The Biobrio
ISSN : 2393-9508
e-ISSN: 2582-4902
An International Quarterly Journal of Life Sciences
Website: www.thebiobrio.in SJIF:8.259

12(3&4): 1595-1600, 2025

Seasonal variation in physico-chemical characteristics of Latratu Dam, Jharkhand, India

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Received : 22nd October, 2025 ; Accepted : 22nd November, 2025

DOI:- https://doi.org/10.5281/zenodo.19606714

ABSTRACT

Seasonal variability plays a central role in regulating the physico-chemical characteristics and ecological functioning of freshwater reservoirs in tropical regions. The present study investigates temporal variation in key water quality parameters of Latratu Dam, Ranchi district, Jharkhand, over a one-year period (April 2023-March 2024). Monthly sampling was conducted at six ecologically distinct stations to capture both seasonal trends and gradual intra-annual transitions. Parameters including water temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), alkalinity, hardness, nitrate, and phosphate were analysed using standard methods. Water temperature followed a clear annual cycle, increasing from 18.2°C in winter to a peak of 31.5°C in June. Dissolved oxygen showed a progressive decline from 8.4 mg/L in winter to 5.1 mg/L in summer, indicating a substantial reduction in oxygen availability during warmer months. In contrast, BOD increased steadily from 2.4 mg/L in winter to 5.8 mg/L in summer, reflecting intensified microbial activity. Nutrient concentrations exhibited a delayed seasonal response, rising gradually during pre-monsoon months and reaching peak values during monsoon (nitrate: 1.6 mg/L; phosphate: 1.1 mg/L), suggesting strong catchment-driven inputs. The combined monthly and seasonal patterns reveal a continuous cycle of warming, oxygen depletion, and nutrient enrichment followed by partial recovery. The period from late spring to early summer represents a phase of heightened ecological stress marked by elevated temperature, increased organic load, and reduced oxygen availability. Monsoon-driven nutrient influx indicates potential enrichment risk, while winter conditions support relative stabilization of the system. These findings highlight the importance of high-resolution temporal monitoring for understanding reservoir dynamics and guiding sustainable management strategies.

Key Words - Seasonal variation, limnology, water quality, freshwater reservoir, Latratu Dam

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INTRODUCTION

Freshwater ecosystems in tropical regions are inherently dynamic, with seasonal variability acting as a primary driver of their physical, chemical, and biological characteristics. Fluctuations in temperature, precipitation, and evaporation across the year influence water chemistry, nutrient cycling, and primary productivity, thereby shaping the overall ecological functioning of reservoirs (Wetzel, 2001; Chapman, 1996). These seasonal forces operate at multiple scales, affecting not only surface conditions but also internal processes such as stratification, decomposition, and oxygen distribution.

In the Indian subcontinent, where monsoonal climate patterns dominate, freshwater bodies experience three distinct seasonal phases that impose contrasting environmental conditions. During summer, elevated temperatures and reduced water levels lead to concentration of dissolved ions and increased metabolic activity, often resulting in higher biochemical oxygen demand and reduced dissolved oxygen availability (Mishra *et al.*, 2020). The monsoon season introduces substantial hydrological inputs through surface runoff, which carries nutrients, sediments, and organic matter from surrounding catchments into reservoirs (Sharma *et al.,* 2017). This influx alters nutrient dynamics and can stimulate primary productivity, but it may also initiate processes that contribute to oxygen depletion. In contrast, winter is generally characterized by lower temperatures, improved oxygen solubility, and relatively stable physicochemical conditions, providing a phase of partial ecological recovery (Kumar & Dua, 2021).

Among the various factors influencing reservoir water quality, nutrient enrichment plays a central role, particularly in regions with mixed land use. Agricultural activities in the catchment area contribute significantly to the loading of nitrogen and phosphorus compounds, especially during periods of intense rainfall. These nutrients, while essential for aquatic productivity, can disrupt ecological balance when present in excess, leading to eutrophication and associated problems such as algal blooms and hypoxia (Yadav *et al.,* 2021). The interaction between nutrient inputs, organic matter decomposition, and oxygen dynamics creates a complex system in which seasonal variations can either enhance or suppress ecological stability.

