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Temporal Dynamics of Physico-Chemical Characteristics of the Freshwater Ecosystem in Pimpalgaon (Wakhaji) Dam, Nagpur District (M.S)

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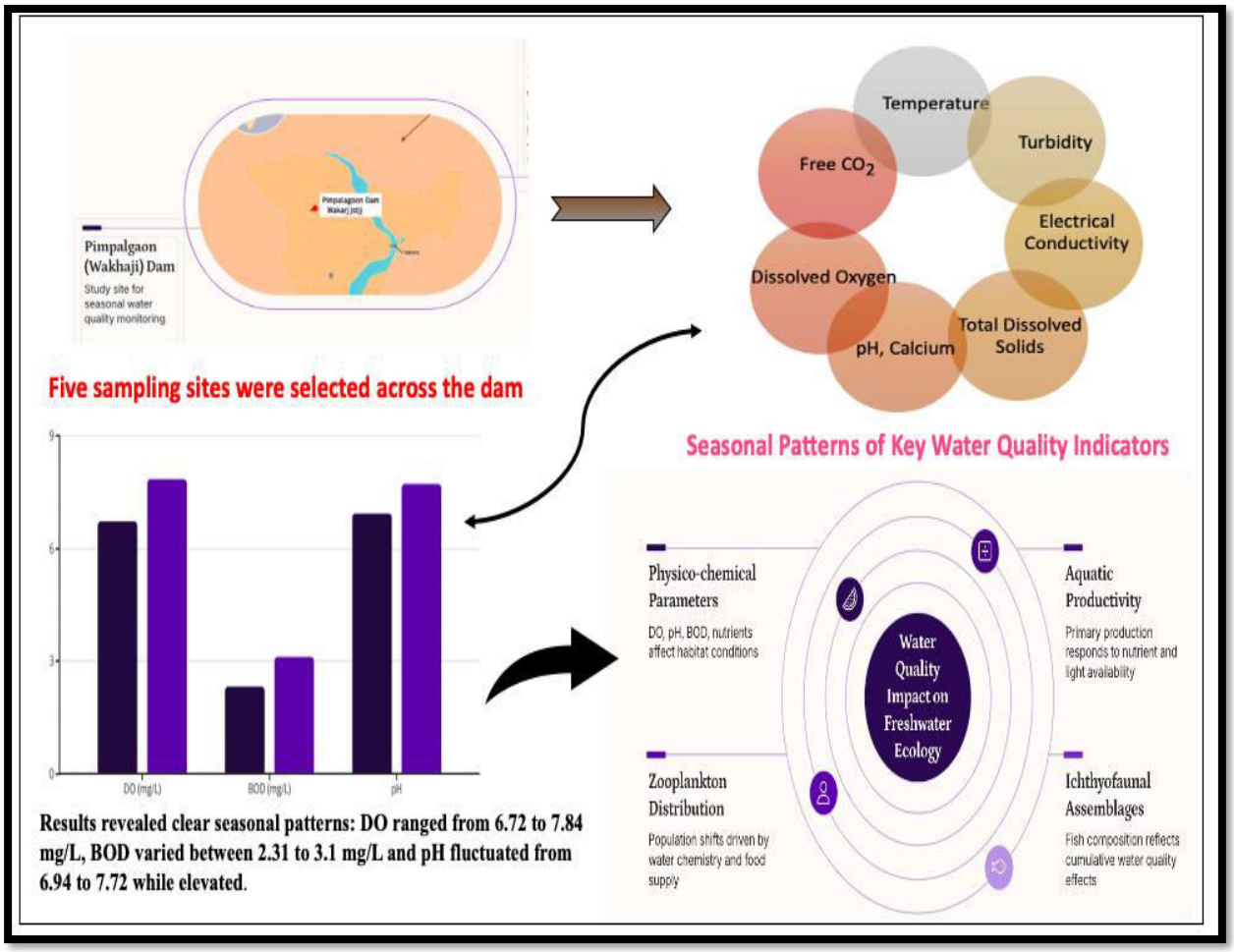
Abstract: Analysis of water quality is important criterion for evaluating suitability of water for drinking and irrigation. The present study investigates the seasonal dynamics of keyphysio-chemical parameters in the freshwater ecosystem of Pimpalgaon (Wakhaji) dam of Nagpur District, Maharashtra, India. Water samples were collected monthly from five distinct sites of dam between June 2023 to May2024.Thirteen standard parameters were assessed using APHA(1999,2017) guidelines including temperature, turbidity, electrical conductivity (EC), total dissolved solids (TDS), pH, dissolved oxygen (DO), free CO_2, alkalinity, chloride, phosphate, calcium, nitrate and biological oxygen demand (BOD). Results revealed clear seasonal patterns: DO ranged from 6.72 to 7.84 mg/L, BOD varied between 2.31to 3.1 mg/L and pH fluctuated from 6.94 to 7.72 while elevated. The interplay of these parameters significantly influences aquatic productivity, nutrient cycling and biotic composition, particularly impacting distribution of zooplankton and ichthyofaunal assemblages. This study provides baseline data essential for ecological monitoring and future sustainable water resource management strategies and mitigate anthropogenic stressors affecting freshwater reservoir ecosystems.

Keywords: Analysis, Physio-chemical Characteristics, Water Quality

Graphical Abstract



Introduction

Dams play a significant role in water storage, agriculture and electricity generation. Physico-chemical characters have a great importance as their relation with fluctuation of zooplankton and necessary for pisciculture (Ayoola,et.al.,2011).Study of various parameters regarding dam water is necessary for understanding the metabolic events of aquatic ecosystem. (Shinde, et.al., 2011). Aquatic biota gets depleted due to indiscriminate use of chemical fertilizers and pesticides in farming causes pollution in aquatic environment (Khan, et al.,2012).Hydrological condition of water affects aquaculture activities, species composition of avifauna, eutrophication and biodiversity (Wankhade, et.al.,2012). Water is important natural resource for all living being, food production and economy growth. Physico-chemical characteristics also influences and regulates flora and fauna (Aazami,et al., 2015). Health of human is directly connected with quality of water and it remains as major concern for man (Dirican, 2015). Decrease in percentage of rainfall and demand of water increasing day by day as increase in population of India (Ajagekar,et.al.,2011). Quality of water with regulating biomass, tropic levels, energy and biodiversity at a given time and space act as limiting factor (Wanjari,et.al.,2020).

