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Research Note

Seasonal Dynamics of Water Quality in the Manohara River: A Physicochemical and WQI Assessment

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Abstract

The Manohara River, a vital tributary of the Bagmati River in Kathmandu Valley, Nepal, is heavily degraded due to urbanization and industrial activities. This study assesses seasonal variations in physicochemical parameters and Water Quality Index (WQI) at ten sites from Sankhu to Jadibuti during pre-monsoon (March 2024) and monsoon (August 2024). Parameters including pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), ammonia, and phosphate were analyzed using standard methods. Monsoon dilution reduced EC (704.3 to 260.7 µS/cm), TDS (351.9 to 130.1 mg/L), and BOD (327.5 to 128.46 mg/L), while DO improved (1.01 to 5.42 mg/L). However, high ammonia, phosphate, and BOD indicated persistent pollution. WQI values (213.86 pre-monsoon, 206.57 monsoon) classified the water as "Very Poor," unfit for drinking or fish culture. Phosphate, ammonia, and low DO were key pollution drivers. Urgent pollution control and monitoring are needed to restore the river's ecological health.

Introduction

Water is fundamental to human health, food production, ecosystems, and economic development. Protecting freshwater from pollutants is essential to safeguard the biosphere (Shukla et al., 2013). Monitoring physico-chemical parameters is key for assessing and restoring water quality (Whitehead et al., 2018; Islam et al., 2021). A recent study on the Bagmati River reported high microbial contamination, organic pollution, low dissolved oxygen, and elevated BOD, indicating the water is unsafe without treatment (Arjyal et al., 2025).Ghimire et al. (2022) reported high BOD, ammonia, and phosphate levels in the Bagmati and its tributaries, including the Manohara, attributing pollution to uncontrolled urbanization and proposing technologies like reed bed systems for mitigation. Similarly, a 2020 assessment of the Manohara River found elevated nutrient loads, linked to activities near cultural sites like Changunarayan Temple, underscoring the need for seasonal water quality studies. Previous studies have documented declining water quality in the Bagmati River basin, with high levels of organic and nutrient pollution (Adhikari et al., 2019; Pal et al., 2021). However, comprehensive seasonal assessments of the Manohara River's water quality, particularly using the Water Quality Index (WQI), are limited, representing a critical research gap.

The Water Quality Index (WQI) combines various physical and chemical measurements into one clear number, making it easier for decision-makers and communities to understand the state of a river's health (Tyagi et al., 2013). This study assesses seasonal changes in Manohara River water quality between pre-monsoon (March 2024) and monsoon (August 2024) using samples from ten sites. It identifies key pollution sources to support river restoration and protection efforts.

Materials and Methods

Study area

The Manohara River lies at 27° 40' 6" N and 85° 21' 8" E, northeast of the Kathmandu Valley. It is long, measuring 28 km from northeast to southwest and encompassing 83 square kilometers. Downstream, this river is large and bends from side to side, while upstream, it is small and goes in a straight line (Bajracharya & Tamrakar, 2008). For this research, the ten sampling stations were selected as shown in the figure 1. Watershed delineation was done using Global Watersheds Web App (MGHydro) with MERIT Hydro, HydroSHEDS, and USGS NLDI data (Yamazaki et al., 2019).

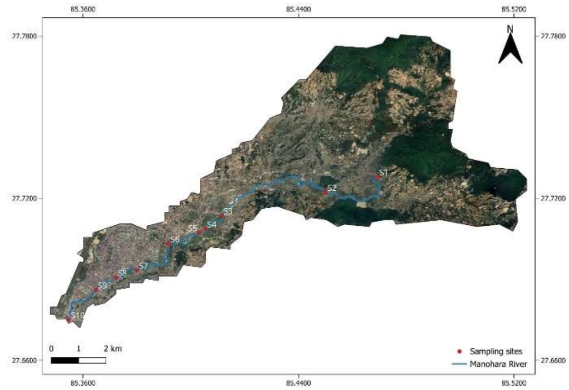

Figure 1: Location of 10 sampling sites along the Manohara River

Sampling and Analysis

Water samples were collected from ten locations along the Manohara River during the pre-monsoon (March 2, 2024) and monsoon (August 16, 2024) seasons using random sampling methods. In-situ measurements of temperature (thermometer), pH (pH meter), EC (EC 59 Milwaukee), TDS (EC 59 Milwaukee), and DO (Winkler's iodometric method) were measured using standard field instruments. Samples were collected in 1-liter bottles, pre-rinsed with river water, and transported to the laboratory at 4°C for further analysis within 48 hours. Laboratory analyses included BOD (5-day incubation at 20°C), chloride (argentometric method), ammonia, phosphate, and nitrate (UV-VIS spectrophotometry), total hardness (EDTA method), and free CO_2 (titration with standard NaOH using phenolphthalein as an indicator). All procedures followed APHA (1998) standards and were conducted at the Environmental Science Laboratory, Tri-Chandra Multiple Campus.

