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Pre-Monsoon Water Quality Degradation Along the Punpun River from Pali to Fatuha Blocks, Patna District: Implications for Aquatic Habitat Suitability

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Abstract

The Punpun River, a major tributary of the Ganga originating near the Palamu region of Jharkhand, traverses roughly 64 km between sampling sites from Pinjrawan (Pali block) to Sammaspur (Fatuha block) of Patna district before its confluence with the Ganga near Fatuha. This study presents a pre-monsoon (18–20 April) comparative assessment of physico-chemical water quality at the river's entry point into the district (Pinjrawan) and its exit point (Sammaspur) immediately before the Ganga confluence. Fourteen parameters—temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), total hardness, calcium, magnesium, chloride, sulphate, nitrate, alkalinity, turbidity, dissolved oxygen (DO) and biochemical oxygen demand (BOD)—were evaluated against BIS (2012) desirable and permissible limits. At Pinjrawan, all major ionic and nutrient parameters remained within desirable limits; DO (7.88 mg L^{-1}) and BOD (2.91 mg L^{-1}) indicated a well-oxygenated, low-pollution stretch, although turbidity (21.82 NTU) exceeded the permissible limit. At Sammaspur, TDS, total hardness, magnesium and alkalinity had crossed the desirable limit (remaining within the permissible limit), DO had declined to 5.77 mg L^{-1}, BOD had risen to 4.93 mg L^{-1}, and turbidity had risen sharply to 158.5 NTU. The consistent downstream increase across nearly all parameters indicates a pronounced longitudinal degradation gradient over the 64 km stretch, plausibly linked to agricultural return flow, domestic sewage inflow and industrial effluent discharge, in addition to natural evaporative concentration and sediment loading. While the river remains largely within drinking-water-adjacent limits for major ions at both sites, turbidity is a basin-wide concern and the exit stretch shows early signs of organic enrichment. Both sites nominally meet CPCB (2008) criteria for fish and wildlife propagation (DO, pH), but literature turbidity–biota thresholds suggest the entry site's benthic community is already under sediment-related stress and the exit site's high turbidity and narrower DO margin are less favourable for fish foraging and respiratory efficiency. Findings are presented as a preliminary longitudinal signal; an expanded, seasonally replicated monitoring design incorporating direct biological survey is recommended.

Keywords: Punpun River; Water quality; Pre-monsoon; Physico-chemical parameters; Turbidity; Dissolved oxygen; BOD; Longitudinal gradient; Aquatic habitat; Patna district; BIS; CPCB

1. Introduction

River water quality is a sensitive indicator of the cumulative interaction between natural catchment processes and anthropogenic pressures, and its systematic monitoring is central to both water-resource management and public-health planning in densely populated river basins such as those of the Middle Gangetic Plain (Iqbal et al., 2019).

Despite a growing body of work on Ganga-basin tributaries, site-specific, within-district longitudinal comparisons—contrasting a river's condition where it enters a district with its condition where it leaves the district and merges with the Ganga—remain limited. Such an entry–exit comparison is useful because it isolates the net water-quality change accrued specifically over the district's approximately 64 km reach, a scale directly relevant to local land-use planning, block-level pollution-source identification and district administration.

The Punpun River, a significant right-bank tributary of the Ganga, originates in the Palamu region of Jharkhand and flows through parts of Bihar before joining the Ganga near Fatuha. Along its course through Patna district it receives agricultural return flows, domestic sewage and industrial effluents. Previous hydrochemical studies have shown that the river's chemistry is shaped jointly by natural weathering and evaporative-concentration processes and by anthropogenic inputs (Ranjan et al., 2024). Comparable deterioration has been documented on the adjoining Ganga stretch at Patna, linked to sand mining, construction activity and untreated sewage discharge (Zafar & Kumari, 2024).

The present study therefore undertakes a focused pre-monsoon comparison of fourteen physico-chemical parameters at the river's entry point into Patna district (Pinjrawan, Pali block) and its exit point (Sammaspur, Fatuha block), with the dual aims of quantifying the longitudinal degradation gradient and drawing preliminary inferences for aquatic-habitat suitability.

