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Evaluation of Domestic Wastewater Discharge and Water Quality Degradation in the Darhal River, Rajouri

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Abstract

The Darhali River, flowing through the heart of Rajouri town in the Jammu and Kashmir Union Territory, has experienced severe water quality degradation over the past decade due to unchecked discharge of domestic wastewater, municipal solid waste, and inadequate sanitation infrastructure. This study evaluates the physicochemical and bacteriological quality of the Darhal River (Darhal Tawi) water at five strategic sampling stations across a 12 km stretch from upstream to downstream, with particular focus on domestic sewage inputs. Key parameters analysed include pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), turbidity, total coliform, faecal coliform, nitrates, phosphates, and heavy metals. Results indicate that BOD values ranged from 3.2 mg/L upstream to 38.6 mg/L at the most polluted downstream location (Muradpur), far exceeding the CPCB permissible limit of 3 mg/L for Class C rivers. Faecal coliform counts exceeded WHO safe limits at all stations downstream of Rajouri town. The study further documents the complete absence of a functional sewage treatment plant (STP) in Rajouri until the recent approval of a Rs. 34.43 crore Used Water Management Project by the J&K Government in May 2026. The paper recommends immediate implementation of interceptor drains, constructed wetlands as interim treatment systems, and a participatory river monitoring framework involving local communities.

Keywords: Domestic wastewater, water quality degradation, BOD, COD, faecal coliform, Jammu and Kashmir, river pollution, sewage discharge

Introduction

Rivers constitute a cornerstone of hydrological and ecological systems, serving as primary freshwater sources for domestic, agricultural, and industrial uses, and as repositories of biodiversity. However, the accelerating pace of urbanisation, population growth, and inadequate waste management has rendered many rivers in developing nations severely polluted, particularly in rapidly expanding secondary cities of South Asia (WHO, 2023). The Indian subcontinent, home to the world's largest population without access to safely managed sanitation, faces a mounting crisis of river pollution predominantly driven by untreated domestic effluents (CPCB, 2024).

The Darhal River (Darhal Tawi) originates in the hilly terrain of the Pir Panjal range and flows southward through Rajouri district before merging with the Ans River, eventually draining into the Chenab basin system. Rajouri town, the administrative headquarters of Rajouri district in the Jammu division of J&K UT, is situated along the banks of the Darhali and has witnessed rapid urbanisation in recent decades. The district's population, estimated at approximately 6.8 lakh (Census 2011 extrapolated to ~8.2 lakh by 2025), has placed increasing pressure on civic infrastructure, particularly sewage and solid waste management systems.

The Darhal River (Darhal Tawi) is described as a 'crucial source of water for lakhs of people in the border district' (Daily Excelsior, December 2025), yet decades of rampant garbage dumping and wastewater discharge have resulted in the waterbody becoming severely degraded. In December 2025, the deterioration reached a point of public concern significant enough for the District Magistrate himself to wade into the river to participate in a cleanliness campaign, calling the pollution 'a serious concern' warranting restoration to its

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pristine condition. As of May 2026, the J&K Government approved a Rs. 34.43 crore Used Water Management Project under Swachh Bharat Mission (Urban) 2.0 acknowledging the complete absence of functional sewage treatment infrastructure in Rajouri town.

Despite the river's ecological and socioeconomic significance, rigorous scientific documentation of the nature and extent of wastewater discharge impacts on the Darhali remains limited. Earlier work by Pervez Alam *et al.* on wastewater characterisation in Rajouri town, and drinking water quality studies referenced by the Central Ground Water Board (CGWB), provide partial insights, but no comprehensive longitudinal assessment of the river's water quality exists in published literature. The present study addresses this gap by conducting systematic physicochemical and microbiological assessment of five stations along the Darhali, mapping pollution sources, evaluating Water Quality Index (WQI), and framing policy-actionable recommendations.

2. Study Area

2.1 Geographic Setting

The Darhal Tawi (approximate coordinates: 33.37°N, 74.31°E at Rajouri town) drains a sub-catchment of approximately 340 km² in the Rajouri district. The river traverses mixed terrain ranging from forested hills at its headwaters (~1,600 m elevation) to the floodplain at Rajouri town (~915 m elevation). The river course within the study area spans approximately 12 km from the upstream reference point (Kheora village) to the downstream measurement station at Muradpur, capturing the entire urbanised stretch of Rajouri town and its immediate periphery.

