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RESEARCH ARTICLE

Hydrochemical assessment of Bageshwori pond of Nepalgunj (Nepal): implications for water quality management and sustainability

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ABSTRACT

This study assesses the hydrochemistry and water quality status of Bageshwori Pond located in Nepalgunj, Lumbini Province, Nepal. The objective of the research was to evaluate the physicochemical characteristics of the pond and understand its environmental condition considering its religious and cultural importance. Water samples were collected from six different sites within the pond and analyzed for major hydrochemical parameters including temperature, pH, electrical conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, nitrate, ammonia, phosphate, chloride, alkalinity, hardness and iron using onsite measurements probes and standard laboratory methods. The results showed noticeable spatial variations in several physicochemical parameters across the sampling sites. Concentrations of ammonia (0.461 ± 0.010 mg/L) and phosphate (0.330 ± 0.233 mg/L) indicated localized nutrient variability, particularly for phosphate, which may be associated with organic matter decomposition, religious activities and urban runoff surrounding the pond. DO levels ranged between 3.10 and 4.10 mg/L, indicating moderate oxygen availability in the aquatic system. Turbidity values varied considerably (1-8 NTU), with Site 5 exceeding the NDWQS permissible limit of 5 NTU, suggesting differences in suspended particles and sediment disturbance. BOD values were relatively low (15.4 ± 2.10 mg/L), indicating limited biodegradable organic pollution, while comparatively higher COD values (159.33 ± 34.88 mg/L) suggested the presence of oxidizable organic and inorganic substances. The Weighted Arithmetic Water Quality Index (WQI) values ranged from 69.15 to 75.61 (mean 71.13), classifying all sampling sites within the "poor" water-quality category. Overall, the hydrochemical analysis0 indicates that Bageshwori Pond currently maintains poor water quality conditions, although few parameters reflect the influence of anthropogenic activities and surrounding urban pressures. Considering the religious, cultural and aesthetic significance of the pond adjacent to Bageshwori Temple, regular monitoring, proper waste management, and effective conservation strategies are recommended to maintain the ecological health and sustainability of this important freshwater resource.

Keywords: ***Physicochemical analysis, water quality management, urban pond, Bageshwori temple, WQI***

INTRODUCTION

1.1 Background

Water is a vital natural resource that promotes socioeconomic growth and ecological balance. Important ecosystem services including drinking water supply, irrigation, fisheries, groundwater recharge, nutrient cycling and habitats for aquatic species are provided by freshwater ecosystems like rivers, lakes, wetlands and ponds (Pal et al., 2021). Despite their significance, rapid urbanization, industrial discharge, agricultural runoff, population growth and climate variability are posing an increasing threat to freshwater bodies globally (WHO, 2017; United Nations Environment Programme UNEP, 2021). In addition to upsetting aquatic ecosystems, declining water quality poses major threats to human health and sustainable development.

Understanding hydrochemistry, the study of the chemical composition of water and the mechanisms that influence it is necessary to comprehend the dynamics of water quality. The hydrochemical characteristics of surface water are controlled by both the natural processes, including rock-water interactions, weathering, precipitation, evaporation, and biological activity, together with anthropogenic influences such as urban runoff, domestic wastewater discharge agricultural practices and industrial effluents. These processes are commonly evaluated using physicochemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), total hardness, alkalinity, turbidity etc. Collectively, these parameters provide a comprehensive assessment of water quality and are widely used to determine the suitability of water for domestic, agricultural, industrial, recreational and ecological purposes (Bohara et al., 2024; Pant et al., 2023).

Water Quality Index (WQI) techniques have been used more frequently in recent decades to combine intricate hydrochemical data into a single figure that represents the general state of water quality. The WQI method streamlines interpretation and makes it easier for the public and policymakers to understand scientific findings (UNEP, 2021). A thorough understanding of pollution sources, seasonal variation and human influences on freshwater systems can be obtained by combining hydrochemical investigations with WQI assessment (Khanal et al., 2025).

Freshwater resources are plentiful in Nepal, but rising urbanization, poor wastewater treatment facilities and improper solid waste disposal are putting increasing pressure on their quality. Existing infrastructure is under stress due to rapid population growth, the expansion of built-up regions and an increase in the demand for water resources (Molden, 2019). According to reports from the Ministry of Forests and Environment (MoFE, 2020), numerous urban wetlands and ponds are experiencing environmental degradation due to encroachment, sedimentatio and nutrient enrichment. In a similar vein, the Department of Water Supply and Sewerage Management (DWSSM, 2022) emphasized that urban runoff and household sewage can contaminate surface water bodies in towns.

The increasing concern in freshwater pollution has been demonstrated by several hydrochemical and water quality investigations carried out in Nepal. Anthropogenic factors and rising nutrient concentrations were found to have an impact on the water quality of Phewa Lake in Pokhara Valley (Poudel et al., 2023). Similarly, hydrochemical analyses of Rajarani Lake in Dhankuta and Jhilmila Lake in Kanchanpur revealed seasonal and geographical differences in physicochemical parameters which leads to changes in land use and human activity (Pal et al., 2021; Pant et al., 2020). Further research on the Ghodaghodi Lake Complex shows that agricultural runoff and urbanization have a major impact on ecological health and hydrochemical features (Paudel et al., 2020). These findings emphasize the need for the regular monitoring and scientific assessment of freshwater bodies throughout Nepal.

In Nepal, ponds and lakes have significant cultural and religious significance in addition to their ecological and economic significance. Numerous sources of water are connected to temples and other hallowed locations where religious sacrifices, ritual bathing, and celebrations are frequently held. Even though these customs are deeply ingrained in the culture, improper management could lead to contamination and nutrient loading. A recent study from Kathmandu Valley demonstrated a widespread degradation of pond water quality, along with increasing microbial contamination highlighting the influence of urbanization and human activities on Nepalese pond ecosystems (Pokharel et al., 2025). Studies of lowland wetlands in Nepal have also reported spatial and seasonal variations in nutrients, dissolved oxygen, and other hydrochemical parameters associated with runoff and human activities (Diwakar et al., 2008). A study done at an urban pond ecosystem in Kirtipur Municipality showed that the human activities such as religious activities and rainfall regime is also a major factor affecting the water quality (Shrestha & Adhikari, 2016). Another research done in holy waters in Kathmandu showed the alarming status of water quality requiring better sanitation, cleaning and stronger efforts for protection and conservation of culturally valuable water sources (Nakarmi et al., 2026). Situated in the Terai area of southwest Nepal, Nepalgunj is a fast-expanding sub-metropolitan city. High summer temperatures and seasonal rainfall are hallmarks of the region's subtropical monsoon climate, which affects the hydrology and chemical makeup of surface water. Local water resources are under pressure due to urbanization, rising population density and growing commercial activity.

One of the most important religious sites in Nepalgunj Sub-metropolitan City is the Bageshwori Temple that welcomes thousands of worshipers every year. Bageshwori Pond, a culturally significant freshwater pond utilized for ritual bathing, ceremonial offerings, aesthetic enjoyment, and local recreation, is located next to the temple. The pond contributes to Nepalgunj's social and cultural character by acting as a communal area and a spiritual hub. Despite its religious and aesthetic significance, Bageshwori Pond is also an important urban freshwater ecosystem whose water quality may influence aquatic habitat and the environmental quality of the surrounding area. Its location adjacent to Bageshwori Temple and within an urban setting makes the pond potentially vulnerable to surface runoff, solid-waste accumulation, ritual activities, and wastewater inputs, which may alter nutrient levels, DO, turbidity and other hydrochemical characteristics. Recent research on 27 ponds in Kathmandu Valley documented widespread physicochemical and microbial contamination and identified increasing anthropogenic pressure as an important concern for pond ecosystems, emphasizing the need for improved sewage and runoff management and expanded seasonal monitoring (Pokharel et al., 2025). Similarly, recent research on pond ecosystems in Kirtipur Municipality demonstrated spatial differences in hydrochemical characteristics and identified multiple controlling sources of water chemistry, highlighting the scientific importance of systematic assessment of urban ponds in Nepal (Awasthi et al., 2025). Therefore, scientific assessment of Bageshwori Pond is important not only for understanding its hydrochemical condition but also for establishing baseline information to support conservation, pollution management, and future monitoring of this culturally significant urban freshwater resource. To collect baseline data, identify probable sources of pollution, and evaluate Bageshwori Pond's suitability for various uses, a thorough hydrochemical and water quality investigation is necessary. Specifically, this study aims to: 1. Establish baseline hydrochemical parameters by assessing the physicochemical water quality within Bageshwori Pond, 2. Identify key sources of pollution affecting the pond ecosystem, focusing on anthropogenic activities, nutrient inputs, and wastewater discharge, and 3. Create evidence-based recommendations to support the sustainable management, conservation, and environmental protection of Nepal's culturally significant freshwater bodies.

