Inventum Biologicum: *An International Journal of Biological Research*
2026, Vol. 6, Issue 4, pp. 104-108

Inventum Biologicum

Journal homepage: www.journals.worldbiologica.com/ib

Research paper

Physicochemical Characteristics of Riverine Water and Sediments Association with Primary Productivity in Selected Sites of North Bihar, India

Shweta Kumari [a] *, **Nivedita Priyadarshini** [b]

[a] *Research Scholar, Department of Zoology, Jai Prakash University, Chapra, Bihar, India*
[b] *Assistant Professor, D.A.V. PG College, Siwan, Bihar, India*

ARTICLE INFO

Keywords

river sediment
nutrient availability
primary productivity
Saryu river
freshwater ecosystem

DOI
10.5281/ib-2650126

***Corresponding author**
Shweta Kumari

Email
shweta9746@gmail.com

ABSTRACT

Riverine sediment and water chemistry together influence nutrient availability and primary production, yet the spatial variability of these factors is not well understood for many small and seasonal rivers in the Indo-Gangetic plain. This research assessed certain physicochemical characteristics of bottom sediment and the water above it at three locations within the Saryu river system in north Bihar, exploring their relationship with gross primary productivity (GPP). Sediments were taken from the top 15 cm, processed, and analyzed for physicochemical properties, organic carbon, and micronutrients. GPP and net primary productivity (NPP) were measured using the light–dark bottle method, with dissolved oxygen estimated through the Winkler technique. At the three sites, sediment pH rose from 5.6-6.2 at Site 1 to 6.3-7.2 at Site 3, while mineralizable nitrogen increased from 56.24-63.32 to 124.3-156.22 mg kg-1, and available phosphorus rose from 25.13-31.24 to 48.21-53.62 mg kg^{-1}. The pH of the water column increased from 5.9-6.5 to 6.6-7.5, and dissolved nitrogen rose from 10.32-12.23 to 24.31-27.22 mg L^{-1}. GPP increased from 32.13-33.22 to 56.62-57.71 mg/$cm^{-3}h^{-1}$ across the sites. Pearson correlations from the original data indicated positive relationships between GPP and sediment pH (r=0.3241), mineralizable nitrogen (r=0.3180), available phosphorus (r=0.4164), and available potassium (r=0.2842), with stronger positive correlations for water-column nitrogen (r=0.5264) and potassium (r=0.5161). These findings suggest that nutrient availability and sediment-water interactions may lead to spatial variations in riverine primary production. This study offers a foundational framework for nutrient-sensitive river management, emphasizing the need for seasonally detailed monitoring and more robust statistical designs before recommending site-specific nutrient enrichment.

1. Introduction

Riverine productivity is shaped by the interplay of hydrology, sediment properties, nutrient availability, light conditions, and biological uptake. Bottom sediments are dynamic, capable of storing, transforming, and releasing nutrients, thus affecting the chemistry of the water above and the productivity of aquatic food webs. Recent research highlights that the movement of nitrogen and phosphorus is significantly influenced by hydrological connectivity, land use in catchments, and the biogeochemistry of sediments (Van Vliet *et al.,* 2023; Kamjunke & Sanders, 2024). Specifically, riparian soils and streambed sediments can function as nutrient sinks or sources, contingent on redox conditions, flow patterns, and sediment composition (Clayton et al., 2025; Wang *et al.,* 2023).

Therefore, freshwater productivity should be viewed as a combined sediment–water process rather

than solely based on water chemistry. Nutrient levels can fluctuate greatly along a river's course, and riverine primary producers may quickly absorb dissolved nitrate, phosphate, and silicate when residence time and light conditions are favorable (Li *et al.,* 2023). On the other hand, storm flows, sediment movement, and shifts in hydrological connectivity can redistribute nutrients and change their bioavailability (Xie *et al.,* 2022; Majumdar & Avishek, 2024). Hydroclimatic extremes add complexity to these interactions, as droughts and heatwaves can decrease dilution and dissolved oxygen, while floods can mobilize suspended sediment, nutrients, and other pollutants (Islam *et al.,* 2024).

