



River Quality Management: A Solution for Urban Water Crisis in India

Prof. Dr. M. Sundararajan¹, Prof. Dr. Anand Mohan² Ms. Marina Lallawmzuali³

¹ Professor & HoD, Department of Mathematics and Computer Science, Mizoram University
E-mail: dmsrajan.mzu@gmail.com

² Professor and Principal, ABS Academy of Management and Health Science, Durgapur
Corresponding author: anand.mohandhn@gmail.com

³ Research Scholar, Department of Mathematics & Computer Science, Mizoram University
E-mail: lallawmzuali1999@gmail.com

Abstract: *Water scarcity has emerged as a critical challenge in India, affecting not only rural populations but also rapidly expanding urban centers, ecosystems, and agricultural productivity. Apart from the limited availability of freshwater, excessive pollution has led to the deterioration of river systems, drying of reservoirs during lean seasons, and declining groundwater recharge. Although several river-cleaning initiatives have been launched by the Government of India, inadequate infrastructure, weak enforcement mechanisms, and uncontrolled discharge of industrial and domestic effluents continue to undermine river health. According to the National Institution for Transforming India (NITI Aayog), nearly 21 major Indian cities are at risk of exhausting their groundwater resources, and unsafe drinking water causes approximately 200,000 deaths annually. This article emphasizes the urgent need for comprehensive river quality management as a sustainable solution to the urban water crisis in India. It critically reviews existing river-cleaning initiatives in India and abroad and discusses physical, chemical, biological, and ecological remediation technologies that can be adopted for sustainable river restoration and water resource management.*

Key Words: *River quality, river cleaning, riverbank filtration, bioremediation, urban water crisis.*

1. INTRODUCTION:

Rapid population growth, urbanization, and industrialization have placed immense pressure on India's freshwater resources. Rivers, which traditionally served as lifelines for drinking water, irrigation, and ecological balance, have increasingly become sinks for untreated sewage, agricultural runoff, and industrial effluents. Urban sewage, pesticide-laden agricultural wastewater, and industrial discharges are continuously released into river systems, leading to severe degradation of water quality and riverine ecosystems. Consequently, many rivers have lost their natural capacity for self-purification, rendering their waters unsuitable for drinking, domestic use, and even irrigation in certain stretches. River pollution is one of the most pressing environmental challenges in developing countries. Polluted rivers not only spread waterborne diseases but also emit foul odors, degrade aquatic habitats, and reduce the aesthetic and recreational value of urban environments. By the early twentieth century, many rivers worldwide had already lost significant ecological functions due to anthropogenic pressures [1]. In India, water scarcity affects nearly one million people annually, with severe implications for public health, agriculture, and biodiversity [2,3]. The problem is exacerbated during lean periods before the monsoon when rivers and reservoirs dry up due to over-extraction and insufficient recharge. Delayed and erratic monsoons in recent years have further intensified the crisis, causing reservoirs to dry up in several regions. While agriculture consumes nearly 80% of the country's water resources, inefficient irrigation practices and pollution from fertilizers and pesticides add to the stress on river systems [3].

Urban water shortages have become increasingly frequent. The 2019 water crisis in Chennai led to the closure of businesses, hotels, and restaurants, highlighting the vulnerability of urban centers. NITI Aayog has warned that cities such as New Delhi, along with at least 21 others, face the imminent risk of groundwater depletion, and inadequate access to safe drinking water contributes to approximately 200,000 deaths annually in India [4]. Given these challenges, there is an urgent need to develop cost-effective, sustainable technologies to control river pollution at its source and restore



river water quality. This article reviews the state-of-the-art river-cleaning projects and remediation technologies, with a focus on their applicability to Indian conditions.