MATERIALS AND METHODS

Study area

Located in the Terai plains close to the border between Nepal and India, Nepalgunj is a significant sub-metropolitan city in Banke District, southwestern Nepal. With hot summers exceeding 40 °C, mild winters and a prominent monsoon season from June to September during which most of the yearly rainfall occurs, the area experiences a subtropical monsoon climate that directly affects the hydrology of nearby water bodies (Subedi et al., 2022). The flat terrain, alluvial soils and shallow groundwater of the Terai plain contribute to the creation and sustainability of regional ponds, lakes and wetlands. Situated adjacent to Shree Bageshwori Temple at a latitude of 28° 03' 41.7" N and a longitude of 81° 37' 29.0" E, Bageshwori Pond is a culturally and religiously significant freshwater body covering a surface area of approximately 4,901 m^2 (0.49 ha). The sampling sites across the pond lie at an average elevation of 170.55 m above sea level, ranging from 167.99 m to 173.17 m above sea level (Table 1, Figure 1).

The pond is relatively shallow, with its water level fluctuating annually in response to seasonal monsoon precipitation, evaporative loss and surface runoff. Hydrologic inputs maintaining the pond primarily include direct monsoon rainfall, urban stormwater runoff from surrounding paved surfaces and channels, and subsurface seepage from the shallow alluvial groundwater table. Bageshwori Pond is closely integrated with a dense urban built-up landscape comprising paved temple courtyards, stone ghats, commercial vendor stalls, municipal roads, residential housing, and Bageshwori Park with ornamental urban vegetation. The pond is heavily used for ceremonial offerings, ritual bathing, and leisure, especially during major Hindu festivals like Maha Shivaratri and Dashain. Through surface runoff from surrounding impervious surfaces, solid waste buildup (including decayed floral and organic ritual offerings), and potential localized residential wastewater discharge, the pond experiences continuous pressure from growing urbanization, population increase, and nearby commercial operations, all of which influence its hydrochemical properties.

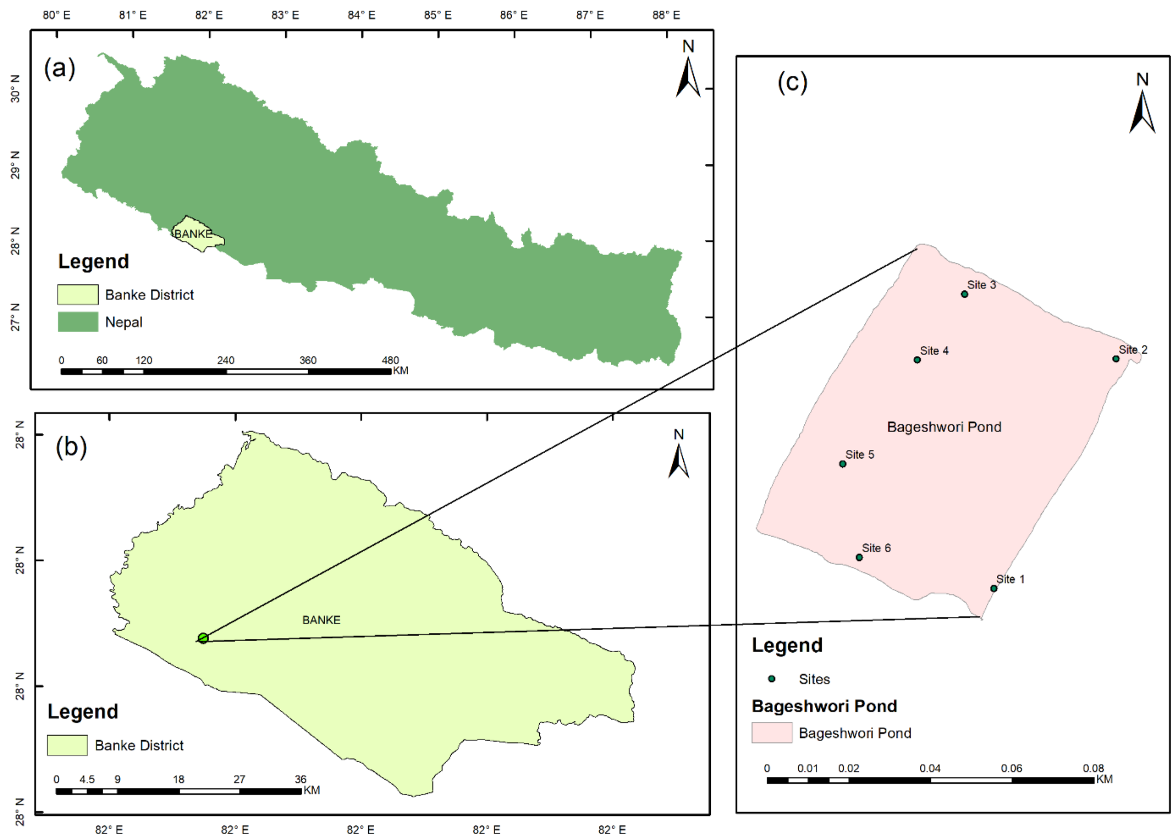

Fig. 1: The Map showing the Study Area (a) Geographical location of Nepal (b) Location of Banke district (c) Location of Bageshwori pond

Table 1 Sampling locations in the Bageshwori Pond

Sites	Longitude	Latitude	Environmental Characteristics
Site 1	81.62447185	28.0612448	High organic load from sewage inflow and ritual waste, dense algal blooms, foul odor, and low dissolved oxygen. Heavy presence of plastics, food remnants, and urban runoff.
Site 2	81.62474142	28.0617513	Effluents from temple area and household waste dominate, turbid water with visible suspended solids. Poor light penetration due to high suspended solids.
Site 3	81.62440721	28.0618942	Mixed pollution sources including domestic discharge and partial stormwater inflow, water clarity slightly better, but nutrient enrichment persists. Moderate algal growth, occasional foul smell and some invertebrates were visible from outside.
Site 4	81.62430348	28.0617487	Reduced contamination compared to sites 1, 2 and 3, water shows moderate transparency, with patches of algal growth, lesser organic matter accumulation.

Sites	Longitude	Latitude	Environmental Characteristics
Site 5	81.62413891	28.0615197	High anthropogenic impacts with turbid water, minimal direct waste inflow, relatively clearer water, balanced nutrient levels, healthy aquatic vegetation supports some fish and insects. Suitable for limited ritual and recreational use.
Site 6	81.62417548	28.0613135	Relatively pristine condition with minimal disturbance; high water clarity, stable oxygen levels; low aquatic biodiversity, including sensitive species; functions as a natural refuge, ecological buffer for the pond.

Sampling Procedure

A total of six water samples were collected from the study site to analyze physico-chemical parameters of the pond. This sampling strategy was designed to provide the overall water quality conditions of the pond. The field data collection was conducted at Bageshwori pond, located in Nepalgunj, on December 6, 2025.

The samples were collected at around 2:00 PM to capture the afternoon state of the pond's ecosystem. Pre-cleaned and sterilized sampling bottles were used to collect water from the surface of the pond. The collected samples were then transported to the laboratory at the Central Department of Environmental Science (CDES) for further lab analysis. Some parameters were analyzed within 24 hours of the sample taken and samples were stored at 4^{o}C in the laboratory for further analysis.

The samples were analyzed for physicochemical and hydrochemical parameters including temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), nitrate, ammonia, phosphate, iron, chloride, alkalinity, total hardness, calcium hardness, magnesium hardness, and free carbon dioxide (CO_2). The analyses were conducted using standard laboratory procedures, with analytical methods based primarily on *Standard Methods for the Examination of Water and Wastewater* (APHA, 2017), where applicable. The specific analytical methods used for each parameter are presented in Table 2. The 23rd edition of *Standard Methods* is a widely used reference containing standardized procedures for water and wastewater analysis.