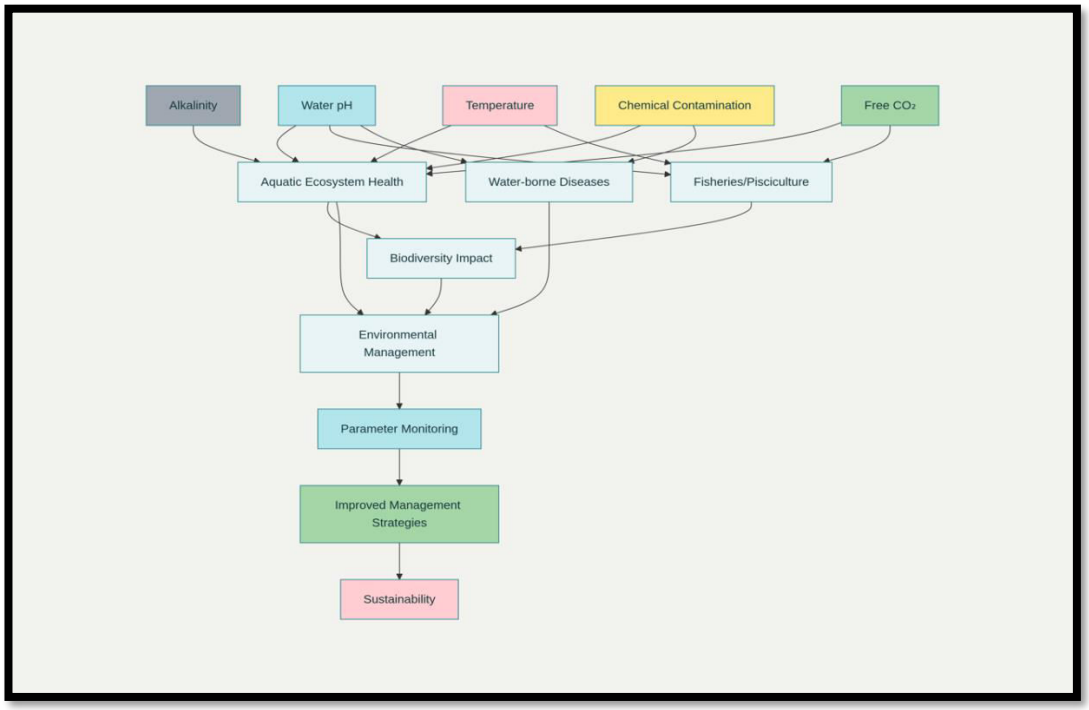


Figure 1. Influence of Dam Physico-Chemical Attributes on Aquatic Ecosystems, Fisheries, Biodiversity, and Human Health

Immune system of fishes affected by change in water quality directly or indirectly through pollution (Bassem, 2020).Water pH, temperature, free CO_2, alkalinity like parameters play important role in growth and development of ichthyofauna. Any variation in these characters of water affects the growth and development of fishes. Due to contamination many water-borne diseases arise which suffers population of human (Makode, 2020). Physio-chemical characteristics analysis also helps to initiate necessary affirmative actions against contamination of water bodies (Gaikwad, et.al., 2021). So, it is mandatory to analyse important characteristics of water quality for aquatic ecosystem. To formulate appropriate management strategies and protect rich biodiversity of dam adequate information about various parameters and delicate dynamics sustained by dam have great importance. At regular intervals, quality of water must be checked. The study aims to provide insights into its quality dynamics throughout the year to aid in environmental management and policy decisions.

Table 1: Importance of Physico-Chemical Characteristics of Dam Water

Parameter / Aspect	**Importance in Aquatic Ecosystem**	**Impact on Biota & Human Health**
Water Storage in Dams	Facilitates irrigation, potable water supply, and electrical production	Facilitates economic expansion and agricultural output
Physico-chemical Characters	Impact Fluctuations in zooplankton, aquaculture, fish well-being	Regulate plant life, animal species, and aquatic biodiversity
Chemical Fertilizers & Pesticides	Induce marine pollution	Depletion of aquatic biota
Hydrological Conditions	Impact aquaculture, eutrophication and avifaunal species composition	Impact biodiversity and ecological equilibrium
Water Quality and Rainfall	Decreased precipitation diminishes water quality amid increasing demand.	Constraints on biomass, trophic strata, energy cycles
pH, Temperature, Free CO_2, Alkalinity	Crucial for the growth and development of fish species	Variations influence fish immunity, reproduction, and survival.
Water Contamination	Induces waterborne illnesses in people	Direct threat to public health
Water Quality Monitoring	Helpful in identifying sources of pollution and contamination	Establishes a foundation for governance and policy formulation
Management Strategies	Consistent monitoring of water quality contributes to sustainability.	Safeguards biodiversity and guarantees safe utilization

Materials and Methods

Study Area: The present study was conducted at Pimpalgaon (Wakhaji) dam located in Narkhed Taluka, Nagpur District, Maharashtra, India. The dam isgeographically positioned at latitude 21.45°Nand longitude 78.55°E, approximately 3.6 km east of Narkhed. This dam is the largest irrigation reservoir in taluka, supports local agricultural practices and biodiversity. Hence, Pimpalgaon (Wakhaji) dam plays vital role in agriculture.

