Impact Factor (QJIF): 8.47 E-ISSN: 2583-1615, P-ISSN: 3049-3498

International Journal of Research in Academic World

Received: 19/May/2026 **IJRAW:** 2026; 5(7):174-180 **Accepted:** 22/June/2026

Assessment of Physico-Chemical Characteristics of Pond Water in Madhepura District, Bihar, India

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Abstract

Water quality plays a crucial role in maintaining the ecological balance and biological productivity of freshwater ecosystems. The present study was conducted to assess the physico-chemical characteristics of pond water in Madhepura District, Bihar, India, during the pre-monsoon season. Water samples were collected from selected ponds and analyzed for various physicochemical parameters including pH, temperature, turbidity, total dissolved solids (TDS), electrical conductivity, total hardness, alkalinity, chloride, sulphate, nitrate, fluoride, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and selected heavy metals.

The results revealed that the pond water was moderately alkaline with a pH of 8.56 and a temperature of 28.5°C. The concentration of TDS (276 mg/L) and electrical conductivity (415 µS/cm) indicated moderate mineralization of water. Dissolved oxygen was recorded at 5.3 mg/L, suggesting the capability of the pond to support aquatic organisms. However, elevated BOD (14 mg/L) and COD (60 mg/L) values indicated considerable organic pollution. Iron (4.66 mg/L) and chromium (0.13 mg/L) concentrations were found to be comparatively high, suggesting possible anthropogenic and geogenic influences.

The study highlights the importance of regular monitoring of pond water quality for sustainable management of freshwater resources and conservation of aquatic biodiversity in rural ecosystems. The findings may provide valuable information for environmental planners, policymakers, and aquaculture practitioners in the region.

Keywords: Pond Water, Physico-Chemical Parameters, Water Quality, Dissolved Oxygen, BOD, COD, Madhepura District, Bihar.

1. Introduction

Freshwater ecosystems represent one of the most dynamic and ecologically significant components of the natural environment (Wetzel, 2001; Chapman, 1996). Among these ecosystems, ponds occupy a unique position, particularly in rural regions where they support a wide range of ecological, economic, and social functions. In India, ponds have traditionally served as multipurpose water resources, providing water for domestic needs, livestock, irrigation, aquaculture, and groundwater recharge (Boyd & Tucker, 2012). Beyond their utilitarian value, ponds also function as important habitats for aquatic flora and fauna, contributing significantly to local biodiversity and ecological stability (Boyd, 2015).

The ecological health of a pond is closely linked to the quality of its water. Water acts as the primary medium through which biological, chemical, and physical processes interact within an aquatic ecosystem. Any alteration in water quality can directly influence species composition, biological productivity, nutrient cycling, and overall ecosystem functioning (Wetzel, 2001). Consequently, the assessment of water quality has become a fundamental aspect of freshwater ecosystem management and environmental monitoring (Chapman, 1996).

Over the past few decades, freshwater resources across many parts of the world have experienced increasing environmental stress due to expanding human activities. Rapid population growth, changing land-use patterns, agricultural intensification, urban expansion, and the discharge of untreated domestic wastes have significantly altered the natural characteristics of many aquatic ecosystems (Sharma & Kansal, 2011; Kumar *et al*., 2021). Rural ponds, despite their ecological and socio-economic importance, are particularly vulnerable to such pressures because they often receive surface runoff carrying sediments, nutrients, fertilizers, pesticides, and other contaminants from surrounding catchment areas (Verma *et al*., 2022).

The quality of pond water is generally evaluated through a range of physicochemical parameters that provide insight into the condition of the aquatic environment. Parameters such as pH, temperature, turbidity, total dissolved solids (TDS), electrical conductivity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), alkalinity, hardness, chloride, sulphate, nitrate, and fluoride

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are widely used as indicators of water quality (APHA, 2023; Boyd, 2015). These parameters not only reflect the chemical composition of water but also help in understanding the ecological processes operating within the pond ecosystem. Variations in these characteristics may influence the survival, growth, reproduction, and distribution of aquatic organisms and can ultimately affect the productivity of fisheries and other ecosystem services (Boyd & Tucker, 2012).