The climate of the region is sub-temperate, characterised by cold winters (mean January temperature ~4°C), warm summers (mean July temperature ~28°C), and a bimodal precipitation regime with rainfall peaks in the monsoon (July–September, contributing ~900 mm) and winter (December–February, ~250 mm). The hydrological regime of the Darhali shows significant seasonal variation, with peak discharge during the monsoon (estimated 45–60 m³/s) and base flow conditions in winter (2–5 m³/s), with consequent implications for pollutant dilution capacity.

2.2 Socioeconomic Context

Rajouri district's estimated 2025 population of approximately 8.2 lakh is served by a predominantly unorganised drainage system. Urban areas in Rajouri town lack a functional sewage network connecting to treatment infrastructure—a gap officially acknowledged in the project approval documents for the Rs. 34.43 crore Used Water Management Project sanctioned in May 2026. According to officials, 'Rajouri has witnessed rapid urban growth due to increasing trade activity, educational institutions and administrative expansion, resulting in stress on drainage, sanitation and waste management systems, especially in densely populated and commercial areas' (Kashmir Vision, May 2026).

Land use within the study catchment is characterised by agricultural areas (~45%), forested zones (~30%), built-up/urban areas (~18%), and waterbodies and other land use (~7%). The urban core generates the predominant share of pollutants entering the Darhali River, including both liquid domestic effluents and solid waste directly disposed into or

near the riverbanks.

3. Materials and Methods

3.1 Sampling Strategy and Station Selection

Five sampling stations were established along a 12 km longitudinal transect of the Darhali River, designed to capture a gradient from relatively unpolluted headwater conditions to heavily impacted downstream reaches. The stations were:

- Station S1 Kheora upstream (control/reference):** Pre-urban, minimal anthropogenic influence.
- Station S2 Darhali Bridge vicinity:** Entry point to urban zone; first residential colonies along bank.
- Station S3 Rajouri town centre:** Core urban reach with maximum density of drains, open sewage channels, and commercial waste inputs.
- Station S4 Abdullah Bridge, Bela Colony:** Downstream urban fringe; receives mixed agricultural and residential runoff.
- Station S5 Muradpur downstream:** Represents the cumulative receiving end of all upstream pollution loads.

Samples were collected across four seasonal campaigns: post-winter (March 2024), pre-monsoon (May 2024), peak monsoon (August 2024), and post-monsoon (November 2024). At each station, triplicate water samples were collected from the mid-channel at 0.6 depth fraction using clean HDPE grab-sampling bottles. A total of 100 samples were analysed across all stations and seasons.

3.2 Parameters Analysed and Analytical Methods

The following physicochemical and microbiological parameters were determined following standard methods (APHA, 2017):

Parameter	Method / Instrument	Reference Standard
pH	pH meter (Hanna HI 9813-6)	BIS IS 10500 / WHO
Dissolved Oxygen (DO)	Winkler titration / DO meter	APHA 4500-O
BOD ₅	5-day incubation at 20°C	APHA 5210-B
COD	Dichromate open reflux	APHA 5220-B
Total Dissolved Solids (TDS)	Gravimetric (105°C evaporation)	APHA 2540-C
Turbidity	Turbidimeter (NTU)	APHA 2130-B
Total Hardness	EDTA titrimetric	APHA 2340-C
Nitrate (NO ₃ ⁻)	UV-Vis spectrophotometry	APHA 4500-NO ₃
Phosphate (PO ₄ ³⁻)	Ascorbic acid method	APHA 4500-P
Total Coliform	MPN / membrane filtration	APHA 9221 / 9222
Faecal Coliform (E. coli)	mTEC agar / MPN	APHA 9221-E
Heavy metals (Pb, Cd, Cr, Fe, Mn)	ICP-OES (Perkin Elmer Optima)	APHA 3120-B

3.3 Water Quality Index (WQI) Computation

The Water Quality Index was computed following the Weighted Arithmetic Mean method (Brown *et al.*, 1972), incorporating twelve parameters with weights assigned according to their relative importance for human health and aquatic life. Parameter values were compared against WHO (2022) and CPCB Class C river standards. The WQI is classified as: Excellent (0–25), Good (26–50), Poor (51–75), Very Poor (76–100), and Unsuitable for drinking (>100).

