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Assessment of Seasonal Variation in Physicochemical Characteristics of Water in the Kadvi River Basin, Maharashtra, India

Ganesh S. Shinde[1*]; Sambhaji D. Shinde[2]; Prakash S. Shinde[3]

[1;3]Ph.D. Research Scholar, Shivaji University, Kolhapur, Maharashtra, PIN-416004, India
[2]Professor, Department of Geography, Shivaji University, Kolhapur, Maharashtra, PIN-416004, India

Corresponding Author; Ganesh S. Shinde[1*]

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Abstract: Assessment and monitoring of physicochemical parameters are crucial for sustainable water resource management and the protection of public health. The present study evaluates water quality in the Kadvi River Basin, Maharashtra (India), through systematic sampling of river, lake, pond, and well water sources during pre- and post-monsoon seasons. Key physicochemical parameters, including pH, electrical conductivity (EC), salinity, dissolved oxygen (DO), total alkalinity, chlorides, carbonates, bicarbonates, total dissolved solids (TDS), and major ions such as calcium, magnesium, sodium, potassium, and phosphate, were analyzed using standard laboratory methods. Significant fluctuations in physicochemical parameters were observed in villages such as Bhadale and Bambawade. The post-monsoon samples recorded comparatively higher concentrations of sodium (up to 99.44 mg/L) and potassium (up to 53.82 mg/L). Hydrochemical characterization using Piper plot analysis revealed that the dominant water type is Ca–Mg–HCO_3 facies, indicating carbonate weathering as the primary geochemical control. During the pre-monsoon season, water samples exhibited a transition towards mixed Ca–Mg–Cl facies with increased sodium content, attributed to evaporation effects and prolonged water–rock interaction. In contrast, post-monsoon samples were predominantly clustered within the freshwater zone, reflecting dilution effects and improved water quality due to rainfall recharge. The findings emphasize the need for regular monitoring and the implementation of location-specific water management strategies, particularly in high-elevation and resource-limited villages, to ensure long-term water sustainability and ecosystem health.

Keywords: *Physicochemical Analysis; Water Quality Assessment; Seasonal Variation; Environmental Monitoring; River Basin Management.*

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I. INTRODUCTION

Water is fundamental to life and serves as a universal solvent, supporting drinking, sanitation, agriculture, industry, and ecosystem functioning. Despite its essential role, rapid population growth, urbanization, and unsustainable exploitation of natural resources have placed immense pressure on water systems, leading to widespread degradation (Ghosh, 2002). In recent decades, the deterioration of water quality has emerged as a critical global issue due to the increasing discharge of industrial and domestic effluents into natural water bodies (Tyagi et al., 2025). Continuous monitoring and assessment of water quality parameters have therefore become essential for ensuring the safety and sustainability of water resources.

A primary concern is the contamination of water resources through soil pollution. The introduction of hazardous substances—such as heavy metals (lead, mercury, cadmium), pesticides, industrial chemicals, and untreated sewage—into the environment compromises soil quality, which in turn affects water sources via runoff and leaching. Major contributors include mining and refining operations, improper waste management, excessive agricultural inputs, and accidental spills. These contaminants persist in the environment, accumulate in food chains, and pose long-term risks to human health and aquatic ecosystems (Environmental Protection Agency, 2022). Studies have shown that water quality is significantly influenced by geological formations, sediment interactions, and environmental conditions, which control the concentration

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of dissolved substances and overall water chemistry (Sreelatha et al., 2022).

The availability of safe and accessible water is not only a public health imperative but also a recognized human right. In 2010, the United Nations General Assembly affirmed the right to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic use (UN General Assembly, 2010). Improved water supply and sanitation are closely linked to economic development and poverty reduction. Recent research has emphasized the importance of integrated approaches in water quality assessment, combining physico-chemical analysis with socio-economic and behavioral factors to better understand water usage patterns and risks (Ajith et al., 2023). Additionally, tools such as the Water Quality Index (WQI) have been widely used to simplify complex datasets into a single value, enabling effective evaluation of water suitability for drinking purposes (Prajapati and Bilas).

