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Study of seasonal variations in physicochemical and microbial parameters of the Diyala River after joining the Tigris river

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Abstract
The Diyala River, a significant tributary of the Tigris River, plays a vital role in the hydrology and ecology of the region. This study investigates the seasonal variations in physicochemical and microbial parameters of the Diyala River after its confluence with the Tigris River. Water samples were collected quarterly over one year to assess parameters including temperature, pH, dissolved oxygen (DO), turbidity, electrical conductivity (EC), total dissolved solids (TDS), nutrients (nitrate, phosphate), and microbial indicators such as total coliforms and fecal coliforms. Results revealed marked seasonal fluctuations, with higher nutrient concentrations and microbial loads during the summer and lower values in winter, correlating with changes in water flow, temperature, and anthropogenic activities. The physicochemical parameters mostly complied with international water quality standards, but microbial contamination occasionally exceeded safe limits, indicating potential health risks. The findings underscore the need for continuous monitoring and effective management strategies to safeguard water quality in the Diyala-Tigris river system, especially considering increasing human and agricultural pressures.

Keywords: Diyala River, tigris river, seasonal variation, physicochemical parameters, microbial contamination, water quality, nutrients, Iraq

Introduction

Rivers are dynamic ecosystems that play a crucial role in supporting biodiversity, providing water resources for domestic, agricultural, and industrial uses, and maintaining ecological balance. The Diyala River is one of the major tributaries of the Tigris River, flowing through eastern Iraq and western Iran before merging with the Tigris near Baghdad. Due to its significant contribution to the Tigris River system, the water quality of the Diyala River directly impacts the ecological health and usability of the Tigris downstream.

Water quality in rivers is influenced by a variety of physical, chemical, and biological factors that can vary widely with seasonal changes. Seasonal variation impacts parameters such as water temperature, dissolved oxygen, nutrient concentrations, and microbial loads. These variations are often driven by fluctuations in river flow, precipitation, temperature, agricultural runoff, urban effluents, and other anthropogenic activities. Understanding these variations is critical for water resource management, pollution control, and public health protection.

Physicochemical parameters such as temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), and nutrient concentrations (e.g., nitrate and phosphate) serve as important indicators of water quality. Elevated nutrient levels, particularly nitrogen and phosphorus compounds, can lead to eutrophication, which adversely affects aquatic life. Similarly, microbial contamination, indicated by the presence of total coliform and fecal coliform bacteria, reflects potential fecal pollution and poses health risks to communities depending on river water for drinking, irrigation, or recreation.

The Diyala River basin has experienced increasing anthropogenic pressure from urbanization, agricultural activities, and industrial discharges. These factors contribute to the degradation of water quality and pose challenges for sustainable river management. Previous studies in the region have reported varying degrees of pollution and highlighted the need for continuous monitoring and assessment.

Despite the importance of the Diyala River, comprehensive studies examining seasonal changes in both physicochemical and microbial parameters, especially after its confluence with the Tigris River, are limited. This study aims to fill this gap by systematically investigating the seasonal dynamics of key water quality parameters over a full annual cycle. The results will provide valuable insights into the temporal patterns of water quality and identify periods of increased pollution risk, helping to inform policymakers and stakeholders involved in water resource management in Iraq.

The objectives of this study are to

1. Evaluate the seasonal variations of physicochemical parameters in the Diyala River post-confluence with the Tigris.
2. Assess the levels of microbial contamination and their seasonal dynamics.
3. Identify potential sources and contributing factors to water quality changes.
4. Provide recommendations for improving water quality management in the Diyala-Tigris river system.

By understanding these variations and their causes, this research contributes to the broader goal of preserving water quality, protecting aquatic ecosystems, and ensuring safe water use for local communities.

Methods

Study Area and Sampling Sites

The study was conducted on the Diyala River after its confluence with the Tigris River near Baghdad, Iraq. Four sampling sites were selected along the Diyala River stretch post-confluence to represent different points of interest influenced by natural and anthropogenic factors.