2. Study Area

The study covers approximately 64 km of the Punpun River's course through Patna district, Bihar, from its entry at Pinjrawan in Pali block to its exit near Sammaspur in Fatuha block, just before the river drains into the Ganga (Fig. 1). Along this stretch the river traverses the Pali, Naubatpur, Punpun, Sampatchak and Fatuha blocks, an area forming part of the Middle Gangetic Alluvial Plain (Ranjan & Singh, 2023).

The terrain is characterised by gently north-sloping alluvial land built up by sediment from the Southern Chotanagpur Plateau. Agriculture is the dominant land use, with increasing peri-urban influence toward the Fatuha–Patna urban agglomeration near the exit site. The combination of intensive agriculture, domestic sewage and documented industrial discharges (including paper-mill effluent) along this reach provides the anthropogenic context for the observed water-quality gradient.

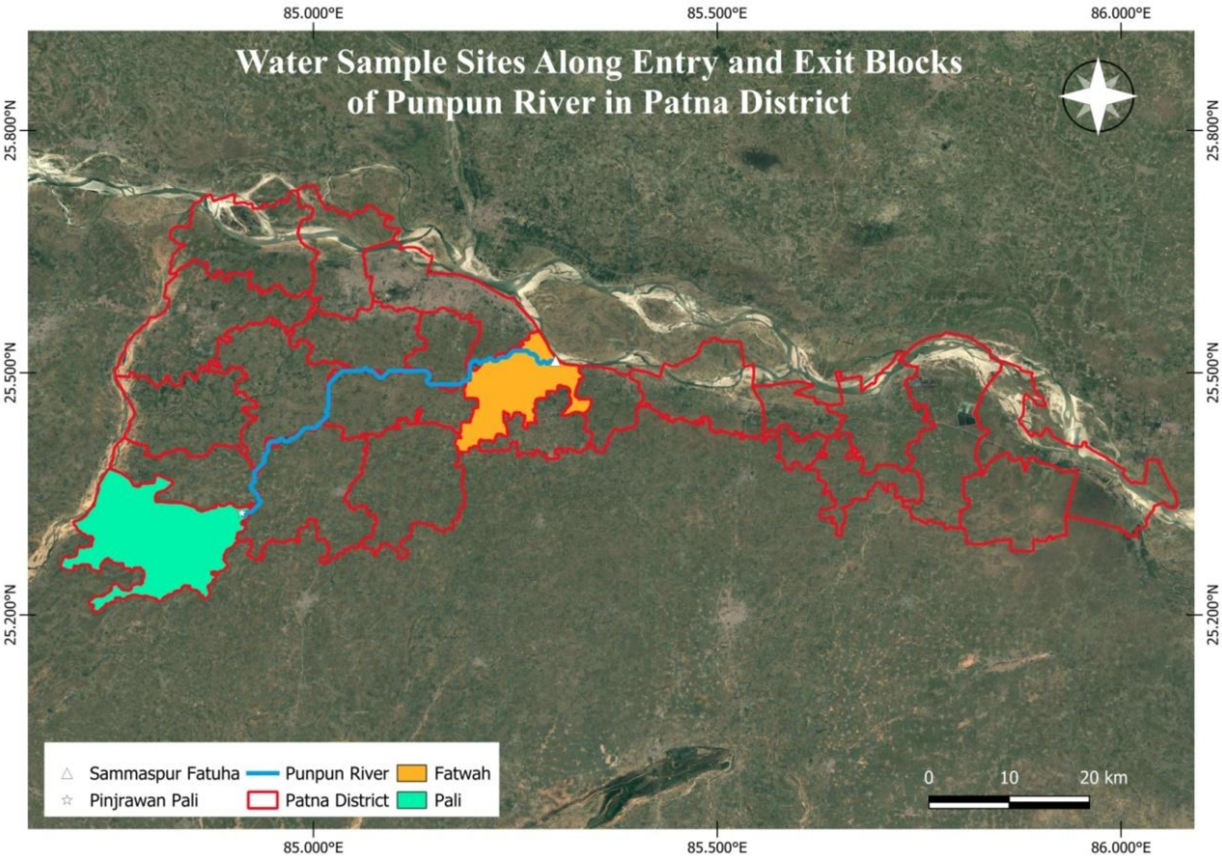

Fig. 1. Location of the Pinjrawan (entry, Pali block) and Sammaspur (exit, Fatuha block) water-sampling sites along the Punpun River in Patna district, Bihar. Map prepared in QGIS 3.44 on a satellite base layer.

