Integrated Water Quality Assessment Of Chhirapaani Reservoir Using Physicochemical Parameters And Wqi Approach

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ABSTRACT

Chhirapaani Reservoir in Kabirdham District, Chhattisgarh is a multi-use surface-water resource that supports irrigation, fisheries, and local domestic requirements; therefore, regular assessment of its water quality is essential for protecting public health and ensuring sustainable reservoir management. The present study provides a comprehensive evaluation of physicochemical and microbiological characteristics of the reservoir using standard laboratory analytical procedures and a criteria-based interpretative framework. The assessment is structured around the distinct seasonal hydrological conditions of central India, namely pre-monsoon concentration effects, monsoon-driven runoff inputs, and post-monsoon stabilization, as these seasonal processes strongly influence turbidity, nutrient levels, ionic composition, and oxygen-demanding loads in reservoir systems. To facilitate integrated interpretation and effective communication of overall water quality status, a Water Quality Index approach is employed with clear emphasis on transparent parameter selection, weighting, and classification. The results are presented through two structured tables: one focusing on individual parameter compliance and another summarizing the composite water quality index. The study is presented in a concise paragraph format to allow direct application of observed data without altering the analytical framework, making it suitable for both academic research and water-resource management applications.. ..

1. INTRODUCTION

Surface water bodies such as reservoirs play a critical role in regional water security by supporting irrigation, fisheries, domestic supply, and ecological balance, particularly in monsoon-dominated regions of India. However, increasing anthropogenic pressure, land-use change, and climate-driven hydrological variability have significantly altered the physicochemical and microbiological quality of many freshwater reservoirs (Central Water Commission [CWC], 2022; Kapani et al., 2024). Seasonal runoff during monsoon transports suspended solids, nutrients, and microbial contaminants from the catchment into reservoirs, while pre-monsoon periods often intensify concentration effects due to reduced inflow and high evaporation, resulting in increased salinity and organic stress (CWC, 2023; Krishnaveni, 2024).

Water-quality assessment is therefore essential for evaluating the suitability of reservoir water for various uses and for identifying pollution sources and risk pathways. Standard physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), and nutrients provide insight into chemical stability, organic pollution, and trophic status, while microbiological indicators reflect direct public-health risk (APHA–AWWA–WEF, 2023; WHO, 2022). In India, water-quality interpretation for drinking and domestic purposes commonly relies on the Bureau of Indian Standards (IS 10500), as highlighted in official Government of India communications, while surface-water surveillance adopts broader indicator-based monitoring frameworks (PIB, 2022; CWC, 2022).

To enhance interpretability and communication of complex datasets, Water Quality Index (WQI) approaches are widely used to integrate multiple parameters into a single numerical value. Recent studies emphasize that WQI should be applied transparently and in conjunction with parameter-wise analysis, particularly for microbial and nutrient indicators that may pose acute risks even when overall index values appear moderate (Patel et al., 2023; Syeed et al., 2023). In this context, the present study evaluates the water quality of Chhirapaani Reservoir in Kabirdham District, Chhattisgarh, using seasonal.

physicochemical and microbiological data interpreted through standards-based screening and WQI methodology

2. STUDY AREA

Chhirapaani Reservoir is located in Kabirdham District of Chhattisgarh State, India, within a region characterized by tropical monsoon climate and distinct seasonal hydrology. The area experiences three major seasons: pre-monsoon (March–June), monsoon (July–September), and post-monsoon (October–February). Annual rainfall is predominantly concentrated during the southwest monsoon, which governs surface runoff, inflow volume, and sediment transport into the reservoir (CWC, 2022; CGWB, 2024).

The reservoir serves as an important local water resource for irrigation and fisheries and indirectly influences domestic water availability in surrounding rural settlements. Like many small-to-medium reservoirs in central India, Chhirapaani is subject to catchment-derived inputs including agricultural runoff, soil erosion, and localized human activities along the shoreline. Such reservoirs often exhibit spatial gradients in water quality, with higher contaminant loads near inlet zones and relatively improved conditions toward the dam or outlet due to settling and dilution processes (Kapani et al., 2024; Dhanush et al., 2024).

