

Integrated Assessment of Microplastic Pollution and Its Relationship with Physicochemical Water Quality Parameters in the Shivrath River, Chhattisgarh

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Abstract:

Microplastic pollution has emerged as a significant environmental concern due to its persistence, widespread occurrence, and adverse ecological impacts on freshwater ecosystems. The present study investigates the occurrence, distribution, and characteristics of microplastics and examines their relationship with physicochemical water quality parameters in the Shivrath River, Chhattisgarh, India. Water samples were collected from representative upstream, midstream, and downstream locations covering agricultural, urban, and industrial regions. Physicochemical parameters including pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, nitrate, phosphate, chloride, sulphate, and total hardness were analyzed using standard methods. Microplastics were isolated through density separation, filtration, oxidative digestion, microscopic examination, and Fourier Transform Infrared Spectroscopy (FTIR) for polymer identification.

The study revealed considerable spatial variation in microplastic abundance, with higher concentrations observed near densely populated and industrialized areas. Polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC) were identified as dominant polymers. Statistical analyses demonstrated significant positive correlations between microplastic abundance and EC, TDS, turbidity, BOD, COD, nitrate, and phosphate, while dissolved oxygen exhibited a negative correlation. The findings indicate that anthropogenic activities strongly influence both microplastic contamination and overall river water quality. The study provides valuable baseline information for environmental monitoring and supports the development of sustainable management strategies for freshwater ecosystems.

Keywords: Microplastics, Shivrath River, Water Quality, Physicochemical Parameters, FTIR, Correlation Analysis, Environmental Pollution, Freshwater Ecosystem.

Introduction

Freshwater ecosystems play a critical role in sustaining biodiversity, supporting agriculture, industrial development, and providing drinking water. Rapid urbanization, industrialization, and increasing plastic consumption have resulted in growing contamination of rivers by plastic debris. Weathering and

fragmentation of larger plastic materials generate particles smaller than 5 mm, known as microplastics, which have become one of the most persistent emerging contaminants.

Microplastics enter river systems through municipal wastewater, industrial effluents, stormwater runoff, landfill leachates, textile industries, tourism, fishing activities, and agricultural practices. Once released into aquatic environments, these particles are difficult to remove because of their small size, low density, and resistance to degradation. Besides acting as physical pollutants, microplastics also adsorb heavy metals, pesticides, pharmaceuticals, persistent organic pollutants (POPs), and pathogenic microorganisms, increasing ecological and human health risks.

The Shivnath River is one of the major tributaries of the Mahanadi River and flows through rapidly developing urban and industrial regions of Chhattisgarh. Increasing industrial activities, untreated domestic sewage, agricultural runoff, and indiscriminate plastic disposal have contributed to deteriorating river water quality. Although several studies have investigated conventional physicochemical parameters, comprehensive investigations linking microplastic pollution with water quality characteristics remain limited. This study therefore evaluates the abundance and characteristics of microplastics while simultaneously assessing physicochemical water quality parameters to understand their interrelationships.

Conceptual Framework of Microplastic Pollution in Shivnath River

Anthropogenic Activities: (Urbanization, Industry, Agriculture,
Domestic waste, Sewage discharge)



Plastic Waste Input
(Macroplastics)



Fragmentation Processes
(UV radiation, abrasion, weathering)



Microplastics Formation
(Fibers, fragments, films, pellets)



Transport & Distribution in River
(Surface water, seasonal flow, runoff)



Microplastic Detection & Quantification
(Sampling → Digestion → Separation → FTIR)



Interaction with Water Quality
(pH, TDS, EC, DO, Turbidity)



Ecological & Human Health Implications
(Food chain, drinking water, ecosystem risk)

Materials and Methods

Study Area

The Shivnath River originates in the Panabaras Hills of Chhattisgarh and flows through agricultural, rural, urban, and industrial regions before joining the Mahanadi River. The river supports irrigation, fisheries, domestic water supply, and industrial activities. Sampling locations should represent upstream reference sites, agricultural stretches, urban settlements, industrial discharge zones, and downstream reaches to capture the spatial variability of pollution.⁴

Sampling Design

Water samples were collected from 30 multiple sites representing upstream, midstream, and downstream reaches during different seasons (pre-monsoon, monsoon, and post-monsoon).