3. Materials and Methods

3.1 Sampling Design

Grab water samples were collected from two sites bracketing the Patna district reach of the Punpun River: Pinjrawan (Pali block), representing the river's entry point into the district, and Sammaspur (Fatuha block), representing its exit point immediately upstream of the Ganga confluence (Fig. 1). Sampling was carried out during the pre-monsoon season between 18 and 20 April 2026, with triplicate sub-samples collected at each site and the mean value used for site-level interpretation. Surface-water samples were taken to a depth of one metre from both river banks and the middle of the channel.

Table 1. GPS coordinates and sampling details of the two monitoring sites

Sample Site	Coordinates	Sampling Depth / Method
Pinjrawan (Pali)	25° 19′ 33.9816″ N 84° 54′ 40.6584″ E	Surface water up to 1 m depth from both banks and mid-channel
Sammaspur (Fatuha)	25° 30′ 52.7868″ N 85° 17′ 59.5068″ E	Surface water up to 1 m depth from both banks and mid-channel

Source: Field survey, April 2026.

3.2 Parameters and Analytical Methods

Fourteen physico-chemical parameters were determined: temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), total hardness, calcium, magnesium, chloride, sulphate, nitrate, total alkalinity, turbidity, dissolved oxygen (DO) and five-day biochemical oxygen demand (BOD_5). All analyses followed standard protocols of APHA (2017) and were evaluated against BIS (2012) desirable and permissible limits.

Table 2. Analytical methods used for determination of physico-chemical parameters

Parameter	Method Principle	Instrument / Technique	Reference
Temperature	Thermometric (in-situ)	Mercury/digital thermometer	APHA 2550 B
pH	Electrometric	Digital pH meter	APHA 4500-H^+ B
EC	Electrometric (in-situ)	Conductivity meter	APHA 2510 B
TDS	Gravimetric / conductivity-based	Gravimetric / TDS meter	APHA 2540 C
Turbidity	Nephelometric	Nephelometer (NTU)	APHA 2130 B
Total Hardness	EDTA titrimetric	Titration (EDTA, EBT)	APHA 2340 C

Calcium	EDTA titrimetric	Titration (EDTA, Murexide)	APHA 3500-Ca B
Magnesium	Computed / EDTA titration	Titration	APHA 3500-Mg B
Chloride	Argentometric (Mohr's)	Titration ($AgNO_3$, K_2CrO_4)	APHA 4500-Cl^- B
Sulphate	Turbidimetric	UV–Vis spectrophotometer	APHA 4500-SO_4^{2-} E
Nitrate	Spectrophotometric (UV / brucine)	UV–Vis spectrophotometer	APHA 4500-NO_3^- B
Alkalinity	Acid titration	Titration (H_2SO_4, indicators)	APHA 2320 B
BOD_5	5-day BOD test (20 °C)	BOD incubator + Winkler titration	APHA 5210 B
DO	Winkler iodometric / electrometric	Titration / DO meter	APHA 4500-O C/G

Source: After APHA (2017) and BIS (2012).

3.3 Data Evaluation

Site means of the triplicate samples were compared against BIS (2012) desirable and permissible limits for drinking-water parameters and against CPCB (2008) criteria for Class D waters (fish and wildlife propagation). Longitudinal change was expressed as absolute and relative differences between the entry and exit sites. Ecological inferences for habitat suitability were drawn from published dose–response and threshold relationships for turbidity, DO, BOD and conductivity, recognising that direct biological sampling lay outside the scope of the study.

4. Results

4.1 Pinjrawan (Entry Site, Pali Block)

Table 3. Pre-monsoon physico-chemical characteristics at Pinjrawan (Pali block)

Parameter	Value	Desirable limit	Permissible limit	Remark
Temperature (°C)	29.95	–	–	No BIS limit
pH	8.1	6.5–8.5	NR	Within desirable

TDS (mg L^{-1})	192.82	500	2000	Within desirable
EC (µmhos cm^{-1})	296.65	–	–	No BIS limit
Total Hardness (mg L^{-1})	98	200	600	Within desirable
Calcium (mg L^{-1})	22.84	75	200	Within desirable
Magnesium (mg L^{-1})	9.96	30	100	Within desirable
Chloride (mg L^{-1})	34.98	250	1000	Within desirable
Sulphate (mg L^{-1})	20.8	200	400	Within desirable
Nitrate (mg L^{-1})	≈0 (BDL)	45	NR	Below detection
Alkalinity (mg L^{-1})	59	200	600	Within desirable
Turbidity (NTU)	21.82	1	5	Exceeds permissible
DO (mg L^{-1})	7.88	–	–	No BIS limit
BOD (mg L^{-1})	2.91	–	–	No BIS limit

Source: Field analysis, April 2026. BDL = below detection limit; NR = no relaxation.

