Spatial Water Quality Profiling and Ecological Management Framework for the Vishwamitri River in Vadodara, India

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Abstract

Growing human populations, concurrent urban development, and industrialization exert unprecedented environmental pressure on seasonal riverine ecosystems, deteriorating their natural serenity and ecological integrity. The Vishwamitri River, flowing through the urban landscape of Vadodara, Gujarat, suffers from an acute scarcity of natural freshwater flow and severe pollutant loading. This river acts as a critical, unique habitat for a breeding population of threatened mugger crocodiles (Crocodylus palustris). This study utilizes a comprehensive spatial water quality baseline profile established across five strategic monitoring stations along a 13 km urban stretch, ranging from upstream rural areas to heavily impacted downstream nodes. Laboratory analysis of the baseline spatial degradation revealed that while the upstream control remains relatively clean, midstream and downstream urban locations exhibit Dissolved Oxygen (DO) levels below detectable limits, Biological Oxygen Demand (BOD) peaks of 26.81 mg/L, and Ammonical Nitrogen spikes reaching 126.28 mg/L. Positioned against the city's environmental and infrastructural realities in 2026, this paper provides a quantitative assessment of these pollution dynamics and proposes an updated ecological management framework that integrates recent municipal infrastructure modifications with local conservation initiatives.

Keywords: Ammonical Nitrogen, Biological Oxygen Demand, Ecological Restoration, Sewage Treatment, Spatial Profiling, Vishwamitri River.

INTRODUCTION

Water is the fundamental source of energy, ecological sustainability, and human civilization. However, rapid global urbanization and industrial expansion have turned natural river systems into recipients of massive pollutant discharges. In developing nations like India, seasonal rivers traversing municipal corridors face severe ecosystem degradation due to the lack of dedicated environmental flows and inadequate wastewater treatment infrastructure. The Vishwamitri River, an important west-flowing seasonal river originating from the Pavagadh Hills in Gujarat, serves as a prime example of this ecological crisis.

As the river runs through the heart of Vadodara city, it transitions from a clean natural stream into a heavily contaminated urban channel. Despite its highly polluted state, the Vishwamitri River supports an endemic population of vulnerable mugger crocodiles (Crocodylus palustris), making its restoration not only a public health necessity but also a critical wildlife conservation priority. The Central Pollution Control Board (CPCB) historically classified the Vishwamitri River among the 351 most polluted river stretches in India.

Looking at the river system from the perspective of 2026, rapid urban expansion into peripheral zones has further complicated the watershed's hydrology. The primary objective of this research is to evaluate the spatial water quality dynamics along the urban corridor of Vadodara using a definitive seasonal baseline profile. By assessing physical and chemical parameters across five distinct sampling stations, this study identifies the primary point and non-point sources of pollution. Furthermore, it outlines an integrated environmental management framework updated for 2026, combining recent structural engineering interventions with eco-centric conservation strategies to restore the river's historical baseline quality.

MATERIALS AND METHODS

The study area focuses on a 13-kilometer urban segment of the Vishwamitri River that cuts directly through Vadodara, dividing the metropolis into northern and southern halves. Under natural historical conditions, the river maintained a seasonal flow regime, swelling during the monsoon and receding into interconnected pools during the dry season. Today, the non-monsoon baseflow of the river consists almost entirely of municipal and industrial effluents.

To quantitatively capture the spatial degradation of the river, water samples were gathered across five strategic monitoring nodes. The selection of these stations was designed to track the river's water quality as it transitions from a rural baseline environment into the high-density urban core, and finally out into the downstream rural-urban fringe.

• Station 1 (S-1) - Pilol Village Bridge: Situated 16 kilometers upstream from the municipal borders of Vadodara, this station serves as the baseline environmental control. Field observations noted clear, transparent water entirely devoid of anthropogenic odor.

• Station 2 (S-2) - Sama Savli Bridge: This node marks the official entry point of the Vishwamitri River into the urban limits of Vadodara. The water exhibits a transitional phase, turning slightly yellowish with initial evidence of shoreline plastic pollution.

• Station 3 (S-3) - Kala Ghoda Bridge: Located within the geographic center of the city, this station represents a highly urbanized zone. Field observations recorded significant water turbidity and persistent foul odors.

• Station 4 (S-4) - Vadsar Bridge: Positioned downstream within the dense municipal boundary, this station experiences heavy wastewater loading from multiple major city nallahs. The water appeared highly turbid and dark, with thick accumulations of floating garbage and domestic residues.

• Station 5 (S-5) - Khalipur Bridge: Located 15 kilometers downstream from the city center, this station captures the cumulative pollution load of Vadodara. At this junction, the Vishwamitri confluences with the Jambuva River, which introduces its own substantial load of untreated regional sewage.

Water sampling, preservation, and laboratory testing were performed according to standard protocols established by the Bureau of Indian Standards (BIS) and the American Public Health Association (APHA). The physical and chemical parameters analyzed included pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Ammonical Nitrogen (NH4-N).

RESULTS

The quantitative results of the laboratory analysis across the five designated sampling locations are presented in Table I.

The pH values ranged from 7.72 at S-1 to 7.90 at S-5. Total Dissolved Solids (TDS) increased progressively across the spatial gradient, beginning at 342.15 mg/L upstream (S-1) and peaking at 688.37 mg/L downstream (S-5). Dissolved Oxygen (DO) concentration showed a severe declining trend, dropping from 4.20 mg/L at S-1 to 0.40 mg/L at S-3, and falling entirely Below Detectable Limits (BDL) at both S-4 and S-5.

