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Root Cause Analysis of Untreated Sewage Discharge in the Gomti River, Lucknow

Ajita Singh[1], Dr. Pawan Kumar Singh[2]

[1]Master's of Arts, National Post Graduate College (Autonomous) (Affiliated to the University of Lucknow) Hazratganj, Lucknow, uttar Pradesh 226001,India
[2]Head department of Geography, National Post Graduate College (Autonomous) (Affiliated to the University of Lucknow) Hazratganj, Lucknow, uttar Pradesh 226001,India

ABSTRACT:
The Gomti River, a perennial and monsoon-fed tributary of the Ganga, serves as an important ecological foundation and a primary water source for major urban centers in Uttar Pradesh, including Lucknow, Sitapur, Sultanpur, and Jaunpur. However, in recent decades, rapid urbanization and industrial growth have led to significant ecological degradation of the river. This study conducts a systematic **Root Cause Analysis (RCA)** to examine the continuous discharge of untreated sewage into the river basin, with a particular focus on the urban stretch of Lucknow. Using analytical frameworks such as the **Ishikawa (Fishbone) Diagram** and the **5 Whys methodology,** the study identifies key contributing factors, including gaps in infrastructure, shortcomings in policy implementation, increasing population pressure, and seasonal hydrological variations. Water quality assessments within the urban region reveal critically low Dissolved Oxygen (DO) levels, often falling below 1.0 mg/L, along with high Biochemical Oxygen Demand (BOD) and extremely elevated fecal coliform counts exceeding 100,000 MPN per 100 mL. The paper further reviews existing government initiatives, such as the **Gomti Rejuvenation Mission** and **Namami Gange Phase-2** infrastructure developments, while also proposing long-term strategic solutions to address these challenges.

Keywords: Gomti River , Sewage Dischagre ,STP, sustainable restoration, urban wastewater.

Introduction

Background of the Study

Rivers are fundamental to supporting human populations and ecosystems, serving as critical sources of water for drinking, agriculture, industry, and biodiversity (Wohl, 2004). The Gomti River originates from the alluvial plains at Gomat Taal (historically Fulhaar Jheel) near Madho Tanda in the Pilibhit district of Uttar Pradesh. It traverses approximately 940 to 960 kilometers through rich agricultural flatlands before merging with the Ganga River at Kaithi in the Ghazipur district. As a major tributary of the Ganga River, the Gomti River holds significant ecological and socio-economic importance, particularly for the urban population of Lucknow.However, rapid urbanization, increasing wastewater generation, and unsustainable sewage discharge have resulted in significant deterioration of the Gomti River's water quality, creating risks for both environmental sustainability and human health (Singh et al., 2005). Recent studies indicate that socio-economic factors such as population growth, urbanisation, and sewage treatment systems play a major role in influencing water quality compared to climatic

factors (Akhtar et al., 2021). The river is subjected to increasing pressure from untreated sewage, industrial effluents, and agricultural runoff, which become more severe during low-flow conditions due to reduced dilution capacity and declining natural self-purification processes.Water Quality Index (WQI) has been widely used to assess river health and pollution status in different geographical regions, including studies on the Yamuna River in India, the Huangpu River in China, and several rivers across Europe and the Middle East (Jin et al., 2022). In the case of Lucknow, rapid urban expansion has intensified pressure on the Gomti River due to increasing wastewater generation. According to available reports, the city generates nearly 675 million litres per day (MLD) of sewage, of which only about 396 MLD is treated, while the remaining volume is discharged into the river through multiple drains (NDTV, 2019).Despite the implementation of large-scale river conservation programmes such as the Namami Gange Mission, continuous discharge of untreated or partially treated sewage indicates significant infrastructural and operational challenges. Recent reports reveal that several major drains continue to discharge untreated waste directly into the Gomti River, affecting the effectiveness of ongoing river-cleaning initiatives (The Times of India, 2025a). Furthermore, assessments by the Uttar Pradesh Pollution Control Board reveal that water quality deteriorates significantly downstream of urban stretches due to continuous sewage inflow, reflected through low dissolved oxygen levels and high biochemical oxygen demand (Uttar Pradesh Pollution Control Board, 2025). Although new sewage treatment plants (STPs) are being proposed and developed to enhance treatment capacity, limitations related to sewerage connectivity and inefficiencies in existing systems continue to restrict effective pollution control (The Times of India, 2025b).