2. STATE-OF-THE-ART RIVER CLEANING PROJECTS:

2.1 River Cleaning Projects in India:

India's monsoon-driven hydrology results in highly seasonal rainfall, with over half of the cultivated area dependent on rainfall. To manage spatial and temporal variability, extensive irrigation infrastructure, including dams, reservoirs, and canals, has been developed. Historically, India has constructed complex hydraulic systems such as embankments, reservoirs, and canals to support agriculture and water management [5]. In modern India, dams serve multiple purposes including irrigation, flood control, hydropower generation, inland navigation, domestic and industrial water supply, fisheries, and recreation. Post-independence, integrated water resources management emphasized multipurpose river valley projects as drivers of economic development. However, large dams have increasingly faced criticism due to their environmental and social impacts [6]. These include altered natural flow regimes, disrupted sediment transport, loss of aquatic habitats, barriers to fish migration, submergence of floodplains, geological instability, and inter-state water disputes. Despite significant investment in river basin projects, priority has largely been given to water storage and utilization rather than pollution control and water quality management. Initiatives such as the Damodar Action Plan and studies on the assimilative capacity of rivers primarily focused on impact assessment rather than active river cleaning. Recognizing these limitations, the Government of India launched comprehensive programs under the National Mission for Clean Ganga (NMCG). The Executive Committee of NMCG approved multiple projects worth over 1,573 crore for sewerage infrastructure, interception and diversion works, and sewage treatment plants (STPs) in cities such as Agra, Kasganj, Sultanpur, and others [7]. These projects aim not only to reduce pollution loads entering rivers but also to improve groundwater quality, urban sanitation, and overall aesthetics. However, challenges remain in ensuring effective operation, maintenance, and integration of these systems with broader river basin management strategies.

2.2 River Cleaning Projects Abroad:

International experiences provide valuable insights into advanced river-cleaning technologies. In countries such as Japan, South Korea, China, and parts of Europe, biofilm-based purification technologies have been widely studied and implemented. Research indicates that biofilm structure and performance depend on water quality, substrate composition, and environmental conditions [7–10].

Technologies such as gravel contact oxidation, underground purification systems, thin-layer flow methods, and artificial packing contact oxidation have been used effectively. For instance, Japan's Nogawa River utilized gravel contact oxidation to remove biochemical oxygen demand (BOD) and suspended solids (SS). In China, advanced treatments combining ultrafiltration, ozonation, and biological activated carbon achieved high removal efficiencies for organic pollutants and ammonia [11–13]. Riverbank filtration systems have also shown high potential for removing organic matter and nutrients such as nitrate and ammonium from polluted rivers [12–26]. In situ bioremediation technologies, first commercialized in the United States in the 1970s, have since evolved into effective large-scale solutions for hydrocarbon and nutrient pollution [27]. These international examples demonstrate the feasibility of integrating physical, biological, and chemical processes for sustainable river restoration.

3. PHYSICAL REMEDIATION TECHNOLOGIES:

3.1 Hydraulic Structures

Hydraulic structures such as weirs and small barrages can enhance natural purification processes by increasing hydraulic retention time. Reduced flow velocity facilitates sedimentation, sunlight exposure, aeration, and biological activity, thereby improving water quality for irrigation and ecological restoration [28]. Additionally, riverbank protection using natural materials, geotextiles, and vegetation enhances slope stability, biodiversity, and ecosystem resilience [29].

3.2 Riverbank Filtration:

Riverbank filtration (RBF) is a widely recognized technique that combines physical filtration with chemical and biological processes. Water pumped from wells along riverbanks undergoes natural filtration through riverbed sediments and aquifers, reducing pathogens, suspended solids, organic matter, and nutrients such as nitrate and ammonium [18–21]. The efficiency of RBF depends on hydrogeological conditions, sediment characteristics, temperature, and redox processes [22–24,30].



3.3 River Cleaning Boats:

Floating debris and solid waste transported by rivers often accumulate along banks and coastal areas, degrading aquatic and marine ecosystems. Remotely operated and manually operated river-cleaning boats have been developed to remove floating waste efficiently. These systems reduce labor requirements, operational costs, and time, while improving cleanliness and aesthetics [31–33].