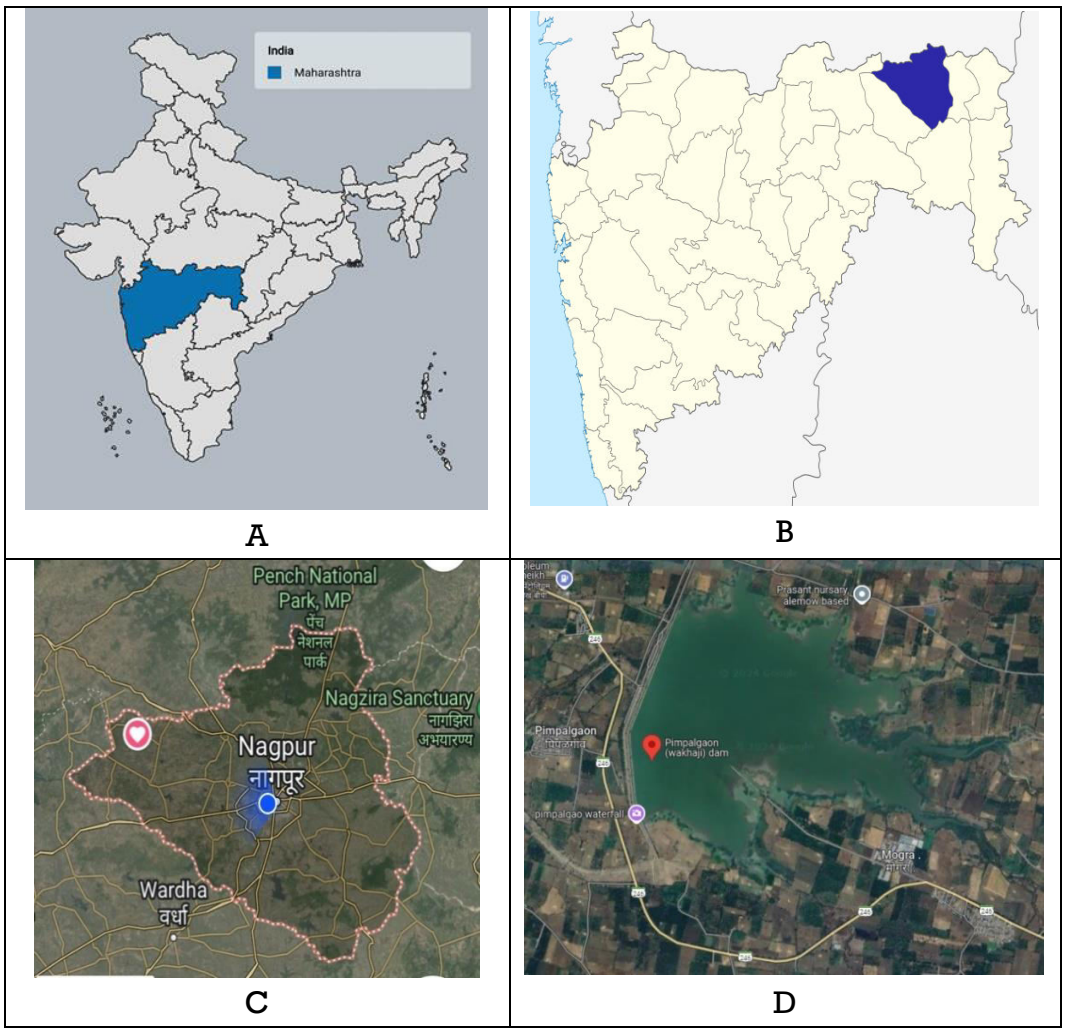


Figure 2. Location of the study area A) Map of India highlighting the state of Maharashtra; B)Maharashtra map showing Nagpur District; C)Satellite image showing location of Pimpalgaon (Wakhaji) dam (symbol of heart) within Nagpur district, Maharashtra; D) Zoomed satellite view of precise location of Pimpalgaon (Wakhaji) dam indicating general geographic region. Map A prepared from (www.Map Chart.net) and B from Wikimedia Commons (File:Nagpur in Maharashtra (India).svg),licensed under CC BY-SA 3.0. for illustrative purpose while Map C and D were previously used in a study of icthyofaunal diversity (Gurchal and Bhatkulkar,2024) and it is reused here to illustrate the same location of Pimpalgaon (Wakhaji) for physico-chemical analysis.

Sampling Design: Water samples were collected monthly from five pre-selected sampling stations in the dam for a continuous period of 12 months from June 2023 to May 2024. The stations were chosen to cover diverse ecological zones within the dam. Sampling was consistently carried out during early morning hours (7.00 A.M to 9.00 A.M) to avoid diurnal variations and maintain consistency.

Sampling Methodology: Water samples were collected from surface (approx..15-30 cm depth) using pre-cleaned polyethylene bottles of one litre capacity from five

different sites of Pimpalgaon (Wakhaji) dam. Bottles were rinsed thrice with sample water before final collection.

Parameters Analyzed: Thirteen physico-chemical parameters were analyzed:

- **Physical:** Temperature, Electrical Conductivity (EC), Total Dissolved Solids(TDS), Turbidity
- **Chemical:** pH, Alkalinity, Free Carbon Dioxide (CO_2), Dissolved Oxygen (DO), Chloride, Nitrate, Calcium, Phosphate, Biological Oxygen Demand

All physico-chemical parameters estimated as per standard procedures outlined in the APHA (1999 and 2017) manuals. To ensure data accuracy all samples were processed in triplicate and mean values with standard deviation were calculated. Instruments were calibrated before use and reagent blanks were run for chemical tests. Any deviations from standard limits were cross-checked through repeat analysis.

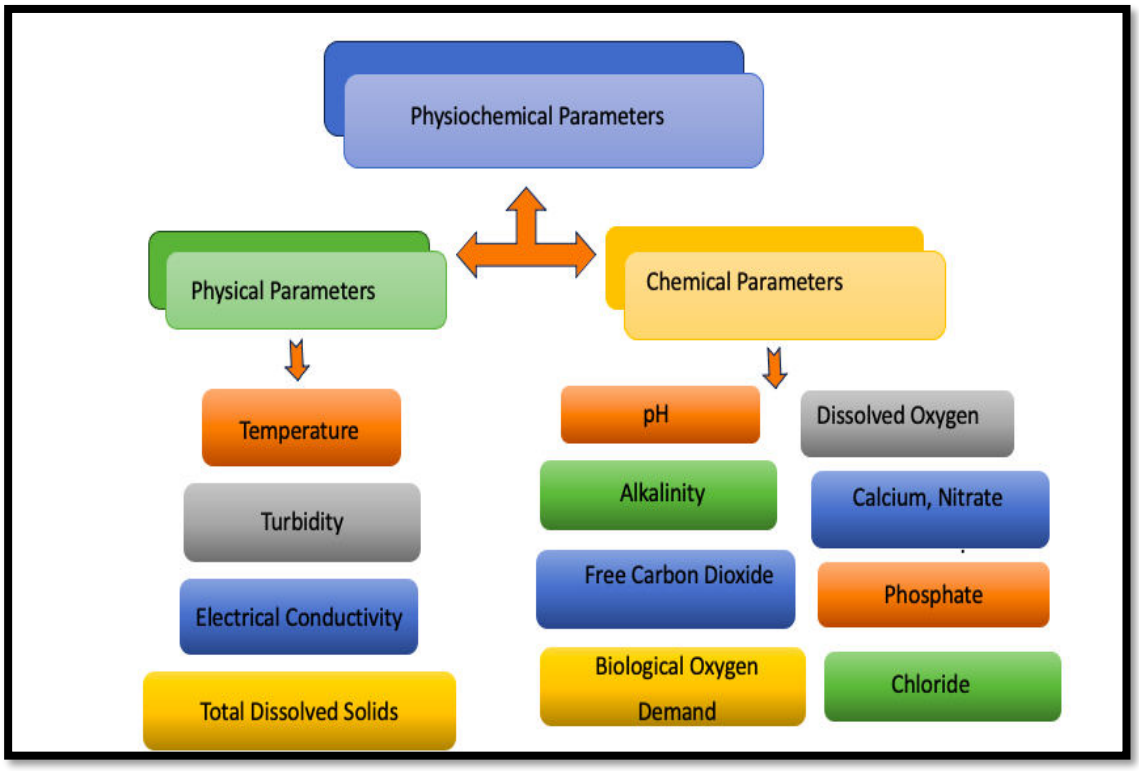


Figure 3. Figure depicting 13 physiochemical parameters including physical and chemical parameters

