, mainly calcium, magnesium, bicarbonates, and chloride, together with the total alkalinity and total hardness, is responsible for the total dissolved solids load. in close association with electrical conductivity (EC). TDSs consist mostly of inorganic salts dissolved in water, including bicarbonates, chlorides, sulfates, potassium, sodium, magnesium, and minor quantities of organic material. It represents the flavor of groundwater. In accordance with the WHO (2011) guidelines, drinking water is deemed pleasant if the total dissolved solids (TDS) concentration is less than 600 mg/l; if the TDS concentration exceeds 1000 mg/l, it is deemed unappealing. Water conductivity increases in response to an increase in dissolved solids. Throughout the research period, the TDS averaged 757.2 mg/l ±10.3, with the minimum TDS (753.6 mg/±26.5) recorded at Site-1 and the maximum TDS (774.8 mg/l ±16.8) recorded at Site-5. The TDS was shown to be higher than the BIS standard limit (500 mg/l) at every study location. The values obtained surpassed the range (514.0–549.3 mg/l) found in the NCR region reports by Singh and Tripathi (2016) and Agarwal *et al.* (2019). Large amounts of organic and inorganic trash were brought to the lake by rainwater, where they were partially dissolved and partially not. According to Mayanglambam and Neelam (2022), electrical conductivity (EC) measures how much water-soluble product is present in an environment and hence its mineralization state. The winter months were determined to have the greatest EC since there was less water intake and less bacterial breakdown. There were consistent decreases in electrical conductivity levels during the wet season, which may have been caused by dilution from precipitation. In summary, there was a gradual decrease in bacterial decomposition and nutrient uptake. It has been proposed that elevated specific conductivity readings are a sign of a high trophic level (Mayanglambam and Neelam, 2022). Many employees associated increased electrical capacity with enrichment. During the study period, the average conductivity was 1113.5 µS/cm±15.1, and the lowest average EC (1108.2 µS/cm±38.9) was detected at Site-1, while the greatest EC (1139.4 µS/cm±24.8) was identified at Site-5. pH is the negative log of the hydrogen ion concentration. The intensity of the acidic or basic solution is indicated by the water's pH. It establishes water corrosivity and typically has no direct effect on human health (WHO 2011). The pH of water is influenced by the local geology, atmospheric precipitation, and human activity type. Site 1 (7.4) had the highest pH over the research period, while all other sites (2 to 5) had pH values of 7.5 but with varying standard deviations. The pH was found to be between 6.5 and 8.5, which is the BIS limit.

Table 3: Average values of all the parameters at all the selected sites

Parameters/Site	Site-1	Site-2	Site-3	Site-4	Site-5	Average± SD
Turbidity	9.8±2.3	10.4±3.0	11.2±2.4	12.2±1.9	15.4±2.7	11.8±2.2
TDS	753.6±26.5	750.0±22.9	750.4±20.9	757.0±15.3	774.8±16.8	757.2±10.3
EC	1108.2±38.9	1102.9±33.7	1103.5±30.8	1113.2±22.5	1139.4±24.8	1113.5±15.1
pH	7.4±0.1	7.5±0.1	7.5±0.0	7.5±0.0	7.5±0.0	7.5±0.0
TH	271.2±13.3	269.4±11.6	271.0±9.0	277.8±7.7	295.0±8.7	276.9±10.6
Chloride	71.2±4.5	71.8±3.8	73.4±2.8	78.0±4.5	81.0±3.2	75.1±4.2
DO	5.7±0.5	5.5±0.4	5.5±0.5	5.4±0.5	4.6±0.4	5.3±0.4
BOD	8.2±0.8	8.6±0.7	8.5±0.8	8.9±0.9	10.1±0.5	8.9±0.8
COD	46.3±2.1	46.8±1.7	48.7±2.9	50.1±2.1	50.8±4.4	48.5±2.0
Sulphate	83.8±3.4	83.4±2.4	83.9±2.9	82.5±3.1	76.5±1.8	82.0±3.1
Nitrate	11.9±0.4	11.7±0.2	11.8±0.2	11.6±0.2	12.4±0.2	11.9±0.3
Phosphate	3.9±0.4	3.9±0.5	3.9±0.5	3.6±0.5	4.2±0.1	3.9±0.2
Copper	0.026±0.006	0.027±0.006	0.028±0.007	0.028±0.005	0.030±0.004	0.028±0.001
Zinc	3.8±1.0	3.8±0.9	3.9±0.8	3.8±0.5	3.5±0.5	3.752±0.169
Iron	0.28±0.05	0.29±0.04	0.31±0.03	0.31±0.03	0.30±0.03	0.296±0.014
Lead	0.004±0.002	0.004±0.001	0.003±0.001	0.003±0.001	0.005±0.001	0.004±0.001

