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Assessment of Water Quality Index (WQI) in Pond Water Samples from Birkona Region, Chhattisgarh

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ABSTRACT

This study assesses the water quality of ten key ponds in the Birkona region of Chhattisgarh using the Water Quality Index (WQI) method over a three-year period (2021-2023). The WQI was calculated based on an analysis of multiple physicochemical and biological parameters, including pH, dissolved oxygen, total dissolved solids, and biochemical oxygen demand. The results revealed significant spatial and temporal variations in water quality, with some ponds showing consistently high WQI values, indicating poor water quality and the need for treatment before use. These findings underscore the importance of regular monitoring and proactive management to ensure the safety and sustainability of these vital water resources for the local population.

1. Introduction

Water is a vital resource for sustaining life, and its quality is paramount to ensuring the health and well-being of populations, especially in rural areas where surface water bodies like ponds are often the primary sources of water for domestic and agricultural purposes. The quality of water can be influenced by a variety of factors, including natural processes, human activities, and seasonal variations. In rural settings, where water treatment facilities may be limited, maintaining high water quality is crucial to preventing waterborne diseases and ensuring safe water for the community.
The Water Quality Index (WQI) is a widely recognized tool for assessing and communicating the overall quality of water. It simplifies the complexity of water quality data by integrating multiple physicochemical parameters into a single numerical value. This value reflects the suitability of water for specific uses, such as drinking, and provides a clear and concise way to compare water quality across different locations and over time.

The concept of WQI was first introduced by Tiwari and Mishra (1985), who developed a systematic approach to calculating the index by assigning weights to various water quality parameters based on their relative importance and the recommended standards for each parameter. This method has been widely adopted in water quality studies across different regions and has become a standard tool for evaluating the potability of water. Several studies have demonstrated the effectiveness of WQI in assessing water quality in different environmental settings. For instance, Sinha (1995) applied WQI to evaluate the potability of rural pond water in Muzaffarpur, highlighting significant variability in water quality across different ponds. The study emphasized the importance of identifying areas where water quality is compromised and implementing appropriate treatment interventions.

Recent studies have expanded the application of WQI to urban environments, where water quality is often influenced by industrial activities and urbanization. Roy and Manna (2021) assessed the surface water quality in the West Tripura District of India using WQI and multivariate statistical techniques. Their study revealed significant spatial variations in

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water quality and underscored the need for continuous monitoring and management of water resources, particularly in areas vulnerable to contamination.

In Chhattisgarh, studies such as those by Nayar (2019) and Tamrakar et al. (2022) have focused on the impact of cultural practices and urbanization on water quality. Nayar's study on the effects of idol immersion in the Dulahra Pond in Ratanpur used WQI to quantify the degradation in water quality, offering insights into seasonal fluctuations similar to those observed in the present study of the Birkona region. Tamrakar et al.'s evaluation of urban ponds in Raipur District highlighted the influence of urbanization and the need for proactive water management strategies to maintain water quality.

The Birkona region, located 5 km from Bilaspur city in Chhattisgarh, is a rural area characterized by high population density and a significant reliance on surface water for domestic purposes. Despite achieving notable water system coverage, challenges persist in maintaining water quality, as indicated by preliminary observations. This study aims to assess the water quality of ten major ponds in the Birkona region using the WQI method. By systematically sampling water from these ponds and analyzing various physicochemical parameters, this study seeks to identify major sources of contamination, assess temporal and spatial variations in water quality, and provide recommendations for water management and protection in the region.

This research builds on the existing body of literature on WQI by applying it to a rural context in the Birkona region, contributing valuable data and insights that can inform water quality management practices in similar settings.

2. Materials and Methods

2.1 Study Area and Sampling

This study was conducted in the Birkona region, with water samples collected from ten ponds. The specific sampling locations are listed in Table 1.

Table 1. Sampling locations at different ponds

Pond name	Sampling location
Ramsagar	S-1
Harsagar	S-2
Kapoortal	S-3
Naiya	S-4
Mishir	S-5
Aashabandh	S-6
Bamuri	S-7
Hagani	S-8
Sonatariya	S-9
Tikari	S-10

Sampling was conducted monthly over a three-year period (2021-2023) to capture seasonal variations in water quality. This study focused on analyzing the water quality and environmental pollution of stagnant surface water in the rural area of Birkona, specifically targeting ten ponds: Ramsagar, Harsagar, Kapoortal, Naiya, Misir, Aashabandh, Bamuri, Hagani, Sontariya, and Tikari in the Bilaspur District (Chhattisgarh). The analysis included a comprehensive assessment of the physical characteristics of the water, such as transparency, color, odor, temperature, and specific conductivity. The chemical properties were also thoroughly evaluated, encompassing total solids, total dissolved solids, pH, electrical conductivity, total hardness, alkalinity, nitrogen content, chloride content, calcium, sulfate, and fluoride levels. Additionally, the biological characteristics, including Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), and Chemical Oxygen Demand (COD), were measured. These parameters were monitored throughout the three-year period to assess seasonal variations. Water samples were systematically collected from the margins in the four cardinal directions—North, South, East, and West—as well as from the center of each pond.

