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Impact of microplastic contamination on freshwater biodiversity and ecosystem services in Peri-Urban river catchments: A multi-site assessment

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Abstract
Microplastic pollution has emerged as a critical environmental challenge, with freshwater systems serving as major conduits and sinks for plastic debris from terrestrial and municipal sources. To investigate distribution, concentration, and ecological impact of microplastics (<5 mm) across three peri-urban river catchments, with emphasis on macroinvertebrate community structure and ecosystem services.
Water and sediment samples were collected across 18 sampling stations over 12 months. Microplastic characterisation used stereomicroscopy and ATR-FTIR spectroscopy. Shannon-Wiener H' and EPT richness were computed.
Mean microplastic concentration reached 847 ± 213 particles/L (water) and 3,240 ± 680 particles/kg (sediment). Sites with higher contamination showed significantly lower EPT richness ($r = -0.81$, $p < 0.001$). Fiber-type plastics dominated (62%).
Microplastic accumulation in peri-urban catchments demonstrably degrades macroinvertebrate biodiversity and threatens ecosystem services. Regulatory interventions targeting point-source discharge are recommended.

Keywords: Microplastics, freshwater biodiversity, macroinvertebrate communities, ecosystem services

Introduction

Global plastic production now surpasses 400 million metric tonnes annually, with 4.8–12.7 million tonnes estimated to enter aquatic systems each year. Freshwater ecosystems harbour approximately 10% of all known species despite covering less than 1% of Earth's surface, and deliver critical provisioning, regulating, and cultural services. Fragmentation of macro-plastics into microplastics (<5 mm) through photodegradation, mechanical abrasion, and biological action has elevated ecological risk considerably.

Peri-urban river catchments occupy an ecologically precarious position at the interface of urban land use and semi-natural environments. They receive disproportionate pollutant loads from combined sewer overflows, stormwater runoff, and illegal dumping, while simultaneously supporting biodiversity corridors and rural water supply infrastructure. Despite increasing marine microplastic research, freshwater systems remain comparatively understudied.

Macroinvertebrates widely used as bioindicators of freshwater health—ingest plastic particles, suffer feeding disruption, and exhibit reduced reproductive fitness. Community-level responses through diversity indices and functional trait analysis offer sensitive indicators of ecosystem degradation. Research objectives include: (i) characterising microplastic occurrence and polymer composition; (ii) assessing relationships with macroinvertebrate metrics; and (iii) evaluating impacts on provisioning ecosystem services.

Literature Review

1. Microplastic Sources and Pathways

Thompson *et al*. identified synthetic textile fibers as the dominant freshwater sediment microplastic type, accounting for 55–78% by count. Urban wastewater treatment plants remove 95–99% of microplastics yet their effluent remains a substantial point source given treatment volumes. Atmospheric deposition has been recognised as an underappreciated diffuse pathway.

2. Ecological Impacts on Benthic Communities

Scherer *et al*. demonstrated that polyester fiber exposure at environmentally relevant concentrations reduced Gammarus fossarum feeding rates by 23% under controlled conditions. Field surveys across European rivers have reported negative correlations between microplastic density and EPT richness. Polystyrene bead exposure has been associated with oxidative stress and genotoxic responses in Chironomus riparius larvae.

3. Ecosystem Services Framework

The Millennium Ecosystem Assessment classifies ecosystem services into provisioning, regulating, cultural, and supporting categories. Microplastic contamination directly threatens provisioning services (fisheries, drinking water) and may compromise regulating services through disruption of decomposer communities. Economic valuation of these losses remains methodologically underdeveloped.

4. Research Gap

Comparative multi-site studies linking quantitative microplastic characterisation with biological and ecosystem service metrics in peri-urban tropical catchments remain scarce. This study addresses that gap by integrating chemical, biological, and functional dimensions across co-varying catchments.

Methodology

Three peri-urban river catchments (R1, R2, R3) were selected based on differential urbanisation gradients (low to high). Eighteen stratified sampling stations (six per catchment) were established at 2 km intervals, sampled quarterly over 12 months. Water samples (5 L) were collected in pre-cleaned stainless-steel bottles and filtered through stainless-steel sieves (500 µm, 300 µm, 100 µm). Sediment grab samples (200 g dry weight) used a Ponar grab sampler.

Microplastic identification employed stereomicroscopy for morphological characterisation and ATR-FTIR (Thermo Nicolet iS10) for polymer verification. Macroinvertebrate sampling used standardised kick-net protocol (500 µm mesh, triplicate per station). Shannon-Wiener H', Margalef richness (d), and EPT richness were computed in PAST v4.0. Spearman's rank correlation assessed associations between microplastic load and biological metrics. Analyses were conducted in IBM SPSS v27 and R v4.3.2.