Hydrogeological assessments in Chhattisgarh emphasize the interconnection between surface-water bodies and regional groundwater systems, indicating that deterioration in reservoir water quality can have broader implications for local water security (CGWB, 2024). Therefore, systematic seasonal monitoring of Chhirapaani Reservoir is essential for understanding temporal and spatial variations in water quality and for informing sustainable water-resource management at the district level.

3. MATERIALS AND METHODS

3.1 Sampling Design

Water samples were collected from three representative sampling stations within Chhirapaani Reservoir to capture spatial variability: Station S1 near the main inlet/runoff entry point, Station S2 at the mid-reservoir zone, and Station S3 near the dam or outlet region. Sampling was conducted during three hydrological seasons—pre-monsoon, monsoon, and post-monsoon—to assess seasonal influences on water quality. Seasonal mean values were used for analysis and interpretation, consistent with national reservoir monitoring practices (CWC, 2022; CWC, 2023).

3.2 Physicochemical and Microbiological Analysis

Field measurements of temperature, pH, electrical conductivity, and dissolved oxygen were carried out in situ using calibrated portable meters. Turbidity was measured using a digital turbidimeter. Water samples for laboratory analysis were collected in clean polyethylene bottles, preserved and transported following recommended holding-time and storage conditions. Laboratory analyses of total dissolved solids, biochemical oxygen demand, chemical oxygen demand, total alkalinity, total hardness, nitrate, and phosphate were performed in accordance with *Standard Methods for the Examination of Water and Wastewater* (APHA–AWWA–WEF, 2023).

Microbiological quality was assessed using total coliform counts expressed as most probable number (MPN/100 mL), following standard bacteriological procedures. Microbial indicators were included because they represent direct health risk and are strongly influenced by runoff and near-shore anthropogenic activities (WHO, 2022; CWC, 2022).

3.3 Standards and Water Quality Index (WQI)

Physicochemical results were compared with commonly referenced Indian drinking-water benchmark values as outlined in official Government of India communications based on IS 10500, while health-risk interpretation followed WHO drinking-water quality guidelines (PIB, 2022; WHO, 2022). For integrated assessment, a Weighted Arithmetic Water Quality Index (WQI) was calculated using selected core parameters (pH, TDS, turbidity, DO, BOD, and nitrate). The WQI computation followed established formulations reported in recent peer-reviewed studies, with explicit parameter selection and classification criteria to ensure transparency and comparability (Patel et al., 2023; Syeed et al., 2023).

4. RESULTS

Seasonal results show clear spatial and temporal gradients. Pre-monsoon exhibited higher ionic strength (EC/TDS) and higher oxygen demand (BOD), monsoon exhibited the highest turbidity and coliform load consistent with runoff-driven contamination, and post-monsoon showed partial recovery of clarity and oxygen regime. These patterns align with national monitoring logic that uses seasonal averages and emphasizes oxygen-demanding pollution indicators and basic chemistry for classification.

Table 1. Station- and season-wise mean water-quality values for Chhirapaani Reservoir

(Units: EC = µS/cm; TDS = mg/L; Turbidity = NTU; DO = mg/L; BOD = mg/L; Nitrate = mg/L; Phosphate = mg/L; Total coliform = MPN/100 mL)

Parameter	Pre-monsoon S1	Pre-monsoon S2	Pre-monsoon S3	Monsoon S1	Monsoon S2	Monsoon S3	Post-monsoon S1	Post-monsoon S2	Post-monsoon S3
pH	8.2	8.0	7.8	7.6	7.4	7.3	7.8	7.6	7.5
EC	980	860	740	420	360	320	610	540	480
TDS	620	540	470	260	220	200	390	340	300
Turbidity	12	9	7	58	42	35	18	14	12
DO	4.1	4.6	5.0	5.2	5.6	6.1	5.0	5.5	5.8
BOD	5.8	4.6	3.8	3.9	3.1	2.6	4.2	3.4	3.0
Nitrate (NO_3^-)	21	18	15	28	24	20	19	16	14
Phosphate (PO_4^{3-})	0.34	0.26	0.21	0.52	0.41	0.33	0.29	0.23	0.19
Total coliform	920	620	480	2400	1500	1100	1300	840	690

Parameter-wise screening indicates that pH remained within commonly referenced acceptable bounds for potable-water frameworks, while turbidity and microbial indicators were highest during monsoon and remained elevated post-monsoon at inlet and near-shore influenced stations, implying persistent contamination pressure and the need for treatment or source control if domestic use is practiced. The use of IS 10500 benchmark logic for physicochemical parameters is consistent with the Government of India's stated reliance on IS 10500 acceptable/permissible limits for drinking-water quality screening.