Understanding these seasonal patterns is important for evaluating the health and sustainability of freshwater reservoirs, especially those that serve as sources of water for domestic, agricultural, or ecological purposes. Despite the growing number of limnological studies in India, many region-specific reservoirs remain under-documented, particularly in terms of integrated seasonal assessments that link physico-chemical parameters with climatic and catchment influences.

Latratu Dam, located in the Ranchi district of Jharkhand, represents a typical tropical reservoir influenced by a combination of forested landscapes and agricultural land use. These surrounding features contribute to spatial and temporal variability in water quality through differential nutrient input, sediment transport, and organic matter loading. However, systematic studies focusing on seasonal variation in its physico-chemical characteristics remain limited.

The present study aims to evaluate seasonal changes in key physico-chemical parameters of Latratu Dam over an annual cycle and to interpret these variations in relation to climatic conditions and catchment-driven processes. By examining parameters such as temperature, dissolved oxygen, biochemical oxygen demand, and nutrient concentrations, the study seeks to provide insights into the ecological status of the reservoir and identify periods of potential stress that may influence its long-term sustainability.

MATERIALS & METHODS

Study Area

The study was conducted at Latratu Dam (23.2240°N, 85.0741°E) located in the Lapung Block of Ranchi district, Jharkhand, India. The reservoir receives inflow from forested catchments and agricultural land, influencing nutrient input and sediment transport. The region experiences a tropical monsoonal climate with distinct summer, monsoon, and winter seasons.

Sampling Design and Period

Sampling was carried out from April 2023 to March 2024 at six stations selected based on ecological characteristics such as inflow zones, vegetation cover, and anthropogenic influence. Samples were collected monthly. For seasonal analysis, the year was categorized as: summer (April-June), monsoon (July-September), and winter (October-March), with late winter months (February-March) included to maintain continuity and avoid classification gaps.

Sample Collection and Analysis

Water samples were collected during morning hours (07:00-09:00 AM) using pre-cleaned containers.

Temperature and pH were measured in situ, while dissolved oxygen was determined using Winkler's method. Biochemical oxygen demand was measured through a 5-day incubation method. Alkalinity, hardness, nitrate, and phosphate were analysed using standard titrimetric and spectrophotometric techniques following APHA (2012).

Statistical Analysis

Seasonal means were calculated for all parameters. Pearson's correlation analysis was used to assess relationships among variables. Linear regression analysis was performed to examine the dependence of dissolved oxygen on temperature.

RESULTS

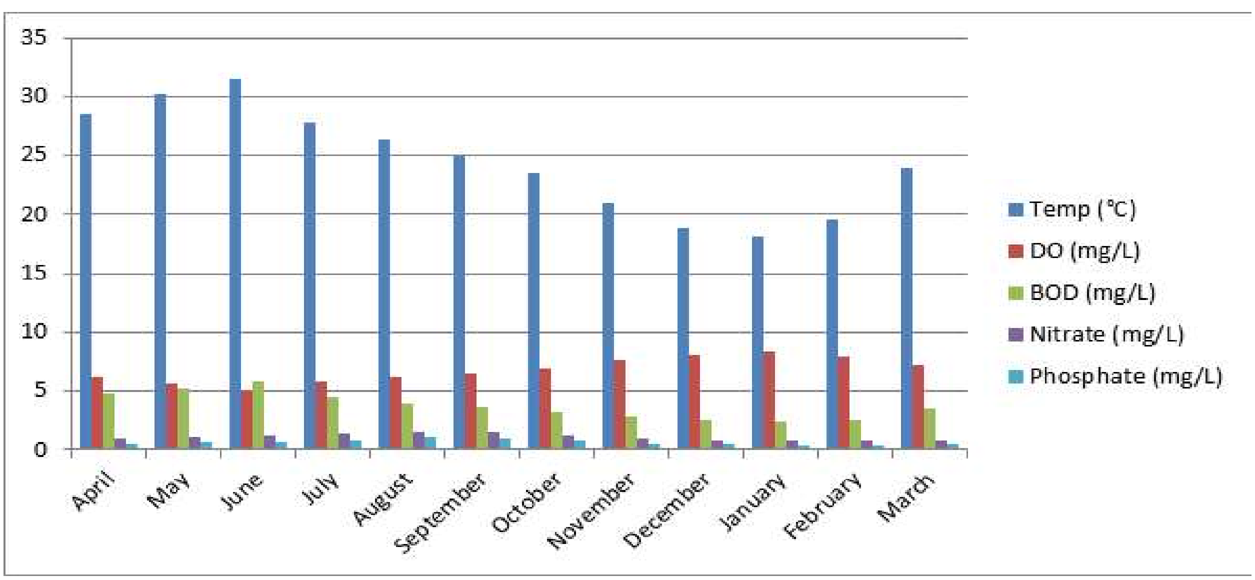
Seasonal Variation of Physico-Chemical Parameters