The Indo-Gangetic river system is crucial because its waters and sediments support fisheries, agriculture, domestic needs, and diverse aquatic life. Recent studies on Indian rivers have highlighted the need for comprehensive assessments of physicochemical properties, nutrients, and pollution, considering the impact of tributaries and human activities on river-water quality (Das *et al.,* 2022; Koue *et al.,* 2024). Research from the Brahmaputra basin has also demonstrated that nutrient limitations and sediment phosphorus fractions vary by location and season (Liu *et al.,* 2022). This evidence suggests that local evaluations are vital, as nutrient dynamics cannot be accurately deduced from a single parameter or regional averages.

The study provided examined three specific sites, focusing on sediment pH, mineralizable nitrogen, available phosphorus and potassium, electrical conductivity, organic carbon, and micronutrients, along with corresponding water chemistry and primary productivity. The aim of the current study is to contextualize these findings within the modern sediment-water nutrient framework while maintaining the measured values and reported correlations from the original dataset. The main hypothesis is that spatial differences in sediment and water nutrient availability are positively linked to variations in riverine primary productivity.

2. Materials and Methods

2.1 Study design and sampling

Samples of bottom sediment were taken from the top 15 cm at three distinct river locations, each characterized by different sediment textures: hard, soft, and a combination of alluvial types. At each location, three samples were collected. These samples were then air-dried, ground, and sieved using an 80-mesh screen. For analyses excluding texture and organic carbon, the samples were incubated in submerged conditions for 10 days with a soil-to-water ratio of 1:10 to simulate semi-aerobic riverine environments.

2.2 Sediment Analyses

Sediment pH, organic carbon, mineralizable N, available P and available K were determined using the analytical procedures reported in the APHA (2017). DTPA-extractable micronutrients were also assessed.

2.3 Water-quality analyses

Water pH, total alkalinity, TDS, EC and water-soluble N, P and K were measured. Gross primary productivity (GPP) and net primary productivity (NPP) were estimated followed previous researchers (APHA, 2017).

2.4 Statistical Analysis

The connections between environmental factors and GPP were assessed through correlation coefficients. The initial manuscript presents Pearson correlation coefficients along with significance levels for specific sediment and water variables. As the provided paper lacks details on the sample size for each correlation, confidence intervals, precise P values, or assumption testing, the statistical findings are viewed as exploratory associations instead of causal relationships.

3. Results and Observations

3.1 Sediment physicochemical characteristics

Analysis of sediment chemistry revealed a uniform rise in pH, mineralizable nitrogen, available phosphorus, available potassium, organic carbon, and the aggregate micronutrient measure from Site 1 through to Site 3. Consequently, Site 3 exhibited the sediment with the highest nutrient status among the three sites. Similarly, the EC values followed this increasing trend. These observations indicate a spatial gradient in the chemical properties of the sediment, although the data at hand does not allow for the identification of the underlying causes (Table 1).

Table 1 Sediment analysis of Saryu river

Parameter	Site 1	Site 2	Site 3
pH	5.6-6.2	5.8-6.4	6.3-7.2
Mineralizable N (mg kg^{-1})	56.24-63.32	62.46-73.12	124.3-156.22
Available P (mg kg^{-1})	25.13-31.24	36.42-47.23	48.21-53.62
Available K (mg kg^{-1})	48.23-52.54	56.23-61.21	71.23-74.92
EC (dS m^{-1})	11.2-11.4	13.4-13.6	14.2-14.4
Organic carbon (%)	1.12-1.15	1.21-1.24	1.36-1.39
Micronutrients (%)	16-18	18-20	21-23

Water chemistry varied along the sediment gradient. Site 1 recorded the lowest levels of pH, dissolved nitrogen, potassium, alkalinity, total dissolved solids, and productivity, while Site 3 exhibited the highest levels. Gross primary productivity (GPP) rose from about 32-33 to 56-58 mg $cm^{-3}h^{-1}$, and net primary productivity (NPP) increased from roughly 16 to 29 mg $cm^{-3}h^{-1}$. This simultaneous rise in nutrient availability and productivity aligns with the idea that nutrient status influences spatial variations in primary production, even though factors like light, flow, temperature, phytoplankton biomass, and community composition were not assessed (Table 2).