Results and Discussion

1. Microplastic Concentrations

River R3 (high urbanisation) exhibited peak water-column concentrations of 1,247 particles/L during post-monsoon sampling, compared to 312 particles/L at R1 in the pre-monsoon period. Sediment concentrations followed similar gradients (Table 1).

Table 1: Mean Microplastic Concentrations by River Catchment and Sample Matrix

Catchment	Urbanisation	Water (particles/L)	Sediment (particles/kg)	Dominant Type
R1	Low	312 ± 87	890 ± 210	Fiber (58%)
R2	Medium	641 ± 154	2,190 ± 430	Fiber (61%)
R3	High	1,247 ± 312	5,840 ± 780	Fiber (68%)
Overall Mean	—	847 ± 213	3,240 ± 680	Fiber (62%)

Source: Simulated field survey data, 2025. Values expressed as mean ± SD.

2. Macroinvertebrate Community Metrics

EPT richness at R3 (mean= 4.2 ± 1.1 taxa) was significantly lower than at R1 (11.6 ± 1.8 taxa) (Kruskal-Wallis $H = 42.1$, $p < 0.001$). Shannon-Wiener diversity showed analogous trends. Spearman's correlation between microplastic concentration and EPT richness was strongly negative ($r_s = -0.81$, $p < 0.001$) (Table 2).

Table 2: Macroinvertebrate Community Indices by Catchment

Catchment	EPT Richness	Shannon H'	Margalef d	Total Taxa
R1 (Low)	11.6 ± 1.8	2.47 ± 0.31	3.12 ± 0.42	34 ± 4
R2 (Medium)	7.8 ± 1.4	1.98 ± 0.28	2.54 ± 0.38	26 ± 3
R3 (High)	4.2 ± 1.1	1.31 ± 0.22	1.78 ± 0.29	18 ± 3
F-statistic	F = 38.7	F = 29.4	F = 22.1	F = 31.6
p-value	< 0.001	< 0.001	< 0.001	< 0.001

Source: Simulated field survey data, 2025.

3. Polymer Composition

ATR-FTIR analysis identified six polymer types. Polyethylene terephthalate (PET, 34%) and polypropylene (PP, 28%) were most prevalent, consistent with textile fiber and packaging waste dominance in the catchment (Table 3).

Table 3: Polymer Composition Identified by ATR-FTIR Analysis

Polymer Type	Abbreviation	% Composition	Primary Source
Polyethylene terephthalate	PET	34%	Textile fibers, bottles
Polypropylene	PP	28%	Packaging, ropes
Polyethylene	PE	17%	Bags, films
Polystyrene	PS	10%	Foam, food packaging
Nylon/Polyamide	PA	7%	Fishing lines, textiles
Others	—	4%	Various

Source: Simulated ATR-FTIR analysis, 2025.

River Catchment	Value / Bar
R1 (Low Urban)	312 p/L
R2 (Medium Urban)	641 p/L
R3 (High Urban)	1247 p/L

Fig 1: Microplastic Concentration by Catchment Urbanisation Level (particles/L) — Recreate as Grouped Bar Chart in Excel

Season	Value / Bar
Q1 Pre-monsoon	520 p/L
Q2 Monsoon	1100 p/L
Q3 Post-monsoon	980 p/L
Q4 Winter	790 p/L

Fig 2: Seasonal Variation in Microplastic Loads (particles/L) — Recreate as Multi-Series Line Graph

Polymer	Value / Bar
PET	34 %
PP	28 %
PE	17 %
PS	10 %
PA	7 %
Others	4 %

Fig 3: Polymer Type Distribution (% by Count) — Recreate as Pie/Donut Chart in Excel

Conclusion

This study demonstrates a significant negative relationship between microplastic contamination and freshwater macroinvertebrate biodiversity across peri-urban catchments. Fiber-type PET and PP dominate the pollutant profile, implicating textile and packaging waste streams. Declining EPT richness and Shannon diversity at high-contamination sites signal compromised ecosystem integrity with downstream consequences for drinking water and artisanal fisheries. Recommendations include mandatory microplastic filtration at wastewater treatment facilities, extended producer responsibility targeting textile manufacturers, and integration of microplastic monitoring into national freshwater quality standards. Limitations include absence of toxicological bioassays and single-year temporal coverage. Future research should incorporate mesocosm experiments and social cost-benefit analyses.

Ethical Statement

This article is an original academic writing training document. All data are simulated for illustrative purposes and clearly labelled. No real sampling was conducted; no real institutions, authors, or datasets are represented. References follow sample APA format.

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