Journal of Multidisciplinary Sciences
www.multidisciplines.com

Evaluation of surface water quality by analyzing physicochemical and microbiological properties in Chimdi (Barju) Lake of Koshi Province, Nepal

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Received: 18 February 2025; Accepted: 04 April 2025; Published online: 10 April 2025

Abstract. This study evaluated the water quality of Barju Lake in Sunsari District, Nepal, focusing on physicochemical, heavy metal, and microbiological parameters during post-monsoon 2022 and pre-monsoon 2023. The average temperature of the lake water was recorded at 26.4°C±0.5983 and 33.6°C±0.6519, with TDS levels of 18.2±6.0166 mg/L and 22.8±5 mg/L. The pH levels were 6.6±0.5477 and 7±0.5, and DO levels were 7.1±0.5522 mg/L and 6.4±0.4183. The total dissolved solids (TA) and total suspended solids (TH) levels were 38±2.7386 mg/L and 40±3.5355 mg/L, respectively. The concentrations of heavy metals were found in S1, S2, S3, S4, and S5 during post-monsoon 2022 and pre-monsoon 2023, respectively. The average concentrations of fecal coliforms were recorded at 20±3.5355 CFU/100 mL during post-monsoon 2022 and at 10±3.847 CFU/100 mL during pre-monsoon 2023. The study highlights the importance of monitoring water quality and addressing potential issues in order to maintain a healthy ecosystem.

Keywords: *Heavy metals, physicochemical parameters, seasonal variation, and water quality.*

Cite this as: Das B.D. & Sharma U. (2025). Evaluation of surface water quality by analyzing physicochemical and microbiological properties in Chimdi (Barju) Lake of Koshi Province, Nepal. J. Multidiscip. Sci. 7(1), 26-32.

1. Introduction

The most vital element for all life on earth is water, which is also a valuable resource for human civilization. The amount of unfit-for-drinking water in seas is approximately 97%. Glaciers and ice caps absorb 2.97% of the fresh water, immersing only 3% of the Earth's surface. The remaining 0.3% is available as surface and ground water for human consumption (Miller, 1997). The wetlands of Nepal, which make up around 5% of the country's total land area and have an immense 225 billion m³ of water storage capacity, are made up of rivers, lakes, reservoirs, ponds, marshy plains, and irrigated paddy fields (Water Resource Strategy, 2002).

Wetlands provide essential ecological services, rank among the world's most productive and fragile ecosystems, and are crucial to both human development and biodiversity preservation (Söderqvist et al., 2000; Vélez et al., 2018; Chen et al., 2019). The concerned ministries have made efforts to restore natural wetlands for human welfare (Wang et al., 2012). Anthropogenic pressure and global change have led to the loss of more than half of the planet's wetlands over the past century (Davidson, 2014). It is important to track changes over time and where water quality and heavy metal pollution come from in wetlands because healthy wetlands can offer many benefits to the environment. Wetlands, a highly productive environment, deliver humankind cultural, regulatory, and other benefits (Gautam et al., 2014).

Wetland water has mostly been monitored to evaluate water quality and heavy metal concentrations in comparison to current criteria and to determine if they are sustainable for ecosystem services. In addition to examining trends in the aquatic environment, wetland water research has developed to find their probable causes and pinpoint the sources of pollution (Peters et al., 2013; Tang et al., 2014; Wang et al., 2014; Duan et al., 2016). With the goal of determining the state of the wetlands and aiding their protection, the current effort has been designed to quantify water quality and heavy metal concentrations.

2. Materials and Methods

2.1. Study area

The study area falls in the Sunsari District of Koshi Province. The location of the study area is shown in Figure 1. Chimdi Lake (Barju Tal) is located in the Chimdi Village Development Committee of the Sunsari district of Nepal, 15 km west of Biratnagar metropolitan city in Morang district. It has an area of about 101.6 hectares. Its geographical coordinates are 87°10'51.3" E longitude and 26°29'23.5" N latitude. It is situated at an elevation of 70m above mean sea level (Das, 2017).