2.2 Physicochemical Parameters

The study measured a comprehensive range of physicochemical parameters, which are essential for calculating the WQI. These parameters include:

Transparency: Measured using a Secchi disc.

Temperature: Recorded using a mercury thermometer.

pH: Determined with a digital pH meter.

Conductivity: Measured by a digital conductivity meter.

Total Solids (TS): Determined by the gravimetric method.

Total Suspended Solids (TSS): Measured by filtration.

Total Dissolved Solids (TDS): Measured by the gravimetric method.

Total Alkalinity: Assessed using titration methods.
Total Hardness (TH): Measured by EDTA titrimetric method.
Calcium Hardness (CaH): Measured by EDTA titrimetric method.
Magnesium Hardness (MgH): Measured by EDTA titrimetric method.
Chloride: Measured by the argentometric method.
Sulphate: Assessed using the turbidimetric method.
Phosphate: Measured by the stannous chloride solution method.
Nitrate: Determined using the phenoldisulphonic acid method.
Dissolved Oxygen (DO): Measured by the Winkler method.
Biochemical Oxygen Demand (BOD): Assessed using the dilution method.
Chemical Oxygen Demand (COD): Measured by the potassium dichromate method.
Fluoride: Assessed using the SPADNS method.

2.3 Calculation of WQI

The WQI was calculated using the method proposed by Tiwari and Mishra (1985), where each parameter's weight is determined based on its relative importance and recommended standard values. The WQI is then computed by aggregating the weighted quality ratings for each parameter, providing an overall index that reflects the water quality of each pond.

The Water Quality Index (WQI) is calculated using the following formula:
WQI = (Sum of (quality rating of each parameter multiplied by its unit weight)) / (Sum of unit weights)

Where:
The quality rating (q_i) for each parameter is calculated as:
*q_i = (Observed value of the parameter / Standard value of the parameter) * 100*
Here, "Observed value" is the measured concentration of the parameter in the water sample, and "Standard value" is the recommended or acceptable concentration of the parameter.

The unit weight (w_i) for each parameter is calculated as:
$w_i = K / S_i$
where "K" is a constant of proportionality, and "S_i" is the standard value of the parameter. The constant K is determined by ensuring that the sum of all unit weights equals 1.

This method assigns greater importance to parameters with stricter standards, thereby reflecting their potential impact on human health. The overall WQI is then used to assess the water quality, with higher WQI values indicating poorer water quality.

3. Results and Discussion

The WQI values for each pond, presented in Table 2, reveal significant variability in water quality across different locations.

Ashaband Pond (S-6): This pond consistently exhibited the highest mean WQI value (11.57), indicating poor water quality that requires treatment before use. The high WQI values in this pond suggest persistent contamination issues.

Ramsagar Pond (S-1): Ramsagar pond displayed a wide range of WQI values, with a mean value of 7.2. The highest WQI was recorded in April, suggesting seasonal influences on water quality.

Harsagar Pond (S-2): Harsagar pond showed the lowest mean WQI value (4.36), indicating good water quality. The stable and low WQI values suggest that this pond is relatively free from significant contamination.

Table 2. Overall average results for the 3 year period

Pond	Minimum	Maximum	Mean
Ashaband	10.71	13.36	11.57
Ramsagar	3.33	11.77	7.2
Kapoortal	3.82	12.69	6.08
Bamuri	3.69	6.92	4.94
Sontariya	3.87	6.31	4.73
Naiya	3.78	5.92	4.71
Hagani	3.69	5.63	4.53
Tikari	3.3	6.44	4.53
Mishir	3.34	5.5	4.4
Harsagar	2.21	8.76	4.36

3.1 Seasonal Variation

The seasonal variation in WQI values is illustrated in Figure 1, where ponds like Ashaband and Ramsagar show significant fluctuations. These variations may be attributed to seasonal factors such as agricultural runoff, changes in water levels, and other environmental influences.