Table 1. Seasonal variation of physico-chemical parameters of Latratu Dam (April 2023–March 2024)

Season	Temperature (°C)	pH	DO (mg/L)	BOD (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
Winter	18.2	7.4	8.4	2.4	98	110	0.8	0.4
Summer	31.5	8.2	5.1	5.8	146	178	1.2	0.7
Monsoon	26.4	7.8	6.3	3.9	120	140	1.6	1.1

Table 2. Monthly variation in selected physico-chemical parameters of Latratu Dam

Month	Temp (°C)	DO (mg/L)	BOD (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
April	28.5	6.2	4.8	1	0.6
May	30.2	5.6	5.3	1.1	0.7
June	31.5	5.1	5.8	1.2	0.7
July	27.8	5.8	4.5	1.4	0.9
August	26.4	6.3	3.9	1.6	1.1
September	25	6.5	3.7	1.5	1
October	23.5	7	3.2	1.2	0.8
November	21	7.6	2.8	1	0.6
December	18.8	8.1	2.5	0.9	0.5
January	18.2	8.4	2.4	0.8	0.4
February	19.5	8	2.6	0.8	0.4
March	24	7.2	3.5	0.9	0.5



Graph 1. Monthly variation in selected physico-chemical parameters of Latratu Dam

The physico-chemical characteristics of Latratu Dam showed consistent seasonal variation supported by gradual month-to-month transitions (Table 1 and Table 2). The dataset reflects a continuous progression of changes rather than abrupt seasonal shifts, indicating strong climatic control on reservoir dynamics.

Water temperature followed a clear annual cycle, increasing steadily from 18.2°C in January to a peak of 31.5°C in June. The rise from March (24.0°C) to June marks a rapid warming phase associated with increasing solar radiation and reduced water volume. A decline in temperature begins with the onset of monsoon, dropping to 26.4°C in August and further to winter minima. This thermal pattern forms the basis for changes observed in other parameters.

Dissolved oxygen exhibited a gradual inverse response to temperature. Peak values were recorded during winter, reaching 8.4 mg/L in January and remaining above 8.0 mg/L during December and February. A steady decline is observed from March (7.2 mg/L) through April and May, reaching the lowest value of 5.1 mg/L in June. The reduction in oxygen availability is not abrupt but progressive, indicating increasing biological consumption coupled with declining solubility. During monsoon, DO levels begin to recover, rising to 6.3-6.5 mg/L between August and September, reflecting partial re-aeration and dilution effects.

Biochemical oxygen demand displayed an opposite trend, increasing from winter values of 2.4-2.6 mg/L (December-February) to a maximum of 5.8 mg/L in June. The increase is gradual, with intermediate values recorded in March (3.5 mg/L), April (4.8 mg/L), and May (5.3 mg/L), indicating progressive intensification of microbial activity. Following the monsoon onset, BOD declines to 3.9 mg/L in August and further to 3.2 mg/L in October, suggesting dilution and reduced organic load. The monthly pattern shows a sustained phase of elevated biological demand extending from late spring to early monsoon.

The pH of the reservoir remained within a narrow alkaline range throughout the study period, varying from 7.4 in winter to 8.2 in summer (Table 1). The increase during warmer months coincides with higher photosynthetic activity and reduced dilution, while relatively stable values during monsoon and winter indicate balanced carbonate dynamics.