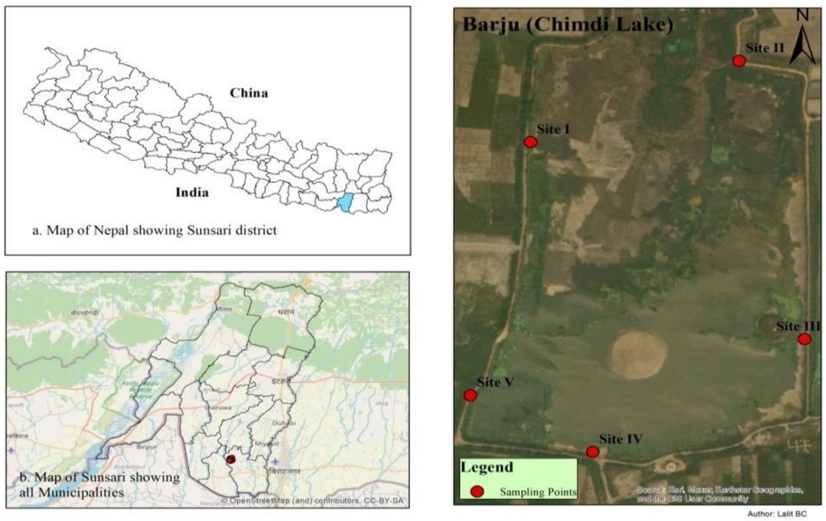

Figure 1. Map of Chimdi (Barju) Lake of Sunsari, Nepal.

2.2. Data collection

Water samples from 5 different sampling points in the lake were collected between 8:00 a.m. and 11:00 a.m. in plastic bottles rinsed with distilled water for the determination of important variables. The water samples were transported to the Department of Botany, MMAM Campus, Biratnagar. For the estimation of microbiological examination, water samples were collected and transported to the laboratory of Nepal Batawaraniya Sewa Kendra, Biratnagar, for analysis. Water quality parameters were analyzed following standard methods (Trivedy & Goel, 1986; APHA, 2005).

The data were collected for the pre-monsoon and post-monsoon seasons for the overall research. Lake water samples were tested for various physical and chemical properties using different methods, like measuring temperature with a thermometer and a hand kit, checking TDS and pH with a hand kit (HANNA), testing TSS using the APHA-2540 B method, measuring DO with the APHA-4500 method, assessing TA and FCO_2 with the phenolphthalein indicator method, determining TH with the EDTA method, and analyzing NO_3-N and PO_4-P with the APHA-4500 method, while BOD and COD were measured using the APHA-5210 and APHA-5220 methods, respectively. Heavy metals, including chromium (Cr), arsenic (As), lead (Pb), zinc (Zn), and cadmium (Cd), were analyzed by the APHA-3111B method.

3. Results and Discussion

3.1. Physicochemical parameters

The air temperature at the site varies from site to site. The temperature of site I was 29°C, site II was 28°C, site III was 30°C, site IV was 27°C, and site V was 29°C. The water temperature of the lake ranged from 25.7°C (S2) to 27.1°C (S5) with an average value of 26.4°C±0.5983 and from 330°C (S2 and S4) to 34.50°C (S5) with an average value of 33.6°C±0.6519 during post-monsoon 2022 and pre-monsoon 2023, respectively. The values of TDS on sites I, II, III, IV, and V were found to be 023, 014, 017, 027, and 013 ppm, respectively. The value of TDS ranged from 13 mg/L (S1) to 27 mg/L (S4) with an average of

18.2±6.0166 and 17 mg/L (S5) to 30 mg/L (S4) with an average of 22.8±5.8480 during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were under the WHO guideline value of 500-1000 mg/L.

Table 1. Physicochemical parameters in Barju Lake, Sunsari (Post-monsoon 2022)

Parameters	Units	Post Monsoon (2022)					Average	Std.dev.	WHO Guideline
		SiteI	SiteII	SiteIII	SiteIV	SiteV			
Temp.	°C	26.5	25.7	26.7	25.8	27.1	26.4	±0.5983	12-25
TDS	mg/L	23	14	17	27	13	18.2	±6.0166	500-1000
TSS	mg/L	4	6	4	6	4	4.8	±1.095	1000
p^H		7	7	6	7	6	6.6	±0.5477	6.5-8.5
DO	mg/L	6.5	7	8	7.1	6.9	7.1	±0.5522	4-6
T. Alkalinity	mg/L	40	35	40	40	35	38	±2.7386	125-350
T. Hardness	mg/L	24	24	30	24	28	26	±2.8284	500
Free CO_2	mg/L	14.6	11.1	10.8	13.2	12.4	12.42	±1.5594	10
(NO_3-N)	mg/L	0.35	0.36	0.37	0.43	0.38	0.38	±0.031	10
(PO_4-P)	mg/L	0.14	0.09	0.11	0.12	0.08	0.18	±0.0024	0.01
BOD	mg/L	23	14	17	24.5	19.5	18.8	±4.2924	2
COD	mg/L	50	50	40	50	40	4.8	±5.477	80
E. Cond.	(μ℧)	68.1	61.8	54.8	76.2	45.2	61.2	±11.9365	1500
F. Coliform	CFU/ 100mL	20	20	20	15	25	20	3.5355	00

