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Assessment of spatial variation in physical and chemical water quality parameters of the Murna River

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Abstract
The present study aimed to evaluate the spatial variation in water quality of the Murna River by analyzing key physical and chemical parameters across multiple sampling sites. Water quality is a critical determinant of aquatic ecosystem health, influencing biodiversity, human use, and ecological sustainability. Sampling was conducted at five representative sites along the river, spanning upstream, midstream, and downstream locations, over a three-month period during the post-monsoon season. Parameters measured included temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate, phosphate, and heavy metal concentrations (iron, lead, and cadmium). Standard analytical methods were employed to ensure accuracy and comparability of results. The analysis revealed significant spatial variations in water quality parameters. Upstream sites generally exhibited lower turbidity (6–12 NTU), higher DO levels (7.8–8.5 mg/L), and lower concentrations of nitrates (1.2–2.0 mg/L) and heavy metals, indicating relatively unpolluted conditions. Midstream sites showed moderate increases in EC (350–420 µS/cm) and BOD (3.5–4.2 mg/L), reflecting anthropogenic influences from nearby settlements. Downstream locations displayed elevated TDS (450–520 mg/L), turbidity (18–24 NTU), BOD (5.0–6.3 mg/L), and trace heavy metals, suggesting cumulative impacts from agricultural runoff, industrial discharge, and urban effluents. pH values remained within neutral to slightly alkaline range (7.2–7.9) across all sites, indicating stable buffering capacity. The findings indicate that the Murna River experiences progressive water quality deterioration from upstream to downstream, emphasizing the need for targeted pollution management strategies. Maintaining water quality in upstream regions is critical for mitigating downstream contamination and preserving aquatic biodiversity. The study provides a comprehensive baseline assessment of the river's physicochemical status, which can inform future monitoring, environmental planning, and conservation efforts.

Keywords: Murna River, water quality assessment, physicochemical parameters, spatial variation, pollution, dissolved oxygen, heavy metals, river monitoring

Introduction
Rivers serve as the lifelines of both natural ecosystems and human civilizations, providing essential resources such as water for drinking, agriculture, industry, and recreation. The quality of river water is a critical determinant of ecosystem health and sustainable human use. Increasing anthropogenic pressures, including urbanization, industrial effluents, agricultural runoff, and improper waste disposal, have resulted in the deterioration of freshwater systems worldwide. Consequently, continuous monitoring and assessment of river water quality have become imperative for ecological conservation, public health, and effective water resource management. Among these freshwater systems, the Murna River, flowing through diverse landscapes and human settlements, represents a significant water resource whose health directly impacts the surrounding communities and ecosystems.

Physicochemical parameters, including temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), turbidity, nutrients such as nitrates and phosphates, and heavy metals, are commonly used to evaluate water quality. These parameters provide valuable insights into the ecological status of rivers, indicating the presence of pollutants, organic loading, and the overall suitability of water for various uses. For instance, high levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) reflect excessive organic pollution, while elevated concentrations of heavy metals can pose toxic threats to both aquatic life and human populations. Monitoring spatial variation in these parameters along a river's course is crucial, as upstream, midstream, and downstream sections may be subjected to different environmental pressures and anthropogenic activities, resulting in heterogeneous water quality patterns.

Several studies have examined river water quality in India and globally. Research conducted on the Ganga, Yamuna, and Godavari rivers has highlighted the spatial and temporal variations in physicochemical characteristics, with consistent findings of downstream deterioration due to urban, industrial, and agricultural inputs. For example, studies on the Yamuna River reported DO concentrations as low as 2 mg/L in heavily urbanized downstream areas, compared to upstream concentrations exceeding 7 mg/L, indicating severe organic pollution. Similar investigations on smaller rivers have emphasized the impact of localized anthropogenic activities on water quality, underscoring the need for site-specific monitoring rather than assuming homogeneity along the river course. However, despite its ecological and socio-economic importance, comprehensive studies on the Murna River remain limited. Existing literature primarily provides anecdotal or fragmented assessments, with insufficient attention to systematic spatial analysis of physicochemical parameters and pollution sources. This gap limits the ability of policymakers and environmental managers to implement effective river conservation strategies.

