Guarding The River Ganges - Mirzapur's Comprehensive Plan for Sustainable Wastewater Management and Reuse

PLANNING THESIS PROJECT [APIDPTP100]

BACHELOR OF PLANNING

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BATCH: 2021 - 25

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This project was part of the Planning Thesis Project (APIDPTP100) and the Student Thesis Competition (STC) – Season 5, in collaboration between the National Institute of Urban Affairs (NIUA), Namami Gange, and the Amity School of Architecture and Planning, Amity University, Noida.

Declaration

I, Charu Middha, Enrollment No. A4134921003, hereby declare that the thesis titled " Guarding The River Ganges - Mirzapur's Comprehensive Plan for Sustainable Wastewater Management and Reuse " in partial fulfilment for the award of Bachelor of Planning at Amity School of Architecture & Planning, Amity University, Uttar Pradesh, India, is a record of genuine work carried out by me. This thesis and the work it presents have not been submitted to any other academic institution for credit towards another degree.

Besides the works listed and referenced, this is an honest account of all the work I did for the the even semester of Academic Year 2024-25

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B. Plan (2021 - 2025)

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Certificate

This is to certify that the declaration of **Ms. Charu Middha** with Enrollment Number **A4134921003**, a student of Undergraduate Programme in **Bachelor of Planning** (Batch **2021-2025)** at **Amity School of Architecture & Planning (Noida)** is true to the best of my knowledge and the student has worked for the even semester of Academic Year 2024-25 in preparing the **Planning Thesis Project** (APIDPTP100) on topic **"Guarding The River Ganges - Mirzapur's Comprehensive Plan for Sustainable Wastewater Management and Reuse"** under my guidance.

Ms. Charu Middha has successfully completed the Thesis work and the work done is satisfactory.

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B. Plan (2021 - 2025)

Executive Summary

The rapid pace of urbanization has intensified the demand for freshwater, placing immense pressure on urban water systems. Wastewater, often perceived as a liability, holds significant potential to be transformed into a valuable resource. This thesis focuses on Mirzapur, a city in Uttar Pradesh located along the Ganga River, which faces acute challenges in wastewater management due to inadequate infrastructure, untreated discharges, and growing industrial and domestic demands for freshwater—particularly from its renowned carpet industry.

Currently, a large portion of Mirzapur's wastewater is discharged untreated into natural water bodies, contributing to the severe pollution of the Ganga River and posing risks to both environmental and public health. The study identifies critical gaps in wastewater infrastructure and highlights the absence of effective treatment, reuse, and regulatory mechanisms.

This project aims to formulate a comprehensive wastewater management plan for Mirzapur that aligns with the principles of circular water economy. The proposed strategy emphasizes reducing freshwater consumption, enhancing wastewater treatment capacity, and promoting reuse of treated wastewater for industrial, ecological, and non-potable urban purposes. Through policy recommendations, stakeholder engagement, and an integrated urban planning approach, the study envisions a sustainable, resilient, and water-secure future for Mirzapur.

The outcomes of the research will support informed decision-making, guide future investments in infrastructure, and contribute to the broader goal of Ganga River rejuvenation, making wastewater management a central pillar of sustainable urban development in Mirzapur.

Keywords

Wastewater Management, Treated Wastewater Reuse, Circular Water Economy, Ganga River Pollution, Water Resource Recovery

सारांश

शहरीकरण की तीव्र गति ने ताजे पानी (फ्रेशवॉटर) की मांग को अत्यधिक बढ़ा दिया है, जिससे शहरी जल प्रणालियों पर भारी दबाव पड़ रहा है। अपशिष्ट जल (वेस्टवॉटर), जिसे अक्सर एक बोझ के रूप में देखा जाता है, वास्तव में एक मूल्यवान संसाधन में परिवर्तित होने की बड़ी क्षमता रखता है। यह शोध उत्तर प्रदेश के मिर्जापुर शहर पर केंद्रित है, जो गंगा नदी के किनारे स्थित है और जहां अपशिष्ट जल प्रबंधन से जुड़ी गंभीर समस्याएं हैं — जैसे अपर्याप्त बुनियादी ढांचा, अनुपचारित जल का सीधे जल स्रोतों में प्रवाह, और घरेलू व औद्योगिक (विशेष रूप से प्रसिद्ध कालीन उद्योग) क्षेत्र में ताजे जल की बढ़ती मांग।

वर्तमान में, मिर्जापुर का एक बड़ा हिस्सा अपशिष्ट जल बिना उपचार के सीधे नदियों और अन्य प्राकृतिक जल स्रोतों में प्रवाहित किया जाता है, जिससे गंगा नदी का प्रदूषण स्तर गंभीर रूप से बढ़ रहा है और पर्यावरणीय व सार्वजनिक स्वास्थ्य को खतरा उत्पन्न हो रहा है। इस अध्ययन में मिर्जापुर की अपशिष्ट जल अवसंरचना की प्रमुख खामियों को चिन्हित किया गया है और यह बताया गया है कि प्रभावी उपचार, पुनः उपयोग (रीयूज़) और नियामक तंत्र की भारी कमी है।

इस परियोजना का उद्देश्य मिर्जापुर के लिए एक समग्र अपशिष्ट जल प्रबंधन योजना तैयार करना है, जो सर्कुलर वाटर इकोनॉमी (परिपत्र जल अर्थव्यवस्था) के सिद्धांतों पर आधारित हो। यह रणनीति ताजे पानी की खपत को कम करने, अपशिष्ट जल उपचार की क्षमता को बढ़ाने, और उपचारित जल को औद्योगिक, पारिस्थितिकीय एवं गैर-पीने योग्य शहरी उपयोगों में दोबारा इस्तेमाल को बढ़ावा देने पर केंद्रित है। नीतिगत सुझावों, हितधारकों की भागीदारी, और एकीकृत शहरी नियोजन दृष्टिकोण के माध्यम से, यह अध्ययन मिर्जापुर के लिए एक टिकाऊ, लचीले और जल-सुरक्षित भविष्य की कल्पना करता है।

इस शोध के निष्कर्ष निर्णय-निर्माण को सशक्त बनाएंगे, बुनियादी ढांचे में भविष्य के निवेश का मार्गदर्शन करेंगे, और गंगा नदी के पुनर्जीवन के व्यापक लक्ष्य में योगदान देंगे — जिससे अपशिष्ट जल प्रबंधन, मिर्जापुर के सतत शहरी विकास की एक केंद्रीय आधारशिला बन सकेगा।

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1. Introduction

1.1. Background

Water is the elixir for human life, sustainable development, and ecosystem health, yet the world faces growing challenges related to water scarcity and pollution. The right to water entitles everyone to have access to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic use. Still, at least 1.8 billion people globally use drinking water sources contaminated with faecal matter.

India, like many other developing nations, faces significant challenges in managing its growing water demand. Rapid urbanisation, industrialization, and population growth have exacerbated the strain on water resources. Urban areas produce a large amount of wastewater that is either untreated or insufficiently treated, which poses serious health and water pollution hazards. The mismatch between water supply and demand, coupled with inefficient water use practices, has necessitated innovative solutions to ensure water security and environmental sustainability.

In our country, approximately 72% of the urban wastewater is left untreated and is often discharged directly into rivers, lakes, or groundwater, further worsening the situation. This gap is exacerbated by several challenges, including the scarcity of land for new treatment facilities, difficulties in mapping drainage systems, identifying leaks and illegal sewage disposal, and the lack of data on wastewater generation and collection points. Additionally, the use of a “one size fits all” approach, the unavailability of advanced technologies to reduce costs and improve treatment efficiency, public opposition to the reuse of treated wastewater, and the lack of collaborative efforts among stakeholders further complicate the issue.

Addressing these challenges requires a shift toward a circular approach in water resource management, emphasising the reuse and recycling of water to bridge the existing gap in wastewater treatment and synchronise future treatment capacity needs.

This study focuses on Mirzapur, a city located along the Ganga River in Uttar Pradesh, which faces unique challenges in wastewater management. With its population of 2.34 lakhs (census 2011) and an area of 38.85 sq km, Mirzapur is facing both wastewater treatment capacity limitations and severe pollution of the Ganga due to untreated sewage and industrial effluents. The existing STPs in the city fall short of meeting the demand, especially with the projected population increase to 5.12 lakh by 2031. There is a significant gap between the wastewater generation and the capacity of the treatment plants.

Many of the city's untapped drains, including the Khajuri Nala, directly discharge untreated wastewater into the Ganga, contributing to severe pollution of this sacred river. In addition to these challenges, Mirzapur is an industrial hub with a large number of carpet industries that heavily rely on water. This creates an opportunity for wastewater reuse, which could significantly reduce the demand for freshwater and minimise the pressure on the city's water resources. The situation is further complicated by the frequent flooding along the riverbanks, which, combined with inadequate wastewater management in these areas, aggravates the pollution problem. The discharge of untreated wastewater and industrial effluents into the Ganga compromises water quality, posing severe risks to public health, biodiversity, and the environment.

The Ganga River, one of India's holiest rivers, is heavily polluted by untreated wastewater, industrial waste, and agricultural runoff. This project aims to find sustainable wastewater management solutions for Mirzapur, reduce the gap between wastewater generation and treatment, encourage the reuse of treated water, and help reduce pollution in the Ganga.

1.2. Aim

To develop a comprehensive strategy for wastewater management, focusing on reducing river pollution and fostering a circular water strategy through reducing and reuse practices.