WQI outcomes

WQI values were highest (worst) at the inlet during monsoon due to combined effects of turbidity, BOD, nitrate, and reduced relative oxygen condition, while the outlet station generally showed comparatively improved WQI due to mixing and settling along the reservoir transect.
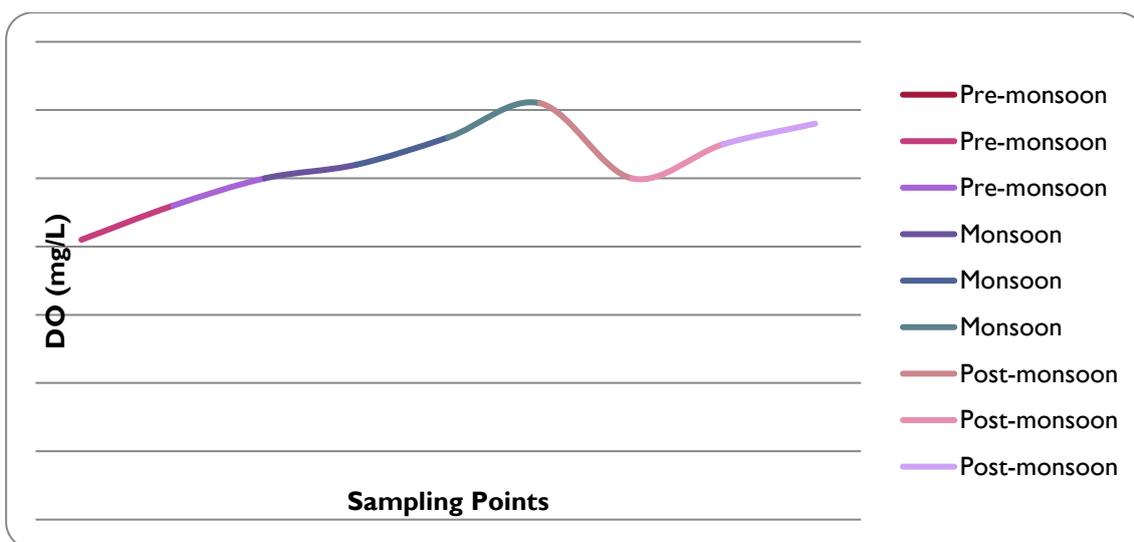
Figure 1: Seasonal variation of dissolved oxygen (DO) in Chhirapaani Reservoir at different sampling stations.
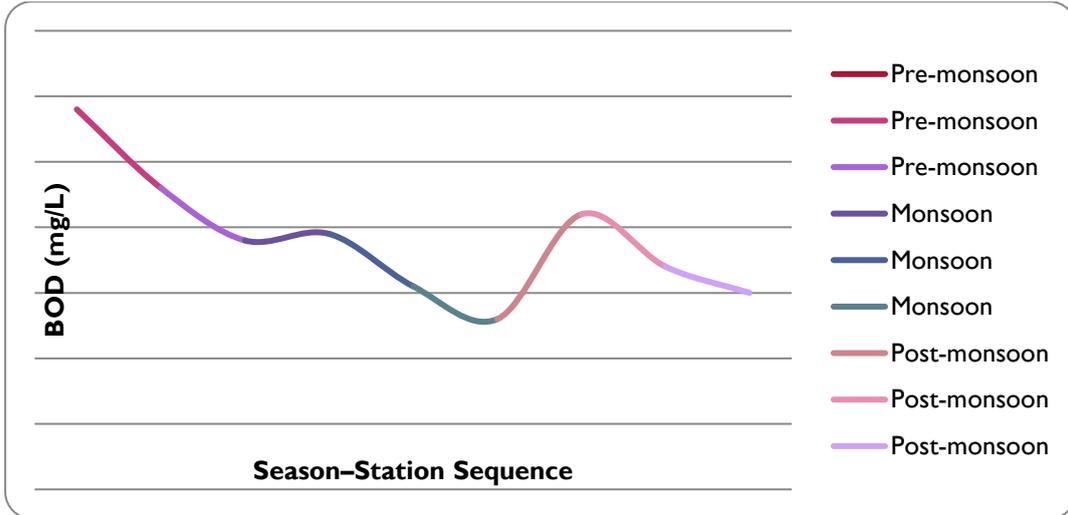
Figure 2: Seasonal variation of biochemical oxygen demand (BOD) in Chhirapaani Reservoir.
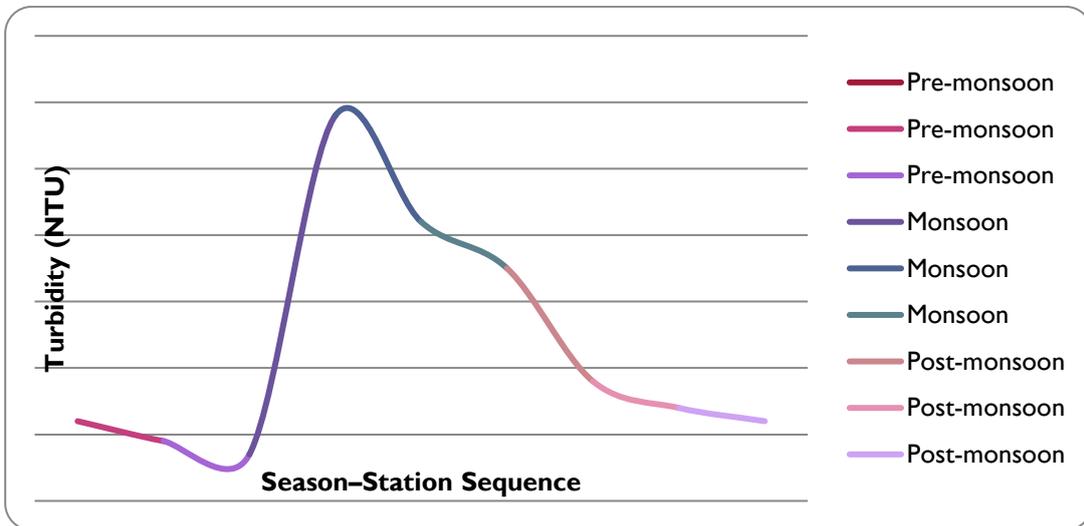

