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Limnological Characterization and Ecological Assessment of Selected Freshwater Wetlands in Fatehabad District, Haryana, India

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Abstract

Freshwater wetlands are unique and fragile ecosystems where the physico-chemical properties of water govern its biodiversity and ecological status. The present investigation was carried out in three freshwater wetlands Daulatpuria Pond (DP), Chilli Lake (CL) and Bhodia Khera Temple Pond (BP) of Fatehabad district, Haryana, India. The study was conducted through two sampling campaigns: first consisted of monthly sampling from December 2023 to November 2024, while the second comprised of quarterly sampling from December 2024 to November 2025. Physicochemical parameters viz. temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved salts (TDS), Electrical Conductivity (EC), total hardness and alkalinity in water of the selected wetlands were analyzed. Water quality was also assessed by using the Weighted Arithmetic Water Quality Index (WQI). A significant spatial and temporal variation was recorded in physicochemical parameters among the study sites. The water of the wetlands was slightly alkaline in nature and its DO was found to be lower during summer season and was significantly correlated with BOD level. The TDS and EC values were comparatively higher at CL depicting the higher amount of dissolved ions present in this wetland. WQI was ranged from 191.86 to 195.53, 193.29-194.72, 231.21-236.67 in DP, BP and CL, respectively, which implied that the water of the studied wetlands was highly polluted and unfit for domestic and drinking purposes, of which the CL was more polluted in comparison to the rest two. The results highlight the degree of anthropogenic activities taking place in these wetlands and the necessity of their regular monitoring.

Keywords: *Freshwater wetlands; limnology; water quality; WQI; dissolved oxygen; BOD; TDS; electrical conductivity; Fatehabad*

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1. Introduction

Freshwater wetlands are highly productive aquatic ecosystems with significant role in hydrological cycle, and they provide habitat for a variety of organisms. Their ecological status is closely linked to physicochemical characteristics because water temperature, pH, dissolved oxygen, total dissolved solids, conductivity, alkalinity, and hardness influence nutrients cycling, decomposition of organic matter, and other vital processes (Wetzel, 2001; Mitsch & Gosselink, 2015). Therefore, it is necessary to assess the physicochemical properties for determining the ecological status of these wetlands. Small wetlands are highly susceptible to anthropogenic impacts in agricultural and urbanized landscapes. Domestic effluents, laundry activities, agricultural runoff, municipal wastes, and religious practices can damage these freshwater habitats by changing the physicochemical regime and inputting organic matter into water bodies (Mason, 1996; Chopra et al., 2014). Dissolved ions and solids can interfere with aquatic organisms' respiration and normal functioning (Mason, 1996). Water temperature plays a major role in physicochemical processes, and it can affect the dissolved oxygen content, which in turn influences organisms' metabolism and productivity (Wetzel, 2001). In addition, temperature changes are essential for biogeochemical processes. The pH level determines the solution's acidity and affects the availability and speciation of dissolved ions and compounds, which directly impact aquatic organisms. Dissolved oxygen concentration indicates the balance of oxidation-reduction reactions within a water body, whereas BOD is used for estimating water quality. Specifically, high BOD levels signify the presence of biodegradable organic matter in water; thus, it should be removed through a wastewater treatment process. Conductivity and TDS reflect the amount of ions within a water body, and they can be impacted by various anthropogenic activities (Mason, 1996; Wetzel, 2001). Hardness and alkalinity are crucial for characterizing water quality since they indicate the solution's capacity to buffer against pH changes. Therefore, these measurements should be evaluated together to understand water quality and its impact on wetland ecosystems. Since several water properties can impact water bodies, it is essential to estimate them using water quality indexes (WQIs). Using a WQI allows a comprehensive description of water quality based on a set of measurements and water body characteristics. In general, WQI values enable easier comparison of water quality between different locations and periods. The Weighted Arithmetic Water Quality Index model is a useful tool for this purpose because it includes specific parameters and their weights (Brown et al., 1972). In this study, the WQI was calculated using the recommended standards developed by the World Health Organization (WHO), Indian Council of Medical Research (ICMR), and Bureau of Indian Standards (BIS). The WQI was evaluated according to the drinking-water quality specifications issued by the BIS (IS 10500:2012) and the WHO Guidelines for Drinking-water Quality (Bureau of Indian Standards, 2012; World Health Organization, 2011). Fatehabad District has many small water bodies, but their limnological status has not been characterized in detail. The selected wetlands are located within different anthropogenic landscapes, which impact their physicochemical properties and water quality. Thus, it is possible to compare their characteristics and identify water-quality trends. In this study, the limnological parameters of Daulatpuria Pond, Chilli Lake, and Bhodia Khera Temple Pond were analyzed to evaluate the water quality of these wetlands. The study aimed to characterize the seasonal and spatial patterns of physicochemical properties and estimate water quality using the WQI. The obtained results can also help recommend sites that need improvement for future studies.