1.3. Objectives

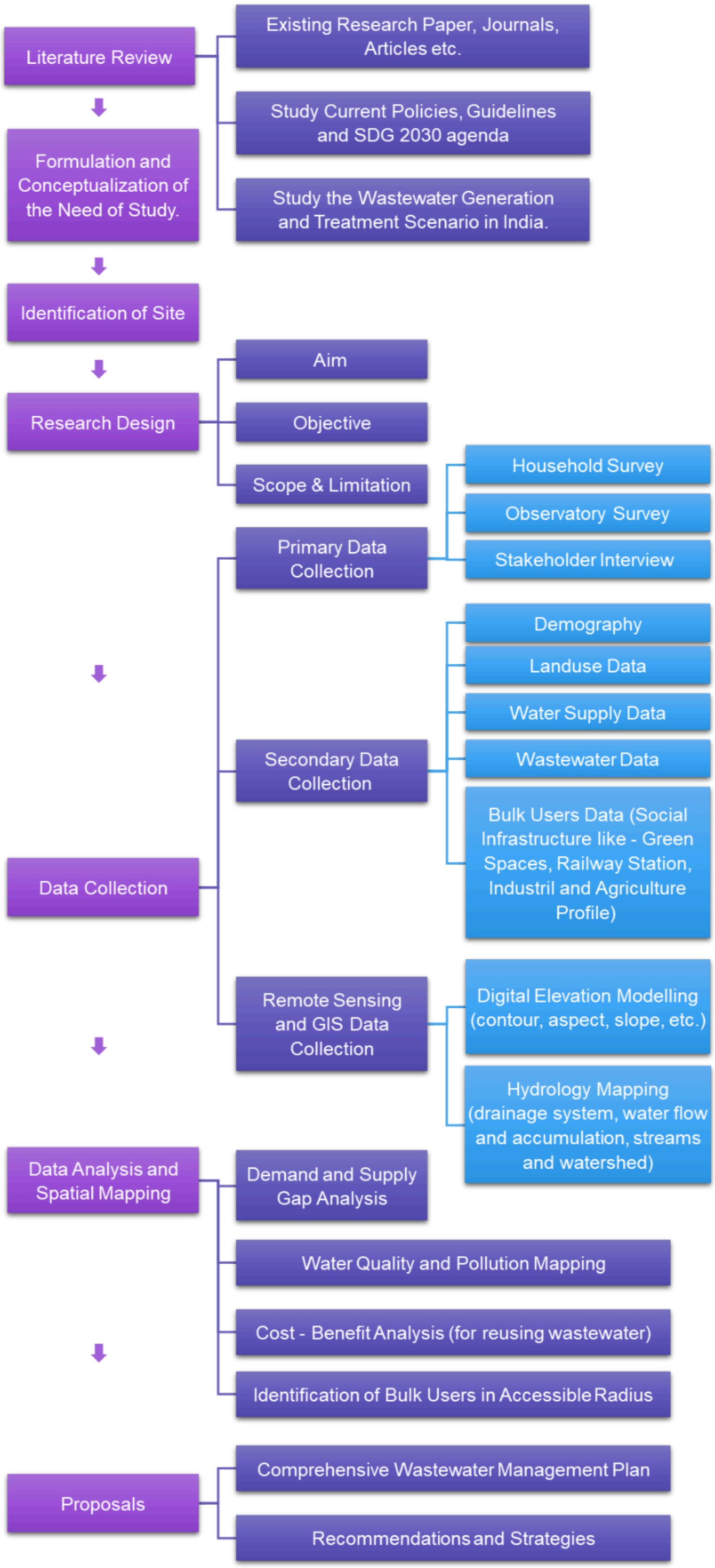
I. To review the existing scenarios, practices and policies of wastewater management, at study area level.

II. To identify the gaps in wastewater generation, collection and treatment, with a focus on challenges in infrastructure and financial aspects of wastewater management.

III. To assess the feasibility of reusing treated wastewater for ecological, industrial, agricultural, and civic uses through mapping the potential bulk user.

IV. To develop a sustainable comprehensive framework for wastewater management, fostering a circular economy.

1.4. Methodology



1.5. Scope and Limitations

1. Findings will be focused on Mirzapur, providing insights tailored to its specific challenges.
2. While the Ganga faces multiple pollution challenges, this study concentrates only on wastewater-related issues in the Mirzapur stretch.
3. The study is limited to point source pollution (domestic & industrial wastewater), while excluding non-point sources (agricultural & stormwater runoff).
4. The study focuses solely on liquid waste, excluding solid waste at all stages of the wastewater management process.

2. Literature Review

2.1. Current Trends and Scenario

Globally, approximately 60% of household wastewater is discharged into the environment without adequate treatment in countries representing 80% of the world's population (UN Habitat and WHO, 2021).

Different income groups exhibit varying wastewater management practices. High-income countries produce 42% of global wastewater, almost double that of low- and lower-middle-income nations. Conversely, low-income nations collect only 9% and treat a mere 4% of their wastewater. High-income countries lead in both wastewater collection (82%) and treatment (74%), while less than 50% of wastewater in middle-income nations is treated. The reuse of treated wastewater is more common in upper-middle and lower-middle-income countries (both at 25%) than in high-income countries (19%), whereas low-income countries only manage to reuse 8% of treated wastewater. This disparity in treatment and reuse rates underscores the need for tailored solutions to improve wastewater management practices across different income levels.

Regionally, East Asia and the Pacific produce the most wastewater, consistent with their high population share of 31%. The greatest rates of collection and treatment are found in Western Europe, while Southern Asia lags considerably behind with low rates of reuse and treatment.

According to the CPCB (2021), India generates an estimated 72,368 million liters per day (MLD) of urban wastewater, but only 28% (20,236 MLD) of this is treated, leaving 72% of the wastewater untreated and likely to be discharged into rivers, lakes, or groundwater. This issue extends beyond urban centers, with rural areas generating an additional 39,604 MLD of wastewater. The gap between wastewater generation and treatment is a critical issue that demands urgent attention. India’s water demand is projected to double the available supply in the coming decades, making wastewater management a key factor in addressing the country’s water crisis.

A deeper look into the wastewater scenario in India's cities reveals substantial gaps in treatment capacity. For instance, Class-I cities like Delhi (with populations exceeding 1 million) face a 67% shortfall in wastewater treatment capacity, while smaller Class-II towns (population between 50,000 and 100,000) experience gaps as high as 95%. Several factors contribute to these alarming shortfalls, including a lack of land for new treatment facilities, challenges in mapping drainage systems, and difficulty identifying leaks or illegal sewage disposal. Furthermore, there is insufficient data on wastewater generation and collection points, and many cities employ a “one size fits all” approach, which fails to address the specific needs of different regions.

Another critical issue is the absence of advanced, cost-effective treatment technologies that could enhance efficiency and reduce the financial burden of wastewater treatment. Public opposition to the reuse of treated wastewater also plays a role, fueled by misconceptions and inadequate awareness about the safety and benefits of water reclamation. Additionally, the lack of coordinated efforts among stakeholders—from wastewater generation to reuse—has hampered progress. These concerns were highlighted in the NITI Aayog report (2022), which underscores the urgency of developing comprehensive, localised solutions to bridge the gap between wastewater generation and treatment.

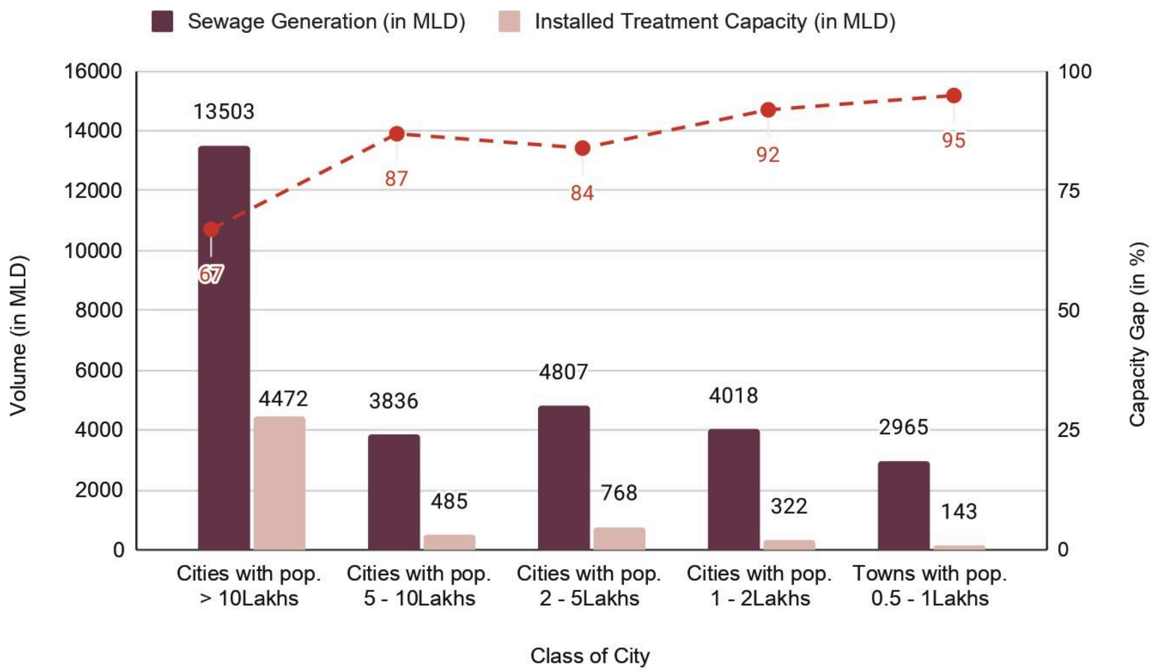


Figure 1: Wastewater generation and treatment capacity gap at city level in India (Source: CPCB, 2022)

2.2. Insights on Existing Research

2.2.1. Policy and Governance

- Many STPs in India do not meet regulatory standards, and enforcement actions are often limited, with more than half of the violations left unaddressed (CPCB, 2020).
- The shortage of staff in scientific, technical, and administrative roles ranges between 37.6% - 52.3%, making it difficult for institutions to function effectively.
- WWT can generate energy through biogas recovery and nutrient recycling, but infrastructure, policy, and cost challenges persist.
- The cost of water reuse services, social resistance, & lack of clear governance structures hinder the transition to a circular model.

2.2.2. Circular Economy

- The use of biogas from wastewater, organic manure generation, and phosphorus recovery can enhance CE but requires better policy and investment support.
- 3 Million ha of land can be fertilised annually with the sludge from treated wastewater, & reduces the need for fertilisers by 40%.
- By 2050, the freshwater abstraction by industries will be 10.1%. All these factors make a strong case for a circular economy pathway in the wastewater sector.
- A paradigm shift from “use and throw” to a “use, treat, and reuse” approach is required.

2.2.3. Wastewater Reuse

- Rainwater harvesting and recycling could supply up to 50% of domestic water demand in some regions.
- Through the utilisation of 110 major cities’ 80% untreated wastewater, the nation could meet 75% of its anticipated industrial water needs by 2030.
- Drip irrigation using treated wastewater can reduce freshwater demand by 30-40%.

- CEEW estimates suggest that by 2050, over 96,000 million litres per day of treated used water (TUW) will be available for reuse in India.

2.2.4. Wastewater Treatment

- Decentralized systems and AI-driven systems enhance efficiency and sustainability.
- Technologies like dual systems and natural treatments enhance safe reuse.
- Localized treatment can reduce costs and promote resource regeneration.
- More research is required to reduce the resource requirement associated with using advanced technologies.
- Decentralised systems are currently popular, they are detached from governance, regulatory, and political complexities.