Conceptual Framework of Untreated Sewage Discharge in the Gomti River

The concept of untreated sewage discharge in the Gomti River is based on the understanding that river pollution is not caused by a single factor but results from the interaction of multiple environmental, infrastructural, and institutional factors. In urban areas like Lucknow, untreated sewage enters the river system due to increasing wastewater generation, insufficient treatment capacity, inadequate sewer connectivity, and operational limitations of sewage treatment plants.The study conceptualizes untreated sewage discharge as a result of interconnected factors including urban growth, domestic wastewater generation, industrial and municipal waste management practices, infrastructure gaps, and governance-related challenges. These factors collectively contribute to increased pollutant loads in the river, affecting important water quality indicators such as dissolved oxygen (DO), biochemical oxygen demand (BOD), and microbial contamination.Therefore, this study focuses on identifying the underlying causes responsible for the continuous discharge of untreated sewage into the Gomti River rather than only examining the pollution status. A root cause analysis approach is adopted to understand the relationship between sewage management failures and river degradation.

Research Problem

Although several river restoration programmes and sewage management initiatives have been implemented, untreated sewage discharge into the Gomti River continues to remain a major environmental challenge. The persistence of sewage inflow indicates a gap between wastewater generation, treatment capacity, infrastructure availability, and effective management practices. The major research problem addressed in this study is to identify and analyze the root causes responsible for the continuous discharge of untreated sewage into the Gomti River, with particular emphasis on

infrastructural limitations, operational inefficiencies, governance challenges, and localized pollution sources.

Objectives of the Research

1. To identify the major factors responsible for untreated sewage discharge into the Gomti River.
2. To analyze the infrastructural, operational, and institutional causes contributing to sewage management failure.
3. To examine the existing gaps and challenges in sewage collection, treatment, and disposal systems responsible for continuous sewage inflow into the Gomti River.
4. To investigate the role of urban growth, inadequate sewer connectivity, and management inefficiencies in increasing untreated sewage discharge.
5. To provide insights for improving sustainable sewage management and river restoration strategies.

Significance of the Research

The present study is significant as it focuses on the underlying causes of persistent sewage pollution rather than only assessing the existing level of river contamination. Understanding these causes is essential for developing effective strategies for urban wastewater management and sustainable river restoration.The findings of this research can support policymakers, urban planners, and environmental management agencies in identifying gaps within existing sewage management systems. Furthermore, the study contributes to the broader understanding of urban river degradation by highlighting the relationship between urbanization, infrastructure efficiency, governance mechanisms, and environmental sustainability in rapidly growing cities.

Literature Review

Several studies have examined the impact of urbanization, wastewater discharge, and human activities on river ecosystems. Wohl (2004) highlighted the ecological importance of rivers and their role in sustaining human populations and biodiversity. However, increasing anthropogenic pressure has significantly altered river systems by affecting their natural quality and ecological functions.Singh et al. (2005) investigated the degradation of the Gomti River and reported that rapid urbanization and increasing pollution loads have negatively affected river water quality. The study emphasized the influence of untreated wastewater discharge and human activities as major contributors to river degradation. Akhtar et al. (2021) examined the factors influencing river water quality and found that socio-economic factors, including population growth, urbanization, and sewage treatment practices, play a significant role in determining water quality conditions. Their findings suggest that effective wastewater management is essential for maintaining river health.Jin et al. (2022) discussed the application of Water Quality Index (WQI) for evaluating river health and highlighted its usefulness in assessing pollution levels across different river systems. However, such approaches mainly focus on measuring pollution status rather than identifying the underlying causes responsible for continuous pollution. Previous studies and reports on the Gomti River have mainly focused on water quality assessment, pollution levels, and the impacts of untreated sewage discharge. Reports indicate that increasing sewage generation, inadequate treatment capacity, poor sewer connectivity, and operational inefficiencies of sewage treatment plants remain major challenges in controlling river pollution (NDTV, 2019; The Times of India, 2025a; The Times of India, 2025b).Although existing studies provide