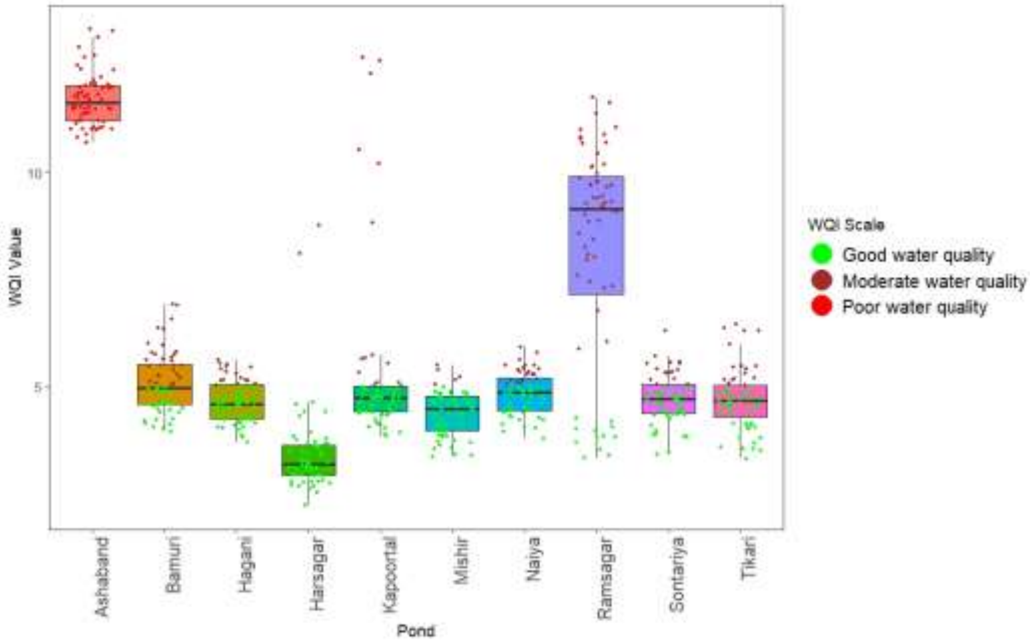

Fig 1: Boxplots illustrating variability in water quality index for the ponds in Birkona region

3.2 Correlation Analysis

The correlation matrix (Figure 2) identifies the relationships between different physicochemical parameters. Chloride, fluoride, and TDS were found to have the most significant impact on WQI, indicating that these parameters are the primary contributors to poor water quality in the ponds studied. Figure 2 presents a correlation matrix that visually represents the relationships between various water quality parameters and the Water Quality Index (WQI).

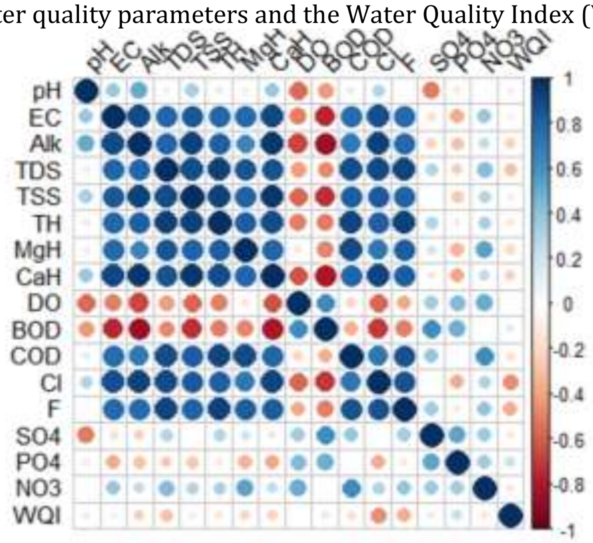

Fig 2. Correlation matrix based on mean values for the 3 year period

This matrix is a crucial tool for understanding how different physicochemical parameters interact with each other and contribute to the overall water quality as indicated by the WQI. The matrix displays the correlation coefficients between pairs of parameters, with the strength and direction of these correlations illustrated by both the color and size of the circles in each cell. The color spectrum ranges from dark blue, indicating a strong positive correlation (close to +1), to dark red, representing a strong negative correlation (close to -1). Lighter shades indicate weaker correlations. The size of the circles corresponds to the magnitude of the correlation, with larger circles representing stronger correlations.

3.3 Key Observations

3.3.1 Correlation with WQI: The final column and row in the matrix depict the correlation of each parameter with the Water Quality Index (WQI). Parameters such as Total Dissolved Solids (TDS), Chlorides (Cl), and Electrical Conductivity (EC) exhibit strong positive correlations with WQI, as indicated by large, dark blue circles. This suggests that increases in these parameters are associated with higher WQI values, reflecting poorer water quality. Conversely, Dissolved Oxygen (DO) shows a strong negative correlation with WQI, represented by a large dark red circle. Higher DO levels are typically associated with better water quality (lower WQI), highlighting its critical role in maintaining water quality.