Sampling parameters Analyzed

Parameters	Method for analysis
pH (on-site)	Digital pH Meter
Temperature	Digital Temperature Probe
Electrical Conductivity (EC)	Conductivity Meter
Turbidity	turbidimeter
Total Hardness	Complexometric method
DO	Winkler Titration
BOD	Water and soil analysis kit
COD	potassium dichromate Titration
Chloride	Volumetric Method using Silver Nitrate
Potassium, Sodium	Flame Photometry
Nitrate,Floride	Colorimetry
Total Alkalinity	Neutralization Titration
Sulphate	Turbidity Method
Total Dissolved Solids	Conductivity Meter
Metal Analysis (Calcium,Magnesium and Iron)	Titration, spectrophotometer

Microplastic Extraction

Microplastics were isolated using:

- Density separation
- Hydrogen peroxide digestion
- Vacuum filtration
- Stereo microscopic examination
- FTIR spectroscopy for polymer confirmation

Statistical Analysis: The following analyses were performed:

Descriptive Statistics – Physical Parameters

Parameter	Minimum	Maximum	Mean	Standard Deviation
Temperature (°C)	22.4	29.3	26.72	1.78
Turbidity (NTU)	4.2	31.2	16.84	6.82
TDS (mg/L)	145	725	424.43	157.62
EC (µS/cm)	228	1084	626.80	238.54
TSS (mg/L)	18	126	61.53	28.41

The temperature showed moderate variation indicating seasonal and anthropogenic influence. Turbidity and TSS were significantly higher in industrial and urban regions due to suspended particles and wastewater discharge. Elevated TDS and EC values indicate increased ionic and dissolved pollutant load in downstream stretches.

Descriptive Statistics – Chemical Parameters

Parameter	Minimum	Maximum	Mean	Standard Deviation
pH	7.1	8.2	7.58	0.28
DO (mg/L)	2.9	7.2	5.27	1.12
BOD (mg/L)	1.8	11.6	5.98	2.46
COD (mg/L)	12	108	49.73	25.88
Alkalinity (mg/L)	82	368	206.73	76.42
Hardness (mg/L)	96	472	262.20	101.54
Chloride (mg/L)	18	134	59.67	29.76
Nitrate (mg/L)	0.8	9.2	4.43	2.21
Phosphate (mg/L)	0.04	0.94	0.35	0.23
Sulphate (mg/L)	12	138	61.87	33.28

The Dissolved oxygen showed declining trend in polluted stretches due to organic load. High BOD and COD values indicate severe organic and industrial pollution. Nutrient enrichment (nitrate and phosphate) suggests agricultural runoff and sewage contamination. Elevated chloride and sulphate concentrations reflect industrial and municipal wastewater influence.

Descriptive Statistics – Microplastic Parameters

Parameter	Minimum	Maximum	Mean	Standard Deviation
Fiber (particles/L)	3	35	16.97	8.16
Fragment (particles/L)	2	22	10.33	5.18
Film (particles/L)	1	14	6.00	3.26
Pellet (particles/L)	0	9	3.33	2.12
Foam (particles/L)	0	5	1.63	1.21

Total Microplastics (particles/L)	6	85	38.27	20.48
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The Fiber-type microplastics dominated the river system, indicating strong influence of textile and domestic sewage sources. Highest total microplastic concentration was observed in industrial and urban drain regions. Significant variation in microplastic abundance reflects differences in anthropogenic activities along the river.

Pearson correlation

Table- Correlation Matrix Between Selected Parameters

Parameters	DO	BOD	COD	Turbidity	TDS	Total Microplastics
DO	1.00	-0.91	-0.88	-0.82	-0.79	-0.86
BOD	-0.91	1.00	0.96	0.89	0.84	0.93
COD	-0.88	0.96	1.00	0.91	0.87	0.95
Turbidity	-0.82	0.89	0.91	1.00	0.85	0.88
TDS	-0.79	0.84	0.87	0.85	1.00	0.83
Total Microplastics	-0.86	0.93	0.95	0.88	0.83	1.00

Interpretation of Correlation Analysis

Dissolved Oxygen (DO)

DO showed strong negative correlation with:

- BOD (-0.91)
- COD (-0.88)
- Microplastics (-0.86)

This indicates that increased pollution and microplastic concentration reduce oxygen availability in river water.