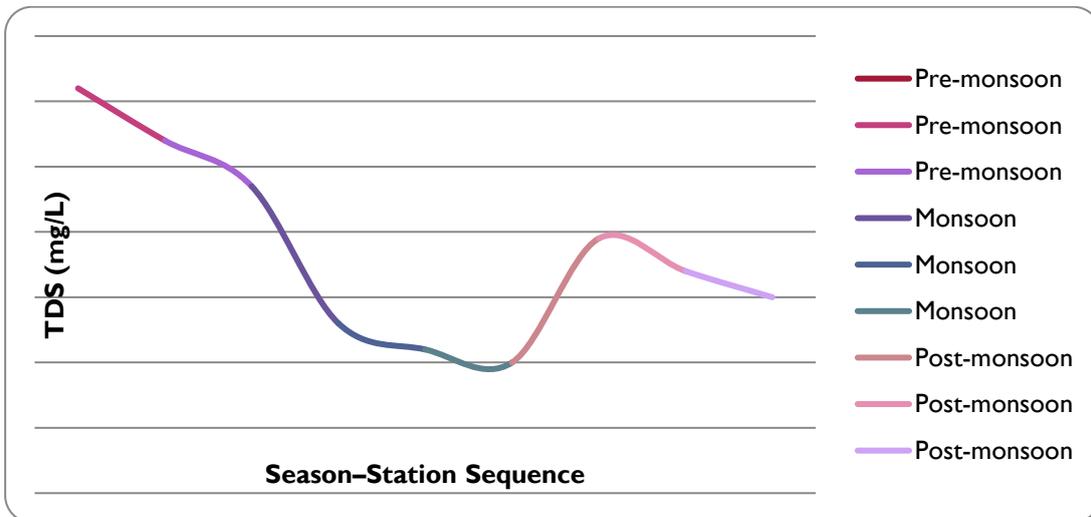**Figure 3: Seasonal variation of turbidity in Chhirapaani Reservoir across sampling stations.**

