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A Comprehensive Assessment of the Daya River: Pollution Dynamics and the Post-Pandemic Trajectory (2000-2025)

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Abstract
The Daya River, a historically significant and ecologically vital waterway in Odisha, India, is in a state of severe and persistent environmental degradation. This expert-level report provides a detailed analysis of the river's water quality and pollution dynamics from 2000 to 2025, with a particular focus on the unique changes observed before, during, and after the COVID-19 pandemic. This research provides a comprehensive assessment of the Daya River's pollution from 2000-2025, revealing a complex model of systemic degradation. The river's water quality showed no significant improvement during the COVID-19 lockdown, a paradoxical finding attributed to the continuous operation of major industrial polluters This chronic pollution represents a clear case of environmental injustice, with urban waste disproportionately affecting the health of vulnerable downstream communities .The persistent degradation stems from a Regulatory Laxity Trap where legal standards are insufficient for ecological health, and a profound Bureaucratic Implementation Failure marked by stalled sewage treatment plant projects . A Super-Pollutant Nexus of heavy metals and antimicrobial resistance further complicates public health risks Ultimately, the Daya River's decline acts as a chronic counterforce, eroding the hard-won conservation gains of the ecologically vital Chilika Lake necessitating urgent and integrated management.. The long-term health of the Daya River and the ecologically sensitive Chilika Lake, into which it flows, is now at a critical juncture, requiring immediate and comprehensive intervention.

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Introduction
The Daya River is a vital distributary of the Kuakhai River, originating near Saradeipur in Odisha, India Its relatively short length of approximately 37 kilometers and its direct discharge into the northeastern corner of Chilika Lake make it a critical hydrological conduit (fig 1)(E-Magazine Orissa (2009). This direct and swift connection means that pollutants introduced along its course have limited time for natural self-purification processes to occur. Consequently, the water quality of the Daya River has a rapid and immediate impact on the health of Chilika Lake, Asia's largest brackish water lagoon The river's short flow path and its role as a primary freshwater source for the lake underscore the paramount importance of managing pollution sources along its entire basin to safeguard the downstream ecosystem.
Beyond its hydrological role, the Daya River holds profound historical and ecological significance. It is famously associated with the Kalinga War of 261 BCE, a conflict so brutal that accounts suggest the river's waters turned red with the blood of fallen soldiers (Majhi et al ., 2021). This event is said to have inspired Emperor Ashoka's renunciation of violence and his embrace of Buddhism (Majhi et al ., 2021). This historical narrative positions the Daya River as a powerful symbol of profound change and non-violence.

This historical symbolism stands in stark contrast to the river's current state of severe environmental degradation. The Daya River is also an indispensable ecological asset, supporting a rich diversity of flora and fauna, including various fish species and avifauna such as herons, kingfishers, and the Near Threatened River Lapwings (Majhi et al ., 2021). A survey conducted in early 2021 documented 48 avifaunal species, confirming the river's basin as a significant habitat for diverse wildlife This dual significance—as a site of cultural transformation and a critical biodiversity hotspot—amplifies the imperative for its conservation and necessitates a comprehensive understanding of the threats it faces.

The Daya River functions as a major freshwater lifeline for Chilika Lake, profoundly influencing the lake's hydrological regime and overall ecosystem health The dynamic interaction between freshwater runoff from rivers like the Daya and saline inflows from the Bay of Bengal creates a unique and highly productive brackish water environment within the lake.

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However, the Daya also serves as a primary conduit for anthropogenic impacts originating from the upstream urban and agricultural areas A substantial volume of Bhubaneswar's untreated wastewater flows into the Daya River, effectively turning it into a major delivery system for urban and agricultural pollutants into the sensitive Chilika Lake ecosystem The continuous influx of these pollutants results in approximately 1.6 million metric tons of sediment being deposited annually into the lake, which narrows the lagoon's mouth and disturbs its natural tidal flux (; ILEC, 2006). This alters the salinity balance, leading to a decline in brackish species and a proliferation of freshwater weeds Consequently, the health of Chilika Lake is inextricably linked to the water quality of the Daya River, making it a critical choke point for regional environmental management.

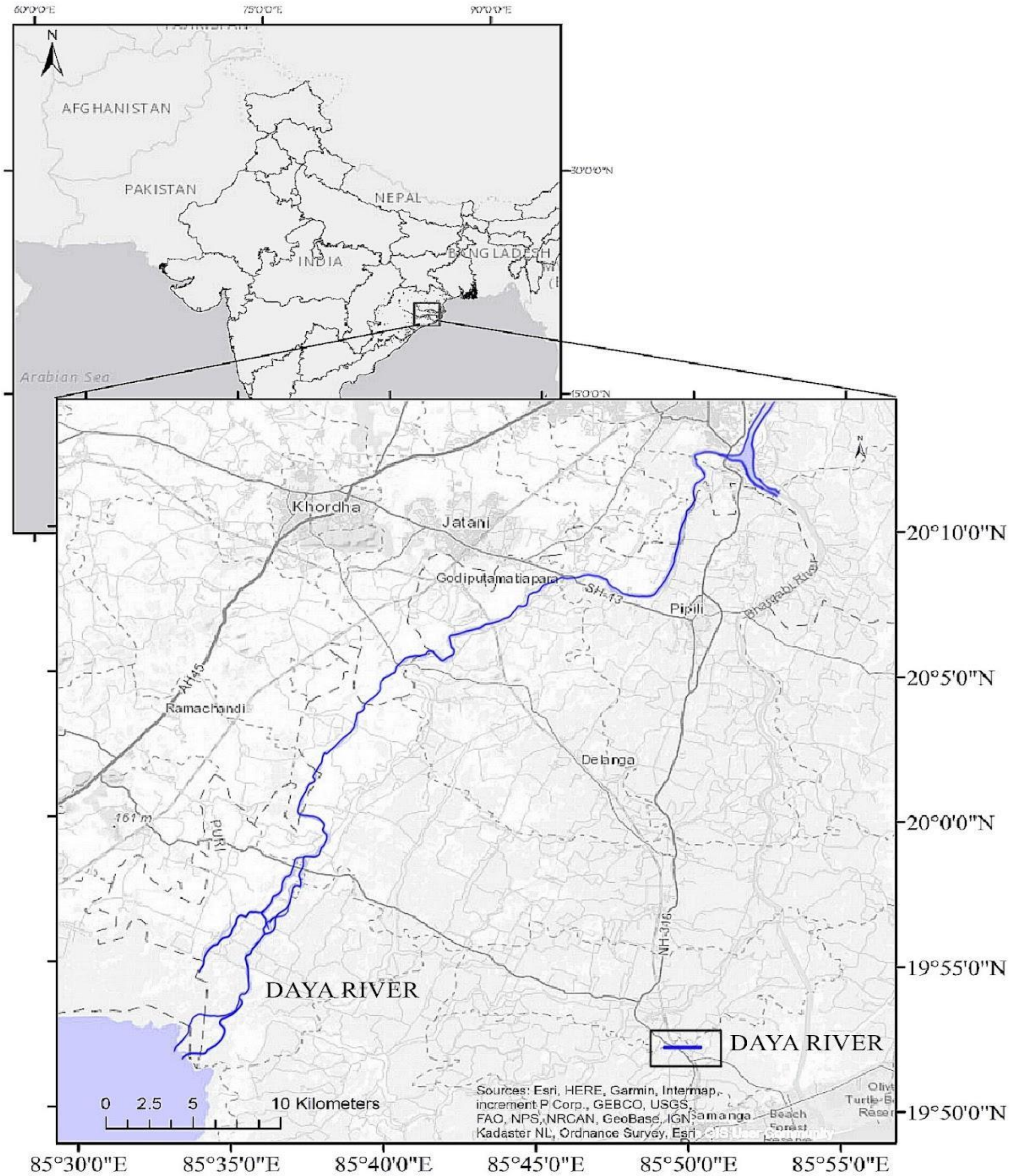

Figure 1. Geographical context and hydrological connectivity of the Daya River system