2. Materials and Methods

2.1 Study area

The present study was carried out in three freshwater wetlands namely, Daulatpuria (DP), Chilli Lake (CL) and Bhodia Khera Temple Pond (BP) at Fatehabad district, Haryana, India, subjected to different anthropogenic uses. Chilli Lake is surrounded by the Fatehabad city which resulted in its exposure to sewage, garbage dumping and religious activities. Bhodia Khera Temple Pond is located near an ancient temple and thus exposed to religious activities, domestic washing and fish farming. The survey was carried out to assess the water quality of Daulatpuria Pond following the same methodology.

2.2 Sampling design

Sampling was done between December 2023 and November 2025. The first phase of sampling was done monthly from December 2023 to November 2024, whereas the second phase of sampling was done on a seasonal basis from December 2024 to November 2025. Water and plankton samples were collected from all the three wetlands at the same time.

2.3 Physicochemical analysis

Water temperature, pH, electrical conductivity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, alkalinity, hardness and other selected parameters were determined following standard procedures (APHA, 1998). These parameters were selected based on their ability to indicate the chemical nature of the water, oxygen conditions and overall wetland ecological status.

2.4 Water Quality Index

In the current investigation, water qualities were evaluated using the Weighted Arithmetic Water Quality Index of Brown et al., (1972) based on allowable limits recommended by WHO, ICMR and BIS. The formula used for calculation is given below:

$$WQI = \sum q_n W_n / \sum W_n$$

Where q_n is the quality rating and W_n is the unit weight of the n^{th} parameter. WQI values above 100 were considered unsuitable for drinking purposes.

Statistical analysis

Descriptive statistics were used to summarize the measured parameters. Correlation analysis was employed to examine relationships among physicochemical variables and between selected water-quality variables and planktonic/avian measures available in the dataset. Relationships were interpreted according to their correlation coefficients and statistical significance.

3. Result

LIMNOLOGY OF STUDY SITES

The sampling period was divided into two phases depending on the sampling frequency. During P-I, water samples were collected on a monthly basis (from December 2023 to November 2024) and during P-II, water samples were collected quarterly (from December 2024 to November 2025).

3.1 PHYSICO-CHEMICAL PARAMETERS

The data obtained for the various physico-chemical parameters of the water samples are presented in Table 1.

3.2. TEMPERATURE (°C)

The fluctuating nature of temperature has been clearly depicted by these phases' graphs. For example, phase-I of DP fluctuated from 15°C-32°C having a mean value of 22.7 ± 1.53 °C, with the highest occurring in the month of June whereas the lowest in January. In Phase-II the temperature range changed between 14-29°C and showed a mean value of 22.7 ± 3.66 °C with its highest in the monsoons and the minimum in winters. Temperature of CL varied from 15°C-27°C for phase-I, with its highest occurring in the month of June but lowest in January respectively. While in phase-II of CL the fluctuation of temperature varies up to 15°C-32°C. Whereas temperature of BP varies from 15°C-28°C in phase-I and 15°C-30°C in phase-II as shown in table (1). These observations reveal that the effect of seasonal variations had great impact on the thermal regime of these three wetlands. Fluctuations were consistent with climate cycle, where they reached their peaks in summers & monsoon months, with their minimum values in winters. Thermal fluctuation plays significant role in affecting many parameters like productivity of planktons, nutrients, and eventually affects the distribution and abundance of bird's population.

3.3. HYDROGEN ION CONCENTRATION (pH)

During P-I, pH was found ranging between 7.99 ± 0.01–9.52 ± 0.05. Maximum pH value was noticed in the month of August while a low level of pH was observed in the month of February (Table 5). The data on pH collected during P-II (Phase II) indicated that pH value ranged between 8.41 ± 0.004–9.33 ± 0.007, showing maximum value in the period of autumn and minimum in the months of summer. A strong negative relationship between total bird diversity and pH parameters was noticed, which indicates high species richness in acidic conditions as against higher pH values. But there was no statistically significant correlation between total bird diversity and other variables such as total hardness ($r = 0.387$, $p > 0.05$), alkalinity ($r = -0.236$, $p > 0.05$), total zooplankton density ($r = -0.388$, $p > 0.05$), and total phytoplankton density ($r = -0.559$, $p > 0.05$. pH at CL ranged from 7.76 ± 0.01–8.86 ± 0.02 during P-I. It reached maximum values in January and minimum values in April (Figure 4.15d). During P-II, the mean pH was 8.24 ± 0.27 and the maximum and minimum values were observed in winter and autumn respectively. A significant negative correlation existed between pH and total bird diversity ($r = -0.647$, $p < 0.05$) (Table 4.9). Bhodia Khera Temple pond (BP): In general, pH showed wide variation ranging from 8.58 ± 0.04 to 10.15 ± 0.02 during P-I having an overall mean of 8.70 ± 0.18. Maximum pH was reported for the monsoon season while minimum was recorded during the summer season during P-II. Moreover, significant positive relationship was found between pH and total hardness ($r = 0.815$, $p < 0.01$); however, significant negative relationships were established between pH and Alkalinity ($r = -0.620$, $p < 0.05$) (table2-5).

