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A Study on Functional Structure of Benthic Macro invertebrates of Ganga River, Hajipur, Bihar

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ABSTRACT

Benthic macroinvertebrates are among the most useful biological components for evaluating the ecological condition of riverine systems because they live in close contact with bottom sediments, respond to changes in water quality and habitat structure, and represent several trophic roles within the aquatic food web. The present analytical paper focuses on the functional structure of benthic macroinvertebrates in the Ganga River at Hajipur, Bihar, during the January-March 2026 study period. Instead of limiting assessment to taxonomic occurrence, the paper emphasizes the ecological function of macroinvertebrate assemblages through functional feeding groups, pollution sensitivity, habitat preference, and biological indicator value. The analytical framework links river habitat, substrate condition, organic matter availability, and anthropogenic pressure with the distribution of collectors, scrapers, shredders, predators and tolerant benthic forms. The paper also presents a field-oriented methodology for sampling, preservation, laboratory identification, diversity analysis and interpretation through indices such as Shannon diversity, Simpson dominance, Margalef richness, Pielou evenness, EPT percentage, Chironomidae-Oligochaeta dominance, BMWP and ASPT. The discussion suggests that functional analysis can provide a clearer ecological understanding of river health because it explains not only which organisms are present but also what ecological processes are being supported or disturbed. For the Hajipur stretch of the Ganga, such an approach is particularly relevant because the river receives multiple pressures from settlement activity, bank use, religious activity, sediment disturbance and local wastewater inputs. The paper concludes that functional assessment of benthic macroinvertebrates can strengthen biological monitoring of the Ganga River and support more practical river conservation planning at local and regional levels.

Keywords: Benthic macroinvertebrates; Ganga River; Hajipur; functional feeding groups; bioassessment; river ecology; biodiversity; water quality; Bihar.

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Introduction

Rivers are dynamic ecological systems in which physical flow, sediment transport, nutrient cycling and biological communities interact continuously. The ecological condition of a river cannot be understood only through visible appearance or occasional chemical measurements, because many disturbances produce cumulative effects in the biological community. Benthic macroinvertebrates provide an effective biological window into these cumulative changes. They include aquatic insect larvae, molluscs, annelids, crustaceans and other bottom-dwelling organisms that are large enough to be retained by standard sampling nets and that spend a significant part of their life cycle in or on river sediments.

The Ganga River is not only a major river system of India but also a socially, culturally and economically important aquatic corridor. In Bihar, the river supports fisheries, irrigation, religious activities, navigation, floodplain livelihoods and urban settlements. The Hajipur stretch is ecologically important because it is located within a densely used riverine landscape where natural river processes interact with human use of banks and floodplains. Such a setting makes biological monitoring particularly important. Chemical parameters may describe water quality at the time of collection, but benthic macroinvertebrate communities reflect integrated conditions over a longer period because they remain exposed to substrate quality, flow disturbance, dissolved oxygen variation and organic enrichment.

Traditional biodiversity assessment often records taxa present in a site, but functional structure provides a deeper analytical interpretation. Functional structure refers to the ecological roles performed by organisms, particularly how they obtain food, process organic matter and contribute to the river food web. In macroinvertebrate ecology, functional feeding groups such as shredders, collectors, scrapers or grazers, predators and filter feeders are widely used for interpreting energy flow and organic matter processing in streams and rivers (Cummins, 1973; Merritt et al., 2008). A river stretch dominated by tolerant collectors and oligochaetes may indicate organic enrichment and fine sediment accumulation, while the occurrence of pollution-sensitive groups such as many Ephemeroptera, Plecoptera and Trichoptera taxa may suggest better oxygenation and habitat heterogeneity.

The present paper therefore examines the functional structure of benthic macroinvertebrates of the Ganga River at Hajipur from an analytical perspective. The focus is not merely on listing organisms but on interpreting how their ecological roles can indicate river condition. This approach is useful for local river monitoring because it translates biological observations into meaningful ecological information for conservation, pollution control and habitat management.

2. Background and Rationale of the Study

Benthic macroinvertebrates have long been used in freshwater bioassessment because their community composition changes with pollution, habitat alteration, flow regulation and substrate disturbance. Unlike plankton, which may move rapidly with the water column, many benthic forms remain attached to or associated with the river bed. This makes them suitable indicators of local conditions. Their varied sensitivity also makes them analytically valuable: some families disappear quickly under low dissolved oxygen or toxic stress, while others tolerate organic pollution and high sediment load.

