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Water quality index determination of a freshwater inland lake in Jaipur, Rajasthan

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Abstract
The goal of the current study was to determine the water quality for public consumption, recreation, and other uses by computing the Water Quality Index (WQI) of a freshwater inland lake in Jaipur, Rajasthan. The study of how environmental factors affect the lake's water quality is the subject of this essay. Water quality can be assessed using a variety of techniques for industrial, agricultural, and drinking purposes. For the general public or for any intended purpose, as well as in efforts to decrease pollution and manage water quality, the Water Quality Index, which describes water quality in terms of an index number, offers a valuable picture of the general water quality. The suitability of water for a certain function is influenced by a variety of factors. In this study, Water Quality Index of an inland lake, Lake Chandlai in Jaipur district of Rajasthan was determined on the basis of various physico-chemical parameters like pH, turbidity, electrical conductivity, total dissolved solids, total alkalinity, chloride, dissolved oxygen, phosphate and nitrate studied for a period of two years (2018-20).

Keywords: anthropogenic, lentic, eutrophic, physicochemical parameters and water quality

Introduction

Being closely related to human welfare, fresh water is of crucial concern for humanity. The most significant supplies of water for human activities are surface waterbodies. Lakes, whether they are created naturally or artificially, serve as filters for underground water, but since they lack the ability to clean themselves and are more likely to acquire contaminants, their ecosystems are more complicated and delicate. These bodies of water also serve as temporary nesting sites for migratory birds and as habitats for a wide variety of aquatic microflora. The past decades have seen an increase in anthropogenic influence in and surrounding ecosystems and their catchment region, which has significantly impacted water quality and increased eutrophication. The global phenomenon of eutrophication is linked to the enrichment of water bodies with nutrients. It is a very gradual process that takes hundreds of years to complete naturally, causing succession and ageing in the lake. The water level of these water bodies, however, has been rapidly declining in more recent times as a result of a variety of anthropogenic activities, including the use of lakewater for multiple uses, such as bathing, washing clothing, swimming, cleaning kitchenware, irrigation, as well as other recreational pursuits. Additionally, because they include a lot of chemical fertilizers, agricultural runoff laced with insecticides, and other industrial discharges, the water sources that feed the lakes are also highly contaminated. This leads to very rapid and severe eutrophication in such lakes. Lakes in cities are frequently nourished by the direct drainage of the cities' residential and commercial surroundings. Thus, these urban waterbodies are regrettably under high environmental stress and are in danger as a result of development activities.

Based on a number of water quality parameters, the Water Quality Index (WQI) delivers a single value that indicates the total water quality at a specific location and time. The water quality index aims to convert voluminous data on water quality into knowledge that the general public can use and comprehend. A single number is used to represent the state of the water by taking into numerous water quality criteria into account. A water quality index, which is based on a few very important features, can offer a concise indication of water quality. Generally speaking, water quality indices combine information from various water quality measures into a mathematical equation that assigns a number to the healthiness and ecological status of a waterbody.

The present study was carried out on an inland urban freshwater lake, Chandlai Lake of Jaipur city in Rajasthan. The district capital of Jaipur is located in the foothills of the Aravalli mountain range and contains a few lentic waterbodies like this one. These wetlands are artificial or man-made reservoirs that were built to store water for home or agricultural usage. These water bodies have a very appealing quality on both an intellectual and visual level. They don't just reflect their surroundings but they also reflect the civilization around them. Most of these water bodies are in poor condition due to neglect by the conservation authorities. Due to encroachment and pollution, the majority of the waterbodies (like Ramgarh lake of Jaipur) have perished. This context led to the current work on Chandlai lake which is facing all similar serious threats to its existence. The study was completed between October 2018 and September 2020.

Study Area

Jaipur is the biggest and the capital city of Rajasthan, located in the eastern part of the state. The central coordinates of the Jaipur district are 26.55° North latitude and 75.52° East longitude, located at 390 meters altitude from mean sea level. It is situated in the foothills of the Aravali range, surrounded by hillocks in northern and eastern sides and plains in western and southern sides. It also has many small water bodies, sometimes the only sources of water on which most of the agricultural lands are dependent for irrigation. For the present study, an urban wetland, Chandlai lake was selected.