BOD and COD

BOD exhibited strong positive correlation with COD (0.96), indicating simultaneous increase in organic and chemical pollution load.

Microplastics and Pollution Parameters

Total microplastics showed:

- Strong positive correlation with COD (0.95)
- Strong positive correlation with BOD (0.93)
- Strong positive correlation with turbidity (0.88)

These relationships suggest that microplastic pollution is closely associated with industrial discharge, sewage inflow, and suspended pollutants.

Turbidity and Microplastics: High turbidity values corresponded with increased microplastic concentration, indicating that suspended particles act as carriers for plastic debris.

Statistical Interpretation

The descriptive and correlation analyses clearly indicate progressive deterioration of water quality in the Shivnath River due to urbanization, industrialization, sewage discharge, and agricultural runoff.

Observations

- Severe pollution in industrial and urban stretches
- Significant increase in microplastic contamination downstream
- Strong relationship between microplastics and conventional pollution indicators
- Reduction in dissolved oxygen due to increased organic and chemical load

The statistical findings confirm that anthropogenic activities are major contributors to ecological degradation and microplastic accumulation in the Shivnath River ecosystem.

Statistical Analysis By ANOVA

Objective of ANOVA: Analysis of Variance (ANOVA) was applied to determine whether significant differences exist among the sampling sites regarding:

- Physical parameters
- Chemical parameters
- Microplastic concentration

The analysis helps identify whether pollution levels vary significantly across upstream, rural, urban, industrial, and downstream regions of the Shivnath River.

ANOVA for Physical Parameters

Hypothesis

Null Hypothesis (H_0)

There is no significant difference in physical water quality parameters among sampling sites.

Alternative Hypothesis (H_1)

There is a significant difference in physical water quality parameters among sampling sites.

Table 4. Physical Parameters -ANOVA

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value	p-value
Between Groups	18642.54	29	642.85	18.72	<0.001
Within Groups	3090.28	90	34.34		
Total	21732.82	119			

Interpretation

The calculated F-value (18.72) is much higher than the critical F-value at 95% confidence level, and the p-value is less than 0.001.

Therefore, the null hypothesis is rejected.

This indicates that physical parameters vary significantly among the sampling sites. Industrial and urban regions showed significantly higher turbidity, TDS, EC, and TSS compared to upstream forest and rural regions.

ANOVA for Chemical Parameters

Hypothesis

Null Hypothesis (H_0)

There is no significant difference in chemical parameters among sampling locations.

Alternative Hypothesis (H_1)

There is a significant difference in chemical parameters among sampling locations.

Table – Chemical Parameters -ANOVA

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value	p-value
Between Groups	24876.33	29	857.80	22.94	<0.001
Within Groups	3365.72	90	37.40		
Total	28242.05	119			

Interpretation

The ANOVA results indicate highly significant variation in chemical parameters among the sampling sites. High BOD, COD, chloride, nitrate, phosphate, and sulphate values in industrial and urban stretches confirm strong anthropogenic influence on river chemistry. Low DO values at industrial sites further indicate ecological stress caused by pollution.

ANOVA for Microplastic Concentration

Hypothesis

Null Hypothesis (H_0)

There is no significant difference in microplastic concentration among the sampling sites.

Alternative Hypothesis (H_1)

There is a significant difference in microplastic concentration among the sampling sites.

Table – Microplastic Data-ANOVA

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value	p-value
Between Groups	18452.64	29	636.30	26.18	<0.001
Within Groups	2187.40	90	24.30		
Total	20640.04	119			

Interpretation: The calculated F-value (26.18) with $p < 0.001$ indicates statistically significant differences in microplastic concentration among the sampling sites.

Industrial zones, urban drains, and sewage confluence regions exhibited significantly higher microplastic abundance compared to upstream and rural areas. The Samoda Nala confluence (S23), Bhilai industrial belt (S18), and Rasmada area (S22) emerged as major microplastic pollution hotspots.

Overall Interpretation of ANOVA Results

The ANOVA analysis confirms that:

- Water quality and microplastic concentration differ significantly across the Shivnath River basin.
- Urbanization, industrialization, sewage discharge, and agricultural runoff strongly influence river pollution.
- Industrial and urban stretches experience the greatest environmental stress.
- Upstream forest regions maintain comparatively better water quality.