Water resources are derived from multiple sources, each with distinct characteristics and vulnerabilities. Rainwater, collected through harvesting techniques, provides a renewable supply, particularly in regions with seasonal precipitation (UN Water, 2021; UNEP, 2020). Groundwater, stored in aquifers, supplies nearly 50% of the world's drinking water and 40% of agricultural water but is increasingly threatened by over-extraction and contamination (WHO, 2023). Surface water bodies such as rivers, lakes, and reservoirs are highly dynamic and sensitive to land-use changes and anthropogenic activities. Studies conducted in regions like Pandharpur and other parts of Maharashtra indicate that human activities, including mass gatherings and improper waste disposal, significantly influence water quality, necessitating spatial and seasonal assessment of water parameters (2022 study). Rivers, wells, lakes, and ponds collectively form an interconnected hydrological system that requires careful management.

Given the interconnected nature of these water sources and their vulnerability to anthropogenic and seasonal pressures, systematic monitoring of physicochemical water quality is essential. Therefore, the present study focuses on assessing water quality in the Kadvi River Basin (Maharashtra, India) across pre- and post-monsoon seasons. The study aims to analyze seasonal variations, identify influencing factors, and provide a scientific basis for sustainable water resource management and planning.

➢ *Objectives*

This study addresses the need for a comprehensive assessment of water quality dynamics in the Kadvi River Basin by analyzing physicochemical parameters across pre- and post-monsoon seasons. The specific objectives are:

- To evaluate the spatial and seasonal variations of physicochemical parameters and identify the dominant hydrochemical facies governing water quality.
- To assess the influence of seasonal variability and anthropogenic activities on water quality.

➢ *Study Area*

The Kadvi River originated from the high altitude of the Amba village area. This is a heavy rainfall-receiving area in the Kadvi River basin. The Kadvi River basin extends between 16°48' 51.369" to 17° 3' 5.686" north latitudes and 73°45'58.957" to 74° 05' 35.303" east longitudes. The Kadvi River basin area covers 428.81 sq. km concerning SOI toposheets 47G16, 47H13, and 47L1. Kadvi River originated in the western ghat near Amba village, Shahuwadi, Kolhapur, and Maharashtra, India. Kadvi River is the main tributary of the Warna River. Kadvi River flows west to the eastern side and meets the Warna River near Thergaon village. Lombardi, Potphogi, and Shali Rivers are sub-tributaries of the Kadvi River. The length of the Kadvi River is 48.66 km. Kadvi River basin covers nearly 41.50% of Shahuwadi tehsil, so Kadvi River is known as the backbone of Shahuwadi tehsil (Chougale & Sapkale). The climate of the basin is generally moderate temperate. Heavy rainfall is found at an average of 1680 mm in this basin from June to October.

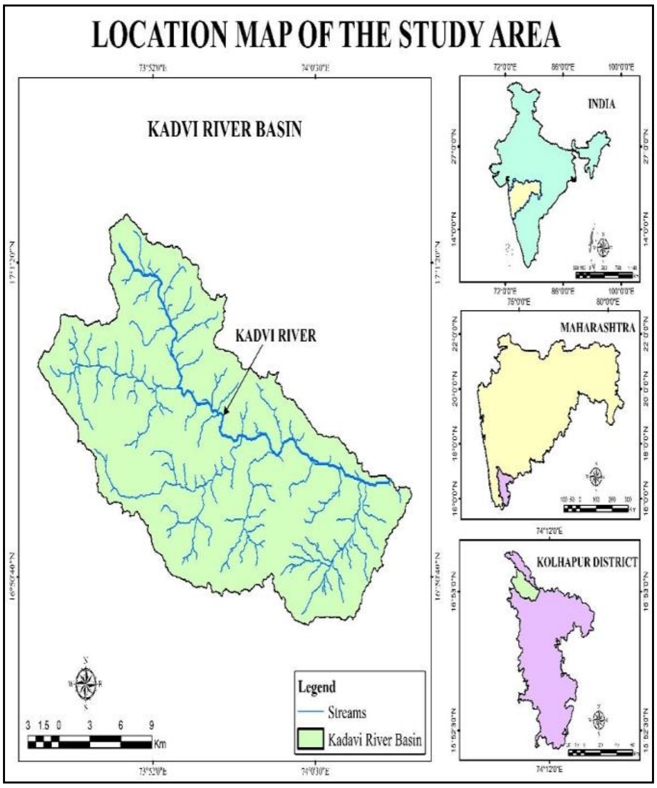

Fig 1 Location Map and Drainage Network of Kadavi River Basin
(Source: Based on Survey of India Maps)

The study area includes several villages such as Bhadale, Bambawade, Shahuwadi, Malkapur, and Donoli representing a mix of rural and peri-urban settlements. Water sources within the basin comprise rivers, lakes, ponds, wells, and borewells, which serve as critical resources for drinking, domestic use, agriculture, and livestock. The region's dependence on seasonal rainfall, coupled with anthropogenic activities including agriculture and aquaculture, makes it particularly vulnerable to seasonal fluctuations in water quality.