The value of TSS ranged from 4 mg/L (S1, S3, S5) to 6 mg/L (S2, S4) with an average of 4.8±1.095 and 6 mg/L (S1, S3, S5) to 7 mg/L (S2, S4) with an average of 4.8±1.095 during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were under the WHO guideline of 1000 mg/L. The value of pH varies from 6 (S3, S5) to 7 (S1, S2, S4) with an average of 6.6±0.5477 and from 6.5 (S3, S5) to 7.5 (S1, S4) with an average of 7±0.5 during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were under the WHO guideline value of 6.5-8.5 mg/L.

Table 2. Physicochemical parameters in Barju Lake, Sunsari (Pre-monsoon 2023)

Parameters	Units	Pre Monsoon (2023)					Average	Std. dev.	WHO Guideline
		Site I	Site II	Site III	Site IV	Site V			
Temp.	°C	34.5	33	33.5	33	34	33.6	±0.6519	
TDS	mg/L	27	17	23	30	17	22.8	±5.8480	500-1000
TSS	mg/L	6	7	6	7	6	6.4	±0.5	1000
pH		7.5	7	6.5	7.5	6.5	7	±0.5	6.5-8.5
DO	mg/L	6	6.5	7	6.5	6	6.4	±0.4183	4-6
T. Alkalinity	mg/L	45	40	35	40	40	40	±3.535	125-350
T. Hardness	mg/L	35	40	35	30	30	34	±4.1833	500
Free CO2	mg/L	16.6	13.1	13.8	15.2	17.4	15.22	±1.8143	10
(NO3-N)	mg/L	0.34	0.35	0.33	0.40	0.35	0.354	±0.027	10
(PO4-P)	mg/L	0.11	0.12	0.13	0.11	0.11	0.12	±0.0089	0.01
BOD	mg/L	20	20	22	25.5	21.5	21.8	±2.253	2
COD	mg/L	40	30	30	30	30	32	±4.472	80
E. Cond.	(μ℧)	72.2	67.1	63.2	79..2	55.2	64.425	±7.169	1500
F. Coliform	CFU/ 100mL	10	16	12	8	6	10.4	±3.847	0

The value of DO ranged from 6.5 mg/L (S1) to 8 mg/L (S3) with an average of 7.1±0.5522 mg/L and from 6 mg/L (S1, S5) to 7 mg/L (S3) with an average of 6.4±0.4183 during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values of DO were below the WHO guideline value of 4-6 mg/L. The total alkalinity of the lake water ranged from 35 mg/L (sites II and V) to 40 mg/L (sites I, III, and IV), with an average of 38±2.7386 mg/L, and 35 mg/L (S3) to 45 mg/L (S1), with an average of

40±3.5355 mg/L during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were below the WHO guideline value of 125-350 mg/L.

The value of total hardness ranged from 24 mg/L (S1, S2, S4) to 30 mg/L (S3) with an average of 26±2.8284 mg/L and from 30 mg/L (S4, S5) to 40 mg/L (S2) with an average of 34±4.1833 during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were below the WHO guideline value of 500 mg/L. The value of free carbon dioxide ranged from 10.8 mg/L (S3) to 14.6 mg/L (S2) with an average of 12.42±1.5594 mg/L and from 13.1 mg/L (S2) to 17.4 mg/L (S5) with an average of 15.22±1.8143 during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were above the WHO guideline value of 10 mg/L.

