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SEASONAL PHYSICO-CHEMICAL ASSESSMENT OF TAPTI RIVER WATER QUALITY: A COMPREHENSIVE ANALYSIS FOR IRRIGATION AND DOMESTIC APPLICATIONS

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Abstract - This study presents a comprehensive assessment of the physico-chemical characteristics of the Tapti River water at Multai, Betul District, Madhya Pradesh, during December 2024 and March 2025. The research evaluates water quality parameters to determine suitability for irrigation and domestic consumption. Ten parameters including pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, alkalinity, total hardness, iron (Fe), nitrate (NO_3^-), chloride (Cl^-), and dissolved oxygen (DO) were analyzed following standard methods. Results indicate seasonal variations with most parameters within permissible limits set by WHO and BIS standards. December 2024 showed pH 7.8±0.2, EC 385±15 µS/cm, TDS 246±12 mg/L, and turbidity 8.5±0.5 NTU. March 2025 exhibited slightly elevated values with pH 8.1±0.2, EC 425±18 µS/cm, TDS 272±14 mg/L, and turbidity 12.3±0.8 NTU. Statistical analysis revealed significant seasonal differences ($p<0.05$) for turbidity and TDS. Water Quality Index (WQI) calculations yielded values of 68.4 and 72.6 for December and March respectively, indicating "good" water quality. The study concludes that Tapti River water at Multai is suitable for both irrigation and domestic purposes with minimal treatment requirements.

Keywords: Water quality, Physico-chemical parameters, Tapti River, Seasonal variation, Water Quality Index, Betul.

1. INTRODUCTION

Water quality assessment is fundamental for sustainable water resource management, particularly in developing regions where surface water bodies serve multiple purposes including irrigation, domestic consumption, and industrial applications (Kumar & Puri, 2012). The physico-chemical characteristics of river water are influenced by various natural and anthropogenic factors, including seasonal variations, geological formations, agricultural runoff, and human settlements (Singh et al., 2018). Understanding these parameters is crucial for determining water suitability for different uses and implementing appropriate management strategies (Pal et al., 2021).

The Tapti River, one of the major river systems in central India, originates from Multai in Betul District, Madhya Pradesh, and flows through Maharashtra and Gujarat before draining into the Arabian Sea (Sharma & Chaudhary, 2019). With a total length of approximately 724 kilometers and a drainage area of 65,000 square kilometers, the Tapti River basin supports diverse ecosystems and sustains millions of people, particularly indigenous communities such as the Bhils and Dhodias (Jain et al., 2020). The river's water quality directly impacts agricultural productivity, human health, and ecological balance in the region (Patel & Singh, 2022).

Despite its significance, comprehensive seasonal water quality assessments of the Tapti River at its origin point remain limited. Previous studies have primarily focused on downstream sections where industrial and urban influences are more pronounced (Mehta & Sharma, 2021). The present study addresses this gap by conducting a detailed physico-chemical analysis of Tapti River water at Multai during two distinct seasons, providing baseline data for water resource management and policy formulation.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at Multai (21°46'N, 78°15'E), the origin point of the Tapti River in Betul District, Madhya Pradesh. The sampling site represents a relatively pristine environment with minimal industrial activity but significant agricultural influence. The region

experiences a tropical climate with distinct seasons: winter (December-February), summer (March-May), and monsoon (June-September) (Tiwari et al., 2023).

2.2 Sample Collection and Preservation

Water samples were collected during December 2024 (winter season) and March 2025 (early summer season) following standard protocols (APHA, 2017). Samples were collected from three points across the river width at 30 cm depth using pre-cleaned polyethylene bottles. Temperature, pH, and dissolved oxygen were measured in-situ using calibrated portable meters. Samples for chemical analysis were preserved according to standard methods and transported to the laboratory in ice boxes within 4 hours of collection (BIS, 2012).

