Water Quality Assessment Based on Physico-Chemical Parameters of Pond and Surface Water in Chhapra

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Abstract: ***Water quality assessment is essential for evaluating the ecological condition of freshwater resources and their suitability for domestic and agricultural use. The present study investigates the physico-chemical characteristics of pond and surface water sources in Chhapra, Bihar, India. A total of 30 water samples, comprising pond water and surface water samples, were collected from representative locations and analysed using standard methods prescribed by the American Public Health Association. Key parameters such as pH, temperature, electrical conductivity, turbidity, total dissolved solids, total suspended solids, alkalinity, total hardness, chloride, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, nitrate, phosphate, sulphate, and fluoride were evaluated. The results indicated that pH values of both water sources were near neutral, suggesting chemically stable conditions. Surface water samples exhibited higher electrical conductivity, turbidity, nutrient levels, and dissolved solids, indicating greater influence of agricultural runoff and domestic discharges. In contrast, pond water showed relatively higher biochemical oxygen demand, reflecting accumulation of biodegradable organic matter under stagnant conditions. Elevated nutrient concentrations in surface water suggest a potential risk of eutrophication. Overall, the findings reveal significant spatial variations in water quality influenced by anthropogenic activities. The study emphasizes the necessity of regular monitoring, improved waste management, and sustainable water resource management strategies to safeguard freshwater bodies in the Chhapra region.***

Keywords: Physico-chemical evaluation, Total microbial count, Physico-chemical parameters, Water quality indicators & Water safety

1. Introduction

Water quality assessment is essential for understanding the ecological health of aquatic ecosystems and ensuring the safety of water used for drinking, domestic activities, and agriculture. Freshwater bodies such as ponds and surface water sources play a crucial role in rural and semi-urban regions, especially in states like Bihar, where a significant proportion of the population relies on natural water bodies for daily needs **(Bhatnagar *et al.,* 2023)**. However, rapid population growth, agricultural runoff, open defecation, sewage discharge, and improper waste disposal have increasingly degraded water bodies, altering their physico-chemical characteristics **(Kumari *et al.,* 2023)**.

Physico-chemical parameters such as pH, temperature, turbidity, dissolved oxygen (DO), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, nitrate, and phosphate serve as important indicators of water quality. Deviations in these parameters influence the biological productivity of water, reduce ecological stability, and accelerate the deterioration of aquatic ecosystems **(Sawyer *et al.,* 2003)**. Continuous monitoring of these variables provides valuable information on pollution sources and determines the suitability of water for domestic, agricultural, and environmental purposes **(APHA *et al.,* 2017).**

In **Chhapra**, stagnant pond water and surface water bodies are particularly vulnerable to contamination due to intensive agricultural practices, livestock activities, bathing, washing, and household waste discharge. The district is characterized by dense population, reliance on open water sources, and limited wastewater treatment infrastructure, which further contribute to the degradation of water quality **(Tamrakar *et al.,* 2022).** Irregular monitoring and unmanaged anthropogenic activities pose serious challenges to the sustainability of local water resources.

The present study aims to assess the physico-chemical characteristics of pond and surface water samples collected from **Chhapra, Bihar, India**. The findings of this study will help determine the suitability of these water resources for domestic and agricultural use and provide a scientific basis for sustainable water management and environmental protection strategies in the region.

2. Materials and Methods

2.1 Sampling Design & Sample Collection

Water samples were collected from two representative sites in Chhapra, Bihar, India, including pond water (lentic) and surface water sources (streams, drains, and reservoirs). Samples (1 L) were collected from a depth of 10–20 cm using clean, pre-rinsed glass bottles, with flowing waters sampled against the current. In-situ parameters (temperature, pH, EC, and DO) were measured using calibrated portable instruments, and GPS coordinates were recorded. Samples were preserved at 4 ± 2 °C, transported to the laboratory within 6 h, and analyzed within 24 h. Nutrient subsamples were filtered (0.45 µm), stored at 4 °C, and preserved as per APHA (2017) guidelines.

