RESEARCH PAPER

Physicochemical Water-Quality Variability and Its Relevance to Environmental Monitoring of Indian Major Carp Aquaculture in Maihar, India

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Abstract
Water quality influences oxygen availability, nutrient cycling, and the capacity of pond ecosystems to support fish growth and survival. This study describes monthly variation in physicochemical water-quality parameters at five sites (A–E) at Pondi Fish Farm, Maihar, Madhya Pradesh, using records covering the three-year monitoring period described in the study materials. The recorded variables included temperature, transparency, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), alkalinity, hardness, conductivity, free carbon dioxide, chloride, nitrate, phosphate, and other indicators. The tabulated observations show a marked seasonal temperature cycle: values were generally highest in late spring and early summer and lowest in winter. Transparency also changed over the annual cycle, while pH and oxygen-related variables varied by site and month. Site E displayed a distinct profile for several parameters, suggesting that spatial heterogeneity should be considered in pond monitoring and management rather than assuming uniform conditions throughout the farm. The analysis is descriptive because the available records do not specify the number of independent replicates, the sampling time of day, or the statistical basis of the reported means and dispersion values. These findings provide a preliminary environmental baseline for future studies that combine water-quality monitoring with verified fish-growth, age-class, and tissue-metal data.

Keywords: pond aquaculture; seasonal variation; physicochemical parameters; dissolved oxygen; nutrient dynamics; Indian major carps; Maihar

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1. Introduction

Freshwater aquaculture depends on the interaction of physical, chemical, and biological processes within culture ponds. Temperature affects fish metabolism, feeding activity, and oxygen solubility, whereas dissolved oxygen is essential for aerobic metabolism. pH, alkalinity, and hardness influence buffering capacity and can affect the chemical behaviour of nutrients and contaminants. Nitrogen and phosphorus support primary production; however, excessive nutrient inputs can promote algal growth and increase the decomposition of organic matter, potentially intensifying daily fluctuations in dissolved oxygen and placing cultured fish under stress (Boyd, 1990; Boyd & Tucker, 1998; Wetzel, 2001).

Pond environments should not be assumed to be chemically uniform. Differences in depth, water exchange, sediment properties, feed inputs, algal communities, and organic loading may produce spatial gradients in water quality. Seasonal weather can modify these gradients through changes in temperature, rainfall, dilution, mixing, and biological productivity. Routine monitoring is therefore most informative when repeated observations are interpreted by site and season and considered alongside biological measurements, rather than being reduced to a single annual average (APHA et al., 2017; Chapman, 1996).

Water chemistry is also relevant to investigations of heavy-metal exposure in Indian major carps. Factors such as pH, hardness, dissolved organic matter, and redox conditions can influence metal speciation and bioavailability. Sediments may act as contaminant reservoirs and can release metals when environmental conditions change. Nevertheless, conventional physicochemical measurements cannot substitute for direct analyses of metals such as cadmium (Cd), lead (Pb), chromium (Cr), mercury (Hg), and arsenic (As). Water-quality records can establish environmental context, but they cannot independently demonstrate metal contamination or a metal-associated effect on fish growth.

This study characterises the monthly and site-specific patterns recorded at Pondi Fish Farm during 2023–2025. Its objectives are to describe the seasonal range of the measured water-quality variables, identify contrasts among the five monitoring sites, and establish how the observations may inform a future integrated assessment of carp growth and environmental exposure.

2. Materials and Methods

2.1 Study area and monitoring design

The monitoring records identify five sampling locations, designated Sites A–E, at Pondi Fish Farm in the Maihar region of Madhya Pradesh, India. The records indicate monthly water sampling from January 2023 to December 2025. However, the information available for manuscript preparation does not specify the exact coordinates, dimensions of the ponds or sampling areas, sampling

depth, individual collection dates, time of day, or number of independent replicates.

2.2 Water-quality measurements

The recorded variables included temperature, transparency, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), alkalinity, hardness, electrical conductivity, free carbon dioxide, chloride, nitrate, phosphate, and additional indicators listed in the monitoring sheets. According to the accompanying method notes, temperature, pH, transparency, and DO were measured in the field, while other chemical parameters were analysed in the laboratory. The described procedures included thermometer readings, Secchi-disc measurements of transparency, a calibrated pH meter, titrimetric determination of DO, EDTA titration for hardness, acid titration for alkalinity, and colorimetric or titrimetric procedures for selected nutrients and ions. The precise protocols, instrument models, calibration procedures, and analytical quality-control measures should be confirmed before submission.