Table 2 Water chemistry and Primary productivity

Parameter	Site 1	Site 2	Site 3
pH	5.9-6.5	6.1-6.7	6.6-7.5
Available N (mg L^{-1})	10.32-12.23	12.46-14.12	24.31-27.22
Available P (mg L^{-1})	1.32-1.41	1.33-1.54	1.42-1.63
Available K (mg L^{-1})	18.23-20.54	26.23-28.21	31.23-34.32
EC (dSm^{-1})	0.452-0.456	0.563-0.565	0.737-0.740
Total alkalinity (ppm)	21.12-21.23	32.36-32.43	46.22-47.12
TDS (g L^{-1})	1.52-1.54	2.14-2.16	2.34-2.36
GPP (mg cm^{-3} h^{-1})	32.13-33.22	46.56-47.63	56.62-57.71
NPP (mg cm^{-3} h^{-1})	16.23-16.42	24.21-24.42	28.48-28.64

Table 3 Association between environmental variables and GPP

Sediment variable	r with GPP	Significance
pH	0.3241	0.05
Mineralizable N	0.3180	0.05
Available P	0.4164	0.05
Available K	0.2842	0.05
Water variable	**r with GPP**	**Significance**
pH	0.2256	0.05
Mineralizable N	0.5264	0.01
Available P	0.2873	0.05
Available K	0.5161	0.01

All observed correlations were positive (Table 3). Within sediment variables, available phosphorus exhibited the highest correlation with GPP (r=0.4164). In contrast, the strongest associations were found with water-column mineralizable/available nitrogen (r=0.5264) and potassium (r=0.5161). These findings imply that nutrient availability in the water column might be more closely linked to current productivity compared to certain sediment variables. However, the limited sampling design hinders a definitive ranking of nutrient limitation.

3. Discussion

The main feature is the synchronized spatial rise in sediment nutrients, water-column nutrients, and primary productivity from Site 1 to Site 3. Modern river biogeochemistry acknowledges that sediments can both retain and release nutrients, with this balance influenced by factors such as hydrology, oxygen levels, organic matter, and mineral surfaces (Van Vliet *et al.,* 2023; Kamjunke & Sanders, 2024; Clayton et al., 2025; Wang *et al.,* 2023). The current positive links between sediment nutrient levels and GPP are thus ecologically reasonable, but they should be viewed as associations rather than proof that increasing a nutrient will automatically boost fish production.

Nitrogen was identified as a significant correlate in the current dataset. Recent studies indicate that riverine nitrogen is governed by both catchment connectivity and sediment transformations, including nitrification, de-nitrification, and sediment-mediated retention (Li *et al.,* 2023; Xie *et al.,* 2022; Majumdar & Avishek, 2024). The dynamics of dissolved inorganic nitrogen can also be significantly altered by dissolved oxygen and turbulence (Islam *et al.,* 2024). Therefore, the elevated nitrogen levels observed at Site 3 might be due to variations in nutrient supply, sediment mineralization, hydrological exchange, or external inputs rather than a single local process.