WQI Computation Equations

The weighted arithmetic index method (Brown et al., 1972) is applied through a series of steps, which are presented below:

Calculation of unit weight (W_n) for each parameters:

$W_n = K/S_n$ …………… (1)

Where, W_n = unit weight for the nth parameters; S_n = standard value for nth parameter; K = constant for proportionality.

Calculation of sub-index (Q_n):

$Q_n = [(V_n - V_o) / (S_n - V_o)] * 100$ …………… (2)

Where, Q_n = quality rating for the nth water quality parameter; V_n = estimated value of the nth parameter at a given sampling station; S_n = standard permissible value of the n^{th} parameter; V_o = ideal value of n^{th} parameter. For all parameters, ideal values (V_o) were taken as zero for drinking water except for pH = 7.0 and DO = 14.6 mg/L.

Calculation of WQI, combining equation (1) and (2):

$WQI = \sum(W_n.Q_n) / \sum W_n$ ……………….. (3)

WQI has been categorized into 5 classes based on weighted WQI method as shown in table 2.

Table 1: Classification of Water Quality Index (WQI) ranges with corresponding status and possible usage

WQI range	Water Quality Status	Possible Usage
0-5	Excellent water quality	Drinking, irrigation and industrial
26-50	Good water quality	Drinking, irrigation and industrial
51-75	Poor water quality	Irrigation and industrial
76-100	Very poor water quality	Irrigation
Above 100	Unsuitable for drinking and propagation of fish culture	Proper treatment required before use

Source: Brown et al. (1972)

Data analysis

WQI calculations were performed using Microsoft Excel 365, and the paired sample t-test was performed using Past 4.03 software to determine significant differences in physicochemical parameters between the pre-monsoon and monsoon seasons. The normality of each parameter was tested using the Shapiro–Wilk test. Parameters that followed a normal distribution ($p > 0.05$) were analyzed using the paired Student's t-test, while those not normally distributed ($p < 0.05$) were analyzed using the Wilcoxon signed-rank test. A significance level of 5% ($p = 0.05$) was applied.

Results

Temperature: Water temperature ranged from 12.7°C to 14.3°C during the pre-monsoon season and increased to 21.0°C to 23.9°C in the monsoon season. A significant seasonal difference was observed ($p < 0.05$). **pH**: The pH values ranged from 5.8 to 7.5 in pre-monsoon and 6.5 to 7.3 in monsoon. The paired sample t-test showed no significant difference in pH between seasons ($p > 0.05$). **EC**: EC values were significantly higher in pre-monsoon (520-859 µS/cm) than in monsoon (115-360 µS/cm) with a statistically significant seasonal difference ($p < 0.05$).

TDS: TDS levels followed the same trend as EC, decreasing from 260-429 mg/L in pre-monsoon to 57-180 mg/L in monsoon. This difference was significant ($p < 0.05$).