Results

The present study was carried out to analyzed and determined physico-chemical status of Pimpalgaon (Wakhaji) dam water. The data collection spanned a full annual cycle (June 2023 to May 2024).To maintain diurnal consistency all samples collected consistently between 7:00 AM to 9:00 AM morning. The monthly variation in key physico-chemical parameters (temperature, electrical conductivity, turbidity, total dissolved solids, pH, free CO_2,dissolved oxygen, chloride, nitrate, calcium, phosphate, biological oxygen demand) including mean±

SDis represented graphically in Figures 2 to 14 for study period of June 2023 to May 2024.

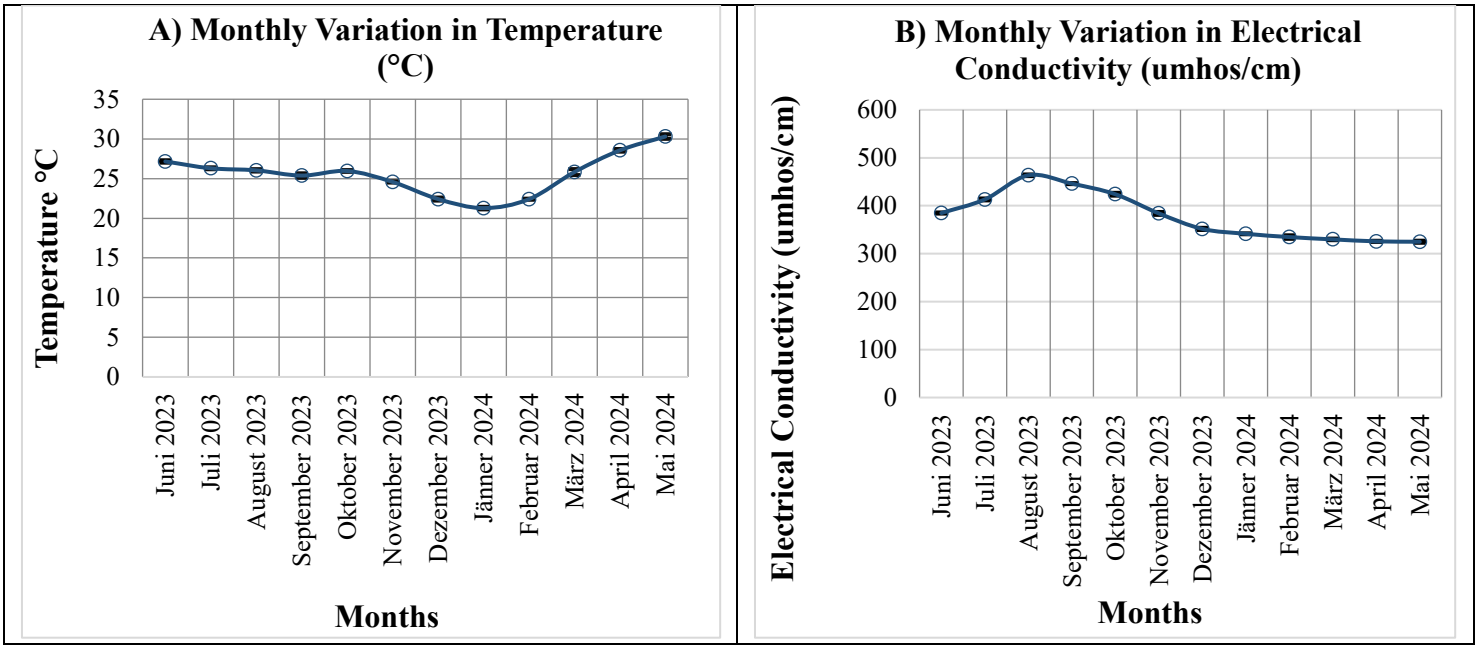
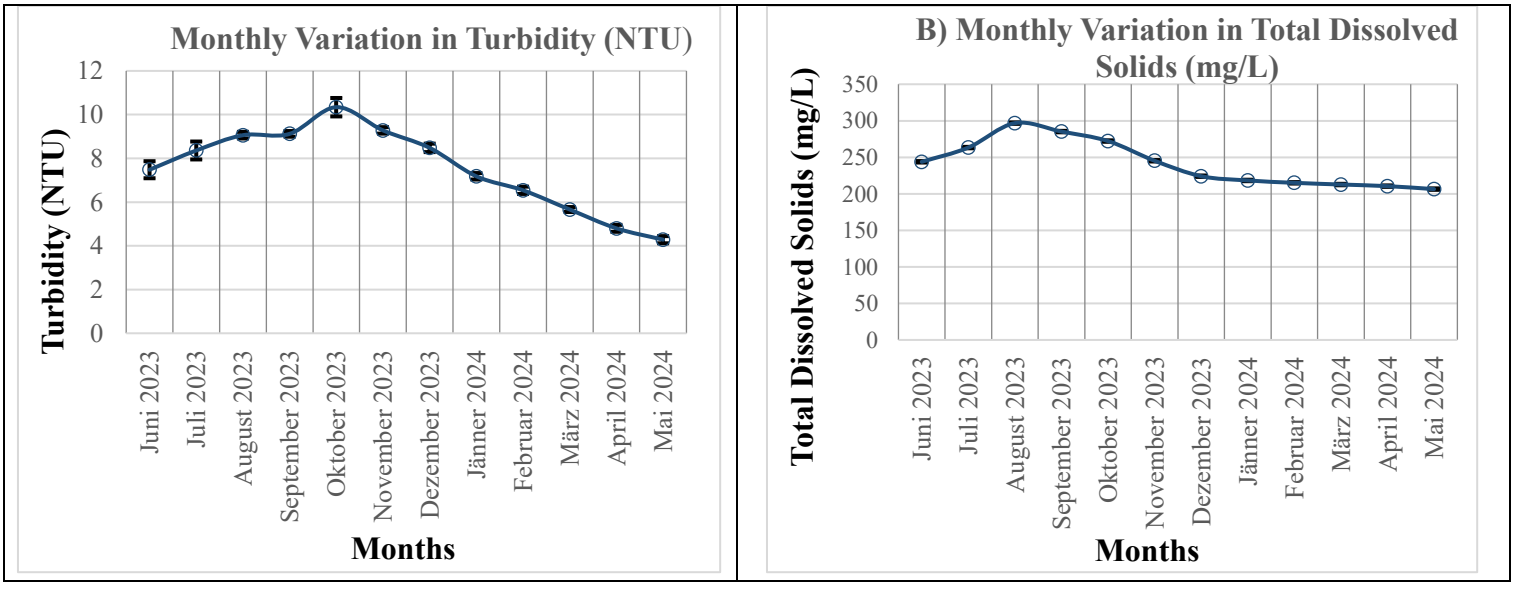