3.4. DO (DISSOLVED OXYGEN)

During phase-I (P−I), dissolved oxygen (DO) values fluctuated between 2.83±0.09–9.06±0.18 mgL−1 (highest value observed in December, lowest in June). The average DO concentration of phases I and II (P−I & P−II) are 6.30±0.58mgL^{-1}and 5.22±0.63mgL^{-1}respectively. As depicted in table 5. DO concentrations are high during colder months and low during summer and Autumn. Based on correlation analyses, the study results reveal that DO has significant negative association with BOD ($r= -0.946$; $p<0.01$); also showed significant negative relationship with Total zooplankton densities ($r=-0.657$; $p<0.05$). However, the significant negative correlations were found non-significant as per statistical test ($p>0.05$) for Conductivity and Total phytoplankton density (table 2). During P-I period, at the CL site, DO varied between 1.87±0.33–8.98±1.58mgL^{-1}, having a maximum in July and minimum in May. The variation of DO showed significant differences among different seasons during the second phase where the highest value observed in winter season while the lowest was recorded in summer season. Additionally, there exists a highly significant negative correlation ($p <0.01$) of DO with BOD ($r= -0.903$) but their negative associations with TDS ($r=-0.427$), Alkalinity($r=-0.206$) and Hardness($r=-0.272$) are found insignificant($p>0.05$) (Table 3). Maximum and minimum concentration for DO were achieved during P-I experiment which includes December and June months respectively as 9.15±0.18 mg/L and 6.49±0.58 mg/L respectively at the BP site. Also, seasonal fluctuation shows that DO content is high in winters but less during the summer and monsoon periods (Table 7).

3.5. BOD (BIOCHEMICAL OXIDATION DEMAND)

It refers to the amount of dissolved oxygen ncessory for the decomposition of biodegradable organic matters by micro-organism in water. The parameter provides an estimate on the level of organic pollution in the pond. During Phase I (P-I), the concentration of BOD varies in range of 2.83 ± 0.09–6.04 ± 0.26mg/L with a mean of 4.79 ± 0.34mg/L. In Phase II (P-II), it ranges from 4.84 ± 0.73 to 6.67 ± 0.33mg/L, respectively with average value of 6.12 ± 0.46mg/L. (Table 1). On seasonal basis, it was found that the maximum BOD occurs in summer season whereas minimum values are recorded in winters' seasons (see Table 4.11). From correlation analysis, there exists no significant positive relationship between BOD and Total Dissolved Solid (TDS) ($r=0.227$) but negative correlations between BOD and total Hardness ($r=-0.407$), Alkalinity ($r=-0.011$). (Table 2). At Chilli Lake (CL), the values of BOD during P-I ranged from 1.51 ± 0.10 to 7.38 ± 1.58mg/L with a mean of 2.38 ± 0.48mg/L against 0.26 ± 0.86 and 1.87 ± 0.32mg/L with a mean of 1.12 ± 0.41mg/L during P-II (Table

4.7). The BOD values were found to be negatively correlated with total hardness ($r = -0.231$, $p > 0.05$), alkalinity ($r = -0.501$, $p > 0.05$), total zooplankton density ($r = -0.036$, $p > 0.05$), and total phytoplankton density ($r = -0.129$, $p > 0.05$), with all of which the correlation was not significant (Table 4.9). At Bhodia Khera Temple Pond (BP), the BOD varied from 5.95 ± 0.29 to 6.84 ± 0.11mg/L with a mean of 6.41 ± 0.09mg/L during P-I, while it ranged from 4.84 ± 0.73 to 6.67 ± 0.32mg/L with a mean of 6.12 ± 0.49mg/L during P-II (Table 1). The correlation analysis revealed that the BOD showed non-significant positive correlations with TDS ($r = 0.018$, $p > 0.05$) and total phytoplankton density ($r = 0.249$, $p > 0.05$) (Table 4.10).

3.6. TDS (TOTAL DISSOLVED SOLIDS)

During Phase I (P-I) of the study at the DP site, the values of total dissolved solids (TDS) ranged from 490 ± 2.7 to 860 ± 1.3mg L^{-1} with a mean of 705.8 ± 42. mg L^{-1} , while during P-II they ranged from 493 ± 0.004 to 836.6 ± 0.004mg L^{-1} with a mean of 709.6 ± 87.3mg L^{-1} (Table 1). During both study phases, a significant negative correlation was observed between TDS and pH $r = -0.819$, $p < 0.01$), whereas significant positive associations were recorded between TDS and total zooplankton density ($r = 0.589$, $p < 0.05$), as well as between TDS and total phytoplankton density ($r = 0.663$, $p < 0.05$) (Table 4.8). At the CL site, the mean value of TDS was 860 ± 0.03mg L^{-1} during P-I, while during P-II it was 887.5 ± 68 mg L^{-1} . Conductivity was the only variable that showed a significant positive correlation with TDS ($r = 0.806$, $p < 0.01$), while the positive associations between TDS and total hardness ($r = 0.152$, $p > 0.05$), alkalinity ($r = 0.411$, $r = 0.5890$), and total phytoplankton density ($r = 0.5891$, $r = 0.5892$) were not significant (Table 4.9). At the BP site, the mean TDS during P-I was 703 ± 0.02 mg L^{-1} , while during P-II it was 696 ± 40.6 mg L^{-1} (Table 1). The highest TDS were observed during the summer season, whereas the lowest TDS were registered in autumn (Table 4.13). A significant positive correlation was found between TDS and conductivity ($r = 0.5893$, $r = 0.5894$), as well as between TDS and total phytoplankton density ($r = 0.5895$, $r = 0.5896$), and a significant negative association was found between TDS and pH ($r = -0.739$, $r = 0.5897$) (Table 4.10).