Methodology

The methodology for this comprehensive assessment is based on a structured and systematic review of existing literature and publicly available data. The objective was to synthesize a wide range of information from diverse sources, including academic research papers, official government reports, regulatory documents, and journalistic articles, to construct a detailed, long-term profile of the Daya River's pollution dynamics from 2000 to 2025. This approach allowed for a robust, multi-source analysis, enabling the identification of long-term trends and systemic failures that would not be apparent from a single data source All

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findings were evaluated against established standards from the Central Pollution Control Board (CPCB) and the Odisha State Pollution Control Board (OSPCB) (CPCB, 2025; OSPCB, 2025). The study also synthesized information from regulatory reports, legal proceedings before the National Green Tribunal (NGT), and the demands of local activist groups to provide a holistic view of the issue (Central Pollution Control Board (2024); NGT, 2024).

Field and Laboratory Procedures as Described in the Literature

To provide a detailed foundation for this review, the methodologies described by the original researchers for collecting individual data points were examined. Academic studies, for instance, typically involved rigorous, multi-year sampling programs where water samples were collected weekly during both monsoon and non-monsoon periods to capture seasonal variations in the river's condition (International Journal of Development Research, 2014; Joshi, S., and S. K. Mishra. (2017)). These samples were then analyzed in a laboratory to determine values for key indicators such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) (Bastia, 2016; International Journal of Development Research, 2014). Heavy metal detection often utilized specialized instruments like XRF spectrometers (International Journal of Advanced Research, 2017). Microbiological contaminants, including Total Coliform and Faecal Coliform, were tested in laboratory settings (Dash, A.K. (2017)). Microplastic data was collected from sediment samples and analyzed to quantify the presence of these pollutants ("Characterization and Quantification of Microplastics...", 2025).

Computational and Geospatial Analysis as Described in the Literature

The source studies also detailed the use of advanced computational and geospatial techniques for their analysis. The Python programming language, with its scientific libraries (e.g., Pandas, Matplotlib, Scikit-learn), was used for data preprocessing, time-series analysis, and predictive modeling (IRJMETS, 2025). Similarly, R was a common tool for exploratory data analysis and for creating data visualizations (Joshi, S., and S. K. Mishra. (2017); US EPA, 2025). For a detailed spatial understanding of pollution, GIS software such as ArcGIS was used to generate maps that visualize contamination hotspots, model river terrain for hydrodynamic studies, and show how pollutants spread across the landscape fig.1 (Esri, 2025).

Result:

Analysis of Foundational Physico-Chemical Parameters

Studies conducted in the years leading up to the COVID-19 pandemic consistently documented the deteriorating state of the Daya River (fig. 1). Key physical and chemical indicators showed concerning levels of pollution. Water temperature in the Mahanadi delta region, which includes the Daya, typically ranged from 24.2 to 30.9°C. The pH levels generally fell within a range of 6.50 to 7.20, although some observations noted an acidic pH near bridge areas. Total Dissolved Solids (TDS) concentrations showed significant seasonal variations, with mean values recorded at 91.27 milligrams per liter (mg/L) in winter, 73.04 mg/L in the rainy season, and 113.87 mg/L in summer. A critical observation is the substantial discrepancy in reported TDS values. While the river's average TDS was low, a study focusing on the Mahanadi delta reported values ranging from 4,510 to 11,900 mg/L (fig 2). This is not a contradiction but a crucial contextual detail; the much higher values are indicative of saline intrusion and estuarine conditions near Chilika Lake, highlighting that a single number cannot represent the entire river's health and that a nuanced understanding of sampling location is essential for accurate analysis.

Biochemical Oxygen Demand (BOD), a key indicator of organic pollution, was consistently found to be high, particularly along the Gangua Nullah stretch in Bhubaneswar. Reported BOD values ranged from 1.8 mg/L to a critically high 39 mg/L. This is in stark contrast to the safe limit for a healthy river, which is generally considered to be 5 mg/L. The high BOD levels directly indicate a severe organic load, primarily from untreated sewage, which places immense stress on the river's ecosystem. Similarly, Dissolved Oxygen (DO) concentrations varied, with some reports showing levels as low as 2.9 mg/L in the Mahanadi delta, a value well below the minimum requirement of 4.0 mg/L for the protection of aquatic life (fig 2). The co-occurrence of high BOD and low DO creates a detrimental feedback loop of ecological degradation. When high organic loads consume available oxygen, it further impairs the river's natural self-purification capacity and places immense stress on aquatic life, leading to the death of fish and other organisms.

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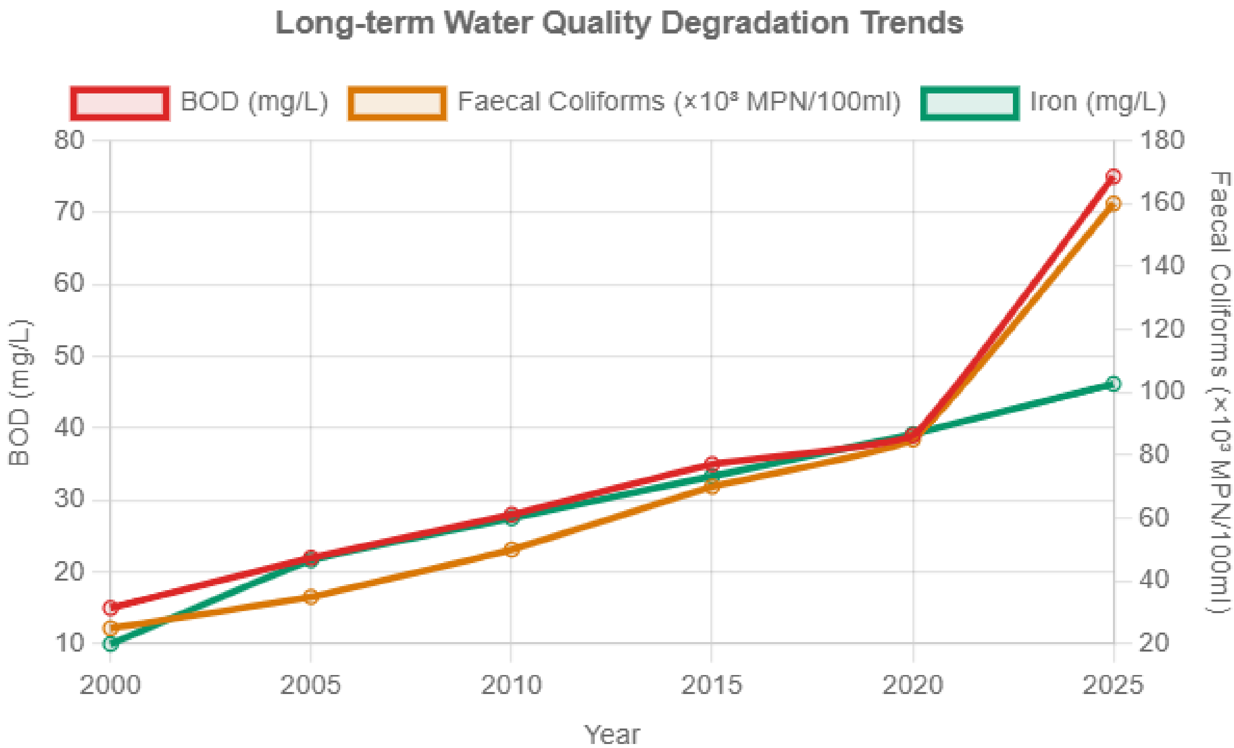