significant information regarding the pollution status of the Gomti River, limited attention has been given to understanding the root causes behind the persistence of untreated sewage discharge. Therefore, the present study attempts to address this research gap by applying a root cause analysis approach to identify infrastructural, operational, and institutional factors responsible for continuous sewage inflow into the Gomti River.

Research Gap in literature Review

Previous studies on the Gomti River have primarily focused on assessing water quality status, identifying pollution levels, and examining the impact of urban activities on river degradation. However, limited research has been conducted to understand the underlying causes responsible for the continuous discharge of untreated sewage into the river.Existing studies have mainly analyzed the consequences of sewage pollution, whereas the interrelationship between infrastructural limitations, sewage treatment capacity, sewer connectivity gaps, operational inefficiencies, and institutional challenges has received comparatively less attention. Furthermore, there is a lack of systematic root cause analysis approaches that identify why untreated sewage discharge continues despite the implementation of sewage management programmes and river restoration initiatives.Therefore, this study attempts to address this gap by applying a root cause analysis framework to identify the major factors responsible for untreated sewage discharge into the Gomti River, Lucknow, with emphasis on infrastructural, operational, and governance-related challenges.

Study Area

The study is concentrated on selected urban stretches of the Gomti River in Lucknow, Uttar Pradesh, with particular focus on areas experiencing visible environmental stress. Primary observational zones include the Hussainabad riverfront region and the vicinity of Kukrail Nala, a major drainage channel discharging into the Gomti River. Gau Ghat (Upstream),Daliganj bridge, Gomti barrage. These locations were selected due to their high exposure to untreated domestic wastewater and urban runoff. Preliminary field visits to these sites indicated noticeable signs of ecological degradation, including reduced river width, strong odor indicative of organic pollution, and visible stagnation in certain stretches. These characteristics suggest significant localized pollution loading and inefficient wastewater management. Given the limited number of field visits, these observations are used qualitatively to support secondary data analysis rather than as standalone empirical evidence.

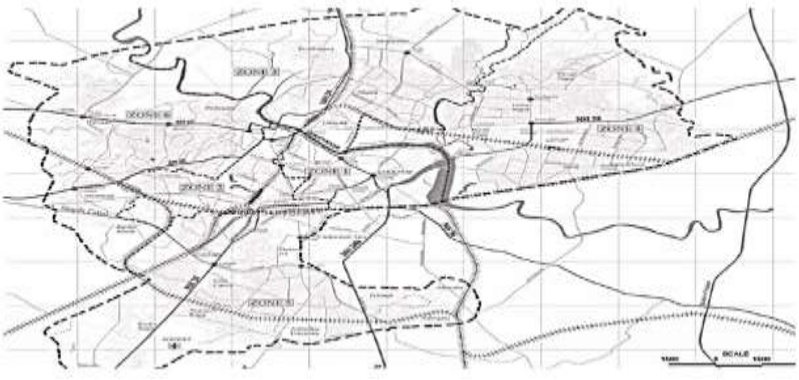


Figure:1 Different Districts of Wastewater Treatment in Lucknow

(source: http://jklmc.gov.in/map.aspx)

Methodology

Research Design

This study adopts a **descriptive and analytical research design** to investigate the causes and impacts of untreated sewage discharge into the Gomti River, particularly within the urban stretch of Lucknow. The approach focuses on combining empirical data analysis with structured diagnostic tools to develop a comprehensive understanding of river pollution dynamics.