2.3 Data handling and analysis

Monthly mean values and their associated dispersion terms were transcribed from the monitoring tables. Seasonal patterns were assessed descriptively by comparing monthly observations and site-specific ranges. Because the number and structure of replicates and the meaning of the reported ± values were not documented fully, no inferential tests, confidence intervals, or claims of statistical significance were generated. The ranges presented in Table 5 represent the minimum and maximum of the tabulated monthly central estimates; they are not regulatory limits and should not be interpreted as estimates of uncertainty.

2.4 Data-quality and interpretation boundaries

The available records do not provide measured concentrations of Cd, Pb, Cr, Hg, or As in water or sediment from Pondi Fish Farm. A separate table in the working materials cites concentrations reported for another lake or pond; those values have not been treated as observations from the present study site. Accordingly, the physicochemical data alone do not support causal conclusions about fish growth or heavy-metal toxicity.

3. Results and Discussion

3.1 Seasonal variation in reported carp-sample metal concentrations

The seasonal table reports concentrations of Pb, Cd, Cr, and Hg (ppm, on a dry-weight basis) for Rohu (Labeo rohita) and Catla (Catla catla) across the pre-monsoon, monsoon, post-monsoon, and winter seasons. In the displayed data, Rohu had its highest reported values for all four metals during the monsoon: Pb, 4.32 ± 1.56 ppm; Cd, 1.63 ± 0.13 ppm; Cr, 1.01 ± 0.09 ppm; and Hg, 0.72 ± 0.08 ppm. Catla also had its highest reported Cd (1.32 ± 0.61 ppm), Cr (0.82 ± 0.17 ppm), and Hg (0.69 ± 0.06 ppm) values during the monsoon; its reported Pb value was also highest in that season (1.62 ± 0.99 ppm). These entries indicate seasonal differences in the values presented, but they do not identify the processes responsible for those differences. Before these results are interpreted, the authors should verify the tissue analysed, sample preparation, analytical method, units, quality-control results, and replicate structure.

Species	Season	Pb (ppm, dry wt.)	Cd (ppm, dry wt.)	Cr (ppm, dry wt.)	Hg (ppm, dry wt.)
Rohu (Labeo rohita)	Pm	1.92 ± 0.21	1.02 ± 0.10	0.82 ± 0.07	0.61 ± 0.05
Rohu (Labeo rohita)	M	4.32 ± 1.56	1.63 ± 0.13	1.01 ± 0.09	0.72 ± 0.08
Rohu (Labeo rohita)	PoM	2.04 ± 0.99	1.28 ± 0.11	0.91 ± 0.05	0.68 ± 0.06
Rohu (Labeo rohita)	W	2.00 ± 0.99	1.14 ± 0.12	0.89 ± 0.06	0.65 ± 0.04
Catla (Catla catla)	Pm	1.01 ± 0.93	0.93 ± 0.08	0.68 ± 0.06	0.32 ± 0.02
Catla (Catla catla)	M	1.62 ± 0.99	1.32 ± 0.61	0.82 ± 0.17	0.69 ± 0.06
Catla (Catla catla)	PoM	1.13 ± 0.96	1.01 ± 0.08	0.71 ± 0.06	0.64 ± 0.05
Catla (Catla catla)	W	1.02 ± 0.11	1.00 ± 0.09	0.70 ± 0.08	0.52 ± 0.04

Table 1. Seasonal concentrations of Pb, Cd, Cr, and Hg reported for carp samples. The units and dry-weight basis are reproduced from the source table; the tissue analysed and replicate structure require verification.

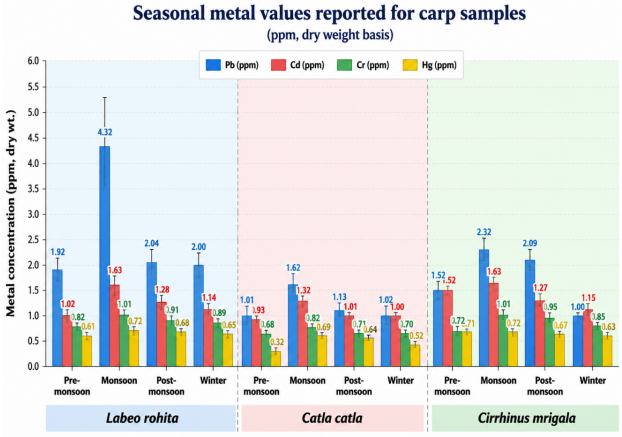


Fig. 1: Seasonal metal values reported for carp samples

3.2 Seasonal temperature pattern

The monthly temperature records show a clear seasonal cycle across the five sites. Temperatures increased from winter into spring, reached their highest reported levels around May–June, and declined during the monsoon and post-monsoon period. June values were generally in the mid-30 °C range, whereas January values were approximately 13–14 °C. This pattern is consistent with the pronounced seasonal climate of inland central India. As water warms, fish metabolic demand may increase while oxygen solubility decreases; therefore, high-temperature periods warrant concurrent monitoring of predawn DO, feeding response, and fish behaviour. Temperature alone, however, is insufficient to determine whether pond conditions are unsuitable, because its effects depend on species, acclimation, oxygen availability, and exposure duration.