The Chandlai lake, situated near Chandlai Village, is at an altitude of 333 meters above Sea Level having geographical coordinates: 26°41'45''N and 75°52'36''E. The lake is 10 feet deep, covers an area of 195 hectares with a total catchment area of 4,096 hectares. Most of its catchment area is already converted into residential site by Housing board. Throughout the year, this water body pretty much receives household waste and drainage water from surrounding areas.

Materials and Methods

The water samples from the lake were collected every month and analysed for ten physicochemical parameters. Some parameters like pH, water temperature, turbidity, total dissolved solids and electrical conductivity were monitored at the sampling locations with the help of portable instruments and other parameters like total alkalinity, chloride, nitrate, phosphate and dissolved oxygen were tested in the laboratory as per the standard procedures. (Trivedi & Goel 1986; APHA 1992a, 1992b, 1999, 2012) [22, 2-5].

For the calculation of Water Quality Index (WQI) of the lake in this study, nine important parameters were chosen. The WQI has been calculated by using the permissible limits of water quality recommended by Bureau of Indian Standards (BIS 2012) [7] and United States Environmental Protection Agency, (US EPA 1986) [23].

The weighted arithmetic index method (Brown *et al*. 1972) [6] has been used for the calculation of WQI of the waterbody. It is an increasing value index, that is, WQI values gets bigger with increasing pollution. The overall Water Quality Index is calculated by aggregating the quality rating with the unit weight of each parameter into consideration linearly, using following equation:

$$WQI=\sum Wn*Qn/ \sum Wn$$

n = number of water quality parameters
Wn = unit weight (Wn) for each parameter
Qn = quality rating corresponding to n^{th} parameter

Unit Weight (Wn) for each parameter is calculated by using the recommended permissible standard limit (S_n) of that parameter. It is calculated by using following expression:

$$Wn = K/ S_n$$

Wn= unit weight for the n^{th} parameter
S_n = Standard value for n^{th} parameter
$K=1/\sum 1/S_n$ (Constant for proportionality)
Quality rating (Qn) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value and unit weight. Quality rating (Qn) is calculated using the following expression:

$$Qn = 100[V_n - V_o] / [S_n - V_o]$$

Qn =Quality rating for the nth water quality parameter
V_n =Observed value of the nth parameter
S_n =Standard permissible value of the nth parameter
V_o = Ideal value of nth parameter in pure water. (i.e., 0 for all parameters except pH (V_o value is 7) and Dissolved oxygen (V_o value is 14.6 mg/l) (Tripathy and Sahu 2005) [21].

Table 1: Classification of water quality based on weighted arithmetic method* (Brown *et al*. 1972) [6]

WQI Values	Status
0-25	Excellent
26-50	Good water
51-75	Poor water
76-100	Very poor water
>100	Unsuitable for human consumption

*increasing value index, i.e., WQI values gets bigger with increasing pollution.

Table 2: Permissible Water standards and their calculated unit weights.

Parameter	Standard Permissible limits (BIS 2012; US EPA 1986)	Individual Unit weights (Wn)
Dissolved Oxygen (mg/L)	4	0.024
pH	8.5	0.011
Turbidity (NTU)	5	0.019
Phosphorus (mg/L)	0.1	0.943
Nitrate (mg/L)	45	0.0021
Total Dissolved Solids (mg/L)	500	0.0002
Alkalinity (mg/L)	200	0.0005
Conductivity (µmho/cm)	250	0.0004
Chloride (mg/L)	250	0.0004
		∑Wn=1

RESULTS

The mean value of the values observed for every season in two years was computed and listed in Table 3. WQI of the lake for four seasons, post rainy, winter, summer and rainy was calculated separately in tables 4, 5, 6 and 7 respectively.

Table 3: Seasonal variations of the physicochemical parameters of Chandlai lake (2018-2020)

Seasons → / Parameters ↓	Post rainy	Winter	Summer	Rainy
Dissolved Oxygen (mg/L)	3.3	3.7	1.6	3.7
pH	7.6	7.4	7.6	7.5
Turbidity (NTUs)	71	66	71	83
Phosphorus (mg/L)	0.03	0.03	0.05	0.03
Nitrate (mg/L)	3.8	3.9	4.7	5.0
Total Dissolved Solids (mg/L)	965	1262	1186	979
Alkalinity (mg/L)	349	407	425	388
Conductivity (µmho/cm)	1508	1972	1852	1529
Chloride (mg/L)	250	292	309	245
WQI	60	57	74	59

Table 4: Calculation of Water Quality index in Post Rainy season (2018-2020)