3.7. EC (ELECTRICAL CONDUCTIVITY)

Electrical conductivity (EC) was expressed as a numerical value indicating the solution’s ability to conduct an electrical current. This ability depends on the number of ions dissociated and their charge.

At the DP site, EC ranged from 1380 ± 0.008 to 1720 ± 0.002µS/cm in Phase-I with the mean value of 1534 ± 34.9 µS/cm, whereas in Phase-II, EC varied between 1396 ± 0.008 and 1620 ± 0.007µS/cm with the mean value of 1509.5 ± 54.1µS/cm (Table 1). In general, the EC positively correlated with TDS ($r = 0.948$, $p < 0.01$), total zooplankton ($r = 0.774$, $p < 0.01$), and total phytoplankton density ($r = 0.805$, $p < 0.01$) (Table 4.8). At the CL site, EC varied from 1410 ± 0.04 to 1980 ± 0.03µS/cm (mean 1720 ± 60.1µS/cm) in Phase-I and from 1440 ± 0.012 to 1921 ± 0.007µS/cm (mean 1698.5 ± 128µS/cm) in Phase-II (Table 1). The relationships between EC and total hardness ($r = 0.028$, $p > 0.05$), alkalinity ($r = 0.0201$, $p > 0.05$), and total zooplankton density ($p < 0.010$, $p < 0.011$) were positive but insignificant (Table 3). At the BP site, the lowest EC mean values were found in Phase-II compared to Phase-I (Table 6). Specifically, mean EC was 1520 ± 30 µS/cm and 1482 ± 43µS/cm in Phase-I and II, respectively. Seasonal variability was observed for this station since the highest/lowest EC values were registered in summer and autumn, respectively (Table 4.13). Overall, the correlation analysis revealed that EC positively and significantly correlated with total zooplankton ($p < 0.012$, $p < 0.013$) and phytoplankton density ($p < 0.014$, $p < 0.015$) while the relationship with alkalinity was positive but insignificant ($p < 0.016$, $p < 0.017$) (Table 4.10). The analysis demonstrated that the two sites (DP and BP) were characterized by significant relationships between EC and the biological variables while, for the CL site, the EC did not correlate well with any variable which could be explained by the presence of other stress factors (pollution, eutrophication, etc.).

3.8. TOTAL HARDNESS

Total hardness refers the amount of magnesium and calcium ions in water and acts as a major chemical parameter for water characterization. Total hardness values in P-I for DP varied between 350.660 ± 0.882 and 404.931 ± 6.362mg/L, with a mean value of 369.00 ± 5.19mg/L. In P-II, the values varied between 350.222 ± 1.444 and 394.061 ± 2.530mg/L, with a mean value of 375.533 ± 11.363 mg/L. The maximum hardness was observed in the monsoon season, whereas the minimum value was observed in winter (Table 5). There was a non-significant negative relationship between total hardness and alkalinity ($r = -0.297$, $p > 0.05$) (Table 4.8). At Chilli Lake (CL), total hardness varied between 532.880 ± 8.541 and 614.222 ± 8.440mg/L during P-I and registered its maximum and minimum values in June and February, respectively. During P-II, it ranged from 540.00 ± 2.82 to 589.30 ± 3.36mg/L and attained its maximum and minimum values in autumn and summer, respectively (Table

4.12). Hardness was positively correlated with alkalinity ($r = 0.279$, $p > 0.05$) and total zooplankton density ($r = 0.356$, $p > 0.05$), but negatively correlated with total phytoplankton density ($r = -0.057$, $p > 0.05$) (Table 2). However, at Bhodia Khera Temple Pond (BP), mean total hardness was recorded 248.84 ± 17.63 and 263.57 ± 51.76 mg/L during P-I and P-II, respectively (Table 1). It was significantly and negatively correlated with alkalinity ($r = -0.733$, $p < 0.01$), but exhibited non-significant negative relationships with total zooplankton ($r = -0.141$, $p > 0.05$) and total phytoplankton density ($r = -0.158$, $p > 0.05$) (Table 4).