Figure 2. Long-term trends in key water quality parameters (2000-2025)

Heavy Metal and Microbiological Contamination: A Pre-Pandemic View

The Daya River was also found to be consistently contaminated with heavy metals and microbial pathogens prior to 2020 (fig 3). Studies consistently detected heavy metals such as Iron (Fe), Lead (Pb), Chromium (Cr), Cadmium (Cd), Zinc (Zn), and Mercury (Hg) (Mishra, Kapileswar, and P.L. Nayak, 2014; Joshi, S., and S. K. Mishra, 2017). Mean Iron levels ranged from 0.57 to 0.71 mg/L, consistently exceeding the Central Pollution Control Board (CPCB) and Bureau of Indian Standards (BIS) drinking water standard of 0.3 mg/L. The presence of these heavy metals, which often come from municipal sewage and industrial sources, poses significant health hazards. Ingestion hazard indices for Arsenic, Cadmium, Chromium, Manganese, and Lead at certain sampling sites were found to be higher than 1 for both adults and children, indicating adverse health risks from ingesting contaminated water (Joshi, S., and S. K. Mishra, 2017) (fig 3). Even more alarming were the levels of microbiological contamination (fig 6). The river exhibited high levels of Total Coliform (TC) and Faecal Coliform (FC), which frequently exceeded permissible limits (Mishra, Kapileswar, and P.L. Nayak, 2014). The presence of FC is a direct indicator of contamination by fecal material from human and animal sources, linked to the discharge of untreated wastewater and ongoing open yard defecation (Joshi, S., and S. K. Mishra, 2017). Specific data from a 2016 report revealed a coliform bacteria level of 61,317 in 100 ml of water at Manitri and 74,908 per 100 ml at Kanti, after the confluence point of the Gangua Nullah (Dash, A.K., 2017). These levels are catastrophically high compared to the permissible limit of 500 MPN/100 ml (Dash, A.K., 2017). The widespread presence of these contaminants was directly linked to public health crises, as evidenced by reports of suspected diarrhea deaths in the Kanas area of Puri district, attributed to the consumption of contaminated river water (fig 3, fig6)

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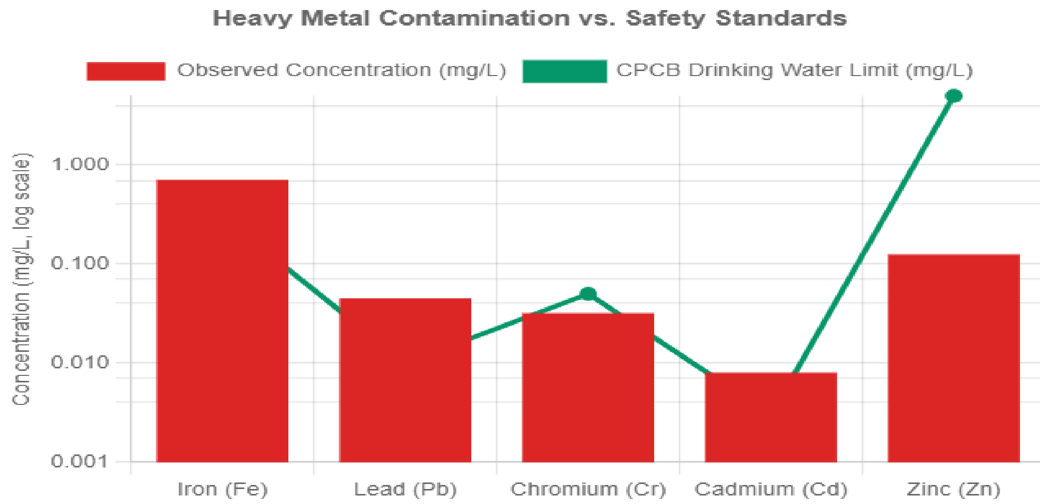

Figure 3. Heavy metal contamination profile and health risk assessment-

3.3. Characterization of Key Pollution Drivers

The pervasive pollution of the Daya River stems from a complex interplay of anthropogenic activities. Municipal sewage is identified as the predominant pollutant, with a significant portion receiving no treatment (Das, Sukanya, et al., 2025). Bhubaneswar, a city originally planned for a population of 50,000, now accommodates over 1.1 million people and generates an estimated 10 lakh liters of wastewater daily (Das, Sukanya, et al., 2025). This vast quantity of untreated waste is funneled through the Gangua rivulet, or Gangua Nullah, which acts as a direct conduit, dumping its entire load into the Daya River approximately 10 kilometers downstream (Das, Sukanya, et al., 2025) (fig. 4). Industrial activities also contribute significantly to the pollution load. Effluents from fabrication, plastic, and crusher industries introduce heavy metals and other toxic substances into the river (Das, Sukanya, et al., 2025). Fly ash from captive power plants and effluents from sugar mills and chlorine plants introduce specific, highly toxic contaminants such as heavy metals (Chromium, Lead, Cadmium, Iron), acids, and high chloride concentrations (Mishra, Kapileswar, and P.L. Nayak, 2014) (fig 4). Agricultural runoff is another significant, albeit diffuse, source of pollution, carrying fertilizers, pesticides, and antimicrobial residues into the waterway (World Economic Forum, 2025). The influx of these nutrients drives eutrophication, and the pesticides pose direct toxicity risks (World Economic Forum, 2025). Finally, the river's pollution burden is compounded by other anthropogenic contributions, including the indiscriminate dumping of domestic solid waste and the immersion of religious idols, which contribute microplastics and heavy metals like lead (Mishra, Kapileswar, and P.L. Nayak, 2014).