2.3. Policies and Legal Regulation Frameworks

2.3.1. The Water (Prevention & Control of Pollution) Cess Act, 1977

It aimed to fund Central and State Pollution Control Boards by levying a cess on water consumed by industries and local bodies. It incentivized wastewater treatment by offering a 25% rebate to industries operating effluent treatment plants. The Act promoted the "polluter pays" principle and encouraged pollution control, though it faced challenges like poor compliance and monitoring. Repealed in 2017 with the introduction of GST, it played a key role in integrating fiscal tools into India's environmental governance.

2.3.2. The National Water Quality Monitoring Programme, 1978

It plays a crucial role in assessing the status of water bodies by regularly monitoring rivers, lakes, wells, and other surface and groundwater sources. It advises central and state governments on the prevention, control, and abatement of water pollution and sets water quality standards for various uses. Operated primarily by the Central Pollution Control Board (CPCB) in collaboration with State Pollution Control Boards, the program helps identify pollution trends, evaluate policy effectiveness, and guide corrective measures. Its data supports planning for clean water initiatives and ensures compliance with environmental regulations.

2.3.3. The Environment (Protection) Act, 1986

The Environment (Protection) Act, 1986 empowers the Central Government to set standards for sewage and effluent discharge, regulate industrial pollution, and enforce environmental compliance. It serves as an umbrella legislation for various environmental issues and embeds the "polluter pays" principle into Indian policy. The Act enables authorities to take preventive action, impose penalties, and promote sustainable practices across sectors.

2.3.4. The Ganga Action Plan (GAP-I in 1985 and GAP-II in 1993) and the National River Conservation Plan

They were launched to reduce pollution in the Ganga and its major tributaries like the Yamuna and Gomti. Initially focused on cleaning the Ganga, these initiatives later expanded to cover other polluted rivers across India. They aimed to improve water quality through interventions like sewage treatment, riverfront development, and public awareness.

2.3.5. The National Environment Policy, 2006

The National Environment Policy promotes the treatment, recycling, and reuse of wastewater to address water pollution, especially in urban areas. It encourages the development of city-level action plans, stricter regulations, and incentives to reduce freshwater demand and minimize environmental degradation. The policy supports sustainable water management as part of broader environmental conservation efforts.

2.3.6. The National Urban Sanitation Policy, 2008

It focuses on ensuring the sanitary and safe disposal of human waste to protect public health and the environment. It emphasizes the need for comprehensive city sanitation plans and promotes the recycling and reuse of treated wastewater. The policy aims to make cities "totally sanitized, healthy, and livable," with a special focus on inclusive sanitation services for all, including the urban poor.

2.3.7. The National Water Mission, 2008

The National Water Mission, under the National Action Plan on Climate Change, promotes the recycling and reuse of wastewater to meet the growing water demands of urban areas. It emphasizes integrated water resource management, improved water-use efficiency, and the adoption of sustainable practices to ensure long-term water security amid climate challenges.

2.3.8. The National Water Policy, 2012

It encourages sustainable water management by promoting decentralized sewage treatment, recycling, and reuse of treated water. It advocates for planned tariff systems to incentivize conservation and supports subsidized treatment of industrial effluents. The policy aims to reduce freshwater demand, protect water bodies from pollution, and promote a circular water economy.

2.3.9. The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013

It bans the employment of individuals for manual cleaning of sewers and septic tanks and mandates the elimination of insanitary latrines. It focuses on the dignity, safety, and rehabilitation of manual scavengers by providing alternative livelihoods, skill development, and financial assistance, aiming to end caste-based discrimination and ensure humane sanitation practices.

2.3.10. The Swachh Bharat Mission, 2014

It significantly reduced open defecation by promoting large-scale toilet construction across urban and rural areas. It helped minimize the flow of untreated waste into water bodies, improved overall sanitation, and encouraged the establishment of sewage treatment plants (STPs) to enhance urban wastewater management. The mission aimed to create cleaner, healthier communities through behavioral change and infrastructure development.

2.3.11. Namami Gange Program, 2015

The Namami Gange Program aims to clean and rejuvenate the Ganga River by focusing on sewage infrastructure, riverfront development, and pollution control. It sanctioned 161 projects to create or rehabilitate 5,501 MLD of sewage treatment capacity and 5,134 km of sewer network. As of now, 92 projects have been completed, delivering 1,643 MLD of STP capacity and 4,156 km of sewer lines, marking significant progress in reducing untreated wastewater discharge into the river.

2.3.12. The Atal Mission for Rejuvenation and Urban Transformation (AMRUT), 2015

It focuses on improving urban infrastructure, with a key emphasis on enhancing sewage management. It aims to expand sewer connections, increase sewage treatment plant (STP) capacity, and promote efficient sewage disposal. By strengthening these systems, AMRUT contributes to better environmental cleanliness, improved public health, and sustainable urban living.

2.3.13. The National Guidelines on Zero Liquid Discharge, 2015

It was developed by the Central Pollution Control Board (CPCB), aiming to ensure that industries treat and recycle all wastewater, resulting in zero discharge of effluents into the environment. These guidelines promote resource recovery, water reuse, and stricter compliance in highly polluting industrial sectors, contributing to sustainable industrial practices and water conservation.

2.3.14. The National Building Code, 2016

It promotes sustainable water management by emphasizing the reuse of treated sewage and sullage in multi-storeyed residential and commercial complexes. It recommends using recycled water for non-potable purposes such as toilet flushing, horticulture, and fire-fighting, thereby reducing freshwater demand and encouraging eco-friendly building practices.

2.3.15. The National Faecal Sludge and Septage Management Policy, 2017

It aims to ensure 100% access to safe sanitation by promoting integrated urban sanitation systems. It focuses on the safe collection, transport, treatment, and disposal of faecal waste, particularly in areas not connected to underground sewer networks. The policy also mandates strict environmental discharge standards to prevent pollution and protect public health.

2.3.16. The Uttar Pradesh State Septage Management Policy, 2019

It focuses on the safe collection, treatment, and disposal of wastewater from septic tanks to reduce pollution in water bodies. It aims to improve urban sewage management, especially in areas without sewer networks, by ensuring proper treatment before disposal. The policy supports decentralized treatment solutions and promotes environmental and public health protection.

2.3.17. The Uttar Pradesh State Water Policy, 2020

It emphasizes enhanced wastewater treatment, reuse, and effective septage management to curb pollution in water bodies. It focuses on developing proper sewage systems, particularly in urban areas, and encourages the recycling of treated water for non-potable uses, promoting sustainable and integrated water resource management across the state.

2.3.18. The National Framework on the Safe Reuse of Treated Water, 2021

It envisions large-scale, safe reuse of treated wastewater to address freshwater scarcity, minimize environmental pollution, and safeguard public health. It promotes the adoption of circular economy principles by encouraging the integration of treated water reuse into urban planning, agriculture, and industry, ensuring sustainability and resource efficiency.

2.4. Wastewater Management and SDGs

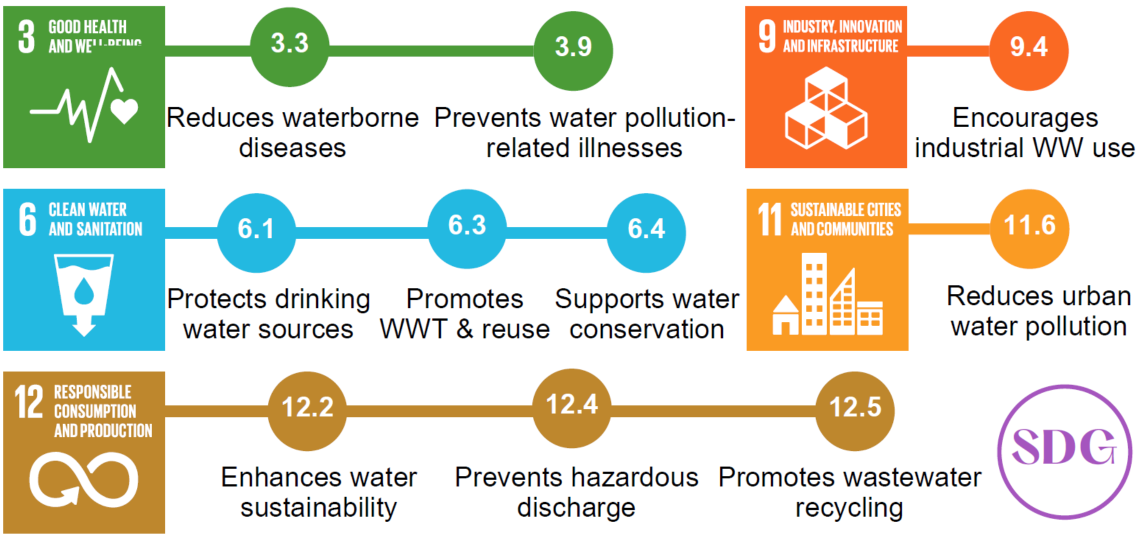


Figure 2: Wastewater & SDGs: Cleaner water, better future

Wastewater treatment and reuse play a vital role in improving **public health (SDG 3)** by reducing waterborne diseases (target 3.3) and preventing illnesses caused by polluted water (target 3.9). Ensuring safe treatment and reuse of wastewater minimizes the risks of contamination and exposure, particularly for vulnerable populations in urban and peri-urban areas.

Effective wastewater management is at the heart of **SDG 6: Clean Water and Sanitation**, particularly targets 6.1 (protecting drinking water sources), 6.3 (promoting wastewater treatment and reuse), and 6.4 (supporting water conservation). It helps safeguard freshwater supplies, especially in water-scarce regions, by reducing dependency on freshwater sources. Furthermore, it supports **SDG 12 (Responsible Consumption and Production)** by enhancing water sustainability (target 12.2), preventing hazardous discharges (target 12.4), and promoting recycling of treated wastewater (target 12.5). Additionally, reusing treated water in industrial processes (SDG 9.4) and in cities (SDG 11.6) contributes to reduced pollution and promotes circular water use in urban planning and industrial development.

In essence, wastewater management is a key enabler of sustainable development. It strengthens urban resilience, protects ecosystems, and fosters a circular economy. By integrating wastewater reuse into national and local strategies, countries can achieve multiple SDG targets simultaneously while addressing climate, water, and health challenges.