Table 2: Analytical methods and instruments used for determination of water-quality parameters

S.N.	Parameter	Method	Instrument/Equipment
1	Temperature	Electrometric	Milwaukee pH55, UK
2	pH	Electrometric	Milwaukee pH55, UK
3	EC and TDS	Electrometric	Milwaukee EC59, Europe
4	Dissolved oxygen (DO)	Electrometric	YSI Professional Plus Multiparameter Instrument
5	Turbidity	Nephelometric	Wagtech 2100 AN Turbidity Meter
6	Free CO_2	Titrimetric (sodium hydroxide method)	Conical flask, measuring cylinder, pipette, burette and burette stand

S.N.	Parameter	Method	Instrument/Equipment
7	Chloride	Argentometric method	Conical flask, measuring cylinder, pipette, burette and burette stand
8	Total alkalinity	Titrimetric	Conical flask, measuring cylinder, pipette, burette and burette stand
9	Total hardness	Titrimetric (EDTA method)	Conical flask, measuring cylinder, pipette, burette and burette stand
10	Calcium hardness	Titrimetric (EDTA method)	Conical flask, measuring cylinder, pipette, burette and burette stand
11	Sodium	Flame photometric	Flame Photometer (Model 1382)
12	Potassium	Flame photometric	Flame Photometer (Model 1382)
13	Sulphate	Turbidimetric	Spectrophotometer (SS1 UV 2101)
14	Phosphate	Ammonium molybdate method	Spectrophotometer (SS1 UV 2101)
15	Ammonia	Nessler's reagent method	Spectrophotometer (SS1 UV 2101)
16	Iron	Phenanthroline method	Spectrophotometer (SS1 UV 2101)
17	Biological oxygen demand (BOD_5)	Five-day incubation method	Incubation setup and dissolved oxygen meter
18	Chemical oxygen demand (COD)	Open reflux method using potassium dichromate (APHA 5220 B)	Conical flask, reflux setup and titration apparatus

Note: Laboratory analyses of physicochemical parameters were conducted following the procedures described in Standard Methods for the Examination of Water and Wastewater *(APHA, AWWA, WEF, 2017), using the respective analytical procedures and instruments indicated above.*

Water Quality Index (WQI)

The Weighted Arithmetic Water Quality Index (WQI) method was used to assess the overall water quality of Bageshwori Pond. The WQI was calculated using parameters with applicable permissible values in the National Drinking Water Quality Standards (NDWQS, 2022), namely pH, turbidity, electrical conductivity (EC), total ammonia, nitrate, chloride, total hardness, and iron. Temperature, dissolved oxygen (DO), phosphate (PO_4^{3-}), BOD_5, COD, total alkalinity, calcium hardness, magnesium hardness, and free CO_2 were excluded from the WQI because directly applicable reference values were not available within the selected standard framework; however, these parameters were considered separately for ecological interpretation.

The quality rating (Q_i) and unit weight (W_i) for each parameter were calculated as:

$$Q_i = 100\left(\frac{V_i - V_o}{S_i - V_o}\right)$$

$$W_i = \frac{K}{S_i},$$

where (V_i) is the measured value, (S_i) is the permissible standard value, and (V_o) is the ideal value (7.0 for pH and 0 for other parameters). The overall WQI was calculated as:

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

The standard values used were pH (6.5–8.5), turbidity (5 NTU), EC (1500 µS/cm), total ammonia (1.5 mg/L), nitrate (50 mg/L), chloride (250 mg/L), total hardness (500 mg/L), and iron (0.3 mg/L), based on NDWQS (2022). WQI values were classified as excellent (0–25), good (26–50), poor (51–75), very poor (76–100), and unsuitable for drinking (>100) (Brown et al., 1972).

RESULTS

There is noticeable spatial variation in water quality across Bageshwori Pond based on six sampling locations (Table 1; Figures 1–3). Temperature, DO, major ions, nutrients and organic-load indicators differed among sites, but most parameters remained within NDWQS (2022) and WHO drinking-water limits. The only exceedance of a cited drinking-water standard was turbidity at Site 5. Site-to-site differences in phosphate, chloride, hardness speciation and COD point to localized inputs rather than pond-wide non-compliance.

Descriptive statistics

Descriptive statistics (mean ± SD, minimum, maximum; n = 6 sites) are given in Table 3. Because each site is represented by a single laboratory value, the SD and coefficient of variation (CV) describe spatial variability among sites, not analytical replicate error.

Table 3: Descriptive statistics of hydrochemical parameters of Bageshwori Pond

Parameter	Unit	Mean ± SD	Min	Max	CV (%)
Temperature	°C	24.08 ± 0.80	23.2	25.2	3.3
pH	—	7.81 ± 0.28	7.26	8.02	3.6
Dissolved Oxygen	mg/L	3.60 ± 0.34	3.1	4.1	9.4
Total Ammonia	mg/L	0.461 ± 0.010	0.451	0.474	2.2
Phosphate	mg/L	0.330 ± 0.233	0.021	0.549	70.6
Turbidity	NTU	2.83 ± 2.64	1	8	93.3
BOD_5	mg/L	15.4 ± 2.1	12.4	18.67	13.6
Nitrate	mg/L	0.175 ± 0.087	0.089	0.316	49.7
Chloride	mg/L	35.26 ± 7.90	19.88	41.18	22.4
Total Alkalinity	mg/L	55.33 ± 11.22	44	72	20.3
Total Hardness	mg/L $CaCO_3$	101.67 ± 11.41	84	114	11.2
Calcium Hardness	mg/L $CaCO_3$	64.00 ± 12.52	50	84	19.6
Magnesium Hardness	mg/L $CaCO_3$	37.67 ± 15.92	10	56	42.3
Electrical Conductivity	µS/cm	922.5 ± 71.96	781	971	7.8
Total Dissolved Solids	mg/L	500.5 ± 31.60	480	600	8.8
Iron	mg/L	0.244 ± 0.0015	0.242	0.246	0.6
Free CO_2	mg/L	0.233 ± 0.103	0.1	0.4	44.2
COD	mg/L	159.33 ± 34.88	110	210	21.9

Note: CV = Coefficient of Variation = SD/Mean × 100

Physical parameters

Mean water temperature was 24.08 ± 0.80 °C (range 23.2–25.2 °C; CV = 3.3%), indicating limited thermal variation. Site 4 was warmest (25.2 °C) and Site 5 coolest (23.2 °C). pH was slightly alkaline on average (7.81 ± 0.28; range 7.26–8.02) and stayed within the NDWQS range of 6.5–8.5 at every site. The lowest pH occurred at Site 5 (7.26); Sites 1 and 6 were highest (8.01 and 8.02).

DO averaged 3.60 ± 0.34 mg/L (range 3.10–4.10 mg/L). The lowest DO was at Site 1 (3.10 mg/L) and the highest at Site 5 (4.10 mg/L). DO levels averaged 3.60 ± 0.34 mg/L (range: 3.10–4.10 mg/L). When evaluated against aquatic ecosystem protection criteria, all sampling sites fell below the recommended minimum threshold of ≥ 5.0 mg/L required to maintain healthy warmwater fish populations and aquatic organisms (CCME, 1999; US EPA, 1986). DO concentrations between 3.0 and 4.0 mg/L indicate moderate hypoxia and oxygen stress in the pond ecosystem, likely driven by restricted water circulation, elevated chemical oxygen demand, and microbial decomposition of organic ritual offerings at the pond bed.

Turbidity showed the highest spatial variability of all parameters (mean 2.83 ± 2.64 NTU; range 1–8 NTU; CV = 93.3%). Sites 1, 3, 4 and 6 were ≤2 NTU. Site 5 (8 NTU) exceeded the NDWQS limit of ≤5 NTU, indicating localized suspended-solids loading at that station.

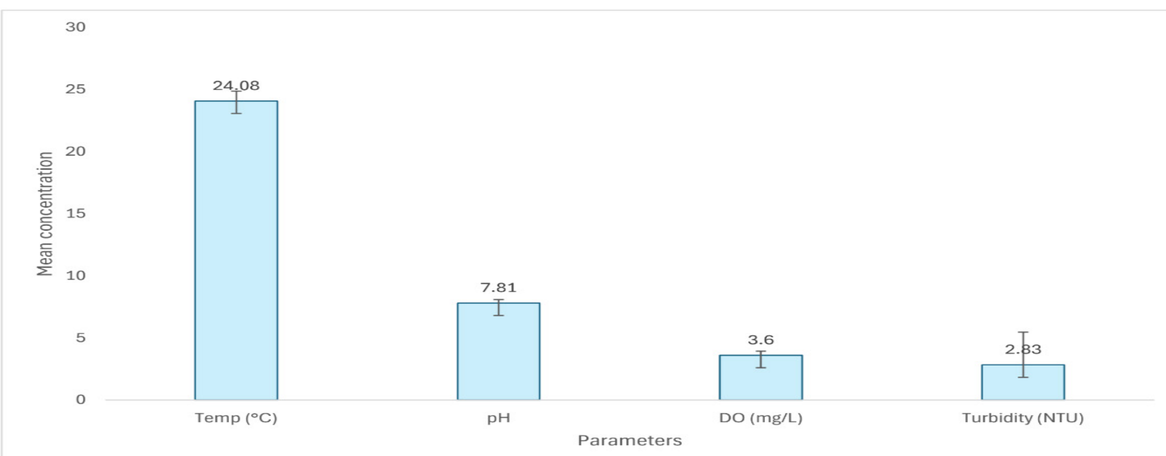

Fig. 2: Mean concentrations (± standard deviation) of physical water quality parameters

EC, TDS, major ions, total alkalinity and hardness

Electrical conductivity averaged 922.5 ± 71.96 µS/cm (range 781–971 µS/cm; CV = 7.8%), below the NDWQS limit of ≤1500 µS/cm. Site 2 had the lowest EC (781 µS/cm); Sites 1 and 5 were highest (971 and 968 µS/cm) and TDS was fluctuate accordingly.

