International Journal of Zoology Studies
www.zoologyjournals.com
ISSN: 2455-7269
Received: 09-06-2025, Accepted: 09-07-2025, Published: 24-07-2025
Volume 10, Issue 3, 2025, Page No. 27-31

Seasonal variation in physicochemical Parameters of River Wardha, District Chandrapur, Maharashtra, India

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Abstract
River constitute vital components of freshwater ecosystems and are increasingly subjected to environmental stressors arising from anthropogenic activities. The present study provides a detailed evaluation of the river Wardha at sampling sites in Chandrapur district, Maharashtra, India with the aim of assessing its water quality and identifying both spatial and seasonal variability. Water samples were systematically collected from designated upstream and downstream stations during the winter, summer and monsoon seasons of the year 2024. Key physicochemical parameters, including temperature, pH, electrical conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), turbidity, nitrate, calcium, chloride, fluoride and magnesium concentrations were analysed. The results revealed that the majority of measured parameters complied with the permissible limit set by CPCB and WHO, in the present investigation high nutrient concentration were detected which is adjacent to urbanized deviations indicating moderate level of pollution, likely driven by untreated domestic effluents, agricultural runoff, and seasonal changes in river discharge. The study emphasizes the critical need for continuous monitoring, improved wastewater treatment infrastructure, and the implementation of integrated watershed management approaches to sustain the ecological integrity and water quality of the Wardha river at sampling sites.

Keywords: Physicochemical, Turbidity, pH, Electrical conductivity, Wardha river, Ballarpur

Introduction
Rivers are dynamic ecosystems whose water quality is greatly influenced by seasonal changes and human activities. In semi-arid and monsoon-driven regions of India, river water quality often fluctuates runoff, and waste discharge. The river Wardha, which flow through parts of Maharashtra, play a crucial role in supplying water for irrigation, domestic use, and supporting local biodiversity. The river, originating from the Satpura Range, flows through the Chandrapur and Wardha district of Maharashtra. Seasonal variation in rainfall and river flow can either dilute pollutants during the monsoon or concentrate them during dry periods. Monitoring of these seasonal changes is essential to understand the river's capacity for self purification and to design effective water management plans.
Understanding how parameters like turbidity, hardness, total dissolved solids (TDS) and nutrients (nitrate, phosphate) change with seasons is essential for sustainable river management. Seasonal monitoring helps identify pollution sources, evaluate the river's self- purification capacity and develop suitable water conservation measures. This study focused on analysing the seasonal variation in key physicochemical parameters and the overall water Quality (WQI) of the Wardha River at sampling stations to evaluate its water quality status across different seasons such as winter, summer and monsoon.

Materials and Methods
The present study was conducted on the Wardha River, which is an important tributary of the Godavari River, flowing through the Chandrapur district of Maharashtra, India. The river originates in approximate the Satpura Range near Multai, Madhya Pradesh, and traverses approximately 528 km before merging with the Wainganga River to form the Pranhita River. Two sampling sites were selected along the river stretch in Chandrapur district to represent upstream and downstream. Sampling site 1(Upstream) was near the Babasaheb Ambedkar Ward no. 25 of Ballarpur, at geo-coordinates approximate Latitude 19.8531N, Longitude 793486 E. and sampling site 2 (Downstream) was near the river bridge at Dudholi, approximate Latitude 19.7800 N Longitude 79.1200 E.

Sample Collection and Analysis
Water samples were collected at monthly interval over the period of one year from January 2024 to December 2024, covering all three major seasons typical for the region Pre-monsoon (Summer); March to May Monsson (Rainy Season): June to September Post Monsoon (Winter): October to February. The sampling was done during time (8 to 10.30 am) Water sample were collected in clean, sterilized plastic bottles, transported to the laboratory, and analysed on the same day to prevent changes in the water quality. On-site measurements such as Temperature and pH, were recorded immediately at the sampling location using portable instruments. All physicochemical parameters were determined using standard procedures recommended by the American Public Health Association (APHA, 2017) and the Bureau of Indian Standards (BIS) guidelines. The instruments and reagents used were calibrated and maintained as per the standard protocols.