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II. MATERIALS AND METHODOLOGY

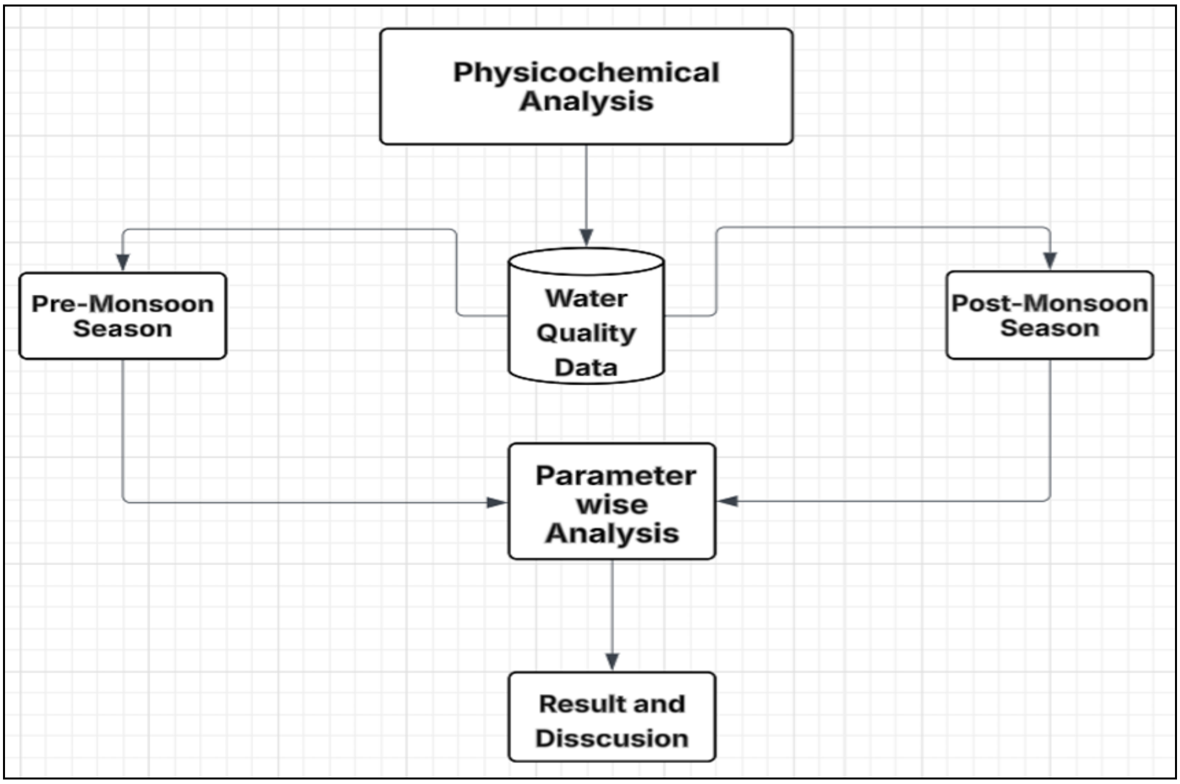

Fig 2 Methodology Chart

Water and soil samples will be collected from diverse aquatic sources—including rivers, lakes, ponds, wells, and tube wells—using a high-quality sampling kit. The basin will be segmented into sampling zones based on hydrological characteristics, and samples will be gathered regularly following identification of potential pollutant sources. Physicochemical parameters were analyzed using standard methods. pH was measured using a pH meter, while electrical conductivity (EC) and total dissolved solids (TDS) were determined using a conductivity/TDS meter. Turbidity was assessed with a turbidity meter. Dissolved oxygen (DO) was analyzed via Winkler's titration method. Alkalinity, hardness, calcium, magnesium, carbonates, bicarbonates, chloride, sodium, and phosphorus were quantified through titration techniques. Fluoride and nitrate levels were determined using a UV spectrophotometer and the SPADNS method (Prajapati et al., 2015).