Chloride averaged 35.26 ± 7.90 mg/L (range 19.88–41.18 mg/L), well below ≤250 mg/L. Site 3 was distinctly lower (19.88 mg/L) than the other five sites (34.08–41.18 mg/L). Total alkalinity averaged 55.33 ± 11.22 mg/L (range 44–72 mg/L). Site 1 was highest (72 mg/L) and Site 2 lowest (44 mg/L).

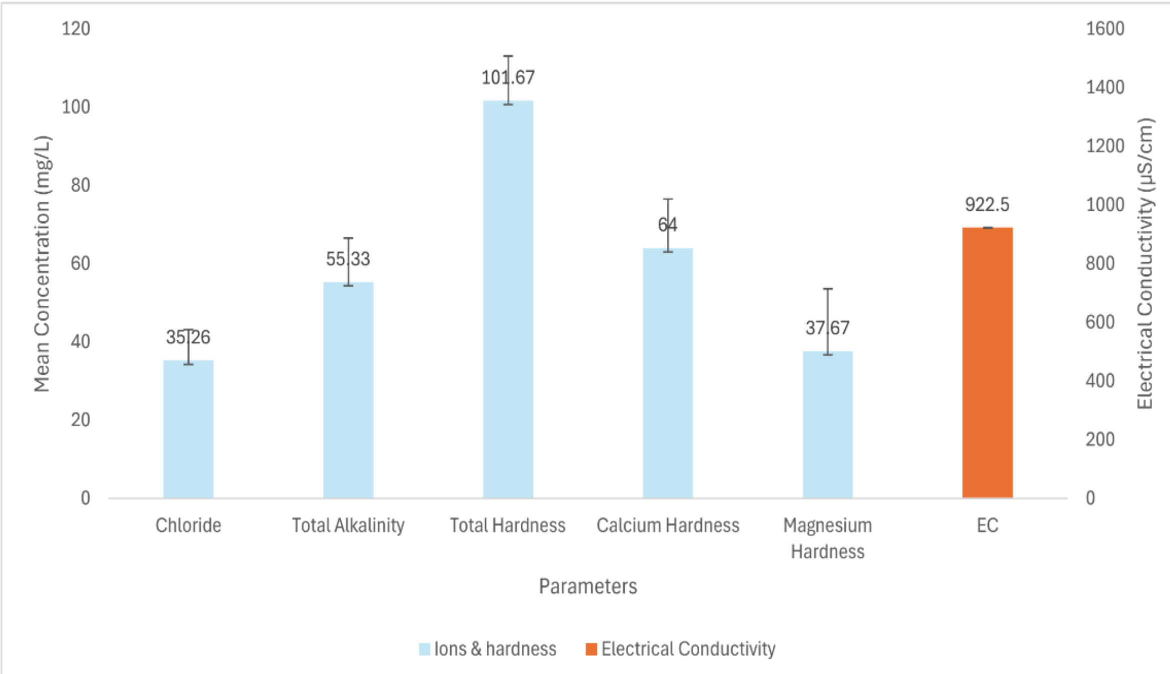

Fig. 3: Mean concentrations (± standard deviation) of major ions and hardness parameters

Total hardness averaged 101.67 ± 11.41 mg/L as $CaCO_3$ (range 84–114 mg/L), well below ≤500 mg/L, and corresponds to moderately hard water. Calcium hardness (64.00 ± 12.52 mg/L as $CaCO_3$) exceeded magnesium hardness (37.67 ± 15.92 mg/L as $CaCO_3$) at most sites. Site 1 was Ca-dominated (Ca-H 84; Mg-H 10), whereas Site 4 was relatively Mg-rich (Ca-H 50; Mg-H 56). Calcium plus magnesium hardness equalled total hardness at every site, confirming internal consistency of the hardness data (Figure 2).

Nutrients and organic load

Total ammonia was nearly uniform (0.461 ± 0.010 mg/L; range 0.451–0.474 mg/L; CV = 2.2%) and far below the NDWQS limit of 1.5 mg/L. Nitrate averaged 0.175 ± 0.087 mg/L (range 0.089–0.316 mg/L), far below ≤50 mg/L. The highest value was at Site 6 (0.316 mg/L); Sites 1 and 3 were lowest (0.089 mg/L).

Phosphate showed strong spatial heterogeneity (mean 0.330 ± 0.233 mg/L; range 0.021–0.549 mg/L; CV = 70.6%). Sites 1 and 3 were low (0.021 and 0.048 mg/L); Sites 2, 4, 5 and 6 were an order of magnitude higher (0.418–0.549 mg/L). No universal drinking-water guideline for phosphate was applied. Iron was essentially constant (0.244 ± 0.0015 mg/L; range 0.242–0.246 mg/L; CV = 0.6%) and below ≤0.3 mg/L at all sites. Free CO_2 averaged 0.233 ± 0.103 mg/L (range 0.1–0.4 mg/L), highest at Site 1 (0.4 mg/L) and lowest at Site 3 (0.1 mg/L).

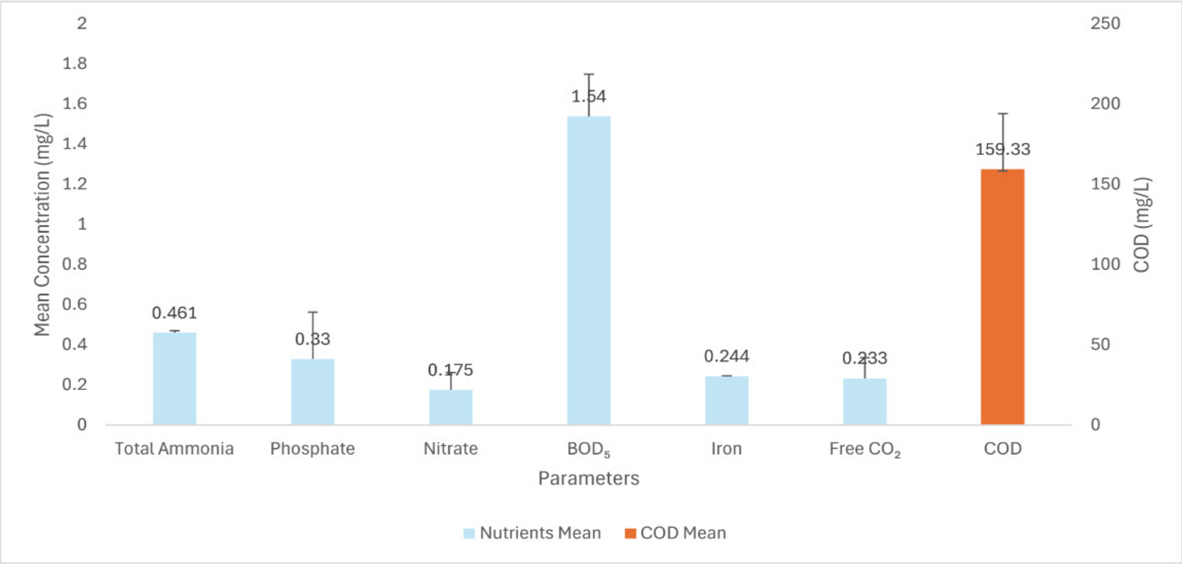

Fig. 4: Mean concentrations (± standard deviation) of nutrient and organic load parameters

BOD_5 was low (1.54 ± 0.21 mg/L; range 1.20–1.80 mg/L). COD was much higher (159.33 ± 34.88 mg/L; range 110–210 mg/L). Site 1 had the highest organic-load pair (BOD_5 1.8 mg/L; COD 210 mg/L); Site 5 had the lowest (BOD_5 1.2 mg/L; COD 110 mg/L). The high COD relative to BOD_5 indicates a larger fraction of chemically oxidizable than readily biodegradable organic matter. Neither parameter has a WHO health-based drinking-water guideline; both are reported as organic-load indicators (Figure 3).