2.5. Expert's Opinion on Wastewater Management

The expert surveys were conducted, involving participants from government bodies like CPCB, SPCB, UNEP, academicians, and NGOs. It was identified as two key causes of water scarcity in urban areas: **poor water management practices** and **inefficient wastewater treatment systems**, highlighting significant challenges in implementing effective wastewater management solutions. These issues are due to **inadequate public awareness** and **policy inefficiencies**, making it difficult to implement effective wastewater management solutions. The lack of public engagement and weak regulatory frameworks further undermine progress in addressing water scarcity challenges.

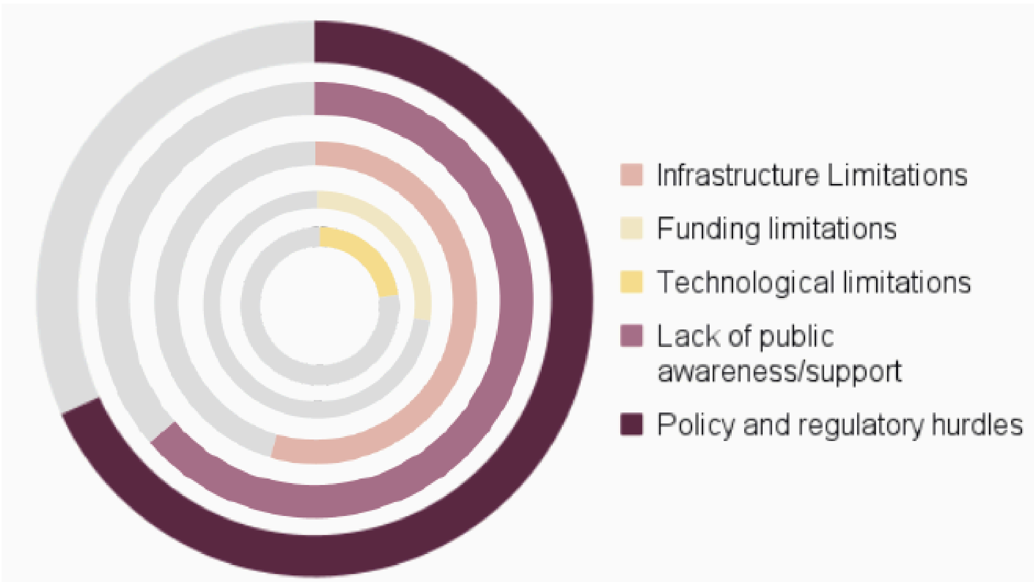


Figure 3: Issues in wastewater management in India by experts

In **tier-1 and tier-2 cities**, sewage treatment plants (STPs) are perceived as **moderately effective or neutral**, indicating some confidence in their performance. However, these systems are often insufficient to handle growing urban populations, leading to untreated wastewater being discharged into the environment. The situation is more critical in **tier-3 cities**, where a significant proportion of experts view STPs as **highly ineffective**, pointing to serious deficiencies in infrastructure, inadequate funding, and a lack of technical expertise.

Experts stress the need for a localised approach to improve wastewater treatment, particularly in smaller cities. They recommend targeted investments in infrastructure, stricter enforcement of regulations, and enhanced public awareness and participation. An integrated strategy that combines regulatory reforms, technological innovations, and community involvement is essential to bridge the wastewater management gap and ensure sustainable water resource management across urban centres.

Through surveys it was highlighted that there is a need for strict enforcement of rules and penalties for those who don't follow them, ensuring that wastewater is managed properly. They also emphasized the role of community education and awareness programs to help people understand the issue better. In addition, they stressed the importance of improving infrastructure to handle sewage collection and treatment more efficiently.

It was mentioned that public perception and decision-making around wastewater reuse need to be addressed. They recommended encouraging public participation, building skills, and raising awareness through workshops and incentives. They also suggested exploring new treatment methods, including traditional and eco-friendly techniques, to make wastewater management more sustainable.

The experts further noted the need for technological innovations and community involvement, supported by legal enforcement, to improve the overall approach to wastewater management. Instead of just treating wastewater, they urged a focus on recovering valuable resources from it. They also highlighted the connection between wastewater management and climate change as an important factor in ensuring sustainable water resources. Finally, they called for policies that promote wastewater reuse, in line with Sustainable Development Goals (SDGs) and Public-Private Partnerships (PPPs) to boost collaboration and progress in the field.

2.6. Case Studies

2.6.1 National Case Study : Pune

Pune, one of Maharashtra's prominent urban centers, is intersected by three key rivers — the Mula, the Mutha, and the combined Mula-Mutha River. The city currently supplies approximately 1,250 million litres per day (MLD) of water to its population and boasts a sewerage network coverage of about 92%. However, despite generating 850 MLD of sewage, the city's sewage treatment infrastructure remains insufficient. Pune has 10 Sewage Treatment Plants (STPs) with a total installed capacity of 567 MLD, out of which one STP with a capacity of 90 MLD is non-functional. This reduces the effective treatment capacity to 477 MLD. As a result, nearly 50% of the city's sewage remains untreated and is directly discharged into the Mula-Mutha River, which further pollutes the downstream Bhima and Krishna Rivers.

In response to this growing challenge, the Pune Municipal Corporation (PMC) has implemented a series of regulatory interventions aimed at improving wastewater management and promoting reuse. One such mandate requires all new residential housing schemes with more than 150 tenements to install decentralized STPs and reuse treated wastewater for non-potable uses such as flushing and gardening. Failure to comply with this rule attracts penalties that are determined based on the STP's capacity. In addition, to reduce groundwater extraction and conserve potable water, the PMC now requires construction sites to exclusively use treated greywater for all construction-related activities.

Pune has also emerged as a leader in the reuse of treated wastewater. Approximately 400 MLD of treated effluent is pumped from the rising main of the Mula-Mutha River and directed into a canal system managed by the Agriculture Department. This treated water is then distributed for irrigation across surrounding agricultural lands, reducing the dependency on freshwater sources. Beyond agriculture, treated wastewater is also used extensively across the city for construction, road cleaning, gardening, and horticulture projects through tanker supply and distribution systems. Additionally, industrial units are increasingly using this water for cooling processes.

The city's approach reflects a shift towards a circular economy model for water management, where wastewater is not seen as a burden but as a valuable resource. With strong policy measures, decentralized treatment, and increasing public-private participation, Pune is making strides in creating a sustainable, climate-resilient urban ecosystem. However, to bridge the existing treatment gap, there is still a pressing need to enhance treatment capacities, ensure efficient operation of STPs, and invest in innovative, eco-friendly technologies to safeguard river ecosystems and support future urban growth.

2.6.2. International Case Study : Singapore

Singapore, despite being surrounded by seawater, ranks among the most water-stressed countries globally concerning drinking water. With a small territory of just over 700 sq. km, it faces unique challenges in water management. The country is not water-scarce due to a lack of rainfall—receiving about 2,400 mm annually—but due to its limited land area, which restricts the storage capacity for rainwater. Ensuring a sustainable water supply is, therefore, a top priority for the city-state's 5.7 million inhabitants.

A significant issue for Singapore is the limited availability of freshwater resources needed to support its growing population and robust economy. The country's water demand is approximately 2 million cubic meters per day (PUB, 2023a), with around 80 percent of this water generated as wastewater (WHO, 2020). Unlike many countries, where 80 percent of wastewater flows untreated into the environment (UN estimates), Singapore treats and reuses 100 percent of its wastewater. This comprehensive approach not only conserves valuable resources but also minimizes environmental pollution.

To address these challenges, Singapore has adopted the "Four National Taps" strategy to diversify its water sources: local catchment water, water imported from Johor, NEWater (reclaimed water), and desalinated water (WHO, 2017a). NEWater, produced by advanced water reclamation plants, plays a crucial role in meeting nearly 40 percent of the nation’s water demand through its four operational plants located at Bedok, Kranji, Ulu Pandan, and Changi (Yue Choong Kog, 2020). By 2060, NEWater is projected to satisfy up to 55 percent of Singapore's total water demand (PUB, 2023a).

In addition to NEWater, the country also relies heavily on desalinated water, which currently provides up to 30 percent of Singapore's water supply. This dual approach creates a 'drought-proof' water source, effectively preserving potable water for consumption. The integration of advanced desalination technologies ensures that Singapore can augment its water resources, even during dry spells.

Singapore's water management strategy is further complemented by an extensive network of sewers leading to four water reclamation plants, which collectively treat around 595 million cubic meters of wastewater annually to meet international standards (WHO, 2020). This sophisticated treatment process involves multiple stages, including microfiltration and reverse osmosis, ensuring the highest quality of reclaimed water.

Moreover, the nation places a strong emphasis on public awareness and education regarding water conservation. Initiatives such as the "Save Water" campaign aim to engage the community in sustainable water practices, encouraging citizens to take an active role in conserving water. Additionally, Singapore's government invests heavily in research and development to explore innovative solutions for water management, including smart water technologies and alternative water sources.

In summary, Singapore's proactive approach to water management, characterized by diversification of water sources, extensive treatment and reuse of wastewater, and public engagement, serves as a model for other water-stressed nations. By continuously adapting and innovating its water management strategies, Singapore demonstrates how to effectively balance the needs of a growing population while preserving environmental integrity (WHO, 2020).