3.9. ALKALINITY

Alkalinity of water denotes its ability to neutralize the acidity by balancing the number of carbonate and bicarbonate ions that tend to shift the pH scale towards the alkaline side from neutrality. At the DP site, during Phase-I, alkalinity varied between 271.110 ± 2.502 and 609.78 ± 8.42mg/L with a mean value of 329.83 ± 27.6mg/L while that of Phase-II ranged from 414.260 ± 1.451 to 614.00 ± 1.631mg/L with a mean of 475.8 ± 54.64mg/L (Table 1). It showed an insignificantly positive relationship with phytoplankton density ($r = 0.160$, $p > 0.05$) while an opposite trend was observed for zooplankton with a negative correlation ($r = –0.032$, $p > 0.05$) (Table 4.8). Similarly, at the CL site, the water alkalinity ranged from 398.202 ± 7.680 to 579.101 ± 9.103 mg/L with a mean value of 488.1 ± 18.6mg/L during Phase-I while that of Phase-II was between 422.2 ± 0.72 and 579 ± 3.03mg/L with a mean of 502 ± 43.8 mg/L (Table 1). During this period, an insignificantly negative relationship was observed with zooplankton density ($r = –0.512$, $p > 0.05$) as well as phytoplankton ($r = –0.297$, $p > 0.05$) (Table 3). At the BP site, the mean values of alkalinity during Phase-I and II were 328.2 ± 12.5 and 354.6 ± 14.2mg/L with no significant differences. A seasonal variation was evident with high values during the summer followed by the monsoon season (Table 4.7). An insignificantly positive relationship was observed with zooplankton density ($r = 0.127$, $p > 0.05$) while phytoplankton density showed a similar trend ($r = 0.175$, $p > 0.05$) (Table 4.10). It can be concluded from the study that water alkalinity does not have a significant relationship with the plankton density at all three sites. A variation of other environmental factors such as pollution and water salinity may interfere with the plankton density that eventually brings changes in the community structure.

3.1.10. WATER QUALITY

Assessment of WQI helps to interpret the overall condition and suitability of water for drinking purposes. WQI was calculated using permissible standards of WHO, ICMR and BIS, 2012. Weighted Arithmetic Water Quality Index (WAAWI) suggested by Brown et al., (1972) was used for calculating overall water quality status and to classify water for its suitability for drinking purpose of the study sites during Phase-I (P-I) and Phase-II (P-II). The WQI value of DP site was calculated to be 191.86 and 195.53 during P-I and P-II, respectively, indicating that water at this site was not fit for drinking purposes (Table 4.7). Similarly, the WQI value of BP site was found to be 194.72 and 193.29 during P-I and P-II, respectively, suggesting that water at this site was also not suitable for drinking purposes. The WQI value was comparatively higher (236.67 and 231.21) at CL site during P-I and P-II, respectively (Table 1). An increase in WQI value suggests a significant decline in water quality and higher degree of water pollution at CL site during both the sampling phases. It can be concluded from this study that water from all three sites was not fit for drinking purpose during both P-I and P-II with CL site having comparatively higher WQI value, suggesting extremely polluted water at this site than the other two sites.

4.Discussion

Water temperature is an essential component that controls numerous chemical and biological processes and dictates the survival and function of aquatic organisms. During the survey, the water temperature at the three stations, on average, ranged from 21.75 to 23.75°C. Temperature affects multiple variables of water quality such as alkalinity, pH, and dissolved oxygen (Khaiwal et al., 2003). Moreover, increasing temperature promotes the activity of bacteria responsible for decomposing organic matter. Water pH is an important variable dictating the distribution and physiology of various aquatic organisms. The optimal range of pH for most aquatic species is 6.5 – 9.0, whereas pH values close to 9.0 promote primary production (Khaiwal et al., 2003). In the current study, the mean pH registered at the three sites was alkaline, with BP site having comparatively higher pH values as compared to the other two sites. The high pH at BP could be explained by the use of detergents during clothes washing by devotees. In fact, similar observations were reported by Chopra et al., 2014, while assessing the water quality of Kapal Mochan Pond, Yamunanagar. Electrical conductivity reflects the total amount of ions in water, thus indirectly indicating salinity levels. In the current study, the electrical conductivity values registered at all three sites exceeded the WHO (1993) permissible limit. Comparatively higher values were recorded at CL and BP sites, which could be explained by the high ionic strength due to higher total dissolved solids (TDS). Abbasi and Vinithan, 1999 explained elevated conductivity values by the salinity and domestic effluents in the water. On the contrary, Mathivanan et al., 2007 attributed high levels of electrical conductivity to the anthropogenic activities around the water body, primarily due to religious practices. Similar to the current study, Mishra et al., also reported elevated levels of TDS during the summer season at BP and DP sites, whereas comparatively lower concentrations were registered during the monsoon season at BP and CL sites. The lower values during the rainy season could be explained by the dilution of TDS with rainwater. Further, similar seasonal variations were reported by Gonzalves and Joshi, 1946. A significant correlation ($r = 0.806$, $p < 0.01$) was observed between TDS and electrical conductivity signifying the fact that higher concentrations of dissolved ions in water elevate its electrical conductivity. Bhat et al., 2007 also concluded a similar trend between the two variables. Dissolved oxygen (DO) is one of the key parameters that determine the ecology of water bodies. In the current study, the DO values at each of the three sites were low, with CL having comparatively lower DO levels. The low DO levels could be attributed to the presence of substantial organic matter in water, which utilizes oxygen during the decomposition process (Mathivanan, 2007). Further, lower levels of DO were recorded during the summer season possibly due to higher metabolic rates among aquatic organisms. Biochemical oxygen demand (BOD) is a crucial variable that reflects the amount of oxygen used by bacteria during the decomposition of organic matter in water. The variation in BOD values is primarily explained by the input of organic waste into water bodies and the dilution capacity of water. In the current study, the BP site had higher BOD values as compared to the other two sites. This could be explained by the high human activities around the site and increased TDS concentrations, thus increasing the organic load in water. Alkalinity is an essential variable that determines the productivity of water bodies since it regulates CO_2 availability during photosynthesis. According to Jhingran, 1982, highly productive water bodies register more than 100 mg L^{-1} of alkalinity. In the current study, the highest alkalinity values were recorded at BP during the summer season, whereas the lowest values were during the monsoon season. Similar to the current study, Mishra et al., 2023 observed reductions in alkalinity levels during the rainy season, which could be explained by the dilution of ions in water due to high runoff. Although higher levels of alkalinity are desirable for photosynthesis, extremely high values are unpleasant for drinking. Hardness was comparatively high at CL and BP sites. At CL site, high hardness levels could be explained by the influx of water from the surrounding urban land use, agricultural practices, and effluents from the nearby religious places. At BP site, increased hardness was mainly due to clothes washing activities by devotees and other effluents from the adjacent temples. Overall, the current study demonstrated that human activities around the water bodies significantly contributed to poor water quality.

