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# Assessing Turbidity Trends in the Himalayan Foothills: A Case Study of the Gaula River in Nainital District, Uttarakhand

**Arti Bisht**

*IPGGPG College of commerce Haldwani, Kumaun University Nainital, India*

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**Abstract:** Turbidity is one of the most important parameter for assessing the health of river ecosystems in mountainous regions. In the Himalayan foothills, seasonal and anthropogenic disturbances frequently leads to elevated turbidity levels, negatively impact aquatic habitats and human water usage. The Gaula River, which flows through Nainital district of Uttarakhand, plays a vital role in regional hydrology and supports both ecological and domestic functions. Despite its importance, limited research focusing on turbidity variation and spatial distribution along its course exists. This study examine monthly turbidity data from three monitoring sites—Amritpur (upstream), Ranibagh (midstream), and Kathgodam (downstream)—from March 2019 to February 2020. Descriptive statistical technique is used to evaluate temporal and spatial patterns in turbidity. Findings shows turbidity level peaked during the monsoon, especially in July (mean: 113 NTU), indicating significant sediment influx likely driven by rainfall and upstream erosions. Post-monsoon and winter months observed lower turbidity values, with November been the least turbid (mean: 0.9 NTU). Among sites, Kathgodam records the highest turbidity, suggesting strong influence of urbanization and sediment transport dynamics downstream. Amritpur, located in a less disturbed forested zones, displays more stable turbidity except during monsoon peaks. These finding reflect a dynamic sediment regime controlled by climate and land uses patterns. The study reveals periods of concerns and highlights the downstream zone needing focused management. Data from these studies can serve as baseline for future assessments, planning, and hydrological model efforts. In addition, the research underscores need for integrated watershed strategies to minimize sediment input, especially in urbanizing stretches.

**Keywords:** Anthropogenic, Himalayan River, Seasonal, Sediments, Urbanization, Uttarakhand

## I. Introduction

Turbidity in freshwater systems have emerged as a vital parameter for monitoring sediment transport, aquatic health, and the impacts caused by anthropogenic activities (Jain et al., 2015). Rivers that originates in the Himalayan foothills are particularly vulnerable to turbidity variations due to their steep gradients, intense rainfall events, and rapidly changing land-use patterns (Negi et al., 2018). Seasonal spikes in turbidity, which are especially prominent during the Indian summer monsoon, leads to increased erosion and surface runoff, thereby degrading overall water quality and altering the natural habitat of aquatic organisms (Sharma & Tiwari, 2019). However, despite extensive hydrological research being conducted throughout the Indian Himalayan Region (IHR), there has been only a few studies that specifically analyze monthly turbidity patterns in medium-sized river basins like the Gaula. The Gaula River, which is a crucial tributary of the Ramganga River, has been experiencing growing pressure from various stressors including riverbed mining, urban expansion, and climate-induced changes in the pattern and intensity of rainfall (Bist et al., 2022; Mishra et al., 2020). Although multiple studies have acknowledged sedimentation issues across several rivers in Uttarakhand, there still exists a major knowledge gap in terms of continuous seasonal monitoring across spatially distributed sites. The main objective of this present study were threefold:

**(i)** To quantify monthly variations in turbidity along three spatial monitoring points.

**(ii)** To identify the key periods of elevated sediment risk that may threaten ecosystem and water use.

**(iii)** To provide practical management recommendation for reducing excessive turbidity loads in the Gaula basin.

## II. Materials and methods

### Study Area

The Gaula River originates from the Motia Pather in the Gajar range (Madan Mohan, 2004) and flows southward through the districts of Nainital in Haldwani before merging into the Ramganga River. Covering a catchment of approximately 500 km², it traverse areas of varying land use including forests, farmlands, and urban settlements. This study selected three monitoring sites:

- **Amritpur (Site I)** – upstream, with maximum human disturbance and sand mining.(29°17'49" N, 79°33'51" E)
- **Ranibagh (Site II)** – midstream, transitional zone.( 29°16'57" N, 79°32'56" E)
- **Kathgodam (Site III)** – downstream, heavily impacted by urbanization. (29°16'18" N and 79°32'50" E,)

