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Water Quality Variation of Rewalsar Lake, Mandi District (H.P.), India

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ABSTRACT

The present study was conducted from March, 2020 to February, 2023 to examine the ecological health of Rewalsar lake at Mandi district of Himachal Pradesh. In order to determine the fluctuations in the lake's water quality and to determine the factors that contributed to these variations in three distinct seasons-the post-monsoon, monsoon and pre-monsoon in the selected study area was conducted. There were thirteen physio-chemical and biological water quality parameters-pH, temperature, turbidity, TDS, DO, BOD, COD, Ca, Mg, Cl, Fl, Ni, and total coliform were evaluated. In the 2020–2021 rainy season, the computed water quality index peaked at 108.3854, followed by the summer season (57.5606) and the winter season (50.4625). The water quality index was highest during the rainy season (191.6324) in 2021–2022, followed by the summer season (114.6108) and the winter season (61.4355). Following analysis, the water quality index for the winter of 2022–2023 was 65.5439. The lake's computed water quality index was found to be at a moderate level, indicating that the water was unfit for domestic use and drinking. This was because of nearby construction and demolition, improper waste management, and an increase in pollution due to a lack of sustainable tourism development. It was discovered that the water quality was low and unfit for human consumption. The current study made management recommendations for Rewalsar town, including implementing an efficient waste management strategy, conducting routine environmental monitoring, and encouraging sustainable tourism.

KEYWORDS: Ecological health, physio-chemical and biological parameters, seasonal variation, WQI

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1. INTRODUCTION

Water bodies carry out a number of crucial functions for both human existence and the environment. On the surface of the Earth, water can exist in a variety of forms. Lakes and rivers are the two primary categories of surface water. Other types of surface water include wetlands, reservoirs, rivers, ponds, streams, and seas (Supriya, 2018b; Puri, 2011). Surface water resources are bodies of water that include lakes, rivers, and freshwater wetlands (Supriya et al., 2018b; Varas et al., 2021 ; Singh et al., 2022 and Kumar et al., 2022). The hydrological cycle is maintained and surface water supplies are naturally replenished by precipitation. The same applies to human endeavours that can improve water use efficiency, such as building artificial dams and reservoirs (Sharma and Walia, 2016). A lake is a body of water that is filled with water, enclosed in a basin, surrounded by land, and cut off from any rivers or other outlets that contribute to its input or drainage. Lakes, like the big seas, are part of the Earth's water cycle despite being on land as opposed to in the ocean (Supriya et al., 2018a). It has been observed that the term "lake" is used to refer to a wide variety of water bodies, both natural and man-made, as well as transient water bodies like wetlands (Supriya et al., 2019a; Supriya et al., 2018b; Richardson et al., 2022). Unlike a lake, a lagoon is typically a coastal location. Ponds are also found on land, although lakes are larger and deeper. Lakes are comparable to rivers and streams, which often flow along terrestrial channels. The majority of streams and rivers fill and empty the lakes. The mountainous locations, rift valleys, glacier regions, and historic river courses are all home to naturally occurring lakes as many are the consequence of the previous Ice Age's erratic drainage patterns. Many lakes are artificially created for recreational, hydroelectric, industrial, or water supply purposes. They are essential freshwater resources and home to a wide variety of aquatic creatures (Tawati, 2018; Kamboj and Kamboj, 2019). Because these lakes are close to cities and other densely populated places, they are especially susceptible to diminishing water quality. Rewalsar Lake, sometimes called Tso Pema, is a square-shaped lake with a mid-altitude location in the Mandi district of Himachal Pradesh, India. The increasing population, high rates of erosion, sewage discharge, and the lake's close vicinity to residential areas and places of worship have all contributed to the lake's diminishing water quality, which also has an impact on the lake's flora and wildlife (Banu et al., 2024) Water quality fluctuated due to sewage discharge, household trash, industrial effluents, and agrochemicals, making it harder for macroinvertebrates to live in highly contaminated water bodies (Mahadev and Gholamis, 2010; Bhatta and Patra, 2020). The most important environmental stressors for lakes are excessive nutrient loading from municipal and municipal waste runoff, eutrophication, algal blooms, and fish farming, which enhances the nitrogen cycle and water deteriorates day by day (Supriya et al, 2018a; Alaidi and Aldhahi, 2019; Nizamani et al., 2020). As a result, a variety of other elements, including places of worship, recreational activities, and construction projects in the watershed, have an impact on the physiochemical properties of the lake environment. This study evaluated the water quality of Rewalsar Lake and contrasts approaches to support efficient management of the aquatic environment.