At Pinjrawan the water was near-neutral to mildly alkaline (pH 8.1). Ionic load, reflected in TDS (192.82 mg L^{-1}) and EC (296.65 µmhos cm^{-1}), was low to moderate, consistent with a relatively undisturbed upper reach. Total hardness (98 mg L^{-1}), calcium (22.84 mg L^{-1}) and magnesium (9.96 mg L^{-1}) placed the water in the moderately hard category, well within BIS desirable limits. Chloride, sulphate and alkalinity likewise remained comfortably below their respective desirable thresholds. Nitrate was below the analytical detection limit, indicating negligible nutrient enrichment. Turbidity (21.82 NTU) was the only parameter to exceed the BIS permissible limit of 5 NTU, consistent with suspended sediment typical of active alluvial river flow. DO (7.88 mg L^{-1}) and BOD (2.91 mg L^{-1}) together indicated a well-oxygenated stretch with low organic-pollution load at the point where the river enters the district.

4.2 Sammaspur (Exit Site, Fatuha Block)

Table 4. Pre-monsoon physico-chemical characteristics at Sammaspur (Fatuha block)

Parameter	Value	Desirable limit	Permissible limit	Remark
Temperature (°C)	31.1	–	–	No BIS limit
pH	7.46	6.5–8.5	NR	Within desirable
TDS (mg L^{-1})	613.55	500	2000	Exceeds desirable; within permissible
EC (µmhos cm^{-1})	943.15	–	–	No BIS limit
Total Hardness (mg L^{-1})	310	200	600	Exceeds desirable; within permissible
Calcium (mg L^{-1})	68.13	75	200	Within desirable
Magnesium (mg L^{-1})	33.78	30	100	Exceeds desirable; within permissible
Chloride (mg L^{-1})	81.96	250	1000	Within desirable
Sulphate (mg L^{-1})	26.4	200	400	Within desirable
Nitrate (mg L^{-1})	≈0 (BDL)	45	NR	Below detection
Alkalinity (mg L^{-1})	232	200	600	Exceeds desirable; within permissible
Turbidity (NTU)	158.5	1	5	Exceeds permissible
DO (mg L^{-1})	5.77	–	–	No BIS limit
BOD (mg L^{-1})	4.93	–	–	No BIS limit

Source: Field analysis, April 2026. BDL = below detection limit; NR = no relaxation.

At Sammaspur, pH (7.46) remained within the desirable range, but the ionic load had risen markedly: TDS (613.55 mg L^{-1}) and EC (943.15 µmhos cm^{-1}) were more than three times their Pinjrawan values. Total hardness (310 mg L^{-1}), magnesium (33.78 mg L^{-1}) and alkalinity (232 mg L^{-1}) had each crossed the BIS desirable threshold, though all remained within the permissible limit. Calcium, chloride and sulphate stayed within desirable limits, and nitrate remained below detection. Turbidity rose sharply to 158.5 NTU—roughly seven times the Pinjrawan value and more than 30 times the BIS permissible limit—indicating a substantial sediment or particulate load. DO had declined to 5.77 mg L^{-1} and BOD had risen to 4.93 mg L^{-1} relative to Pinjrawan, together suggesting a shift toward moderate organic loading and a reduced self-purification capacity, without indicating gross pollution.

4.3 Longitudinal (Entry-to-Exit) Trend

Table 5. Comparative summary of key indicators between entry and exit sites

Site	pH	TDS (mg L^{-1})	Turbidity (NTU)	Alkalinity (mg L^{-1})	DO (mg L^{-1})	BOD (mg L^{-1})
Pinjrawan (entry)	8.1	192.82	21.82	59	7.88	2.91
Sammaspur (exit)	7.46	613.55	158.5	232	5.77	4.93

Source: Field analysis, April 2026.