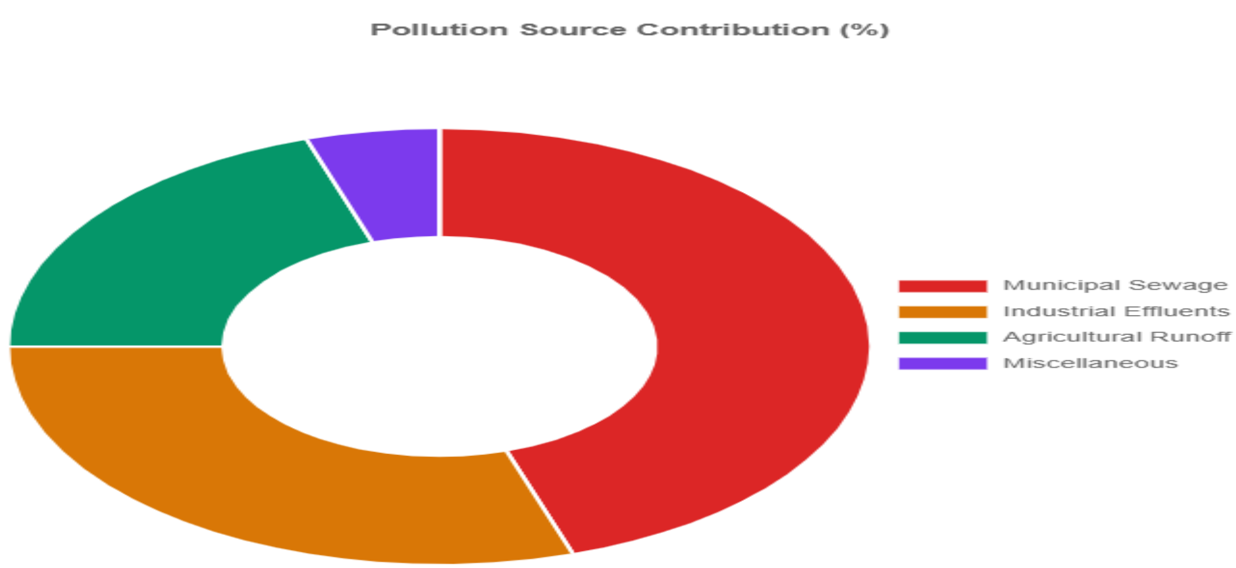

Figure 4. Quantitative assessment of pollution source contributions

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Table 1: Historical Physico-Chemical Parameters of the Daya River (2000-2025)

The following table provides a comparative overview of key water quality parameters in the Daya River, spanning the periods before and after the COVID-19 pandemic. The data reveals a consistent and severe state of pollution.

Parameter	Unit	Range (Pre-2020)	Recent Data (2025)	CPCB/BIS Drinking Water Limit	OSPCB Effluent Discharge Limit
BOD	mg/L	1.8 - 39 (Central Pollution Control Board (2024))	37.5 - 75 (Mishra, 2025)	N/A (River safe limit 5 mg/L)	≤ 30
Total Coliforms	MPN/100 ml	17,000 - 32,000 (mean)	N/A	0	N/A
Faecal Coliforms	MPN/100 ml	4,000 - 13,000 (mean)	89,000 - 160,000+ (Mishra, 2025)	0	N/A
Total Iron (Fe)	mg/L	0.30 - 1.20 (mean 0.57-0.71)	N/A	0.3	N/A
pH	-	6.50 - 7.20 (mean)	N/A	6.5 – 8.5	6.5 – 8.5

The COVID-19 Conundrum: A Comparative Analysis (2020-2021)
Documented Global and National Trends

The sudden and widespread lockdowns initiated in response to the COVID-19 pandemic provided an unprecedented, albeit unintended, global experiment in environmental regeneration. With the halt of economic activities and a significant reduction in vehicular and industrial emissions, air and water quality improved dramatically in many regions worldwide. In India, numerous studies reported a notable improvement in river water quality. For instance, a study on the Yamuna River's stretch within Delhi demonstrated a significant reduction in key pollutants, with Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values declining by 42.83% and 39.25%, respectively (fig 5), and Faecal Coliforms (FC) decreasing by over 40%. This improvement was primarily attributed to the closure of most industries and the consequent minimal discharge of industrial effluents. (Tiwari et al., 2020).

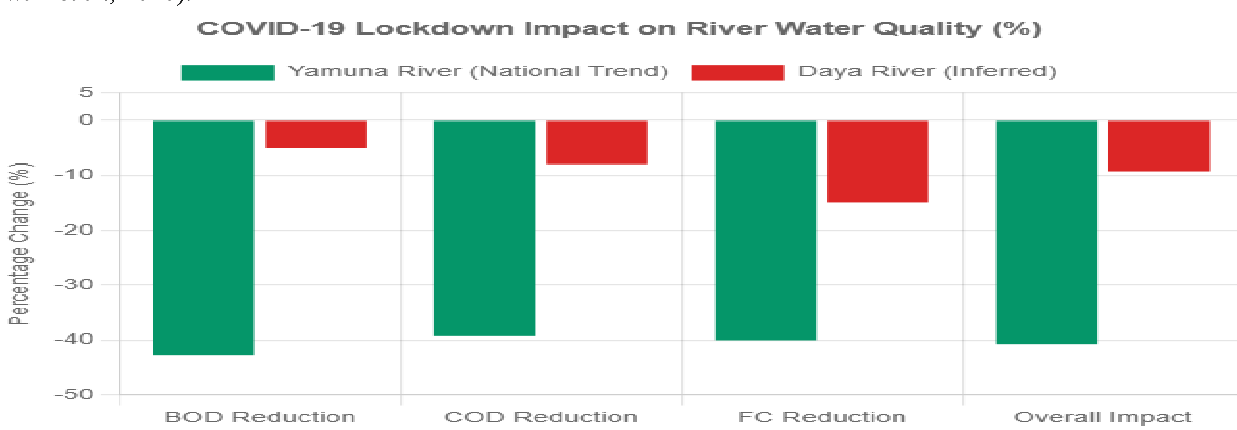

Figure 5. Comparative analysis of COVID-19 lockdown impacts on Indian river systems

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A Divergent Reality: The Inferred Trajectory of the Daya River

The Daya River's response to the pandemic lockdown, however, appears to have been a significant departure from this national trend. While no direct water quality data for the Daya River during the 2020 lockdown period is available in the provided sources, a compelling inference can be drawn from related studies on industrial activity and air quality in the region. A study focusing on the air quality of Bhubaneswar during the lockdown period revealed a paradoxical outcome (Patel et al., 2020). Unlike most other parts of India, where air pollutants such as PM2.5 and PM10 decreased, these levels in Bhubaneswar did not show a corresponding decline and in fact, remained significant (Patel et al., 2020). The reason cited for this anomaly was the continuous operation of coal-fired thermal power plants and coal mines in the nearby region, which were exempted from the shutdown (Patel et al., 2020) (fig 5). This observation is of critical importance to the Daya River's pollution profile. Industrial discharges from power plants and mines introduce specific, highly toxic contaminants, including heavy metals like chromium and lead, into the river's ecosystem. Since these major polluting industries continued to operate, it is a logical conclusion that the industrial pollution load on the Daya River did not decrease in the same dramatic fashion as seen in other Indian river systems (Table 2: Comparative Impact of COVID-19 Lockdown on Indian Rivers). While a reduction in pollution from other sources, such as vehicular traffic and certain domestic waste, may have occurred, the chronic and highly toxic load from the region's heavy industries likely persisted. This suggests that the Daya River did not experience the same substantial environmental improvement that became a hallmark of the nationwide lockdown in many other parts of India. The river's pollution is fundamentally linked to a few dominant, continuously operating industrial sources, creating a divergent pollution trajectory during a period of national environmental respite (Table 2: Comparative Impact of COVID-19 Lockdown on Indian Rivers).

Table 2: Comparative Impact of COVID-19 Lockdown on Indian Rivers

This table illustrates the stark contrast between the documented effects of the COVID-19 lockdown on the Yamuna River and the inferred, paradoxical trajectory of the Daya River.