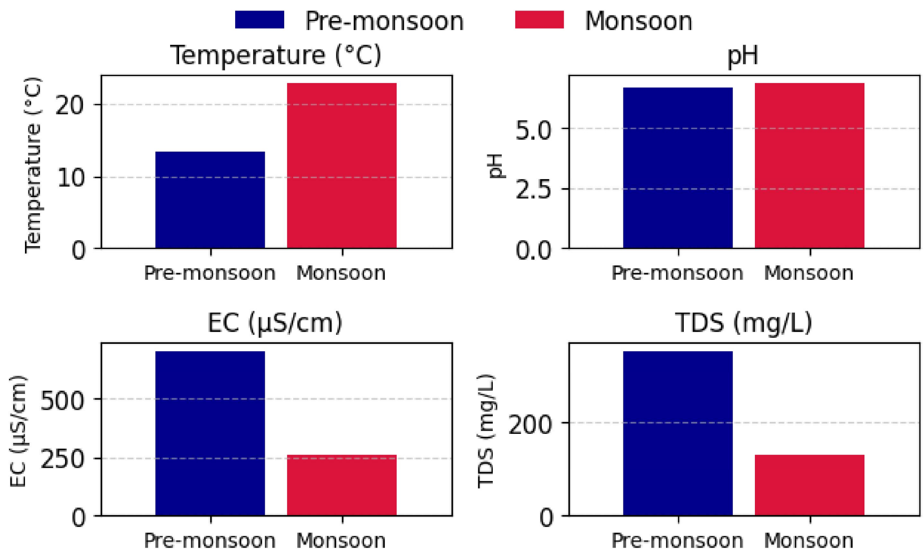

Figure 2: Seasonal comparison of average concentrations of physical parameters (temperature, pH, EC and TDS)

DO: DO concentrations showed a notable increase from critically low levels in pre-monsoon to improved levels in monsoon (3.96-7.68 mg/L), with a significant difference ($p < 0.05$). **BOD**: BOD levels were exceptionally high in both seasons but decreased from 162.06–413.34 mg/L in pre-monsoon to 48.8–187.19 mg/L in monsoon. The difference was statistically significant ($p < 0.05$). **Chloride**: Chloride concentrations decreased from 77.23-115.56 mg/L in pre-monsoon to 19.23-32.6 mg/L in monsoon, with a significant seasonal difference ($p < 0.05$). **Total Hardness**: Total hardness was higher in pre-monsoon (109-144 mg/L) compared to monsoon (76-134 mg/L), showing a statistically significant difference ($p < 0.05$).

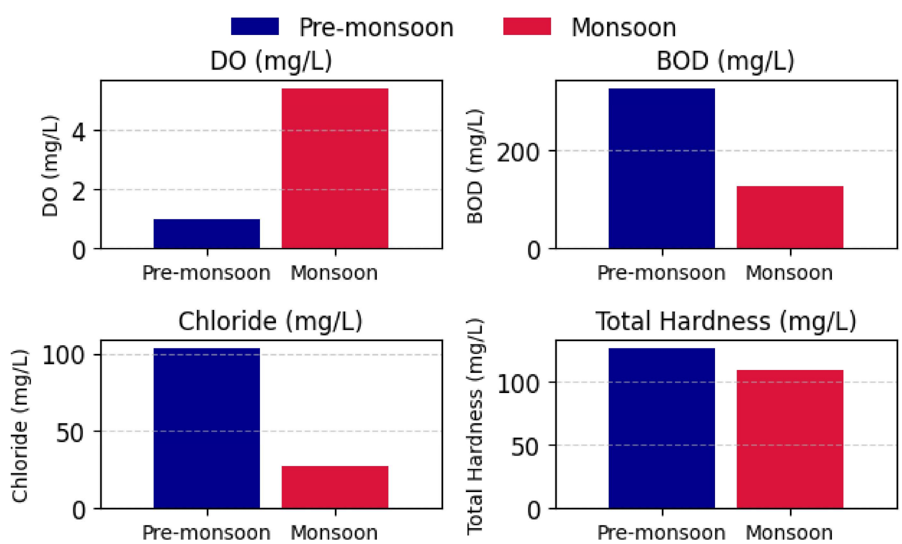

Figure 3: Seasonal comparison of average concentrations of chemical parameters (DO, BOD, chloride and total hardness)

Ammonia: Ammonia levels remained high in both seasons, ranging from 1.37-1.81 mg/L in pre-monsoon and 0.90-1.94 mg/L in monsoon. The seasonal difference was not statistically significant ($p > 0.05$). **Phosphate**: Phosphate concentrations were 0.169-0.289 mg/L in pre-monsoon and 0.138-0.278 mg/L in monsoon. No significant seasonal variation was found ($p > 0.05$). **Nitrate**: Nitrate levels were within acceptable limits, showing a seasonal decrease from 5.08-8.91 mg/L in pre-monsoon to 4.73-7.81 mg/L in monsoon. The difference was significant ($p < 0.05$). **Free CO_2:** Free CO_2 concentrations were significantly higher in pre-monsoon (80.4-278.3 mg/L) compared to monsoon (69.3-234.3 mg/L), with a significant difference ($p < 0.05$).