Bihar is one of the states where ponds continue to play a vital role in supporting rural livelihoods and local economies. The state possesses thousands of small and medium-sized ponds that are extensively utilized for fish culture, agriculture, and domestic purposes. In many villages, ponds serve as the principal source of water for several daily activities and remain closely associated with the socio-cultural life of local communities. However, increasing anthropogenic pressure, sediment accumulation, nutrient enrichment, and inadequate management practices have raised concerns regarding the long-term sustainability of these water bodies (Kumar *et al*., 2019).

Madhepura District, situated in the floodplain region of the Kosi basin in North Bihar, is characterized by an abundance of natural and man-made ponds. The district experiences periodic flooding, intense seasonal rainfall, and substantial agricultural activity, all of which influence the hydrological and ecological characteristics of local water bodies. The ponds of this region support fish farming, livestock rearing, irrigation, and various domestic activities. Despite their importance, systematic scientific investigations concerning the water quality status of these ponds remain relatively scarce. Available information is fragmented and insufficient to provide a comprehensive understanding of the physicochemical conditions prevailing within these aquatic ecosystems.

A detailed assessment of pond water quality in Madhepura District is therefore essential for several reasons. First, it provides baseline scientific information regarding the present condition of freshwater resources in the region. Second, it helps identify potential environmental threats that may compromise ecosystem health and aquatic biodiversity. Third, it contributes to the development of sustainable management strategies for fisheries, water conservation, and environmental protection (Tyagi *et al*., 2020). Finally, such studies generate valuable data that can assist policymakers, environmental planners, and local communities in making informed decisions regarding the conservation and utilization of pond ecosystems.

In view of these considerations, the present investigation was undertaken to evaluate the physicochemical characteristics of pond water in selected ponds of Madhepura District, Bihar, India. By analyzing key water quality parameters and examining their ecological implications, the study seeks to provide a scientific understanding of the current status of pond ecosystems in the region and contribute to the broader discourse on freshwater resource management and environmental sustainability.

Objectives of the Study

i). To assess the physicochemical characteristics of pond water in selected ponds of Madhepura District, Bihar.
ii). To evaluate the suitability of pond water for aquatic life, fisheries, and related ecological functions.
iii). To compare the observed water quality parameters with established national and international standards.
iv). To identify possible environmental factors influencing water quality deterioration.
v). To provide scientific recommendations for the sustainable management, conservation, and utilization of pond ecosystems in the study area.

2. Materials and Methods

2.1. Study Area

The present investigation was conducted in selected rural ponds of Madhepura District, Bihar, India, during the pre-monsoon season of 2026. Madhepura District is situated in the northeastern part of Bihar and forms an integral part of the Kosi River basin. The region is characterized by a subtropical monsoon climate, marked by high summer temperatures, moderate winter conditions, and substantial seasonal rainfall. Owing to its floodplain topography and abundant freshwater resources, the district possesses numerous natural and man-made ponds that play a significant role in fisheries, agriculture, livestock rearing, groundwater recharge, and domestic water utilization (Government of Bihar, 2024).

The selected ponds represent typical freshwater ecosystems of the region and are subjected to varying degrees of anthropogenic influence. These water bodies serve as important ecological habitats and contribute substantially to the socio-economic well-being of rural communities (Boyd & Tucker, 2012).

2.2. Sample Collection

Water samples were collected from representative locations of the selected ponds during the pre-monsoon period (April–May 2026). Sampling was carried out following the standard procedures recommended by the American Public Health Association (APHA, 2023). Prior to sampling, all collection containers were thoroughly cleaned and rinsed with distilled water to prevent contamination.

Samples were collected in pre-cleaned polyethylene bottles from approximately 20–30 cm below the water surface to obtain representative water conditions. Necessary precautions were taken during collection, handling, and transportation to preserve the original characteristics of the samples. The collected samples were properly labeled and transported to the laboratory for detailed physicochemical analysis within the prescribed holding period (APHA, 2023).

2.3. Physico-Chemical Analysis

The collected water samples were analyzed in a NABL-accredited environmental laboratory using standard analytical techniques. Various physicochemical parameters were selected for assessment because of their direct influence on water quality and aquatic ecosystem health (Boyd, 2015).

The parameters analyzed included pH, temperature, turbidity, total dissolved solids (TDS), electrical conductivity (EC), total hardness, total alkalinity, chloride, sulphate, nitrate, fluoride, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD). These parameters are widely recognized as reliable indicators of freshwater quality and provide valuable information regarding the suitability of water for aquatic organisms, fisheries, and other beneficial uses (APHA, 2023; Chapman, 1996).

