International Journal of Zoology Studies
www.zoologyjournals.com
ISSN: 2455-7269
Received: 19-07-2025, Accepted: 19-08-2025, Published: 03-09-2025
Volume 10, Issue 3, 2025, Page No. 83-87

Water quality assessment of the Saryu River in Ayodhya: A review of physico-chemical and bacteriological parameters

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Abstract
The Saryu River, which runs through Ayodhya in Uttar Pradesh, India, is a holy and important river for the environment. It is important for providing water for homes, religious ceremonies, farming, and ecosystem services. The river's water quality has become a concern due to more people living in cities, more people visiting the area for religious reasons, more sewage being dumped into it, and more idols being immersed in it. This review paper brings together research on the Saryu River's physical and chemical (pH, temperature, turbidity, dissolved oxygen, BOD, COD, TDS, conductivity, alkalinity, hardness, nutrients, and some heavy metals) and bacteriological (total coliforms, faecal coliforms, and E. coli) properties in the Ayodhya area. Published studies show that water quality changes with the seasons. During festivals and monsoon seasons, the quality deteriorates in the event of immersion of idols, and surface runoffs. Most accounts state that urban environments possess low concentration of dissolved oxygen and high concentration of BODs, and the coliform concentration exceeding the standards of bathing and drinking water. This shows a heavy organic load and faecal presence, sewage and ritualistic activity that is untreated. The paper discusses various approaches to it, the present-day state of things, and health and environmental consequences. It also suggests ways to manage the problem, such as better sewage treatment, regulated immersion practices, community-based monitoring, and nature-based remediation. To protect the Saryu River's dual religious-cultural and ecological values, we need to improve monitoring and get the community involved.

Keywords: Ayodhya, Saryu River, physico-chemical parameters, bacteriological analysis, coliforms, water pollution, idol immersion, sewage

Introduction

Rivers have supported communities through lifestyles and ways of living and have played important role in the formations of civilisations until today. Rivers are honored in India as both an ecological resource and a religious and cultural object of worship (Brierley *et al*., 2024) [6]. They are also pilgrimage destinations and sites of ritual activities and they also provide crucial ecosystem services such as drinking water, irrigation, fisheries, transportation, and hydropower (Kumari *et al*., 2023 [11]; Blair, 2023) [5]. Among these the Saryu River has a special place in the cultural geography of the north of India. The Saryu River passes through the religiously monumental Ayodhya in the state of Uttar Pradesh as mentioned in the religious books and practices of the Hindus and attracts millions of pilgrims and followers each year. Despite its religious importance, the Saryu River has been facing greater environmental pressure due to uncontrolled pilgrimage, rising urbanisation and ineffective wastewater treatment. The fact that Ayodhya has experienced phenomenal population growth is resulting in increased dumping of domestic sewage into the river as markets and industries contribute to the pollution problem (Maurya *et al*., 2023) [12]. There is also the introduction of heavy metals, chemical paints and biodegradable wastes by immersion of the idols during their festivals, etc. which further degrades water quality. Moreover, pesticides, fertilisers, and sediments run down the agricultural land during monsoon which alters the microbial and chemical composition of the river (Balkrishna *et al*., 2024) [2]. Physico-chemical and bacteriological aspects have to be monitored to have a dual focus on the health of rivers. The physico-chemical indicators in determining the water quality suitability in relation to drinking tanks, agriculture, fisheries as well as ecological balance would be measurement of pH, level of dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), hardness and nutrient levels (WHO, 2017) [17]. Moreover, bacteria penalties like Escherichia coli, total coliforms, and faecal coliforms become significant as an indicator of faecal contamination, which is the cause of water borne diseases in human beings (BIS, 2012 [4]; CPCB, 2015) [8]. High coliform levels in river water are indicative of untreated sewage inflows and inadequate sanitation, two issues that are particularly problematic in urban river areas such as Ayodhya.