Data Sources

The present study is based on both secondary data and field observations. Secondary data were collected from various reliable sources, including government reports, official documents, research articles, and media reports. Water quality data and pollution-related information were obtained from the Uttar Pradesh Pollution Control Board (UPPCB), National Mission for Clean Ganga (NMCG), and Central Pollution Control Board (CPCB) reports and guidelines. Additionally, published research articles related to Gomti River pollution, sewage discharge, and Water Quality Index (WQI) assessments were reviewed to understand existing scientific findings. Recent developments, infrastructure-related issues, and challenges associated with sewage discharge were also examined through reliable media sources such as The Times of India and NDTV.

Analytical Framework

The present study employs a structured analytical framework to identify and examine the underlying causes responsible for untreated sewage discharge into the Gomti River. The framework integrates water quality indicators, empirical data evaluation, field observations, and root cause analysis tools to understand the complex relationship between sewage management systems and river pollution.

Water Quality Parameters

The study considers key water quality indicators, including Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Fecal Coliform. These parameters are widely used to evaluate organic pollution, oxygen depletion, and microbial contamination in river ecosystems. The analysis of these indicators helps in understanding the impact of untreated sewage inflow on river water conditions**. The table 1 below outlines standard water quality readings recorded across key urban monitoring hotspots in Lucknow.**

TABLE 1 Selected physicochemical & organic-pollution parameters

Monitoring Station	DO (>=5.0 mg/L)	BOD (<=3.0 mg/L)	Fecal Coliform	Primary Drivers
Gau Ghat (Upstream)	4.8 - 5.5	3.5 - 5.0	4,500 - 8,000	Agricultural runoff; local discharge
Daliganj Bridge	1.2 - 2.0	14.0 - 22.0	65k - 90k	Overflowing urban drains; dense housing

Gomti Barrage	**< 0.5**	**32.0 - 45.0**	**> 150,00**	**Stagnant pool behind barrage gate**

Empirical Data Evaluation

Empirical analysis was conducted using spatial and temporal water quality data obtained from pollution control board records, published research studies, and municipal-level reports. This approach helped identify variations in pollution levels and understand the changing pattern of river water quality across different locations and time periods. The collected information was further analyzed to identify factors contributing to persistent sewage discharge.

Ishikawa (Fishbone) Diagram Approach

The Ishikawa (Fishbone) Diagram approach was applied to systematically categorize the major causes associated with untreated sewage discharge. The identified factors were classified into five major dimensions: infrastructure, urban planning, policy and enforcement, hydrological factors, and operational efficiency. This approach helped in understanding the interconnection between different systemic factors responsible for sewage management failures.

5 Whys Technique

The 5 Whys technique was applied to selected pollution sources, particularly major urban drainage points, to trace the underlying causes behind continuous untreated sewage discharge. Through iterative questioning, this method helped identify deeper issues related to institutional inefficiencies, governance limitations, inadequate infrastructure, and operational constraints.

Biochemical Analysis

The biochemical impact of untreated sewage discharge on the Gomti River was examined through secondary data obtained from government reports and published research studies. Untreated sewage contains high levels of biodegradable organic matter, which increases microbial activity and oxygen consumption in the river system. This process results in increased Biochemical Oxygen Demand (BOD) and reduced Dissolved Oxygen (DO), affecting aquatic life and overall river health. Continuous organic loading may also promote anaerobic conditions, leading to foul odour and further ecological degradation.

Field Observations

Field observations were conducted at selected locations along the Gomti River, particularly near major drainage points such as Kukrail Nala and other urban stretches. These observations focused on identifying direct sewage discharge pathways, sanitation gaps, and unregulated drainage systems. Field-based observations were used to validate secondary information and provide a better understanding of localized pollution sources.

Results and Discussion

Root Cause Analysis 1(RCA)

The Volumetric Mismatch: Rapid urban expansion and population growth in Lucknow have significantly increased municipal wastewater generation Available reports indicate that the city generates approximately 730–750 MLD of sewage, whereas the operational sewage treatment capacity remains around 584–605 MLD, resulting in a treatment gap of nearly 130–150 MLD. This untreated wastewater ultimately enters the Gomti River through urban drains, increasing organic pollution loads and deteriorating river water quality (Gautam et al., 2018).