3. Site Context and Analysis

3.1. Study Area Background

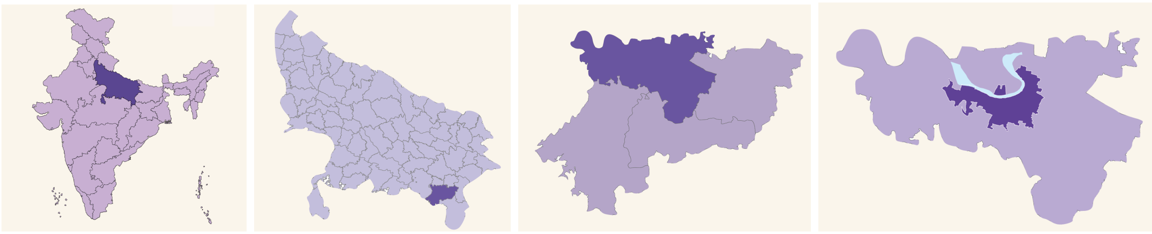


Figure 4: Site area delineation

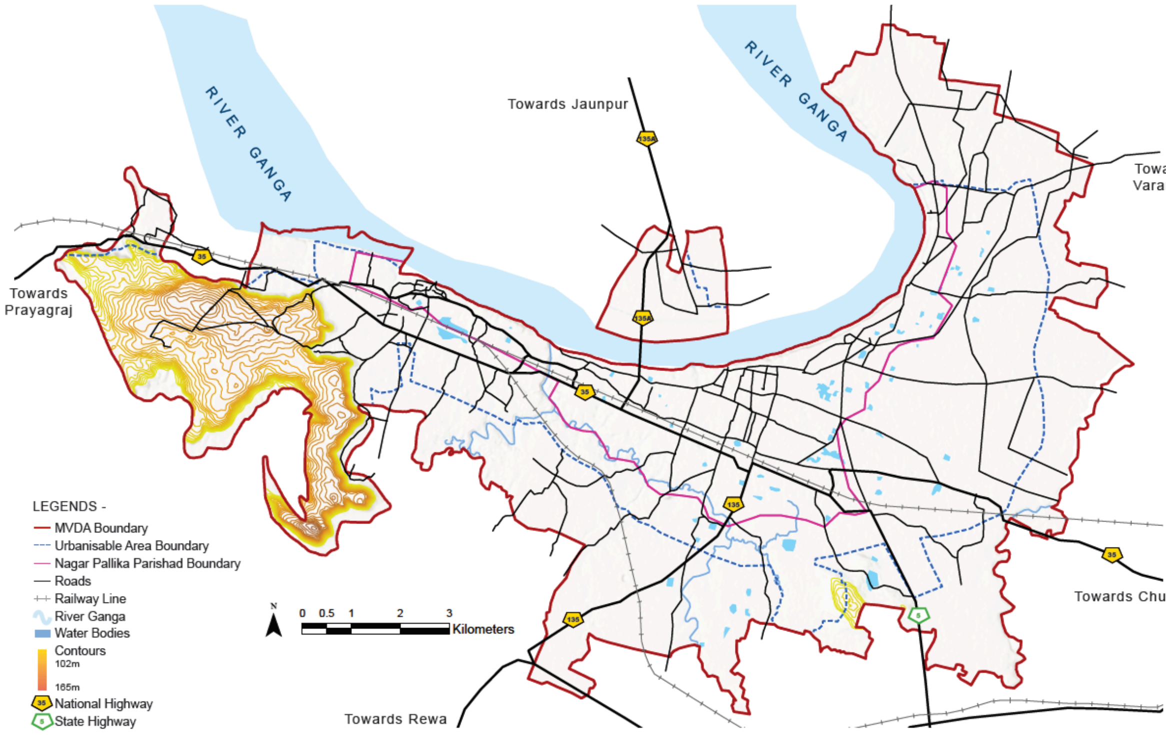


Figure 5: Basemap of Mirzapur - Vindhyachal Development Authority Area

The study area has a total area of 114.85 km² within the Mirzapur - Vindhyachal Development Authority (MVDA) Area, with the Nagar Palika Parishad Boundary Area covering 38.85 km² and Urbanisable Area Boundary of 83.2 km². It is divided into 68 revenue villages and consists of 38 municipal wards. According to the 2011 Census, the MVDA's population is 3,53,547, with a population of 2,46,920 in the Urbanisable Area (UA) and 2,34,871 in the Nagar Palika Parishad Area (NPP).

The Mirzapur city is notably recognized for its carpet industries and is geographically surrounded by the Vindhya Range, contributing to its unique environmental and cultural landscape. The climate varies between 7°C and 36.8°C, with an annual average rainfall of

978 mm. These demographic and geographic details provide essential insights into the city's growth, environmental conditions, and economic characteristics, relevant to the scope of urban wastewater management and resource reuse within the region.

3.2. Land Use

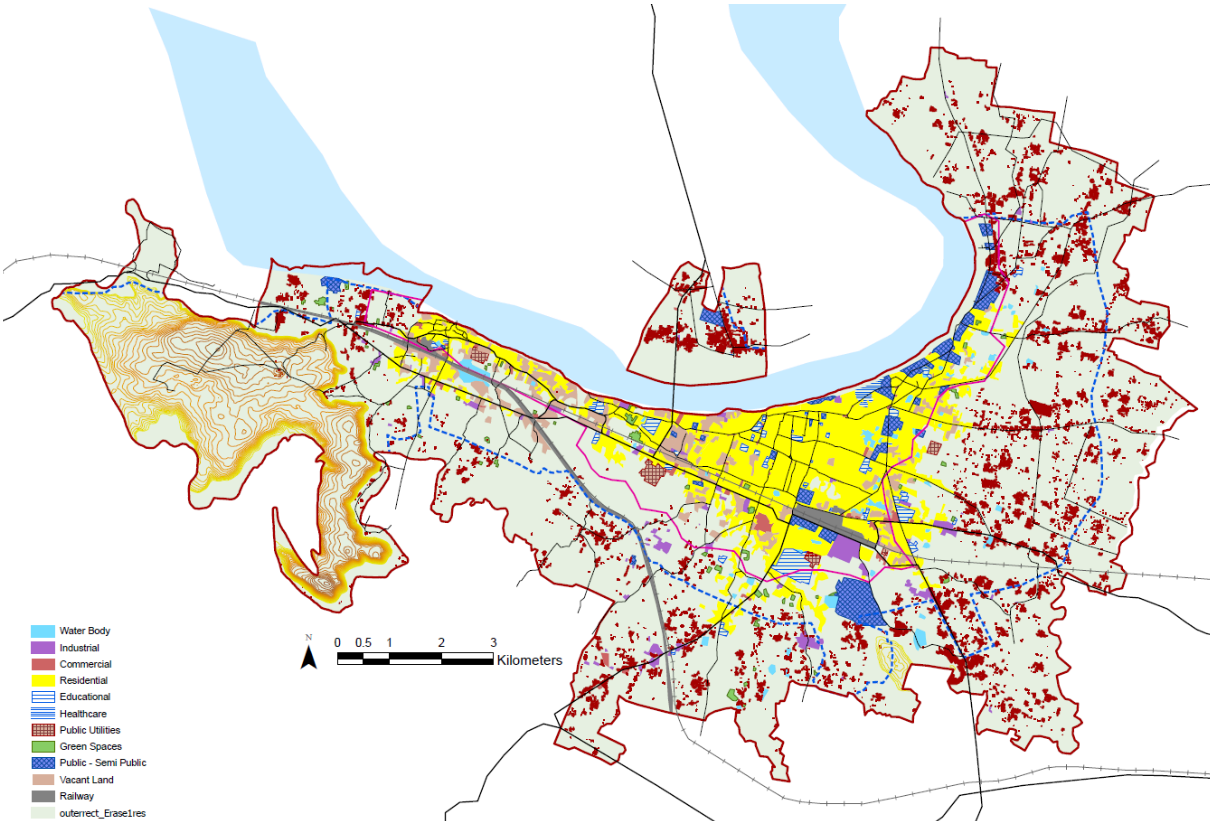


Figure 6: Land Use Map of Mirzapur - Vindhyachal Development Authority Area

Percentage Distribution of various land use -

- Residential - 12.48 %
- Commercial - 0.5 %
- Industrial - 1.06 %
- Public - Semi Public - 1.85 %
- Educational - 0.85 %
- Healthcare - 0.16 %
- Public Utilities - 0.29 %
- Vacant Land - 2.69 %
- Green Spaces - 0.34 %
- Waterbody - 0.84 %

- Railways - 1.24 %
- Rural Area - 49.83 %
- Agriculture - 27.82 %

3.3. Water Scenario

Population of MVDA
MVDA = Urbanisable Area + Revenue Villages

- Census 2001 - 2,97,838
    - Urbanisable Area - 2,15,450
    - Revenue Villages - 82,388
- Census 2011 - 3,53,547
    - Urbanisable Area - 2,46,920
    - Revenue Villages - 1,06,627

Projected Population for 2025

- Arithmetic Increase Method - 4,31,540
    - Urbanisable Area - 2,90,978
    - Revenue Villages - 1,40,562
- Geometric Increase Method - 4,51,308
    - Urbanisable Area - 2,98,754
    - Revenue Villages - 1,52,554
- Incremental Increase Method - 4,40,540
    - Urbanisable Area - 2,94,578
    - Revenue Villages - 1,45,962
- Exponential Growth Method - 4,41,500
    - Urbanisable Area - 2,94,818
    - Revenue Villages - 1,46,682

Population of 2025 MVDA (avg of all method) - 4,41,222

- Population of 2025 UA (avg of all method) - 2,94,782

- Population of 2025 RV (avg of all method) - 1,46,440

Total Water Consumption

- UA Population of 2025 x 135 LPCD - 39.7 MLD
- RV Population of 2025 x 55 LPCD - 8.05 MLD

3.3.1. Water Supply Zones

There are a total of 8 Water Supply Zones in the area, mostly covering Municipal Area Boundary.