	Observed values (V_n)	Standard values (S_n)	Unit weights (Wn)	Quality rating (Qn)	Wn*Qn
Dissolved Oxygen (mg/L)	3.3	4	0.024	107	2.511
pH	7.6	8.5	0.011	37	0.413
Turbidity (NTUs)	71	5	0.019	1413	26.654
Phosphorus (mg/L)	0.03	0.1	0.943	32	29.860
Nitrate (mg/L)	3.8	45	0.0021	8	0.018
Total Dissolved Solids (mg/L)	965	500	0.0002	193	0.036
Alkalinity (mg/L)	349	200	0.0005	175	0.082
Conductivity (µmho/cm)	1508	250	0.0004	603	0.228
Chloride (mg/L)	250	250	0.0004	100	0.038
			∑Wn=1		∑Wn*Qn=60
Water Quality Index (∑Wn*Qn/∑Wn) = 60					

Table 5: Calculation of Water Quality index in Winter season (2018-2020)

	Observed values (V_n)	Standard values (S_n)	Unit weights (Wn)	Quality rating (Qn)	Wn*Qn
Dissolved Oxygen (mg/L)	3.7	4	0.024	103	2.428
pH	7.4	8.5	0.011	24	0.267
Turbidity (NTUs)	66	5	0.019	1329	25.062
Phosphorus (mg/L)	0.03	0.1	0.943	31	28.813
Nitrate (mg/L)	3.9	45	0.0021	9	0.018
Total Dissolved Solids (mg/L)	1262	500	0.0002	252	0.048
Alkalinity (mg/L)	407	200	0.0005	203	0.096
Conductivity (µmho/cm)	1972	250	0.0004	789	0.297
Chloride (mg/L)	292	250	0.0004	117	0.044
			∑Wn=1		∑Wn*Qn=57
Water Quality Index (∑Wn*Qn/∑Wn) = 57					

Table 6: Calculation of Water Quality index in summer season (2018-2020)

	Observed values (V_n)	Standard values (S_n)	Unit weights (Wn)	Quality rating (Qn)	Wn*Qn
Dissolved Oxygen (mg/L)	1.6	4	0.024	123	2.888
pH	7.6	8.5	0.011	43	0.471
Turbidity (NTUs)	71	5	0.019	1419	26.764
Phosphorus (mg/L)	0.05	0.1	0.943	46	43.612
Nitrate (mg/L)	4.7	45	0.0021	11	0.022
Total Dissolved Solids (mg/L)	1186	500	0.0002	237	0.045
Alkalinity (mg/L)	425	200	0.0005	213	0.100
Conductivity (µmho/cm)	1852	250	0.0004	741	0.279
Chloride (mg/L)	309	250	0.0004	124	0.047
			∑Wn=1		∑Wn*Qn=74
Water Quality Index (∑Wn*Qn/∑Wn) = 74					

Table 7: Calculation of Water Quality index in Rainy season (2018-2020)

	Observed values (V_n)	Standard values (S_n)	Unit weights (Wn)	Quality rating (Qn)	Wn*Qn
Dissolved Oxygen (mg/L)	3.7	4	0.024	103	2.435
pH	7.5	8.5	0.011	34	0.374
Turbidity (NTUs)	83	5	0.019	1666	31.411
Phosphorus (mg/L)	0.03	0.1	0.943	26	24.465
Nitrate (mg/L)	5.0	45	0.0021	11	0.023
Total Dissolved Solids (mg/L)	979	500	0.0002	196	0.037
Alkalinity (mg/L)	388	200	0.0005	194	0.091
Conductivity (µmho/cm)	1529	250	0.0004	612	0.231
Chloride (mg/L)	245	250	0.0004	98	0.037
			∑Wn=1		∑Wn*Qn=59
Water Quality Index (∑Wn*Qn/∑Wn) = 59					

Discussion

Water quality Index (WQI) of Chandlai lake is established from the mean observational data of various physicochemical parameters for four different seasons in the period of two years (2018-20) i.e., post rainy season, winter season, summer season and rainy season. The observed mean values of various physicochemical parameters seasonally are given in Table 3. Season wise WQI calculations are depicted in the Table 4, 5, 6 and 7. For post monsoon season, the WOI was calculated 60; for Winter, WQI amounted to 57; for Summer season, WQI was as high as 74 and for monsoon, WQI value of lake was 59, which indicate the poor quality of water throughout the year (Chatterjee & Raziuddin 2007) [8]. This water quality assessment analysis demonstrates unequivocally that the waterbody's status is beginning to be eutrophic and that it is of low quality for human consumption. Additionally, it has been noted that the pollutant load is significantly higher in the summer than it is in the post-rainy, winter, and rainy seasons. The following physicochemical parameter fluctuations, which were seen across the study's different seasons, further support the above water quality indices.