Sampling Frequency and Duration

Water samples were collected seasonally, four times over the course of one year (Winter, Spring, Summer, Autumn) to capture seasonal variations in water quality parameters.

Sample Collection and Preservation

At each site, surface water samples were collected in pre-cleaned polyethylene bottles following standard procedures. Samples for microbial analysis were collected in sterile containers and stored in iceboxes for transport to the laboratory within 4 hours. Physicochemical samples were preserved as per standard guidelines (e.g., acidification for nutrient analysis).

Physicochemical Analysis

Parameters measured in the field included

- Temperature (°C) using a calibrated digital thermometer.
- pH using a portable pH meter.
- Dissolved oxygen (DO) using a DO meter.
- Electrical conductivity (EC) and total dissolved solids (TDS) using a conductivity meter.
- Turbidity using a turbidity meter.

In the laboratory, water samples were analyzed for nutrient concentrations:

- Nitrate (NO3-) and phosphate (PO43-) were determined using colorimetric methods with a spectrophotometer following APHA (2017) [1] standard methods.

Microbial Analysis

Microbial contamination was assessed by quantifying total coliform and fecal coliform bacteria using the membrane filtration technique. Samples were filtered through sterile membranes, which were then incubated on selective media (e.g., m-Endo agar for total coliforms, m-FC agar for fecal coliforms) at specified temperatures. Colony-forming units (CFU) per 100 mL were counted and recorded.

Quality Control

All instruments were calibrated before use, and blank samples and duplicates were analyzed to ensure data accuracy and precision. Standard protocols were strictly followed to minimize contamination and sampling errors.

Data Analysis

Seasonal variations were statistically analyzed using ANOVA to determine significant differences between sampling periods. Correlation analyses were performed to explore relationships among physicochemical and microbial parameters.

Results

Seasonal Variation in Physicochemical Parameters

The physicochemical parameters of the Diyala River after its confluence with the Tigris River exhibited significant seasonal fluctuations over the one-year sampling period.

- **Temperature:** Water temperature ranged from 12.5°C in winter to 31.2°C in summer. The highest temperatures were recorded in summer, correlating with ambient air temperatures and reduced flow rates.
- **pH:** The pH values varied between 7.1 and 8.3, indicating generally neutral to slightly alkaline water throughout the year. The lowest pH was observed during winter, while summer samples showed slightly higher alkalinity.
- **Dissolved Oxygen (DO):** DO levels fluctuated from a low of 5.1 mg/L in summer to a high of 9.4 mg/L in winter. The decrease in DO during warmer months is consistent with the reduced solubility of oxygen at higher temperatures and increased biological oxygen demand.
- **Electrical Conductivity (EC):** EC ranged from 320 µS/cm in winter to 480 µS/cm in summer, indicating moderate ionic content with higher conductivity during low flow periods due to concentration of dissolved ions.
- **Total Dissolved Solids (TDS):** TDS followed a similar trend to EC, with values ranging from 210 mg/L in winter to 335 mg/L in summer.
- **Turbidity:** Turbidity values showed clear seasonal variation, with the highest readings during spring (up to 45 NTU), likely due to increased runoff and sediment transport, and the lowest in autumn (around 12 NTU).
- **Nutrients:** Nitrate (NO3-) concentrations ranged from 1.8 mg/L in winter to 4.2 mg/L in summer. Phosphate (PO43-) levels were generally low but showed a peak in spring at 0.65 mg/L, possibly linked to agricultural runoff.

Seasonal Variation in Microbial Parameters

Microbial contamination exhibited notable seasonal differences, with fecal and total coliform counts generally increasing during warmer months.

- **Total Coliforms:** Counts ranged from 200 CFU/100 mL in winter to 1,200 CFU/100 mL in summer. The highest microbial counts coincided with increased water temperatures and decreased flow, facilitating bacterial growth.
- **Fecal Coliforms:** Fecal coliform levels followed a similar pattern, with values ranging from 50 CFU/100 mL in winter to 650 CFU/100 mL in summer. This indicates elevated fecal contamination during warmer periods, possibly due to increased human and animal activity and reduced dilution.