III. RESULTS AND DISSCUSSION

Water samples were collected from the same locations during pre- and post-monsoon seasons and analyzed using standardized laboratory procedures. Results revealed that Bhadale Village exhibited high pre-monsoon salinity and notable chloride variation, while post-monsoon total hardness was lower across most areas. Water from Bhadale's small pond and borewell showed elevated bicarbonates and total dissolved solids. Bhedvade Village recorded low phosphate, sodium, and sulfate levels, whereas Gholaswadi Village had low magnesium, calcium, potassium, and sodium. These discrepancies were attributed to anthropogenic activities such as aquaculture and wastewater discharge, alongside natural factors including precipitation, water flow, and local geomorphology.

- pH : The pH values in the study area range from 6.05 to 7.69 (pre-monsoon) and 5.63 to 7.44 (post-monsoon), indicating slightly acidic to neutral conditions. A marginal decrease in pH during the post-monsoon season suggests the influence of rainwater recharge and dissolved carbon dioxide. Overall, the pH values fall within permissible limits, indicating suitability for most domestic purposes.
- Electrical Conductivity (EC): Electrical Conductivity shows significant variation, ranging from 60.82 to 817.3 mS/cm (pre-monsoon) and 52.5 to 1615 mS/cm (post-monsoon). The highest value recorded in the post-monsoon period indicates increased ionic concentration due to runoff and possible contamination sources. Higher EC reflects elevated dissolved salts and minerals in water.
- Chlorides: Chloride concentration varies from 26.19 to 139.70 mg/L (pre-monsoon) and 34.92 to 296.87 mg/L (post-monsoon). The sharp increase in post-monsoon values indicates the influence of surface runoff, wastewater discharge, and anthropogenic inputs. Elevated chloride levels may affect taste and indicate pollution.
- Salinity: Salinity ranges between 0.0473–0.2524 ppt (pre-monsoon) and 0.0631–0.5363 ppt (post-monsoon). Higher salinity in post-monsoon samples, especially at specific locations, suggests the accumulation of dissolved salts from runoff and localized contamination.

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- Carbonates (CO_3^{2-}): Carbonate concentrations are generally low in both seasons, with values ranging from 0 to 18 mg/L. Their limited presence indicates that carbonate alkalinity is less dominant compared to bicarbonates, and the water chemistry is primarily governed by bicarbonate ions.
- Bicarbonates (HCO_3^-): Bicarbonate values range from 6.1 to 140.3 mg/L (pre-monsoon) and 6.1 to 158.6 mg/L (post-monsoon). The increase during the post-monsoon season reflects enhanced carbonate weathering and dissolution processes due to rainfall recharge.
- Total Alkalinity: Total alkalinity varies from 18.1 to 146.3 mg/L (pre-monsoon) and 12.1 to 170.6 mg/L (post-monsoon). The higher alkalinity in post-monsoon samples indicates increased buffering capacity due to dissolved bicarbonates and carbonates.
- Calcium (Ca^{2+}): Calcium concentration ranges between 4 to 50 mg/L (pre-monsoon) and 4 to 46 mg/L (post-monsoon). The values indicate moderate contribution from carbonate rock dissolution, with slight seasonal variation due to dilution during monsoon recharge.
- Magnesium (Mg^{2+}): Magnesium levels vary from 1.2 to 18 mg/L (pre-monsoon) and 1.2 to 24 mg/L (post-monsoon). The increase in post-monsoon values suggests leaching of minerals from soil and rocks during rainfall.
- Total Hardness: Total hardness ranges from 14.93 to 189.12 mg/L (pre-monsoon) and 14.93 to 203.64 mg/L (post-monsoon). Most samples fall under moderately hard to hard water category, indicating the presence of calcium and magnesium salts.
- Sodium (Na^+): Sodium concentration varies from 2.85 to 30.91 mg/L (pre-monsoon) and 2.52 to 99.44 mg/L (post-monsoon). The significant increase in post-monsoon samples suggests anthropogenic influences such as agricultural runoff, domestic wastewater, and aquaculture activities.