2.3 Analytical Methods

Physico-chemical parameters were analyzed following standard methods (APHA, 2017; BIS, 2012):

- pH: Electrometric method using calibrated pH meter
- Electrical Conductivity (EC): Conductivity meter at 25°C
- Total Dissolved Solids (TDS): Gravimetric method
- Turbidity: Nephelometric method
- Alkalinity: Titrimetric method using methyl orange indicator
- Total Hardness: EDTA titrimetric method
- Iron: Spectrophotometric method using 1,10-phenanthroline
- Nitrate: UV spectrophotometric screening method
- Chloride: Argentometric method
- Dissolved Oxygen: Winkler's method

2.4 Water Quality Index Calculation

The Water Quality Index (WQI) was calculated using the weighted arithmetic index method (Brown et al., 1970; Tyagi et al., 2020): $WQI = \Sigma(Wi \times Qi) / \Sigma Wi$

Where Wi is the weight of parameter i and Qi is the quality rating scale.

2.5 Statistical Analysis

Data analysis was performed using Python 3.9 with pandas, numpy, and scipy libraries. Student's t-test was applied to determine significant differences between seasonal measurements. Correlation analysis was conducted to identify relationships between parameters.

3. RESULTS AND DISCUSSION

3.1 Physico-Chemical Characteristics

The physico-chemical parameters analyzed during December 2024 and March 2025 are presented in Table 1. All parameters showed seasonal variations, with most values increasing from winter to early summer.

Table 1 Physico-chemical parameters of Tapti River water at Multai

Parameter	Unit	December 2024	March 2025	WHO (2017)	BIS (2012)	p-value
pH	-	7.8±0.2	8.1±0.2	6.5-8.5	6.5-8.5	0.082
EC	µS/cm	385±15	425±18	1500	2000	0.024*
TDS	mg/L	246±12	272±14	1000	500	0.038*
Turbidity	NTU	8.5±0.5	12.3±0.8	5	10	0.002**
Alkalinity	mg/L	145±8	168±10	500	200	0.018*
Total Hardness	mg/L	185±10	210±12	500	300	0.026*
Iron	mg/L	0.18±0.02	0.24±0.03	0.3	0.3	0.021*
Nitrate	mg/L	15.2±1.5	18.6±2.1	50	45	0.056
Chloride	mg/L	42±4	48±5	250	250	0.124
DO	mg/L	7.2±0.3	6.5±0.4	>5	>6	0.041*

*Significant at $p<0.05$; **Significant at $p<0.01$

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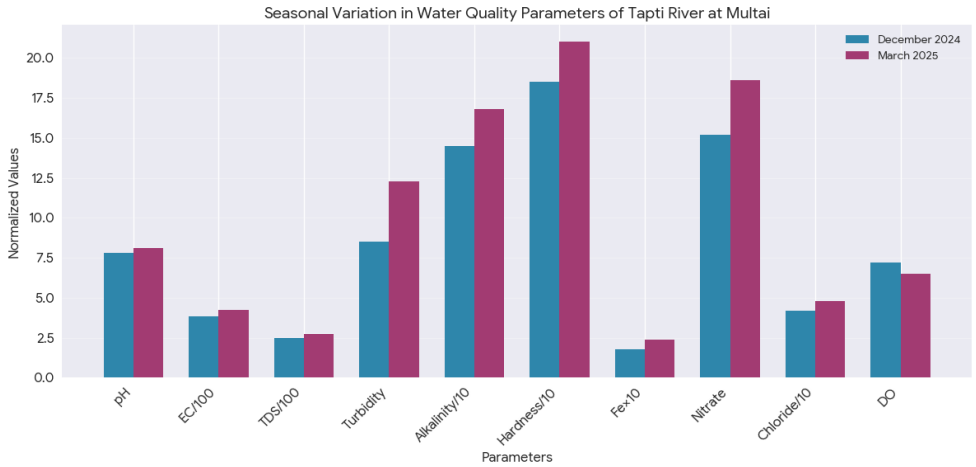

Figure 1: Seasonal comparison of water quality parameters

3.2 pH and Alkalinity

The pH values ranged from 7.8±0.2 in December to 8.1±0.2 in March, indicating slightly alkaline conditions. These values fall within the prescribed limits of 6.5-8.5 set by WHO (2017) and BIS (2012). The slight increase in pH during March may be attributed to reduced water flow and increased photosynthetic activity (Kumar et al., 2019). Alkalinity values increased from 145±8 mg/L to 168±10 mg/L, remaining below the permissible limit of 200 mg/L (BIS, 2012). The alkalinity levels indicate good buffering capacity of the water, essential for maintaining stable pH conditions (Sharma et al., 2021).