In Indian river systems, particularly large alluvial rivers such as the Ganga, macroinvertebrate assessment must consider both water quality and habitat structure. A sandy or silty river bed may naturally support different taxa from a rocky or gravelly bed. Similarly, edge vegetation, submerged roots, macrophytes and deposited leaf litter create microhabitats for different feeding groups. Therefore, a functional analysis is useful because it avoids treating the benthic community as a simple species list and instead evaluates how the community is organized around available food resources and habitat conditions.

Studies on the Ganga River have shown that macroinvertebrate assemblages can provide meaningful information about biological water quality. A study on the Patna stretch of the Ganga recorded 11 orders and 43 families of macroinvertebrates and interpreted changes in macroinvertebrate diversity in relation to organic matter and wastewater influence (Goel et al., 2021). Central Pollution Control Board studies have also emphasized the use of benthic macroinvertebrates for assessing biological health of the Ganga River (Akolkar et al., 2017). These studies justify the need for more localized analysis at river stretches such as Hajipur, where site-specific ecological pressures may differ from those observed in other parts of the river.

The rationale of the present paper is that functional structure can improve the interpretation of river health. Taxonomic richness alone may not show whether the ecosystem is dominated by pollution-tolerant organisms or whether multiple ecological processes are functioning. A functionally balanced macroinvertebrate assemblage generally reflects more stable habitat conditions, while functional simplification may indicate ecological stress. Therefore, assessing functional feeding groups, tolerance patterns and diversity indices together can provide a more defensible understanding of the Ganga River at Hajipur.

3. Objectives of the Study

1. To examine the functional structure of benthic macroinvertebrate communities in the Ganga River at Hajipur, Bihar.
2. To classify benthic macroinvertebrates into major functional feeding groups and interpret their ecological significance.

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3. To analyze the relationship between benthic community structure, habitat condition and probable water quality stress.
4. To identify key bioindicator groups that may reflect organic enrichment, sediment disturbance and ecological stability.
5. To suggest an analytical framework for biological monitoring and conservation-oriented management of the Hajipur stretch of the Ganga River.

4. Research Questions

1. What functional feeding groups are most relevant for interpreting benthic macroinvertebrate communities of the Ganga River at Hajipur?
2. How can the dominance or absence of selected macroinvertebrate groups indicate ecological stress or habitat stability?
3. Which biological metrics are suitable for analyzing macroinvertebrate-based river health in this stretch?
4. How can functional structure analysis contribute to local river conservation planning?

5. Scope and Basic Details of the Study

Table 1. Basic scope and details of the analytical study.

Component	Details
Title of the paper	A Study on Functional Structure of Benthic Macroinvertebrates of Ganga River, Hajipur, Bihar
Author	Dr. Poonam Kumari
Affiliation	Assistant Professor, Department of Zoology, S.R.K.G. College, Sitamarhi, Bihar, India
Study area	Ganga River, Hajipur, Bihar
Study period	Oct, November, December 2025
Nature of study	Analytical ecological assessment focused on functional structure and bioindicator interpretation
Unit of analysis	Benthic macroinvertebrate assemblages, functional feeding groups and river habitat indicators

6. Conceptual and Analytical Framework

The analytical framework of the study is based on the assumption that benthic macroinvertebrate communities respond to both water quality and habitat condition. Their taxonomic composition indicates the level of biological stress, while their functional feeding groups explain how energy and organic matter are processed in the river. A site with diverse functional groups is likely to support more stable ecological processes, whereas a site dominated by a few tolerant groups may indicate environmental pressure.