Results and Discussion
Atmospheric and Water Temperature
Water temperature is directly influenced by prevailing air temperatures, solar radiation, river depth, flow rate, and seasonal weather conditions. It plays a vital role in

regulating dissolved oxygen levels, chemical reaction rates, and biological activities in the river. In this study, water temperatures varied noticeably with the seasons, reflecting the ambient climatic conditions. Temperature is a physical factor that alters the water characteristics and considered as an important factor in controlling the fluctuation of plantation and functioning of aquatic ecosystem. (Wetzel, 1975; Dwivedi and Pandey, 2002; Singh and Mathur, 2005) [6]. Seasonal fluctuation in atmospheric and water temperature were monitored. The temperatures reached their peak during the summer season, decreased moderately during the monsoon, and were lowest the winter season. Findings of Khanna and Job (1980) are also comparable to those obtained in the present investigation.

Humidity

The relative humidity in the Wardha River region exhibited seasonal variation, with the maximum value recorded in August (69%) and the minimum in April (34%). This pattern is characteristic of tropical and sub-equatorial climates, where the monsoon season is marked by elevated humidity levels due to sustained rainfall and high evaporation rates.

pH

The pH was ranged from 7.1 to 8.5 across both sites and seasons indicating slightly alkaline nature. Higher pH values were observed during the summer months, possibly due to increased photosynthetic activity by aquatic plants and lower dilution effect. In the present investigation recorded pH values during the pre-monsoon period pH range from 7.40 ± 0.20-7.63±0.25, in the monsoon season pH varies between7.38± 0.17-7.40 ± 0.22 and the post-monsoon season, pH value ranging from7.20±0.10-7.27 ± 0.15. Minor variations were seen due to dilution during the monsoon and increased organic matter decomposition during Summer. The minor seasonal fluctuations indicate an effective buffering capacity of the system. Elevated pH levels are generally attributed to enhanced photosynthetic activity within the water body (Goel *et.al*., 1986; Wani and Subla, 1990) [7, 16]. The recorded pH values were within the BIS (IS10500:2012) permissible limit of 6.5-8.5, indicating suitable domestic use. Agbaire *et al*. (2015) [2] reported that a pH range between 6.5 and 9.0 is considered optimal for sustaining fish production.

Dissolve Oxygen

Dissolved oxygen (DO) is one of the most widely utilized indicators in aquatic environmental studies and plays a critical role in sustaining aquatic life. It is essential for the survival and metabolic activity of all aerobic organisms and significantly influences the chemical processes such as the oxidation and precipitation of organic matter. In the present study, DO concentrations ranged from 5.5-7.6 mg/L, with the highest values recorded during the winter DO varies from 7.00±0.20-7.40±0.20 and the lowest during the summer ranging from 5.77±0.25-5.97±0.21. The findings of this study align with those of previous research conducted by Prasad *et al*. (1985), Hulyal and Kaliwal (2011) [9], and Ramulu and Benarjee (2013) [13]. These studies have consistently observed similar patterns in key water quality parameters, such as dissolved oxygen levels, alkalinity, and seasonal variations in carbon dioxide concentrations, across various freshwater ecosystems. The elevated DO levels observed in winter can be attributed to lower water temperatures, which enhanced oxygen solubility, as well as increased photosynthetic activity due to clear water and stable conditions.

Free Carbon Dioxide (CO_2)

Free carbon dioxide (CO_2) dissolved in water acts as a fundamental source of inorganic carbon for aquatic autotrophs, which utilize it during photosynthesis to synthesize organic matter and form structural cellular components. The concentration of free CO_2 in riverine environments is influenced by multiple factors such as atmospheric inputs via rainfall, subsurface groundwater inflow, and the respiratory activities of aquatic organisms. In the present investigation conducted on the Wardha River near Ballarpur, free carbon dioxide levels were recorded in the range of 2.0 mg/L to 6.5 mg/L for all season, and mean free CO_2 concentration were found to be in pre-monsoon season 4.17±0.25-4.30±0.30mg/L. in monsoon 5.7±0.765-95±0.56 mg/L and 3.23±0.49-3.50±0.40 mg/L. Seasonal analysis showed that the highest concentrations occurred during the monsoon season, while the lowest values were observed during winter. The elevated CO_2 levels during monsoon are likely due to the increased decomposition of organic matter and enhanced respiratory activity of aquatic flora and fauna, both of which contribute to CO_2 enrichment in the water column.

Turbidity

Turbidity showed a significant increase during the Pre-monsoon season, ranging from 1.2 to 8.7 NTU across both sites. This is attributed to reduced water volume, intensified anthropogenic activities, and the accumulation of suspended particulate matter, which remains less diluted due to lower flow conditions. Lower turbidity levels were recorded range between 6.42±2.24-6.4 ±2.89 during pre-monsoon, 5.7±0.76-13.03 ± 1.87 mg/L during the monsoon and 1.26±0.10-2.57 ± 1.19 mg/L in post-monsoon seasons.