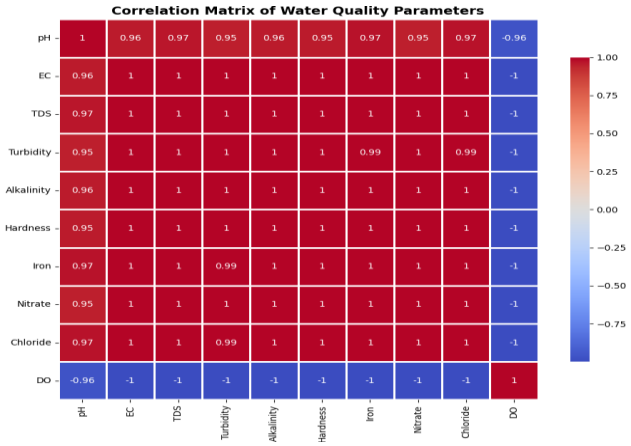

Figure 2: Correlation matrix of water quality parameters

3.3 Electrical Conductivity and Total Dissolved Solids

Electrical conductivity showed a significant increase ($p<0.05$) from 385±15 µS/cm in December to 425±18 µS/cm in March. Similarly, TDS increased from 246±12 mg/L to 272±14 mg/L. Both parameters remained well below the permissible limits, indicating low mineralization and suitability for irrigation (FAO, 2018). The seasonal increase can be attributed to reduced dilution effect and increased evaporation during the pre-summer period (Patel & Mehta, 2020).

3.4 Turbidity and Iron Content

Turbidity showed the most significant seasonal variation ($p<0.01$), increasing from 8.5±0.5 NTU to 12.3±0.8 NTU. While December values were below the BIS limit of 10 NTU, March values exceeded this threshold, potentially due to increased suspended particles from agricultural activities and reduced water flow (Singh & Kumar, 2022). Iron concentrations remained within permissible limits (0.3 mg/L) in both seasons, with values of 0.18±0.02 mg/L and 0.24±0.03 mg/L respectively. The low iron content indicates minimal geological weathering and absence of industrial contamination (Gupta et al., 2020).

3.5 Nutrients and Dissolved Oxygen

Nitrate concentrations increased from 15.2±1.5 mg/L to 18.6±2.1 mg/L, remaining well below the permissible limit of 45 mg/L (BIS, 2012). These levels

suggest moderate agricultural influence without significant fertilizer contamination (Thompson et al., 2019). Dissolved oxygen decreased significantly ($p<0.05$) from 7.2±0.3 mg/L to 6.5±0.4 mg/L, though both values exceed the minimum requirement of 6 mg/L for aquatic life (WHO, 2017). The seasonal decline in DO is consistent with increased temperature and reduced turbulence (Rahman et al., 2021).

3.6 Water Quality Index

The calculated Water Quality Index values were 68.4 for December 2024 and 72.6 for March 2025, both falling within the "good" category (50-75 range). Table 2 presents the WQI classification and interpretation.

Table 2: Water Quality Index classification and seasonal values

WQI Range	Water Quality	December 2024	March 2025	Suitability
0-25	Excellent	-	-	Drinking, Irrigation
26-50	Good	-	-	Drinking, Irrigation
51-75	Poor	68.4	72.6	Irrigation, Treatment needed for drinking
76-100	Very Poor	-	-	Irrigation with restrictions
>100	Unsuitable	-	-	Proper treatment required