2.4. Heavy Metal Analysis

In addition to routine water quality parameters, selected heavy metals were also analyzed to assess possible contamination and ecological risks. The investigated heavy metals included iron (Fe), chromium (Cr), arsenic (As), cadmium (Cd), copper (Cu), nickel (Ni), selenium (Se), mercury (Hg), manganese

(Mn), and lead (Pb).

Heavy metal concentrations were determined using standard laboratory procedures in accordance with APHA guidelines (APHA, 2023). The analysis was undertaken to identify potential environmental contamination arising from natural geological conditions as well as human-induced activities within the surrounding catchment area. Heavy metal monitoring is considered essential because of the potential ecological and toxicological impacts associated with their accumulation in aquatic ecosystems (Ali *et al*., 2024).

2.5. Data Interpretation and Evaluation

The analytical results obtained from laboratory investigations were compiled, tabulated, and interpreted using standard environmental assessment approaches. The observed values of physicochemical and heavy metal parameters were compared with the permissible limits prescribed by the Bureau of Indian Standards (BIS, 2012) and the World Health Organization (WHO, 2022).

Comparative evaluation of the measured parameters was carried out to determine the overall water quality status of the studied ponds and to assess their ecological suitability. Particular emphasis was given to parameters such as dissolved oxygen, biological oxygen demand, chemical oxygen demand, and heavy metal concentrations, as these indicators provide important insights into pollution levels and ecosystem health (Kannel *et al*., 2007). The findings were further utilized to identify potential environmental concerns and to formulate recommendations for the sustainable management and conservation of pond ecosystems in Madhepura District.

3. Results and Discussion

The physicochemical characteristics of water collected from Bhakhri Pond (Pond-5), located in Madhepura District, Bihar, were evaluated during the pre-monsoon season of 2026. The obtained results provide valuable insights into the current ecological status of the pond ecosystem and help in understanding the environmental conditions prevailing within this freshwater body. Water quality parameters are important indicators of ecosystem health because they influence biological productivity, aquatic biodiversity, nutrient cycling, and overall ecological sustainability.

The pH of the pond water was recorded at 8.56, indicating moderately alkaline conditions. The alkaline nature of the water may be attributed to the presence of bicarbonates, carbonates, and other dissolved minerals commonly found in freshwater ecosystems of alluvial regions. Similar alkaline conditions have been reported in several freshwater ponds of northern India, particularly in areas influenced by agricultural activities and nutrient-rich runoff. The observed pH falls within the range considered suitable for most freshwater organisms and fish species. However, prolonged increases in alkalinity may alter nutrient availability and affect the structure of aquatic communities.

The water temperature during the sampling period was found to be 28.5°C. Temperature is a critical environmental variable because it regulates biological metabolism, enzymatic activity, oxygen solubility, and the rate of chemical reactions within aquatic ecosystems. The recorded temperature is typical of tropical freshwater bodies during the pre-monsoon season. Elevated temperatures generally enhance microbial decomposition of organic matter and increase the metabolic demands of aquatic organisms. Such conditions may influence dissolved oxygen availability and ecosystem productivity.

Turbidity was measured at 5.9 NTU, indicating the presence of suspended particles in moderate concentrations. Turbidity in rural ponds commonly results from surface runoff, sediment disturbance, plankton growth, and organic debris. Although the observed value does not indicate severe deterioration of water clarity, increased turbidity may reduce light penetration and subsequently affect photosynthetic activity and primary productivity. Reduced light availability may also influence the distribution of aquatic vegetation and plankton populations.

The concentration of Total Dissolved Solids (TDS) was found to be 276 mg/L, while Electrical Conductivity (EC) was recorded at 415 µS/cm. These parameters provide information regarding the ionic composition and mineral content of water. The moderate TDS and conductivity values observed in the present study suggest that the pond water contains a balanced concentration of dissolved salts and minerals. Such conditions are generally favorable for freshwater aquatic organisms and fish culture. Excessively high TDS and conductivity values often indicate chemical contamination or salinity problems; however, the values recorded in the present investigation do not suggest any serious deterioration of water quality in this regard.