Figure 2. Graphs presented seasonwise monthly variation in key physico-chemical parameters (A-Temperature, B-Electrical Conductivity) of water in Pimpalgaon (Wakhaji) dam during study period (June 2023-May 2024).Data from five sampling stations were averaged for each parameter.



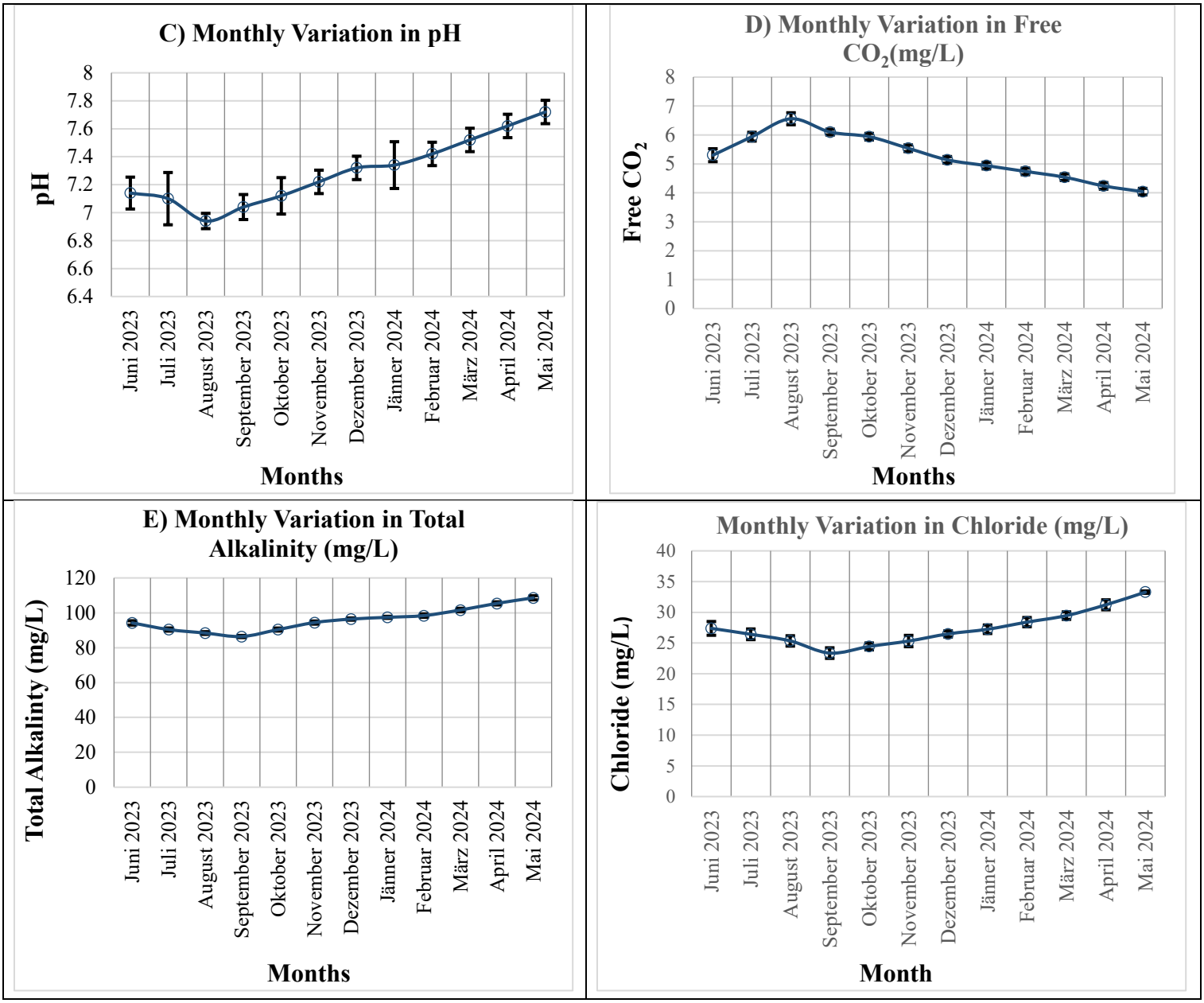
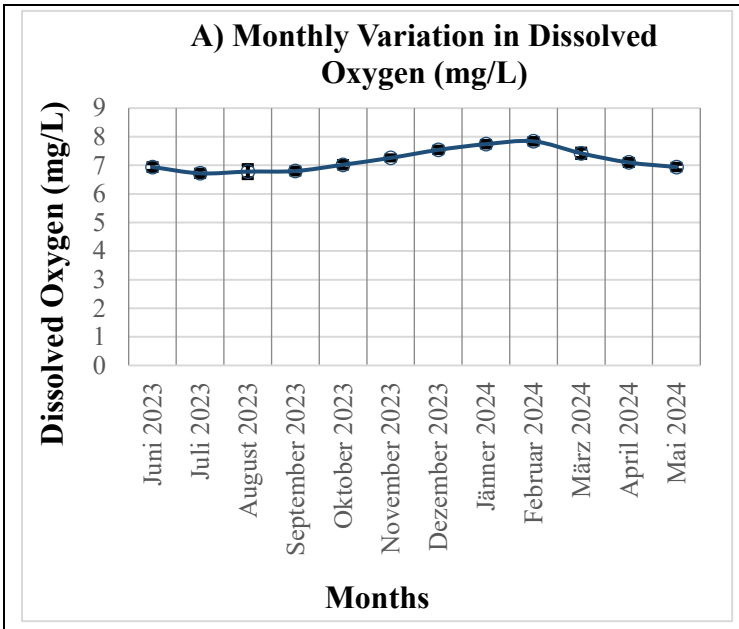
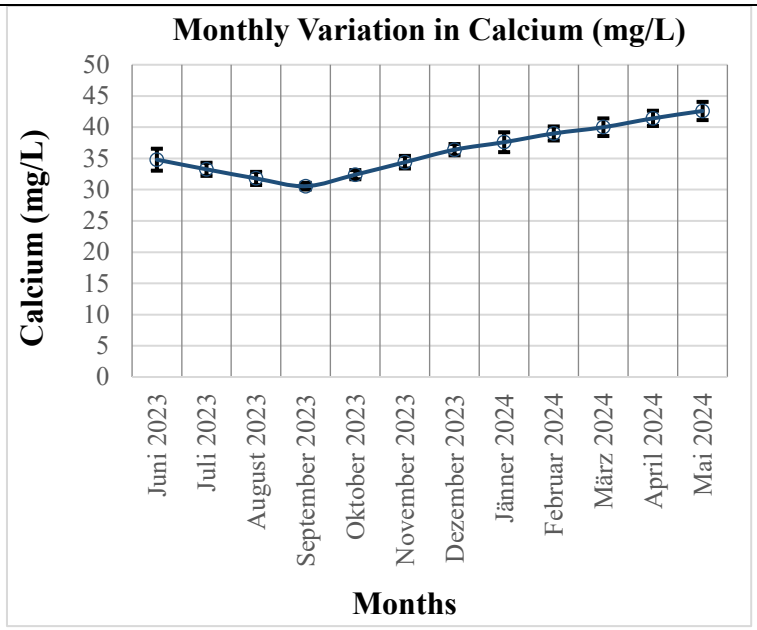