Tables 3–5 show a consistent one-directional shift between the entry and exit sites: TDS, EC, total hardness, magnesium, alkalinity and turbidity all increase substantially downstream, while DO declines and BOD rises. A modest fall in pH toward neutrality was also observed. This pattern is consistent with the cumulative addition of dissolved and suspended material as the river passes through five blocks with mixed agricultural and increasingly peri-urban land use, and aligns with prior findings that Punpun River hydrochemistry is shaped jointly by natural weathering/evaporative-concentration processes and anthropogenic inputs such as agricultural runoff, domestic sewage and industrial effluent (Ranjan et al., 2024). It is also consistent with broader evidence from the adjoining Ganga stretch at Patna, where sand mining, construction activity and untreated sewage discharge have been linked to downstream water-quality deterioration (Zafar & Kumari, 2024).

5. Discussion

5.1 Interpretation of the Longitudinal Pattern

The downstream shift—TDS and EC roughly tripling, turbidity rising ~7.3-fold, alkalinity ~3.9-fold, DO falling ~27 percent and BOD rising ~69 percent, against a modest fall in pH—is consistent with the well-documented signature of cumulative mid-catchment loading reported for other Indian tropical rivers, where rising ionic load and turbidity typically co-occur with falling DO and rising BOD as a river receives agricultural, domestic and industrial inputs (Ravindra et al., 2003; Sharma & Kansal, 2011). For the Punpun specifically, this pattern aligns with earlier hydrochemical work (Ranjan et al., 2024) and with independent findings on the adjoining Ganga stretch at Patna (Zafar & Kumari, 2024), where TDS, total hardness, total alkalinity and EC were identified as the dominant drivers of water-quality decline—notably the same four parameters that crossed desirable BIS limits at Sammaspur.

The paired decline in DO and rise in BOD toward the exit is a widely reported early-warning signature of organic enrichment in Ganga-basin rivers (Kumar et al., 2011). Against the CPCB bathing-class benchmark of BOD ≤ 3 mg L^{-1}, the Sammaspur value of 4.93 mg L^{-1} falls just outside this criterion, placing the exit reach in a range comparable to other Bihar tributaries of the Ganga that pass through urban-industrial land use (Priyadarshee et al., 2024).

The rise in TDS, calcium, magnesium and total hardness downstream is ecologically relevant beyond compliance status: freshwater macroinvertebrates experience rising energetic costs of ion/water balance as conductivity increases, with community composition shifting toward generalist, pollution-tolerant taxa well before acute-toxicity thresholds are reached (Olson & Hawkins, 2017). The Sammaspur TDS of 613.55 mg L^{-1} remains far below reported acute-toxicity thresholds (Chapman et al., 2000) but sits within the range where such compositional shifts have been documented elsewhere.

Turbidity is the parameter of greatest concern at both sites, and especially at the exit. Published dose–response work indicates that even modest turbidity increases (5–25 NTU above baseline) can reduce primary production by 3–50 percent, with zooplankton feeding efficiency measurably impaired at turbidities as low as 6 NTU (Henley et al., 2000). Both Pinjrawan (21.82 NTU) and Sammaspur (158.5 NTU) exceed the BIS permissible limit of 5 NTU, and the exit value lies well into the range associated with reduced light penetration, suppressed macrophyte growth and impaired visual/drift feeding in fish (Davies-Colley & Smith, 2001; Wilkes et al., 2018). The fact that turbidity already exceeds the permissible limit at the entry site indicates that this is a basin-wide characteristic of the middle Punpun rather than a feature confined to the exit stretch.

5.2 Implications for Aquatic Habitat Suitability

Because biological sampling was outside the scope of this study, the following inferences are drawn from the measured physico-chemical state and from published dose–response and threshold relationships, not as a substitute for direct biological survey. Dissolved oxygen at both sites remains above the 5 mg L^{-1} threshold commonly used to flag ecological impairment in Indian rivers during the pre-monsoon (Antil et al., 2024), but the 27 percent decline between Pinjrawan and Sammaspur, paired with a corresponding rise in BOD, is the classic signature of a river moving from a well-oxygenated to an early organically enriched state (Kumar et al., 2011). Turbidity is the parameter most likely to carry direct ecological consequence at both sites. The rise in TDS and hardness ions toward the exit, while remaining within BIS permissible limits and below acute-toxicity thresholds, falls within the range associated elsewhere with a measurable shift toward more pollution-tolerant macroinvertebrate assemblages (Olson & Hawkins, 2017).