Dissolved Oxygen (DO), one of the most important indicators of aquatic ecosystem health, was recorded at 5.3 mg/L. Dissolved oxygen plays a fundamental role in maintaining aerobic biological processes and supporting aquatic life. The observed concentration indicates that the pond possesses sufficient oxygen to sustain fish and other aquatic organisms. Nevertheless, oxygen availability may fluctuate seasonally due to changes in temperature, biological activity, and organic matter decomposition. Continuous monitoring of dissolved oxygen is therefore essential for maintaining ecological balance and ensuring the sustainability of aquatic resources.

The Biological Oxygen Demand (BOD) value was found to be 14 mg/L. BOD reflects the amount of oxygen required by microorganisms for the decomposition of biodegradable organic matter present in water. The relatively high BOD value observed in the present study suggests a considerable organic load within the pond ecosystem. Such conditions may arise from the accumulation of decaying vegetation, livestock activities, domestic wastewater discharge, and nutrient-rich agricultural runoff. Elevated BOD levels are often associated with declining water quality and increased ecological stress, particularly when accompanied by reductions in dissolved oxygen concentrations.

Similarly, the Chemical Oxygen Demand (COD) value was recorded at 60 mg/L. COD provides an estimate of the total quantity of oxygen required for the oxidation of both biodegradable and non-biodegradable substances present in water. The observed COD concentration indicates the presence of significant organic and inorganic pollutants within the pond environment. High COD values generally signify increased pollution pressure and reduced ecological quality. The combined occurrence of elevated BOD and COD values in Bhakhri Pond suggests that organic enrichment and anthropogenic influences may be affecting the ecological integrity of the water body.

Total hardness and alkalinity were recorded at 174.24 mg/L and 190.08 mg/L, respectively. Hardness is primarily determined by the presence of calcium and magnesium salts and is considered beneficial for fish growth and aquatic productivity when present in moderate concentrations. The observed hardness value indicates moderately hard water, which is generally favorable for freshwater aquaculture. Alkalinity, on the other hand, reflects the buffering capacity

of water and its ability to resist sudden fluctuations in pH. The relatively high alkalinity recorded in the present study indicates a stable aquatic environment capable of supporting biological productivity.

The concentrations of chloride, sulphate, nitrate, and fluoride were observed as 26.16 mg/L, 20.21 mg/L, 3.9 mg/L, and 0.51 mg/L, respectively. These values remained within acceptable environmental limits and did not indicate significant chemical contamination. However, the presence of nitrate suggests nutrient inputs from surrounding agricultural fields and organic matter decomposition. Excessive nutrient enrichment may accelerate eutrophication processes, resulting in algal blooms, oxygen depletion, and ecological imbalance. Although the nitrate concentration recorded in the present study was not alarming, continuous monitoring remains important for preventing nutrient-related environmental problems.

Heavy metal contamination represents an important environmental concern in freshwater ecosystems because of its potential toxic effects on aquatic organisms and human health. In the present investigation, iron (Fe) was detected at a concentration of 4.66 mg/L, whereas chromium (Cr) was recorded at 0.13 mg/L. The elevated iron concentration may be associated with the geological characteristics of the Kosi basin, where iron-rich alluvial sediments are commonly encountered. Iron may also enter aquatic systems through groundwater interactions and natural weathering processes.

The presence of chromium is of particular environmental significance because this metal is often associated with anthropogenic activities and may exert adverse effects on aquatic organisms when present in elevated concentrations. Although the source of chromium in the studied pond requires further investigation, its occurrence highlights the need for periodic environmental monitoring and effective pollution control measures. Long-term accumulation of heavy metals in sediments and aquatic organisms may lead to ecological degradation and biomagnification within food chains.

Overall, the results of the present study indicate that Bhakhri Pond continues to support freshwater ecological functions and aquatic life. However, elevated BOD, COD, iron, and chromium concentrations reveal emerging environmental pressures that require scientific attention. The findings emphasize the importance of regular water quality assessment, sustainable pond management practices, and community-based conservation initiatives to maintain the ecological integrity and long-term sustainability of freshwater resources in Madhepura District.

Table 1: Physico-Chemical Characteristics of Water Sample Collected from Bhakhri Pond (Pond-5), Madhepura District during Pre-Monsoon Season (2026).