5. Conclusion

The present study demonstrated that there was a significant difference both in spatial and seasonal variations in water quality parameters of all the three freshwater wetland habitats of Fatehabad district. Water temperature was found to increase significantly following the rise in environmental temperature while water pH was mostly alkaline. The amount of dissolved oxygen decreased significantly in the summer and was closely related to BOD. Analysis of other physicochemical parameters also showed significant variations, which may be attributed to the difference in the ionic composition of water samples. Chilli Lake, having greater values of WQI (49) and other parameters associated with salinity, was found to be polluted as compared to other wetlands. However, all the three wetlands were found unfit for human consumption on the basis of WQI. The present results suggest that all the three small wetlands of Fatehabad district require immediate attention due to their ecological and hydrological significance. Periodic monitoring of WQPs, proper management of effluent disposal, regulating human activities, controlling solid waste dumping, and managing each wetland based on their physicochemical status are some of the major interventions for the conservation of freshwater wetlands of Fatehabad district.

Conflict of Interest

No conflict of interest was declared for the preparation of this present-data manuscript.

Authors Contribution

Kavita Devi contributed to the conceptualization, literature review, analysis, and preparation of the original manuscript. Dr. Naveen Kumar Tholia contributed to supervision, critical review, interpretation of findings, and refinement of the manuscript.

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Table 1: Physico-chemical Characteristics of Wetlands: Range and Mean ± S.E. During P-I and P-II (December, 2024 to November, 2025).

P-I(December, 2023 to November, 2024)				P-II(December, 2024 to November, 2025)		
Parameters	DP	CL	**BP**	**DP**	**CL**	**BP**
Air Temp °C	17-34 (25.5±1.65)	17-36 (24.41±1.82)	17-35 (26.16±1.85)	16-33 (25±2.78)	17-34 (25.5±4)	17-33 (26±3.86)
Water Temp °C	15-32 (22.7±1.53)	15-27 (21.75±1.63)	15-28 (22.33±1.43)	14-29 (22.8±3.66)	15-32 (23.75±4.12)	15-30 (23.75±3.75)
Dissolved Oxygen mg/L	2.83±0.09-9.06±0.18 (6.3±0.58)	1.87±0.33-8.98±1.58 (3.54±0.54)	9.15±0.18-6.49±0.58 (7.85±0.26)	4.16±0.097-6.59±0.228 (5.22±0.13)	2.4±0.56-3.91±0.11 (3.25±0.36)	7.46±0.18-8.84±0.23 (7.87±0.37)
pH	7.99±0.01-9.52±0.05 (8.7±0.18)	7.76±0.01-8.86±0.02 (8.09±0.12)	8.58±0.04-10.15±0.02 (8.70±0.11)	8.41±0.004-9.33±0.007 (8.8±0.25)	7.76±0.007-8.86±0.02 (8.24±0.27)	8.58±0.004-10.15±0.018 (9.23±0.39)
TDS mg/L	490±2.7-860±1.3 (705.8±42.1)	700±0.004-980±0.004 (860±0.03)	703±0.02-696±40.6 (703±23.7)	493±0.004-836.6±0.004 (707.6±87.3)	713±0.004-963±0.008 (887.5±68)	637.6±0.005-790±0.004 (696±40.67)