The Connectivity Deficit: The presence of treatment infrastructure alone does not ensure effective pollution control. Several older urban settlements and rapidly developing peripheral areas lack complete sewer network connectivity, resulting in direct discharge of domestic wastewater into open drains connected to the Gomti River. The gap between sewage generation areas and treatment facilities remains a major infrastructural limitation.

Sewer–Stormwater Network Mismanagement and Cross-Connection Failures: Effective urban wastewater management requires separate and efficiently maintained sewerage and stormwater drainage systems. However, ageing infrastructure, inadequate maintenance, and unplanned urban expansion can lead to leakage, cross-connections, and mixing of sewage with stormwater networks. Field observations along selected Gomti River stretches, including Hussainabad and Kukrail Nala areas, indicated possible drainage inefficiencies and direct wastewater pathways contributing to river pollution. Such network failures reduce the effectiveness of sewage treatment systems by allowing untreated wastewater to bypass collection and treatment processes. Strengthening drainage segregation, infrastructure maintenance, and regular monitoring is therefore essential for sustainable river pollution control.

Root Cause 2: Operational Inefficiencies and Performance Limitations of Sewage Treatment Plants (STPs)

Treatment Reliability and Operational Challenges: Although sewage treatment capacity has increased in Lucknow, the effective functioning of STPs depends on continuous power supply, regular maintenance, skilled operation, and proper monitoring. Operational interruptions and inadequate management can reduce treatment efficiency, allowing partially treated wastewater to enter the river system.

Technology and Capacity Constraints: Some existing treatment facilities may face limitations due to ageing infrastructure, technology suitability, and increasing wastewater loads. A mismatch between available treatment technology and changing urban wastewater characteristics can affect the ability of STPs to consistently achieve required effluent standards.

Industrial and Chemical Load Interference: The entry of untreated industrial wastewater into municipal drainage networks can affect biological treatment processes by introducing toxic substances and altering wastewater characteristics. Effective industrial effluent monitoring and enforcement are therefore essential to protect STP performance.

Root Cause 3: Inadequate Sanitation Infrastructure in Informal Settlements and Urban Clusters

Unplanned Urban Growth and Informal Settlement Expansion: Rapid urban growth has resulted in the expansion of informal settlements and densely populated clusters along the Gomti River. Inadequate sewer network coverage and limited access to formal wastewater management systems increase the likelihood of untreated domestic wastewater entering open drains and eventually reaching the river. In

Lucknow, incomplete sewer connectivity has been identified as a significant challenge, with several areas remaining outside effective wastewater collection networks (Slum Free City Plan of Action, Lucknow). Field observations conducted near selected Gomti River stretches, including Hussainabad and Kukrail Nala areas, indicated visible drainage-related issues and possible untreated wastewater pathways. These localized sanitation gaps, combined with the presence of multiple urban drains, contribute to cumulative pollution pressure on the Gomti River. Root Cause 4Rapid Urbanization and Alteration of Natural Drainage Systems: The rapid expansion of Lucknow has increased pressure on existing urban infrastructure, with wastewater collection and drainage systems struggling to keep pace with changing land-use patterns. Expansion of residential areas, increasing impervious surfaces, and modification of natural drainage pathways have reduced the capacity of urban landscapes to manage runoff and wastewater effectively.The alteration of floodplain areas, wetlands, and natural drainage corridors, including parts of the Kukrail drainage catchment, may reduce natural filtration and water retention capacity. Consequently, increased surface runoff and pollutant transport during rainfall events can contribute additional stress to the Gomti River ecosystem.

Root Cause 4

Rapid Urbanization and Alteration of Natural Drainage Systems: The rapid expansion of Lucknow has increased pressure on existing urban infrastructure, with wastewater collection and drainage systems struggling to keep pace with changing land-use patterns. Expansion of residential areas, increasing impervious surfaces, and modification of natural drainage pathways have reduced the capacity of urban landscapes to manage runoff and wastewater effectively.