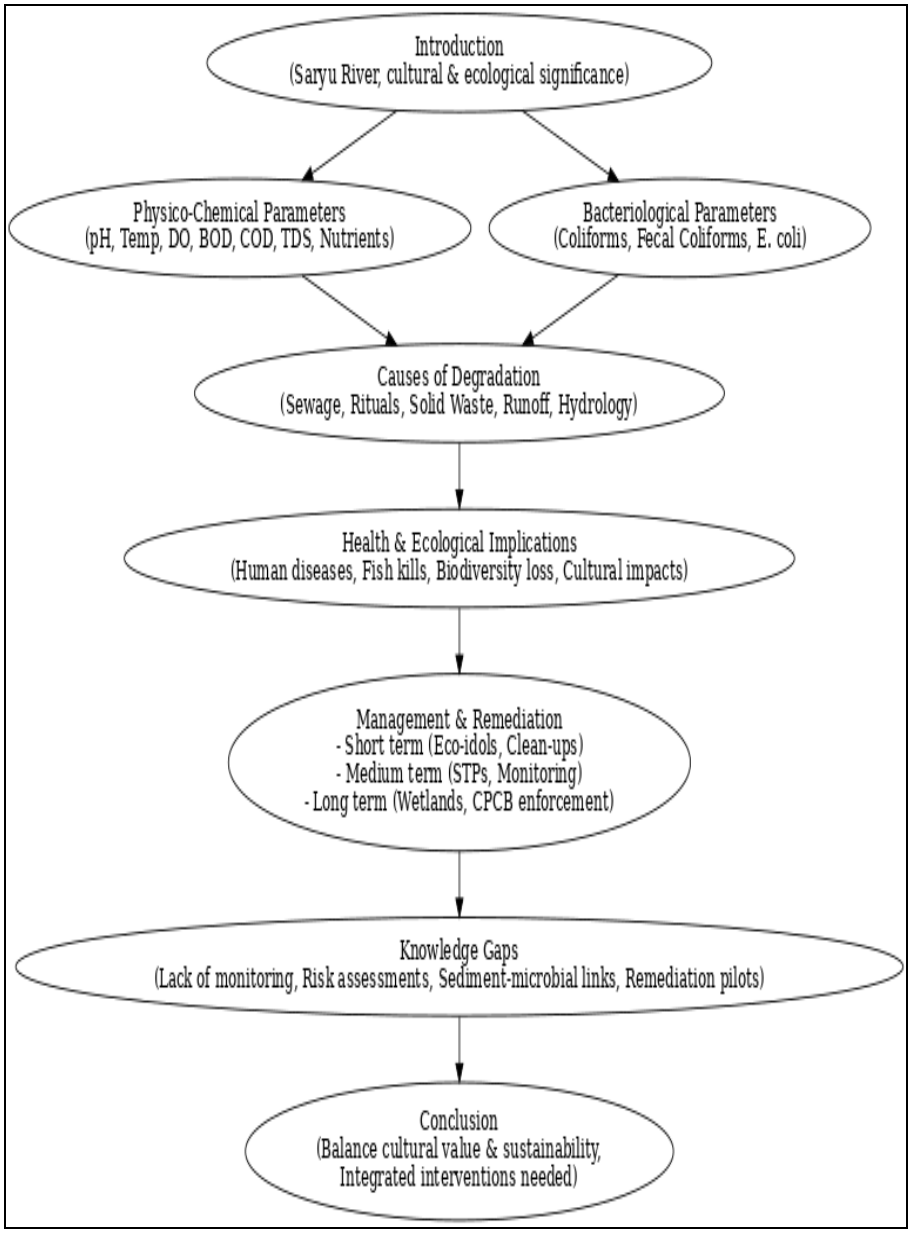

Fig 1: Flowchart summarizing the assessment, causes, implications, and management strategies for water quality in the Saryu River at Ayodhya.

Physico-Chemical Characteristics of the Saryu River

The Saryu River in the Ayodhya region varies with seasons and it is deteriorating due to increased human population in the region. PH is typically neutral to weakly alkaline (approximately 7.2 8.6) and generally within the range of that specified by the Bureau of Indian Standards (BIS IS: 10500). However, this range can change with the seasons: it is higher in the summer because of more evaporation and photosynthesis, and lower in the monsoon because of rainwater dilution. The temperature of the water, which ranges from about 20 °C to 33 °C, affects the amount of dissolved oxygen (DO) in the water, which in turn affects the health of aquatic life (Maurya *et al*., 2023) [12]. During the monsoon, runoff carries silt and suspended solids into the river, which makes the water much cloudier. Total Dissolved Solids (TDS) generally remain within reasonable bands, and there are few spikes around the sewage drains that indicate the inputs of organics and inorganics (Tiwari *et al*., 2019) [16]. The total quantity of ions (electrical conductivity) (EC) ranges between 250 and 750 mS/cm. This means that there are moderate amounts of dissolved salts and organic matter, which is what you would expect from human and agricultural inputs. The levels of dissolved oxygen (DO) change depending on where you are and what time of year it is. Upstream areas typically contain sufficient DO, although in places near the Ayodhya ghats, they frequently fall below the biologically safe level of 5 mg/L, particularly during dry seasons, or when many rituals are in progress. This imposes a strain on aquatic life. The Biological Oxygen Demand (BOD) is much greater in urban locations ranging between 5 and 12 mg/L and a sign of high amounts of organic pollution caused by untreated sewage and ritual waste. Festivals and post monsoon also exceed safe levels in terms of chemical Oxygen Demand (COD) implying that there is excessive chemical organic load. Nitrate and phosphate levels increase significantly in the monsoon due to farm runoff in terms of nutrients. Such circulation of nutrients enhances the risk of eutrophication, which is demonstrated by the presence of an algal bloom in standing water. Lastly, the total hardness tends to be within the BIS standards although in some cases alkalinity may exceed desirable levels. It is largely due to the presence of

carbonate-based sediments and discharges of domestic effluents. The physico-chemical profile of the Saryu River at the Ayodhya stretch all indicate the effects of natural hydrological changes and increasing human activities. Some of the major problems are organic and chemical pollution, shortage of oxygen, and excess of nutrients that may damage the ecology of the river and render it less useful to the people (Tiwari *et al*., 2019 [16]; Maurya *et al*., 2023) [12].