General Hydrochemistry

The mean water temperature of 24.08 °C was recorded at Bageshwori Pond, with values ranging from 23.2 to 25.2 °C across the six sampling sites. The observed temperature reflects the subtropical climatic conditions of Nepalgunj and falls within a range generally suitable for warm-water aquatic organisms. Temperature is an important ecological parameter because it influences metabolic activity, dissolved oxygen availability, microbial processes, and the decomposition of organic matter in aquatic ecosystems. Although the recorded temperatures did not indicate extreme thermal conditions, continued increases in water temperature may alter metabolic processes and community structure, particularly in shallow urban ponds. Therefore, maintaining good water quality and minimizing additional thermal and organic pollution are important for sustaining the ecological condition as well as the religious and aesthetic value of Bageshwori Pond associated with Bageshwori Temple.

The electrical conductivity (EC) values recorded at Bageshwori Pond ranged from 781 to 971 μS/cm across the six sampling sites, with a mean value of 922.5 μS/cm. The relatively high EC values indicate the presence of dissolved ions in the pond water and reflect its overall hydrochemical condition. Elevated conductivity in urban ponds may be associated with the input of dissolved salts and minerals through surface runoff, wastewater inputs, organic matter decomposition, and other human activities around the pond. Spatial variation in EC among the sampling sites may therefore reflect differences in local sources of dissolved materials and hydrological conditions. EC is consequently a useful indicator for assessing changes in the hydrochemical characteristics and overall water quality of Bageshwori Pond. The TDS values are consistent with the measured EC values in the respective sites.

The pH values recorded at Bageshwori Pond ranged from 7.26 to 8.02, with a mean value of 7.81, indicating neutral to slightly alkaline conditions. The observed range falls within the commonly accepted range for freshwater aquatic ecosystems and indicates relatively stable hydrochemical conditions during the sampling period. Variations in pH among the sampling sites may be associated with biological activity, organic matter decomposition, surface runoff, and other anthropogenic influences around the pond. Overall, the observed pH values indicate that the pond water was within the acceptable range for maintaining freshwater ecological conditions during the study period.

Table 4: General hydrochemistry of Bageshwori Pond

Parameter	Unit	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Reference/standard value	Reference source
Temperature (Temp.)	°C	23.6	24.4	23.4	25.2	23.2	24.7	No specific drinking-water guideline	—
pH	—	8.01	7.86	7.78	7.92	7.26	8.02	6.5–8.5	NDWQS, 2022
Dissolved oxygen (DO)	mg/L	3.1	3.45	3.6	3.55	4.1	3.82	No WHO health-based guideline	WHO
Total ammonia (NH_3/NH_4^+)	mg/L	0.451	0.459	0.454	0.474	0.471	0.454	1.5 mg/L	NDWQS, 2022
Phosphate (PO_4^{3-})	mg/L	0.021	0.549	0.048	0.493	0.418	0.449	No directly applicable universal guideline	—
Turbidity	NTU	2	3	1	2	8	1	≤5 NTU	NDWQS, 2022
Biological oxygen demand (BOD_5)	mg/L	1.8	1.7	1.5	1.55	1.2	1.46	No WHO drinking-water guideline	WHO
Nitrate (NO_3^-)	mg/L	0.089	0.152	0.089	0.228	0.177	0.316	≤50 mg/L	NDWQS, 2022; WHO
Chloride (Cl^-)	mg/L	39.76	41.18	19.88	34.08	38.34	38.34	≤250 mg/L	NDWQS, 2022
Total alkalinity (TA)	mg/L	72	44	48	46	64	58	No specific guideline	—
Total hardness (TH)	mg/L as $CaCO_3$	94	114	112	106	84	100	≤500 mg/L	NDWQS, 2022
Calcium hardness (Ca-H)	mg/L as $CaCO_3$	84	68	70	50	54	58	No specific guideline	—
Magnesium hardness (Mg-H)	mg/L as $CaCO_3$	10	46	42	56	30	42	No specific guideline	—
Electrical conductivity (EC)	µS/cm	971	781	958	936	968	921	≤1500 µS/cm	NDWQS, 2022
Total Dissolved Solids (TDS)	mg/L	505	480	590	530	600	520	1000	NDWQS, 2022

Parameter	Unit	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Reference/standard value	Reference source
Iron (Fe)	mg/L	0.243	0.243	0.243	0.245	0.246	0.242	≤0.3 mg/L	NDWQS, 2022
Free carbon dioxide (CO_2)	mg/L	0.4	0.2	0.1	0.2	0.3	0.2	No specific guideline	—
Chemical oxygen demand (COD)	mg/L	210	185	150	160	110	141	No WHO drinking-water guideline	WHO

NDWQS = National Drinking Water Quality Standards, Nepal (2022).
WHO drinking-water guidelines are intended for drinking-water safety and should not be interpreted as ecological standards for pond ecosystems. Dissolved oxygen, BOD_5, COD, and several other parameters listed above do not have WHO health-based drinking-water guideline values applicable to this assessment.

The hydrochemical analysis of water samples collected from six sites of Bageshwori Pond revealed noticeable spatial variation in nutrient concentration and physicochemical properties (Table 4). Nitrate concentrations ranged from 0.089 mg/L to 0.316 mg/L, with the highest concentration recorded at Site 6 (0.316 mg/L) and the lowest at Sites 1 and 3 (0.089 mg/L). These relatively low nitrate concentrations indicate limited nitrate accumulation in the pond water, suggesting that nitrate pollution is not a major concern at present. Ammonia concentrations ranged from 0.451 mg/L to 0.474 mg/L, with the highest value recorded at Site 4 (0.474 mg/L). The presence of ammonia indicates decomposition of organic matter and possible anthropogenic inputs such as ritual offerings, food waste, and organic debris entering the pond.

Phosphate concentrations showed considerable variation among the sampling sites, ranging from 0.021 mg/L to 0.549 mg/L. The highest phosphate concentration was observed at Site 2 (0.549 mg/L), followed by Site 4 (0.493 mg/L) and Site 6 (0.449 mg/L). Elevated phosphate levels suggest potential nutrient enrichment, which may promote algal growth and contribute to eutrophication processes in the pond ecosystem. Iron concentrations were relatively stable across all sampling sites, ranging from 0.242 mg/L to 0.246 mg/L, indicating minimal spatial variation and suggesting that iron is likely derived from natural geological sources or sediment interactions within the pond.

Chloride concentrations varied from 19.88 mg/L to 41.18 mg/L, with the highest concentration recorded at Site 2 (41.18 mg/L). Chloride in freshwater systems often originates from surface runoff, domestic activities, and urban influences surrounding the pond area. Alkalinity values ranged between 44 mg/L to 72 mg/L, indicating that the pond water has buffering capacity and can neutralize minor changes in acidity. Total hardness values ranged from 84 mg/L to 114 mg/L, indicating that the water contains appreciable concentrations of dissolved calcium and magnesium, which is common in many freshwater bodies of the Terai region.

Calcium hardness ranged from 50 mg/L to 84 mg/L, while magnesium hardness varied significantly between 10 mg/L to 56 mg/L, with the highest magnesium hardness observed at Site 4. Higher magnesium hardness may be related to mineral dissolution from sediments and surrounding geological formations. Also, as urban ponds have very low water exchange rates, dissolved minerals may accumulate up over time, especially during dry seasons when evaporation further concentrates dissolved elements (Awasthi et al., 2025). Turbidity values ranged from 1 to 8 NTU, with the highest turbidity recorded at Site 5 (8 NTU). Elevated turbidity indicates higher concentrations of suspended particles, organic matter, or sediment disturbance, which may result from human activities, wind action, or runoff entering the pond.

Free carbon dioxide concentrations ranged from 0.1 to 0.4 mg/L, with the highest concentration observed at Site 1 (0.4 mg/L). Higher free CO_2 concentrations are often associated with respiration of aquatic organisms and decomposition of organic materials. Dissolved oxygen concentrations ranged from 3.10 mg/L to 4.10 mg/L, indicating oxygen availability in the pond water. The highest DO was recorded at Site 5 (4.10 mg/L), while the lowest occurred at Site 1 (3.10 mg/L). Lower dissolved oxygen concentrations may be linked to microbial respiration and decomposition processes occurring within the pond.

Biochemical Oxygen Demand (BOD_5) values ranged from 1.20 mg/L to 1.80 mg/L, indicating relatively low levels of biodegradable organic pollution. The highest BOD value was recorded at Site 1, suggesting slightly higher organic matter concentration at that location.

Chemical Oxygen Demand (COD) values ranged from 110 mg/L to 210 mg/L, with the highest value recorded at Site 1 (210 mg/L). Elevated COD values indicate the presence of oxidizable organic and inorganic substances in the pond water, which may originate from anthropogenic inputs and natural organic matter.

4.2 Water Quality Index

The Weighted Arithmetic Water Quality Index (WQI) values calculated for the six sampling sites ranged from 69.15 to 75.61, with an overall mean of 71.13 ± 2.36 (Table 5). According to the adopted classification (Brown et al., 1972; as cited in NDWQS, 2022), all six sampling sites fell within the "poor" water-quality category (51–75), indicating that the pond water is not suitable for direct human consumption without appropriate treatment.