Table 2. Monthly water temperature (°C) recorded at the five monitoring sites.

Month	Site A	Site B	Site C	Site D	Site E
January	13.2 ± 0.8	13.4 ± 0.7	13.8 ± 0.9	13.3 ± 0.8	13.5 ± 0.7
February	17.1 ± 1.1	17.3 ± 1.0	17.9 ± 1.2	18.3 ± 1.1	19.6 ± 1.0
March	22.9 ± 1.4	21.5 ± 1.2	22.4 ± 1.5	23.5 ± 1.4	23.4 ± 1.2
April	30.2 ± 1.8	29.7 ± 1.6	30.6 ± 1.8	30.4 ± 1.7	30.0 ± 1.5
May	32.4 ± 1.5	32.9 ± 1.7	32.1 ± 1.6	32.4 ± 1.5	32.0 ± 1.4
June	34.5 ± 2.1	34.9 ± 1.9	34.6 ± 2.0	34.8 ± 2.2	33.5 ± 1.8
July	30.3 ± 1.6	30.7 ± 1.5	30.6 ± 1.8	31.0 ± 1.6	30.5 ± 1.5
August	30.2 ± 1.2	30.0 ± 1.1	30.1 ± 1.3	30.9 ± 1.2	30.5 ± 1.2
September	26.1 ± 1.0	26.8 ± 1.2	27.1 ± 1.1	27.3 ± 1.3	26.5 ± 1.1
October	23.3 ± 0.9	23.6 ± 0.8	23.2 ± 0.9	23.3 ± 1.0	23.5 ± 0.9
November	19.2 ± 0.8	19.4 ± 0.7	19.8 ± 0.9	19.0 ± 0.8	19.5 ± 0.8
December	16.4 ± 0.6	16.4 ± 0.5	16.8 ± 0.7	16.2 ± 0.6	16.0 ± 0.6

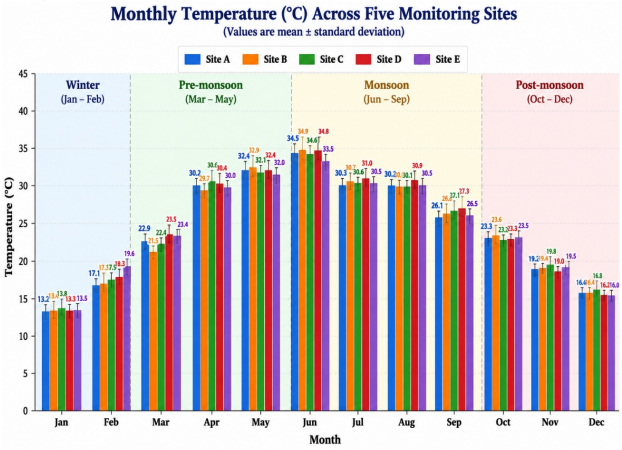


Fig. 2: Monthly Temperature (^{0}C) Across Five Monitoring Sites

3.3 Transparency and suspended material

Transparency varied over the annual cycle. Lower values were recorded in some warm-season months, while higher values occurred during selected winter and pre-monsoon observations. Secchi-disc transparency reflects the combined effects of suspended mineral particles, detritus, and phytoplankton; unless the method is explicitly defined, it should not be treated as a direct measurement of turbidity. Low transparency may be associated with high algal biomass or elevated suspended solids, whereas unusually high transparency may indicate low plankton biomass. Interpretation would be strengthened by concurrent measurements of chlorophyll or plankton abundance, suspended solids, and nutrient concentrations.

Table 3. Monthly transparency values for the five sites, with units reproduced as recorded in the monitoring table.