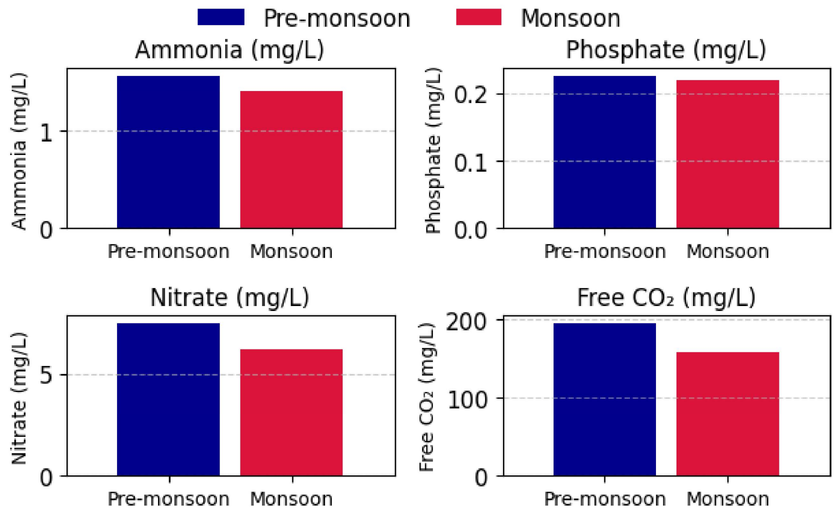

Figure 4: Seasonal comparison of average concentrations of chemical parameters (ammonia, phosphate, nitrate and free CO_2)

Table 2: Paired sample t-test for physio-chemical parameters in the pre-monsoon and monsoon season

Parameters	Pre-monsoon Mean	Monsoon Mean	Test Used	Normal	p-value	Remarks
Temperature	13.44	22.8	Wilcoxon	No	< 0.001	Significant difference
pH	6.7	6.9	t-test	Yes	0.111	No significant difference
EC	704.3	260.7	t-test	Yes	< 0.001	Significant difference
TDS	351.9	130	t-test	Yes	< 0.001	Significant difference
DO	1.013	5.3192	t-test	Yes	< 0.001	Significant difference
BOD	317.52	128.46	Wilcoxon	No	< 0.001	Significant difference
Chloride	103.32	27.25	Wilcoxon	No	< 0.001	Significant difference
Total Hardness	126.6	109.8	t-test	Yes	< 0.001	Significant difference
Ammonia	10.54	9.56	t-test	Yes	0.136	No significant difference
Phosphate	0.225	0.219	t-test	Yes	0.524	No significant difference
Nitrate	7.474	6.201	t-test	Yes	< 0.001	Significant difference
Free CO_2	195.47	158.27	t-test	Yes	< 0.001	Significant difference

Water Quality Index

The Weighted Water Quality Index (WQI) was calculated for the Manohara River based on the average values of the measured physicochemical parameters for both seasons.

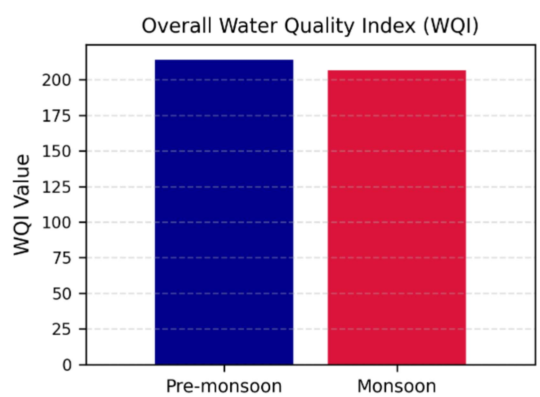

Figure 3: Comparison of overall Water Quality Index (WQI) for pre-monsoon and monsoon seasons.

WQI values of 213.86 (pre-monsoon) and 206.57 (monsoon) classified the river as "Very Poor" (Table 1).