Table 1 Physicochemical Analysis Pre-Monsoon Season.

Sample ID	pH	EC (mS/cm)	Chlorides (mg/L) or (ppm)	Salinity (ppt)	Carbonates	Bicarbonates	Total Alkalinity	Calcium	Magnesium	Total Hardness	Sodium (Na)	Potassium (K)	DO	Total Dissolved Solids (ppt)
1	6.25	80.42	26.1946	0.0473	0	36.6	36.6	4	6	34.66	3.86	0.43	7.651	0.034
2	6.07	67.25	43.6576	0.0789	0	42.7	42.7	4	3.6	24.8	3.29	0.59	7.45	0.03
3	6.05	84.08	52.3892	0.0946	0	36.6	36.6	4	1.2	14.93	4.52	0.18	7.45	0.035
4	7.69	172.9	43.6576	0.0789	12	30.5	42.5	4	1.2	14.93	26.93	0.21	8.054	0.073
5	6.61	67.33	43.6576	0.0789	0	30.5	30.5	8	2.4	29.86	2.85	0.27	8.658	0.028
6	6.26	212	34.9261	0.0631	0	79.3	79.3	14	2.4	44.86	8.25	0.68	8.658	0.092
7	6.72	519.8	69.8522	0.1262	0	140.3	140.3	16	1.2	44.93	30.91	0.48	8.054	0.226
8	7.07	635.5	61.1207	0.1104	6	115.9	121.9	22	14.4	114.18	18.39	0.57	8.054	0.28
9	6.66	816.3	122.2414	0.2208	0	140.3	140.3	44	18	183.98	21.94	3.5	6.846	0.359
10	7.11	731.6	104.7783	0.1893	18	97.6	115.6	40	13.2	154.25	26.04	19.78	5.436	0.32
11	7.14	817.3	139.7044	0.2524	6	140.3	146.3	50	15.6	189.12	22.33	7.62	7.45	0.36
12	6.58	133.6	43.6576	0.0789	6	30.5	36.5	8	3.6	34.8	5.57	0.54	7.853	0.059
13	6.33	60.82	43.6576	0.0789	0	30.5	30.5	6	1.2	19.93	2.98	0.33	8.054	0.027
14	6.18	91.31	34.9261	0.0631	12	6.1	18.1	6	4.8	34.73	4.05	0.28	8.255	0.041

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Table 2 Physicochemical Analysis Post-Monsoon Season.

Sample ID	pH	EC (mS/cm)	Chlorides (mg/L) or (ppm)	Salinity (ppt)	Carbonates	Bicarbonates	Total Alkalinity	Calcium	Magnesium	Total Hardness	Sodium (Na)	Potassium (K)	DO	Total Dissolved Solids (ppt)
1	5.63	229.5	52.3892	0.0946	0	67.1	67.1	18	10.8	89.39	8.09	0.87	7.45	0.103
2	6.02	52.5	43.6576	0.0789	0	30.5	30.5	6	1.2	19.93	2.52	0.28	7.249	0.023
3	6.22	237.9	43.6576	0.0789	0	79.3	79.3	16	1.2	44.93	11.54	0.35	7.853	0.105
4	6.16	99.76	52.3892	0.0946	0	42.5	42.7	6	1.2	19.93	4.74	0.36	7.651	0.042
5	6.59	79.98	34.9261	0.0631	0	36.6	36.6	6	2.4	24.86	3.13	0.36	8.457	0.032
6	6.46	394.9	52.3892	0.0946	0	73.2	73.2	24	8.4	94.52	11.67	0.32	7.853	0.173
7	6.73	322.6	43.6576	0.0789	0	97.6	97.6	18	10.8	89.39	9.5	0.15	8.457	0.141
8	6.83	758.9	113.5099	0.2051	0	140.3	140.3	46	10.8	159.39	21.51	6.29	6.846	0.336
9	7.07	1615	296.8719	0.5363	12	158.6	170.6	42	24	203.64	99.44	53.82	4.228	0.699
10	7.31	832.4	122.2414	0.2208	12	97.6	109.6	32	19.2	158.91	33.03	1.95	4.228	0.369
11	7.44	676.5	87.3153	0.1577	18	115.9	133.9	14	7.2	64.59	43.87	0.9	7.45	0.308
12	6.5	58.16	34.9261	0.0631	0	36.6	36.6	6	2.4	24.86	2.78	0.34	8.054	0.026
13	6.4	58.63	43.6576	0.0789	6	18.3	24.3	8	1.2	24.93	2.79	0.32	8.457	0.026
14	6.15	54.53	43.6576	0.0789	6	6.1	12.1	4	1.2	14.93	2.63	0.35	8.255	0.024