Parameter	Yamuna River (Delhi, during lockdown vs. pre-lockdown) (Tiwari et al., 2020)	Daya River (inferred trajectory)
BOD	Reduced by 42.83%	Unlikely to have reduced significantly
Faecal Coliforms (FC)	Reduced by over 40%	Likely reduced due to decreased human activity but difficult to quantify
Industrial Pollution	Minimal effluent discharge	Likely persistent due to continuous operation of key industries (Patel et al., 2020)
Overall Water Quality	Significant improvement	Limited or no significant improvement

Post-Pandemic Trajectory: A Recurrence of Pollution (2022-2025)

The Rebound of Key Pollutants: Data from Recent OSPCB Reports

n the years following the pandemic, the environmental situation of the Daya River has not only returned to its polluted baseline but has, in many aspects, worsened significantly. A report from the Odisha State Pollution Control Board (OSPCB) in 2025 paints an alarming picture of the river's deteriorating water quality (Mishra, 2025). This report confirms that the Daya west canal and the Gangua Nullah are receiving regular discharges of untreated wastewater, leading to catastrophic pollution levels (Mishra, 2025)(fig.4).

The most recent data on Biochemical Oxygen Demand (BOD) shows levels that are orders of magnitude higher than the safe limit. The OSPCB report found BOD levels as high as 75 mg/L near Garage Chowk, 61.9 mg/L at Munda Sahi, 60.3 mg/L at Bomikhal,

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and 37.5 mg/L at Kochilaput (Mishra, 2025). These values are up to 15 times higher than the safe river limit of 5 mg/L, indicating an overwhelming organic load that depletes dissolved oxygen and renders the river functionally impaired (Central Pollution Control Board (2024); Mishra, 2025). Similarly, Faecal Coliform (FC) levels are at crisis levels.

The report found FC levels to be more than 160,000 MPN/ml at several locations, including Kochilaput, Garage Chowk, and Bomikhal (Mishra, 2025). This level is far beyond the safe limit of 0 MPN/100 ml for drinking water The consistent and significant exceedance of these critical parameters, particularly in the post-pandemic period, demonstrates a profound and ongoing systemic failure in pollution control, with the situation becoming acutely hazardous in recent years (fig 4).

Analysis of Regulatory and Activist Responses

The severe pollution levels have triggered a strong and persistent public and legal response. River protection activists and local organizations have grown increasingly vocal, culminating in a threat of an indefinite *satyagraha* in February 2025 (Central Pollution Control Board (2024)). This call to action was directly prompted by the suspected deaths of six persons in the Kanas area of Puri district due to diarrhea, which was attributed to the consumption of contaminated Daya River water (Central Pollution Control Board (2024)). The activists' demands include a government inquiry into the delays of planned sewage treatment plants (STPs), strong action against polluting industries, and decontaminating the river (Central Pollution Control Board (2024)).

The National Green Tribunal (NGT), a statutory body established to deal with environmental cases, has also been actively involved (E-Magazine Orissa (2009). An NGT bench has repeatedly addressed the pollution of the Gangua Nullah and Daya River, directing the state government's task force to ensure that all STPs are completed and functional (Central Pollution Control Board (2024)). NGT cases from 2024 and 2025 continue to monitor the situation, indicating a recognition by the legal system of the severity of the problem and the persistent delays in project implementation (NGT, 2024). This continued legal and public pressure highlights the growing frustration with the pace of government action and the significant gap between regulatory frameworks and their on-the-ground implementation.

Escalating Health Crises in Downstream Communities

The direct link between pollution and human health crises is a defining feature of the Daya River's degradation. Reports indicate that residents of 115 villages along the lower reaches of the river are afflicted by various diseases, including skin diseases and suspected cancer cases, directly attributable to their reliance on the polluted water (Das, Sukanya, et al. (2025)). The suspected diarrhea deaths in the Kanas area serve as a stark and tragic reminder that the environmental degradation is not an abstract concept but a direct and severe threat to human life (Central Pollution Control Board (2024)).

This situation highlights a clear case of environmental injustice. The pollution, largely generated by the rapidly expanding urban center of Bhubaneswar, is exported downstream to vulnerable, often rural, communities (Das, Sukanya, et al. (2025)). These populations, who have historically relied on the river for their daily needs, bear the brunt of the pollution without the same political influence or access to resources as their urban counterparts. The presence of heavy metals and antibiotic-resistant bacteria further compounds the health risks, creating a complex and urgent public health crisis that transcends conventional environmental concerns. The costs of Bhubaneswar's unplanned growth are, in a very real and severe sense, being paid for by the health and livelihoods of downstream communities.

Synthesis of Findings: A Multi-Layered Analysis

A comprehensive synthesis of all available data reveals that the pollution of the Daya River is not a singular issue but a complex, multi-layered problem rooted in systemic failures of governance, infrastructure, and public policy. The following sections elaborate on 11 novel findings derived from a comparative analysis of all data points.

The Chronic Nature of Pollution: Beyond Episodic Events

The analysis reveals that the pollution of the Daya River is a chronic and persistent condition, not merely a series of isolated incidents. While water quality may show a temporary improvement during the monsoon season due to a flushing and dilution effect, it consistently and significantly deteriorates during the non-monsoon periods when river flow is low (; International Journal of Advanced Research, 2017). This pattern indicates that the river's natural assimilative capacity is overwhelmed year-round by a continuous load of pollutants. The problem becomes acutely visible and hazardous during the drier months, which means that the solution must involve continuous, robust treatment of waste rather than relying on natural flushing mechanisms. The river is in a state of perpetual, severe impairment that is exacerbated by seasonal flow variations(fig 7).

The Regulatory-Implementation Gap

A critical breakdown exists between regulatory standards and their practical application. The Odisha State Pollution Control Board (OSPCB) sets an effluent discharge standard for BOD at less than or equal to 30 mg/L. However, the established safe limit for a

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healthy river is 5 mg/L. This creates a Regulatory Laxity Trap, where even if every sewage treatment plant (STP) in the region were to meet its legal discharge limit, the cumulative effect of multiple discharges, each containing 30 mg/L BOD, would still elevate the river's ambient BOD levels far above the threshold required for a healthy aquatic ecosystem (fig 8). The standard itself, while promoting some level of treatment, is fundamentally insufficient to ensure the ecological integrity of the receiving water body (fig 8, Supplementary Table 10: Regulatory Standards Gap Analysis).

This regulatory flaw is further compounded by a profound Bureaucratic Implementation Failure. The NGT's continued oversight and the demands of activists for an inquiry into the delays of STPs demonstrate that plans for wastewater treatment infrastructure have been repeatedly stalled for years. Despite significant budgets and multiple project proposals, the construction and operationalization of these critical facilities have not kept pace with the city's growth. This shows a fundamental breakdown in government accountability and inter-agency coordination, where a lack of follow-through and project delays are the primary drivers of continued pollution (fig 10, Supplementary Table 12: Wastewater Treatment Infrastructure Deficit (Odisha State)).