The value of nitrate ranged from 0.35 mg/L (S1) to 0.43 mg/L (S4) with an average of 0.38±0.0024 mg/L and from 0.33 mg/L (S3) to 0.35 mg/L (S2, S5) with an average of 0.35±0.027 mg/L during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were below the WHO guideline value of 10 mg/L. The value of phosphate (PO4-P) ranged from 0.08 mg/L (S5) to 0.14 mg/L (S1) with an average of 0.18 ± 0.00238 mg/L and from 0.11 mg/L (S3, S4, S5) to 0.13 mg/L (S3) with an average of 0.17±0.009 mg/L during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were above the WHO guideline value of 0.01 mg/L.

The value of Biological Oxygen Demand (BOD) ranged from 14 mg/L (S2) to 24.5 mg/L (S4) with an average of 18.8±4.2924 mg/L and from 20 mg/L (S1, S2) to 22 mg/L (S3) with an average of 21.8±2.2527 mg/L during post-monsoon 2022 and pre-monsoon 2023, respectively. All the values were above the WHO guideline value of 2 mg/L. The Chemical Oxygen Demand (COD) values were between 40 mg/L (S3, S5) and 50 mg/L (S1, S2, S5) with an average of 46±5.477 mg/L during post-monsoon 2022, and between 30 mg/L (S2, S3, S4, S5) and 40 mg/L (S1) with an average of 32±4.472 mg/L during pre-monsoon 2023. All the values were below the WHO guideline value of 80 mg/L. The electric conductivity of water was measured at 35°C. The EC ranged from 45.2 mg/L (S5) to 76.2 mg/L (S4) with an average of 61.2±11.9365 µ℧ during post-monsoon 2022, and it was 55.2 µ℧ (S5) to 77.2 µ℧ (S1) with an average of 64.425±7.169 in pre-monsoon 2023. All the values were below the WHO guideline value of 1500 µ℧.

3.2. Microbiological characteristics of lake water

All five water samples showed the presence of fecal coliform bacteria. This means the water is contaminated with feces, which can be a health risk. The levels of fecal coliforms were 20 CFU/100 mL for samples S1, S2, and S3, 15 CFU/100 mL for S4, and 25 CFU/100 mL for S5 after the monsoon in 2022, and 10 CFU/100 mL for S1, 16 CFU/100 mL for S2, 12 CFU/100 mL for S3, 8 CFU/100 mL for S4, and 6 CFU/100 mL for S5 before the monsoon in 2023. All these levels were below the WHO guideline of 0 mg/L. The amount of fecal coliforms in freshwater shows that the water may be contaminated with human and animal waste. Water with this type of contamination is a serious health risk and is not safe to drink unless it has been properly treated. Untreated feces add too much organic material to the water, which breaks down and uses up the oxygen. Fecal pollution can harm the variety and number of microorganisms in the water. The presence of fecal contamination indicates a potential health risk for anyone who comes into contact with this water.

3.3. Description of correlation matrix

The correlation coefficient (r) of different physicochemical parameters of Chimdi Lake was calculated using Microsoft Office Excel 2007, and the correlation matrix is represented in the table below. Here, 'r' is a dimensionless index that is in the range of -1.0 to +1.0 inclusive and exhibits the extension of a relation between variables. Statistically, pH had a strong positive relationship with COD (r = 0.936), NO_3-N (r = 0.924), PO_4-P (r = 0.954), and TSS (r = 0.832), and a strong negative relationship with DO (r = -0.905), TH (r = -0.899), BOD (r = -0.833), and TDS (r = -0.759). Similarly, TDS showed a strong positive correlation with BOD (r = 0.986), EC (r = 0.947), DO (r = 0.837), and TH (r = 0.791), and a negative correlation with COD (r = -0.823), NO3-N (r = -0.841), and PO4-P (r = -0.834). Likewise, TSS showed a strong positive correlation with COD (r = 0.858), NO_3-N (r = 0.833), and PO_4-P (r = 0.847) and a negative correlation with TH (r = -0.870) and BOD (r = -0.8711). A strong positive correlation was noticed between EC and TDS (r = 0.947). Furthermore, DO showed a strong positive correlation with TH (r = 0.998) and EC (r = 0.784) and a negative correlation with temperature (r = -0.982).