Parameters	Observed Value	Recommended Standard*	Remarks
pH	8.56	6.5 - 8.5	Slightly alkaline
Temperature (°C)	28.5	-	Typical tropical condition
Turbidity (NTU)	5.9	5.0	Slightly elevated
Total Dissolved Solids (mg/L)	276	500	Within permissible limit
Electrical Conductivity (µS/cm)	415	-	Moderate ionic content
Total Hardness (mg/L)	174.24	200	Within permissible limit
Total Alkalinity (mg/L)	190.09	200	Within acceptable range
Chloride (mg/L)	26.16	250	Within permissible limit
Sulphate (mg/L)	20.21	200	Within permissible limit
Nitrate (mg/L)	3.9	45	Within permissible limit
Fluoride (mg/L)	0.51	1.0	Within permissible limit
Dissolved Oxygen (mg/L)	5.3	>5.0	Suitable for aquatic life
Biological Oxygen Demand (mg/L)	14	<5.0	High organic pollution load
Chemical Oxygen Demand (mg/L)	60	<25 - 30	Elevated pollution level
Iron (mg/L)	4.66	0.3	Significantly higher than recommended limit
Chromium (mg/L)	0.13	0.05	Higher than recommended limit

**Recommended standards based on BIS (IS 10500:2012), WHO Guidelines, and commonly accepted freshwater ecosystem criteria.*

Interpretation of Physico-Chemical Characteristics

The physicochemical analysis of water collected from Bhakhri Pond revealed considerable information regarding the ecological condition and water quality status of the studied freshwater ecosystem. The observed pH value (8.56) indicated a moderately alkaline nature of the pond water, which is generally considered suitable for the survival and growth of most freshwater organisms (Boyd & Tucker, 2012). The recorded temperature (28.5°C) was characteristic of tropical freshwater environments during the pre-monsoon season and may influence biological productivity, metabolic activities, and oxygen dynamics within the aquatic ecosystem (Boyd, 2015).

The turbidity value of 5.9 NTU suggested the presence of suspended particles in moderate concentrations. Turbidity in freshwater ponds is commonly influenced by surface runoff, sediment resuspension, plankton growth, and anthropogenic disturbances (Verma *et al*., 2022). Total Dissolved Solids (276 mg/L) and Electrical Conductivity (415 µS/cm) indicated moderate mineralization of water and reflected the presence of dissolved ionic substances at levels generally considered favorable for freshwater ecosystems (APHA, 2023).

Dissolved Oxygen (DO) was recorded at 5.3 mg/L, suggesting that the pond possessed sufficient oxygen to support aquatic organisms. Adequate dissolved oxygen is essential for respiration, metabolism, and biological productivity in aquatic environments (Kannel *et al*., 2007). However, the Biological Oxygen Demand (BOD) value of 14 mg/L was considerably higher than the recommended level for healthy freshwater systems. Elevated BOD values indicate increased microbial decomposition of organic matter and suggest the presence of

significant organic pollution within the pond (Tyagi *et al*., 2020).

Similarly, the Chemical Oxygen Demand (COD) value of 60 mg/L was found to be relatively high. High COD levels generally reflect the accumulation of oxidizable organic and inorganic substances in water and indicate environmental stress caused by pollution inputs (APHA, 2023). The simultaneous occurrence of elevated BOD and COD values suggests that the pond ecosystem is experiencing organic enrichment, possibly resulting from domestic activities, agricultural runoff, decaying vegetation, and other anthropogenic influences (Verma *et al*., 2022).

The concentrations of total hardness (174.24 mg/L) and alkalinity (190.08 mg/L) indicated moderately hard and well-buffered water conditions. Such characteristics are generally favorable for fish growth and aquatic productivity because they contribute to nutrient availability and pH stability (Boyd & Tucker, 2012). The concentrations of chloride, sulphate, nitrate, and fluoride remained within acceptable limits and did not indicate significant chemical contamination of the pond water (BIS, 2012; WHO, 2022).

Heavy metal analysis revealed comparatively high concentrations of iron (4.66 mg/L) and chromium (0.13 mg/L). The elevated iron content may be associated with the iron-rich alluvial deposits and geological characteristics of the Kosi basin region. Chromium, however, is often regarded as an environmentally significant pollutant because of its persistence and potential toxic effects on aquatic organisms (Ali *et al*., 2024). The presence of chromium above recommended levels highlights the need for periodic monitoring and further investigation of potential contamination sources.