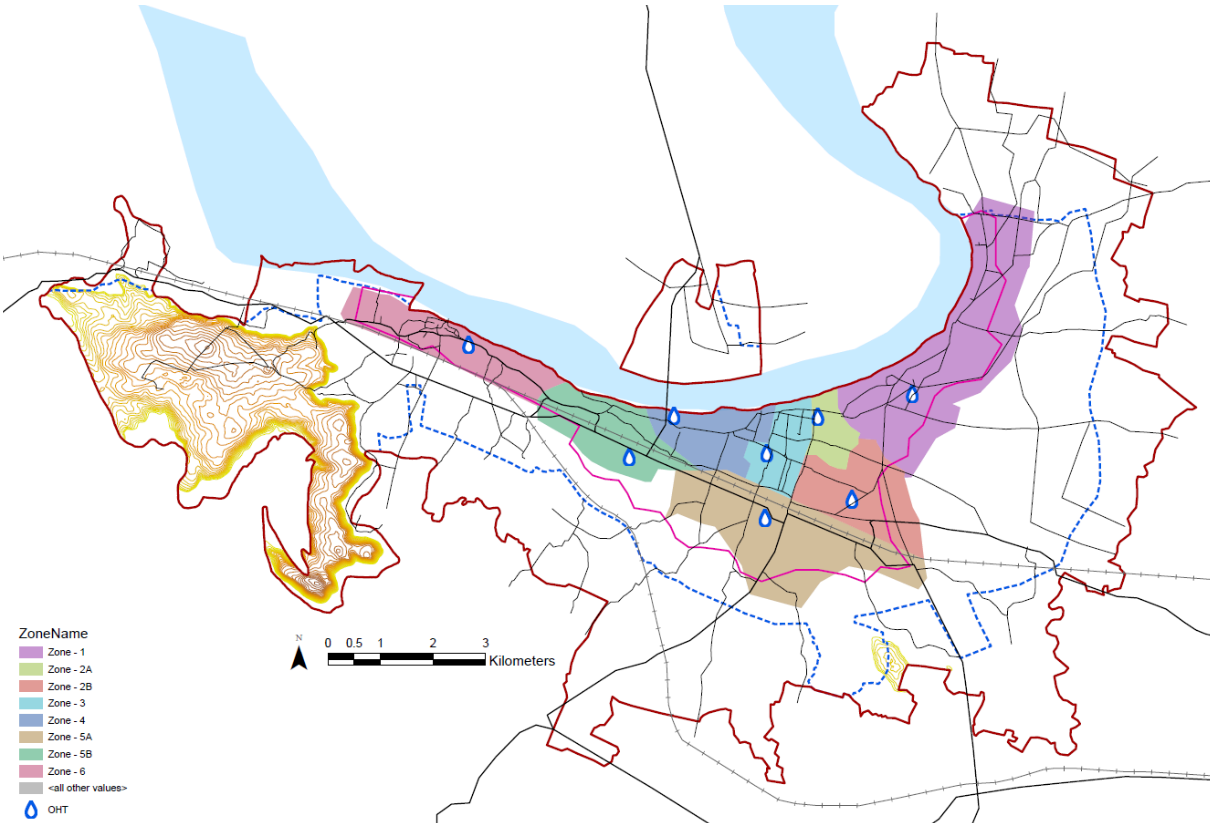


Figure 7: Water Supply Zone Map

3.3.2. Sources of Water

As per the Master Plan Report 2031, the primary source of water in the city is piped supply of treated water, which accounts for 65.67% of the total water sources. This is followed by handpumps, serving 20.63% of the population. Untreated piped water supply contributes to 6.88%, while tubewells account for 5.32% of the sources. A smaller portion of the population, around 1.50%, still depends on traditional wells for their water needs.

These figures indicate a significant reliance on treated piped water supplied by municipal bodies, highlighting the presence and functioning of centralized Water Treatment Plants as part of the city's water infrastructure. However, a considerable portion of the population still depends on groundwater sources such as handpumps, wells, and tubewells, indicating continued extraction of groundwater to meet daily water needs.

3.4. Wastewater Scenario

Population of 2025 MVDA (avg of all method) - 4,41,222

- Population of 2025 UA (avg of all method) - 2,94,782
- Population of 2025 RV (avg of all method) - 1,46,440

Total Water Consumption

- UA Population of 2025 x 135 LPCD - 39.7 MLD
- RV Population of 2025 x 55 LPCD - 8.05 MLD

Total Wastewater Generated in UA

- 80% of Total Water Consumption - 31.76 MLD

Installed Capacity of STP - 38 MLD (14 + 8.5 + 8.5 + 7)

Operation Capacity of STP - 28 MLD (14 + 4 + 6 + 4)

Wastewater Treated - 88 %

Wastewater Reused - 0 %

As per the projected population for 2025, the MVDA is expected to house 4,41,222 people, with 2,94,782 in the Urban Area (UA) and 1,46,440 in the Revenue Villages (RV). Based on standard per capita water demand, the total water consumption in the UA is estimated at 39.7 MLD, while the RVs consume approximately 8.05 MLD. This results in a total urban wastewater generation of around 31.76 MLD, assuming 80% of the consumed water returns as wastewater.

Although the city has an installed sewage treatment capacity of 38 MLD, only 28 MLD is currently operational, leading to a treatment efficiency of 88%. Despite this relatively high treatment rate, there is currently no reuse of treated wastewater, indicating a significant gap in circular water resource management. This highlights the urgent need for integrating reuse strategies and optimizing the functioning of STPs to promote sustainability and reduce pressure on freshwater sources.

3.4.1. Wastewater Collection Zones

The study area is divided into six wastewater collection zones, primarily encompassing the municipal boundary. These zones are integrated into the city's wastewater infrastructure and are connected to four Sewage Treatment Plants (STPs) and six pumping stations, facilitating the collection, conveyance, and partial treatment of the generated wastewater.

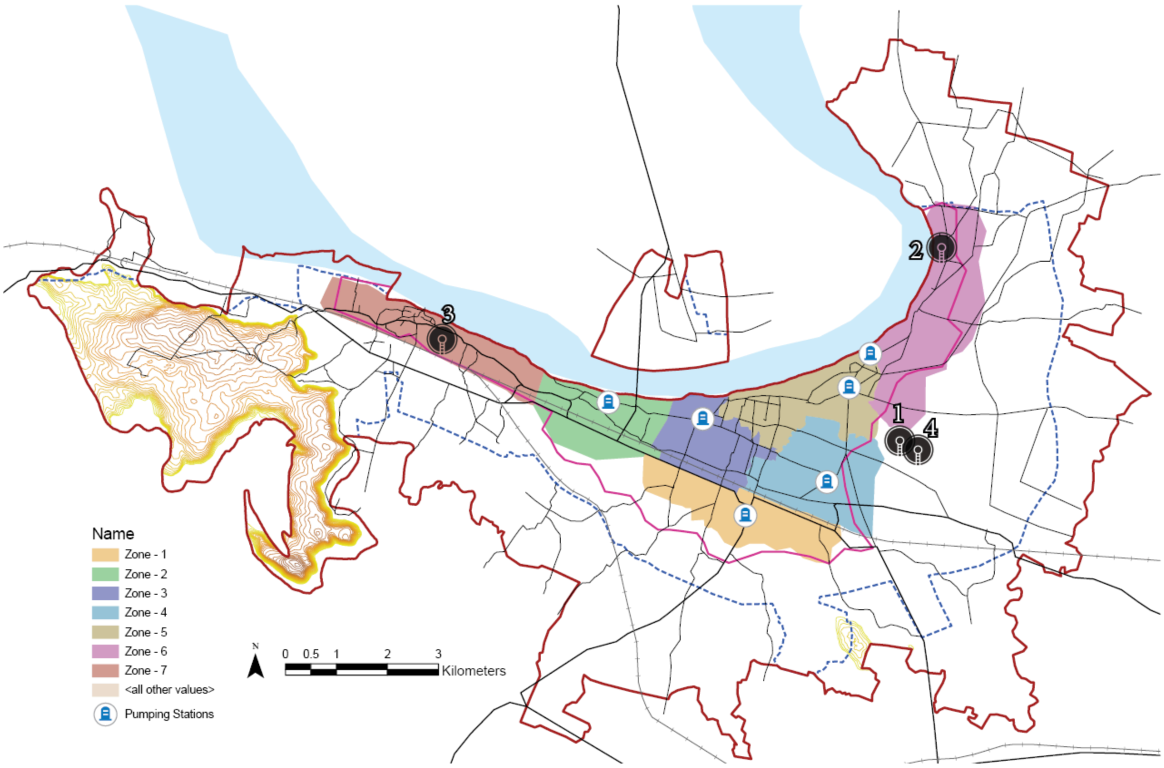


Figure 8: Wastewater Collection Zones

3.4.2. Wastewater Flow

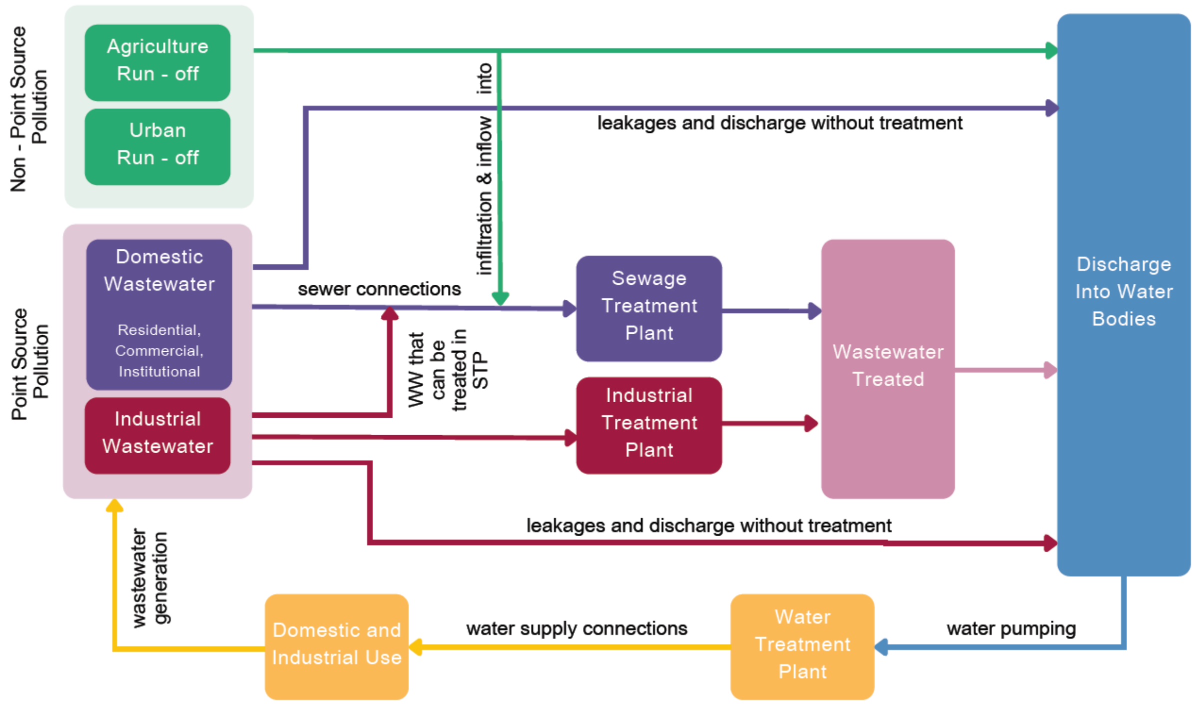


Figure 9: Wastewater Flow

The wastewater management cycle involves both point and nonpoint source pollution. Point sources include domestic (residential, commercial, institutional) and industrial wastewater, which, through sewer connections, are directed towards respective treatment facilities—Sewage Treatment Plants (STPs) and Industrial Treatment Plants (ITPs). A portion of this wastewater, especially from domestic sources, infiltrates the STP system. However, due to infrastructural deficiencies, leakages and untreated discharges from both sources often end up directly contaminating nearby water bodies.

On the other hand, non-point source pollution, such as urban and agricultural runoff, also contributes significantly to water contamination, often bypassing treatment altogether. The treated wastewater, although a potential resource, is typically discharged without reuse. This highlights a linear system where water, after being pumped, treated, and used for domestic and industrial purposes, is mostly wasted post-treatment without reintegration. The cycle indicates urgent needs for leak-proof infrastructure, effective runoff management, and integration of treated wastewater reuse to move towards a sustainable and circular urban water management model.