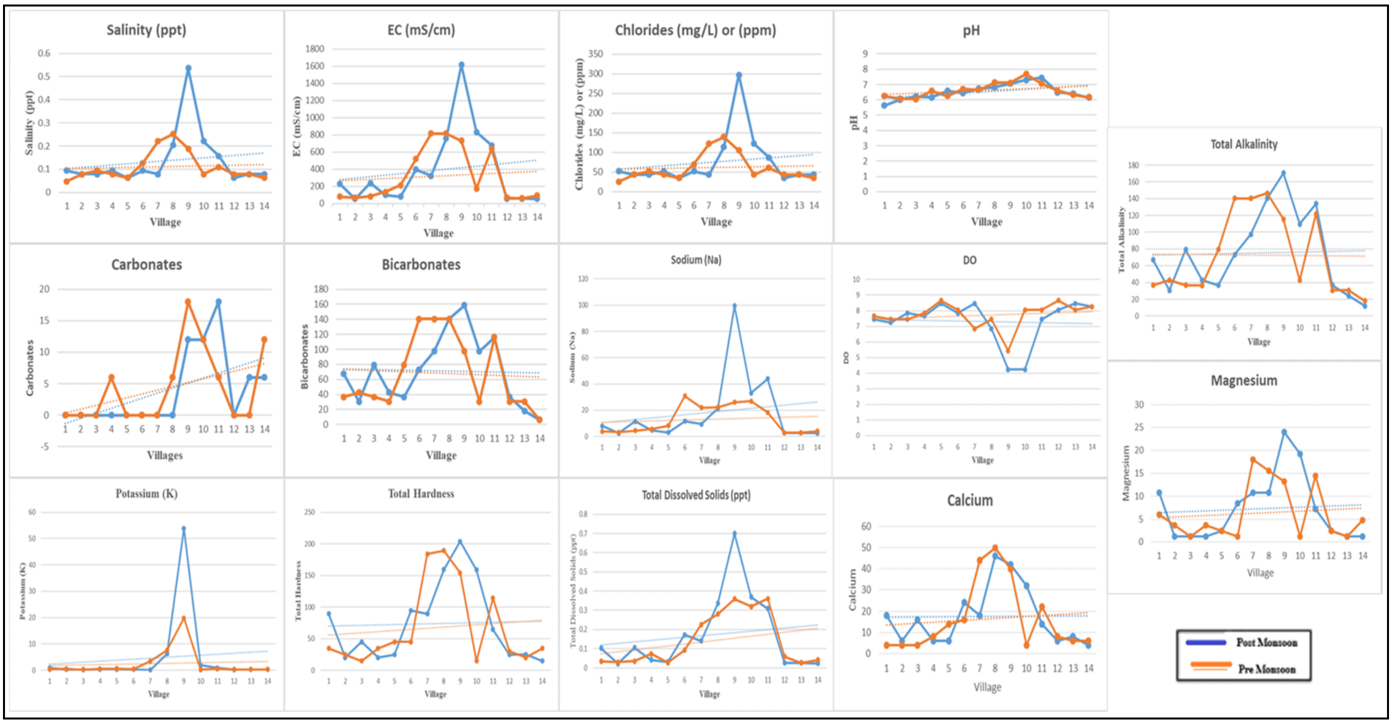

Fig 3 Water Quality Analysis (Pre and Post Monsoon Season).

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- Potassium (K^+): Potassium levels range from 0.18 to 19.78 mg/L (pre-monsoon) and 0.15 to 53.82 mg/L (post-monsoon). Elevated potassium concentrations in post-monsoon samples indicate fertilizer runoff and soil-water interactions.
- Dissolved Oxygen (DO): DO values range from 5.436 to 8.658 mg/L (pre-monsoon) and 4.228 to 8.457 mg/L (post-monsoon). Lower DO levels in certain post-monsoon samples indicate higher organic load and reduced oxygen availability, which may impact aquatic ecosystems.
- Total Dissolved Solids (TDS): TDS values range from 0.027 to 0.36 ppt (pre-monsoon) and 0.023 to 0.699 ppt (post-monsoon). The increase in post-monsoon TDS reflects the addition of dissolved materials through runoff and leaching processes.