Month	Site A	Site B	Site C	Site D	Site E
January	0.72 ± 0.04	0.70 ± 0.03	0.69 ± 0.04	0.74 ± 0.03	0.75 ± 0.03
February	0.67 ± 0.05	0.66 ± 0.04	0.64 ± 0.05	0.68 ± 0.04	0.69 ± 0.04
March	0.83 ± 0.06	0.84 ± 0.05	0.82 ± 0.06	0.86 ± 0.05	0.88 ± 0.05
April	0.93 ± 0.05	0.91 ± 0.04	0.90 ± 0.05	0.92 ± 0.04	0.93 ± 0.04
May	0.88 ± 0.04	0.86 ± 0.03	0.87 ± 0.04	0.88 ± 0.03	0.90 ± 0.03
June	0.70 ± 0.03	0.69 ± 0.03	0.66 ± 0.04	0.72 ± 0.03	0.74 ± 0.03
July	0.50 ± 0.02	0.51 ± 0.02	0.49 ± 0.03	0.53 ± 0.02	0.54 ± 0.02
August	0.45 ± 0.02	0.45 ± 0.02	0.44 ± 0.02	0.46 ± 0.02	0.48 ± 0.02
September	0.67 ± 0.03	0.66 ± 0.03	0.63 ± 0.04	0.68 ± 0.03	0.70 ± 0.03
October	0.59 ±	0.68 ±	0.67 ±	0.71 ±	0.73 ±

	0.03	0.04	0.05	0.04	0.04
November	0.75 ± 0.04	0.74 ± 0.04	0.73 ± 0.04	0.75 ± 0.04	0.77 ± 0.03
December	0.83 ± 0.05	0.83 ± 0.05	0.82 ± 0.04	0.85 ± 0.04	0.87 ± 0.04

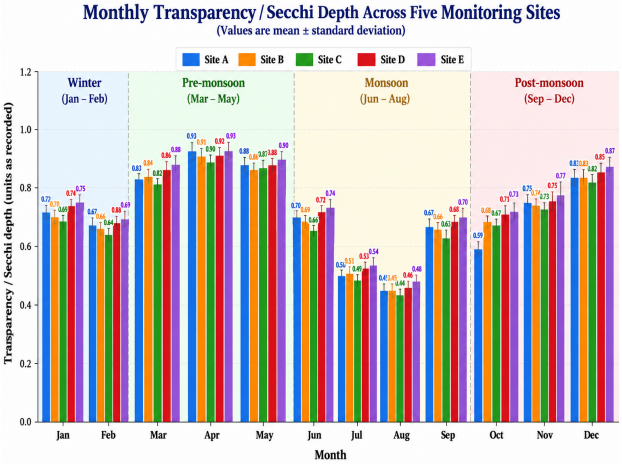


Fig. 3: Monthly Transparency/Secchi Depth Across Five Monitoring Sites

3.4 pH and buffering context

The tabulated pH values at Sites A–D generally increased from mildly acidic or near-neutral conditions in winter to neutral or mildly alkaline conditions in late spring and early summer. Site E showed a comparatively narrower and lower range in the displayed series. In productive ponds, pH may vary over a 24-hour period because photosynthesis removes carbon dioxide during daylight, whereas respiration releases it at night. The sampling time is therefore important when interpreting pH differences. Instrument-calibration records and sampling timestamps should be checked before the values are used for firm comparisons among sites.

Table 4. Monthly pH values recorded at the five monitoring sites.

Month	Site A	Site B	Site C	Site D	Site E
January	6.5 ± 0.2	6.4 ± 0.1	6.6 ± 0.2	6.5 ± 0.2	7.0 ± 0.1
February	6.4 ± 0.1	6.5 ± 0.2	6.7 ± 0.2	6.6 ± 0.1	7.1 ± 0.1
March	6.8 ± 0.2	7.1 ± 0.2	7.2 ± 0.3	7.0 ± 0.2	7.1 ± 0.2
April	7.5 ± 0.3	7.7 ± 0.3	7.8 ± 0.2	7.7 ± 0.3	7.3 ± 0.2
May	7.8 ± 0.2	8.0 ± 0.3	8.1 ± 0.3	7.9 ± 0.2	7.4 ± 0.2
June	8.0 ± 0.3	8.1 ± 0.2	8.4 ± 0.2	8.2 ± 0.3	7.4 ± 0.2
July	7.7 ± 0.2	7.6 ± 0.2	8.0 ± 0.3	7.9 ± 0.2	7.3 ± 0.1
August	7.6 ±	7.5 ±	7.8 ±	7.7 ±	7.2 ±