2. MATERIALS AND METHODS

2.1. Study area

The present study was conducted for two years nine months from March, 2020 to February, 2023 to examine the ecological health of Rewalsar lake at Mandi district of Himachal Pradesh. Rewalsar Lake, also called "Tso Pema Lotus," a mid-altitude lake in the Mandi district, was located between latitudes 31° 38' 2.00" N and longitude 76° 49' 59.99" E on a mountain spur. It was located at an elevation of roughly 1,360 m above sea level, about 22.5 km to the southwest of Mandi (Figure 1). This body of water stands 1,360 m above sea level and had a 735 km shoreline. The catchment region, three seasonal input streams from the lake's northern side, and the town of Rewalsar's drainage system provided the lake with its water. The lake's southernmost point was where the outlet was located, on the other side of the entrance. The people from all walks of life come to Rewalsar during Baisakhi to bath in the lake in holiness.

2.2. Data collection

2.2.1. Water sampling and analysis

A method of systematic random sampling was employed for the purpose of gathering data. In the current study, the Department of Environmental Science, HPU Shimla's laboratory evaluated 13 fundamental water quality parameters. The winter, summer, and rainy season data gathering periods were October, 2020 through February 2023, respectively. The term "water quality index" was a rating system that showed the combined impact of each unique water quality criterion on the overall quality of the water. The Water Quality Index (WQI) has been used to obtain an overall picture of surface and groundwater quality

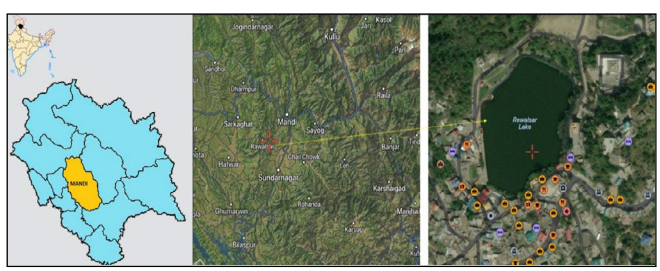

Figure 1: Map of study area (Source: Google Earth)

(Supriya et al., 2018 a, b; Batabyal and Chakraborty, 2015). The following equation was used to compute the weight (Wi) for each of the 13 parameters (pH, temperature, turbidity, TDS, Cl^-, NO^{3-}, Fl Ca, Mg, DO, BOD, COD, and total coliform) based on their relative importance to the overall quality of water for drinking.

$Q_i = \{[(V_{actual} - V_{ideal}) / (V_{standard} V_{ideal})] \times 100\}$

Where, Q_i = Quality rating of i^{th} parameter for a total of n water quality parameters ; V_{actual}=Actual value of the water quality parameter obtained from analysis; V_{ideal}=Ideal value of that water quality parameter can be obtained from the standard. (V_{ideal} for pH=7 and for other parameters it is equalling to zero, but for dissolved oxygen, V_{ideal}=14.6 mg l^{-1}); $V_{standard}$=Recommended standard of the water quality parameter.

Then the relative (unit) weight (W_i) was calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression;

$W_i = I/S_i$

Where, W_i=Relative (unit) weight for nth parameter; S_i=Standard permissible value for nth parameter I=Proportionality constant.

The suggested requirements for the respective parameters were inversely proportional to the relative (unit) weight (W_i) to the various water quality metrics. Lastly, the quality rating and unit weight were aggregated linearly to determine the overall WQI using the following equation:

$WQI = \sum Q_i W_i / \sum W_i$

Where, Q_i =Quality rating W_i=Relative (unit) weight

Five categories were created from the computed WQI values: excellent (WQI=0–25), good (WQI=26–50), bad (WQI51–75), extremely bad (WQI=76–100), and unfit for consumption (WQI≤100). The Microsoft Excel and OPSTAT software were used to perform a two-way ANOVA statistical analysis on the data collected from the current study. At the *p=0.05* and *p=0.01* levels of significance, the significance of the various factors was examined.

2.2.2. Field survey

The study included a semi-structured questionnaire, and data collecting took place online and offline in April and May of 2023, during peak usage periods including weekends and evenings. 128 local respondents were selected for the survey, and before to conducting interviews and group discussions with them, they were informed of the study's goal. During the survey, the participants were categorized into three age groups: group I (over 40), group II (between 30 and 40), and group III (20 to 30). The general inquiries about the ecological well-being of lake water, the interviewees were questioned in their mother tongue, Mandyali. The semi-structured questionnaire was broken down into three sections: Section A covered the respondents' demographic information (Name, Email, Gender, Age, Occupation, and Family Type); Section B dealt with general questions about the lake and its water quality; and Section C included statements from local officials, seasonal visitors, and locals.