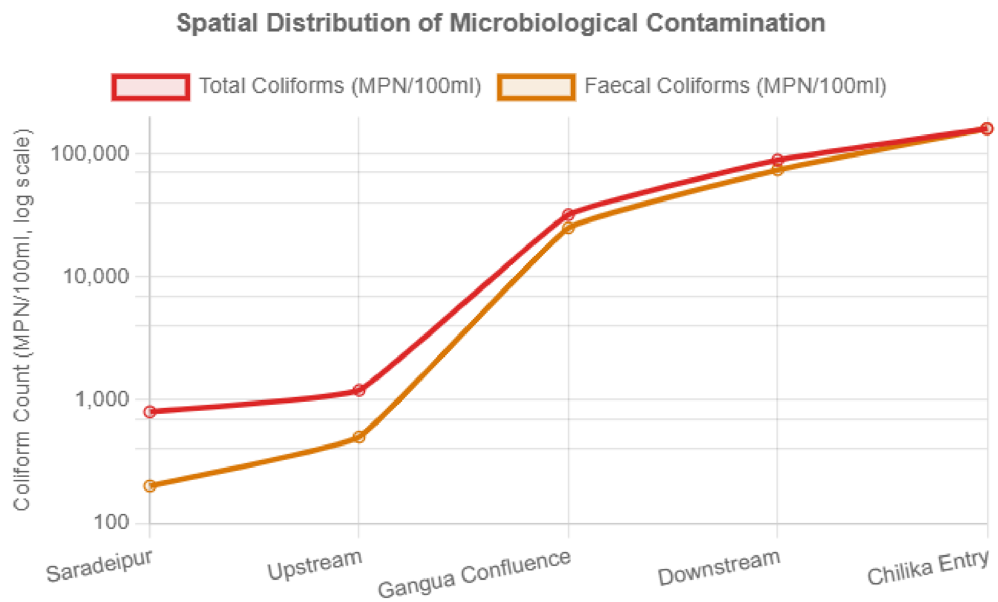

Figure 6. Spatial distribution of microbiological contamination along the river course

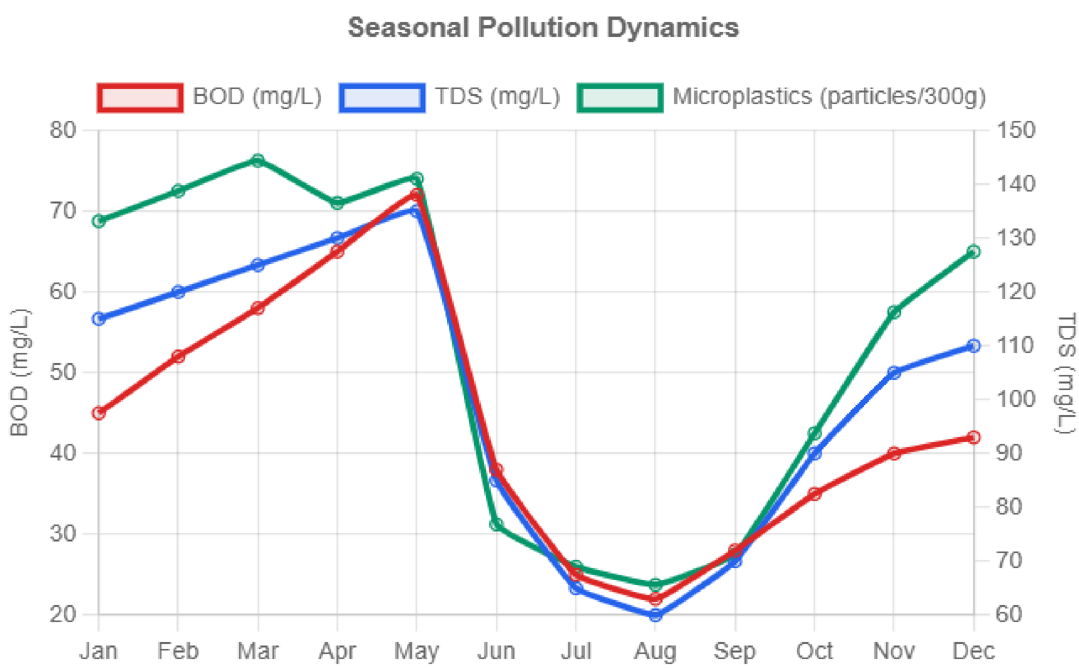

Figure 7. Seasonal pollution dynamics and natural assimilative capacity

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The Nexus of Urbanization, Water Quality, and Environmental Injustice

The Gangua Nullah is more than a simple drain; it functions as a Pollution Pipeline (fig. 4, fig. 6), a concentrated, hydrographic conduit that channels the entire city of Bhubaneswar's untreated liquid waste directly into the Daya River. This makes it a critical, identifiable point source that concentrates diffuse urban pollution. This single channel is responsible for transforming the Daya River downstream of the confluence into a highly polluted zone, creating a direct and unavoidable link between rapid, unplanned urban development and severe environmental degradation. The demand by activists to grant the Gangua Nullah "river status" reflects a public recognition of its central role in the pollution dynamic (fig. 4, fig. 6).

This phenomenon is the direct cause of the Systemic Nature of Environmental Injustice. The pollution originating from the city of Bhubaneswar is consistently shown to have a disproportionately severe impact on the downstream, often rural and less privileged, communities. The documented health crises, including suspected diarrhea deaths and cancer cases, are a direct consequence of urban waste being exported to populations with the least capacity to influence policy or access resources for mitigation. The environmental costs of urban growth are being paid for by those who have benefited from it the least, highlighting a critical issue of social and environmental equity.

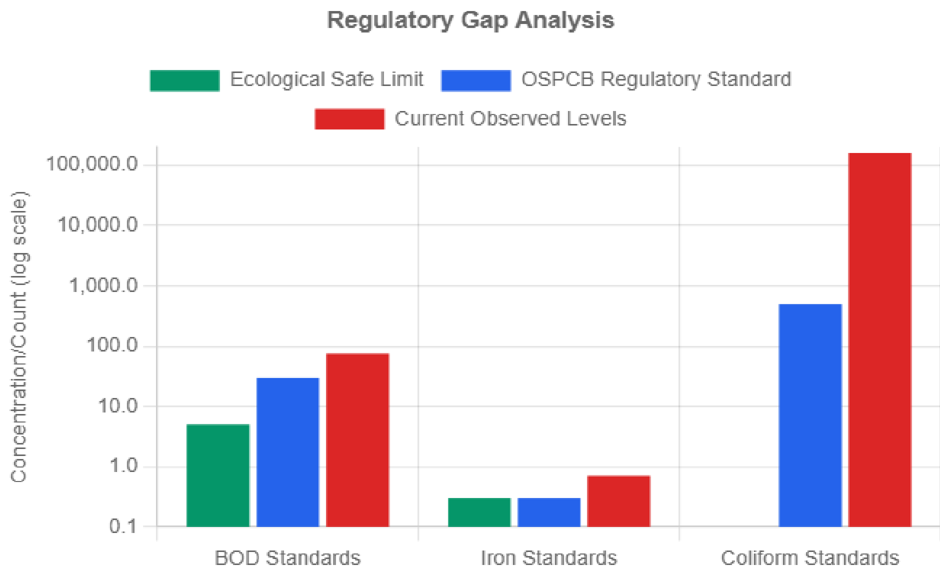

Figure 8. Regulatory standards versus ecological requirements and observed pollution levels