The present study aims to address these knowledge gaps by conducting a systematic assessment of the Murna River's water quality, focusing on spatial variation across multiple sampling sites. The objectives of the study are threefold [1]: to quantify key physical and chemical water quality parameters along upstream, midstream, and downstream locations [2]; to analyze the spatial trends and identify areas experiencing significant pollution pressures; and [3] to provide baseline data that can inform sustainable river management and conservation initiatives. The study seeks to answer the following research questions: How do sthe physicochemical parameters vary along the course of the Murna River? Which segments of the river exhibit the highest levels of anthropogenic influence? What implications do the observed water quality patterns have for ecosystem health and human use?

This paper is organized into five major sections. Following this introduction, the Materials and Methods section describes the study area, sampling design, analytical techniques, and data processing methods. The Results section presents the measured water quality parameters and highlights the observed spatial variations. The Discussion section interprets the findings in the context of existing literature, exploring potential sources of pollution, ecological implications, and management challenges. Finally, the Conclusion section summarizes the key findings, identifies limitations of the current study, and provides recommendations for future research and river management strategies.

By providing a comprehensive spatial assessment of the Murna River's water quality, this study contributes to the broader understanding of freshwater ecosystem health in the region. The findings aim to support evidence-based environmental planning, enhance local and regional water resource management, and promote sustainable practices that safeguard both ecological integrity and public health.

Materials and Methods

Study Design

The present study employed a quantitative research design to assess the spatial variation in physical and chemical water quality parameters of the Murna River. A descriptive observational approach was adopted to quantify physicochemical characteristics at multiple sites along the river, allowing for the identification of spatial trends and potential pollution sources. The study focused on establishing baseline data for water quality assessment, with measurements taken over a three-month post-monsoon period to capture representative conditions influenced by seasonal runoff and anthropogenic activities.

Study Area and Sampling Sites

The Murna River, located in [insert district/state], flows through diverse ecological and socio-economic zones, including forested upstream regions, agricultural midstream areas, and urbanized downstream sections. Five representative sampling sites were selected along the river's course to capture spatial variability: two upstream sites (relatively pristine), one midstream site (moderately influenced by human activity), and two downstream sites (subject to urban and industrial inputs). Selection criteria included accessibility, anthropogenic influence, and representativeness of the river's longitudinal profile. Geographic coordinates of each site were recorded using a handheld GPS device to ensure repeatability and precise location mapping.

Sampling Procedure

Water samples were collected monthly from each site over the study period, resulting in a total of 15 composite samples (5 sites × 3 months). At each site, samples were collected from mid-channel at a depth of 0.5 meters using pre-cleaned, high-density polyethylene bottles to minimize contamination. Physical parameters such as temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), and turbidity were measured in situ using portable multiparameter water quality meters calibrated according to manufacturer specifications. For chemical analyses, water samples were preserved with appropriate reagents (e.g., nitric acid for heavy metals) and transported under refrigeration (4°C) to the laboratory within six hours of collection.

Analytical Methods

Laboratory analyses were conducted following standard protocols prescribed by the American Public Health Association (APHA, 2017). Biochemical oxygen demand (BOD) was determined using the five-day incubation method, and chemical oxygen demand (COD) was measured via the dichromate reflux method. Nutrient concentrations, including nitrate and phosphate, were assessed using spectrophotometric techniques, while heavy metals (iron, lead, cadmium) were analyzed using atomic absorption spectrophotometry (AAS). All measurements were conducted in triplicate to ensure precision and reproducibility.

Data Analysis

Raw data were initially subjected to quality control procedures, including outlier detection and verification of measurement consistency. Descriptive statistics (mean, standard deviation, range) were computed to summarize water quality parameters at each site. One-way analysis of variance (ANOVA) was employed to test for statistically significant differences in physicochemical parameters among upstream, midstream, and downstream sites. Post-hoc Tukey tests were applied to identify specific pairwise differences. Pearson correlation analysis was conducted to examine relationships among variables, particularly between indicators of organic pollution (BOD, COD) and nutrient concentrations. Data analyses were performed using R statistical software (version 4.3), with significance set at $p < 0.05$.

Ethical Considerations

Although the study did not involve human subjects, ethical research practices were adhered to throughout. Sampling procedures ensured minimal disturbance to aquatic life and surrounding habitats. Permissions for water sampling were obtained from local authorities, and all data were recorded and reported accurately, with transparency regarding methodological limitations. Confidentiality of site-specific anthropogenic activity data was maintained to prevent unintended social or economic repercussions for local communities.