3. RESULTS AND DISCUSSION

3.1. Water quality status

3.1.1. Physical parameters

Lake water temperatures in 2020–2021 varied from 16.25 °C to 21.33 °C, with summer (21 °C)>rainy season (19.67 °C)>winter (16.25 °C) being the highest. The lake water's temperature in 2021–2022 varied from 19.60 °C to 21.33 °C, with the rainy season (21.33 °C)>summer season (21 °C)>winter season (19.60°C) being the highest. The water's temperature in 2022–2023 was measured exclusively during the winter, and it was 19.26°C. In the course of the 2020–2021season, the pH of lake water varied from 7.29 to 7.87, with winters (7.87)>summers (7.49)>rainy season (7.29). The pH range of lake water in 2021–2022 was 7.21–7.74, with winters (7.74)>summers (7.60)>rainy season (7.21). The pH in the winter of 2022–2023 was found to be 7.69 (Table 1, 2). In the rainy season (24.67 NTU), summer season (9.37 NTU), and winter season (8.45 NTU), the turbidity of lake water in 2019–2020 varied.

As illustrated in Table 1 and 2, the turbidity of lake water in 2021–2022 varied from 13.10 NTU to 59.63 NTU in the following order: rainy season (59.63 NTU)>summer season (30.20 NTU)>winter season (13.10 NTU). These findings were consistent with those of Trivedi et al. (2010), Supriya et al. (2018a), and Yones et al. (2012), who noted that the rainy season was when turbidity was at its highest. The lake water's turbidity in the winter of 2022–2023 was measured at 13.42 NTU (Table 1, 2, 3). The rainy season (122.67 mg l^{-1})>summer season (114.5 mg l^{-1})>winter season (102.2 mg l^{-1}) was the order in which the total dissolved solids (TDS) in 2020–2021 fluctuated from 102.2 mg l^{-1} to 122.67 mg l^{-1}. The turbidity of lake water in 2021–2022 varied from 90.18 mg l^{-1} to 122.67 mg l^{-1}, with the rainy season having the highest TDS (138.12 mg l^{-1}), summer season having the lowest TDS (96.33 mg l^{-1}), and winter season having the highest TDS (90.18 mg l^{-1}). These findings were consistent with the observations made by Kumari and Sharma, 2018; Singh and Saxena, 2025 and Manjare et al. (2010). Table 2 illustrated the TDS of lake water in the winter of 2021–2022, which was found to be 111.6 mg l^{-1}.

3.1.2. Chemical parameters

The dissolved oxygen varied from 7.70 to 9.43 mg l^{-1} in 2020–2021, with the winter season having the highest

Table 1: Seasonal variations in different physio-chemical and biological parameters of lake water in 2020–2021

Parameter \ Seasons	Winter season (2020–2021)		Summer season (2021)		Rainy season (2021)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
Temp. (°C)	16.25	0.950	21.000	1.780	19.670	0.340
pH	7.87	0.279	7.490	0.136	7.290	0.185
Turbidity (NTU)	8.45	1.274	9.370	0.753	24.670	7.063
TDS (mg l^{-1})	102.75	4.956	114.500	4.213	122.667	5.696
D.O. (mg l^{-1})	9.42	0.634	9.025	0.309	7.700	0.404
COD (mg l^{-1})	29.95	1.184	39.000	14.549	49.000	6.083
BOD (mg l^{-1})	2.80	0.478	4.200	1.643	4.833	0.684
F^- (mg l^{-1})	0.05	0.003	0.060	0.017	0.290	0.110
Cl^- (mg l^{-1})	5.75	1.109	7.500	0.866	7.667	0.882
Ca^{++} (mg l^{-1})	24.74	0.790	27.615	1.746	38.360	2.261
Mg^{++} (mg l^{-1})	4.41	0.092	5.098	0.423	6.700	0.165
$NO_{3-}N$ (mg l^{-1})	0.14	0.006	0.206	0.100	0.824	0.182
T.C. (MPN/100 ml)	540	134.350	682.500	142.500	920	0
CD (*p=0.05*)	107.056		113.925		8.845	
SEm±	37.174		39.560		3.012	
SEd	52.572		55.946		4.260	
C.V.	128.427		110.888		5.607	

concentration (9.43 mg l^{-1})>the summer season (9.03 mg l^{-1})>the rainy season (7.70 mg l^{-1}) (Table 1). Welch (1952) and Adkins (1970) have both reported findings that were comparable. The DO concentration in 2021–2022 was 8.3 mg l^{-1} in the summer and 8 mg l^{-1} in the winter, respectively and during the rainy seasons also (Table 2). The winter time dissolved oxygen content in 2022–2023 was 6.48 mg l^{-1} (Table 3). The lake water's COD (Chemical Oxygen Demand) in 2020–2021 varied from 29.95 mg to 49.0 mg l^{-1}, with the rainy season having the highest COD (49 mg l^{-1}) followed by the summer (39 mg l^{-1}) and the winter (29.95 mg l^{-1}). The COD concentration in 2021–2022 varied from 18.40 mg l^{-1} to 42.30 mg l^{-1}, with the rainy season having the highest concentration (42.30 mg l^{-1}) followed by the summer (41 mg l^{-1}) and the winter (18.40 mg l^{-1}). The COD concentration was determined to be 17.2 mg l^{-1} in the winters of 2022–2023. The highest COD concentration was recorded in the rainy season, and the lowest in the winter, according to Joseph and Jacob's (2010) study on the physicochemical features of river water and Chattopadhyay et al.'s (2005) study on water quality fluctuations which was linked to land use pattern.