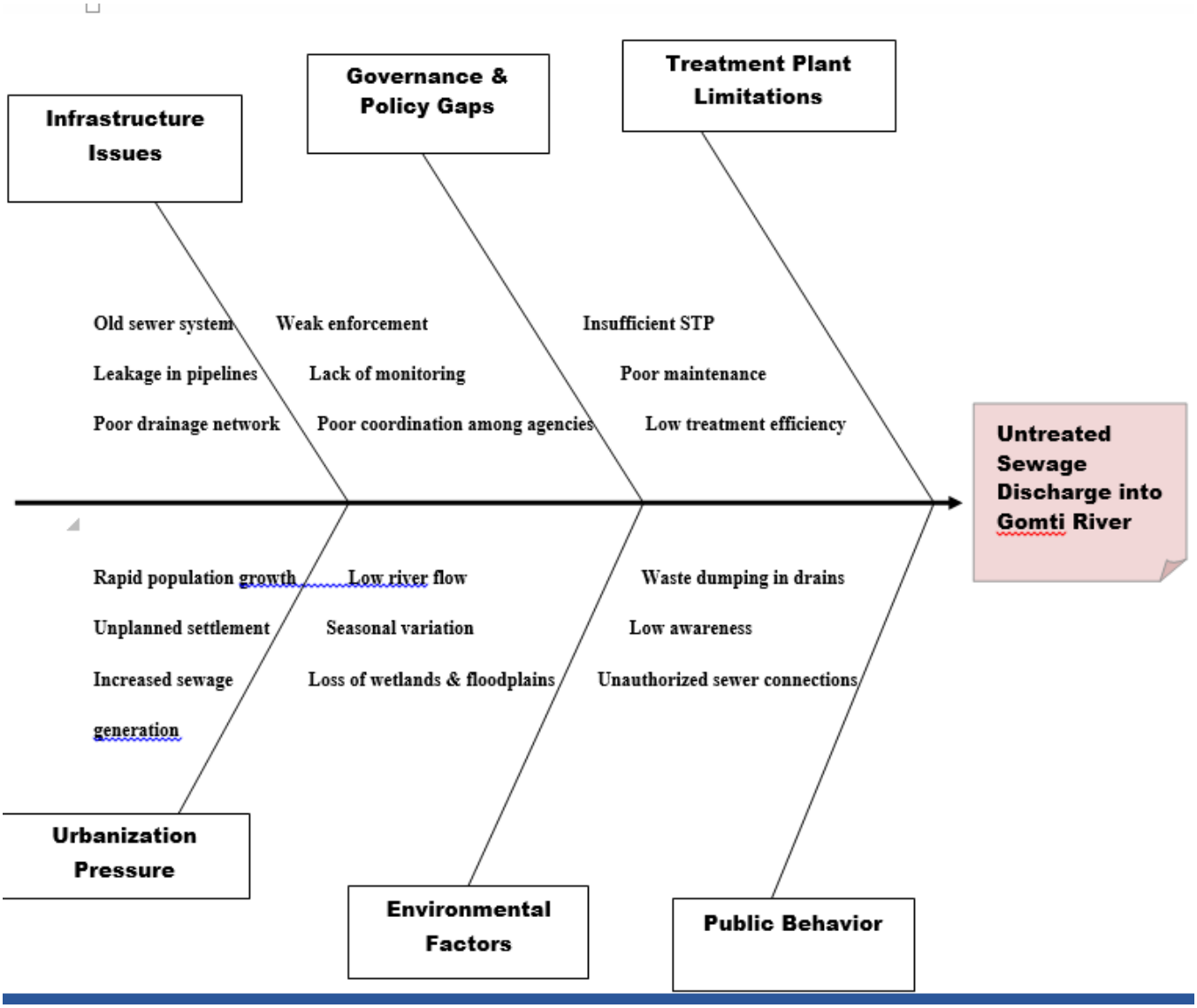
Root Cause 5

Institutional Coordination and Regulatory Implementation Gaps: The management of the Gomti River involves multiple governmental agencies, including Uttar Pradesh Jal Nigam, Lucknow Municipal Corporation, and the Uttar Pradesh Pollution Control Board. The involvement of multiple institutions creates a complex governance framework where responsibilities related to sewage infrastructure, drain management, pollution monitoring, and regulatory enforcement are distributed among different authorities. Inadequate coordination, fragmented responsibilities, and challenges in monitoring and enforcement can affect the effective implementation of wastewater management strategies.

Integrated Cause Analysis using Ishikawa Diagram

To provide a comprehensive and visual understanding of the multiple factors contributing to untreated sewage discharge, an Ishikawa (fishbone) diagram was developed. The diagram categorizes the causes into major groups such as infrastructural limitations, institutional inefficiencies, urbanization pressures, technical failures, human behavior, and environmental factors.

Figure 2: **Ishikawa (Fishbone) Diagram illustrating root causes of untreated sewage discharge into Gomti River.**



Application of the 5 Whys Analysis

The 5 Whys analytical framework was applied to systematically investigate the underlying causes of untreated sewage discharge into the Gomti River. This approach enables the identification of root causes by sequentially examining deeper causal layers beyond the immediate problem.

Why 1: Untreated sewage is discharged into the river through urban drains without any treatment.

Why 2: This occurs because interception and diversion (I&D) systems are inadequate, resulting in the failure to redirect wastewater to treatment facilities.

Why 3: The inadequacy of I&D infrastructure is due to hydraulically overloaded pumping stations and insufficient physical connectivity to Sewage Treatment Plants (STPs).

Why 4: These infrastructural limitations arise from delays in trunk sewer network expansion, as rapid urbanization and real estate development have outpaced sewerage infrastructure growth.

Why 5 This is primarily due to limitations in urban planning and inadequate prioritization of wastewater infrastructure in governance and funding decisions.