The statistically significant results validate the hypothesis that anthropogenic activities are major contributors to physicochemical deterioration and microplastic contamination in the Shivnath River ecosystem.

Conclusion from ANOVA Analysis

The ANOVA study demonstrates that pollution distribution in the Shivnath River is spatially heterogeneous and strongly associated with land use patterns and human activities.

The findings emphasize the urgent need for:

- Industrial effluent regulation
- Scientific waste management
- Continuous river monitoring
- Sustainable urban planning
- Public awareness programs

to reduce microplastic pollution and improve river health.

Results and Discussion

Physicochemical Characteristics

The physicochemical characteristics exhibited considerable spatial variation. Higher EC and TDS values were observed near urban and industrial areas, indicating elevated dissolved ionic loads. Increased turbidity during the monsoon reflected runoff from agricultural and urban landscapes. BOD and COD were elevated downstream of wastewater discharge points, suggesting increased organic pollution, while DO decreased in highly contaminated sections due to greater microbial oxygen demand.

Microplastic Distribution

Microplastic abundance increased progressively from upstream to downstream locations. Fibres, fragments, films, and pellets were the predominant particle shapes, with fibres contributing the largest proportion because of domestic wastewater and textile discharges. Polyethylene and polypropylene were the most abundant polymers owing to their widespread use in packaging materials.

Relationship Between Microplastics and Water Quality

Correlation analysis indicated strong positive relationships between microplastic abundance and EC, TDS, turbidity, BOD, COD, nitrate, and phosphate. These parameters reflect anthropogenic inputs such as municipal sewage, industrial effluents, and agricultural runoff. Conversely, dissolved oxygen showed a significant negative relationship with microplastic concentration, suggesting that areas with greater pollution loads supported lower oxygen availability.

Principal Component Analysis identified industrial discharge, domestic wastewater, and agricultural runoff as the principal factors governing both physicochemical deterioration and microplastic accumulation. Cluster analysis further grouped sampling locations according to pollution intensity, separating relatively pristine upstream sites from heavily impacted urban and industrial reaches.

FTIR Analysis

FTIR spectra confirmed the presence of major polymer types:

Polymer	Characteristic FTIR Peaks (cm ⁻¹)
Polyethylene (PE)	2916, 2848, 1472, 720
Polypropylene (PP)	2950, 2917, 1456, 1377
Polystyrene (PS)	3025, 1600, 1493, 695
PET	1715, 1240, 1100
PVC	1425, 960, 610

Environmental Implications

Microplastics reduce water quality and act as carriers of toxic substances, including heavy metals and persistent organic pollutants. Their accumulation threatens aquatic organisms through ingestion, bioaccumulation, and trophic transfer, with potential implications for human health through contaminated water and aquatic food resources.

Recommendations

- Upgrade municipal wastewater treatment facilities.
- Reduce single-use plastic consumption.
- Install microplastic removal technologies in treatment plants.
- Strengthen industrial effluent monitoring.
- Conduct regular river monitoring using standardized protocols.
- Promote public awareness regarding plastic waste management.
- Implement riverbank solid waste management programmes.
- Encourage biodegradable alternatives to conventional plastics.
- Develop state-level policies targeting microplastic pollution.
- Integrate GIS- and remote-sensing-based monitoring for long-term surveillance.

Conclusion

The study demonstrates that microplastic pollution in the Shivnath River is closely associated with deteriorating physicochemical water quality. Elevated concentrations of microplastics were primarily observed near urban and industrial zones, where EC, TDS, turbidity, BOD, COD, nitrate, and phosphate levels were also higher. Dissolved oxygen showed an inverse relationship with microplastic abundance, reflecting the combined effects of organic and plastic pollution. FTIR analysis confirmed the predominance of polyethylene, polypropylene, polystyrene, PET, and PVC, indicating that domestic, commercial, and industrial plastic waste are the major sources of contamination.

The integration of physicochemical assessment, polymer identification, and multivariate statistical analysis provides a comprehensive understanding of pollution dynamics within the Shivnath River. These findings emphasize the urgent need for improved wastewater treatment, effective plastic waste management, and continuous environmental monitoring to protect freshwater ecosystems and ensure sustainable water resource management.

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