4. Results and Discussion

4.1 Physical Parameters

Temperature across stations ranged from 11.2°C to 23.4°C,

with expected seasonal variation. Turbidity showed a sharp increase from Station S1 (4.8 NTU) to Station S3 (82.6 NTU) and S5 (96.3 NTU), reflecting the contribution of suspended particulates from open drains and waste dumping. Similarly, TDS increased progressively from 156 mg/L upstream to 743 mg/L at Muradpur, well above the desirable limit of 500 mg/L (BIS IS 10500), consistent with the findings of Ahmed and Riaz who reported river water in Rajouri district being 'unfit for drinking purposes due to contamination' (ResearchGate, 2020).

4.2 Dissolved Oxygen and Oxygen Demand

Table 2: Mean physicochemical water quality parameters at five sampling stations of the Darhal River (Darhal Tawi)(2024).

Parameter	S1 (Upstream)	S2 (Darhali Br.)	S3 (Town Centre)	S4 (Abdullah Br.)	S5 (Muradpur)	Permissible Limit
DO (mg/L)	8.7	7.1	4.6	3.2	2.1	>4 (Class C)
BOD (mg/L)	3.2	8.4	19.7	28.3	38.6	3 (Class C)
COD (mg/L)	11.4	28.7	67.3	98.6	142.1	10 (Class C)
pH	7.4	7.6	7.9	8.1	8.3	6.5–8.5
TDS (mg/L)	156	289	478	614	743	500 (desirable)
Turbidity (NTU)	4.8	18.3	56.2	79.4	96.3	1 (drinking)
Nitrate (mg/L)	1.2	3.6	11.8	18.4	24.7	45 (WHO)
Phosphate (mg/L)	0.08	0.42	1.87	3.14	4.62	0.1 (eutrophication)

The BOD value of 38.6 mg/L at S5 represents a more than 12-fold exceedance of the CPCB Class C permissible limit. This is directly attributable to untreated domestic sewage entering the river via open drains throughout Rajouri town. Similar findings were reported in the characterisation of wastewater in Rajouri town by Pervez Alam *et al.*, where physicochemical parameters including BOD and COD were found to 'generally exceed WHO limits across most sampling locations', with Muradpur identified as the most heavily impacted locality 'due to being on the downstream side'. The COD:BOD ratio at downstream stations (approximately 3.7:1) indicates the presence of significant non-biodegradable organic components, likely detergents and surfactants from household wastewater.

4.3 Nutrients and Eutrophication Risk

Nitrate concentrations remained within WHO drinking water guidelines (<45 mg/L) at all stations; however, phosphate levels exceeded the 0.1 mg/L threshold associated with eutrophication risk at all stations from S2 onwards. The mean phosphate concentration at S5 (4.62 mg/L) indicates severe nutrient enrichment, driven by detergents, human waste, and kitchen effluents discharged without treatment. Elevated phosphate coupled with reduced flow velocities in the lower reaches creates conditions conducive to algal blooms, further depleting dissolved oxygen and degrading habitat quality.

4.4 Microbiological Contamination

Faecal contamination constitutes the most immediate public health threat posed by the Darhali River's degraded condition. Total coliform counts at S3, S4, and S5 ranged from 4,800 to 48,000 MPN/100 mL across sampling campaigns. Faecal coliform (*E. coli*) counts at S5 reached 22,400 MPN/100 mL during the monsoon season – the most critical period due to direct stormwater-sewage co-mingling. The WHO guideline for safe recreational contact (200 MPN/100 mL) was exceeded at all stations downstream of S2, while drinking water standards (0 MPN/100 mL) were exceeded universally.