Table 3. Correlation matrix

	Temp	pH	TDS	TSS	TH	EC	TA	FCO_2	DO	BOD	COD	NO_3-N	PO_4-P	F.Coliform
Temp	1													
pH	0.896	1												
TDS	-0.867	-0.759	1											
TSS	0.763	0.832	-0.63	1										
TH	-0.96	-0.899	0.791	-0.870	1									
EC	-0.828	-0.693	0.947	-0.455	0.708	1								
TA	-0.546	-0.59	0.657	-0.479	0.531	0.585	1							
FCO_2	0.720	0.653	-0.426	0.530	-0.727	-0.359	-0.554	1						
DO	-0.982	-0.905	0.837	-0.821	0.998	0.784	0.542	-0.713	1					
BOD	-0.931	-0.833	0.986	-0.711	0.877	0.934	0.636	-0.509	0.914	1				
COD	0.955	0.936	-0.823	0.858	-0.974	-0.771	-0.612	0.663	-0.978	-0.903	1			
NO_3-N	0.988	0.924	-0.841	0.833	-0.971	-0.767	-0.509	0.710	-0.979	-0.911	0.955	1		
PO_4-P	0.968	0.954	-0.834	0.847	-0.969	-0.781	-0.526	0.650	-0.979	-0.913	0.982	0.979	1	
E. Cond.	0.226	0.505	0.102	0.611	-0.405	0.218	0.042	0.322	-0.325	-0.034	0.384	0.335	0.402	1
F.Coliform	-0.803	-0.807	0.544	-0.805	0.849	0.447	0.609	-0.794	0.813	0.644	-0.863	-0.815	-0.805	1

3.4. Heavy metals concentrations

In Barju Lake, heavy metals were detected in very low concentrations. Concentrations of chromium (Cr) <0.05 mg/L, arsenic (As) <0.005 mg/L, lead (Pb) <0.01 mg/L, zinc (Zn) <0.05 mg/L, and cadmium (Cd) <0.003 mg/L from S1, S2, S3, S4, and S5 during post-monsoon 2022 and pre-monsoon 2023, respectively (Table 4).

Heavy metals like cadmium, lead, copper, and zinc are the main pollutants in water environments because they are toxic, last a long time in the environment, and can build up in food chains. The majority of heavy metal contaminants reach lakes from human-made sources. They arrived directly by air dust, moist deposition, indirect effluence, or land runoff (Goher et al. 2014). As a result of evapotranspiration and the stagnant water in the lake, they gradually get enriched as contaminants in the sediments (Salomons, 1998).

As a consequence, hazardous heavy metals find their way into food chains like fish and vegetables, eventually making their way into the human body and posing major health risks (WHO, 2006; Zeng et al., 2009). The elemental fluctuation inside the lake primarily depends on natural sources; however, increased human activity can also be responsible for the additional loading of the elemental concentration (Purushothaman & Chakrapani, 2007; Tang et al., 2014). The heavy metals are generally adsorbed on the surface of fine and coarse particles and get deposited on the sediments at the bottom (Tang et al., 2014).

Table 4. Heavy metals concentrations in Barju Lake water, Sunsari (Pre-monsoon 2023)

Parameters	S1	S2	S3	S4	S5	Average	WHO
Cr	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
As	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Pb	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Zn	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Cd	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	

4. Conclusions

The study assessed the water quality of Barju Lake in Nepal between post-monsoon 2022 and pre-monsoon 2023. The average water temperature was below the WHO guideline, while heavy metals were detected in low concentrations. The pH remained alkaline, potentially causing habitat destruction and ecosystem disruption. Changes in water chemistry may disrupt nutrient cycles, affecting aquatic flora and fauna. Excessive free carbon dioxide (FCO_2) can lower pH, harm aquatic life, and affect species diversity. High Biochemical Oxygen Demand (BOD) indicates increased organic pollution, depleting oxygen levels. Elevated phosphate levels can lead to eutrophication, which promotes excessive algal growth and results in hypoxic conditions. These conditions disrupt ecological balance, reduce biodiversity, and compromise aquatic ecosystem health.

Conflicts of interest. The authors mentioned that none of them have a conflict of interest when it comes to this article.

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Acknowledgments

Authors are thankful to University Grants Commission, Sanothimi, Bhaktapur, Nepal, for Small Research and Development and Innovation Grants (SRDIG. 78/79-S&T-03) and the Department of Botany, M.M.A.M. Campus, Biratnagar, and Nepal Batawaraniya Sewa Kendra, Biratnagar, for their help in the laboratory.

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