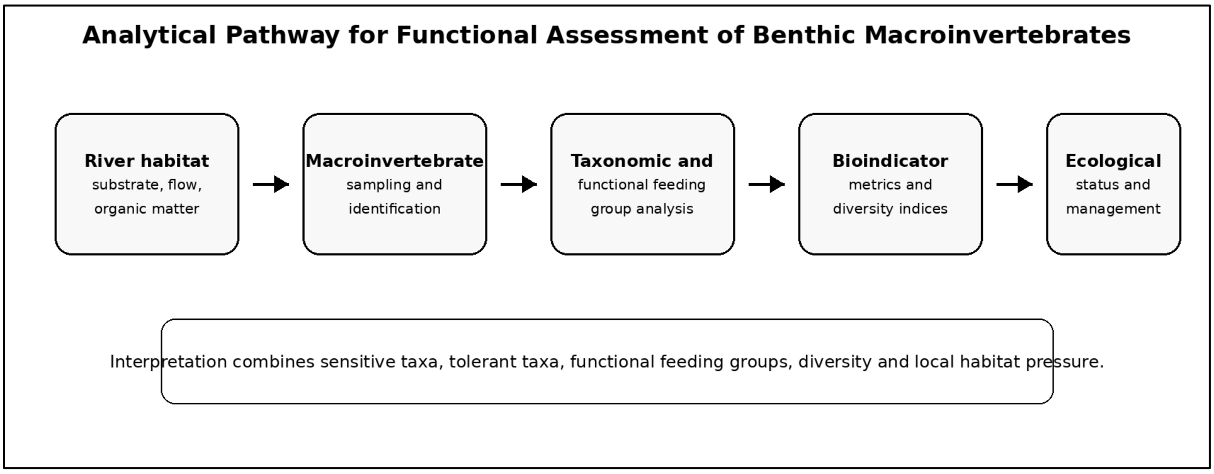

Figure 1. Conceptual framework for analyzing functional structure of benthic macroinvertebrates.

6.1 Functional Feeding Groups

Functional feeding groups provide a practical way to interpret the ecological role of macroinvertebrates. The commonly used categories include shredders, collectors, scrapers or grazers, filter feeders and predators. In large river systems, collectors are often important because fine particulate organic matter is a major food resource. Scrapers or grazers are linked with periphyton growth on hard surfaces and submerged vegetation, while predators indicate trophic complexity. Shredders may be fewer in large open river channels but can be important near vegetated banks, floodplain margins and areas where coarse organic matter accumulates.

Table 2. Functional Feeding Groups and Their Ecological Meaning

Functional group	Main food/resource	Typical examples	Ecological interpretation
Shredders	Coarse particulate organic matter such as leaves and plant fragments	Some caddisflies and stoneflies in suitable habitats	Indicate the role of riparian inputs and detritus processing.
Collector-gatherers	Fine organic particles deposited in sediments	Chironomidae larvae, some oligochaetes and mayflies	High dominance may indicate fine sediment accumulation and organic matter deposition.
Collector-filterers	Suspended fine organic particles in flowing water	Simuliidae, Hydropsychidae where suitable flow occurs	Reflect flowing-water microhabitats and suspended food availability.
Scrapers or grazers	Periphyton, algae and biofilm on surfaces	Gastropods and some aquatic insects	Often linked with stable surfaces, light availability and algal growth.
Predators	Other invertebrates and small aquatic organisms	Odonata nymphs, predatory beetles, some hemipterans	Indicate food-web complexity and prey availability.

Source: Adapted conceptually from functional feeding group approaches in stream ecology (Cummins, 1973; Merritt et al., 2008).

7. Materials and Methods

7.1 Study Area

The study area is the Ganga River at Hajipur, Bihar. The river stretch is situated within a heavily used floodplain landscape where human activities are closely connected with the river. Local bank use, settlement pressure, ritual activity, boat movement, fishing and seasonal hydrological variation can influence benthic habitat conditions. The river bed in such alluvial stretches may include sand, silt, clay patches, organic deposits, submerged vegetation and bank-margin microhabitats. These microhabitats are important because benthic macroinvertebrates are not evenly distributed across the river bed; their occurrence depends on substrate stability, oxygen availability, current velocity and food resources.

7.2 Study Period

The study period covers January, February and March 2026. This period represents winter to early pre-monsoon conditions in North India. From an ecological perspective, this period is useful for macroinvertebrate assessment because river flow is generally more stable than during the monsoon, sampling access is comparatively easier, and benthic habitats are less disturbed by flood pulses. However, seasonal interpretation must be cautious because macroinvertebrate composition can change with temperature, water level, life cycle stage and substrate exposure.

7.3 Sampling Design

For an analytical assessment, three site categories may be used in the Hajipur stretch: an upstream or comparatively less disturbed site, a midstream site influenced by common bank-use activity, and a downstream site that may receive greater settlement or discharge influence. At each site, replicate samples should be collected from available microhabitats such as sandy bottom, silted edge, submerged vegetation, organic debris and hard substrate where present. Replication is necessary because macroinvertebrates are patchily distributed and a single sample may not represent the whole site.