### Method

Monthly turbidity data (in NTU) were collected from March 2019 to February 2020 and evaluate annual variation in water quality across the selected sites. Sites Amritpur, Ranibagh and Kathgodam were selected based on their strategic upstream to downstream positioning along the Gaula River, enabling spatial analysis of turbidity variation. These locations exhibit differing anthropogenic

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pressures and hydrological conditions, facilitating a comprehensive assessment of temporal turbidity trends influenced by both natural processes and human interventions. Turbidity was measured using HACH-2100Q equipment. This equipment calculate turbidity by passing a light beam through a water sample and measuring the amount of light scattered by particles. Calibration involves using calibration standards (solution of known turbidity) and following on screen directions to adjust the instruments readings. Descriptive statistics were used to calculate the monthly mean. The analysis focused on temporal shifts and spatial contrasts among sites using graphical methods (Shown in figures 1, 2, 3, and 4).

## III. Results

July recorded the highest turbidity: 182 NTU (Kathgodam), 89.3 NTU (Amritpur), and 67.6 NTU (Ranibagh); the monthly average being 113 NTU. August and September also showed elevated turbidity levels, with site-specific variations. Lowest turbidity values were recorded in November (mean: 0.9 NTU) and December (1.3 NTU). Kathgodam consistently showed the highest turbidity, suggesting cumulative sediment transport and urban runoff impacts. Amritpur remained the least turbid site, except for monsoon peaks, confirming its relatively undisturbed status.

## IV. Discussion

Turbidity patterns observed in the Gaula River are highly seasonally driven, with dramatic increases during monsoon months due to rainfall-induced erosion and surface runoff. These findings align with Bhatt & Dhyani (2020) who noted sediment flux increases up to 5-fold during monsoons in similar Himalayan basins. The July spike corresponds to peak rainfall and also correlates with field observations by Das et al. (2021), which indicate that riverbed mining during rainy seasons worsens sediment loads. The consistently high turbidity at Kathgodam suggests a cumulative effect of upstream erosion and localized human activities, including sand extraction and unregulated construction (Mishra et al., 2020). Ranibagh, located midstream, appears as a transitional zone, echoing trends reported by Pant et al. (2017) in the neighboring Kosi River. Furthermore, post-monsoon stabilization of turbidity is likely due to vegetation regrowth and reduced surface flow, which has also been noted in Nepalese Himalayan basins (Rai et al., 2022). Urban areas like Kathgodam often experience increased turbidity due to the runoff of waterproof surfaces, contributing significantly to the dynamics of sediment (Chauhan et al., 2017). In the central region of the Himalayas, precipitation considerably affects river flows and transport of sediment, which suggests that the levels of turbidity are closely linked to the intensity of precipitation (Baniya et al., 2024). Seasonal sediment transport diagrams in the Kali Gandaki river basin also demonstrate the complexity of sediment supply (Baniya et al., 2019). Understanding these trends is essential to improve water management strategies in Himalayan basins (Sarkar et al., 2023).

Unlike larger-scale studies that rely on annual averages, our data’s monthly resolution enables the detection of critical seasonal windows for policy intervention. Interestingly, the January and February values showed slight increases again, which may relate to late-winter showers or sediment carryover from upstream snowmelt. This finding suggests the need to monitor beyond the traditional monsoon focus. The study contributes to sediment budget modeling and supports arguments made by Singh et al. (2023) that effective sediment control must consider both climatic and anthropogenic components.

## V. Conclusion

The present study offers a detailed seasonal assessment of turbidity trends in the Gaula River, revealing pronounced monsoonal impacts and spatial variation across three monitoring sites. July and August emerged as critical months for sediment influx, while Kathgodam stood out as the most impacted location due to downstream accumulation and local disturbances. When Rivers are polluted, it affects not only fauna but also people who depend on drinking water for their health and livelihoods. To protect fish and communities, we need better water treatment solutions. Clean water is essential for a healthy environment and a strong fishing industry. Reducing the turbidity in the water is vital for health, the environment and the economy. Innovative methods such as the use of plants, filters and natural coagulants can effectively clean water. Natural coagulants such as Moringa seeds, chia seeds and cactus mucilage can help remove turbidity. These natural materials can collect and arrange particles, effectively cleaning the water. Moringa seeds are known for their strong cleaning power, while the chia seeds and cactus mucilage are delicate but still useful. The use of these natural options is good for the environment since they are renewable and safe. Each method shows different results, but everyone contributes positively by improving the quality of the water, protecting ecosystems and lowering treatment costs for communities.