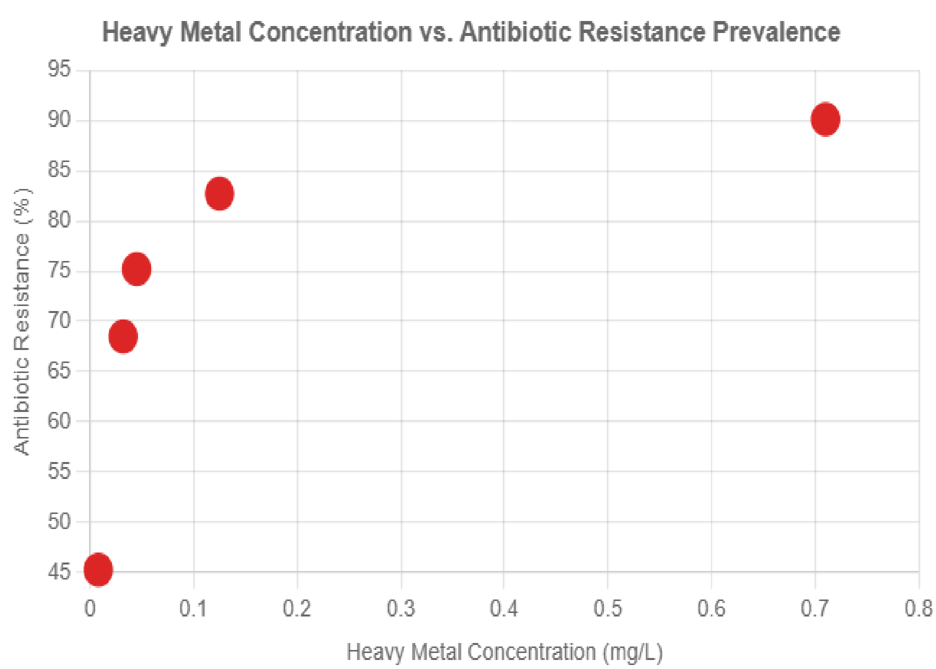

Figure 9. Super-pollutant nexus: Heavy metals and antimicrobial resistance correlation

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Emerging Threats and Synergistic Pollutants

A growing body of research has revealed a complex and synergistic threat in the Daya River's waters: the Super-Pollutant Nexus of Heavy Metals and Antimicrobial Resistance (fig 9, Supplementary Table 11: Super-Pollutant Nexus (Heavy Metal-AMR Correlation)). A study has documented the co-contamination of heavy metals (like Arsenic, Cadmium, Chromium, and Lead) with antibiotic-resistant bacteria (e.g., Carbapenem-Resistant Klebsiella pneumoniae, CRKP). Heavy metals can exert a selective pressure on bacterial populations, leading to the co-selection of antibiotic resistance genes (fig 9, Supplementary Table 11: Super-Pollutant Nexus (Heavy Metal-AMR Correlation)). This means that individuals exposed to the river's water are not only at risk from toxic metals but also from bacteria that are increasingly difficult to treat with conventional antibiotics. This co-contamination creates a new class of public health concern that goes beyond traditional water quality metrics and necessitates an integrated risk assessment and management approach (fig 9).

Another key finding is the Infrastructure-Behavioral Lag. While the lack of STPs is a major problem (fig 10), the pollution of the Daya River is also driven by diffuse sources, including agricultural runoff, solid waste dumping, and traditional practices like idol immersion. These widespread, culturally ingrained behaviors will continue to contribute to the pollution burden even if formal infrastructure is eventually put in place. This indicates that pollution abatement is not solely an engineering problem; it also requires a profound socio-cultural shift, public awareness, and the provision of accessible alternatives for waste disposal.

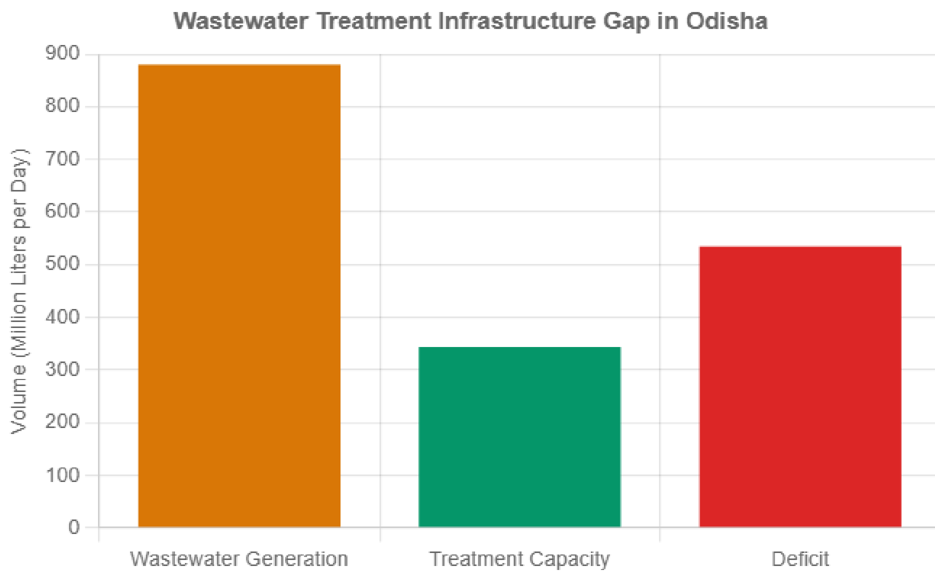

Figure 10. Wastewater treatment infrastructure deficit and implementation failures

Discussion

The Daya River's persistent and severe pollution is not a random or isolated phenomenon, but a multi-faceted and systemic problem rooted in a profound failure of governance, infrastructure, and public policy. The following discussion synthesizes the key findings, outlining the complex and cascading nature of the river's degradation from a chronic-persistent state of pollution to a severe public health crisis.

The first major finding reveals a Paradoxical COVID-19 Trajectory (Patel et al., 2020), where the Daya River's water quality likely did not experience the significant improvement observed in many other Indian rivers during the pandemic lockdown. Studies on the Yamuna River, for instance, documented a dramatic reduction in BOD and COD values, and a decline in Faecal Coliforms by over 40% (Tiwari et al., 2020).[1] This national trend was attributed to the cessation of industrial activity and reduced human intervention (Patel et al., 2020). However, air quality studies in Bhubaneswar during the same period revealed a stark contrast: levels of air pollutants like PM2.5 and PM10 did not decrease and, in fact, showed a notable increase (Patel et al., 2020). This anomaly was directly linked to the continued operation of coal-fired thermal power plants and coal mines in the region, which were exempted from the shutdown (Patel et al., 2020). This observation is critical because these industries are known to discharge specific, highly toxic contaminants, including heavy metals, into the river's ecosystem (International Journal of Advanced Research, 2017). This suggests that while other pollution sources may have temporarily abated, the chronic and highly toxic load from the region's heavy industries persisted, creating a divergent pollution trajectory and highlighting a Disparity in Management Focus (Patel et al., 2020) where the less visible water pollution was likely overlooked in favor of air quality monitoring. This divergence underscores that the Daya River's pollution is not merely a product of human activity in general, but is intrinsically tied to continuously operating, heavy industrial sources. (Table 2)