Organic loading markers escalated significantly across the urban corridor. Biological Oxygen Demand (BOD) values rose from a baseline of 2.10 mg/L (S-1) to a maximum concentration of 26.81 mg/L at S-4, before decreasing slightly to 24.50 mg/L at S-5. Similarly, Chemical Oxygen Demand (COD) measurements spiked from 12.30 mg/L (S-1) to its highest peak of 93.10 mg/L at S-4, followed by 88.65 mg/L at S-5. Ammonical Nitrogen levels expanded continuously from 17.36 mg/L upstream (S-1) to 124.88 mg/L (S-4) and reached a maximum level of 126.28 mg/L at the downstream confluence point (S-5).

Table I: Spatial Water Quality Variations Along the Vishwamitri River

Parameter	**S-1 (Pilol)**	**S-2 (Sama)**	**S-3 (Kala Ghoda)**	**S-4 (Vadsar)**	**S-5 (Khalipur)**
pH	7.72	7.85	7.81	7.88	7.90
TDS (mg/L)	342.15	412.50	520.80	615.45	688.37
DO (mg/L)	4.20	1.80	0.40	BDL	BDL
BOD (mg/L)	2.10	6.45	14.20	26.81	24.50
COD (mg/L)	12.30	28.10	54.30	93.10	88.65
Ammonical Nitrogen (mg/L)	17.36	32.15	74.50	124.88	126.28

(Note: BDL = Below Detectable Limits. All concentrations are expressed in mg/L except for pH)

DISCUSSION

The spatial profiling data clearly indicates that the Vishwamitri River undergoes severe ecological and chemical degradation as it moves through the municipal boundaries of Vadodara. The relative stability of the pH values between 7.72 and 7.90 reflects a robust ambient buffering capacity within the river basin's geological matrix. However, all other parameters reveal heavy anthropogenic contamination.

The steady rise in TDS (reaching 688.37 mg/L at S-5) is a direct consequence of the input of dissolved organic and inorganic ions from domestic greywater, urban storm runoff, and local industrial activities. The most alarming trend is the complete depletion of Dissolved Oxygen at Stations 4 and 5. This occurrence creates critical anaerobic conditions in the downstream segments. According to regulatory criteria set by the CPCB, a healthy surface water body supporting aquatic life must maintain a minimum DO level of 4.0 mg/L. The drop to BDL values signifies an existential threat to higher aquatic organisms, including the resident population of vulnerable mugger crocodiles (Crocodylus palustris).

This anaerobic environment is driven by the massive organic load entering the river. The baseline spike in BOD to 26.81 mg/L at Station 4 (Vadsar Bridge) vastly exceeds the CPCB upper threshold for safe surface waters, which is set at 3.0 to 6.0 mg/L. Historically, the city generated approximately 215 Million Liters per Day (MLD) of domestic sewage against a treatment capacity of 180 MLD. As of 2026, urban growth has pushed wastewater generation even higher. While the Vadodara Municipal Corporation (VMC) has commissioned new sewage treatment capacities over the last few years to bridge the historical 35 MLD deficit, field observations indicate that non-point source leaks, storm-water drain contamination, and illegal industrial bypasses still actively contribute to the river's high organic load.

Furthermore, the exponential increase in Ammonical Nitrogen—surging from 17.36 mg/L upstream to a baseline peak of 126.28 mg/L downstream at S-5—serves as a clear chemical tracer for raw, unmitigated domestic excreta and sewage injection. This finding confirms that during the dry season, the river functions effectively as an open municipal sewer line. This loading is further intensified at Station 5, where the Vishwamitri confluences with the Jambuva River, a tributary that carries its own heavy load of untreated regional wastewater.

Evaluating these dynamics in 2026 underscores that purely structural wastewater additions are insufficient without strict enforcement. To reverse this degradation, the environmental management plan must enforce the complete separation of the city's storm-water drainage network from the municipal sanitary sewer system to prevent overflow discharges into natural nallahs during heavy monsoonal events. Concurrently, existing Sewage Treatment Plants (STPs) must be continuously audited to ensure their advanced secondary and tertiary treatment capabilities—such as Moving Bed Biofilm Reactors (MBBR)—are operating at peak efficiency to target nitrogenous compounds before effluent release.

These structural interventions must be combined with nature-based solutions promoted by local civic bodies and environmental management teams. Establishing native riparian vegetation zones along the banks creates natural biofilters that absorb excess nutrients and trap sediments from agricultural and urban runoff. Additionally, preserving natural mudbanks is critical for maintaining the nesting, basking, and breeding habitats of the river's unique crocodile population. While the VMC has progressed its Riverfront Development Project up to 2026, it must maintain a strictly eco-centric approach. Hard concrete channelization must be minimized to preserve the river's self-purification capacity, avoid hydraulic fragmentation, and safeguard its sensitive native biodiversity.

CONCLUSION

The spatial water quality analysis of the Vishwamitri River demonstrates a severe environmental gradient as the river bifurcates the urban core of Vadodara. The study successfully establishes that while the upstream rural corridor retains baseline ecological health with functional dissolved oxygen and minimal organic variables, the municipal limits impose catastrophic pollutant pressures. The absolute depletion of dissolved oxygen to below detectable limits, paired with a maximum biological oxygen demand of 26.81 mg/L and a critical ammonical nitrogen spike of 126.28 mg/L downstream, directly quantifies the systemic failure of localized wastewater containment. The principal contributions of this research reveal that the non-monsoon volumetric baseflow of the river is completely dominated by untreated municipal fractions, converting a critical breeding habitat of vulnerable mugger crocodiles (Crocodylus palustris) into an open sewer channel. These empirical findings indicate that immediate hydraulic network separation, targeted expansion of tertiary sewage treatment grids, and nature-based vegetative bioshields are mandatory interventions to mitigate toxic loading and preserve the unique endemic biodiversity of the river basin.

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