Overall, the results indicate that Bhakhri Pond continues to support freshwater ecological functions; however, elevated BOD, COD, iron, and chromium concentrations point towards emerging environmental pressures. These findings emphasize the importance of regular water quality monitoring, pollution control measures, and sustainable management practices to maintain the ecological integrity and long-term sustainability of pond ecosystems in Madhepura District.

3.1. Comparison with BIS and WHO Standards

The observed physicochemical parameters of Bhakhri Pond were compared with the recommended limits prescribed by the Bureau of Indian Standards (BIS, 2012) and the World Health Organization (WHO, 2022) to evaluate the overall water quality status. The comparison revealed that most of the analyzed parameters, including Total Dissolved Solids (TDS), chloride, sulphate, nitrate, fluoride, total hardness, and alkalinity, remained within the acceptable limits recommended for freshwater environments.

The pH value of 8.56 indicated slightly alkaline conditions and was found to be close to the upper permissible limit. Such alkaline conditions are commonly observed in freshwater ecosystems receiving nutrient-rich inputs and generally do not pose immediate threats to aquatic life (Boyd, 2015). Similarly, the dissolved oxygen concentration of 5.3 mg/L was within the range considered suitable for the survival and growth of aquatic organisms (Kannel *et al*., 2007).

However, certain parameters exhibited values exceeding recommended standards. The Biological Oxygen Demand (BOD) value of 14 mg/L was considerably higher than the desirable level for healthy freshwater ecosystems, indicating substantial organic pollution. Elevated BOD levels reflect increased microbial activity associated with the decomposition of organic matter and suggest the presence of biodegradable pollutants within the pond environment (Tyagi *et al*., 2020).

The Chemical Oxygen Demand (COD) value of 60 mg/L was also significantly higher than values generally associated with unpolluted freshwater systems. High COD concentrations indicate the presence of oxidizable organic and inorganic substances and serve as an important indicator of environmental stress caused by pollution (APHA, 2023).

Heavy metal analysis revealed that iron (4.66 mg/L) and chromium (0.13 mg/L) concentrations exceeded the recommended limits. The elevated iron concentration may be influenced by natural geological conditions of the region, whereas the presence of chromium suggests possible anthropogenic contamination. Excessive concentrations of these metals may adversely affect aquatic organisms and contribute to long-term ecological degradation if not properly monitored and managed (Ali *et al*., 2024; Zhang *et al*., 2021).

Overall, the comparison with BIS and WHO standards indicates that although the pond maintains several characteristics of a functional freshwater ecosystem, specific indicators such as BOD, COD, iron, and chromium reflect environmental pressures that require immediate attention from environmental managers and local stakeholders.

3.2. Environmental and Ecological Implications

The physicochemical characteristics observed in Bhakhri Pond provide valuable information regarding the ecological health and environmental sustainability of the freshwater ecosystem. Water quality parameters directly influence the structure, function, and productivity of aquatic environments. Therefore, any significant deviation from acceptable limits may have implications for aquatic biodiversity, fisheries, and overall ecosystem stability (Wetzel, 2001; Chapman, 1996).

The dissolved oxygen concentration recorded in the present study indicates that the pond is currently capable of supporting aquatic life. Adequate oxygen availability is essential for respiration, growth, reproduction, and survival of fish, plankton, and other aquatic organisms (Kannel *et al*., 2007). However, the simultaneously elevated Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values suggest increasing organic enrichment within the pond ecosystem. Such conditions may gradually reduce oxygen availability through intensified microbial decomposition processes, particularly during warmer months when oxygen solubility naturally declines (Tyagi *et al*., 2020; Boyd, 2015).

Organic pollution can significantly alter ecological processes by affecting nutrient cycling, biological productivity, and species composition. Continuous accumulation of organic matter may accelerate eutrophication, leading to excessive growth of algae and aquatic weeds. The decomposition of such biomass can further increase oxygen consumption, thereby creating stressful conditions for aquatic organisms and reducing overall ecosystem resilience (Chapman, 1996; Wetzel, 2001).

The moderate levels of hardness and alkalinity observed in the present investigation indicate favorable conditions for aquatic productivity and fish culture. These parameters contribute to nutrient availability and help maintain pH stability within the aquatic environment. Such conditions are generally considered beneficial for freshwater fisheries and support sustainable aquaculture activities when other pollution indicators remain under control (Boyd & Tucker, 2012; Boyd, 2015).