3.4.3. Stakeholder Involved and Their Roles

Wastewater management in Mirzapur involves multiple stakeholders performing distinct yet interconnected functions. Notably, although wastewater is treated, the treated effluent is discharged into the **Ganga River** via city drains, without any current reuse mechanism in place.

Process Stage	Stakeholders Involved	Roles & Responsibilities
Wastewater Generation	Private & Public	Generate wastewater from residential, commercial, institutional, and industrial activities.
Wastewater Collection	Nagar Palika Parishad Mirzapur Uttar Pradesh Jal Nigam (UPJN)	Lay sewer pipelines, establish sewage connections, and ensure operation and maintenance.
Wastewater Treatment	Mirzapur Ghazipur STP Pvt. Ltd. UPJN	MG STP Pvt. Ltd. handles construction and O&M of STPs; UPJN oversees the process.
Sludge Disposal	Uttar Pradesh Jal Nigam (UPJN)	Collects sludge from STPs and disposes of it by transporting via trucks to empty land.
Treated Water Discharge	-	Treated effluent is discharged into the Ganga through city drains.

Figure 10: Stakeholders and Their Roles in Wastewater Management.

3.5. Drains

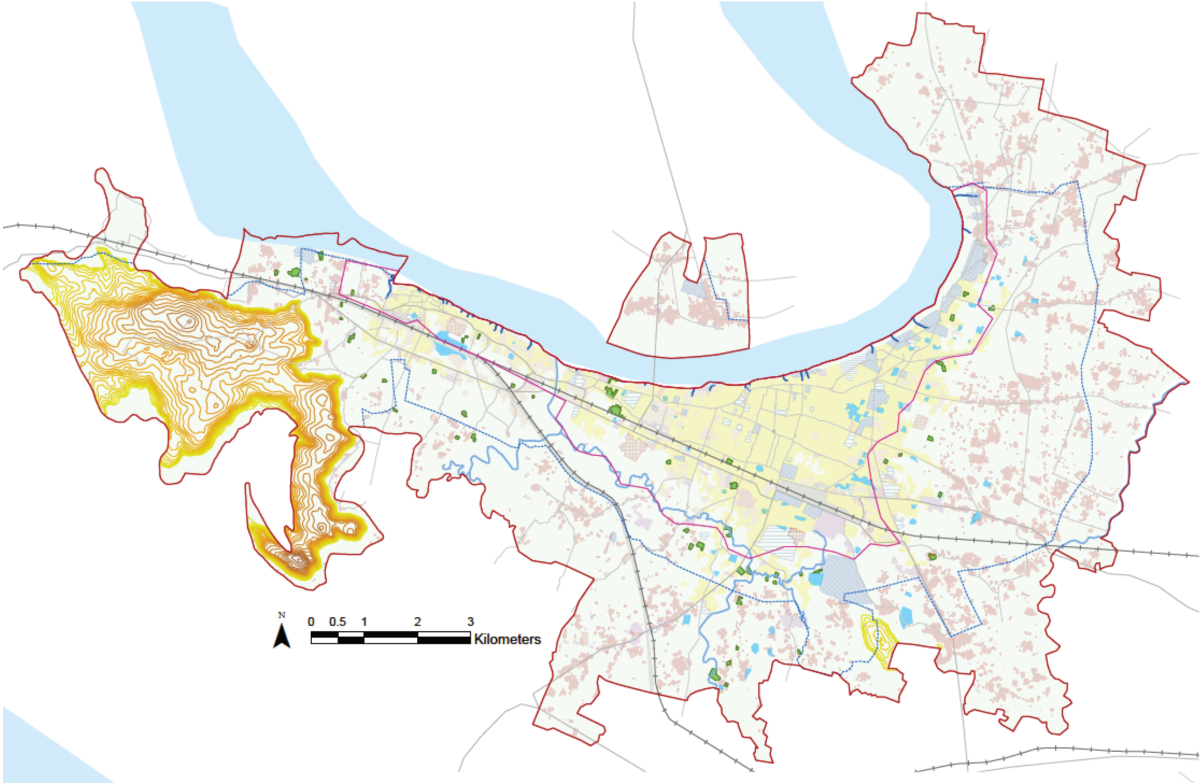


Figure 11: Location of drains

Out of 27 drains, nearly 40% remain untapped, many of which exhibit high BOD levels, indicating significant organic pollution. For example, the Chorawa Drain in Mirzapur, with a BOD of 155 mg/l, and the Ghoreshahid Drain, discharging 5 MLD with a BOD of 24.8 mg/l, are of particular concern due to their potential to pollute natural water bodies and pose public health risks. Moreover, some tapped drains like the Khandwa and Lift Canal drains still show high BOD values (100 mg/l and 110 mg/l, respectively), pointing to either inadequate treatment facilities or improper operation and maintenance.

Immediate attention is needed to tap the remaining drains, especially high-discharge ones like Ghoreshahid and Balaji, and integrate them into a city-wide sewage network with adequate treatment capacity. Existing sewage treatment plants (STPs) must be evaluated for performance and possibly upgraded to ensure compliance with BOD discharge standards. Furthermore, real-time monitoring systems should be implemented to detect illegal discharges or malfunctioning units. Emphasis should also be placed on decentralized wastewater treatment solutions in areas where centralized systems are impractical. This integrated approach will help reduce environmental pollution, improve river health (especially considering proximity to the Ganga), and support long-term urban sustainability goals.

Out of the 27 drains identified in the study area, 15 drains (55.6%) are tapped and connected to sewage treatment plants (STPs), while 12 drains (44.4%) remain untapped, continuing to discharge untreated wastewater directly into natural water bodies, including the Ganga. This indicates that nearly half of the drainage system lacks proper treatment linkage, contributing significantly to pollution and environmental degradation.

Among the tapped drains, the majority are connected to the Pakka Pokhra STPs (14 MLD and 8.5 MLD combined), accounting for 44.5% of the treatment load. The Bisunderpur STP handles 33.4% of the tapped flow, while the Vindhyachal STP treats 22.1%. This distribution shows a heavy reliance on a few centralized STPs

S.No	Area	Drain Name	Drain Type	BOD (mg/l)	Discharge (MLD)
1	Vindhyachal	Shivpur Drain	Untapped	-	0.03
2	Vindhyachal	Malhaya Drain	Untapped	34	0.27
3	Vindhyachal	Balughat Pakka Drain	Tapped	-	0.17
4	Vindhyachal	Balughat Drain	Untapped	-	0.09
5	Vindhyachal	Balughat Kaccha Drain	Untapped	41.4	0.01
6	Vindhyachal	Gudara Drain	Tapped	-	0.2
7	Vindhyachal	Parasuram Drain	Tapped	55.7	1.39
8	Vindhyachal	Diwan Ghat New Drain	Untapped	-	0.02
9	Vindhyachal	Diwan Ghat Old Drain	Tapped	-	0.1
10	Vindhyachal	Patengra Drain	Untapped	19	0.74
11	Vindhyachal	Dargah Sharif Drain	Untapped	-	0.32
12	Mirzapur	Chorawa Drain	Untapped	155	0.25
13	Mirzapur	Basvariya Drain	Untapped	6	1.13
14	Mirzapur	Lift Canal Drain	Tapped	110	0.5
15	Mirzapur	Public Club Drain	Tapped	35.4	0.6
16	Mirzapur	District Judge Drain	Tapped	-	0.4
17	Mirzapur	Khandawa Drain	Tapped	100	4.5
18	Mirzapur	Balaji Drain	Untapped	38	2.2
19	Mirzapur	Narghat Drain	Tapped	-	0.78
20	Mirzapur	Badali Drain	Tapped	-	0.39
21	Mirzapur	Sundar Ghat Drain	Tapped	-	0.24
22	Mirzapur	Oliyar Drain	Tapped	-	0.31
23	Mirzapur	Kachahari Drain	Tapped	35.4	1.2
24	Mirzapur	Ghoreshahid Drain	Untapped	24.8	5
25	Mirzapur	Morchghar Drain	Tapped	24.6	1.64
26	Mirzapur	Hanuman Ghat Drain	Untapped	30.4	0.68
27	Mirzapur	Bisundarpur Drain	Tapped	20.4	1.58
Total Discharge in MLD					24.74

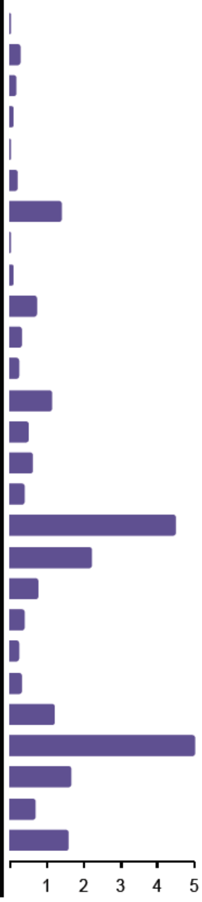


Figure 12: Drains discharging wastewater directly into Ganga

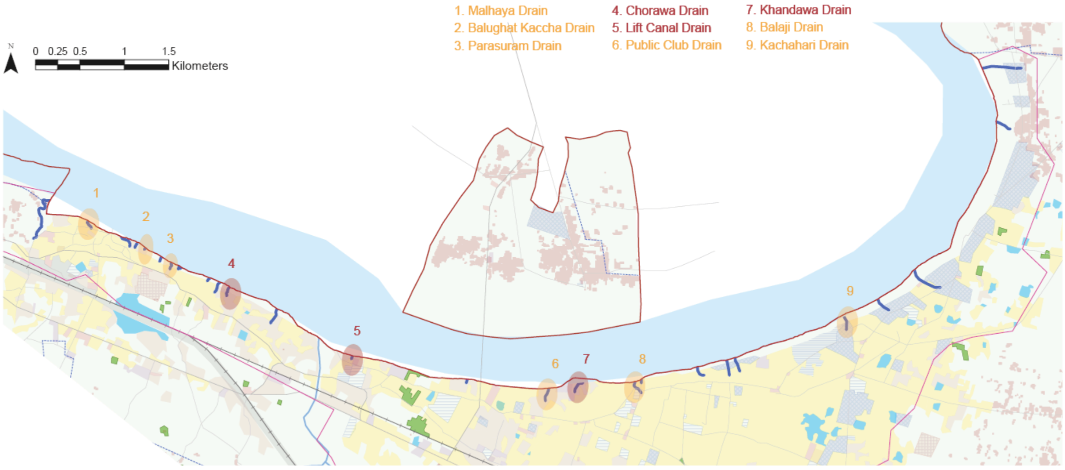


Figure 13: Hotspot Analysis of most polluted drains

In Vindhyachal and Mirzapur, several open drains directly carry untreated wastewater into the Ganga, significantly contributing to river pollution. Many of these drains have high BOD levels and remain untapped, while nearby households often dispose of waste illegally into them, worsening contamination. These open drains pose serious health and environmental risks, especially during monsoons when they overflow into residential areas. There is an urgent need to tap all open drains, expand sewer networks, install localized treatment units, and create awareness to prevent illegal dumping and protect the river.