Table 1 illustrated the BOD (Biological Oxygen Demand) of lake water in 2020–2021, which varied from 2.80 mg l^{-1} to 4.83 mg l^{-1} in the following order: 4.83 mg l^{-1} during the rainy season>4.2 mg l^{-1} during the summer season>2.80 mg l^{-1} during the winter season. The BOD fluctuated in 2021–2022 from 2.0 mg l^{-1} to 3.57 mg l^{-1}, with the rainy season (3.57 mg l^{-1}) surpassing the summer season (3.2 mg l^{-1}) and the winter season (2 mg l^{-1}). The winter time BOD concentration of lake water in 2022–2023 was found to be 2.3 mg l^{-1}, respectively (Table 3). The increased BOD during the rainy season might have resulted from runoff from non-point sources percolating down to the profile, which was consistent with the findings of Supriya et al. (2019a) and Phiri et al. (2011). According to Table 1, the fluoride concentration of lake water in 2020–2021 varied from 0.06 mg l^{-1} to 0.29 mg l^{-1}, with the rainy season (0.29 mg l^{-1}) having a higher concentration than the winter and summer (0.06 mg l^{-1}). In 2021–2022, the fluoride concentration varied between 0.09 and 0.18 mg l^{-1}, with the rainy season having the highest concentration (0.18 mg l^{-1}) followed by the summer (0.16 mg l^{-1}) and the winter (0.09 mg l^{-1}). Table 3 illustrated the fluoride concentration in winter 2022–2023, which was found to be 0.032 mg l^{-1}. As seen in Table 1, the Ca (calcium) content in 2020–2021 varied from 24.74 mg l^{-1} to 38.36 mg l^{-1}, with the rainy season having the greatest value (38.36 mg l^{-1}), summer season following (27.62 mg l^{-1}), and winter season having the lowest value (24.74 mg l^{-1}). The Ca concentration of lake water in 2021–2022 varied from 24.74 mg l^{-1} to 33.22 mg, with the rainy season having the highest concentration (33.22 mg l^{-1} followed by the summer season (31.42 mg l^{-1}) and the winter season (24.74 mg l^{-1}). The winter of 2022–2023 revealed lake water to have

Table 2: Seasonal variations of different physico-chemical and biological parameters of lake water in 2021–2022

Parameter / Seasons	Winter season (2021–2022)		Summer (2022)		Rainy (2022)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
Temp. (°C)	19.600	0.245	21.000	0.408	21.333	0.333
pH	7.740	0.176	7.600	0.101	7.207	0.066
Turbidity (NTU)	13.100	3.508	30.200	2.703	59.633	43.894
TDS (mg l^{-1})	90.176	2.004	96.333	20.850	138.123	4.391
D.O. (mg l^{-1})	8.000	0.641	8.300	0.925	8.300	0.551
COD (mg l^{-1})	18.400	0.927	41.000	2.517	42.300	2.606
BOD (mg l^{-1})	2.000	0.228	3.200	0.616	3.567	0.762
F^- (mg l^{-1})	0.086	0.002	0.160	0.011	0.177	0.061
Cl^- (mg l^{-1})	5.400	0.510	8.250	0.479	28.333	2.963
Ca^{++} (mg l^{-1})	26.738	0.600	31.423	3.802	33.217	0.785
Mg^{++} (mg l^{-1})	4.864	0.432	7.853	0.895	9.543	1.235
$NO_{3-}N$ (mg l^{-1})	0.842	0.214	0.858	0.015	0.877	0.013
T.C. (MPN/100 ml)	1,116.00	209.418	1,146.67	160.278	1,466.670	133.334
CD (*p=0.05*)	165.799		128.555		117.125	
SEm±	58.129		44.64		39.89	
SEd	82.206		63.13		56.413	
C.V.	128.698		82.734		49.371	