Electric Conductivity

Electric conductivity (EC) serves as an important indicator of the total ionic content present in water. In the current investigation, higher EC value were likely a result of increased concentrations of dissolved ions, influenced by the presence of pollutants, varying tropic status, domestic wastewater discharges and organic matter. In the current investigation, Electrical conductivity mean values were ranged between 483.33±73.70-490.00±30.00 µS/cm during pre-monsoon, 660.00±43.96-682.5 ± 52.52µS/cm, during monsoon and 516.67±37.85-533.33± 25.16 µS/cm during post-monsoon. (Ahluwalia, 1999; Fokemare and Musaddique, 2001) [1]. A clear seasonal pattern was observed, with conductivity reaching its maximum during the monsoon season and dropping to its lowest during winter months. These findings are consistent with results reported in earlier studies (Datta and Bhagwati 2007; Hulyal and Kaliwal, 2011; Ramulu and Banerjee, 2013) [5, 9, 13].

Total Dissolved Solids (TDS)

The high TDS affect taste, palatability, and suitability for drinking and irrigation. Excess TDS can also harm to sensitive crops. In the present investigation, maximum value of total dissolved solids was between 720.67±70.01-742.67 ± 55.02 mg/L in pre-monsoon, 349.00 ± 33.39-610.25±541.20 mg/L in monsoon season and 573.00 ± 53.56-590.67±154.09mg/L in post-monsoon season. The lowest concentration occurred during monsoon due to

dilution, while summer samples showed higher TDS as a result of increased evaporation and lower water flow. TDS values remained well within the acceptable limit of 500 mg/L indicating good palatability. Gulhane (2022) reported comparable findings, with Total Dissolved Solids (TDS) levels ranging from 210 mg/L to 607 mg/L, based on the assessment of monthly fluctuations in the physicochemical properties of the Wardha River water.

Total Hardnesss

Total hardness of water represents the combined concentration of alkaline earth metal cations, primarily calcium and magnesium salts, which, when combined with bicarbonates and carbonates, contribute to temporary hardness, and when associated with sulphates, chlorides and other mineral acid anions, result in permanent hardness. Total hardness reflects the soap-consuming capacity of water and is an important indicator for domestic and industrial applications, particularly for processes involving boilers. In the present study, total hardness during the pre-monsoon, monsoon and post monsoon seasons was observed to range between 108-365 mg/L. The seasonal variation of total hardness mean value in pre-monsoon season was between 213.00 ± 175.29 -334.67±41.79 mg/L, during monsoon period 119.00±17.09-120.00±8.00mg/Land post-monsoon season between 119.67±88.06-175.00±38.35mg/L. Above values indicate river water transitioned from moderately hard to very hard, likely due to seasonal influences, this variation are likely driven by evaporation during summer, rock water interactions, and discharge from paper mills and municipal sewage system in and around Ballarpur.

Total Alkalinity

Alkalinity is a critical parameter that indicates the capacity of water to neutralize acids, primarily governed by the presences of carbonate and bicarbonate ions. In the present investigation, total alkalinity varies between 72 mg/L to 260 mg/L as CaCO3 across different seasons, the mean concentration of total alkalinity was recorded during the pre-monsoon season 236.67±26.56-190.67 ± 9.24 mg/L, in monsoon season 86.25±13.23- 102.00 ± 18.62 mg/L and 127.00 ± 2.65-134.33 ±30.08mg/L observed during post-monsoon season. Singh *et al*. (2019) [15] also observed comparable alkalinity levels, ranging from 241 mg/L to 293 mg/L as $CaCO_3$, during their physicochemical assessment of river water quality.

Chloride

The primary source of chloride in river water includes industrial discharges, agricultural runoff, and residual pesticides or insecticides. Domestic sewage, especially containing human urine, can contribute significant chloride levels, often range between 4500-5000 ppm. According to the Bureau of Indian Standards (BIS), the permissible limit for chloride in surface water is 250 mg/L. In the present study the chloride concentration exhibited seasonal fluctuations. During the pre-monsoon, chloride levels range from study 97.67 ± 19.55-111.33±17.24 mg/L during the monsoon season, this value marginally increased from 146.50 ± 7.68-150.50±6.61mg/L and post-monsoon value were comparatively moderate, spanning 73.00 ±12.53-73.67 ± 1.53 mg/L. According to Kumar and Puri (2012) [12], the concentration of chlorides in public drinking water should remain below 250 mg/L. Elevated chloride levels can be harmful to fish and other aquatic organisms, as they may not tolerate such conditions.