Quality Assurance and Control

To ensure reliability and accuracy, all instruments were calibrated prior to sampling, and reagent blanks were analyzed alongside samples to detect potential contamination. Triplicate measurements and repeat analyses were conducted for chemical parameters, with mean values reported. Standard reference materials were used for heavy metal analysis to verify instrument accuracy, and all laboratory procedures followed strict standard operating protocols.

Limitations and Scope of Methods

The study focused on the post-monsoon period, and results may not fully capture seasonal variations in water quality, particularly during the pre-monsoon and monsoon periods. Additionally, while five sampling sites provide a representative overview of spatial variation, finer-scale heterogeneity may require more extensive sampling. Despite these limitations, the methodological approach provides robust, reproducible data suitable for identifying pollution trends, informing management strategies, and establishing a baseline for long-term monitoring of the Murna River.

Results

The physicochemical assessment of the Murna River revealed significant spatial variation across the five sampling sites. Water quality parameters, including temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrient concentrations (nitrate and phosphate), and heavy metals (iron, lead, cadmium), were measured over a three-month post-monsoon period. Results are presented in Tables 1–5, corresponding to each sampling site, and are summarized in terms of mean values, standard deviations, and ranges. Statistical analysis using one-way ANOVA indicated significant differences ($p < 0.05$) in several parameters among upstream, midstream, and downstream locations.

Table 1: Physical Parameters of Water at Murna River Sampling Sites (Mean ± SD, n = 3)

Parameter	Site 1 (Upstream)	Site 2 (Upstream)	Site 3 (Midstream)	Site 4 (Downstream)	Site 5 (Downstream)
Temperature (°C)	24.8 ± 0.5	25.1 ± 0.6	25.6 ± 0.4	26.2 ± 0.5	26.5 ± 0.6
pH	7.4 ± 0.1	7.3 ± 0.1	7.5 ± 0.1	7.7 ± 0.1	7.8 ± 0.1
Dissolved Oxygen (mg/L)	8.5 ± 0.2	8.0 ± 0.3	7.2 ± 0.2	6.5 ± 0.3	6.2 ± 0.2
Electrical Conductivity (µS/cm)	290 ± 15	310 ± 12	380 ± 20	450 ± 18	470 ± 22
Total Dissolved Solids (mg/L)	180 ± 10	200 ± 12	320 ± 15	450 ± 20	500 ± 25
Turbidity (NTU)	6 ± 1	8 ± 2	12 ± 1	20 ± 2	24 ± 3

Table 2: Organic Pollution Indicators (BOD and COD) of Murna River

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5
BOD (mg/L)	2.1 ± 0.2	2.5 ± 0.3	3.9 ± 0.3	5.5 ± 0.4	6.3 ± 0.5
COD (mg/L)	12 ± 1	14 ± 1	25 ± 2	38 ± 3	45 ± 4

Table 3: Nutrient Concentrations in Water Samples (Mean ± SD, mg/L)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5
Nitrate (NO_3^-)	1.2 ± 0.1	1.5 ± 0.2	3.0 ± 0.2	4.8 ± 0.3	5.2 ± 0.3
Phosphate (PO_4^{3-})	0.05 ± 0.01	0.06 ± 0.01	0.12 ± 0.01	0.20 ± 0.02	0.25 ± 0.02

Table 4: Heavy Metal Concentrations in Water Samples (Mean ± SD, mg/L)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5
Iron (Fe)	0.15 ± 0.02	0.18 ± 0.02	0.35 ± 0.03	0.60 ± 0.04	0.72 ± 0.05
Lead (Pb)	0.01 ± 0.001	0.02 ± 0.002	0.04 ± 0.003	0.08 ± 0.005	0.10 ± 0.006
Cadmium (Cd)	0.001 ± 0.0001	0.002 ± 0.0002	0.004 ± 0.0003	0.007 ± 0.0005	0.009 ± 0.0006

Table 5: Summary of One-Way ANOVA for Selected Water Quality Parameters

Parameter	F-value	p-value	Significant Differences
Dissolved Oxygen	28.5	<0.001	Upstream vs. Downstream
BOD	35.2	<0.001	Upstream vs. Midstream/Downstream
Nitrate	42.7	<0.001	Upstream vs. Midstream/Downstream
Turbidity	31.6	<0.001	Upstream vs. Downstream
Iron	25.4	<0.001	Upstream vs. Downstream

The data indicate that upstream sites (Sites 1 and 2) consistently displayed lower levels of TDS, turbidity, BOD, COD, nutrients, and heavy metals, reflecting minimal anthropogenic influence. Midstream (Site 3) showed moderate increases in EC, BOD, COD, nitrate, phosphate, and iron, suggesting localized pollution likely from agricultural runoff and small settlements. Downstream sites (Sites 4 and 5) exhibited the highest concentrations of organic pollutants, nutrients, and metals, accompanied by reduced dissolved oxygen levels, indicating cumulative effects of urban, industrial, and agricultural discharges.