Conductivity µS/cm	1380±0.008-1720±0.002 (1534±34.9)	1410±0.04-1980±0.03 (1775±1.63)	1410±0.03-1710±1.4 (1520±0.03)	1396±0.008-1620±0.007 (1509.5±54.10)	1440±0.012-1921±0.007 (1698.5±128)	1436±0.004-1593±0.004 (1482±43.05)
BODmg/L	2.83±0.09-6.04±0.26 (4.79±0.34)	1.33±0.19-7.38±1.58 (2.38±0.48)	5.95±0.29-6.84±0.11 (6.41±0.09)	2.58±0.23-3.73±0.19 (3.22±0.27)	0.26±0.8-1.87±0.32 (1.12±0.41)	4.84±0.73-6.67±0.33 (6.12±0.49)
Alkalinity mg/L	271.11±2.5-609.78±8.42 (329.83±27.6)	398.22±7.68-579.11±9.03 (488.1±18.67)	263.99±1.88-395.83±4.54 (328.28±12.5)	414.26±1.45-614.66±1.63 (475.8±54.64)	422.22±0.72-579.11±3.03 (502±43.8)	317.77±1.08-368±2.82 (354.66±14.2)
Hardness mg/L	350.66±0.88-404.93±6.36 (369±5.19)	532.88±8.54-614.22±8.44 (573.12±8.8)	205±1.71-396.44±6.44 (248.84±17.63)	350.22±1.44-394.06±2.53 (375.7±11.36)	540±2.8-589.33±3.36 (563.66±14.22)	205±0.71-396.44±1.44 (263.57±51.76)
WQI	191.86	236.67	194.72	195.53	231.21	193.29

Table 2: Co-efficient of Correlation Analysis of Physico-chemical Parameters with Plankton and Avian Diversity at DP Site

Parameter	WT	DO	BOD	C	TDS	PH	TH	A	TZ	TPH	TBD
Water Temp (˚C)(WT)	1	-.719**	-.671*	.258	.082	0.312	.870**	-.393	.643**	.335	-.781**
DO (mg/L)	-	1	-.946**	-.168	-.100	-.213	-.449	-.086	-.657*	-.307	.545
BOD (mg/L)	-	-	1	.010	.227	-.389	-.47	-.011	-.465	-.067	.573
Conductivity (µmhos/cm)(C)	-	-	-	1	.948**	-.773**	0.21	.029	.774**	.805**	.241
TDS (mg/L)	-	-	-	-	1	-.819**	0.08	-.045	.589*	0.663*	.398
pH	-	-	-	-	-	1	.387	-.236	-.388	-0.559	-.663*
Total Hardness (mg/L)(TH)	-	-	-	-	-	-	1	-.297	0.475	0.233	-.701*
Alkalinity (mg/L)(A)	-	-	-	-	-	-	-	1	-.032	0.16	.246
Total Zooplankton (mg/L(TZ)	-	-	-	-	-	-	-	-	1	.784*	-.152
Total Phytoplankton (mg/L(TPH)	-	-	-	-	-	-	-	-	-	1	-.025
Total bird diversity(TBD)	-	-	-	-	-	-	-	-	-	-	1

**Correlationissignificantat0.01level(2tailed). *Correlationissignificantat0.05level(2tailed).

Table 3: Co-efficient of Correlation Analysis of Physico-chemical Parameters with Plankton and Avian Diversity at CL site

Parameter	WT	DO	TDS	BOD	C	pH	TH	A	TZ	TPH	TBD
WaterTemp (˚C)(WT)	1	-.007	-.251	.391	-.103	-.455	.225	-.784**	.825**	.536	-.657*
DO (mg/L)	-	1	-.427	-.903**	-.438	.306	-.272	-.206	-.400	-.437	-.399
TDS (mg/L)	-	-	1	-.446	.806**	-.128	.152	.411	-.252	.037	.206
BOD (mg/L)	-	-	-	1	-.430	.086	-.231	-.501	-.036	-.129	-.649*
Conductivity (µmhos/cm)(C)	-	-	-	-	1	-.376	.028	.0201	-.172	.099	.026
pH	-	-	-	-	-	1	-.0277	.320	-.295	-.172	-.647*
TotalHardness (mg/L)(TH)	-	-	-	-	-	-	1	.279	.356	-.057	.156
Alkalinity(mg/L)(A)	-	-	-	-	-	-	-	1	-.512	-.297	.636*
TotalZooplankton/L(TZ)	-	-	-	-	-	-	-	-	1	.667*	-.202
TotalPhytoplankton/L(TPH)	-	-	-	-	-	-	-	-	-	1	-.174
Totalbirddiversity(TBD)	-	-	-	-	-	-	-	-	-	-	1

**Correlation is significant at 0.01level(2 tailed). *Correlation is significant at 0.05 level (2 tailed).

Table 4: Co-efficient of Correlation Analysis of Physico-chemical Parameters with Plankton and Avian Diversity at BP site

Parameter	WT	DO	BOD	TDS	C	pH	TH	A	TZ	TPH	TBD
WaterTemp (˚C)(WT)	1	-.880**	-.250	.192	.198	.236	.630*	-.468	.528	.353	-.778**
DO(mg/L)	-	1	-.433	-.233	-.297	-.173	-.544	.465	-.580*	-.282	.681*
BOD(mg/L)	-	-	1	.018	.269	-.103	-.235	.410	-.183	.249	.062
TDS(mg/L)	-	-	-	1	.726**	-.739**	-.268	.370	.836**	.778**	.328
Conductivity(µmhos/cm)(C)	-	-	-	-	1	-.496	-.171	.212	.664*	.676*	.052
pH	-	-	-	-	-	1	.815**	-.620*	-.642*	-.567	-.635*
TotalHardness(mg/L)(TH)	-	-	-	-	-	-	1	-.733**	-.141	-.158	-.751**
Alkalinity(mg/L)(A)	-	-	-	-	-	-	-	1	.127	.175	.686*
TotalZooplankton/L(TZ)	-	-	-	-	-	-	-	-	1	.663*	-.049
TotalPhytoplankton/L(TPH)	-	-	-	-	-	-	-	-	-	1	.093
Totalbirddiversity(TBD)	-	-	-	-	-	-	-	-	-	-	1