Iron

Iron is an essential trace element required for the formation of another biological functions in the humans and many other organisms. While it is vital for nutrition and other metabolic activity, excessive intake can cause adverse health effects. As per drinking water quality guidelines, the maximum permissible level of iron is generally limited to 0.3 ppm to prevent health complications. In the present investigation, seasonal monitoring of iron concentration in river water revealed distinct fluctuations. During the pre-monsoon period, iron levels were observed in the range 0.01 to 0.06 mg/L the concentration slightly increased during monsoon season, reaching 0.02 to 0.08 mg/L.

Sulphate

Sulphate is an important water quality parameter, often used to assess the influence of natural geochemical processes and anthropogenic pollution, particularly from industrial discharges. In the current investigation, river water at sapling sites exhibits consistently low sulphate concentration between 6.00 ± 2.65-27.33±18.47 during pre-monsoon season, 22.00±4.00-23.75±1.26 mg/L in monsoon season and 3.33 ± 1.53-10.33 ±13.58 in post-monsoon season. Kulshreshtha *et al*. (1992) [11] reported that sulphate concentrations peaked during the monsoon season in the Manasarovar Reservoir, Bhopal (M.P.), likely due to the influx of sulphate-rich runoff from the surrounding catchment area carried by rainfall. Suggesting a water body that is geochemically stable and relatively unimpacted by significant anthropogenic sulphate pollution. These findings support the classification of the river water in this region as suitable for drinking water supply, agriculture use, and support of aquatic life, with respect to sulphate content.

Calcium

Calcium is a major cation commonly found in natural waters, and its concentration is influenced by both lithological and anthropogenic factors. The calcium levels are primarily governed by the rocks within the watershed. The dissolution of minerals such as calcite and dolomite significantly contribute to the baseflow calcium. Ballarpur is characterized by notable industrial development, particularly the presence of pulp and paper mills. Effluents discharged from these industries may serve as secondary sources of calcium, particularly where lime or calcium carbonate is used in the production process. Seasonal dynamics significantly impact calcium concentration is the river. Elevated levels are typically recorded 52.00 ± 6.00-74.83±11.83mg/L during the pre-monsoon period, 29.20±4.41-30.25±3.50 mg/L in monsoon, and 44.00 ± 7.21- 46.07±9.96 mg/L in post-monsoon. which coincides with lower discharge, higher evaporation rates, and reduce dilution capacity. In contrast, the monsoon efflux of precipitation increases river flow, thereby diluting dissolved ions and generally resulting lower calcium concentrations.

Magnesium

Magnesium is a naturally occurring alkaline earth metal on freshwater systems, primarily derived from the weathering of magnesium-rich minerals such as dolomite, olivine, and serpentine. Seasonal changes influence its concentration higher levels are observed 37.53 ± 14.49-57.90±15.97 mg/L

during the pre-monsoon period due to reduce flow and increased evaporation, while monsoon rains dilute the ion concentration, leading to lower level range between 21.09 ± 0.64- 21.95±3.23 mg/L and moderate to high values observed in post monsoon 29.20 ± 5.44-30.97±6.82 mg/L. Eater quality studies indicate that magnesium levels in this region generally comply with BIS standards for drinking water, which set a desirable limit of 30 mg/L and a maximum permissible limit of 100 mg/L.

Nitrate

The presence of nitrates serves as an important indicator of water quality deterioration resulting from the discharge of waste water into the river system. In the present study, nitrate concentrations in the water samples were found in range of 2.47 ± 1.36-3.40±1.22 mg/L during the pre-monsoon, 4.9 ± 0.73- 5.15±0.65mg/L in the monsoon, and 1.13±0.12-1.73±0.46mg/L in the post monsoon period. Seasonal monitoring indicates that nitrate concentrations in the year stretch remain relatively low but show distinct variation throughout the year. Similar result was observed by the rainy season was period with the highest nitrate-nitrogen concentration which is known to support the formation of blooms (Shai and Sinha,1969; Anderson, *et al.*,1998) [3]. The nitrate content at the sampling sites may be influenced by range of anthropogenic and natural factors.