Heavy metal contamination represents one of the most significant environmental concerns associated with freshwater ecosystems. The elevated concentrations of iron and chromium observed in the pond may influence both water quality and biological communities. Although iron is an essential element for biological processes, excessive concentrations may alter sediment characteristics, affect aquatic habitats, and reduce water transparency. Chromium, on the other hand, is recognized as a potentially toxic heavy metal that may accumulate in aquatic organisms and sediments over time (Ali *et al*., 2024; Zhang *et al*., 2021).

Long-term exposure to elevated heavy metal concentrations may adversely affect fish health, reproductive success, growth performance, and species diversity. The possibility of bioaccumulation and biomagnification within aquatic food chains further increases ecological risks associated with heavy metal contamination (Zhang *et al*., 2021). Consequently, periodic monitoring of heavy metals is essential to safeguard ecosystem integrity and ensure the sustainable utilization of pond resources.

The findings of the present study indicate that Bhakhri Pond remains ecologically functional; however, signs of environmental stress associated with organic pollution and heavy metal enrichment are evident. Effective management interventions, including pollution control, periodic water quality monitoring, public awareness, and scientific conservation practices, are therefore necessary to preserve the ecological health of the pond and maintain its long-term sustainability (WHO, 2022; Tyagi *et al*., 2020).

4. Conclusion and Recommendations

Conclusion

The present study evaluated the physicochemical characteristics of water collected from Bhakhri Pond (Pond-5) in Madhepura District, Bihar, during the pre-monsoon season. The analysis revealed that the pond water exhibited moderately alkaline conditions with a pH value of 8.56 and contained moderate concentrations of dissolved solids and ionic constituents. The observed temperature, turbidity, total dissolved solids, electrical conductivity, hardness, alkalinity, chloride, sulphate, nitrate, and fluoride concentrations were found to be within acceptable environmental limits and indicated the overall suitability of the pond water for sustaining freshwater ecological functions (BIS, 2012; WHO, 2022).

Dissolved oxygen concentration remained at a level capable of supporting aquatic organisms; however, elevated Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values indicated the presence of substantial organic pollution within the pond ecosystem. These findings suggest increased microbial decomposition of organic matter and the influence of external pollutant inputs. The observed pollution load may adversely affect ecological stability if allowed to increase further over time (Kannel *et al*., 2007; Tyagi *et al*., 2020).

Heavy metal analysis revealed elevated concentrations of iron and chromium in the pond water. While the high iron concentration may be partially associated with the geological characteristics of the Kosi basin, the presence of chromium indicates potential anthropogenic influences that warrant further investigation. Long-term accumulation of heavy metals may pose ecological risks to aquatic organisms and affect the sustainability of freshwater resources (Ali *et al*., 2024; Zhang *et al*., 2021).

Overall, the study demonstrates that Bhakhri Pond continues to function as a productive freshwater ecosystem; however, emerging signs of organic pollution and heavy metal enrichment indicate the need for regular monitoring and scientific management. The findings provide valuable baseline information for environmental planning, freshwater conservation, and sustainable fisheries development in Madhepura District.

Recommendations

Based on the findings of the present investigation, the following recommendations are proposed for the sustainable management and conservation of pond ecosystems in the study area:

i). Regular monitoring of physicochemical and heavy metal parameters should be undertaken to assess temporal changes in water quality (APHA, 2023).

ii). Uncontrolled disposal of domestic waste, agricultural runoff, and other pollutant sources into pond ecosystems should be minimized through appropriate management measures.

iii). Community-based awareness programmes should be organized to promote environmental stewardship and responsible utilization of freshwater resources.

iv). Periodic assessment of sediment quality and heavy metal accumulation in aquatic organisms should be conducted to evaluate long-term ecological risks (Zhang *et al*., 2021).

v). Scientific management practices should be adopted to maintain optimal water quality conditions for fisheries and biodiversity conservation (Boyd & Tucker, 2012).

vi). Restoration and conservation programmes should be implemented to protect pond ecosystems from further degradation and ensure their ecological sustainability.

vii). Further investigations covering seasonal variations and multiple pond ecosystems of Madhepura District are recommended to develop a comprehensive understanding of freshwater environmental conditions in the region.

The implementation of these measures will contribute significantly to the conservation of freshwater ecosystems and support the sustainable utilization of pond resources in Madhepura District, Bihar.

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