Site 5 recorded the highest WQI value (75.61), positioning it at the upper limit of the "poor" category and reflecting comparatively poorer water quality compared to other locations. This finding is consistent with the physicochemical results, where Site 5 exhibited the highest turbidity (8 NTU, exceeding the NDWQS limit of ≤5 NTU) and the lowest pH (7.26), both of which negatively influenced the composite index. Conversely, Site 3 recorded the lowest WQI value (69.15), indicating relatively better water quality, supported by its low chloride (19.88 mg/L) and low phosphate (0.048 mg/L) concentrations.

The narrow range of WQI values across sampling sites (span = 6.46 units; CV = 3.3%) demonstrates that the overall water-quality condition of Bageshwori Pond is broadly comparable across all locations, suggesting that contamination sources exert a relatively uniform influence on the entire pond system rather than being confined to isolated stations. Nevertheless, the elevated WQI at Site 5 highlights it as a priority location for targeted intervention and monitoring.

Among the parameters included in the WQI computation, iron carried the highest unit weight (W_i) due to its low permissible limit (0.3 mg/L), followed by ammonia and turbidity. Consequently, even minor variations in iron concentrations (0.242–0.246 mg/L across sites) contributed substantially to the overall WQI scores. This underscores that although iron levels comply with regulatory limits, they remain sufficiently close to the threshold to significantly affect index-based classifications (Figure 4).

Table 5: Weighted Arithmetic Water Quality Index (WQI) values and water-quality classification of Bageshwori Pond across six sampling sites.

Sampling Site	WQI Value	Water-Quality Classification
Site 1	70.46	Poor
Site 2	71.2	Poor
Site 3	69.15	Poor
Site 4	71.05	Poor
Site 5	75.61	Poor
Site 6	69.34	Poor
Overall Mean ± SD	71.13 ± 2.36	Poor

WQI classification (Brown et al., 1972): 0–25 = Excellent; 26–50 = Good; 51–75 = Poor; 76–100 = Very Poor; >100 = Unsuitable for drinking.

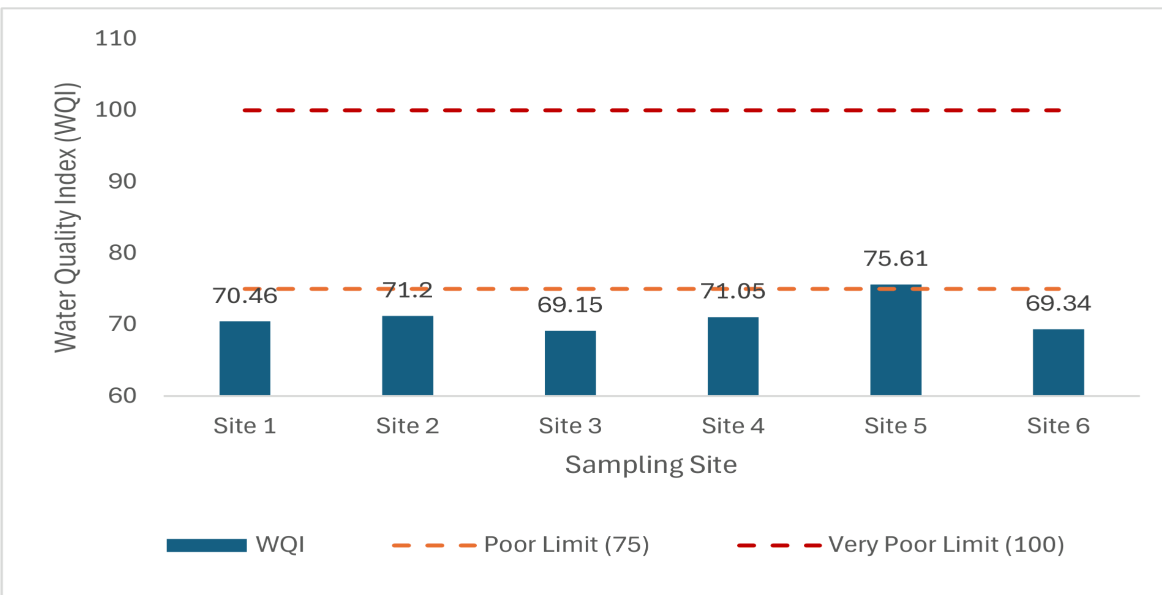

Fig. 5: Weighted Arithmetic Water Quality Index (WQI) of Bageshwori Pond at six sampling sites.

The orange dashed line is the upper bound of the "poor" class (WQI = 75); the red dashed line is the upper bound of the "very poor" class (WQI = 100). All sites fall in the poor category (51–75). Site 5 (75.61) is the highest and sits at the poor–very poor boundary.

Discussion

The hydrochemical evaluation of Bageshwori Pond across six sampling sites revealed spatial variation in several physicochemical parameters, reflecting the combined influence of natural processes and anthropogenic activities on this culturally significant urban water body. Although most parameters remained within the permissible limits established by the National Drinking Water Quality Standards (NDWQS, 2022) and the World Health Organization (WHO, 2022), the calculated Weighted Arithmetic Water Quality Index (WQI = 71.13) classified all six sampling sites as "poor," indicating that the pond water is unsuitable for direct human consumption without appropriate treatment (Brown et al., 1972; Ramakrishnaiah et al., 2009).

Nutrient Enrichment and Phosphate Heterogeneity

Nutrient concentrations exhibited pronounced spatial variability across the pond, particularly for phosphate. Phosphate concentrations ranged from 0.021 mg/L (Site 1) to 0.549 mg/L (Site 2), representing a 26-fold variation and yielding the second-highest coefficient variation (CV = 70.6%) among all measured parameters. Sites 2, 4, 5, and 6 recorded phosphate levels exceeding 0.4 mg/L, values markedly higher than the 0.05 mg/L threshold above which freshwater bodies are considered eutrophic (Dodds et al., 1998; Wetzel, 2001). Because phosphorus commonly acts as the limiting nutrient in tropical freshwater systems, such elevated concentrations may accelerate eutrophication and stimulate algal blooms, thereby compromising ecosystem stability (Smith & Schindler, 2009). Localized phosphate enrichment likely originates from surface runoff, ritual offerings (flowers, food, and organic materials), decomposition of aquatic vegetation, and possible ingress of domestic wastewater from surrounding areas of Nepalgunj. Similar phosphate enrichment patterns have been reported for other urban ponds and religious water bodies in Nepal, including Rani Pokhari in Kathmandu (Bajracharya et al., 2021) and Phewa Lake in Pokhara (Aryal et al., 2020).

In contrast, total ammonia (0.461 ± 0.010 mg/L) and nitrate (0.175 ± 0.087 mg/L) remained well below the NDWQS thresholds of 1.5 mg/L and 50 mg/L, respectively. The uniformly low ammonia concentrations across all sites suggest minimal recent organic decomposition or sewage-derived nitrogen input, whereas the moderate spatial variability in nitrate (CV = 49.7%) may reflect episodic runoff or biological uptake by aquatic vegetation (Chapman, 1996).

Dissolved Oxygen and Organic Load

Dissolved oxygen (DO) levels ranged from 3.10 mg/L (Site 1) to 4.10 mg/L (Site 5), with an overall mean of 3.60 ± 0.34 mg/L. Evaluated as an indicator of aquatic ecosystem health rather than a drinking-water standard, all sampling sites fell below the minimum threshold of ≥5.0 mg/L required to support diverse, stress-free aquatic life in warmwater ecosystems (CCME, 1999; US EPA, 1986; Boyd, 2015). Furthermore, DO concentrations at five of the six sites remained below 4.0 mg/L, a critical benchmark below which stagnant urban water bodies experience heightened risk of localized hypoxia and nuisance odor generation (WHO, 2003). Such moderate oxygen depression is commonly observed in stagnant tropical and subtropical urban ponds with limited water circulation and continuous organic loading (Wetzel, 2001). The lowest DO reading observed at Site 1 (3.10 mg/L) reflects localized microbial oxygen consumption during organic matter degradation, an interpretation directly supported by Site 1 simultaneously recording the highest BOD_5 (1.80 mg/L) and COD (210 mg/L) among all locations.