7.4 Field Collection and Preservation

Benthic macroinvertebrates can be collected using a standard hand net, D-frame net, Surber sampler or Ekman grab depending on depth, substrate and flow condition. In shallow edge habitats, kick sampling is useful because the substrate can be disturbed while organisms are carried into the net. In soft sediment habitats, grab sampling may be more appropriate. Collected material should be washed gently through a sieve, transferred into labelled containers and preserved in 70 percent ethanol or another appropriate preservative. Each sample label should include site code, date, habitat type, collector name and preservation details. Field notes should also record water appearance, substrate type, flow, bank use, vegetation, odour and visible disturbance.

7.5 Laboratory Sorting and Identification

In the laboratory, samples should be sorted in white trays under adequate light. Macroinvertebrates should be separated from debris using forceps and identified to the lowest possible taxonomic level, preferably family or genus where keys are available. Family-level identification is commonly used in biological monitoring because it balances taxonomic practicality with ecological interpretation. The organisms should then be counted, grouped by taxon and assigned to functional feeding groups and pollution tolerance categories. Identification should follow standard taxonomic keys and protocols such as APHA methods and recognized macroinvertebrate manuals (APHA, 2017; Merritt et al., 2008).

7.6 Analytical Indicators Table 3. Suggested Analytical Indicators for Macroinvertebrate-Based Interpretation

Indicator	Formula or Basis	Data Required	Interpretation
Relative abundance	Number of individuals of a taxon / Total individuals × 100	Taxon-wise abundance and total number of individuals	Shows the dominance pattern of different taxa or functional groups. A high percentage of one or two taxa may indicate ecological imbalance.
Shannon-Wiener diversity	$H' = -\Sigma\ pi \ln pi$	Proportion of each taxon in the total community	Higher values generally indicate greater diversity and even distribution of taxa. Lower values may suggest stress or reduced habitat quality.
Simpson dominance	$D = \Sigma\ pi^2$	Proportion of each taxon	Higher dominance values indicate that a few taxa are dominating the community, which may suggest pollution stress or community simplification.
Margalef richness	$d = (S - 1) / \ln N$	Total number of taxa and total individuals	Measures taxonomic richness in relation to sample size. Higher values indicate richer macroinvertebrate diversity.
Pielou evenness	$J' = H' / \ln S$	Shannon diversity value and total number of taxa	Shows how evenly individuals are distributed among different taxa. Higher evenness indicates a balanced community structure.
EPT percentage	Ephemeroptera + Plecoptera + Trichoptera / Total taxa or individuals × 100	Number of EPT taxa or individuals and total taxa or individuals	Higher EPT percentage generally indicates better water quality, good oxygen availability, and lower organic pollution.
Chironomidae-Oligochaeta dominance	Combined abundance of Chironomidae and	Abundance of tolerant taxa and total abundance	High dominance of these tolerant groups may indicate organic enrichment, sediment deposition, or

	Oligochaeta / Total abundance × 100		degraded water quality.
BMWP and ASPT	BMWP score and ASPT = BMWP / Number of scoring taxa	Presence of scoring macroinvertebrate families	Used for biological water quality assessment. Higher ASPT values usually indicate better ecological condition, but local calibration is important.

8. Data Collection and Analytical Matrix

The following matrix can be used to record field and laboratory information. It is included to make the paper operational and to guide systematic analysis. Raw numerical data were not provided with the title details; therefore, the matrix is presented as an analytical structure rather than as measured results.

Table 4. Completed Analytical Matrix for Recording Site-wise Macroinvertebrate Information