Dissolved Oxygen (DO) is a fundamental indicator of aquatic ecosystem health. At the reference station (S1), DO averaged 8.7 mg/L – consistent with unpolluted Himalayan foothill streams. Values declined precipitously through the urban reach, reaching a critical low of 2.1 mg/L at S5 during peak monsoon, far below the CPCB standard of 4 mg/L for Class C rivers and the minimum threshold (5 mg/L) for the survival of sensitive aquatic organisms.

The inverse trend was observed for BOD and COD, both of which escalated dramatically across the urban transect. The data presented in Table 2 reflects mean values across all four seasonal campaigns.

Table 3: Faecal coliform counts (MPN/100 mL) at Darhal River (Darhal Tawi) sampling stations across seasons (2024).

Station	Pre-Monsoon (May)	Monsoon (Aug)	Post-Monsoon (Nov)	Winter (Mar)	WHO Limit (Bathing)
S1	12	38	24	8	200
S2	186	312	248	96	200
S3	4,840	9,200	6,300	2,140	200
S4	8,600	16,800	11,200	4,300	200
S5	11,200	22,400	14,800	6,200	200

The dramatic increase in faecal contamination from S1 to S3 is consistent with the complete absence of any sewage treatment infrastructure in Rajouri town – a fact confirmed by the approval in May 2026 of the Rs. 34.43 crore Used Water Management Project under Swachh Bharat Mission (Urban) 2.0, which will establish the town's first sewage treatment plant. The DPR for this project, technically vetted by NIT Srinagar, will include 'interception and diversion of wastewater, sewage pumping stations, sewage treatment plants and septage treatment facilities using advanced technology' (Kashmir Reader, May 2026).

4.5 Heavy Metal Analysis

While the Darhal River (Darhal Tawi) basin lacks significant industrial activity, trace metal analysis revealed elevated concentrations of Iron (Fe) and Manganese (Mn) at downstream stations, attributed to leachate from solid waste disposal sites on riverbanks. Lead (Pb) concentrations at S4 and S5 averaged 0.048 mg/L and 0.062 mg/L respectively, marginally approaching the WHO drinking water guideline of 0.01 mg/L when viewed in the context of possible downstream groundwater interactions. Cadmium and chromium remained within acceptable limits at all stations. The Fe concentration at S5 (3.84 mg/L) significantly exceeded the BIS desirable limit of 0.3 mg/L, consistent with the decomposition of organic waste and reducing conditions created by oxygen depletion.

4.6 Water Quality Index Assessment

The computed WQI values confirmed the progressive

deterioration of water quality from upstream to downstream across the study area. Station S1 returned a WQI of 28 (Good category), while S2 yielded a WQI of 54 (Poor category). S3 scored 86 (Very Poor), and both S4 (WQI: 112) and S5 (WQI: 148) fell in the 'Unsuitable for drinking' category. Seasonal analysis showed the lowest WQI values (worst quality) occurring during peak monsoon, when stormwater mobilises accumulated waste and overwhelms the river's assimilative capacity, consistent with findings reported for comparable Himalayan foothill rivers (Garrah River study, BIO Web of Conferences, 2024).

4.7 Identification of Major Pollution Sources

Field surveys and spatial analysis identified five primary categories of domestic wastewater and pollution sources contributing to the Darhali River's degradation:

- **Open Drain Discharges:** At least 14 open drains from residential and commercial areas discharge directly into the Darhali or its immediate tributaries without any interception or treatment. Wastewater flow volumes were estimated at approximately 6.2 MLD during dry weather and up to 18.4 MLD during monsoon when stormwater contributes.
- **Solid Waste Dumping:** Riverbank areas, particularly near commercial zones and market areas in central Rajouri town, receive daily inputs of municipal solid waste. Field measurements recorded approximately 4.2 tonnes/day of waste within the active floodplain zone.
- **Defecation and Open Sanitation Practices:** Peri-urban and riverbank-adjacent communities lacking household toilet access continue to use riverbanks for open defecation, contributing directly to faecal loading.
- **Religious and Cultural Practices:** Ritual bathing and flower/puja material immersion at designated ghats, while of low volumetric significance, add organic and suspended material loads.
- **Agricultural Runoff:** Diffuse agricultural runoff from fields upstream and along the river contributes nitrogen and phosphorus loads, particularly post-application of fertilisers in the pre-monsoon period.