Environmental Risk and Impact Assessment of Gomti River (with Risk Index) The continuous discharge of untreated sewage into the Gomti River has resulted in significant environmental risks by altering the physical, chemical, and biological characteristics of the river ecosystem. The assessment of environmental risks was carried out using secondary water quality data and available pollution indicators, including Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Fecal Coliform levels. These indicators represent the extent of organic pollution, oxygen depletion, and microbial contamination caused by sewage inflow.The risk assessment highlights that untreated sewage discharge increases organic loading in the river, reduces oxygen availability, and negatively affects aquatic biodiversity and ecosystem stability. High microbial contamination also increases potential health risks for communities dependent on or exposed to river water. The developed risk index provides an integrated understanding of pollution severity and helps identify critical environmental concerns associated with sewage discharge in different stretches of the Gomti River.

Table:2 Environmental Risk and Impact Assessment of Gomti River (with Risk Index)

Risk Factor	Indicator	Present Impact	Future Risk	Risk Level
Organic Load (BOD/COD)	High BOD, COD	DO depletion, poor water quality	Hypoxia, fish decline	**High**
Microbial Load	Fecal coliform (MPN)	Pathogen presence	Public health hazard	**High**
Nutrient Load	NO_3^-, PO_4^{3-}	Algal blooms	Eutrophication, biodiversity loss	**High**
DO Depletion	Low DO levels	Aquatic stress	Fish mortality	**High**
Toxic Contaminants	Heavy metals/chemicals	Sub-lethal toxicity	Bioaccumulation	**Medium–High**
Hydrological Alteration	Reduced flow/self-purification	Lower dilution capacity	Ecosystem collapse risk	**Medium–High**

Current Interventions and Challenges

Gomti Rejuvenation Mission: The Gomti Rejuvenation Mission, initiated by the Government of Uttar Pradesh, provides a basin-level restoration framework for the Gomti River, covering its stretch from Pilibhit to Ghazipur. The mission aims to significantly reduce pollution loads by targeting the interception and diversion of nearly 95% of untreated urban sewage entering the river system. Despite its ambitious objectives, implementation challenges persist due to incomplete sewer connectivity, operational inefficiencies, and continued inflow from unregulated drains.