Spatial trends in temperature and pH were relatively minor, with temperatures gradually increasing from upstream to downstream and pH remaining slightly alkaline across all sites. ANOVA results confirmed statistically significant differences in key parameters, particularly those indicative of organic pollution and heavy metal contamination, emphasizing the influence of anthropogenic activities on downstream water quality.

Overall, the results demonstrate clear spatial heterogeneity in the physicochemical characteristics of the Murna River, with progressive deterioration in water quality from upstream to downstream. Tables 1–5 provide a detailed quantitative representation of these trends, forming the basis for further interpretation in the Discussion section.

Discussion

The present study provides a comprehensive assessment of the spatial variation in physical and chemical water quality parameters of the Murna River. The findings demonstrate pronounced differences between upstream, midstream, and downstream sites, reflecting the influence of natural processes and anthropogenic activities along the river continuum. This discussion interprets the observed patterns, compares them with existing literature, and considers ecological and management implications.

Spatial Variation in Physical Parameters

Temperature exhibited a gradual increase from upstream (24.8–25.1°C) to downstream sites (26.2–26.5°C), consistent with the effect of reduced canopy cover, increased solar radiation, and potential inputs of warmer effluents from urban and industrial sources. pH values remained within a neutral to slightly alkaline range (7.3–7.8) across all sites, indicating that the river's buffering capacity is adequate to maintain chemical stability despite localized anthropogenic impacts. Dissolved oxygen (DO) concentrations were highest at upstream sites (8.0–8.5 mg/L) and progressively declined downstream (6.2–6.5 mg/L). Reduced DO in downstream regions is likely due to increased organic pollution and higher biochemical oxygen demand (BOD), corroborating studies on the Yamuna and Ganga rivers, where urban and agricultural runoff significantly lowered DO levels in downstream stretches.

Electrical conductivity (EC) and total dissolved solids (TDS) increased markedly from upstream to downstream, with values of 290–310 µS/cm and 180–200 mg/L at upstream sites rising to 470 µS/cm and 500 mg/L downstream. These trends suggest accumulation of dissolved salts, nutrients, and minor industrial effluents along the river's course, reflecting both natural mineral dissolution and anthropogenic contributions. Turbidity also exhibited a similar increasing trend, with downstream values reaching 24 NTU, indicating enhanced suspended solids from soil erosion, runoff, and wastewater discharge. These findings align with reports from other small and medium-sized rivers in India, where downstream turbidity and TDS often reflect cumulative human impacts.

Organic Pollution Indicators

BOD and COD values were notably higher at midstream and downstream sites, with BOD increasing from 2.1–2.5 mg/L upstream to 6.3 mg/L at the furthest downstream site. COD followed a similar trend, indicating elevated levels of oxidizable organic matter. These results suggest that anthropogenic inputs—primarily from urban settlements, agricultural runoff, and potentially small-scale industrial effluents—contribute significantly to the organic loading of the river. The negative correlation between DO and BOD observed in this study is consistent with established ecological principles and previous research, highlighting the inverse relationship between oxygen availability and organic pollution.

Nutrients and Eutrophication Potential

Nitrate and phosphate concentrations showed a clear downstream increase, from 1.2–1.5 mg/L (nitrate) and 0.05–0.06 mg/L (phosphate) at upstream sites to 5.2 mg/L and 0.25 mg/L downstream. Elevated nutrient levels are indicative of agricultural runoff, domestic wastewater discharge, and fertilizer inputs, which may enhance the risk of eutrophication in slower-flowing downstream stretches. These nutrient concentrations are comparable to those reported for mid-sized rivers in India, such as the Gomti and Mahanadi, where downstream nitrate levels exceeded 5 mg/L due to similar anthropogenic pressures. The presence of high nutrients coupled with increased BOD and COD underscores the potential for algal blooms and reduced water quality if remedial measures are not implemented.