3.3.2 Inter-Parameter Correlations: There is a strong positive correlation between parameters such as Electrical Conductivity (EC) and Total Dissolved Solids (TDS), as expected, since higher concentrations of dissolved solids typically increase the water's conductivity. Negative correlations are particularly evident between Dissolved Oxygen (DO) and parameters like Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), suggesting that higher organic pollution (indicated by higher BOD and COD) tends to reduce oxygen levels in the water, which is detrimental to aquatic life and overall water quality.

3.3.3 Implications for Water Quality Management: The correlation matrix clearly identifies key parameters that significantly impact the WQI. For instance, managing levels of TDS, Chlorides, and Electrical Conductivity could be essential strategies for improving water quality in the Birkona region. Additionally, maintaining adequate levels of Dissolved Oxygen is vital for ensuring the health of aquatic ecosystems and overall water quality.

By providing a comprehensive overview of how different water quality parameters interact, this correlation matrix serves as a valuable tool for prioritizing management actions and improving the water quality in the ponds studied. The results of this study emphasize the importance of continuous water quality monitoring, particularly in ponds with high WQI values such as Ashaband and Ramsagar. These ponds exhibit poor water quality due to high levels of pollutants like chlorides and fluorides, which may be linked to agricultural runoff or other anthropogenic activities. In contrast, ponds like Harsagar, with low and stable WQI values, demonstrate the importance of preserving good water quality. These ponds likely benefit from natural filtration processes and lower levels of contamination sources.

The seasonal fluctuations in WQI values observed in some ponds suggest that water quality is influenced by seasonal factors, which may include increased runoff during the rainy season or decreased water levels during dry periods. Addressing these seasonal variations through targeted interventions could help mitigate the impact on water quality. The correlation analysis underscores the need for targeted management of key pollutants such as chloride, fluoride, and TDS. By addressing these specific parameters, water quality in the affected ponds can be significantly improved. The water quality assessment of the ten ponds in the Birkona region revealed significant spatial and temporal variations, with several ponds exhibiting poor water quality that necessitates treatment before use. These findings align with the results of other studies conducted in similar rural environments.

In the present study, high WQI values were observed in ponds such as Ashabandh and Ramsagar, indicating elevated levels of pollutants like total dissolved solids (TDS), chlorides, and low dissolved oxygen (DO). This is consistent with the findings of Sinha (1995), who reported similar issues in rural ponds in Muzaffarpur, where high concentrations of dissolved solids and low oxygen levels were primary contributors to poor water quality. Sinha's study highlighted the need for immediate intervention to treat and manage these water bodies, particularly in densely populated rural areas where surface water is a primary resource.

Similarly, Roy and Manna (2021) observed significant spatial variations in water quality across different ponds in the West Tripura District, India, where WQI values were influenced by local environmental factors, including agricultural runoff and seasonal changes. The present study corroborates these findings, as seasonal fluctuations were also noted in the Birkona ponds, particularly during the monsoon season, which likely exacerbates the influx of pollutants from surrounding agricultural activities. The strong correlation between WQI and parameters such as TDS and electrical conductivity (EC) in both studies underscores the impact of dissolved solids on overall water quality.

In Chhattisgarh, Nayar (2019) examined the effects of cultural practices, such as idol immersion, on water quality in the Dulahra Pond in Ratanpur. Nayar reported a marked decline in water quality following these events, reflected in increased biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels. The current study similarly observed elevated BOD and COD levels in several ponds, particularly in the post-monsoon period, suggesting that both natural and anthropogenic factors contribute to the observed water quality degradation. These findings further reinforce the need for regular monitoring and community awareness to mitigate such impacts.

Tamrakar et al. (2022) assessed the water quality of urban ponds in Raipur District, Chhattisgarh, and highlighted the significant influence of urbanization and industrial activities on water quality. While the Birkona region is less urbanized, the study's findings indicate that similar pollutants, including high levels of nitrates, chlorides, and phosphates, affect the water quality, particularly in more populated areas of the district. This suggests that even in rural settings, water bodies are susceptible to pollution from both agricultural runoff and localized urban activities. In conclusion, the water quality issues identified in the Birkona region are consistent with findings from other studies in similar settings, where dissolved solids, oxygen depletion, and seasonal variations are key factors influencing WQI. These results emphasize the importance of implementing effective water management strategies, including regular monitoring, pollution control, and public education, to preserve the quality of these vital water resources. Comparing the current study's results with those of other authors provides a broader context for understanding the challenges and potential solutions in managing water quality in rural areas.

4. Conclusion
This study highlights the need for ongoing assessment and proactive management of water quality in the Birkona region. The WQI method has proven to be an effective tool for identifying ponds that require immediate intervention to ensure safe water for the local population. Ponds with high WQI values, such as Ashaband and Ramsagar, should be prioritized for treatment and management efforts. Additionally, maintaining the good water quality observed in ponds like Harsagar should be a priority to ensure their continued use as a safe water resource.

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