Namami Gange Phase-II Infrastructure Upgrades: Under the Namami Gange Programme (Phase-II), substantial investments have been made to enhance wastewater treatment capacity in Lucknow. The Uttar Pradesh Jal Nigam is currently developing four new Sewage Treatment Plants (STPs) with a cumulative capacity of approximately 342 MLD.This includes a major 145 MLD STP at Basant Kunj, designed to intercept wastewater from key open drains. However, the effectiveness of these upgrades remains constrained by gaps in last-mile sewer connectivity and fluctuating inflow conditions.

Strategic Interventions and Policy Recommendations

Transition towards Decentralized Sewage Treatment Systems (DSTPs): A shift from centralized

wastewater management towards decentralized systems is recommended to improve treatment efficiency and reduce transmission losses. Decentralized Sewage Treatment Plants (DSTPs), implemented at neighborhood or ward levels, can significantly reduce the burden on large-scale STP. Technologies such as Membrane Bioreactors (MBR) and Moving Bed Biofilm Reactors (MBBR) offer higher treatment efficiency, compact design, and better adaptability to variable flow conditions, making them suitable for dense urban settings.

Retrofitting with Sequencing Batch Reactor (SBR) Technology: Existing treatment facilities operating on outdated or low-efficiency technologies should be progressively upgraded to advanced systems such as Sequencing Batch Reactors (SBR),SBR technology enables enhanced removal of organic pollutants and nutrients while efficiently managing variations in daily inflow. This makes it particularly effective for urban wastewater systems experiencing fluctuating hydraulic loads.

Conclusion

The present study clearly establishes that the degradation of the Gomti River is not attributable to a singular cause, but is a systemic outcome of interlinked infrastructural, operational, and institutional deficiencies. Empirical water quality assessment across key urban stretches of Lucknow reveals critically low dissolved oxygen levels, elevated biochemical oxygen demand, and alarmingly high fecal coliform concentrations, collectively indicating severe organic and microbial contamination. These findings demonstrate that the river has, in several segments, lost its inherent self-purification capacity and is increasingly functioning as an urban wastewater conduit rather than a sustainable riverine ecosystem. The Root Cause Analysis (RCA), supported by the Ishikawa framework and 5 Whys methodology, further identifies untreated sewage discharge as the principal driver of degradation, arising from a significant mismatch between sewage generation and treatment capacity, incomplete sewer network connectivity, and inefficiencies in interception and diversion systems. Additional contributing factors include operational constraints in sewage treatment plants, unregulated discharges from informal settlements, rapid urban expansion, and institutional fragmentation, all of which collectively undermine the effectiveness of existing management frameworks. While initiatives such as the Gomti Rejuvenation Mission and Namami Gange Programme have established a critical foundation for pollution abatement, their overall impact remains limited due to persistent challenges in infrastructure integration, last-mile connectivity, and long-term operational sustainability. This study therefore underscores the urgent need for a paradigm shift in urban wastewater management—from conventional, centralized, and reactive approaches toward more integrated, decentralized, and adaptive systems. Moving forward, sustainable restoration of the Gomti River will depend on strengthening sewerage networks, enhancing treatment efficiency through advanced technological interventions, and enforcing stringent monitoring and regulatory compliance. Equally important is the adoption of circular economy principles, wherein treated wastewater is recognized and utilized as a valuable resource, thereby reducing stress on freshwater systems. In conclusion, the restoration of the Gomti River represents both an environmental imperative and a complex governance challenge; however, through a holistic, data-driven, and system-oriented approach, it is feasible to reverse current degradation trends and transform the river into a resilient, ecologically functional, and sustainable water system that supports long-term human and environmental well-being.

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