	0.2	0.2	0.2	0.3	0.1
September	7.4 ± 0.2	7.5 ± 0.1	7.4 ± 0.2	7.5 ± 0.1	7.2 ± 0.1
October	7.3 ± 0.1	7.1 ± 0.2	7.3 ± 0.1	7.2 ± 0.2	7.1 ± 0.1
November	7.1 ± 0.2	7.2 ± 0.1	7.3 ± 0.2	7.0 ± 0.1	7.2 ± 0.1
December	6.9 ± 0.1	6.8 ± 0.2	7.1 ± 0.2	7.0 ± 0.1	7.1 ± 0.1

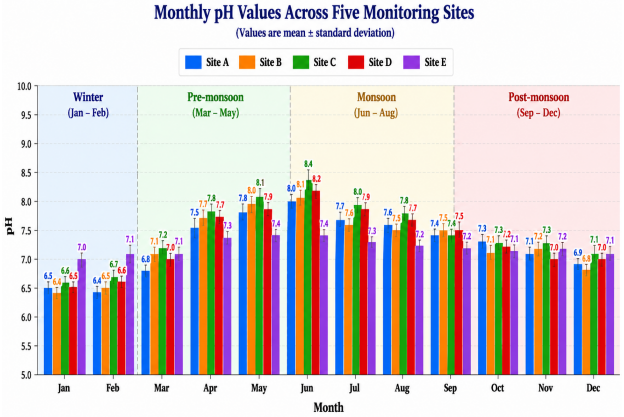


Fig. 4: Monthly pH Values Across Five Monitoring Sites A–E

3.5 Variation in oxygen-related and nutrient indicators

The monthly records for DO, BOD, alkalinity, hardness, chloride, and nutrient indicators show variation among sites and across the year rather than one uniform pattern. DO responds to temperature, photosynthesis, respiration, water mixing, and organic-matter decomposition. BOD reflects oxygen consumption associated with biodegradable material and must be interpreted in light of the incubation duration and temperature used in the assay. The method notes describe a three-day incubation at 27 °C; this procedure is not equivalent to the conventional five-day BOD method. The parameter should therefore be labelled according to the method actually used, and the protocol should be reported clearly.

Table 5. Observed monthly ranges of selected water-quality indicators across the five sites. Values are ranges of monthly central estimates; units follow the original parameter tables and require confirmation.

Parameter	Site A (mg/L)	Site B (mg/L)	Site C (mg/L)	Site D (mg/L)	Site E (mg/L)
Dissolved oxygen	3.9–8.6	3.9–8.6	4.3–8.8	4.1–8.7	6.5–8.8
Biochemical oxygen demand	6.9–9.7	5.3–7.2	7.7–10.5	5.9–8.6	3.9–6.2
Total alkalinity	69–91	68–89	69–90	73–110	82–115
Total	167–	167–	172–	140–	143–

hardness	240	245	241	240	230
Total dissolved solids	454–910	453–920	446–908	447–907	385–575
Chloride	30.9–81.1	32.5–83.4	34.7–89.8	33.2–87.6	16.4–36.4
Sodium	6.1–74.6	4.9–72	6.9–75.4	7.3–76.9	8.3–32.2
Potassium	1.38–3.23	1.39–3.39	1.48–3.65	1.36–3.56	1.19–2.33
Reactive silicate	14.3–19.9	14.6–19.9	15.2–20.6	14–19.7	12.6–15.9
Nitrate	0.21–2.94	0.24–3.31	0.25–3.42	0.29–3.37	0.15–1.31
Phosphate	0.07–1.87	0.07–1.94	0.11–2.01	0.16–2.02	0.04–0.83

3.6 Relevance to heavy-metal exposure and carp growth

These physicochemical observations may serve as environmental covariates in a broader investigation of metal exposure and carp growth because pH, hardness, alkalinity, and dissolved organic matter can influence metal bioavailability. However, the concentrations of individual metals in water, sediment, and fish tissue must be measured directly to establish exposure. Published research indicates that metal-related effects on fish growth and reproduction vary with the metal, concentration, exposure pathway, duration, and developmental stage. Such findings support the rationale for targeted sampling, but they cannot be interpreted as evidence of contamination at Pondi Fish Farm.

4. Conclusion

The monitoring records indicate pronounced seasonal variation in water temperature and variation in transparency, pH, and other physicochemical indicators across five sites at Pondi Fish Farm. The observed spatial differences suggest that monitoring and pond management should account for site-specific conditions and seasonal risk periods, particularly during warmer months when oxygen demand may increase. These findings provide environmental context for research involving Indian major carps, but they do not establish heavy-metal contamination at the study site or a causal relationship between metal exposure and fish growth.

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