Phosphorus showed a positive correlation with GPP in both sediment and water, although these correlations were weaker than those for water nitrogen and potassium. This is crucial because

phosphorus is often retained in sediments and may be released sporadically during disturbances or changes in redox conditions. High-frequency studies indicate that labile sediment phosphorus can become particularly mobile during storm events, while sediment phosphorus attenuation and release vary across space and time (Das et al., 2022; Koue *et al.,* 2024). Recent modeling further confirms that sediment–water phosphorus exchange can regulate phosphorus concentrations in overlying water under low-flow and oxygen-limited conditions (Liu *et al.,* 2022). This study did not measure phosphorus fractions or redox status, so it cannot differentiate between externally supplied phosphorus and internally recycled phosphorus.

The rise in pH, alkalinity, and electrical conductivity from Site 1 to Site 3 also aligns with a shift in sediment–water geochemistry. However, pH alone is not an adequate indicator of productivity. River phytoplankton can quickly deplete dissolved nutrients under favorable light and residence-time conditions, while nutrient concentrations may also rise due to external loading.

Recent findings show that dissolved nutrients can be nearly depleted in free-flowing sections through biological uptake, while river inflows can create strong seasonal nutrient gradients in receiving waters (Li *et al.,* 2023; Dael *et al.,* 2024; Tellbüscher *et al*., 2025). As a result, nutrient concentrations should be considered alongside discharge, water residence time, suspended solids, chlorophyll-a, and dissolved oxygen.

Fish production relies on factors such as trophic transfer efficiency, plankton and benthic food-web structure, habitat, recruitment, fishing pressure, and species composition. Current aquaculture literature similarly highlights that nutrient inputs do not directly convert into biomass because significant portions of nutrients can remain in sediments or exit the system through water discharge (Lavrentyeva & Lavrentyeva, 1996; Barbosa *et al*., 2024). Therefore, management strategies should focus on maintaining balanced nutrient availability rather than indiscriminately adding fertilizers.

Recent investigations into Indian rivers highlight the necessity for monitoring tailored to specific sites. Research indicates that the Ganga experiences changes in water quality linked to agricultural practices, industrial operations, sewage, and contributions from tributaries. Meanwhile, analyses of Indian tributaries reveal significant spatial differences in physicochemical properties and pollution levels. Consequently, a future monitoring plan for the study river should encompass sediment and water nutrients, hydrology, dissolved oxygen, chlorophyll-a, phytoplankton composition, suspended sediment, trace metals, and land-use data.

4. Conclusion

The research highlights a distinct spatial relationship between the chemistry of river sediments, the nutrient levels in the water column, and primary productivity across three chosen locations in north Bihar. Among these, Site 3 consistently showed elevated levels of sediment N, P, and K, as well as higher nutrient concentrations in the water column to Sites 1 and 2. Positive correlations were observed for all sediment and water parameters studied, with the most significant links found between water N and K. These results suggest that the interaction between sediment and water nutrients plays a crucial role in riverine productivity. Nonetheless, the evidence remains in correlation and does not support direct nutrient enrichment as a fisheries management strategy. Future research should address the noted data inconsistencies and employ seasonally repeated and sampling that includes biological, trace-metal, and nutrient-fraction analyses. This comprehensive approach would greatly enhance the ecological understanding and management significance of river productivity evaluations in the Indo-Gangetic plain.