The pH of water is a crucial characteristic that defines its acceptability for a variety of applications among all the physicochemical factors chosen for the Water Quality Index computations. The pH in this study ranged from 7.1 to 8.2. pH levels mostly stayed in a range of neutral in many samples. However, the lake was found to be slightly alkaline when the average values for four seasons were considered. In their research on several waterbodies, Ambasht (1971) [1], Shardendu and Ambasht (1988) [18], Swarnalatha and Narasingarao (1993) [20], and Rani *et al*. (1995) also made similar comparable observations. The total dissolved solids and electrical conductivity levels were both found to be exceptionally high, being highest during the summer season. Higher levels of total dissolved solids may be ascribed to the presence of lots of iwaste water runoffs which potentially pollute water sources through their solid and liquid wastes, as also noted in another study by Rana *et al*. (2016) [15]. High levels of electrical conductivity is probably due to the developmental activities like construction of roads and buildings, improper disposal of garbage and sewage leading to high amounts of dissolved inorganic substances in ionized form, as also reported by Kerketta *et al*., (2013) [10]. Another of the most crucial factors in determining the water quality is chloride. According to Munawar (1970) [14], higher chloride concentrations are an indication of greater organic pollution. In the present study the concentration of chloride fluctuated between 192mg/l and 412mg/l in the study period. Seasonally, chloride was found to be highest during summer season and low during rainy season. A similar observation has been made by Shastry *et al*. (1972) [19] and Rani *et al*. (1995). Turbidity values observed in Chandlai Lake were much above the desirable limit of 4 NTU in freshwater bodies (BIS 2012) [7]. It ranged between very high values of 52 to 91 NTUs which clearly indicate to the opacity of the upper layers of this lake. The phosphates are found in permissible levels in this lake (<0.1mg/l) and these low contents (only highest in summer season due to reduced flows) may be due to utilization of the nutrients by phytoplanktons (Froelich *et al*. 1985) [9]. Its considerable level of availability in water bodies, often leading to eutrophy may be accounted to both naturogenic and anthropogenic reasons (Ghosh 2021) [12]. The nitrate concentrations ranged from 1.1 to 9.6 mg/l in Lake Chandlai during the study period. Such values indicate the unsuitability of water for domestic use. The concentration of dissolved oxygen regulates the distribution of flora and fauna. The present investigation indicated that the concentration of dissolved oxygen fluctuated between 1mg/1 and 5.6mg/1. Seasonally, the concentration of dissolved oxygen was more during monsoon and winter and least during summer due to less rainfall and elevated water temperatures which enhance the decomposition of dissolved organic matter by microbes, thus depleting the oxygen content of the water. The findings of Reddy *et al*. (1982), Ghosh and George (1989) [13], Swarnalatha and Narasingarao (1993) [20], and Venkateswarlu (2019) [24] are all consistent with this observation. It can be inferred from the physicochemical data previously observed that the waterbody exhibits eutrophication-related characteristics. The lake's poor ecological condition is indicated by low dissolved oxygen, high electrical conductivity and total dissolved solids concentrations, and a very high turbidity. Although, the water of Lake Chandlai is good for aquaculture as fishes can easily tolerate total dissolved solid levels of more than 1000 mg/l in such aquatic ecosystems (Hameed-ur-Rehman *et al*. 2015).

The following reasons were identified for the deterioration of Chandlai lake during the study: massive water extraction for irrigation and other purposes, pollution and massive sedimentation, intensive fishing practices, shrinking of the area due to encroachment and constructions, neglection by Government for conservation purposes, reduction in the number and stay of migratory birds and garbage disposal are reducing its recreational value and ecological status as is also evident by its high values of water quality index almost throughout the year. High WQI values of this fresh water body show that the condition of the lake is deteriorating due to lack of proper conservation strategies. Thus, application of Water Quality Index technique for the overall assessment of the water quality of a waterbody is a useful tool in deciding their conservation management plans.

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