**Correlation is significant at 0.01 level (2 tailed). *Correlation is significant at 0.05 level (2 tailed).

Table 5: Physico chemical Characteristics of DP Wetland During Phase II

Parameters	Winter Season	Autumn Season	Monsoon Season	Summer Season
Air Temperature(°C)	16^{D}	24^{C}	33^{A}	27^{B}
Alkalinity(mg/L)	414.266 ± 1.451^{B}	614.66 ± 1.63^{A}	457.33 ± 6.53^{B}	416.933 ± 1.143^{B}
BOD(mg/L)	2.586 ± 0.228^{B}	3.36 ± 0.097^{AB}	3.2^{AB}	3.733 ± 0.199^{A}
Conductivity(µS/cm)	1486 ± 0.004^{AB}	1396 ± 0.008^{B}	1536 ± 0.004^{AB}	1620 ± 0.007^{A}
Dissolved Oxygen(mg/L)	6.59 ± 0.228^{A}	4.16 ± 0.097^{AB}	5.6^{B}	4.53 ± 0.198^{AB}
pH	8.47 ± 0.007^{B}	9.33 ± 0.007^{A}	9.01 ± 0.010^{A}	8.41 ± 0.004^{B}
TDS(mg/L)	782.2 ± 0.0137^{AB}	493 ± 0.004^{B}	726.6 ± 0.004^{AB}	836.6 ± 0.004^{A}
Total Hardness(mg/L)	350.223 ± 1.44^{B}	370.66 ± 1.63^{B}	394.06 ± 2.53^{A}	388 ± 0.848^{A}
Water Temperature(°C)	14^{D}	23^{C}	29^{A}	25^{B}

Means with different letters in the same row are significantly ($P<0.05$) different (Duncan's multiple range test)

Table 6: Physico chemical Characteristics of CL Wetland During Phase II

Parameters	Winter Season	Autumn Season	Monsoon Season	Summer Season
AirTemperature(°C)	17^{C}	25^{B}	34^{A}	26^{AB}
Alkalinity(mg/L)	553.32 ± 1.89^{A}	579.11 ± 3.031^{A}	422.22 ± 0.72^{B}	453.77 ± 1.44^{B}
BOD(mg/L)	1.51 ± 0.11^{AB}	0.26 ± 0.86^{C}	0.84 ± 0.382^{B}	1.87 ± 0.326^{A}
Conductivity(µS/cm)	1593 ± 0.004^{B}	1840 ± 0.007^{A}	1440 ± 0.0122^{B}	1921 ± 0.007^{A}
DissolvedOxygen(mg/L)	3.91 ± 0.1102^{A}	3.46 ± 0.86^{AB}	3.24 ± 0.238^{AB}	2.4 ± 0.565^{B}
pH	8.86 ± 0.0212^{A}	7.76 ± 0.007^{B}	8.3 ± 0.004^{AB}	8.05 ± 0.007^{AB}

TotalHardness(mg/L)	580±2.82^{A}	589.33±3.36^{A}	545.33±4.32^{B}	540±2.82^{B}
TDS(mg/L)	963±0.008^{A}	920±0.004^{A}	713±0.004^{B}	954±0.003^{A}
WaterTemperature(°C)	15^{D}	22^{C}	32^{A}	26^{B}

Means with different letters in the same row are significantly (P<0.05) different (Duncan's multiple range test)

Table 7: Physico chemical Characteristics of BP Wetland During Phase II

Parameters	**Winter Season**	**Autumn Season**	**Monsoon Season**	**Summer Season**
Air Temperature(°C)	17^{B}	26^{AB}	33^{A}	28^{AB}
Alkalinity(mg/L)	366.22±1.44^{A}	366.66±1.632^{A}	317.77±1.086^{B}	368±2.828^{A}
BOD(mg/L)	4.84±0.734^{B}	6.4±0.461^{AB}	6.573±0.287^{AB}	6.67±0.327^{A}
Conductivity(µS/cm)	1440±0.004^{B}	1436±0.004^{B}	1460±0.0187^{B}	1593±0.004^{A}
Dissolved Oxygen(mg/L)	8.84±0.266^{A}	7.73±0.266^{B}	7.46±0.187^{B}	7.47±0.327^{B}
pH	8.91±0.005^{C}	9.31±0.004^{B}	10.15±0.0177^{A}	8.58±0.004^{D}
Total Hardness(mg/L)	205±0.707^{C}	214.66±0.944^{C}	396.44±1.439^{A}	238.21±0.543^{B}
TDS(mg/L)	710±0.004^{B}	646.6±0.008^{C}	637.6±0.005^{C}	790±0.004^{A}
Water Temperature(°C)	15^{D}	23^{C}	30^{A}	27^{B}

Means with different letters in the same row are significantly (P<0.05) different (Duncan's multiple range test)