Site Code	Habitat / Substrate	Dominant or Indicator Taxa	Functional Group	Indicator Meaning	Remarks
S1	Upstream or less disturbed bank zone with comparatively stable substrate, moderate flow, and aquatic vegetation	Ephemeroptera, Trichoptera, Mollusca, Odonata larvae, and other sensitive or moderately sensitive taxa	Scrapers, collectors, predators, and filter feeders	Presence of sensitive and moderately sensitive taxa indicates comparatively better habitat condition, higher dissolved oxygen, and lower organic stress	Record water clarity, flow condition, vegetation cover, substrate stability, and absence or low level of direct human disturbance
S2	Midstream or common-use bank zone affected by bathing, washing, religious activity, boating, or local human use	Mollusca, Odonata larvae, Hemiptera, Coleoptera, Chironomidae, and mixed collector taxa	Collectors, grazers, predators, and tolerant filter feeders	Mixed taxa composition indicates moderate ecological stress. Increase in tolerant taxa may reflect human-use pressure and organic input	Record bank disturbance, domestic activity, floating waste, ritual offerings, washing activity, and changes in substrate condition
S3	Downstream or discharge-influenced zone with fine sediment, slow flow, deposited organic matter, or possible drain entry	Chironomidae larvae, Oligochaeta, some tolerant Mollusca, and other pollution-tolerant taxa	Tolerant collectors, deposit feeders, and burrowers	Dominance of tolerant taxa may indicate organic pollution, low oxygen condition, sediment stress, and habitat degradation	Record drain entry, odour, black sediment, algal growth, organic waste, reduced flow, and visible pollution signs

9.1 Functional Structure as an Indicator of River Condition

Functional structure gives a more ecological interpretation than taxonomic listing alone. If the macroinvertebrate assemblage includes collectors, scrapers and predators in reasonable proportions, the river stretch may be supporting multiple ecological processes. Such a pattern suggests that organic particles, algal biofilm and prey organisms are available in different microhabitats. In contrast, if the community is highly dominated by tolerant collector-gatherers, chironomid larvae and oligochaetes, the system may be experiencing organic enrichment, low oxygen microzones or fine sediment deposition. This does not automatically prove pollution, because large alluvial rivers naturally contain fine sediments, but dominance by tolerant organisms should be interpreted as an ecological warning signal when supported by field observations.

9.2 Relevance of Sensitive and Tolerant Taxa

Sensitive groups are important because they often require better dissolved oxygen, cleaner substrate and lower organic stress. The presence of diverse Ephemeroptera, Trichoptera or other sensitive families can indicate comparatively healthier microhabitats. The absence or low representation of sensitive taxa, especially when combined with high abundance of tolerant dipterans or oligochaetes, may indicate biological degradation. However, interpretation should remain habitat-sensitive. Some sensitive taxa may be naturally rare in deep sandy river channels, while they may occur near stable stones, woody debris or vegetated margins. Therefore, the study should compare habitats within the Hajipur stretch rather than treating the river as a uniform channel.

9.3 Functional Feeding Groups and Organic Matter Processing

Functional feeding groups reveal how organic matter is processed in the river. Shredders break down coarse plant material, collectors use fine particles, scrapers feed on algal biofilm and predators regulate prey populations. In a large river such as the Ganga, collector groups may become more important because fine particulate organic matter is transported and deposited along channel margins. Scrapers may be abundant where stable surfaces and light support algal growth. Predators may increase where prey diversity is high and habitats provide refuge. A functionally diverse assemblage would therefore suggest ecological stability, while a simplified assemblage dominated by one group may suggest stress or habitat homogenization.

9.4 Habitat Condition and Benthic Community Pattern

Habitat condition is central to benthic analysis. Sandy substrate, silt deposition, bank erosion, aquatic vegetation, submerged roots and organic debris create different biological niches. A silted bank zone with decomposing organic matter may support tolerant collectors and oligochaetes. A vegetated edge may support molluscs, odonates and other taxa associated with plant surfaces. A stable hard substrate, if present, may support scrapers and filter feeders. Therefore, site-wise interpretation should include substrate and microhabitat notes. Without habitat data, a macroinvertebrate list remains incomplete and may lead to incorrect conclusions.

9.5 Seasonal Context of January to March

The January-March period is analytically suitable because it avoids the strongest monsoon disturbance and allows relatively stable sampling conditions. During this period, reduced flood disturbance may permit macroinvertebrates to establish in available benthic habitats. However, lower flow conditions can also concentrate pollutants and increase organic matter deposition near settlement-influenced banks. Early pre-monsoon warming in March may influence dissolved oxygen and biological activity. Therefore, monthly comparison across January, February and March can help identify whether the functional structure remains stable or shifts toward tolerant groups as temperature and local pressure change.