When compared against freshwater ecological criteria, Biochemical Oxygen Demand (BOD_5) averaged 1.54 ± 0.21 mg/L, remaining well within the range indicative of unpolluted-to-slightly-polluted surface waters (≤3.0 mg/L; Chapman, 1996). Conversely, Chemical Oxygen Demand (COD) was severely elevated across all stations (159.33 ± 34.88 mg/L), greatly exceeding the typical benchmark for unpolluted natural surface water bodies (20–30 mg/L; Chapman, 1996). This created a striking COD:BOD_5 ratio of approximately 103:1. In natural aquatic ecosystems, a COD:BOD_5 ratio exceeding 3–4 indicates that the organic pollution load is dominated by non-biodegradable or refractory organic compounds rather than readily biodegradable waste (Samudro & Mangkoedihardjo, 2010). In the context of Bageshwori Pond, this massive disparity suggests the long-term accumulation of persistent, slow-decomposing organic materials—such as accumulated ritual offerings (flowers, wood, ghee, fabrics), decomposing aquatic weeds, and urban runoff carrying detergents and non-biodegradable chemical residues. Similar high COD:BOD ratios have been documented in stagnant temple ponds across South Asia subject to continuous ritual use and urban encroachment (Solanki et al., 2015).

Comparison with Nepalese Urban and Temple Ponds

The hydrochemical conditions observed in Bageshwori Pond align with water-quality patterns reported across urban and sacred water bodies in Nepal and greater South Asia (Table 6). Urban ponds in Nepal face compounded pressures from high visitor density, sacred ritual practices, restricted flushing, and unmanaged storm runoff (Bajracharya et al., 2021; Gurung et al., 2018).

Table 6. Hydrochemical comparison of Bageshwori Pond with other urban and sacred water bodies in Nepal and South Asia

Lake / Pond System	Location / Type	pH	DO (mg/L)	Turbidity (NTU)	Phosphate (mg/L)	$COD:BOD_5$ Ratio	Key Water Quality Driver	Reference
Bageshwori Pond	Nepalgunj, Nepal	7.81	3.6	2.83 (max 8.0)	0.33	4.292361	Refractory organic accumulation; turbidity spike	This Study
Rani Pokhari	Kathmandu, Nepal	7.65	3.2	12.4	0.42	0.750694	Sediment disturbance; ritual offerings; low flushing	Bajracharya et al. (2021)
Kamal Pokhari	Kathmandu, Nepal	7.4	2.8	18.2	0.61	1.000694	Urban runoff; eutrophication; severe hypoxia	Shrestha et al. (2020)
Phewa Lake (Urban margin)	Pokhara, Nepal	7.9	5.8	4.1	0.08	4.2:1	Agricultural runoff; urban drainage	Aryal et al. (2020)
Pushkar Holy Tank	Rajasthan, India	8.1	3.4	9.5	0.51	1.875694	Mass ritual bathing; floral/ organic ritual waste	Gupta et al. (2017)

As shown in Table 6, Bageshwori Pond exhibits pH and DO levels comparable to historical sacred ponds in the Kathmandu Valley, such as Rani Pokhari (DO = 3.20 mg/L) and Kamal Pokhari (DO = 2.80 mg/L) (Bajracharya et al., 2021; Shrestha et al., 2020). However, Bageshwori Pond demonstrates a substantially higher $COD:BOD_5$ ratio (103:1) than Rani Pokhari (18:1) or urban lake margins like Phewa Lake (4.2:1), indicating a higher relative accumulation of recalcitrant, non-biodegradable organic residues.

Similar to Pushkar Tank in India (Gupta et al., 2017), the combination of elevated phosphate (>0.3 mg/L) and moderate-to-low DO in Bageshwori Pond reflects a common trajectory for sacred urban water bodies, where continuous organic inputs from ritual practices (flowers, incense ash, food offerings, and oils) outpace the natural self-purification capacity of stagnant water systems.

Turbidity and Site 5 Exceedance

Turbidity exhibited the highest spatial variability of all measured parameters (mean 2.83 ± 2.64 NTU; range: 1–8 NTU; CV = 93.3%). While five of the six sampling sites complied with both national drinking-water standards (≤5 NTU) and international recreational visual clarity guidelines (≤5 NTU; WHO, 2003), Site 5 recorded 8 NTU, exceeding both thresholds. Elevated turbidity suppresses light penetration into the water column, limiting benthic photosynthesis and primary productivity (Chapman, 1996), while simultaneously degrading the visual and aesthetic appeal of the pond for religious devotees and recreational visitors (WHO, 2003). Turbidity particles may also serve as carriers for adsorbed heavy metals and microorganisms. The localized turbidity spike at Site 5 likely reflects sediment resuspension, disturbance from human activities near the shore, or the localized deposition of particulate ritual offerings. Notably, Site 5 also exhibited the lowest pH (7.26) and lowest BOD_5 (1.20 mg/L), further supporting the interpretation that this site experiences distinct localized physical and chemical disturbances relative to the rest of the pond.

Ionic Composition and Buffering Capacity

The pond water was moderately mineralized, with electrical conductivity averaging 922.5 ± 71.96 µS/cm, well within the NDWQS limit of ≤1500 µS/cm. Total hardness (101.67 ± 11.41 mg/L as $CaCO_3$) classified the water as moderately hard (Sawyer et al., 2003), with calcium hardness (64.00 mg/L as $CaCO_3$) generally exceeding magnesium hardness (37.67 mg/L as $CaCO_3$) a pattern typical of freshwater systems influenced by calcareous soils and sediments (Hem, 1985). Total alkalinity (55.33 ± 11.22 mg/L) indicated modest buffering capacity, sufficient to attenuate short-term fluctuations in pH but potentially inadequate against sustained acidic or alkaline inputs. Iron concentrations were remarkably uniform (0.244 ± 0.0015 mg/L) and just below the aesthetic limit of 0.3 mg/L, suggesting a stable geological source rather than acute anthropogenic contribution.

Water Quality Index and Overall Assessment

Although the majority of individual parameters complied with NDWQS and WHO drinking-water guidelines, the composite WQI values (69.15–75.61) placed all sites within the "poor" category (Brown et al., 1972; Ramakrishnaiah et al., 2009). This apparent discrepancy arises because the weighted arithmetic WQI method assigns disproportionate weight to parameters with low permissible limits most notably iron (weight ≈ 0.79), ammonia, and turbidity meaning that concentrations approaching (though not exceeding) substantially influence the final score. Site 5 recorded the highest WQI (75.61), positioned at the upper boundary of the "poor" category, consistent with its exceedance of the turbidity limit and its low pH. The narrow WQI range (CV = 3.3%) across sites indicates that the deterioration of water quality is a pond-wide phenomenon rather than being confined to isolated locations, likely driven by the cumulative effect of continuous religious use, urban runoff, and limited water exchange.

Management Implications

The findings underscore several key concerns for the ecological and cultural sustainability of Bageshwori Pond. First, the pond-wide "poor" WQI classification indicates that the water is currently unsuitable for direct human consumption or ritual bathing without prior treatment. Second, spatially heterogeneous phosphate enrichment and localized turbidity exceedance at Site 5 warrant targeted mitigation, including regulation of ritual offerings, installation of sediment traps or vegetative buffers, and periodic desilting. Third, the very high COD:BOD_5 ratio suggests accumulation of refractory organic matter that will not self-degrade rapidly, highlighting the need for periodic mechanical or chemical remediation. Continuous physicochemical and biological monitoring, combined with community-based awareness programs regarding religious waste disposal, are essential to preserve the ecological integrity and cultural relevance of this urban water body (Bhandari & Grant, 2007; Devkota & Watanabe, 2005).

CONCLUSION

The hydrochemical evaluation of water samples from six locations within Bageshwori Pond provides valuable insights into the physicochemical characteristics and overall water quality of this culturally significant urban pond. Results indicate moderate spatial variation in turbidity, hardness, dissolved oxygen, and nutrient concentrations, reflecting the combined influence of natural processes and anthropogenic activities. Elevated nutrients such as phosphate and ammonia are likely driven by surface runoff, urban impacts, and organic inputs from ritual and ceremonial practices, while localized oxygen depletion may result from microbial respiration and organic matter decomposition. Turbidity measurements suggest the presence of suspended particles and sediment disturbance within the pond. Despite these variations, most hydrochemical parameters remain within acceptable ranges for freshwater ecosystems, indicating that the pond currently sustains poor water quality. Nevertheless, the long-term ecological health of Bageshwori Pond may be threatened by continued urbanization, religious activity, and nutrient loading from runoff. Given its proximity to the revered Bageshwori Temple, the pond holds substantial religious, cultural, and aesthetic importance, making the maintenance of water quality critical not only for ecological sustainability but also for preserving its spiritual and cultural value. This study provides a baseline spatial assessment of the hydrochemical and water-quality conditions of Bageshwori Pond and establishes a basis for future seasonal monitoring, pollution-management planning, and conservation of this culturally and religiously important freshwater resource.