2.2 Reagents and instruments

Physico-chemical analyses utilized calibrated portable instruments for on-site measurements (digital pH meter, EC/TDS meter, DO meter, thermometer, turbidity meter/nephelometer; daily calibration with standard buffers/reference standards) and laboratory equipment (UV-Vis spectrophotometer, COD reflux apparatus, hotplate/muffle furnace, analytical balance, burettes). Analytical-grade reagents included $K_2Cr_2O_7$, H_2SO_4, Ag_2SO_4, ferrous ammonium sulphate, $Na_2S_2O_3$, EDTA (hardness), $AgNO_3$ (chloride), and nitrate/phosphate standards per APHA protocols **(Siddiqui *et al.,* 2025)**.

2.3 Physico-Chemical Evaluation

Physico-chemical parameters were analyzed per APHA (2017) standard methods: titrimetric for alkalinity, hardness, and chloride; spectrophotometry for phosphate, sulphate, nitrate, and fluoride **(Gupta *et al.* 2009)**; gravimetry for TDS and TSS; Jackson Turbidity Units for turbidity; and DO, BOD_5, COD for organic pollution levels. Trace metals (e.g., arsenic) were detected via hydride generation AAS. **(Nayar *et al.,* 2020).**

2.3.1 pH

pH was measured in situ using a calibrated portable digital pH meter (buffers: pH 4.0, 7.0, 9.2), with electrode rinsed in distilled water between readings. Stable values were recorded per APHA (2017).

2.3.2 Temperature

Temperature was measured at sampling sites using a calibrated digital thermometer immediately post-collection to minimize atmospheric effects **(Wetzel, 2001),** expressed in °C.

2.3.3 Electrical Conductivity (EC)

EC was measured in situ using a portable meter calibrated daily with standard potassium chloride (KCl) solution. The probe was immersed in samples, and stable readings were recorded in µS/cm per APHA (2017). EC reflects water's ability to conduct electricity due to dissolved ions **(Saod *et al.,* 2022)**.

2.3.4 Total Alkalinity

Alkalinity was determined titrimetrically per APHA (2017). A 100 mL sample was titrated with 0.02 N H_2SO_4 using phenolphthalein (P-alkalinity; pink endpoint) followed by methyl orange (M-alkalinity; yellow-to-orange), with values calculated as mg/L $CaCO_3$ **(Kaur *et al.,* 2023)**

2.3.5 Total Hardness

Total hardness was determined by EDTA titrimetry per APHA (2017). A 50 mL sample was buffered to pH 10 ± 0.1 with ammonia buffer, Eriochrome Black T added (wine-red color), and titrated with 0.01 M EDTA to blue endpoint **(Kar *et al.,* 2018)**. Hardness was calculated as mg/L $CaCO_3$.

2.3.6 Chloride

Chloride was determined by Mohr's argentometric titration per APHA (2017). A 20 mL sample received 1 mL potassium chromate indicator (yellow color) and was titrated with 0.01 N $AgNO_3$ to permanent reddish-brown endpoint (silver chromate formation). Concentration was calculated as mg/L **(Sawyer *et al.,* 2003).**

2.3.7 Phosphate (Molybdenum Blue)

Phosphate was determined by the molybdenum blue spectrophotometric method per APHA (2017). Filtered (0.45 µm) samples received ammonium molybdate, antimonyl potassium tartrate, and ascorbic acid to form phosphomolybdenum blue complex, reacted for 10 min, and measured at 880 nm using UV-Vis spectrophotometer **(Ahmad *et al.,* 2016)**. Concentrations were derived from a standard calibration curve.

2.3.8 Sulphate (Spectrophotometric)

Sulphate was determined by the spectrophotometric turbid metric method. Filtered samples received conditioning reagent, followed by $BaCl_2$ crystals to form barium sulphate precipitate (turbidity). After reaction time, absorbance was measured at 420 nm using UV-Vis spectrophotometer, with concentrations (mg/L) derived from a standard calibration curve **(Bhatta *et al.,* 2022).**

2.3.9 Nitrate (Phenol Disulphonic Acid Method)

Nitrate was determined by the phenol disulphonic acid (PDA) colorimetric method. Filtered samples were evaporated to dryness, treated with PDA reagent (yellow nitro-derivative formation), neutralized with concentrated ammonia (alkaline, deeper yellow), diluted, and measured at 410 nm using UV-Vis spectrophotometer. Concentrations (mg/L) were derived from a standard calibration curve.

2.3.10 Fluoride (SPADNS Method)

Fluoride was determined by the SPADNS colorimetric method per APHA (2017). Filtered samples were mixed with SPADNS reagent (color intensity reduction proportional to fluoride), and absorbance measured at 570 nm using UV-Vis spectrophotometer. Concentrations (mg/L) were derived from a standard calibration curve.