Taken together, the entry site's chemistry is broadly consistent with conditions supportive of a relatively intact, sensitive aquatic community, constrained mainly by elevated turbidity; the exit site's chemistry—lower DO, higher BOD, markedly higher turbidity and TDS—is consistent with an early-stage organically enriched state in which pollution-tolerant taxa would be expected to become more prevalent. These are inferences drawn from literature thresholds rather than direct observations and should be treated as testable hypotheses for future biological survey.

5.3 Limitations

This assessment is based on two sites and a single pre-monsoon sampling event; the findings should therefore be read as a preliminary longitudinal signal rather than a comprehensive basin-wide characterisation. The absence of intermediate sampling points along the Naubatpur, Punpun and Sampatchak blocks means the entry–exit change cannot yet be attributed to specific reaches or point sources. Seasonal variation (monsoon, post-monsoon) was not captured, and microbiological and trace-metal parameters—both relevant given documented industrial discharge—were outside the scope of this dataset. A statistically robust water-quality index was not computed given the two-site sample size.

6. Conclusions

This pre-monsoon comparison of the Punpun River's entry point at Pinjrawan (Pali block) and exit point at Sammaspur (Fatuha block) in Patna district reveals a clear downstream deterioration in several physico-chemical parameters over the ~64 km reach. While pH, calcium, chloride, sulphate and nitrate remained within BIS desirable limits at both sites, TDS, total hardness, magnesium and alkalinity crossed the desirable (though not permissible) threshold at the exit site, and turbidity exceeded the permissible limit at both sites—dramatically so at the exit. A concurrent decline in DO and rise in BOD toward the exit point to incipient organic enrichment.

Viewed ecologically, both sites nominally meet CPCB Class D (fish/wildlife propagation) criteria for DO and pH, but their turbidity levels already lie within or beyond ranges associated in the literature with reduced benthic macroinvertebrate diversity and impaired fish feeding/respiration (Henley et al., 2000), suggesting that the river's aquatic-habitat quality is more compromised than the drinking-water-oriented BIS comparison alone would indicate. These findings are consistent with the combined influence of natural weathering/evaporative processes and cumulative anthropogenic inputs—agricultural runoff, domestic sewage and industrial effluent—documented elsewhere in the Punpun and adjoining Ganga stretch at Patna (Shil et al., 2019; Ranjan et al., 2024; Zafar & Kumari, 2024).

Given the limited spatial and temporal scope of the present dataset, we recommend an expanded monitoring programme covering additional intermediate sites across the Naubatpur, Punpun and Sampatchak blocks, replicated across pre-monsoon, monsoon and post-monsoon seasons, and incorporating microbiological, trace-metal and direct biological (macroinvertebrate/zooplankton and fish multimetric) survey data, to build a robust water-quality and ecological-health index for the Punpun River within Patna district.

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Author Contributions

Md. Ashraf: Conceptualisation, methodology, field sampling, formal analysis, writing original draft and supervision. Zaofeshan Anjum: Laboratory analysis, data curation, writing review and editing. Both authors approved the final manuscript.

Data Availability Statement

The raw physico-chemical data generated during this study are available from the author upon reasonable request. Standard methods followed APHA (2017) and BIS (2012).

Declaration of Competing Interests

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

References

Antil, S., Maurya, S., Dagar, J., Bhagat, P., Makhija, S., & Toteja, R. (2024). Insights into water quality of River Yamuna, India: A comprehensive spatial-temporal analysis using advanced indices and multivariate statistical techniques. Research Square. https://doi.org/10.21203/rs.3.rs-4072812/v1

APHA. (2024). Standard methods for the examination of water and wastewater (25th ed.). American Public Health Association.

BIS. (2012). IS 10500:2012 — Indian standard drinking water specification (second revision). Bureau of Indian Standards.

Central Pollution Control Board. (2008). Guidelines for water quality management. CPCB, New Delhi.