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## Conflict of interest

The author has no conflict of interest to declare.

**Author`s contribution:** The author (Arti Bisht) designed, collected, and analyzed data and prepared the final draft of the manuscript.

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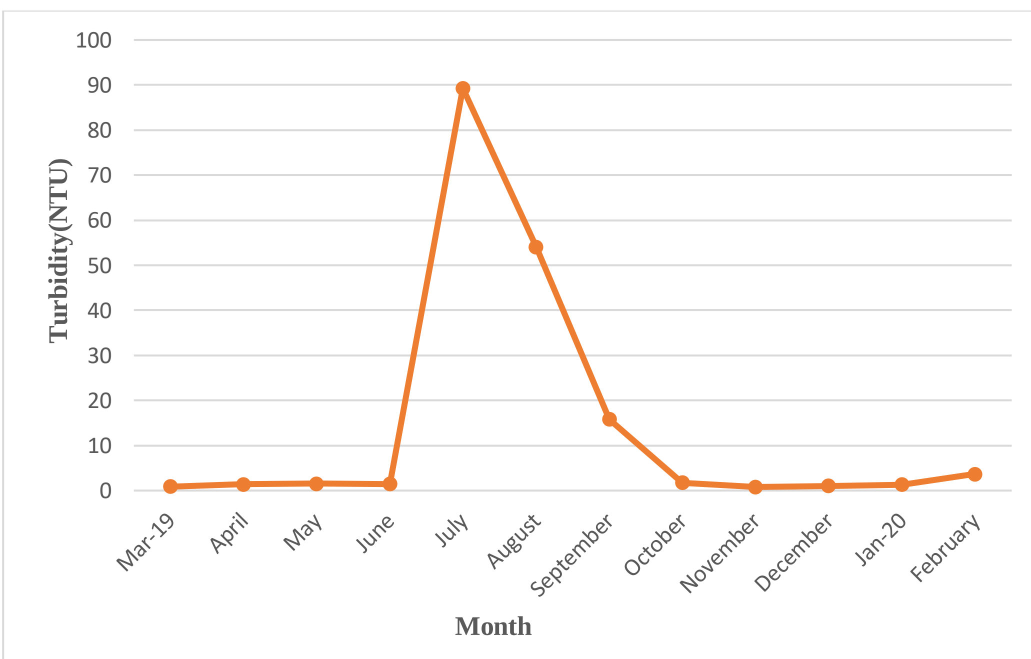


Figure 1: Monthly turbidity concentration at Amritpur (site I).

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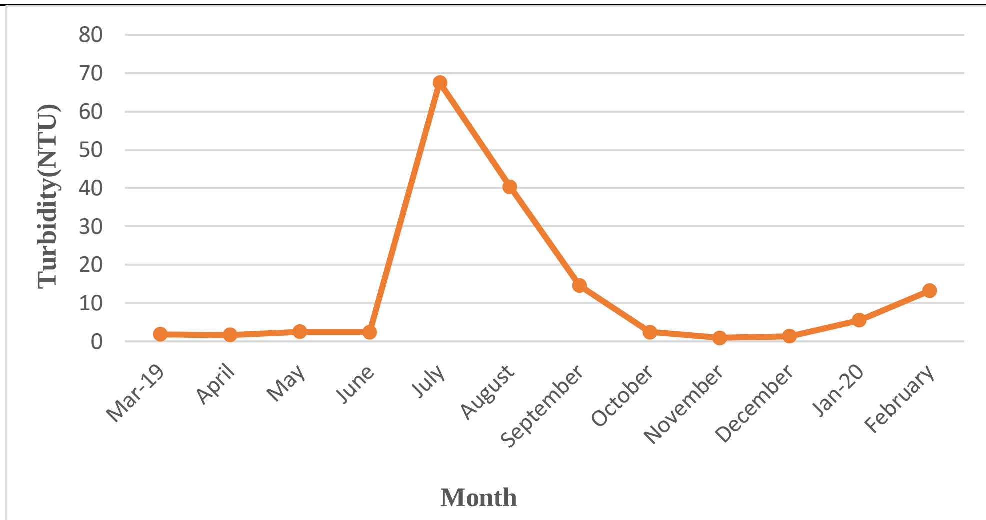


Figure 2: Monthly turbidity concentration at Ranibagh (site II).