2.3.11 Total Dissolved Solids (TDS)

TDS was determined gravimetrically per APHA (2017). Filtered samples were evaporated to dryness in pre-weighed dishes on a water bath, dried at 103–105°C to constant weight, cooled in a desiccator, and reweighed. TDS (mg/L) was calculated as:

2.3.12 Total Suspended Solids (TSS)

TSS was determined gravimetrically per APHA (2017). Pre-weighed GF/C filters (dried at 103–105°C, cooled in desiccator) received well-shaken samples, which were filtered. Retained solids were dried at 103–105°C to constant weight, cooled, and reweighed. TSS (mg/L) was calculated as:

2.3.13 Turbidity

Turbidity was measured using the Jackson Candle Turbidimetric Method per APHA (2017). Samples were poured into a turbidity tube above the candle flame; level adjusted until flame disappeared from view, with values read in Jackson Turbidity Units (JTU) from the graduated scale (WHO, 2017). Digital meters used standard calibration, reported in NTU.

2.3.14 Dissolved Oxygen (DO)

DO was determined by the Winkler iodometric method per APHA (2017). A 300 mL BOD bottle sample (no air bubbles) received 2 mL each manganous sulphate and alkaline iodide–azide (brown $Mn(OH)_2$ precipitate), followed by 2 mL conc. H_2SO_4 to liberate iodine. An aliquot was titrated with 0.025 N $Na_2S_2O_3$ to pale straw, then starch indicator to colourless endpoint (Sarkar *et al.,* 2022). DO was calculated as mg/L.

2.3.15 Biochemical Oxygen Demand (BOD)

BOD_5 was determined by the 5-day incubation method per APHA (2017). Fresh samples (no air entrapment) had initial DO measure via Winkler titration (Day 0). BOD bottles were sealed, incubated in dark at 20°C for 5 days, then final DO measured (Day 5). BOD_5 (mg/L) was calculated as initial DO minus final DO, with dilution/seed corrections as applicable.

2.3.16 Chemical Oxygen Demand (COD)

COD was determined by the open reflux dichromate method per APHA (2017). A 20 mL sample received 10 mL 0.25 N $K_2Cr_2O_7$, refluxed with H_2SO_4–Ag_2SO_4 for 2 h, cooled, and excess dichromate titrated with 0.1 N ferrous ammonium sulphate (ferroin indicator; blue-green to reddish-brown endpoint). COD (mg/L) was calculated from blank-sample titration differences.

3. Result & Discussion

3.1 pH

The pH of pond water (7.67) and surface water (7.69) was found to be near neutral. This indicates chemically stable conditions favourable for aquatic organisms and suitability for domestic and agricultural use. Similar neutral pH ranges have been reported in freshwater bodies influenced by mixed natural and anthropogenic inputs.

3.2 Temperature

Pond water showed a slightly higher temperature (30 °C) compared to surface water (28 °C). Higher temperature in ponds may be attributed to stagnation and prolonged exposure to sunlight, which can enhance biological activity and organic matter decomposition.

3.3 Electrical Conductivity (EC)

Electrical conductivity was higher in surface water (928.66 ± 2.89µS/cm) than pond water (711.67 ± 12.58µS/cm), indicating a greater concentration of dissolved ions. Elevated EC values reflect the influence of agricultural runoff, domestic wastewater, and mineral dissolution.

3.4 Total Dissolved Solids (TDS)

Surface water exhibited higher TDS (473.30 ± 11.51 mg/L) compared to pond water (312.50 ± 17.50 mg/L). Increased TDS in surface water suggests enrichment with dissolved salts and inorganic matter from runoff and human activities, which may affect palatability and water usability.

3.5 Total Suspended Solids (TSS)

TSS values were slightly higher in surface water (73.40 ± 1.50 mg/L) than in pond water (66.71 ± 3.51 mg/L). High suspended solids indicate erosion, runoff, and resuspension of sediments, leading to reduced transparency and water quality degradation.

3.6 Turbidity

Surface water showed significantly higher turbidity (208.0 ± 4.0 JTU) compared to pond water (90.0 ± 2.0 JTU). Elevated turbidity in surface water is associated with suspended particles and runoff, which can reduce light penetration and impair aquatic productivity.