Chapman, P. M., Bailey, H. C., & Canaria, E. (2000). Toxicity of total dissolved solids associated with two mine effluents to chironomid larvae and early life stages of rainbow trout. Environmental Toxicology and Chemistry, 19(1), 210–214. https://doi.org/10.1002/etc.5620190125

Davies-Colley, R. J., & Smith, D. G. (2001). Turbidity, suspended sediment, and water clarity: A review. Journal of the American Water Resources Association, 37(5), 1085–1101. https://doi.org/10.1111/j.1752-1688.2001.tb03624.x

Henley, W. F., Patterson, M. A., Neves, R. J., & Lemly, A. D. (2000). Effects of sedimentation and turbidity on lotic food webs: A concise review for natural resource managers. Reviews in Fisheries Science, 8(2), 125–139. https://doi.org/10.1080/10641260091129198

Iqbal, K., Ahmad, S., & Dutta, V. (2019). Pollution mapping in the urban segment of a tropical river: Is water quality index (WQI) enough for a nutrient-polluted river? Applied Water Science, 9(8), Article 191. https://doi.org/10.1007/s13201-019-1083-9

Kumar, A., Paul, B., Mudra, L., & Kishor, N. (2011). Studies of selected water quality parameters of River Ganges at Patna, Bihar. SHILAP Revista de Lepidopterología.

Olson, J. R., & Hawkins, C. P. (2017). Effects of total dissolved solids on growth and mortality predict distributions of stream macroinvertebrates. Freshwater Biology, 62(4), 779–791. https://doi.org/10.1111/fwb.12901

Preetham, K. P., G, P. G. T., Sahana, A. S., Shridhara, J. K., & Mahadevaiah, T. (2023). Analysis of drinking water quality in Honakere Hobli. International Journal for Research in Applied Science and Engineering Technology, 11(6), 2996–3018. https://doi.org/10.22214/ijraset.2023.54162

Priyadarshee, A., Rahul, A. K., Kumar, V., Kumar, A., & Kumar, N. (2024). Spatial variation in water quality of the Burhi Gandak River: A multi-location assessment. Frontiers in Environmental Science, 12, Article 1487469. https://doi.org/10.3389/fenvs.2024.1487469

Ranjan, R., Kaushik, H., & Ranjan, R. K. (2024). Assessment of hydrochemical characteristics and trace metals of Punpun River water – a tributary of the Ganga River. Water Science & Technology: Water Supply, 24(5), 1875–1892. https://doi.org/10.2166/ws.2024.096

Ranjan, S., & Singh, V. P. (2023). ANN and GRNN-based coupled model for flood inundation mapping of the Punpun River Basin. Engineering, Technology & Applied Science Research, 13(1), 9941–9946. https://doi.org/10.48084/etasr.5483

Ravindra, K., Ameena, Meenakshi, Monika, Rani, & Kaushik, A. (2003). Seasonal variations in physico-chemical characteristics of River Yamuna in Haryana and its ecological best-designated use. Journal of Environmental Monitoring, 5(3), 419–426. https://doi.org/10.1039/b301723k

Sharma, D., & Kansal, A. (2011). Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000–2009). Applied Water Science, 1, 147–157. https://doi.org/10.1007/s13201-011-0011-4

Shil, S., Singh, U. K., & Mehta, P. (2019). Water quality assessment of a tropical river using water quality index (WQI), multivariate statistical techniques and GIS. Applied Water Science, 9(7), Article 168. https://doi.org/10.1007/s13201-019-1045-2

Tejprakash. (2020). Assessment of quality characteristics of underground water using water quality index – A case study of rural areas from Gwalior District. International Journal for Research in Applied Science and Engineering Technology, 8(8), 671–679. https://doi.org/10.22214/ijraset.2020.30993

Wilkes, M., Gittins, J. R., Mathers, K. L., Mason, R., Casas-Mulet, R., Vanzo, D., Mckenzie, M., Murray-Bligh, J., England, J., Gurnell, A. M., & Jones, J. I. (2018). Physical and biological controls on fine sediment transport and storage in rivers. WIREs Water, 6(2), e1331. https://doi.org/10.1002/wat2.1331

Zafar, M. M., & Kumari, A. (2024). Spatio-temporal evaluation of the impact of anthropogenic stressors on physico-chemical characteristics and water quality of the River Ganga using GIS-based approach in the middle Gangetic Plains at Patna, Bihar, India. Water Science & Technology, 89(5), 1382–1400. https://doi.org/10.2166/wst.2024.053