a calcium content of 34.277 mg l^{-1} (Table 3). Similar results were consistent with studies conducted by Supriya et al. (2019a), who during their seasonal research of the monsoon season reported the largest Ca concentration and the lowest in the post monsoon. The Mg (magnesium) content of lake water in 2020–2021 varied from 4.41 mg l^{-1} to 6.70 mg l^{-1}, with the rainy season having the highest value, summer having the next highest value, and winter having the lowest value, at 6.70 mg l^{-1}, 5.10 mg l^{-1}, and 4.41 mg l^{-1}, respectively (Table 1). In 2021–2022, the Mg content varied from 4.86 mg l^{-1} to 9.54 mg l^{-1}, with the rainy season having the highest concentration (9.54 mg l^{-1}), summer having the second highest concentration (7.85 mg l^{-1}), and winter having the lowest concentration (4.86 mg l^{-1}) as shown in Table 2. In the winter of 2022–2023, the Mg concentration was 5.02 mg l^{-1}, correspondingly (Table 3). The increased magnesium content during the rainy season might have resulted from agrochemicals, sewage discharge, urban runoff, waste dumping, and effluents that contained soap and detergent residues. These results were consistent with those of Patel et al. (2014) and Supriya et al. (2019a), who found that during their seasonal investigation of drinking water in the Khed (lote) industrial region, magnesium concentrations were highest during the monsoon and lowest following it. The lake water nitrate concentrations in 2020–2021 ranged from 0.14 mg l^{-1} to 0.82 mg l^{-1}, with the highest concentrations occurring during the rainy season, summer, and winter, respectively, at 0.82 mg l^{-1}, 0.21 mg l^{-1}, and 0.14 mg l^{-1} (Table

Table 3: Estimated value of different physico-chemical and biological parameters of lake water in winters, 2022–2023

Parameter / Seasons	Winters (2022–2023)	
	Mean	S.E.
Temp. (°C)	19.260	0.394
pH	7.688	0.248
Turbidity (NTU)	13.420	0.506
TDS (mg l^{-1})	111.600	1.99
D.O. (mg l^{-1})	6.480	0.348
COD (mg l^{-1})	17.200	0.663
BOD (mg l^{-1})	2.136	0.323
F^- (mg l^{-1})	0.134	0.034
Cl^- (mg l^{-1})	5.200	0.374
Ca^{++} (mg l^{-1})	24.476	1.519
Mg^{++} (mg l^{-1})	5.018	0.216
$NO_{3-}N$ (mg l^{-1})	0.768	0.086
T.C. (MPN/100 ml)	1,580.00	20
CD (*p=0.05*)	15.953	
SEm±	5.593	
SEd	7.91	
C.V.	9.066	

Table 4(a): WQI of winter season (2021–2022)

Sl. No.	Parameter	Observed values (OV)	Standard values (SV)	Unit weight (W_i)	Quality rating (Q_i)	$W_i \times Q_i$
1.	Temp. (°C)	16.2500	20	0.0327	81.2500	2.6589
2.	pH	7.8650	8.5	0.0770	57.6667	4.4404
3.	Turbidity	8.4500	5	0.1309	169.0000	22.1223
4.	TDS mg l^{-1}	102.7500	500	0.0013	20.5500	0.0269
5.	D.O. mg l^{-1}	9.4250	6	0.1091	60.1744	6.5641
6.	COD mg l^{-1}	29.9500	20	0.0327	149.7500	4.9006
7.	BOD mg l^{-1}	2.8000	5	0.1309	56.0000	7.3305
8.	F^- mg l^{-1}	0.0570	1.5	0.4363	3.8000	1.6581
9.	Cl^-mg l^{-1}	5.7500	250	0.0026	2.3000	0.0060
10.	Ca^{++} mg l^{-1}	24.7430	75	0.0087	32.9907	0.2879
11.	Mg^{++} mg l^{-1}	4.4100	30	0.0218	14.7000	0.3207
12.	$NO_{3-}N$ mg l^{-1}	0.1440	45	0.0145	0.3200	0.0047
13.	T.C. (MPN/100 ml)	540.0000	500	0.0013	108.0000	0.1414
				$\sum w_i = 1$		$\sum W_i Q_i = 50.4625$

Water quality index $\{\sum W_i \times Q_i / \sum w_i\} = 50.4625$

Table 4(b): WQI of Summer season (2021)

Sl. No.	Parameter	Observed values (OV)	Standard values (SV)	Unit weight (W_i)	Quality rating (Q_i)	$W_i \times Q_i$
1.	Temp. (°C)	21.0000	20	0.0327	105.0000	3.4362
2.	pH	7.4850	8.5	0.0770	32.3333	2.4897
3.	Turbidity	9.3680	5	0.1309	187.3600	24.5257
4.	TDS mg l^{-1}	114.5000	500	0.0013	22.9000	0.0300
5.	D.O. mg l^{-1}	9.0250	6	0.1091	64.8256	7.0715
6.	COD mg l^{-1}	39.0000	20	0.0327	195.0000	6.3814
7.	BOD mg l^{-1}	4.2000	5	0.1309	84.0000	10.9957
8.	F^- mg l^{-1}	0.0600	1.5	0.4363	4.0000	1.7454
9.	Cl^-mg l^{-1}	7.5000	250	0.0026	3.0000	0.0079
10.	Ca^{++} mg l^{-1}	27.6150	75	0.0087	36.8200	0.3213
11.	Mg^{++} mg l^{-1}	5.0980	30	0.0218	16.9933	0.3707
12.	$NO_{3-}N$ mg l^{-1}	0.2060	45	0.0145	0.4578	0.0067
13.	T.C. (MPN/100 ml)	682.5000	500	0.0013	136.5000	0.1787
				$\sum w_i = 1$		$\sum W_i Q_i = 57.5606$