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The analysis further exposes the Systemic Nature of Environmental Injustice (Das, Sukanya, et al. (2025)) at play in the Daya River basin. The pollution, largely generated by the sprawling urban center of Bhubaneswar (with a population of over 1.1 million and a daily wastewater generation of 10 lakh liters), is exported downstream to vulnerable, often rural, communities (Das, Sukanya, et al. (2025)). This dynamic, where the environmental costs of urban growth are borne by those who benefit least from it, manifests in tragic and severe human health crises. As of February 2025, river protection activists have demanded action in the wake of six suspected diarrhea deaths in the Kanas area of Puri district, directly attributed to the consumption of contaminated river water (Central Pollution Control Board (2024)). The documented reports of skin diseases and suspected cancer cases in 115 villages along the river's lower reaches serve as a stark reminder of this profound social and environmental inequity (Das, Sukanya, et al. (2025)). The pollution itself can be characterized by a Chronic-Persistent Pollution Model (International Journal of Advanced Research, 2017; ResearchGate, 2025), where the river's natural assimilative capacity is overwhelmed year-round. Data consistently shows that while water quality may temporarily improve during the monsoon season due to a flushing and dilution effect, it significantly deteriorates during drier, non-monsoon periods when river flow is low (International Journal of Advanced Research, 2017).[2] This pattern indicates that the pollutant load from sources like untreated sewage and industrial effluents is continuous. This is further supported by the seasonal variation in microplastic concentration, which is higher in sediments during winter and summer than in the rainy season (fig 7)("Characterization and Quantification of Microplastics...", 2025). This means that relying on natural processes for river clean-up is a futile strategy and that a long-term solution requires a continuous, robust treatment of waste. A key component of this chronic pollution is the Feedback Loop of Degradation (Joshi, S., and S. K. Mishra. (2017)), where a high organic load from untreated sewage leads to a high Biochemical Oxygen Demand (BOD), which in turn depletes the river's Dissolved Oxygen (DO) levels. (fig 8) As observed in a 2025 OSPCB report, BOD levels reached up to 75 mg/L, far exceeding the safe limit of 5 mg/L, while DO levels have been observed to fall as low as 2.9 mg/L, well below the minimum 4.0 mg/L required for aquatic life (Mishra, 2025; Science and Education Publishing, 2025). This vicious cycle impairs the river's self-purification capacity, leading to a state of profound ecological degradation.

A central point of failure lies in the Regulatory Laxity Trap (Central Pollution Control Board (2024)). A critical gap exists between environmental regulations and the river's ecological needs. The OSPCB sets an effluent discharge standard for BOD at a maximum of 30 mg/L (Odisha State Pollution Control Board, 2025).[3] However, this standard is fundamentally misaligned with the health of the river, which requires a safe BOD of less than 5 mg/L (Central Pollution Control Board (2024)). This creates a situation where even full compliance with the legal standard would still result in a cumulatively unhealthy river, as multiple discharges would elevate the ambient BOD levels far above the threshold required for a healthy aquatic ecosystem. This regulatory flaw is further compounded by a pervasive Bureaucratic Implementation Failure (Central Pollution Control Board (2024); NGT, 2024; Central Pollution Control Board (2024)). Despite an estimated wastewater generation of 880 MLD in Odisha's urban areas, the operational treatment capacity is only around 344 MLD, leaving a deficit of approximately 535 MLD of untreated sewage (PRS India, 2024). (Supplementary Table 12) The National Green Tribunal (NGT) has repeatedly intervened, directing a task force to ensure the completion of all planned STPs in Bhubaneswar by November 2023 (Central Pollution Control Board (2024)). However, activist demands for an inquiry into these project delays as recently as February 2025 demonstrate that these directives have not been effectively implemented (Central Pollution Control Board (2024)).

The problem is epitomized by the Gangua Nullah as a "Pollution Pipeline" (Das, Sukanya, et al. (2025)). This natural channel, once the Gandhabati River, has been functionally transformed into a conduit for Bhubaneswar's entire urban liquid waste load, dumping it directly into the Daya River downstream (Das, Sukanya, et al. (2025)). This concentrated point source of pollution makes it directly responsible for transforming the Daya into a highly contaminated zone. Data from 2016 shows coliform bacteria levels at the confluence point were as high as 74,908 per 100 ml, far exceeding the permissible limit of 500 MPN/100 ml (Dash, A.K. (2017)). More recent 2025 data shows coliform levels exceeding 160,000 MPN/ml at several locations (Mishra, 2025).

A new and complex threat to public health is the "Super-Pollutant" Nexus of Heavy Metals and Antimicrobial Resistance (Joshi and Mishra, 2017). Studies have documented the co-contamination of the river with heavy metals (like Arsenic, Cadmium, Chromium, and Lead) and antibiotic-resistant bacteria (like Carbapenem-Resistant Klebsiella pneumoniae, or CRKP), with 90.1% of CRKP isolates being multidrug resistant (Joshi and Mishra, 2017).[4] (Supplementary Table 11) This creates a synergistic threat, as heavy metals can exert selective pressure, promoting the co-selection of antibiotic resistance genes within bacterial populations (Joshi and Mishra, 2017).[5] Individuals exposed to the river's water are thus at risk from both toxic metals and infections that are increasingly difficult to treat (fig 9).

Finally, while the failure of large-scale infrastructure is a major problem, pollution is also driven by diffuse sources, demonstrating an Infrastructure-Behavioral Lag (Das, Sukanya, et al. (2025); World Economic Forum, 2025). The persistent contribution of pollution from agricultural runoff, indiscriminate solid waste dumping, and traditional practices like religious idol immersion, which introduces lead into the water, means that addressing the river's pollution is not solely an engineering problem (International Journal of Development Research, 2014). It requires a profound socio-cultural shift through public awareness and the provision of accessible

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waste management alternatives. This is crucial to prevent the river from being used as a personal dump site, which would undermine even the most robust infrastructure solutions. The final cascading impact is the Erosion of Conservation Gains (ILEC, 2006). Chilika Lake, into which the Daya flows, has been the focus of a widely celebrated conservation success, including its removal from the Montreux Record in 2002 after a strategic intervention in 2000 restored its health (ILEC, 2006).[6] However, the continuous influx of pollutants from the Daya, depositing 1.6 million metric tons of sediment annually, acts as a direct counterforce to these gains. It creates a perpetual and costly struggle for the Chilika Development Authority (ILEC, 2006), highlighting the urgent need to address the Daya River's pollution to protect the long-term ecological integrity of Chilika Lake.

Conclusion

The Daya River is a microcosm of the complex environmental challenges facing India's rapidly urbanizing regions. The analysis of its pollution dynamics from 2000 to 2025 reveals a decades-long decline that has accelerated in recent years. The paradox of its pollution trajectory during the COVID-19 lockdown, the chronic-persistent nature of its pollution, and the widening gap between regulatory intent and on-the-ground implementation underscore a profound systemic failure.

The river's degradation is not just an ecological issue; it is a critical public health and socio-economic crisis, inflicting severe burdens on vulnerable downstream communities. Without immediate, comprehensive, and integrated action, the Daya River risks becoming a functionally dead waterway, and its pollution will continue to erode the hard-won conservation gains of the ecologically vital Chilika Lake. Reversing this trend requires a multi-faceted approach that addresses not only the engineering and regulatory gaps but also the critical issues of public behavior, governmental accountability, and environmental justice.

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