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Buried Warnings: Sediment Quality Assessment in Polluted River Ecosystems

Dr. Kunal S. Mehta
Associate Professor
Department of Environmental Engineering,
Horizon Institute of Technology
Email: *kunal.mehta@horizontech.edu.in*

Priya L. Vyas
M.Tech Scholar
Department of Environmental Sciences,
Horizon Institute of Technology
Email: *priya.vyas@horizontech.edu.in*

Abstract

Sediments in riverbeds act as both sinks and sources of pollutants, making them critical in understanding long-term contamination in aquatic ecosystems. This paper delves into sediment quality assessment in polluted rivers, with emphasis on chemical composition, biological implications, and methods of evaluation. It discusses heavy metal accumulation, organic matter content, and toxicological indices used globally. Through case studies and index comparisons, this paper identifies spatial patterns of pollution and links sediment quality with ecosystem and human health risks. The assessment methods highlighted provide insights for sustainable river management and restoration strategies.

Keywords*: Sediment quality, Polluted Rivers, Heavy metals, Contamination indices, River ecology*

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INTRODUCTION

Sediments serve as both sinks and secondary sources of contaminants in freshwater systems, particularly in polluted rivers. Their composition reflects long-term pollution trends, making them key indicators in environmental quality monitoring. Pollutants such as heavy metals, persistent organic compounds, nutrients, and pathogens accumulate in sediments and can be remobilized through various physical, chemical, and biological processes. Sediment quality assessment has gained global significance as rivers ...

Understanding the geochemical composition and ecological risks associated with sediment pollution is vital for water quality management and ecosystem conservation. This paper explores assessment methods, contamination indices, pollutant types, and case studies of sediment quality in Indian and global river systems.

Major Pollutants In River Sediments

1. **Heavy Metals** : These include lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), and arsenic (As). They are non-biodegradable and toxic even at low concentrations.

2. **Persistent Organic Pollutants (POPs):** Includes polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PC Bs), and pesticides. These substances persist in the environment and bioaccumulate.

3. Nutrients: Phosphorus and nitrogen compounds contribute to eutrophication, especially in urban and agricultural watersheds.

4. Microbial Contaminants: Pathogens from sewage sludge and animal waste can survive in sediment layers and re-enter the water column.

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Assessment Techniques

1**. Physico-Chemical Analysis:** Sediment samples are analyzed for pH, electrical conductivity, organic matter, and heavy metal concentration using techniques such as ICP-MS or AAS.

2**. Sediment Quality Guidelines (SQGs):** Provide thresholds to determine toxicity. **Common indices include:**

TEC/PEC (Threshold Effect Concentration/Probable Effect Concentration)** TEL/PEL (Threshold Effect Level/Probable Effect Level)

Contamination Indices:

Geo-accumulation Index (Igeo): Measures the enrichment of metals relative to background levels.

Enrichment Factor (EF): Differentiates between anthropogenic and natural sources.

Pollution Load Index (PLI): Provides an overall view of heavy metal contamination.

4**. Ecotoxicological Tests:** Use bioassays with organisms like Chironomus*, Daphnia, or Lumbriculus* to assess toxicity.

5. Statistical Tools: Principal Component Analysis (PCA) and Cluster Analysis help identify pollution sources and spatial patterns.

Case Study: Yamuna River, Delhi Stretch

The Yamuna River, one of India's most polluted rivers, reveals heavy contamination in its sediment layer. A study conducted across five locations along the Delhi stretch reported the following heavy metal concentrations (mg/kg):

Table 1: Sediment Heavy Metal Concentration in Yamuna River |

|---|---|---|---|---|---Location

| Pb | Cd | Cr | Ni | Zn |

|---|---|---|---|---|---|

| Wazirabad | 86.2 | 2.3 | 67.1 | 39.8 | 250.7 |

| Kashmere Gate | 92.5 | 2.7 | 70.3 | 43.5 | 273.9 |

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ITO	89.3	2.9	74.8	41.2	298.5
Okhla	95.1	3.5	77.9	47.8	310.4
Downstream Okhla Barrage	100.4	3.9	81.6	50.2	325.1

Table 1 shows increasing concentrations of metals downstream, indicating continuous pollutant accumulation and anthropogenic input.

INTERPRETATION USING INDICES

Igeo values for Zn and Cd ranged from moderately to heavily polluted. PLI across sites exceeded 1.5, confirming significant anthropogenic impact. EF for Cr and Cd indicated industrial origins.

These findings correlate with industrial effluents and untreated sewage entering the river from adjacent settlements.

IMPACTS ON AQUATIC LIFE

Bioaccumulation: Toxic metals accumulate in benthic organisms, altering food chains and increasing risks to fish and birds.

Reduced Biodiversity: Toxic sediments lead to a decline in macroinvertebrate populations and sensitive aquatic species.

Bioavailability : Acidic conditions and microbial action can remobilize pollutants from sediments to water, exacerbating water pollution.

Management Strategies

1. **Source Identification and Control:** Industries must adopt zero liquid discharge (ZLD) systems, and untreated sewage must be curtailed.

2. Sediment Dredging: Controlled dredging can remove contaminated layers but must be cautiously executed to avoid pollutant release.

3. In-situ Remediation: Use of adsorbents, phytoremediation plants, and capping techniques help stabilize contaminated sites.

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4. Long-Term Monitoring: Establishing sediment monitoring stations enables time-based pollution tracking.

5. Policy Enforcement: Implementing sediment quality standards and revising effluent norms are necessary.

GLOBAL PERSPECTIVES

Countries like Canada and the Netherlands have incorporated sediment quality assessments into national water frameworks. The US EPA recommends using SQGs for site-specific risk assessment. India's CPCB has initiated river sediment studies, but implementation remains inconsistent.

CHALLENGES

Lack of Standard Guidelines : India lacks specific sediment quality criteria. Urban Encroachments**: Obstruct river flows and alter sedimentation patterns. Lack of Interdisciplinary Coordination**: Sediment quality is often ignored in integrated river basin management (IRBM).

Future Recommendations

- Develop National Sediment Quality Guidelines** in line with international best practices.
- Use AI and Remote Sensing to predict pollutant hotspots based on land use. Community Involvement in sediment clean-up and awareness campaigns.
- Integrated Sediment-Water Monitoring** as a unified river health approach.

CONCLUSION

Sediment quality assessment is a cornerstone of comprehensive river pollution monitoring. It not only captures the historical imprint of contamination but also serves as a predictor for future ecological risks. The Yamuna River case study underscores the urgent need for integrating sediment monitoring into national water quality frameworks.

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As urbanization and industrialization accelerate, proactive sediment management will be key to river restoration and public health protection.

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