Fig. 1. Trashes and debris floating on River Ganga [31]



Fig. 2. Deposition of trashes and debris at banks of the river Ganga [32]



Fig. 3. Manual removal of water hyacinth and debris using cleaning boats [33]

3.4 Trash and Debris Booms

Trash and debris booms are floating barriers installed in drains and waterways to intercept waste before it enters rivers or coastal zones. These systems can recover up to 99% of floating waste, control weed spread, and significantly reduce cleaning costs [34,35].



Fig. 4. Waste deposition along Mumbai shoreline during high tide [34]



Fig. 5. Debris accumulation along coastal areas [35]



Fig. 6. Trash boom installed in drainage channel [35]



Fig. 7. Debris exclusion barrier for waste collection [35]

3.5 Aeration:

Aeration enhances dissolved oxygen levels, promotes microbial activity, and facilitates the oxidation of dissolved metals and gases. Since the 1960s, mobile and fixed aeration systems have been used worldwide to rapidly improve water quality in polluted rivers. Studies confirm that artificial aeration can significantly enhance river self-purification [36–38].

3.6 Flushing Method:

The diversion of clean water to flush polluted river stretches can dilute contaminants and eliminate foul odors rapidly. Although effective in the short term, this method requires careful design and can be costly [39].

3.7 Dredging Method:

Sediment dredging removes contaminated sediments that hinder river flow and act as secondary pollution sources. Environment-friendly dredging techniques such as cutter suction dredgers and water injection dredging have been successfully applied in several countries [40–42].

4. CHEMICAL REMEDIATION TECHNOLOGIES:

4.1 Flocculation and Sedimentation:

Flocculation and sedimentation are commonly used to remove suspended solids and algal blooms. While effective, these methods are often expensive and may cause secondary pollution, limiting their application to pre-treatment stages. Environmentally friendly flocculants such as poly aluminum chloride and casein have shown promising results [43].



Fig. 8. River sediments caused by mining activities in Africa

4.2 Chemical Algae Control:

Chemical agents such as copper sulfate, alum, and bleaching powder are effective in controlling algal blooms and odors. Experimental studies have demonstrated significant reductions in cyanobacterial blooms using environmentally compatible algicides [44].



5. BIOREMEDIATION TECHNOLOGIES:

Bioremediation involves the use of microorganisms, plants, and animals to degrade or remove pollutants. It can be implemented as in situ or ex situ processes, with in situ methods preferred for large river systems.

5.1 Indigenous Microorganisms:

Indigenous and cultivated microbes degrade organic pollutants through biofilm formation, adsorption, and metabolic processes. Studies report significant improvements in water quality using microbial consortia combined with aeration [45,46].

5.2 Aquatic Animals:

Filter-feeding fish such as silver carp and common carp can reduce phytoplankton levels and help control eutrophication.

5.3 Aquatic Plants:

Aquatic plants such as reeds, water hyacinth, cattails, and pondweeds remove nutrients and heavy metals through uptake and adsorption. Research indicates high efficiency in removing total nitrogen and phosphorus from polluted waters [9,15].

6. ECOLOGICAL REMEDIATION:

6.1 Constructed Wetlands::

Constructed wetlands utilize natural processes involving plants, soil, and microorganisms to treat wastewater. Inoculation with pollutant-degrading bacteria enhances removal efficiencies for COD, BOD, and nutrients [47,48].

6.2 Floating Treatment Wetlands

Floating treatment wetlands use buoyant mats to support plant growth, enabling nutrient uptake and microbial degradation without soil. These systems are cost-effective, efficient, and suitable for urban rivers with limited space [49–53].

7. CONCLUSION AND RECOMMENDATIONS:

River quality management is essential for addressing India's urban water crisis. International experiences demonstrate that integrated approaches combining physical, chemical, biological, and ecological remediation are most effective. Bioremediation should be prioritized due to its sustainability, cost-effectiveness, and minimal environmental impact, supported by physico-chemical methods where necessary. Strict enforcement of pollution control policies, investment in sewage treatment infrastructure, and adoption of innovative river-cleaning technologies are crucial. Greater emphasis on practical implementation, monitoring, and community participation will ensure long-term restoration and sustainable management of India's rivers.

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