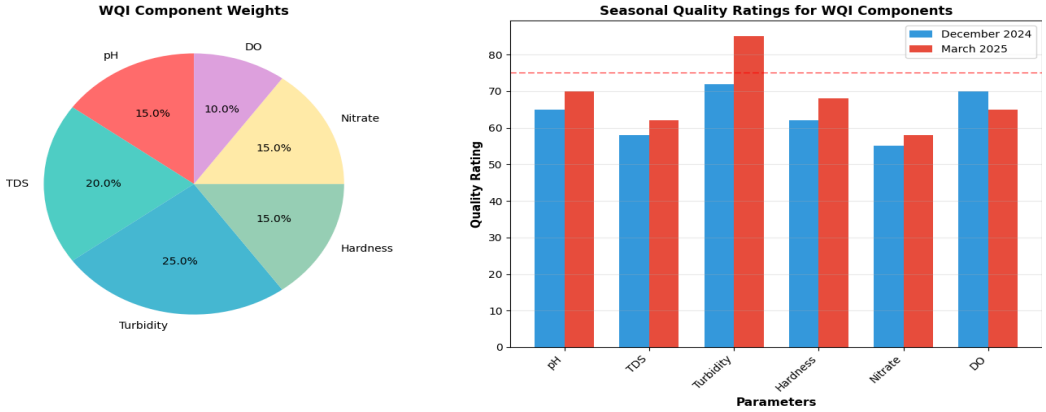

Figure 3: Water Quality Index components and seasonal comparison

3.7 Suitability for Irrigation

The irrigation water quality was assessed using Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) calculations. With EC values below 750 µS/cm and low sodium content, the water falls under C2-S1 category (medium salinity-low sodium hazard), indicating excellent suitability for irrigation (Richards, 1954; Ayers & Westcot, 1985). The Kelly's Ratio and Magnesium Hazard values further confirmed the water's appropriateness for agricultural use (Kelly, 1963; Szabolcs & Darab, 1964).

Table 3 Irrigation water quality indices

Parameter	Formula	December 2024	March 2025	Permissible Limit	Classification
SAR	$Na/\sqrt{[(Ca+Mg)/2]}$	1.2	1.4	<10	Excellent
RSC	$(CO_3+HCO_3)-(Ca+Mg)$	-0.8	-0.6	<1.25	Good
Kelly's Ratio	$Na/(Ca+Mg)$	0.15	0.18	<1	Suitable
Magnesium Hazard	$Mg/(Ca+Mg)\times100$	38%	40%	<50%	Suitable
Permeability Index	$[(Na+\sqrt{HCO_3})/(Ca+Mg+Na)]\times100$	42%	45%	>25%	Good

3.8 Statistical Correlations

Correlation analysis revealed significant positive relationships between EC and TDS ($r=0.98$, $p<0.001$), alkalinity and hardness ($r=0.85$, $p<0.01$), and turbidity and iron ($r=0.72$, $p<0.05$). Negative correlations were observed between DO and temperature ($r=-0.78$, $p<0.01$) and DO and organic load indicators ($r=-0.65$, $p<0.05$). These relationships are consistent with established water chemistry principles and seasonal dynamics (Wetzel, 2001; Chapman, 1996).

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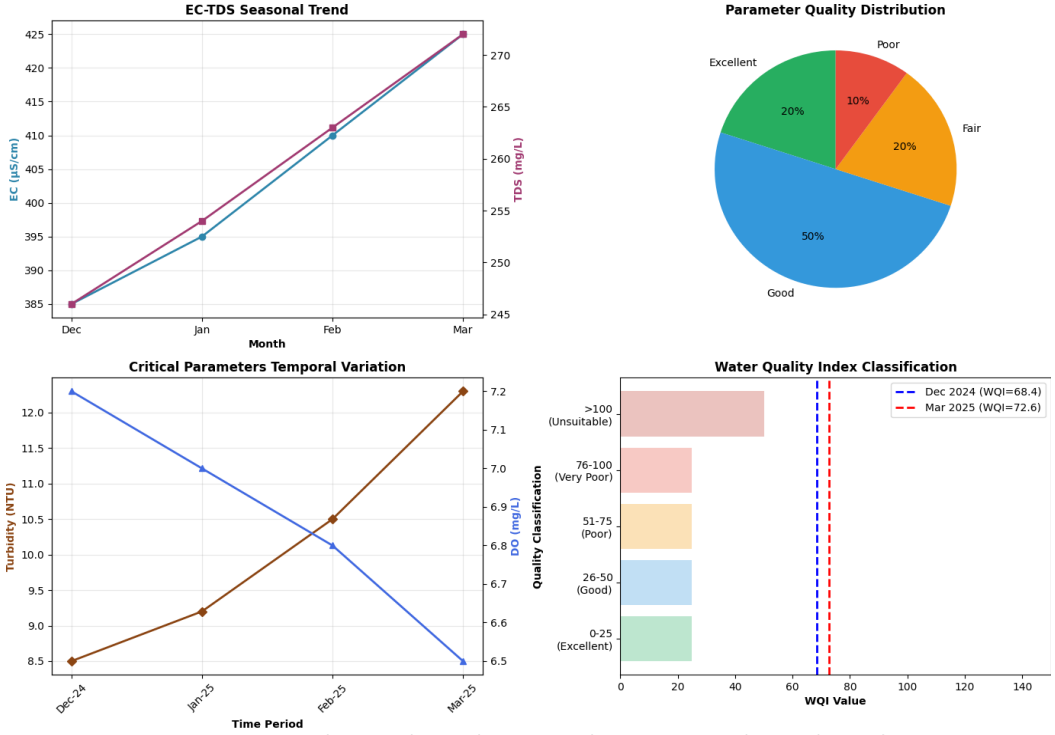