3.7 Alkalinity

Alkalinity was higher in surface water (314.40 ± 1.91 mg/L) than pond water (299.27 ± 2.00 mg/L), indicating a stronger buffering capacity. Increased alkalinity may result from bicarbonate and carbonate inputs through soil leaching and domestic discharges.

3.8 Total Hardness

Surface water showed greater hardness (169.48 ± 4.17 mg/L) compared to pond water (127.44 ± 3.05 mg/L). This reflects higher concentrations of calcium and magnesium ions, mainly derived from geological formations and anthropogenic sources.

3.9 Chloride

Chloride concentration was higher in surface water (72.98 ± 2.50 mg/L) than in pond water (64.65 ± 3.82 mg/L). Elevated chloride levels are often indicative of sewage intrusion, domestic waste, and agricultural runoff.

3.10 Dissolved Oxygen (DO)

Pond water exhibited higher DO (26.39 ± 2.30 mg/L) compared to surface water (21.94 ± 1.27 mg/L). Higher DO in ponds may be attributed to photosynthetic activity of algae, whereas lower DO in surface water may reflect higher organic load and oxygen consumption.

3.11 Biochemical Oxygen Demand (BOD)

BOD values were higher in pond water (47.57 ± 5.45 mg/L) than in surface water (52.15 ± 3.23 mg/L). Elevated BOD in pond water indicates greater biodegradable organic matter accumulation due to stagnant conditions.

3.12 Chemical Oxygen Demand (COD)

High COD values were observed in both pond (193.33 ± 4.62 mg/L) and surface water (186.66 ± 2.31 mg/L), suggesting the presence of oxidizable organic and inorganic pollutants. Such elevated COD values reflect significant pollution stress on water bodies.

3.13 Sulphate

Sulphate concentration was higher in surface water (63.42 ± 0.30 mg/L) compared to pond water (59.71 ± 0.36 mg/L), likely due to agricultural inputs and natural mineral dissolution.

3.14 Nitrate

Surface water showed higher nitrate levels (45.07 ± 0.33 mg/L) than pond water (38.09 ± 0.45 mg/L). This enrichment indicates fertilizer runoff and domestic waste inputs, increasing the risk of eutrophication (WHO, 2004).

3.15 Phosphate

Phosphate concentration was elevated in surface water (56.17 ± 0.31 mg/L) compared to pond water (49.57 ± 0.42 mg/L). High phosphate levels promote algal growth and may lead to eutrophic conditions if not controlled.

3.16 Fluoride

Fluoride concentrations in pond (50.44 ± 0.52 mg/L) and surface water (61.30 ± 0.50 mg/L) were within permissible limits, indicating no immediate fluoride-related health risk.

Table summarized below (table 1) presents the comparative physico-chemical characteristics of pond and surface water samples collected from Chhapra, Bihar. The results indicate noticeable variations between the two water sources, reflecting differences in hydrological conditions and anthropogenic influences. Surface water generally exhibited higher values of electrical conductivity, total dissolved solids, turbidity, alkalinity, hardness, nutrients (nitrate and phosphate), and sulphate, suggesting greater ionic load and nutrient enrichment due to surface runoff, domestic discharge, and agricultural activities. In contrast, pond water showed comparatively higher biochemical oxygen demand, indicating increased organic matter accumulation under stagnant conditions. Dissolved oxygen levels were higher in pond water, likely due to photosynthetic activity, while surface water recorded lower DO values, possibly resulting from higher pollution stress. The pH of both water sources remained near neutral, indicating relatively stable chemical conditions.

Table 1: Physico-chemical characteristics of pond and surface water samples from Chhapra, India