Water quality index $\{\sum W_i \times Q_i / \sum w_i\} = 57.5606$

1). In the same way, the nitrate concentration in 2021–2022 varied from 0.82 mg l^{-1} to 0.88 mg l^{-1}, with the rainy season (0.88 mg l^{-1}) surpassing the summer (0.86 mg l^{-1}) and the winter (0.82 mg l^{-1}) (Table 2). Similar findings supported the conclusions of Supriya et al. (2018b), Yones et al. (2012), Anyanwu et al. (2021), Supriya et al. (2019a) and Patel et al. (2014), who discovered that nitrate concentrations were highest during the monsoon season and lowest during the post-monsoon, suggesting that the latter might be caused by nutrient runoff from rain. The lake water in the winter of 2022–2023 had nitrate levels of 0.77 mg l^{-1}, according to Table 3. In the rainy season (7.67 mg l^{-1}), summer (7.50 mg l^{-1}), and winter (5.75 mg $^{l-1}$), the Cl (chloride) content of lake water in 2020–2021 ranged from 5.75 mg l^{-1} to 7.67

Table 4(c): WQI of rainy season (2021)

Sl. No.	Parameter	Observed values (OV)	Standard values (SV)	Unit weight (W_i)	Quality rating (Q_i)	$W_i \times Q_i$
1.	Temp. (°C)	19.6670	20	0.0327	98.3350	3.2180
2.	pH	7.2900	8.5	0.0770	19.3333	1.4887
3.	Turbidity	24.6670	5	0.1309	493.3400	64.5788
4.	TDS mg l^{-1}	122.6670	500	0.0013	24.5334	0.0321
5.	D.O. mg l^{-1}	7.7000	6	0.1091	80.2326	8.7521
6.	COD mg l^{-1}	49.0000	20	0.0327	245.0000	8.0177
7.	BOD mg l^{-1}	4.8330	5	0.1309	96.6600	12.6529
8.	F^- mg l^{-1}	0.2900	1.5	0.4363	19.3333	8.4359
9.	Cl^-mg l^{-1}	7.6670	250	0.0026	3.0668	0.0080
10.	Ca^{++} mg l^{-1}	38.3600	75	0.0087	51.1467	0.4463
11.	Mg^{++} mg l^{-1}	6.7000	30	0.0218	22.3333	0.4872
12.	$NO_{3-}N$ mg l^{-1}	0.8240	45	0.0145	1.8311	0.0266
13.	T.C. (MPN/100 ml)	920.0000	500	0.0013	184.0000	0.2409
				$\sum w_i = 1$		$\sum W_i Q_i = 108.3854$

Water quality index $\{\sum W_i \times Q_i / \sum w_i\} = 108.3854$

Table 4(d): WQI of Winter season, 2021–2022

Sl. No.	Parameter	Observed values (OV)	Standard values (SV)	Unit weight (W_i)	Quality rating (Q_i)	$W_i \times Q_i$
1.	Temp. (°C)	19.600	20.00	0.0327	98.000	3.2071
2.	pH	7.740	8.50	0.0770	49.333	3.7987
3.	Turbidity	13.10	5.00	0.1309	262.000	34.2961
4.	TDS mg l^{-1}	90.176	500.00	0.0013	18.035	0.0236
5.	D.O. mg l^{-1}	8.00	6.00	0.1091	76.744	8.3716
6.	COD mg l^{-1}	18.400	20.00	0.0327	92.000	3.0107
7.	BOD mg l^{-1}	2.00	5.00	0.1309	40.000	5.2361
8.	F^- mg l^{-1}	0.086	1.50	0.4363	5.733	2.5017
9.	Cl^-mg l^{-1}	5.400	250.00	0.0026	2.160	0.0057
10.	Ca^{++} mg l^{-1}	26.738	75.00	0.0087	35.651	0.3111
11.	Mg^{++} mg l^{-1}	4.864	30.00	0.0218	16.213	0.3537
12.	$NO_{3-}N$ mg l^{-1}	0.842	45.00	0.0145	1.871	0.0272
13.	T.C. (MPN/100 ml)	1,116.00	500.00	0.0013	223.200	0.2922
				$\sum w_i = 1$		$\sum W_i Q_i = 61.4355$

Water quality index $\{\sum W_i \times Q_i / \sum w_i\} = 61.4355$

mg l^{-1}. Comparably, from 2021 to 2022, the Cl concentration in lake water varied from 5.40 mg l^{-1} to 28.33 mg l^{-1}, with the rainy season having the greatest concentration (28.33 mg l^{-1}) followed by the summer (8.25 mg l^{-1}) and the winter (5.40 mg l^{-1}). The findings supported those of Supriya et al. (2019a), Khound et al. (2012), and Puri et al. (2011), who found that the monsoon season was when chloride concentrations are at their maximum. As seen in table 3, the Cl content of lake water was determined to be 5.2 mg l^{-1} during the winter of 2022–2023.