➢ *Piper Plot Analysis (Pre and Post Monsoon Seasonal Interpretation):*

The Piper diagram clearly distinguishes pre-monsoon samples (triangles) and post-monsoon samples (squares), allowing comparison of seasonal hydrochemical behavior. A noticeable clustering pattern shows that post-monsoon samples are more compact, whereas pre-monsoon samples are relatively scattered, indicating higher chemical variability before rainfall recharge.

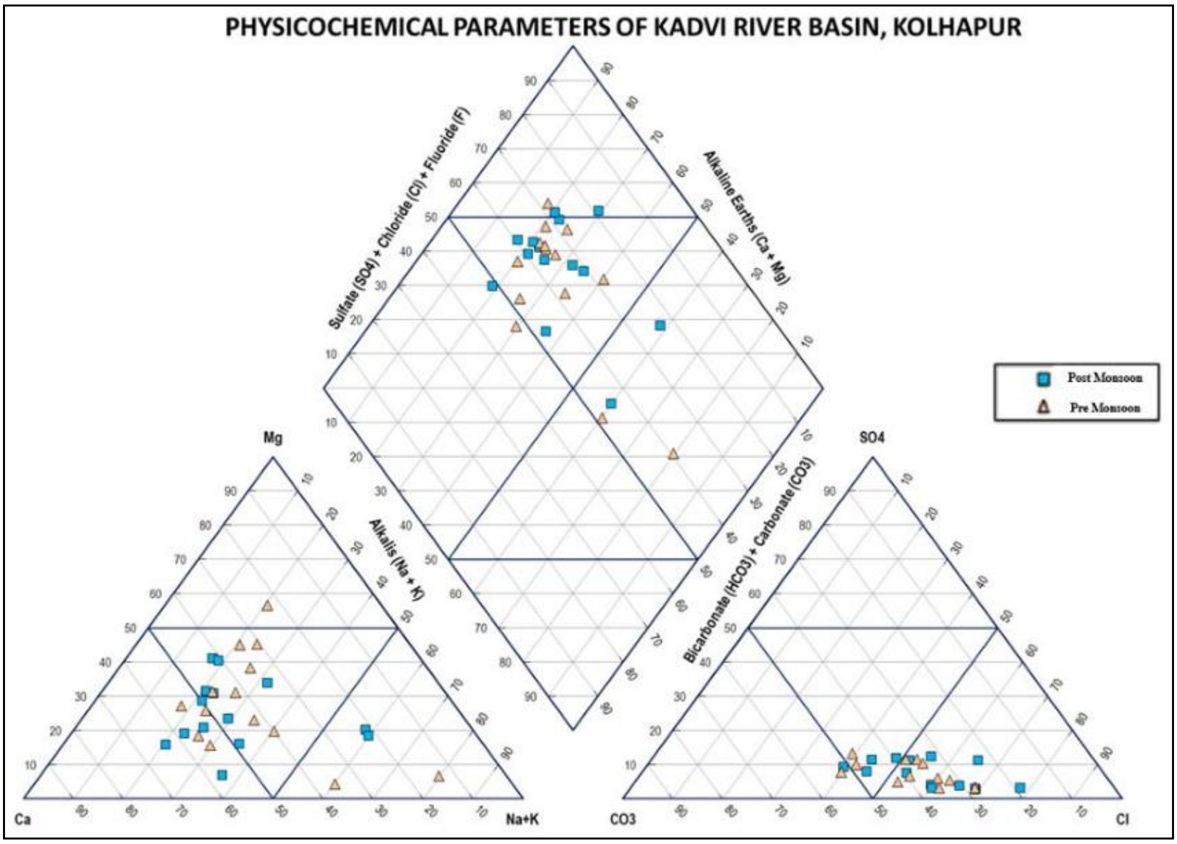

Fig 4 Piper Plot of Water Quality Analysis (Pre and Post Monsoon Season).