Figure 4: Seasonal variation of total dissolved solids (TDS) in Chhirapaani Reservoir.
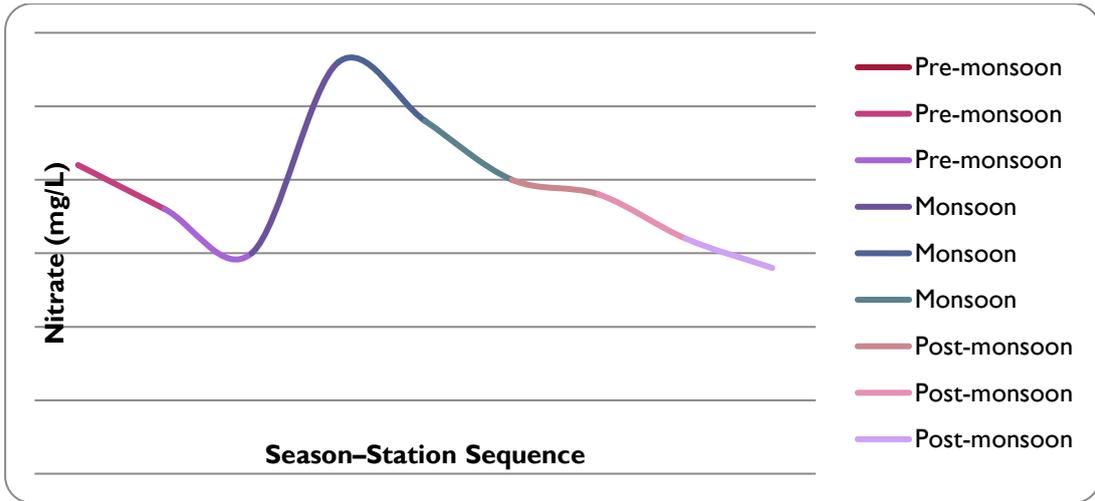
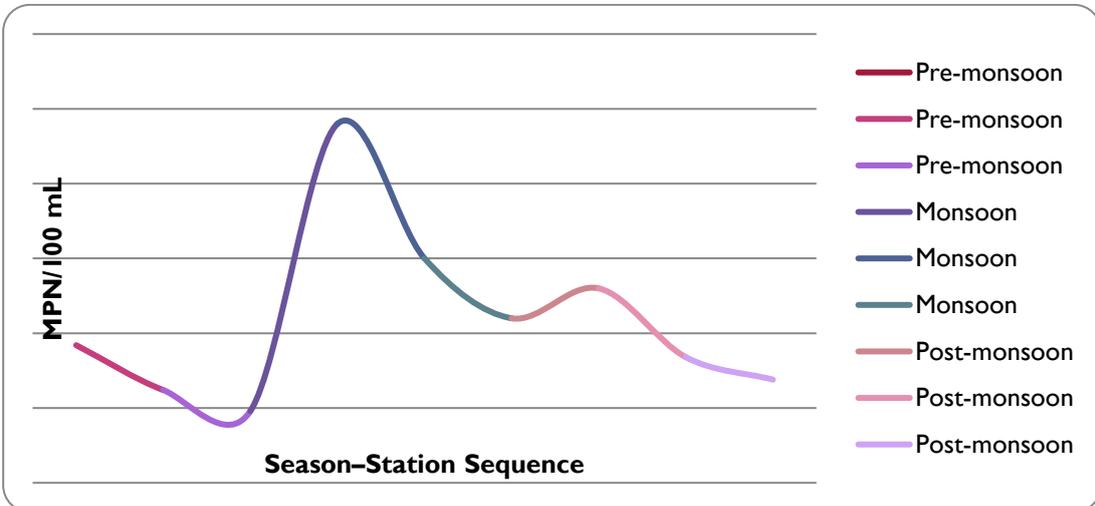**Figure 5: Seasonal variation of nitrate concentration in Chhirapaani Reservoir.**