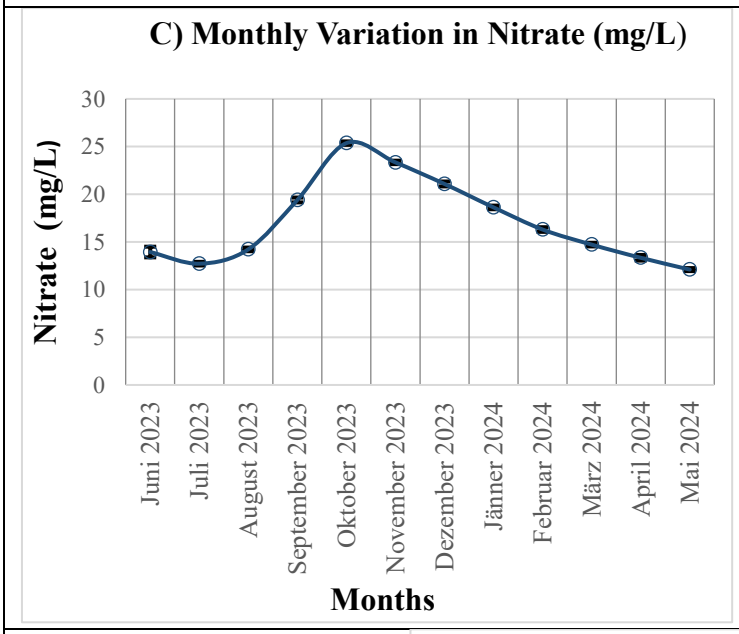
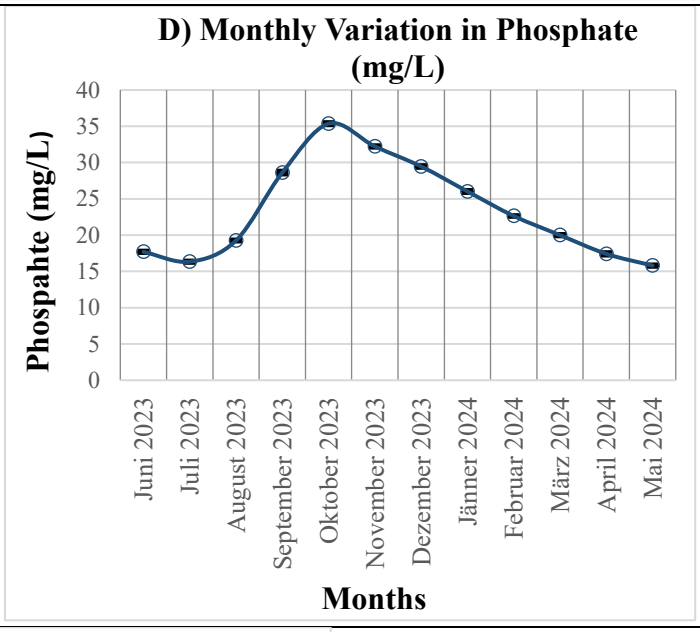


Figure 4. Graphs presented seasonwise monthly variation in key physico-chemical parameters (A-Turbidity, B-Total Dissolved Solids, C-pH, D-Free CO_2,E-Total Alkalinty, F-Chloride) of water in Pimpalgaon (Wakhaji) dam during study period (June 2023-May 2024). Data from five sampling stations were averaged for each parameter.


