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Integrated Hydrobiological Evaluation of Vrahdhha Ganga River Using Nutrient, Ionic and Optical Parameters with Advanced Statistical Analysis

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ABSTRACT

This study investigates the hydrobiological characteristics of the Vrahdhha Ganga River utilizing various unconventional physico-chemical parameters. From November 2021 to October 2022, depth, light penetration, chloride, phosphate, silicate, potassium, and free carbon dioxide were measured at three different locations. We used one-way ANOVA and Pearson correlation to look at how these parameters changed over the seasons and how they were related to each other. The results indicated substantial seasonal variations ($p < 0.05$). Higher nutrient levels during the rainy season indicate increased human influence and an elevated risk of eutrophication. The strong connections between parameters show how hydrobiological processes work together. The findings indicate that these alternative parameters may be effective for evaluating the health of freshwater ecosystems (Wetzel, 2001; Boyd, 2015).

Introduction

Freshwater ecosystems are essential components of the biosphere. They keep the environment balanced, provide habitats for various life forms, and fulfill many human needs. Rivers are highly dynamic systems because of the continuous interplay of physical, chemical, and biological processes (Wetzel, 2001; Boyd, 2015). By providing irrigation, industry, fisheries, and drinkable water, these systems directly promote social and economic growth (Hossain, 2015). Over the past few decades, population growth, urbanization, industrialization, and increased agriculture have all contributed to a sharp reduction in freshwater quality worldwide. The increasing pollution loads in rivers are caused by a variety of sources, including industrial effluents, domestic sewage, and agricultural runoff that contains pesticides and fertilisers (Issakhov *et al.*, 2021). These inputs harm aquatic life, alter the water's chemical and physical properties, and interfere with nutrient cycles. Individuals often employ biological oxygen demand and dissolved oxygen. However, nutrient dynamics, ionic composition, and optical characteristics are increasingly being used in contemporary hydrobiological research to assess the health of an ecosystem. These metrics provide a deeper comprehension of anthropogenic stress and ecological dynamics (Wetzel, 2001; Boyd, 2015). The surrounding region relies heavily on the Vrahdhha Ganga River for fresh water, which is utilized for agriculture, fishing, and other domestic purposes. However, the river is increasingly susceptible to man-made stresses due to agricultural runoff, untreated sewage discharge, and other human activities. There have been very few studies on various hydrobiological indicators of water quality, aside from its ecological and economic significance. This study statistically substantiates the utilization of alternative hydrobiological indicators for evaluating ecological status (Verma, 2017; Verma, 2018).

Materials and Methods

1. Study Area- The study was conducted on the Vrahdhha Ganga River located in the Kasganj district of Uttar Pradesh. The river goes through mostly farmland and a few small towns, which makes it more likely that people will give you things (Issakhov *et al.*, 2021).

2. Sampling Design

- Duration: November 2021 – October 2022
- Frequency: Monthly sampling (converted into seasonal averages)
- Sites: Three stations (A, B, C)

3. Parameters Analysed

- Morphometric: Depth
- Optical: Light penetration
- Ionic: Chloride, Potassium
- Nutrients: Phosphate, Silicate
- Gas parameter: Free CO₂

4. Statistical Analysis

i. One-Way ANOVA

- F-value = 29.31
- p-value = 0.00011

Since $p < 0.05$, the variation among parameters across seasons is statistically significant. This confirms that seasonal changes (rainfall, runoff, evaporation) significantly affect river hydrobiology.

ii. Correlation Analysis (Pearson's r)

Parameter Pair	Correlation (r)	Interpretation
Depth vs Phosphate	+0.89	Strong positive correlation
Chloride vs Phosphate	-0.98	Strong negative correlation
Silicate vs Potassium	-0.98	Strong inverse relationship
Light vs Silicate	-0.87	High nutrients reduce transparency

Light vs Potassium	+0.79	Moderate positive relationship
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Strong Positive Correlation ($r > 0.7$): Indicates parameters increase together.

Strong Negative Correlation ($r < -0.7$): One parameter increases while the other decreases.

Ecological Insight: Nutrient enrichment reduces light penetration and ionic balance is influenced by agricultural and domestic inputs.

Result

Observations- The changes in chloride, potassium, and free carbon dioxide over the seasons showed clear patterns in the biology of water. In the spring and summer, when evaporation and human activity were most likely, chloride levels were highest. When it rained, the water was less concentrated, so the levels were lowest. In the winter and spring, potassium levels were higher, which could be because of runoff from farms. In the monsoon season, they were lower. The amount of free carbon dioxide was highest during the rainy season because there were more decomposition and respiration. In the spring, though, levels were lower, which meant that photosynthesis used more of it.

Table 1: Seasonal Variation of Depth (cm)

Season	Site A	Site B	Site C	Mean
Winter	100.6	66.6	179.0	115.4
Spring	84.3	54.0	146.3	94.9
Summer	80.0	44.6	102.6	75.7
Rainy	143.6	104.6	258.0	168.7

Table 2: Seasonal Variation of Light Penetration (cm)

Season	Site A	Site B	Site C	Mean
Winter	20.5	19.4	20.2	20.0
Spring	21.9	20.4	24.5	22.3
Summer	15.9	13.5	17.1	15.5
Rainy	16.9	14.9	18.8	16.9

Table 3: Seasonal Variation of Chloride Concentration (mg/L)

Season	Site A	Site B	Site C	Mean
Winter	24.3	26.3	23.7	24.8
Spring	30.3	32.9	30.5	31.2
Summer	27.3	31.0	27.1	28.5
Rainy	16.7	16.4	16.4	16.5