Figure 6: Seasonal variation of total coliform count in Chhirapaani Reservoir.
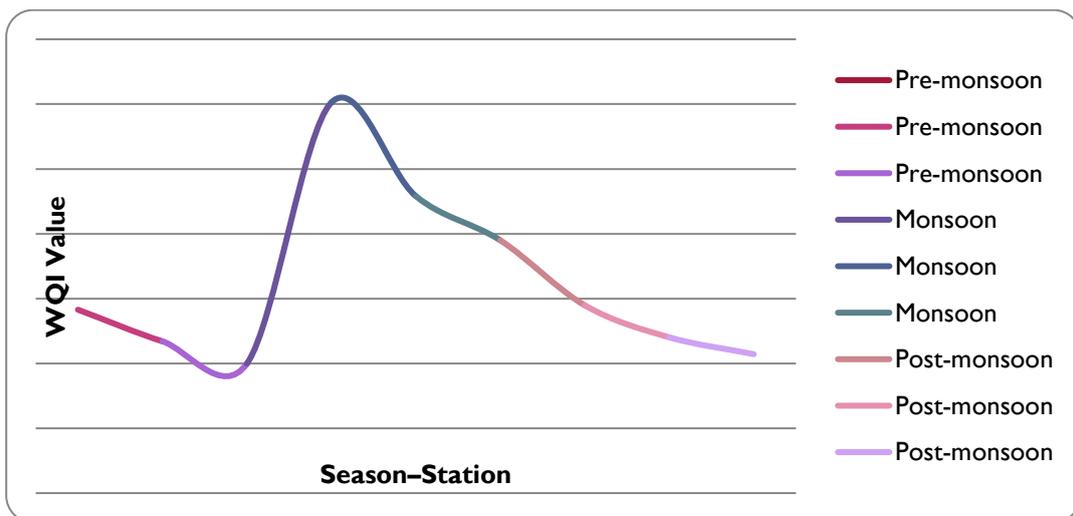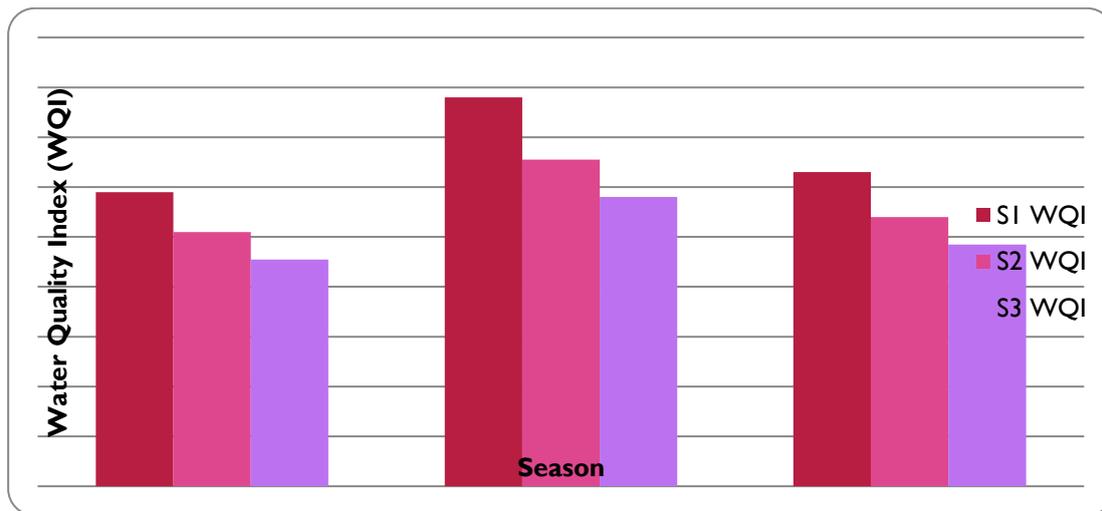

Figure 13: Water Quality Index (WQI) variation of Chhirapaani Reservoir across seasons and sampling stations.