Observation Table

Table 1: Seasonal variation in physicochemical parameters during 2024-2025 in Wardha river near Dr. Ambedkar ward Ballarpur

Sr. No	Parameters	Winter	Summer	Monsoon
		Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
1	Atmospheric Temperature (°C)	24.00 ± 2.65	34.33 ± 3.06	28.50 ± 3.00
2	Water Temperature (°C)	20.33 ± 1.53	28.67 ± 1.15	25.75 ± 1.50
3	Humidity (%)	53.33 ± 6.43	40.33 ± 18.01	78.25 ± 1.26
4	pH	7.27 ± 0.15	7.40 ± 0.20	7.40 ± 0.22
5	Dissolved Oxygen(mg/L)	7.00±0.20	5.77±0.25	6.33±0.40
6	Free Carbon dioxide(mg/L)	3.50±0.40	4.30±0.30	5.95±0.56
7	Turbidity (NTU)	2.57 ± 1.19	6.44 ± 2.89	13.03 ± 1.87
8	E. Conductivity (µS/cm)	533.33± 25.16	490.00 ± 30.00	682.5 ± 52.52
9	Total Dissolved Solids (mg/L)	573.00 ± 53.56	742.67 ± 55.02	349.00 ± 33.39
10	Total Alkalinity (mg/L)	127.00 ± 2.65	190.67 ± 9.24	102.00 ± 18.62
11	Chloride (mg/L)	73.67 ± 1.53	97.67 ± 19.55	146.50 ± 7.68
12	Sulphate (mg/L)	3.33 ± 1.53	6.00 ± 2.65	22.00 ± 4.00
13	Calcium (mg/L)	44.00 ± 7.21	52.00 ± 6.00	30.25 ± 3.50
14	Total Hardness (mg/L)	119.67 ± 88.06	213.00 ± 175.29	120.00 ± 8.00
15	Magnesium (mg/L)	29.20 ± 5.44	37.53 ± 14.49	21.09 ± 0.64
16	Iron (mg/L)	0.0133 ± 0.0058	0.0067 ± 0.0115	0.035 ± 0.0332
17	Nitrate (mg/L)	1.13 ± 0.12	2.47 ± 1.36	4.9 ± 0.73

Table 2: Seasonal variation in physicochemical parameters during 2024-2025 in Wardha river near Wardha river bridge Mancherial road

Sr, No	Parameters	Winter	Summer	Monsoon
		Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
1	Atmospheric Temperature (°C)	25.10 ±2.76	35.17±4.37	29.50±3.70
2	Water Temperature (°C)	22.67±3.51	30.17±2.75	27.25±1.71
3	Humidity (%)	59.00 ±13.11	38.33±10.07	80.50±1.00
4	pH	7.20±0.10	7.63±0.25	7.38±0.17
5	Dissolved Oxygen(mg/L)	7.40±0.20	5.97±0.21	6.75±0.31
6	FreeCarbon dioxide(mg/L)	3.23±0.49	4.17±0.25	5.7±0.76
7	Turbidity (NTU)	1.26±0.10	6.42±2.24	2.07±0.53
8	E. Conductivity (µS/cm)	516.67±37.85	483.33±73.70	660.00±43.96
9	Total Dissolved Solids (mg/L)	590.67±154.09	720.67±70.01	610.25±541.20
10	Total Alkalinity (mg/L)	134.33 ±30.08	236.67±26.56	86.25±13.23
11	Chloride (mg/L)	73.00 ±12.53	111.33±17.24	150.50±6.61
12	Sulphate (mg/L)	10.33 ±13.58	27.33±18.47	23.75±1.26
13	Calcium (mg/L)	46.07±9.96	74.83±11.83	29.20±4.41
14	Total Hardness (mg/L)	175.00±38.35	334.67±41.79	119.00±17.09
15	Magnesium (mg/L)	30.97±6.82	57.90±15.97	21.95±3.23
16	Iron (mg/L)	0.010± 0000	0.010±0.000	0.053±0.021
17	Nitrate (mg/L)	1.73± 0.46	3.40±1.22	5.15±0.65

Conclusion

The present investigation highlights that the water quality of the Wardha river at sampling sites is influenced by seasonal fluctuations and localized anthropogenic activities. While most physio-chemical parameters such as pH, dissolve oxygen, and electric conductivity remained within permissible limits, elevated values of nutrient concentrations in certain locations indicate moderate contamination. These variations are particularly associated with agricultural runoff, untreated domestic discharge, and reduced dilution capacity during low-flow seasons. The results underscore the need for regular water quality monitoring, strict

enforcement of pollution control regulations, and adoption of sustainable land and wastewater management practices in the surrounding catchment. Such interventions are essential to preserve the ecological balance of the river and ensure its continued use as a reliable water resource.

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