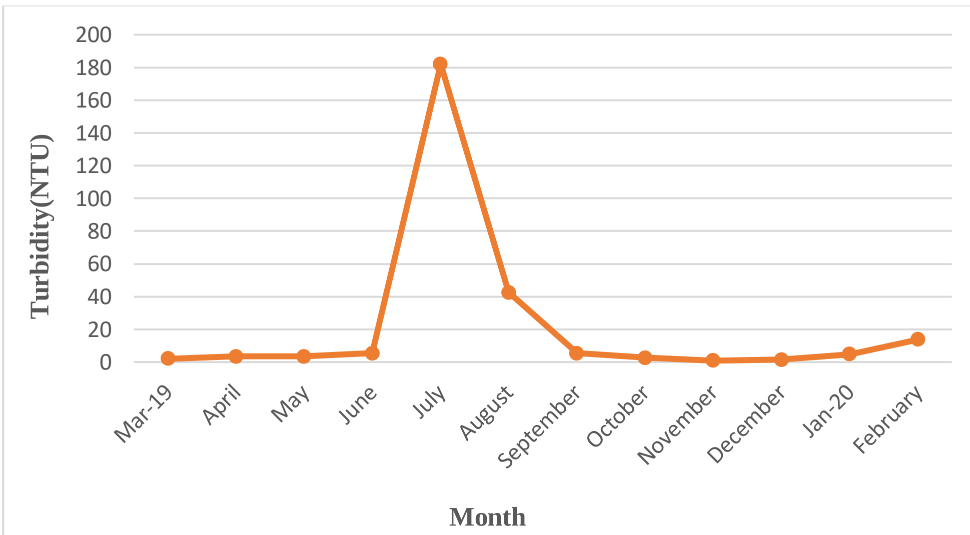


Figure 3: Monthly turbidity concentration at Kathgodam (site III)

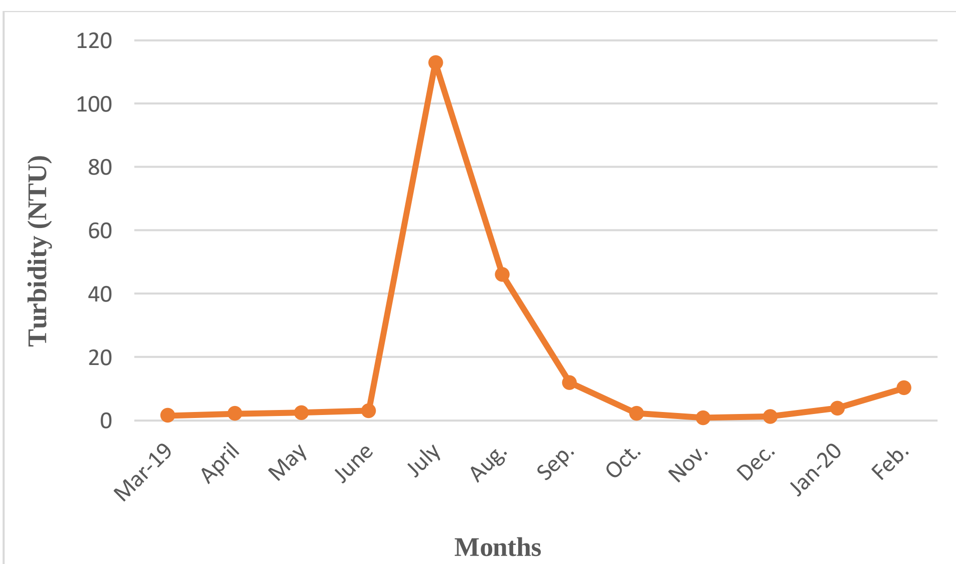


Figure 4: Mean Monthly turbidity in the Gaula River