Discussion

Seasonal variation in the Manohara River is driven by a combination of anthropogenic inputs, monsoon hydrology, and geology. In the pre-monsoon, low flows limit dilution, allowing sewage, effluents, and runoff to raise EC, TDS, BOD, and nutrients. Monsoon rains, however, create a flushing effect that dilutes pollutants and improves DO, as also reported in other Himalayan rivers (Seth et al., 2016). Geology further shapes water chemistry: alluvial and metasedimentary deposits contribute Ca, Mg, and bicarbonates (Bajracharya & Tamrakar, 2008), which accumulate during dry periods but are mobilized and diluted by monsoon flows, a pattern noted across Himalayan catchments (Ghimire et al., 2024).The marked improvement in parameters such as electrical conductivity (EC), total dissolved solids (TDS), and biochemical oxygen demand (BOD) during the monsoon season can be attributed to dilution caused by increased rainfall and river discharge (Gored, 2013). The river's pH, which measures how acidic or basic the water is, varied slightly between seasons. Most of these values are within the acceptable range for aquatic life (ideally 6.5-8.5), but some pre-monsoon readings leaned toward acidic, which can stress aquatic ecosystems. Higher pH usually changes due to the presence of organic and inorganic pollutants in presence of carbon dioxide (Pal et al., 2019).

Despite this seasonal improvement, several parameters-namely BOD, ammonia, and phosphate-remained above acceptable thresholds in both seasons. Dissolved oxygen (DO) showed significant seasonal variation, improving during the monsoon, which may be linked to increased aeration and decreased microbial oxygen demand due to dilution of organic pollutants. However, the critically low DO values recorded during the pre-monsoon period (average: 1.01 mg/L) reflect severe organic pollution, rendering the river incapable of sustaining most aquatic organisms during the dry season (Lawson, 2011). High BOD values (average of 327.5 mg/L in pre-monsoon and 128.46 mg/L in monsoon) indicate a substantial organic load, likely from untreated domestic and industrial effluents, which rapidly consume available oxygen. BOD was way above the 3-6 mg/L which is considered safe for clean surface water (Regmi & Maharjan, 2020).

Elevated chloride levels can indicate contamination from domestic sewage or industrial effluents (Gautam et al., 2013). The levels of ammonia concentrations are much higher than the trace amounts (<0.1 mg/L) found in unpolluted streams (UNESCO, 1996). High ammonia, often from sewage or organic waste, is toxic to aquatic life and a clear sign the river is struggling with pollution.

Phosphate levels also remained above 0.1 mg/L, promoting eutrophication and algal growth, consistent with patterns reported in other urban river systems in Nepal (Adhikari et al., 2019; ENPHO, 1999). Water phosphorus contamination is mostly caused by industrial wastewater, agricultural runoff, and detergent use (Regmi & Maharjan, 2020). The drop in concentration of nitrate during monsoon likely comes from dilution and plants absorbing nitrates. While within safe limits, the presence of nitrate can originate from industrial wastewater, fertilizer runoff, and human/animal waste (Trivedy and Goel, 1986). However, phosphate and nitrate concentrations did not decline significantly during the monsoon. This persistence can be explained by their continuous inputs from sewage, detergents, and agricultural runoff, which continue regardless of flow (Singh, 2013). High CO_2 often comes from microbes breaking down organic matter, especially in still waters during the dry season. The concentration of free CO_2 tends to increase from upstream to downstream, correlating with an increase in organic load from surface runoff (Gautam et al., 2013).

The Water Quality Index (WQI) further supports this conclusion, both falling into the "Very Poor" category. Phosphate, ammonia, and low DO were primary contributors. Monsoon dilution slightly improved WQI, but persistent pollution from untreated waste and runoff kept water quality unfit for drinking or fish culture. These findings highlight the pervasive nature of pollution in the Manohara River, driven by continuous discharge of untreated domestic and industrial waste, as well as agricultural runoff. The water quality parameters were checked only for two seasons. Few parameters such as turbidity, bacteria, algae were not tested due to the financial constraints.

Conclusion

This water quality assessment revealed significant seasonal variations and an overall decline in water quality. By providing comprehensive seasonal Water Quality Index (WQI) assessments, the study addresses a key research gap and highlights the critical state of the river. The results demonstrate that pollution persists year-round despite monsoon dilution, with organic and nutrient loads as the dominant stressors. These findings underscore the urgent need for pollution control measures, including sewage treatment, agricultural runoff management, and regular monitoring, to restore the river's ecological and cultural value.

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Credit Contribution

BK: Conceptualization (equal), data collection and analysis (lead), writing original draft (lead), review and editing (equal), project execution (lead); RMP: Supervision, review &editing (lead)

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Statement

This study adhered to ethical standards, with data collected and analyzed transparently. AI tools were used only for grammatical refinement

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