References

1. Van Vliet, M.T.H., Thorslund, J. & Strokal, M. et al. (2023). Global river water quality under climate change and hydro-climatic extremes. Nature Reviews Earth & Environment, 4 (10): 687-702. DOI:10.1038/s43017-023-00472-3.
2. Kamjunke, N. & Sanders, T. (2024). Complete exhaustion of dissolved nutrients in a large lowland river. Environmental Monitoring and Assessment, 196 (7): 660. DOI:10.1007/s10661-024-12834-5.
3. Clayton, G.E., Richards, L.A. & Fox, B.G. et al. (2025). Associations of anthropogenic activity and tributaries with the physicochemical, nutrient and microbial composition of the Ganga (Ganges) River, India. Water Research, 278: 123374. DOI:10.1016/j.waters.2025.123374.
4. Wang, Y., Lin, J., Wang, F., Tian, Q., Zheng, Y. & Chen, N. (2023). Hydrological connectivity affects nitrogen migration and retention in the land-river continuum. Journal of Environmental Management, 326: 116816. DOI:10.1016/j.jenvman.2022.116816.
5. Li, S., Arnscheidt, J., Cassidy, R., Douglas, R.W., McGrogan, H.J. & Jordan, P. (2023).The spatial and temporal dynamics of sediment phosphorus attenuation and release in impacted stream catchments. Water Research, 245: 120663. DOI:10.1016/j.waters.2023.120663.
6. Xie, H., Gao, T., Wan, N. & Xiong, Z. et al. (2022).Controls for multi-temporal patterns of riverine nitrogen and phosphorus export to lake: Implications for catchment management by high-frequency observations. Journal of Environmental Management, 320:115858. DOI:10.1016/j.jenveman.2022.115858.
7. Majumdar, A. & Avishek, K. (2024). Assessing heavy metal and physiochemical pollution load of Danro River and its management using floating bed remediation.

Scientific Reports, 14 (1): 9885. DOI:10.1038/s.41598-024-60511-x.
8. Islam, A., Hoque, M.M., Ghosh, S., Sarkar B., Sadik, M., Das, B.C., Islam, A.R.M.T., Pal, S.C., Sarkar, M., Khatun, M., Chakraborty, D., Mallick, S. & Alam E. (2024).Hydro-chemical characterization and irrigation suitability assessment of a tropical decaying river in India. Scientific Reports, 14: 20096. DOI:10.1038/s.41598-024-70851-3.[8]
9. Das, A., Kumar, M., Jha, P.K., Kumari, R., Panday, D.P., Hdeib, R., Mahlknecht, J. & Deshpande, R.D. (2022). Isotopic and hydrogeochemical tracking of dissolved nutrient dynamics in the Brahmaputra River System: A source delineation perspective. Chemosphere, 307: 135757. DOI:10.1016/j.chemosphere.2022.135757.
10. Koue, J. (2024). Impact of riverine inputs on nutrient dynamics and water quality in enclosed water bodies. Terrestrial, Atmospheric and Oceanic Sciences, 35: 19. DOI:10.1007/s.44195-024-00081-7.
11. Liu, M., He, Y., Cao, Li., Zhi, Y., He, X., Wei, Y., Yuan, X., Liu, B., He, Q., Li, H. & Miao, X. (2022).Fate of dissolved inorganic nitrogen in turbulent rivers: The critical role of dissolved oxygen levels. Environmental Pollution, 312:120074. DOI:10.1016/j.envpol.2022.120074.
12. A.P.H.A. (2017). Standard Methods for the Examination of Water and Wastewater (23rd ed.). American Public Health Association, Washington, DC, USA.
13. Dael, T.V., Vermeiren, C. & Smolders, E. (2024). Internal loading of phosphorus in streams described by a Sediment-Water Exchange Model for Phosphorus (SWEMP): From lab to field scale. Science of the Total Environment, 912: 168912. DOI:10.1016/j.scitotenv.2023.168912.
14. Tellbüscher, A.A., Gebauer, R. & Mráz, J. (2025). Nutrients revisited: Review and meta-data analysis of nutrient inputs into freshwater aquaculture systems. Aquaculture. 595: 741633. DOI:10.1016/j.aquaculture/595.741633.
15. Lavrentyeva, G.M. & Lavrentyeva, P.J. (1996). The relationship between fish yield and primary production in large European freshwater lakes. Hydrobiol. Vol. 322, (1-3): 261-266.
16. Barbosa, A.P.D., Kosten, S., Muniz, C.C. & Oliveira-Junior, E.S. (2024). From feed to fish-Nutrients' fate in aquaculture systems. Applied Sciences, 14: 6056. DOI:10.3390/app14146056.