3.1.3. Biological Parameters

According to table 1, the total coliform (TC) of lake water in 2020–2021ranged from 540 MPN/1000 ml to 920 MPN/1000 ml in the following order: rainy season (920 MPN/1000 ml)>summer season (682.5 MPN/1000

Table 4(e): WQI of summer season, 2022

Sl. No.	Parameter	Observed values (OV)	Standard values (SV)	Unit weight (W_i)	Quality rating (Q_r)	$W_i \times Q_r$
1.	Temp. (°C)	21	20	0.0327	105.0000	3.4362
2.	pH	7.6	8.5	0.0770	40.0000	3.0800
3.	Turbidity	30.2	5	0.1309	604.0000	79.0644
4.	TDS mg l^{-1}	96.333	500	0.0013	19.2666	0.0252
5.	D.O. mg l^{-1}	8.3	6	0.1091	73.2558	7.9911
6.	COD mg l^{-1}	41	20	0.0327	205.0000	6.7087
7.	BOD mg l^{-1}	3.2	5	0.1309	64.0000	8.3777
8.	F^- mg l^{-1}	0.16	1.5	0.4363	10.6667	4.6543
9.	Cl^-mg l^{-1}	8.25	250	0.0026	3.3000	0.0086
10.	Ca^{++} mg l^{-1}	31.423	75	0.0087	41.8973	0.3656
11.	Mg^{++} mg l^{-1}	7.853	30	0.0218	26.1767	0.5711
12.	$NO_{3-}N$ mg l^{-1}	0.858	45	0.0145	1.9067	0.0277
13.	T.C. (MPN/100 ml)	1,146.67	500	0.0013	229.3334	0.3002
				$\sum w_i = 1$		$\sum W_i Q_r = 114.6108$

Water quality index $\{\sum W_i \times Q_r / \sum w_i\}$ = 114.6108

Table 4(f): WQI of Rainy season, 2022

Sl. No.	Parameter	Observed values (OV)	Standard values (SV)	Unit weight (W_i)	Quality rating (Q_r)	$W_i \times Q_r$
1.	Temp. (°C)	21.333	20	0.0327	106.665	3.4906
2.	pH	7.207	8.5	0.0770	13.8	1.0626
3.	Turbidity	59.633	5	0.1309	1192.66	156.1207
4.	TDS mg l^{-1}	138.123	500	0.0013	27.6246	0.0362
5.	D.O. mg l^{-1}	8.3	6	0.1091	73.25581395	7.9911
6.	COD mg l^{-1}	42.3	20	0.0327	211.5	6.9214
7.	BOD mg l^{-1}	3.567	5	0.1309	71.34	9.3385
8.	F^- mg l^{-1}	0.177	1.5	0.4363	11.8	5.1488
9.	Cl^-mg l^{-1}	28.333	250	0.0026	11.3332	0.0297
10.	Ca^{++} mg l^{-1}	33.217	75	0.0087	44.28933333	0.3865
11.	Mg^{++} mg l^{-1}	9.543	30	0.0218	31.81	0.6940
12.	$NO_{3-}N$ mg l^{-1}	0.877	45	0.0145	1.948888889	0.0283

ml)>winter season (540 MPN/1000 ml). According to table 2, the total concentration (TC) of lake water in 2021–2022 ranged from 1116 MPN/1000 ml to 1466 MPN/1000 ml, with the rainy season (1466.67 MPN/1000 ml)>summer season (1146.67 MPN/1000 ml)>winters (1116 MPN/1000 ml). The winter time TC of lake water in 2021–2022 was found to be 1580 MPN/1000 ml (Table 3). In the present investigation, similar findings were consistent with those of Kumar (2017), Trivedi et al. (2010), and Woldeab et al. (2019), who similarly noted that the concentration of total coliform was highest during the monsoon and lowest during the post-monsoon.