A) Monthly Variation in Dissolved Oxygen (mg/L)
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
Juni 2023
Juli 2023
August 2023
September 2023
Oktober 2023
November 2023
Dezember 2023
Jänner 2024
Februar 2024
März 2024
April 2024
Mai 2024
Months


Monthly Variation in Calcium (mg/L)
Calcium (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Juni 2023
Juli 2023
August 2023
September 2023
Oktober 2023
November 2023
Dezember 2023
Jänner 2024
Februar 2024
März 2024
April 2024
Mai 2024
Months


C) Monthly Variation in Nitrate (mg/L)
Nitrate (mg/L)
0
5
10
15
20
25
30
Juni 2023
Juli 2023
August 2023
September 2023
Oktober 2023
November 2023
Dezember 2023
Jänner 2024
Februar 2024
März 2024
April 2024
Mai 2024
Months


D) Monthly Variation in Phosphate (mg/L)
Phospahte (mg/L)
0
5
10
15
20
25
30
35
40
Juni 2023
Juli 2023
August 2023
September 2023
Oktober 2023
November 2023
Dezember 2023
Jänner 2024
Februar 2024
März 2024
April 2024
Mai 2024
Months

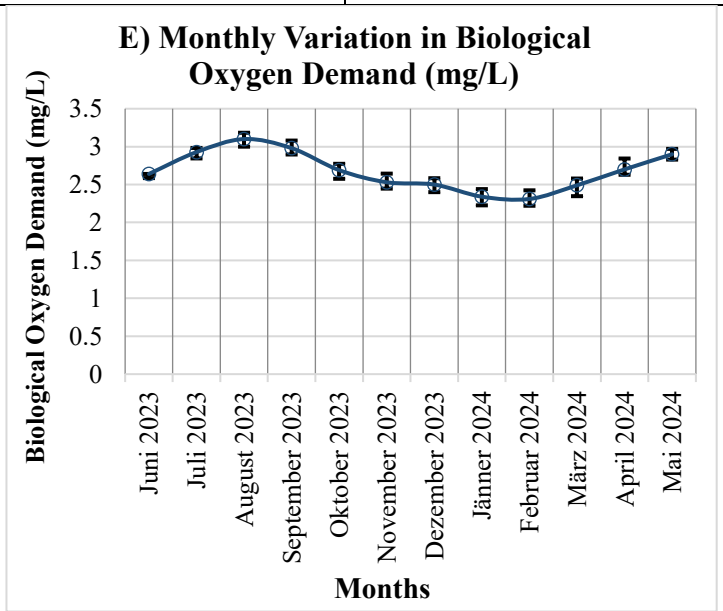

E) Monthly Variation in Biological Oxygen Demand (mg/L)
Biological Oxygen Demand (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
Juni 2023
Juli 2023
August 2023
September 2023
Oktober 2023
November 2023
Dezember 2023
Jänner 2024
Februar 2024
März 2024
April 2024
Mai 2024
Months

Figure 5. Graphs presented season wise monthly variation in key physico-chemical parameters (A- Dissolved Oxygen, B-Calcium, C-Nitrate, D-Phosphate, E-Biological Oxygen Demand) of water in Pimpalgaon (Wakhaji) dam during study period (June 2023-May 2024). Data from five sampling stations were averaged for each parameter.

Temperature: Water temperature clearly exhibited a clear seasonal trend with lowest value ranging from 21.28 ±0.164 °C to highest of 30.3±0.291 °C. Monsoon season presented relatively stable temperatures, whereas winter showed a decline and summer recorded progressively higher values.

Electrical Conductivity: Electrical conductivity values lowest values ranging from 324.96 ± 2.165 umho/cmto highest of463.54± 1.705 umho/cm. Electrical conductivity values showed a rising trend from June to August peaking at 463.54 umho/cm, likely due to increased surface runoff during early monsoon that brought dissolved salts and ions into the reservoir. A gradual decline in EC was observed from September onward, reaching its lowest value in May-2024, which may be attributed to dilution effects during post-monsoon and winter.

Turbidity: Turbidity of water ranged from minimum of 4.28 NTU ±0.16 NTU in May 2024 to a maximum of 10.34 NTU± 0.421NTU. The values gradually increased from June, peaked during the post-monsoon period (October-November) and declined progressively through the winter and summer months. The slight increase in turbidity observed during October coincides with peak levels of nitrate and phosphate indicating nutrient induced algal and suspended matter accumulation during this time.

Total Dissolved Solids: Total dissolved solids values highest values were during August-2023 (296.8± 3.67mg/L) and lowest in summer months with recorded in May-2024 (206.48±2.28mg/L). TDS values exhibited a seasonal trend reaching a maximum of 296.8 mg/L in August 2023, which coincides with the peak monsoon period. This rise is likely due to runoff from surrounding catchment areas carrying dissolved minerals, nutrients and organic matter into the reservoir. A steady decline was observed thereafter with TDS reaching its lowest concentration of 206.48 mg/L in May 2024, likely due to reduced inflow, sedimentation of particulates and possible biological uptake in the summer months.

pH: Concentration of hydrogen ions indicated by values of pH. Present assessment shows pH range from 6.94 ± 0.05to 7.72± 0.083. Indicating the water was slightly acidic to slightly alkaline throughout the year. Influence of rainwater runoff, organic matter and reduced photosynthetic activity might tends to lower pH as lowest values were observed during monsoon (July-2023 to September-2023).pH reach peak in summer months (April-2024 to May-2024).This rise may be due to

enhanced photosynthesis by aquatic plants and algae which utilizing $CO_2$and thereby raise the pH.

Free CO_2: The maximum value of 6.56 ± 0.207 mg/L was recorded in month of August-2023 and minimum value of 4.04± 0.114 mg/Lin month of May-2024. Highest concentration observed during monsoon as likely due to increased organic matter decomposition and lower photosynthetic activity under cloudy conditions which limits CO_2 utilization.

Total Alkalinity: Alkalinity levels in dam water ranged from lowest86.4 ±0.604mg/L to highest 108.6± 1.176mg/L. The lowest values were observed during monsoon season (July-2023 to September-2023), possibly due to dilution caused by heavy rainfall and inflow of freshwater reduces concentration of carbonates and bicarbonates. Alkalinity peaks in summer months (March-2024 to May-2024) after gradual increased through winter. This increase may be attributed to evaporation, concentration of dissolved salts and higher biological activity releasing bicarbonates into water.

Chloride: Lowest chloride levels were recorded of 23.36±0.861mg/L in month of September-2023 due to dilution effects from monsoon rains and maximum value of 33.28±0.192mg/L in month of May-2024 because increased evaporation and concentration of salts in pre-monsoon rains.

Dissolved Oxygen: The maximum value of dissolved oxygen was 7.84 ±0.114mg/L recorded in February-2024 and minimum value of 6.72±0.130 mg/L recorded in July-2023. Low dissolved oxygen observed in July-2023 (6.72 mg/L) and August-2023(6.78 mg/L) which may due to reduced photosynthetic activity due to cloud cover and increased microbial decomposition of organic matter during monsoon.

Calcium: Calcium is helpful for shell construction and also promotes growth of micro-organisms. The minimum value of calcium was 30.56±0.531mg/Lrecorded in September-2023 and maximum value of42.6±1.45 mg/L found in May-2024. Due to dilution by rainfall and surface runoff calcium low levels were observed in monsoon period (June-2023 to September-2024). Reduced rainfall and increased mineral concentration mightlead to gradual increase from October-2023 and high concentration occurred in summer (February-2024 to May-2024).