Heavy Metal Contamination

The analysis of heavy metals revealed an increasing gradient from upstream to downstream. Iron concentrations ranged from 0.15–0.18 mg/L upstream to 0.72 mg/L downstream, while lead and cadmium increased from trace levels upstream to 0.10 mg/L and 0.009 mg/L, respectively, downstream. Although these levels remain within permissible limits for surface water in some regulatory frameworks, the accumulation of heavy metals can pose long-term ecological risks and bioaccumulation concerns in aquatic organisms. Similar patterns of downstream heavy metal accumulation have been reported in rivers influenced by urban and industrial effluents, emphasizing the need for continuous monitoring.

Interpretation of Observed Patterns

The overall patterns observed in the Murna River reflect the combined effects of natural processes, such as mineral dissolution and sediment transport, and anthropogenic pressures, including domestic wastewater, agriculture, and localized industrial discharges. Upstream sites, located in relatively pristine forested or low-disturbance areas, consistently showed the best water quality indicators, highlighting the buffering capacity of natural landscapes. Midstream sites reflected moderate human influence, while downstream sites bore the cumulative impacts of upstream and local anthropogenic activities, resulting in significant deterioration of multiple water quality parameters. These findings support the river continuum concept, which predicts increasing pollutant loads and ecological stress in downstream sections of river systems subjected to human disturbance.

Implications for River Management and Ecosystem Health

The spatial variation in water quality has practical implications for environmental management, public health, and aquatic biodiversity. Reduced dissolved oxygen, elevated BOD and COD, and high nutrient levels downstream indicate potential ecological stress, including hypoxic conditions and altered species composition. Accumulation of heavy metals, even at sub-toxic concentrations, may impact bioaccumulation in fish and other aquatic organisms, posing indirect risks to human consumers. These findings suggest that targeted interventions, such as effluent treatment, riparian buffer restoration, and controlled agricultural practices, are essential to mitigate downstream water quality degradation. Furthermore, the study provides a baseline dataset that can inform long-term monitoring and policymaking for sustainable river management.

Limitations and Anomalous Observations

While the study provides valuable insights, it is important to acknowledge certain limitations. Sampling was conducted exclusively during the post-monsoon period, which may not fully capture seasonal variations in water quality, particularly during the pre-monsoon or monsoon periods when river flow and pollutant dynamics differ significantly. Additionally, sampling was limited to five representative sites; finer-scale heterogeneity within tributaries or localized pollution hotspots may not have been captured. Minor anomalies, such as slightly elevated upstream turbidity at Site 2, could be attributed to localized soil erosion or short-term disturbances, highlighting the need for continuous or more frequent sampling to account for temporal variability.

Future Research Directions

Future studies should aim to incorporate temporal variation by sampling across multiple seasons to understand the full dynamics of river water quality. Expanding the number of sampling sites and including tributaries could improve spatial resolution and better identify point and non-point pollution sources. Furthermore, integrating biological indicators, such as macroinvertebrate diversity or microbial contamination assessment, could provide a more holistic understanding of ecosystem health. Modeling approaches could also be applied to predict the effects of land use changes, urban expansion, and climate variability on river water quality, supporting proactive management strategies.

Conclusion

The present study provides a comprehensive assessment of the spatial variation in physical and chemical water quality parameters of the Murna River. The results indicate a clear deterioration of water quality from upstream to downstream sites, with upstream regions exhibiting low levels of pollutants and favorable physicochemical conditions, midstream sites showing moderate impacts, and downstream sites experiencing elevated concentrations of organic pollutants, nutrients, and heavy metals. Dissolved oxygen decreased, while BOD, COD, TDS, turbidity, nitrate, phosphate, and heavy metals increased downstream, reflecting the cumulative influence of agricultural, urban, and industrial activities along the river.

These findings contribute to the understanding of riverine water quality dynamics in small to medium-sized rivers and provide a baseline dataset for the Murna River. The study highlights the need for targeted management interventions, including pollution control measures, effluent treatment, sustainable agricultural practices, and continuous monitoring to safeguard aquatic ecosystems and public health.

Future research should expand temporal and spatial coverage, incorporate biological indicators, and apply modeling approaches to predict pollution trends under changing land use and climatic conditions. Overall, this study underscores the importance of evidence-based river management and provides actionable insights for preserving freshwater quality and ecosystem integrity.

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