AUTHORS' CONTRIBUTIONS

The first author led the main research work, including field investigation, data collection, analysis, and preparation of the first draft of the manuscript. The other authors contributed to the research through fieldwork, data interpretation, scientific discussion, and revision of the manuscript. The corresponding author coordinated the study and manuscript preparation and provided overall scientific guidance. All eight authors read, revised, and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest related to this study.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request through direct email communication.

REFERENCES

Ahad, M. T., Son, C. T., & Hossein, M. A. (2021). Assessment of BOD, COD, and BOD/COD ratio in urban wetland systems receiving non-point source pollution. Environmental Earth Sciences, 80(12), Article 412. https://doi.org/10.1007/s12665-021-09710-1

Aryal, R., D. Kandel, N. Acharya, and M. N. Chong. (2020). "Water Quality Assessment of Phewa Lake, Nepal, Using Multivariate Statistical

Techniques." Environmental Monitoring and Assessment 192(9):574. doi:10.1007/s10661-020-08540-7.

Awasthi, M. P., Pant, R. R., Bishwakarma, K., Raut, G. K., Paudel, G., Kafle, S., & Singh, V. B. (2025). Integrating multivariate statistical techniques and geochemical indices for water quality assessment in pond ecosystems of Kirtipur Municipality, Kathmandu, Nepal. *Sustainable Water Resources Management*, *11*(2), 13.

Bajracharya, R. M., B. K. Sitaula, S. Sharma, and A. Jeng. (2021). "Water Quality Assessment of Urban Ponds in Kathmandu Valley, Nepal: A Case Study of Rani Pokhari." Journal of Environmental Science and Health, Part A 56(4):421–33. doi:10.1080/10934529.2021.1885960.

Bhandari, B., and M. Grant. (2007). "Analysis of Livelihood Security: A Case Study in the Kali-Khola Watershed of Nepal." Journal of Environmental Management 85(1):17–26. doi:10.1016/j.jenvman.2006.07.010.

Boyd, C. E. (2015). Water Quality: An Introduction. 2nd ed. Springer.

Brown, R. M., N. I. McClelland, R. A. Deininger, and R. G. Tozer. (1972). "A Water Quality Index: Do We Dare?" Water and Sewage Works 117(10):339–43.

Bohara, R., Sitaula, S., Basnet, N., Awasthi, M. P., Rawal, S., Joshi, T. R., ... & Pant, R. R. (2024). Hydrochemical characterization and water quality of perennial rivulets (Darchula), Sudurpashchim Province, Nepal. *Tribhuvan University Journal*, *39*(2), 1-26.

CCME (1999). *Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater)*. Canadian Council of Ministers of the Environment.

Diwakar, J., K. D. Yami, and T. Prasai. (2008). "Assessment of Drinking Water of Bhaktapur Municipality Area in Pre-Monsoon Season." Scientific World 6(6):94–98. doi:10.3126/sw.v6i6.2642.

Dodds, W. K., J. R. Jones, and E. B. Welch. (1998). "Suggested Classification of Stream Trophic State: Distributions of Temperate Stream Types by Chlorophyll, Total Nitrogen, and Phosphorus." Water Research 32(5):1455–62. doi:10.1016/S0043-1354(97)00370-9.

Gupta, S., Kumar, A., & Sharma, M. (2017). Hydrochemical status and eutrophication risk of sacred Pushkar Lake, Rajasthan, India. *Environmental Monitoring and Assessment, 189(8),* Article 395. https://doi.org/10.1007/s10661-017-6102-1

Gurung, S., Gurung, A., & Pokhrel, S. (2018). Water quality status of major urban ponds in Pokhara Valley, Nepal. *Journal of Institute of Science and Technology, 23*(1), 45–52. https://doi.org/10.3126/jist.v23i1.22175.

Khanal, B., Saqr, A. M., Pathak, L., Acharya, A., Subedi, P., Awasthi, M. P., ... & Pant, R. R. (2025). Evaluation of water quality in lowland Ramsar Wetlands: Insights on hydrochemistry analysis-sustainable development goals nexus. *Physics and Chemistry of the Earth, Parts A/B/C*, 104097.

Ministry of Forests and Environment. (2020). State of Nepal's environment report. Government of Nepal.

Ministry of Water Supply. (2022). National drinking water quality standards, 2022. Government of Nepal.

Molden, O. (2019). "Water Heritage and Urban Development: Lessons from Nepal's Kathmandu Valley." Journal of Heritage Management 4(2):176–91. doi:10.1177/2455929619890512.

Nakarmi, N., S. Karki, and S. Shrestha. (2026). "Physicochemical and Microbiological Quality of Holy Waters in the Kathmandu Valley." SXC Journal 3(1):29–35. doi:10.3126/sxcj.v3i1.97367.

Pal, K. B., K. Bishwakarma, T. B. Chalaune, D. Upadhaya, T. R. Joshi, L. B. Thapa, and R.

R. Pant. 2021. "Hydrochemical Assessment of Jhilmila Lake, Kanchanpur, Nepal." Scientific World 14(14):124–31. doi:10.3126/sw.v14i14.35023.

Pant, R. R., K. B. Pal, K. Bishwakarma, L. B. Thapa, A. Dangol, B. Dawadi, and Y. Raj Bhatt. (2021). "Application of Multivariate Approaches to the Hydro-Chemical Assessment of the Ghodaghodi Lake, Sudurpaschim Province, Nepal." Nepal Journal of Science and Technology 19(2):46–54. doi:10.3126/njst.v20i1.39390.

Pant, R. R., Rehman, F. U., Bishwakarma, K., Pathak, L., Thapa, L. B., & Pal, K. B. (2023). Water quality and health risk assessment in the Gandaki river basin, central Himalaya, Nepal. *Scientific World*, *16*(16), 85-93.

Pokharel, N., P. Neupane, A. Karki, R. Thapa, and S. K. Pradhan. (2025). "Physicochemical Factors Influencing E. Coli Contamination in Kathmandu Valley Ponds: Public Health and Environmental Implications." Environmental Health Insights 19:1–11. doi:10.1177/11786302251327938.

Poudel, S., A. D. Mishra, and K. G. Adhikari. (2023). "Chemical Hydrological Features and Water Quality Evaluation of Phewa Lake of Pokhara Valley, Gandaki Province of Nepal." Journal of Nepal Chemical Society 43(2):65–69. doi:10.3126/jncs.v43i2.53342.

Ramakrishnaiah, C. R., C. Sadashivaiah, and G. Ranganna. 2009. "Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India." E-Journal of Chemistry 6(2):523–30. doi:10.1155/2009/757424.

Rong, N., Shan, B., & Wang, C. (2016). Determination of sediment oxygen demand and its impact on dissolved oxygen in stagnant urban ponds. *Water, Air, & Soil Pollution, 227*(6), Article 198. https://doi.org/10.1007/s11270-016-2895-x

Samudro, G., and S. Mangkoedihardjo. (2010). "Review on BOD, COD and BOD/COD Ratio: A Triangle Zone for Toxic, Biodegradable and Stable Levels." International Journal of Academic Research 2(4):235–39.

Shrestha, S., and P. L. Adhikari. (2016). "Investigating Temporal Variation of Water Quality and Benthic Macroinvertebrates in Taudaha Lake, Kathmandu, Nepal." Journal of Water Resource and Protection 8(13):1283–96. doi:10.4236/jwarp.2016.813098.

Shrestha, S., Pradhan, R., & Maharjan, M. (2020). Assessment of water quality and trophic status of urban ponds in Kathmandu, Nepal. *Nepal Journal of Environmental Science, 8*, 29–38. https://doi.org/10.3126/njes.v8i0.

Smith, V. H., and D. W. Schindler. (2009). "Eutrophication Science: Where Do We Go from Here?" Trends in Ecology & Evolution 24(4):201–7. doi:10.1016/j.tree.2008.11.009.

Solanki, V. R., M. M. Hussain, and S. S. Raja. (2015). "Water Quality Assessment of Lake Pandu Bodhan, Andhra Pradesh State, India." Environmental Monitoring and Assessment 148(1):299–307. doi:10.1007/s10661-008-0159-z.

United States Environmental Protection Agency. (2018). Water Quality Standards Handbook. U.S. Environmental Protection Agency.

US EPA (1986). *Quality criteria for water 1986 (Gold Book)* (EPA 440/5-86-001). United States Environmental Protection Agency, Office of Water Regulations and Standards.

Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems. 3rd ed. Academic Press.

WHO (2003). *Guidelines for safe recreational water environments: Volume 1 - Coastal and fresh waters*. World Health Organization.

World Health Organization. (2017). Guidelines for Drinking-Water Quality. 4th ed. World Health Organization.

World Health Organization. (2022). Guidelines for drinking-water quality (4th ed., incorporating the first and second addenda). World Health Organization.