Nitrate: Nitrate levels ranged from (12.1±0.158 mg/L) in May 2023 to (25.36±0.181 mg/L) of October and gradual decline toward May 2024, where values reached around 12.1 mg/L. The peak during post-monsoon suggests enhanced nutrient input likely due to agricultural runoff and organic decomposition.

Phosphate: The value of phosphate fluctuates from (15.8±0.158 mg/L) to (35.36±0.207) during study period. Phosphate concentration showed a trend rising

from around 17.7 mg/L in June to maximum of 35.36 mg/L in October then progressively declines through winter and summer months. The synchronous peaks of both nutrients during October highlight a strong correlation, potentially linked to increased external loading and biological activity during this period.

Biological Oxygen Demand: Biological oxygen demand fluctuated from 2.31±0.089 mg/L rises till 3.1±0.1 mg/L during study period. Comparatively mild high BOD levels were observed during monsoon months (July-August) likely due to increased runoff and organic input, while the low values were occurred in winter months (December-February) when water temperature was lower and DO levels were high. BOD values remained within acceptable limit which indicate satisfactory water quality and minimal organic pollution pressure in dam.

Discussion

The present study assessed the monthly variations with season in physico-chemical parameters of Pimpalgaon (Wakhaji) dam of Nagpur. Water samples were collected monthly from five designated stations between June-2023 to May-2024during morning hours (7:00-9:00).

Temperature ranged from 21.28°C (January-2024) to 30.3°C (May-2024) reflecting natural seasonal transitions from winter to summer. Summer months (March-May) recorded the highest water temperatures influencing the increase in Biological Oxygen Demand (BOD) and reduction in Dissolved Oxygen (DO) due to enhanced metabolic activities and microbial oxygen consumption. Similar seasonal temperature variations affecting Dissolved Oxygen and Biological Oxygen Demand have been reported in Anandpur Dam,Gujarat (Vyas et al., 2024).

pH values remained within a narrow and slightly alkaline range (6.94-7.72) which is favourable for zooplankton and aquatic organisms. Slight alkalinity is necessary for maintaining buffering of carbonate and promoting biological productivity. Comparable pH stability supporting zooplankton diversity was observed in Yaldali dam, Parbhani (Walale & Rathod, 2023).

The electrical conductivity and total dissolved solids values showed seasonal variation with higher levels observed during monsoon and post monsoon months (August-October) due to increased runoff and mineral input. Lower values during summer and winter indicate reduced inflow and evaporation effects. Monsoon and post monsoon months may result from runoff carrying suspended particles, increased suspended solids and organic debris affecting primary productivity by reducing light penetration. This suggests that nutrient driven turbidity possibly from algal growth and organic runoff may temporarily elevated turbidity. The observed decline in turbidity during winter and summer can be attributed to settling of sediment and decreased biological productivity. These findings are similar with previous studies that report seasonal variation in electrical conductivity, total dissolved solids and turbidity corresponding with nutrient enrichment and post-monsoon inflow events in freshwater ecosystem of Kurnur Dam, Maharashtra (Patil and More,2016).

Alkalinity ranged between 86.4-108.4 mg/L throughout study period exhibiting evident seasonal fluctuations with lower alkalinity observed during monsoon months due to dilution from rainwater and comparatively higher values in summer (May-2024) possibly due to increased concentration effects from evaporation. Similar seasonal trends in alkalinity were reported in freshwater ecosystem of Triveni lake in Amravati, Maharashtra (Khan et al., 2012).Dissolved Oxygen remained relatively stable throughout study period (6.72 to 7.84 mg/L).These findings comparable with those reported in Pond of Antargam village, Telangana (Tamlurkar et al., 2023), where dissolved oxygen level ranged between 5 mg/L and 10.41mg/L. Similarly, during rainy season dissolved oxygen values slightly lower due to dilution by rainwater and increased turbidity which affects and limits photosynthesis due to reduced light penetration. Such trends also evident in our study which indicates a well-balanced aquatic system capable of supporting aquatic life.

Free CO_2 showed moderate fluctuations throughout seasons with lower levels in winter and summer due to early morning uptake by phytoplankton where higher values in monsoon months as photosynthesis gets reduced. Such trend has been also documented in studies like that of Jamwadi Medium Dam, Yavatmal (Wankhade, 2016).Minimum level of chloride during monsoon period due to dilution effects from rainfall and surface runoff which reduces concentration of salts in water. Steady increase in chloride levels after monsoon months as reaching their peak in May-2024.This increase attributed to elevated evaporation rate, reduce inflow and concentration of dissolved ions under higher temperature and stagnant water conditions. These findings align with chloride values trend of increased in summer those reported in study of Vishnupuri dam, Maharashtra (Ubarhande, 2017).

The observed peak in both nitrate and phosphate concentration during post-monsoon period can be attributed to surface runoff, agricultural leaching and organic matter decomposition collectively increase nutrient loading into aquatic system. Similar seasonal enrichment patterns have been reported in freshwater reservoirs, particularly during post-monsoon months when catchment inflows intensity nutrient input. Observed seasonal pattern showed a slight decline in calcium levels during monsoon months (June 2023 to September 2023) due to dilution effects caused by heavy rainfall and runoff followed by gradual increase till May-2024 which can be attributed to higher evaporation rates, reduced inflow and possible enrichment from soil and mineral weathering in surrounding area.

Slight increase in Biological Oxygen Demand during (June-2023 to August-2023) is likely due to runoff carrying decomposable organic matter from surrounding agricultural fields and soil erosion into the dam. Biological Oxygen Demand gradually decreases reaching its low in February may be due to lower microbial activity during colder months, reduced biological decomposition and higher dissolved oxygen. Onwards March-2024, biological oxygen demand rise again slightly in late summer generally associated with rising temperatures that promote microbial metabolism and decomposition of accumulated organic

material, reduced dissolved oxygen levels. A comparable trend was reported by Mahajan and Pokale (2017) in their study of Mohabala Lake, Chandrapur, Maharashtra where biological oxygen demand values ranged between 2.8 mg/L and 5.8 mg/L with higher values during summer.

Overall, the water quality parameters recorded throughout year were within favourable limits for sustaining zooplankton communities. This community plays a pivotal role in development of fish species particularly during spawning season.

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