3.2. Water quality index (WQI)

The studied area's water quality index (WQI) values for samples taken during the winter, summer, and rainy seasons were determined individually. It has been found that the maximum calculated WQI of lake has been found in rainy season (2022) and minimum in winter season, 2020–2021 [table 4 (a, b, c, d, e f, g)]. It was observed that lake's water quality differed noticeably when measured using a water quality index. The water quality index was at its highest in

Table 4(g): WQI of winter season, 2022–2023

Sl. No.	Parameter	Observed values (OV)	Standard values (SV)	Unit weight (W_i)	Quality rating (Q_i)	$W_i \times Q_i$
1.	Temp. (°C)	19.26	20	20.0000	96.3	3.1514
2.	pH	7.688	8.5	4.2500	45.86666667	3.5318
3.	Turbidity	13.42	5	1.6667	268.4	35.1339
4.	TDS mg l^{-1}	111.6	500	125.0000	22.32	0.0292
5.	D.O. mg l^{-1}	6.48	6	1.2000	94.41860465	10.2996
6.	COD mg l^{-1}	17.2	20	3.3333	86	2.8144
7.	BOD mg l^{-1}	2.136	5	0.7143	42.72	5.5921
8.	F^- mg l^{-1}	0.134	1.5	0.1875	8.933333333	3.8979
9.	Cl^-mg l^{-1}	5.2	250	27.7778	2.08	0.0054
10.	Ca^{++} mg l^{-1}	24.476	75	7.5000	32.63466667	0.2848
11.	Mg^{++} mg l^{-1}	5.018	30	2.7273	16.72666667	0.3649
12.	$NO_{3-}N$ mg l^{-1}	0.768	45	3.7500	1.706666667	0.0248
13.	T.C. (MPN/100 ml)	1,580.00	500	38.4615	316	0.4136
				1.0000		$\sum W_i Q_i = 65.5439$

Water quality index $\{\sum W_i \times Q_i / \sum w_i\} = 65.5439$

the rainy season of years 2020–2021 (108.3854) followed by summer season (57.5606) and lowest in winter season (50.4625). Similarly in 2021–2022 the rainy season (191.6324) had the highest water quality index, followed by the summer season (114.6108), and the winter season (61.4355) saw the lowest water quality index. After examination, in the winter season of 2022–2023, water quality index was found to be 65.5439. The comparison of the water quality index for each season from winter 2019–2020 to winter 2022–2023 revealed a rise in the index for each season in both years, indicating that the Rewalsar Lake water quality index is rising each year and the lake water quality is declining each year. Table 4 (a, b, c, d, e, f, g) represented the different steps used for the calculation of WQI. In nutshell the overall calculated WQI of lake has been rated under poor (50–75) category in winter season of every year during investigation and in summer season of year 2021 and 2022. Similarly, the rainy season of year 2021 and 2022 have been categorized under unfit and unsuitable for drinking (>100) category under the standard given by CPCB (2019). The current study's results are in line with those of Juneja and Chaudhary (2013), Manjare et al. (2010), Trivedi et al. (2010), Ramachandra et al. (2019), Singh and Saxena (2025), and Nagmani (2015), who noted that higher surface runoff carrying organic and inorganic pollutants into lakes during the monsoon (rainy) season resulted in significantly higher WQI values. The rainy season WQI was also classified as "unsuitable for drinking" in these tests, while the winter WQI readings were consistently lower. During the period of the analysis, it was noted that the lake's seasonal water quality was declining. This might be because a lot of pilgrims travel to the lake area in April for the Hindu Baisakhi fair and the Buddhist Chessu fair, where food is given to the fish despite it being against the law. However, it has been noted that sewage runoff has been lowering the lake's water quality during the wet season. According to the survey results, August was considered the holiest month of the Hindu calendar, visitors make offerings at temples during this month, which eventually end up in nearby water bodies (known as Shravan maas). But when these significant contributions become massive

Table 5: Categorization of lake water quality in selected study area

Sl. No.	Seasons	WQI $_{(calculated)}$	Water quality status
2020–2021			
01.	Winter	50.46	Poor
02.	Summer	57.56	Poor
03.	Rainy	108.38	Unfit and unsuitable for drinking
2021–2022			
01.	Winter	61.43	Poor
02.	Summer	114.61	Unfit and unsuitable for drinking
03.	Rainy	191.63	Unfit and unsuitable for drinking
Winters, 2022–2023			
01.	Winter	65.54	Poor

waste, it leads to a complex issue that is harmful to the aquatic environment. The current study gave management recommendations, including implementing a successful sewage management plan in Rewalsar town, keeping a close eye on the environment, and most importantly encouraging local authorities to run community awareness campaigns and strictly prohibiting fish feeding.

4. CONCLUSION

The water quality of Rewalsar Lake in Himachal Pradesh was declining, and it was deemed unfit for human consumption with a low WQI grade. The study's findings demonstrated that a limited number of communities took steps to keep the lake at its current level after becoming aware of local environmental problems that threatened it. However, waste management problems, increasing urbanization, development and destruction, and a lack of sustainable tourism pose a threat to the ecological health of the lake.

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