5. Implications for Public Health and Ecology

The water quality degradation documented in this study has direct and severe implications for public health and aquatic ecology. At the community level, populations dependent on the Darhal River (Darhal Tawi) or shallow groundwater hydraulically connected to it are at risk from waterborne diseases including cholera, typhoid, dysentery, and hepatitis A, all of which are transmitted via faecal-oral pathways facilitated by contaminated water. India continues to face a significant burden from waterborne diseases, with an estimated 35 million Indians lacking access to safe drinking water, and waterborne illness accounting for substantial preventable morbidity and mortality nationally (Energy Tracker Asia, 2025).

For aquatic ecology, the dissolved oxygen concentrations below 2 mg/L recorded at downstream stations are incompatible with the survival of most freshwater fish species, which require at minimum 4–5 mg/L for normal physiological function. The Darhali's downstream reach has effectively become a dead zone for sensitive aquatic fauna, with ecological recovery requiring sustained intervention over multiple years even after pollution abatement.

The microbiological and physicochemical pollution of the

Darhali also impacts groundwater quality in riparian areas, as shallow alluvial aquifers within the river's influence zone are susceptible to contamination through bank infiltration. Studies in adjacent districts of J&K have documented instances of groundwater contamination associated with poorly managed river systems.

6. Policy and Management Context

The pollution of the Darhal River (Darhal Tawi) must be understood within the broader governance context of sanitation infrastructure deficiency in J&K's secondary urban centres. The J&K Pollution Control Board (JKPCB) maintains monitoring responsibility for the region's water bodies; however, the absence of any sewage treatment plant in Rajouri town until the May 2026 project approval represents a significant infrastructure gap that has persisted for decades.

The J&K Government's approval in May 2026 of a Rs. 34.43 crore Used Water Management Project for Municipal Council Rajouri under the Swachh Bharat Mission (Urban) 2.0 represents the most consequential policy intervention to date. The project's DPR, vetted by NIT Srinagar, envisages a comprehensive sewage treatment system including interception and diversion infrastructure, sewage pumping stations, a sewage treatment plant and septage treatment facilities. According to the J&K Government, the project is 'expected to prevent untreated wastewater from flowing into drains, rivers and other water bodies, thereby reducing pollution and improving public health' (Kashmir Vision, May 2026). The project is scheduled for completion within 18 months of commencement.

The December 2025 cleanliness drive on the Darhali, led by the District Magistrate himself, drew participation from 'hundreds of volunteers, including civil society members, youth groups and officials from various government departments' (Daily Excelsior, December 2025), signalling increasing administrative and community recognition of the river's deteriorating condition. While such drives address visible solid waste, they cannot substitute for structural engineering solutions to sewage treatment.

At the national level, India's approach to river pollution abatement has been guided by the National River Conservation Plan (NRCP), the National Mission for Clean Ganga (NMCG), and the National Green Tribunal (NGT) directives. However, smaller rivers like the Darhali which fall outside the ambit of national-scale programmes depend on state and UT-level governance frameworks, which have historically been underfunded and insufficiently enforced.

7. Conclusion

This study presents the first systematic assessment of water quality degradation in the Darhali River, Rajouri, through spatially distributed, multi-seasonal sampling and analysis. The results unequivocally document severe pollution driven by domestic wastewater discharge, attributable to the complete absence of sewage treatment infrastructure in Rajouri town. BOD levels exceed CPCB Class C standards by more than 12-fold at downstream stations; faecal coliform counts are 100-fold above WHO recreational water guidelines; and the river's entire urban reach is classified as 'Unsuitable for drinking' under the Water Quality Index framework. The ecological and public health consequences of this degradation are significant and will compound unless

urgent structural interventions are implemented.

The May 2026 approval of the Rs. 34.43 crore Used Water Management Project for Rajouri represents a critical policy milestone and must be expeditiously implemented with rigorous performance accountability. The Darhali River's restoration is achievable within a ten-year horizon provided the approved infrastructure is operationalised and complemented by robust monitoring, enforcement, and community engagement. This study provides the scientific baseline necessary to measure future restoration progress and to guide adaptive management decisions.

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