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 (Aziz *et al.*, 2019), 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 (Fuentes *et al.*, 2022). At SS-02, the lowest average TH of 269.4 mg/l ±11.6 was detected, while the highest value of 295.0 mg/l ±8.7 was detected, and the average value detected was 276.9 mg/l ±10.6. Chloride is necessary for autotrophic photophosphorylation processes and plays a metabolic role in photosynthesis.

A water body's high chloride concentration is indicative of its level of pollution, particularly in regard to sewage inputs. This demonstrates that there is more pollution at the location. The higher chloride value in 2020 could be linked to greater evaporative water volume decreases caused by the quantity of salt. The average chloride concentration was 75.1 mg/l ±4.2 mg/l, with the minimum (71.2 mg/l±4.5) found at Site-1 and the highest (81.0 mg/l±3.2) found at Site-5. Dissolved oxygen is vital to all living organisms and allows a deeper exploration of the fundamental components of water systems. Dissolved oxygen (DO) levels are influenced by a number of factors, including water temperature, water disturbance, types and quantities of aquatic plants, light penetration, and amounts of dissolved or suspended materials, such as organic matter. 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 (Rao *et al.*, 2000). During the study period, the average DO concentration was 5.3±0.4 mg/l, with a minimum of 4.6±0.4 mg/l and a maximum of 5.7±0.5 mg/l at Site-1. 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 *et al.*, 2013). During the study period, the average BOD was 8.9 mg/l ±0.8, with the minimum recorded at Site-1 and the maximum at Site-5, both at 10.1 mg/l±0.5.

The amount of organic matter in water that is both biodegradable and non biodegradable is measured by the COD (Khan *et al.*, 2014). Since COD is a quicker test than BOD, it is recommended over BOD (Sharma *et al.*, 2013). The minimum average COD (46.3 mg/l ±2.1) was found at Site-1, the maximum value (50.8 mg/l±4.4) was found at Site-5, and the average COD was 48.5 mg/l±2.0 during the study period. The reasons for sulfate in surface water include the use of sulfate-rich fertilizers and the dumping of business and residential waste. The excess sulfate content in the research region is indicative of heavy industrial activity and human activities. The lowest amount of sulfate (76.5 mg/l±1.87) was detected at Site 5, the highest amount (83.8 mg/l±3.4) was detected at Site 1, and the average amount was 82.0 mg/l±3.1. 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 (Ramakrishnaiah *et al.*, 2009; Khan *et al.*, 2014).

The average sulfate concentration was 11.9 mg/l±0.3 mg/l, while the minimum nitrate concentration was 11.6 mg/l±0.2 mg/l at Site 4, and the maximum nitrate concentration was 12.4 mg/l±0.2 mg/l at Site 5. The reasons for the presence of sulfate in surface water include the use of sulfate-rich fertilizers and the dumping of business and residential waste. The increased phosphate content in the research region is indicative of heavy industrial activity and human activities. The lowest nitrate value (3.6 mg/l±0.5) was detected at Site 4, the highest (12.4 mg/l±0.2) was detected at Site 5, and the average sulfate value was 11.9 mg/l±0.3.

Heavy metals

The lowest copper concentration (0.026 mg/l±0.006) was detected at Site-1, the highest concentration (0.030 mg/l±0.004) was detected at Site-5, and the average copper concentration was 0.028 mg/l±0.001. Zinc levels ranged from 3.5 mg/l±0.5 at the minimum (discovered at SS-05) to 3.9 mg/l±0.8 at the greatest (found at Site-3), with 3.8 mg/l±0.8 being the average. The lowest iron concentration (0.28 mg/l±0.05) was detected at Site-1, the highest concentration (0.31 mg/l±0.03) was detected at Sites 3 and 4, and the average iron concentration was 0.30 mg/l±0.01. Lead levels ranged from minimum (0.003 mg/l±0.001) at Site 3 and Site 4 to high (0.005 mg/l±0.001) at SS-05, with an average of 0.004 mg/l±0.001.