➢ *Cation Composition (Ca–Mg–Na+K):*

In the cation triangle, both seasons are dominated by Ca^{2+} and Mg^{2+} ions, confirming alkaline earth dominance. However, pre-monsoon samples show a wider spread toward the Na+K apex, indicating enrichment of sodium due to evaporation, longer residence time, and possible ion exchange. In contrast, post-monsoon samples are more tightly grouped in the Ca–Mg zone, reflecting dilution and fresh recharge. This suggests that monsoonal recharge reduces sodium concentration and restores calcium dominance.

➢ *Anion Composition (HCO_3–CO_3–Cl–SO_4):*

The anion triangle shows a clear dominance of bicarbonate (HCO_3^-) in both seasons, but with distinct seasonal variation. Pre-monsoon samples exhibit partial shifting toward chloride (Cl^-), indicating concentration of salts and possible anthropogenic inputs (e.g., agriculture). Post-monsoon samples cluster closer to the bicarbonate field, confirming dilution of chloride and sulphate due to rainfall recharge. Carbonate presence in a few samples indicates alkaline conditions in localized zones.

➢ *Hydro chemical Facies (Central Diamond Field):*

The central diamond plot reveals that the dominant hydro chemical facies is Ca–Mg–HCO_3 type in both seasons, representing fresh groundwater controlled by carbonate weathering. However, pre-monsoon samples show a noticeable shift toward mixed Ca–Mg–Cl facies, especially for samples with higher EC and TDS. These mixed facies indicate increased mineralization, ion exchange, and anthropogenic influence during the dry period. In contrast, post-monsoon samples are concentrated in the Ca–Mg–

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HCO_3 field, showing improved water quality and reduced chemical complexity.

➢ *Geochemical Processes Controlling Water Chemistry:*

The Piper plot suggests that carbonate weathering is the primary geochemical process controlling groundwater chemistry throughout the year. During pre-monsoon, evaporation, ion exchange, and concentration effects increase the proportion of Na^+ and Cl^- ions, leading to more dispersed plotting. After monsoon, recharge and dilution processes dominate, reducing ionic concentration and shifting the chemistry toward bicarbonate-rich fresh water. The limited spread toward the SO_4 field indicates minimal influence of sulphate minerals or industrial contamination.

➢ *Water Quality Implications:*

Seasonal variation shows that groundwater quality is comparatively better during the post-monsoon period, as indicated by clustering in the fresh water zone. Pre-monsoon samples, although slightly more mineralized, still largely fall within acceptable limits. The absence of strong Na–Cl type dominance suggests no significant salinity hazard, and the persistence of Ca–Mg–HCO_3 facies indicates suitability for drinking and irrigation, with only a few localized concerns.

IV. CONCLUSION

This study assessed the physicochemical water quality of the Kadvi River Basin across pre- and post-monsoon seasons, revealing significant seasonal variability influenced by both natural hydrological processes and anthropogenic activities. The results demonstrated that water quality parameters—particularly salinity, dissolved oxygen, electrical conductivity, sodium, and potassium—exhibited pronounced fluctuations, with the most marked changes observed in Bhadale and Bambawade villages. Elevated post-monsoon concentrations of sodium and potassium suggest contributions from anthropogenic sources such as aquaculture, agricultural runoff, and wastewater discharge, alongside natural processes like evaporation and weathering. Piper plot analysis confirmed that carbonate weathering is the dominant geochemical process governing water chemistry, with Ca–Mg–HCO_3 as the primary hydrochemical facies. Pre-monsoon samples displayed a shift toward mixed Ca–Mg–Cl facies and sodium enrichment due to evaporation and longer residence time, whereas post-monsoon samples clustered tightly in the fresh water zone, indicating dilution and improved water quality following rainfall recharge. Despite localized mineralization, the absence of strong Na–Cl dominance and the persistence of Ca–Mg–HCO_3 facies suggest that water in the basin remains largely suitable for drinking and irrigation. However, the vulnerability of high-elevation villages with limited water sources underscores the necessity for routine monitoring and targeted management interventions. This study provides a scientific foundation for sustainable water resource management in the Kadvi River Basin and highlights the importance of continued surveillance to safeguard public health and aquatic ecosystems in the face of seasonal and anthropogenic pressures.

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