Alkalinity and hardness exhibited similar seasonal behavior, with both parameters increasing toward summer maxima and declining during monsoon. Alkalinity increased from 98 mg/L in winter to 146 mg/L in summer, while hardness rose from 110 mg/L to 178 mg/L over the same period. These elevated values correspond to months of high evaporation and reduced inflow. During monsoon, both parameters decreased (alkalinity: 120 mg/L; hardness: 140 mg/L), indicating dilution by rainfall, although values remained higher than winter levels.

Nutrient concentrations showed a distinct seasonal peak during monsoon, supported by monthly progression. Nitrate increased from 0.8 mg/L in winter months to 1.2 mg/L in June, followed by a further rise to 1.6 mg/L in August. A similar trend was observed for phosphate, which increased from 0.4-0.5 mg/L in winter to 0.7 mg/L in early summer and peaked at 1.1 mg/L during peak monsoon. The gradual increase from pre-monsoon to monsoon months suggests accumulation followed by transport through surface runoff. Post-monsoon months showed a decline in nutrient levels, indicating reduced external input.

The combined seasonal and monthly patterns demonstrate that the reservoir undergoes a continuous cycle of warming, oxygen depletion, and nutrient enrichment followed by partial recovery. The most pronounced changes occur between March and June, where rising temperature, increasing BOD, and declining DO converge, indicating a period of heightened ecological stress. Monsoon introduces a shift toward nutrient enrichment and moderate recovery of oxygen conditions, while winter stabilizes the system with improved oxygen availability and reduced biological demand.

DISCUSSION

The seasonal patterns observed in Latratu Dam reflect a tightly coupled interaction between climatic forcing, catchment inputs, and internal biogeochemical processes. Temperature emerges as a dominant driver influencing multiple aspects of water chemistry, particularly oxygen dynamics and organic matter decomposition.

A strong inverse relationship between water temperature and dissolved oxygen ($r = -0.92$) demonstrates the combined effect of reduced gas solubility and increased metabolic demand under warmer conditions. As temperature rises during summer, oxygen solubility declines while respiration and microbial activity intensify, leading to measurable oxygen depletion. This dual control mechanism explains the pronounced drop in DO to 5.1 mg/L during summer months. Comparable observations in tropical reservoirs have been attributed to similar thermally driven constraints on oxygen availability (Mishra *et al.,* 2020).

Biochemical oxygen demand increases with temperature ($r = +0.88$), which means microbial activity becomes stronger in warmer conditions. Higher BOD values during summer indicate faster breakdown of organic matter, likely coming from accumulated debris and materials produced within the water body. This supports earlier studies showing that temperature controls microbial activity and organic matter decomposition in freshwater systems (Kaur et al., 2022). When BOD is high and dissolved oxygen is low at the same time, it reflects a stressful condition for the system, where oxygen is being used faster than it is replaced.

Nutrient dynamics during the monsoon season introduce an additional layer of complexity. The observed peaks in nitrate (1.6 mg/L) and phosphate (1.1 mg/L) indicate strong external loading from surrounding agricultural land and catchment runoff. While these inputs can stimulate primary productivity, their ecological implications extend beyond immediate enrichment. Moderate negative associations between nutrient concentrations and dissolved oxygen suggest indirect effects mediated through biological processes. Enhanced nutrient availability promotes algal and microbial growth, which upon decomposition can contribute to subsequent oxygen depletion. This delayed response underscores the importance of considering temporal lags in nutrient-oxygen interactions, particularly in monsoon-influenced reservoirs (Yadav *et al.,* 2021).

The interplay among temperature, organic load, and nutrient availability reveals a system that oscillates between phases of enrichment and stress. Summer conditions are characterized by intensified metabolic activity, elevated organic decomposition, and reduced oxygen availability, creating a biologically demanding environment. In contrast, winter provides relatively stable conditions with improved oxygen solubility and lower biological demand, allowing partial recovery of the system.

CONCLUSION

Seasonal changes shape the chemical environment of Latratu Dam in a predictable yet ecologically significant way. Summer conditions place stress on the system through elevated temperature, higher organic load, and reduced oxygen availability. Monsoon introduces nutrients that support productivity but also raise the risk of enrichment-related issues. Winter offers relatively stable conditions with improved oxygen levels.

These patterns show how closely the reservoir is linked to both climate and land use in the surrounding catchment. Regular monitoring across seasons can help detect early signs of ecological imbalance and support better management practices.

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