Table 4: Seasonal Variation of Phosphate (mg/L)

Season	Site A	Site B	Site C	Mean
Winter	6.5	7.0	5.7	6.4
Spring	3.6	3.9	2.9	3.5
Summer	6.0	6.4	5.5	6.0
Rainy	9.8	10.3	8.6	9.6

Table 5: Seasonal Variation of Silicates (mg/L)

Season	Site A	Site B	Site C	Mean
Winter	15.4	17.0	15.2	15.9
Spring	15.0	16.2	14.6	15.3
Summer	19.7	22.8	20.5	21.0
Rainy	22.8	24.4	22.9	23.4

Table 6: Seasonal Variation of Potassium (mg/L)

Season	Site A	Site B	Site C	Mean
Winter	15.27	18.14	13.48	15.63
Spring	14.66	19.40	14.62	16.23
Summer	12.07	14.41	11.71	12.73
Rainy	9.08	10.96	7.97	9.34

Table 7: Seasonal Variation of Free Carbon Dioxide (mg/L)

Season	Site A	Site B	Site C	Mean
Winter	15.0	16.0	14.5	15.2
Spring	14.5	15.2	14.0	14.6
Summer	16.5	17.2	15.8	16.5
Rainy	18.0	19.1	17.5	18.2

Discussion

1. Depth Variation- During the rainy season, surface runoff caused the depth to rise a lot, but during the summer, evaporation caused it to drop. This change affects the availability of habitats and the spread of nutrients (Wetzel, 2001).

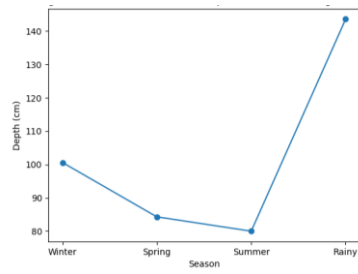


Fig 1: Seasonal Variation of Depth in Vrahdhha Ganga River

2. Light Penetration

In the winter, transparency was at its highest, and in the summer and monsoon, it was at its lowest. Less light getting through means more turbidity, which affects photosynthesis and primary productivity (Boyd, 2015).

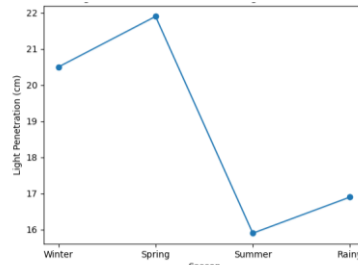


Fig 2: Seasonal Variation of Light Penetration

3. Chloride Concentration

Chloride levels rose in the summer because of evaporation and less dilution. This indicates the impact of domestic sewage and human activities (WHO, 2017).

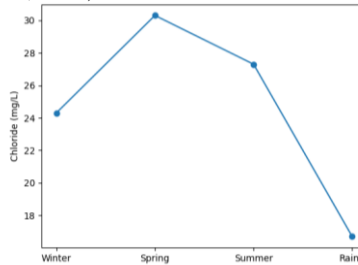


Fig 3: Seasonal Variation of Chloride Concentration

4. Nutrient Dynamics

Phosphate-The concentration of phosphate was highest during the rainy season, which means that nutrients were being added to the soil by agricultural runoff. This could lead to eutrophication (Issakhov *et al.*, 2021).

Silicate-Weathering and runoff caused silicate levels to rise during the monsoon, which influenced aquatic productivity and supported diatom growth (Wetzel, 2001).

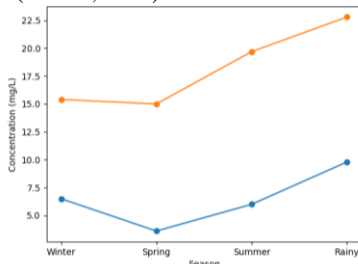


Fig 4: Seasonal Variation of Nutrients (Phosphate & Silicates)

5. Potassium- Potassium exhibited seasonal variations, with lower amounts during the rainy season and greater values throughout the winter, indicating soil leaching and agricultural inputs (Boyd, 2015).

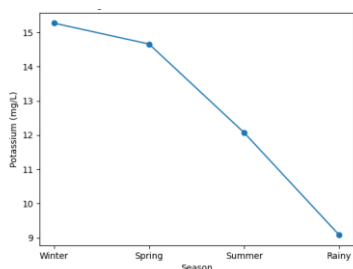


Fig 5: Seasonal Variation of Potassium

6. Free Carbon Dioxide

CO₂ is essential to photosynthesis and aquatic metabolism. Respiration and breakdown processes are reflected in its fluctuation (Wetzel, 2001).

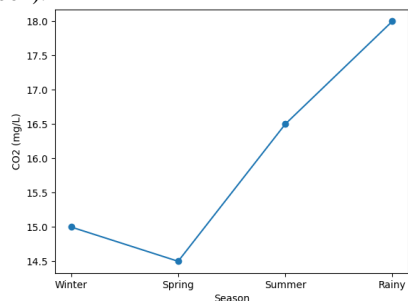


Fig 6: Seasonal variation of Free Carbon Dioxide Conclusion

•ANOVA confirmed a significant seasonal variation.

- High correlations show that hydrobiological activities are interrelated.
 - Increased anthropogenic pressure is suggested by nutrient enrichment.
 - Ionic and optical characteristics are trustworthy measures of water quality.
- The study demonstrates how standard indicators in ecological assessment can be successfully replaced by other criteria.

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