Water quality assessment on the basis of the WQI

The water quality index (WQI) is a commonly used technique to assess whether groundwater is suitable for human use. Eight water quality parameters were used in the WQI approach to estimate the integrated water quality: pH, TDS, TH, Cl, SO_4, NO_3, DO, BOD, and COD. The Bureau of Indian Requirements (BIS)-recommended drinking water quality requirements were used to determine the WQI. The water WQI was determined using the weighted arithmetic index approach (Brown *et al.*, 1972). Because pH has the greatest value quality rating (Qi), it was regarded as a criterion pollutant at all of the study locations. According to Chaterjee and Raziuddin (2002), the groundwater quality is characterized as (I) excellent when the WQI is 0–25, (II) good when the WQI is 26–50, (III) poor when the WQI is 51–75, (IV) extremely bad when the WQI is 76–100, and (V) unfit for drinking when the WQI is > 100 (Table 4 and Figure 2). The WQI values varied from 63.8 to 81.9 at all sites under investigation. Thus, except for site 5, where the water quality is in the extremely low category, groundwater at all of the sites is in the second category, or poor water quality.

Table 4: WQI values at all the studied sites and their water quality

Site 1	WQI=63.8	Poor water quality
Site 2	WQI=71.2	Poor water quality
Site 3	WQI=73.2	Poor water quality
Site 4	WQI=71.6	Poor water quality
Site 5	WQI=81.9	Very poor water quality

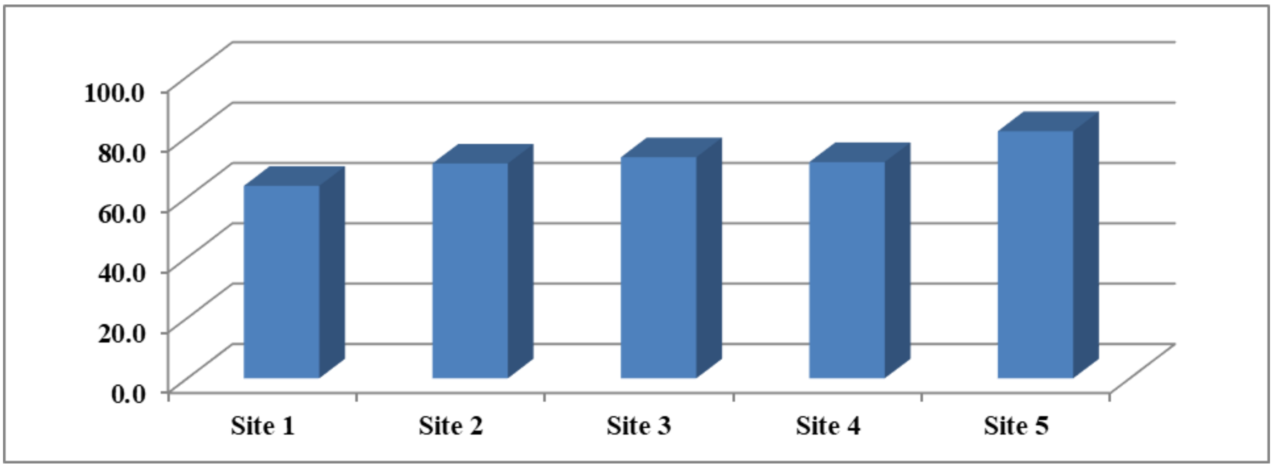

Figure 2: Graphical representation of the average WQI values

Conclusion

The increased industrial and agricultural activities in and around the lake have resulted in increased pollution loads due to the excessive use of chemicals and fertilizers, and the increase in pollution load is a major concern for local people living in and around the lake. To preserve the lake's scenic qualities and water quality, appropriate wastewater treatment is required both inside and outside of Lakhota Lake. Additionally, vegetation should be grown along the lake's edges, acting as a natural cleaner for the lake's water.

Conflict of interest

The authors declare that they have no conflicts of interest.

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