Correlation Analysis

Statistical analysis revealed significant correlations between certain physicochemical and microbial parameters. For instance, water temperature was positively correlated with total coliform counts ($r = 0.76$, $p < 0.05$), while dissolved oxygen was negatively correlated with microbial counts ($r = -0.68$, $p < 0.05$). Nutrient concentrations, particularly nitrates, were moderately correlated with microbial contamination, suggesting nutrient enrichment may support bacterial proliferation.

Discussion

Seasonal Influence on Physicochemical Water Quality

The observed seasonal variations in physicochemical parameters are consistent with natural and anthropogenic influences typical of semi-arid river systems like the Diyala. Higher water temperatures and lower dissolved oxygen during summer reflect the thermal regime and hydrological patterns, including reduced flow and increased evaporation. These conditions can stress aquatic ecosystems and influence the solubility and bioavailability of nutrients and pollutants.

The neutral to slightly alkaline pH range aligns with previous studies of Iraqi rivers, influenced by carbonate geology and limited acid rain. Elevated electrical conductivity and TDS in summer suggest concentration effects due to evaporation and reduced dilution, highlighting seasonal stress on water chemistry.

The spike in turbidity during spring corresponds with the rainy season and increased surface runoff, which transports sediments and nutrients into the river. This sediment influx can reduce light penetration and affect aquatic habitats.

Nutrient dynamics, particularly increased nitrate and phosphate levels during spring and summer, are likely driven by agricultural runoff and wastewater discharge. These nutrients can promote eutrophication, posing risks to aquatic life and water usability. The seasonal nutrient patterns underscore the influence of human land use in the river basin.

Microbial Contamination and Health Implications

Microbial contamination exhibited a clear seasonal pattern, with elevated total and fecal coliforms during warmer months. This is likely due to several factors: increased bacterial growth at higher temperatures, greater human and livestock activities, and decreased river flow reducing dilution and self-purification capacity.

The fecal coliform levels, especially in summer, occasionally exceeded international water quality guidelines for recreational and drinking water, indicating potential health risks. This contamination may arise from untreated sewage discharge, livestock access to riverbanks, and runoff carrying animal waste.

The significant negative correlation between dissolved oxygen and microbial counts suggests that microbial activity may contribute to oxygen depletion, further stressing aquatic organisms. The positive correlation between nutrients and microbial load supports the hypothesis that nutrient enrichment fuels bacterial proliferation.

Implications for Water Management

The seasonal variations and periodic exceedance of microbial limits emphasize the need for robust water quality management in the Diyala-Tigris river system. Continuous monitoring is essential to identify pollution hotspots and temporal trends. Controlling point and non-point sources of pollution, such as wastewater treatment improvements and agricultural best practices, will be critical to maintaining water quality.

Effective management strategies should include public awareness campaigns to reduce direct waste disposal into the river, installation of sanitation infrastructure, and regulation of agricultural runoff. Additionally, preserving riparian buffers could reduce sediment and nutrient loading during rainfall events.

Study Limitations and Future Research

While this study provides valuable seasonal insights, it is limited to surface water sampling and four seasonal points. Future research should include higher-frequency sampling, sediment quality assessments, and broader spatial coverage. Investigating the presence of emerging contaminants and conducting biological assessments (e.g., macroinvertebrate diversity) would also enhance understanding of ecological health.

Conclusion

This study revealed significant seasonal variations in the physicochemical and microbial quality of the Diyala River after its confluence with the Tigris River. Higher temperatures, nutrient concentrations, and microbial loads were observed during summer and spring, indicating increased pollution and potential health risks during these periods. While most physicochemical parameters remained within acceptable limits, microbial contamination occasionally exceeded safe standards, highlighting the need for improved wastewater management and pollution control. These findings emphasize the importance of continuous monitoring and integrated water resource management strategies to protect the ecological integrity and public health of tssshe Diyala-Tigris river system.

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