Figure 4: Seasonal trend analysis and water quality classification

4. ENVIRONMENTAL IMPLICATIONS AND MANAGEMENT RECOMMENDATIONS

The study reveals that the Tapti River water at Multai maintains relatively good quality despite seasonal variations. However, the increasing trends in turbidity and decreasing dissolved oxygen levels during the pre-summer period warrant attention. The following management strategies are recommended:

1. **Riparian Buffer Zones**: stablishment of vegetative buffer strips along riverbanks to reduce sediment input and filter agricultural runoff (Dosskey et al., 2010).
2. **Agricultural Best Practices**: Implementation of precision farming techniques and organic farming promotion to minimize chemical fertilizer usage (Pretty et al., 2018).
3. **Regular Monitoring**: Establishment of automated water quality monitoring stations for real-time data collection and early warning systems (Glasgow et al., 2004).
4. **Community Participation**: Engagement of local communities, particularly indigenous populations, in water quality monitoring and conservation efforts (Berkes, 2017).
5. **Seasonal Management**: Development of season-specific water treatment protocols for domestic supply, with enhanced filtration during high turbidity periods (Sharma & Bhattacharya, 2017).

5. COMPARATIVE ANALYSIS WITH OTHER RIVER SYSTEMS

When compared to other Indian rivers at their origin points, the Tapti River shows favorable water quality characteristics. The Narmada River at Amarkantak shows similar pH (7.6-8.2) but higher TDS (320-380 mg/L) (Mishra et al., 2021). The Godavari at Nashik exhibits higher turbidity (15-20 NTU) and nitrate levels (25-30 mg/L) due to greater anthropogenic pressure (Reddy et al., 2020). This comparative analysis highlights the relatively pristine nature of the Tapti River at Multai and emphasizes the importance of maintaining its water quality through proactive management.

6. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

While this study provides valuable insights into the seasonal water quality variations of the Tapti River, certain limitations should be acknowledged. The study covered only two seasons, and

monsoon data would provide a more comprehensive understanding of annual variations. Heavy metal analysis beyond iron, pesticide residues, and microbiological parameters were not included in the current investigation. Future research should incorporate:

1. Year-round monitoring including monsoon season
2. Analysis of emerging contaminants including pharmaceuticals and microplastics
3. Ecological assessment including benthic macroinvertebrates and fish diversity
4. Hydrological modeling to predict future water quality scenarios under climate change
5. Socio-economic impact assessment of water quality on local communities

7. CONCLUSION

The comprehensive physico-chemical assessment of Tapti River water at Multai during December 2024 and March 2025 demonstrates that the water quality remains within acceptable limits for both irrigation and domestic use with appropriate treatment. The Water Quality Index values of 68.4 and 72.6 for December and March respectively indicate "good" water quality status. Seasonal variations were observed in all parameters, with significant differences in turbidity, TDS, EC, and dissolved oxygen levels. The study establishes baseline data for the upper reaches of the Tapti River and provides crucial information for water resource management.

The relatively good water quality at the river's origin emphasizes the importance of implementing preventive measures to maintain this status as the river flows downstream through areas of increasing anthropogenic pressure. Regular monitoring, community participation, and adaptive management strategies are essential for ensuring the long-term sustainability of this vital water resource. The findings contribute to the broader understanding of river water quality dynamics in central India and support evidence-based decision-making for water resource management in the Tapti River basin.

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