Sr. No.	Parameter	Test Method (APHA, 2017)	Pond Water (Mean ± SD)	Surface Water (Mean ± SD)
1	Alkalinity (mg/L)	Titrimetric (Acid–Base)	299.27 ± 2.00	314.40 ± 1.91
2	Chloride (mg/L)	Argentometric ($AgNO_3$ titration)	64.65 ± 3.82	72.98 ± 2.50
3	Biochemical Oxygen Demand (BOD_5) (mg/L)	5-Day Incubation (Winkler)	47.57 ± 5.45	52.15 ± 3.23
4	Chemical Oxygen Demand (COD) (mg/L)	Open Reflux Dichromate	193.33 ± 4.62	186.66 ± 2.31
5	Dissolved Oxygen (DO) (mg/L)	Winkler Iodometric Method	26.39 ± 2.30	21.94 ± 1.27
6	Sulphate (mg/L)	Turbid metric / Spectrophotometric	59.71 ± 0.36	63.42 ± 0.30
7	Phosphate (mg/L)	Ascorbic Acid (Molybdenum Blue)	49.57 ± 0.42	56.17 ± 0.31
8	Total Hardness (mg/L)	EDTA Titrimetric Method	127.44 ± 3.05	169.48 ± 4.17
9	Nitrate (mg/L)	Phenol Disulphonic Acid Method	38.09 ± 0.45	45.07 ± 0.33
10	Total Dissolved Solids (TDS) (mg/L)	Gravimetric Method	312.50 ± 17.50	473.30 ± 11.51
11	Total Suspended Solids (TSS) (mg/L)	Gravimetric (Filtration)	66.71 ± 3.51	73.40 ± 1.50
12	Fluoride (mg/L)	SPADNS Colorimetric Method	50.44 ± 0.52	61.30 ± 0.50
13	Turbidity (JTU)	Jackson Candle Method	90.0 ± 2.0	208.0 ± 4.0
14	Electrical Conductivity (µS/cm)	Conductivity Meter (In situ)	711.67 ± 12.58	928.66 ± 2.89
15	Temperature (°C)	Digital Thermometer (In situ)	30 °C	28 °C
16	pH	Digital pH Meter (In situ)	7.67	7.69

4. Discussion

The complex relationships between physicochemical parameters in the Indian freshwater habitats underscore their importance in sustaining the ecosystem and species diversity. The reviewed studies reveal the dramatic effects of anthropogenic impacts and climate change on water quality and aquatic organisms. The physico-chemical analysis revealed notable variations between pond and surface water samples from Chhapra, Bihar. The pH of both water sources remained near neutral, indicating suitability for most domestic and agricultural purposes, consistent with BIS and WHO guidelines (WHO, 2017; BIS, 2012). Higher electrical conductivity and TDS values in surface water suggest increased ionic content, likely due to runoff, domestic discharge, and anthropogenic inputs (Sawyer *et al.,* 2003).

Alkalinity and hardness were elevated in surface water compared to pond water, reflecting greater mineral dissolution and possible contamination from surrounding land use. Elevated BOD and COD values in both water types indicate significant organic pollution, with higher BOD in pond water suggesting stagnation and organic matter accumulation (APHA, 2017). Dissolved oxygen levels were comparatively higher in pond water, possibly due to algal photosynthesis and lower flow disturbance.

Nutrient concentrations such as nitrate and phosphate were higher in surface water, indicating nutrient enrichment from agricultural runoff and domestic waste, which may promote eutrophication. Turbidity and TSS were also substantially higher in surface water, reflecting suspended particulates and reduced water clarity.

5. Conclusions

The present study assessed the physico-chemical characteristics of pond and surface water sources in Chhapra, Bihar, to evaluate their overall water quality and environmental status. Freshwater ecosystems in India are vital

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for biodiversity, food production, and water supply, but they face significant threats from changing physicochemical properties. Research over the past decade highlights the negative impacts of fluctuations in pH and temperature remained within acceptable limits; however, elevated values of electrical conductivity, total dissolved solids, turbidity, alkalinity, hardness, nutrients (nitrate and phosphate), and oxygen demand were observed, particularly in surface water sources. These results indicate significant ionic enrichment, nutrient loading, and organic pollution arising from agricultural runoff, domestic wastewater discharge, and unmanaged human activities.

Pond water exhibited comparatively higher biochemical oxygen demand, suggesting accumulation of biodegradable organic matter under stagnant conditions, whereas surface water showed greater mineral and nutrient enrichment. Although dissolved oxygen levels were sufficient to support aquatic life, the overall water quality indicates increasing pollution stress on these freshwater bodies. Based on the observed parameters, the studied water sources may not be suitable for direct consumption without proper treatment but can be used for agricultural purposes with caution.

The study highlights the urgent need for regular monitoring, improved waste management practices, and implementation of effective water treatment and conservation strategies to protect pond and surface water resources in Chhapra, Bihar. Sustainable management of these water bodies is essential to safeguard public health and maintain ecological balance in the region.

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