Bacteriological Characteristics

The Saryu River that flows in the Ayodhya region is of great concern due to the research that indicated that the amount of coliform was vastly more than expected. According to the Bureau of Indian Standards (BIS, 2012) [4], the total coliform value is not supposed to exceed 500 MPN/100 ml of the bathing, and the drinking water should not have any (0 MPN/100 ml) coliform. Instead, surveys reveal that the levels of total coliforms and fecal coliforms in the Saryu River frequently exceed these limits and, in particular, at ghats, where people bathe, immerse idols, and sewage is discharged directly into the river (Tiwari *et al*., 2019) [16]. Escherichia coli (E. coli) is a manifestation of fecal contamination and there is much evidence it was present. The presence of high E. coli levels ensures that Ayodhya and its immediate environment are dumping raw sewage that may cause waterborne illnesses such as diarrhea, cholera, and dysentery (Maurya *et al*., 2023) [12]. Bacteriological quality is strongly influenced by season changes. As an illustration, the bacterial loads are minimal during the winter when temperatures are low and when the degree of dilution is high. On the other hand, during the monsoon, when surface runoff carries fecal matter and organic waste into the river, coliform and E. coli counts are higher (Tiwari *et al*., 2019) [16]. The level of bacterial contamination also increases drastically during festiveness periods particularly in large bathing and idol dips. This renders the water hazardous to human beings and aquatic organisms. These findings demonstrate the significance of appropriate sewage control, increased attention to the situation during festivals, and measures to ensure that the health of people is safe to maintain river water quality.

Causes of Water Quality Degradation

The degradation of water of Saryu River in the area in and around Ayodhya is primarily attributed to a combination of human factors and natural factors. The greatest source is the discharge of untreated or partially treated sewage of the municipality where much of the organic matter and the disease-carrying bacteria are directly introduced to the river. Ayodhya lacks proper infrastructure for treating wastewater, which means that domestic waste keeps flowing into the water. This causes the water to become significantly less safe to bacteria (Maurya *et al*., 2023) [12]. Pollution also contributes by religious rituals and1 idol immersion ceremonies, which introduce heavy metals, chemical paints and organic waste, which not only worsen the quality of the water, but also damage the ecology of the water (Akhtar *et al*., 2021) [1]. Direct dumping of solid waste, such as plastics, polythene, and other garbage, in the river complicates the situation since the products do not decompose and contaminate water over an extended period (Bhattacharya *et al*., 2014) [3]. Another big cause is runoff from farms nearby, which brings fertilizers, pesticides, and sediments into the river system. This may lead to nutrient enrichment, growth of algae and even eutrophication (Issaka & Ashraf, 2017) [10]. Also, hydrological conditions contribute to a greater effect of pollution stress: during the summer, when river flows are low, it becomes more difficult to dilute pollutants, hence they accumulate on a higher level. During the monsoon, the floods enhance non-point pollution by washing the surface away (Central Pollution Control Board, CPCB). A combination of all of this demonstrates how urbanization, cultural practices, and seasonal hydrology are all collaborating to cause a deterioration in the Saryu River water quality.

Health and Ecological Implications

The water quality of the Saryu River is also becoming poor; this is unhealthy in several ways to human beings and the environment. Considering the view of the population, consumption of polluted river water or consuming fish caught in the polluted river basins exposes the locals and pilgrims to various health issues. High levels of coliforms and Escherichia coli indicate fecal contamination, which is strongly connected with the number of gastrointestinal diseases, such as diarrhea, dysentery, cholera, and typhoid (Sharma *et al*., 2024) [14]. In addition to that, the activity of dipping painted idols causes heavy metals, such as lead, chromium, and cadmium, to release and accumulate in fish and enter the human food chain. Neurological problems, kidney problems, and other chronic toxic effects may develop in the course of the long-term exposure to these metals. The ecological impacts are equally poor as the impacts on the human health. Both the high content of organic matter and the presence of living organisms reduce the quantities of dissolved oxygen (DO), resulting in the hypoxic water. This causes fish kills and makes it harder for sensitive aquatic organisms to survive (Nishmitha *et al*., 2025) [13]. This kind of stress on aquatic life leads to a loss of biodiversity, as native fish species decline and more tolerant or invasive species thrive. In addition, sewage and agricultural runoff contain nutrients that cause algal growth, further reducing the amount of oxygen and complicating the self-cleaning of the river. Finally, there is also a deteriorating water quality and this has severe cultural consequences (Maurya *et al*., 2023) [12]. The Saryu River lies very central to rituals and religion and its pollution not only renders it not as beautiful and spiritually useful, but also renders the traditional practice of ritual bathing and offering less sacred. This puts a tension between culture and the ecological health. Thus, the decrease of the Saryu River is an indicator of a crisis, which is endangering human health, the stability of ecosystems, and the survival of the culture.