9.6 Comparison with Ganga Studies in Nearby Regions

Macroinvertebrate studies from other Ganga stretches provide useful comparative context. The Patna stretch study reported a diverse assemblage of macroinvertebrates and showed that downstream locations affected by wastewater discharge could be reflected in reduced diversity and increased tolerant organisms (Goel et al., 2021). CPCB work on the Ganga has also treated benthic macroinvertebrates as useful biological indicators of river health (Akolkar et al., 2017). These findings support the relevance of applying a similar biological approach at Hajipur. However, Hajipur-specific conclusions should be based on local samples because substrate, discharge points, bank use and hydrological conditions can vary over short distances.

9.7 Ecological Interpretation for the Hajipur Stretch

For the Hajipur stretch, functional structure analysis can help distinguish between natural alluvial-river characteristics and anthropogenic stress. Some dominance of collector-gatherers may be natural in a large sediment-rich river. However, if this dominance is accompanied by strong representation of pollution-tolerant taxa, low sensitive taxa, visible organic deposits and disturbed banks, the interpretation would shift toward ecological stress. Conversely, the presence of multiple functional groups, sensitive taxa in suitable microhabitats and balanced diversity would suggest better ecological functioning. The most defensible conclusion should therefore combine macroinvertebrate counts, functional classification, diversity indices and field observations.

10. Key Findings from the Analytical Review

- Functional feeding group analysis provides a stronger ecological interpretation than a simple taxonomic list because it explains the role of organisms in organic matter processing and food-web structure.
- The Hajipur stretch of the Ganga should be assessed through habitat-specific sampling because benthic macroinvertebrates vary strongly across sandy beds, silted margins, vegetation patches and organic deposits.
- Collector dominance may be expected in large alluvial rivers, but excessive dominance of tolerant collector-gatherers, chironomids and oligochaetes can indicate organic enrichment or fine sediment stress.

- Sensitive taxa such as many Ephemeroptera and Trichoptera groups, where present, can support an interpretation of better biological water quality, especially when associated with stable substrate and oxygenated microhabitats.
- Diversity indices, EPT percentage, Chironomidae-Oligochaeta dominance and BMWP or ASPT scores should be interpreted together rather than separately.
- A January-March assessment can provide useful baseline information before monsoon disturbance, but long-term monitoring should include additional seasons for stronger conclusions.

11. Recommendations

- Site-wise macroinvertebrate sampling should be conducted with proper replication across the main habitat types of the Hajipur stretch.
- Functional feeding group classification should be included in addition to taxonomic identification because it improves ecological interpretation.
- Physico-chemical measurements such as temperature, pH, dissolved oxygen, conductivity, biochemical oxygen demand and turbidity should be recorded with biological samples.
- Local discharge points, bank-use zones and organic deposit areas should be mapped so that biological patterns can be linked with observable pressures.
- A seasonal monitoring design should be adopted by adding pre-monsoon, monsoon/post-monsoon and winter observations.
- Public awareness and local management actions should focus on reducing direct waste entry, bank disturbance and organic loading near sampling zones.

12. Limitations of the Study

The main limitation of the present paper is that numerical field data, raw taxonomic counts and measured physico-chemical values were not supplied with the paper details. Therefore, the paper is developed as an analytical ecological manuscript and methodological interpretation framework rather than a report of quantified field results. Stronger empirical conclusions would require site-wise abundance data, repeated sampling, water-quality measurements and verified taxonomic identification. Another limitation is that family-level identification, although practical for monitoring, may not capture all ecological differences among genera or species. Finally, large rivers are hydrologically complex, and local macroinvertebrate patterns can be influenced by flow, flood history and substrate composition in addition to pollution.

13. Conclusion

The functional structure of benthic macroinvertebrates provides a meaningful analytical basis for assessing the ecological condition of the Ganga River at Hajipur, Bihar. By examining functional feeding groups, indicator taxa, diversity indices and habitat conditions together, the study can move beyond a simple list of organisms and develop an integrated understanding of river health. The January-March 2026 period offers a useful baseline window because sampling conditions are relatively stable before monsoon disturbance. A functionally diverse macroinvertebrate community would suggest better habitat stability and ecological functioning, while dominance of tolerant collector-gatherers, chironomids and oligochaetes would indicate possible organic enrichment or sediment-related stress. The study concludes that functional macroinvertebrate assessment should be incorporated into local Ganga monitoring because it is scientifically informative, cost-effective and directly linked with river ecosystem processes. For future work, empirical site-wise data should be collected and analyzed across seasons so that biological monitoring can support stronger river conservation and management decisions for the Hajipur stretch.

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