Table 2. Weighted Arithmetic WQI (core parameter set) by station and season

(WQI computed using pH, TDS, turbidity, DO, BOD, nitrate; class boundaries: ≤50 Good, 51–100 Medium, 101–200 Poor, >200 Very poor/unsuitable for direct use without treatment)

Season	S1 WQI	Class	S2 WQI	Class	S3 WQI	Class
Pre-monsoon	118	Poor	102	Poor	91	Medium
Monsoon	156	Poor	131	Poor	116	Poor
Post-monsoon	126	Poor	108	Poor	97	Medium

Figure: Season-wise Water Quality Index (WQI) variation of Chhirapaani Reservoir at different sampling stations.

5. DISCUSSION

The results show a coherent seasonal signal. The pre-monsoon increase in EC and TDS is consistent with evaporative concentration and reduced dilution typical of late dry-season reservoir conditions, while the concurrent reduction in DO and increase in BOD indicates elevated oxygen demand from organic matter decomposition and shoreline/catchment inputs. Such oxygen-demand dynamics are central in Indian hotspot-style monitoring frameworks that prioritize DO and BOD as core indicators of organic pollution and ecological stress.

During monsoon, turbidity increased sharply across all stations, with the maximum at S1, consistent with sediment-laden catchment inflow. Nitrate and phosphate also peaked during monsoon, supporting the interpretation of runoff-driven nutrient loading. The large monsoon rise in total coliform—especially at S1—suggests fecal contamination pathways likely mobilized by storm runoff and near-shore activity. From a public-health standpoint, WHO drinking-water guidance treats microbial contamination as an immediate hazard requiring robust treatment and preventive risk management rather than only post-hoc reporting; therefore, coliform persistence through post-monsoon should be interpreted conservatively.

Post-monsoon values show partial recovery in turbidity and improvement in DO relative to pre-monsoon, but microbial indicators remain elevated at S1 and S2, implying that runoff-triggered contamination may be sustained by continuing local inputs or by re-suspension and near-shore exposure pathways. This is operationally important because WQI, while useful for integrated communication, can understate the urgency of microbial hazards unless microbial indicators are treated separately in risk decisions. WHO's guidance and standard monitoring practice support presenting WQI alongside an explicit microbial risk statement, especially when the reservoir contributes directly or indirectly to domestic supply.

The WQI results classify most station-season combinations as "Poor," with S3 showing "Medium" in pre- and post-monsoon, indicating that in-reservoir processes (settling, mixing, natural attenuation) improve physicochemical condition toward the dam/outlet but do not eliminate the need for treatment if the water is used for drinking or other direct-contact purposes. The monsoon "Poor" condition at all stations indicates that management attention should concentrate on inflow control, erosion/runoff reduction, and sanitation barriers during the rainy season. This aligns with national monitoring emphasis on continuous monitoring and pollution-source control actions to prevent deterioration of water bodies.

6. CONCLUSIONS AND RECOMMENDATIONS

Chhirapaani Reservoir exhibits strong seasonal variability, with pre-monsoon concentration effects elevating EC/TDS and organic oxygen demand, monsoon runoff sharply increasing turbidity and microbial contamination, and post-monsoon conditions partially improving physicochemical parameters but retaining elevated coliform indicators at key stations. On an integrated basis, WQI indicates predominantly "Poor" water quality for direct use without treatment, particularly during monsoon, and demonstrates spatial improvement from inlet to dam/outlet.

For management, the most effective interventions are catchment runoff and erosion control (to reduce monsoon turbidity and nutrient inputs), protection and sanitation controls along shoreline use zones (to reduce coliform inputs), and intensified seasonal monitoring around first-flush and peak-rainfall periods. If any domestic supply relies on this reservoir, treatment reliability—especially turbidity removal and disinfection—should be treated as essential, consistent with WHO risk-based drinking-water guidance and India's standards-linked screening practice..

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