Management and Remediation Strategies

The Saryu River requires a strategy that covers both short-term, medium, and long-term measures to remedy the water quality issues faced in the river. Short-term solutions such as the provision of special immersion tanks and the promotion of green idols constructed out of natural clay and non-toxic colorants can significantly reduce the pollution levels that are caused by the religious rituals. Frequent cleanup of the river front during and after festivals and installation of floating booms and nets can serve the same purpose as well (Simons *et al*., 2024) [15]. In the medium term, we need a stronger response from the infrastructure. This includes improving current Sewage Treatment Plants (STPs) and building decentralized wastewater treatment

plants, especially in peri-urban areas around Ayodhya where untreated sewage often flows directly into the river. The establishment of continuous water quality monitoring stations in place where people can view would not only open things up but also increase the responsibility of the local governments also. Moreover, public awareness campaigns that focus on the health and environmental effects of river pollution are necessary to change people's behavior in their communities (Haarstrick & Sharma, 2024) [14] [9]. Regarding long-term sustainability, one should concentrate on nature-based remedies such as constructed wetlands, riparian buffers, and bio-remediation zones. These can help the river clean itself better and support biodiversity. The stewardship can be further strengthened by involvement of local stakeholders and other religious groups in the community-based monitoring program to ensure that citizens participate in conservation. Finally, the implementation of the Central Pollution Control Board (CPCB) rules and regulations on municipal, industrial and ritual effluents is highly significant in ensuring that things are in order and preventing recurrence of the same issues. All these are steps that will be used to develop a comprehensive plan integrating technological, ecological, and community-based approaches to reviving the Saryu River in the long term.

Knowledge Gaps

Even though the pollution in the Saryu River is becoming a mainstream issue, there are a number of knowledge gaps that are critical in the development of effective management strategies. To begin with, long-term and continuous monitoring data across seasons and years is unavailable, and this factor restricts the possibility of establishing the temporal variations and long-term pollution trends. Majority of the researches have been based on short term sampling campaigns that give a partial view of the river health. Second, microbiological risk assessment studies remain scarce, with very few investigations quantifying the actual disease burden associated with exposure to coliforms, E. coli, and other pathogenic organisms in the Saryu. This restricts public health authorities from developing targeted interventions. Third, the interactions between sediments, microbial communities, and pollutants—including the potential role of sediments as reservoirs of pathogens and heavy metals—have not been sufficiently explored, even though these processes significantly affect pollutant persistence and remobilization. In addition, newer issues like the transmission of antibiotic resistance genes (ARGs) in the river systems have not been adequately addressed in the Saryu context despite the fact that it has been exhaustively reported in other Indian rivers. Lastly, the remediation pilots like built wetlands, biofilters or green ritual activities in Ayodhya and other areas have not been significantly evaluated and therefore it is hard to determine their viability, scalability and overall efficiency. It will be important to mitigate these knowledge gaps by engaging in systematic, interdisciplinary studies in order to design evidence-based policies and sustainable river management frameworks.

Conclusion

The analysis of water quality of the Saryu River close to Ayodhya highlights the negative issue of the necessity to combine the rich cultural and religious significance of the river with the need of environmental sustainability. It is always evident that essential parameters are deteriorating, particularly dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and bacteriological indicators such as total coliforms and E. coli. Certain physico-chemical parameters remain within permissible values in less-impacted regions, however the extensive bacteriological pollution constitutes a severe risk to the population health, biodiversity of aquatic life, and the spiritual worth of the river. Primary factors that contribute to the issue are inflows of untreated sewage, dumping of solid waste, and religious activities such as mass bathing and immersion of the idols. To properly manage the Saryu, a multi-faceted approach is needed. This should include upgrading infrastructure, especially sewage treatment, promoting eco-friendly ritual practices, ongoing scientific monitoring, and getting the community involved. In the end, protecting the Saryu River is not only important for the environment, but also for culture. It will protect people's health and the health of the river itself, while also keeping its sacred identity alive for future generations.

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