Figure 14: Drains condition

3.6. Sewage Treatment Plant (STP)

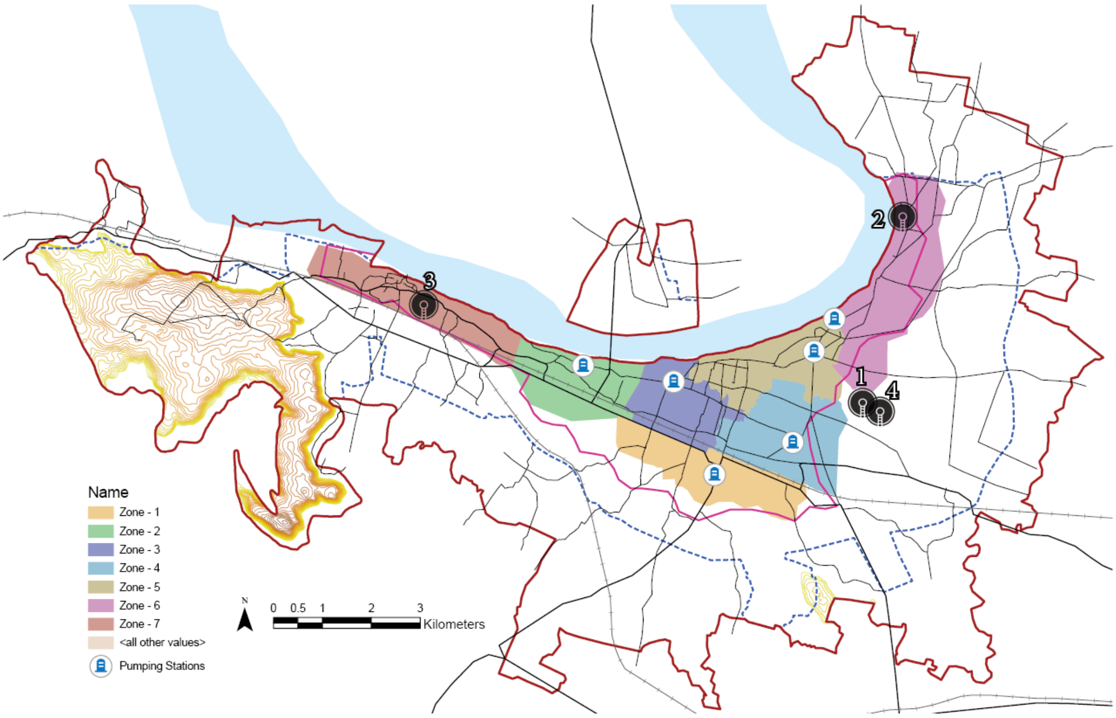


Figure 15: Location of STPs

3.6.1. STP - 1 : Pakka Pokhra

- **Location:** Pakka Pokhra
- **Year of Establishment:** 1992
- **Zones Covered:** Zone 1, 2, 3, 4 and 5
- **Installed Capacity:** 14 MLD
- **Operational Capacity:** 14 MLD
- **Treatment Technology:** UASB (Upflow Anaerobic Sludge Blanket)
- **Treated Water Reused:** 0 MLD
- **Sludge Generated:** 35 kg/MLD
- **Disposal of Sludge:** sent to Kanpur
- **Drainage Network Tapped:**
    - Badali Drain
    - Kachahari Drain
    - Khandawa Drain
    - Narghat Drain
    - Oliyar Drain
    - Sundar Ghat Drain

Treated Water Quality (Outlet Parameters)

Parameter	Value	CPCB 2017 Norm	Compliance
pH	7.89	6.5–8.5	✅ Yes
BOD	16.4 mg/l	≤10 mg/l	❌ No
COD	111.4 mg/l	≤50 mg/l	❌ No
TSS	30.7 mg/l	≤20 mg/l	❌ No

Figure 16: Water Quality Parameters

Issues

- Environmental Standards Compliance:
  - CPCB 1986 Guidelines: Compliant with all 4 parameters
  - CPCB 2017 Guidelines: Compliant with only 1 out of 4 parameters (only pH is within limits)
- Treated water is discharged into an open drain that merges with the Goreshahid Drain, ultimately flowing into the Ganga River.
- Household waste is frequently disposed of into this open channel after the treatment stage, leading to recontamination of the treated water.
- This nullifies the entire treatment effort, as the water re-enters the Ganga in a polluted state, defeating the purpose of investment in sewage treatment.

Figure 17: Outlet Water Chamber after Treatment and Open Outlet Drain from STP

3.6.2. STP - 2: Bisunderpur

- **Location:** Bisunderpur
- **Zones Covered:** Zone 6
- **Installed Capacity:** 8.5 MLD
- **Operational Capacity:** 4 MLD
- **Treatment Technology:** SBR (Sequencing Batch Reactor)
- **Treated Water Reused:** 0 MLD
- **Sludge Generated:** 55–60 kg/MLD
- **Disposal of Sludge:** sent to Kanpur
- **Drainage Network Tapped:**
  - Bisunderpur Drain
  - District Judge Drain
  - Irrigation Colony Drain
  - Lift Canal Drain
  - Morcha Ghar Drain
  - Public Club Drain

Treated Water Quality (Outlet Parameters)

Parameter	Value	CPCB 2017 Norm	Compliance
pH	7.57	6.5–8.5	✅ Yes
BOD	7.0 mg/l	≤10 mg/l	✅ Yes
COD	32.4 mg/l	≤50 mg/l	✅ Yes
TSS	8.1 mg/l	≤20 mg/l	✅ Yes

Figure 18: Water Quality Parameters

Issues

- Environmental Standards Compliance:
  - CPCB 2017 Guidelines: Fully compliant – all 4 discharge parameters are within acceptable limits.

- The STP is operating at less than 50% of its installed capacity (4 MLD vs. 8.5 MLD), indicating inefficiencies in either sewage collection or plant operations.
- Despite achieving excellent effluent quality, none of the treated water is reused.
- Treated water is released into open drains, where domestic and industrial wastewater is further added. This leads to recontamination before the water ultimately reaches the Ganga River, undermining the treatment efforts.

Figure 19: Inlet WW Chamber from Households and Transportation of Sludge

3.6.3. STP - 3: Vindhayachal

- **Location:** Vindhyachal
- **Zones Covered:** Zone 7
- **Installed Capacity:** 7 MLD
- **Operational Capacity:** 4 MLD
- **Treatment Technology:** SBR (Previously WSP – Waste Stabilization Pond)
- **Treated Water Reused:** 0 MLD
- **Sludge Generated:** 75–80 kg/MLD
- **Disposal of Sludge:** to Waste Stabilisation Pond
- **Drainage Network Tapped:**
    - Balughat Pakka Drain
    - Diwan Ghat Old Drain
    - Gudara Drain
    - Parasuram Drain

Treated Water Quality (Outlet Parameters)

Parameter	Value	CPCB 2017 Norm	Compliance
pH	7.39	6.5–8.5	✅ Yes
BOD	7.2 mg/l	≤10 mg/l	✅ Yes
COD	36.0 mg/l	≤50 mg/l	✅ Yes
TSS	8.9 mg/l	≤20 mg/l	✅ Yes

Figure 20: Water Quality Parameters

Issues

- Environmental Standards Compliance:
    - CPCB 2017 Guidelines: Fully compliant – all 4 discharge parameters are within acceptable limits.
- The plant operates at 4 MLD, despite being designed for 7 MLD, pointing towards inefficient sewage inflow, pipeline limitations, or maintenance gaps.
- Treated water is discharged into Diwan Ghat and Parasuram Drains, both of which receive untreated domestic (HH) wastewater, resulting in recontamination.
- The STP previously used WSP (Waste Stabilization Ponds)—a nature-based treatment technology appreciated globally for being cost-effective, low-energy, and sustainable.
- However, it has now been replaced with an energy-intensive SBR system, going against the global trend of promoting nature-based solutions (NBS) for urban wastewater management.
- Countries like Singapore, Germany, and many Indian smart cities are incorporating constructed wetlands, bioremediation, and pond-based systems to integrate water reuse with green infrastructure.


Figure 21: Waste Stabilisation Pond for WW Treatment and Transportation of Sludge

3.6.4. STP - 4: Pakka Pokhra

- **Location:** Pakka Pokhra
- **Zones Covered:** Zone 1, 2, 3, 4 and 5
- **Installed Capacity:** 8.5 MLD
- **Operational Capacity:** 6 MLD
- **Treatment Technology:** Sequential Batch Reactor (SBR)
- **Treated Water Reused:** 0 MLD
- **Sludge Generated:** 41.6 kg/MLD
- **Disposal of Sludge:** sent to Kanpur
- **Drainage Network Tapped:**
    - Barahmilliah Drain
    - Konia Drain

Treated Water Quality (Outlet Parameters)

Parameter	Value	CPCB 2017 Norm	Compliance
pH	8.13	6.5–8.5	✅ Yes
BOD	6.0 mg/l	≤10 mg/l	✅ Yes
COD	29.7 mg/l	≤50 mg/l	✅ Yes
TSS	11 mg/l	≤20 mg/l	✅ Yes

Figure 22: Water Quality Parameters

Issues

- Environmental Standards Compliance:
  - CPCB 2017 Guidelines: Fully compliant – all 4 discharge parameters are within acceptable limits.
- Despite being designed for 8.5 MLD, the plant operates at only 6 MLD, reflecting a 30% underutilization. This could stem from inadequate sewage conveyance, blockages, or poor demand estimation.
- The generated sludge is openly dumped, exposing nearby residents and environments to health hazards, odour, and potential soil and water contamination.

Figure 23: Outlet Water Chamber after Treatment and Treated WW Flowing Back to Ganga

3.7. Industrial Profile

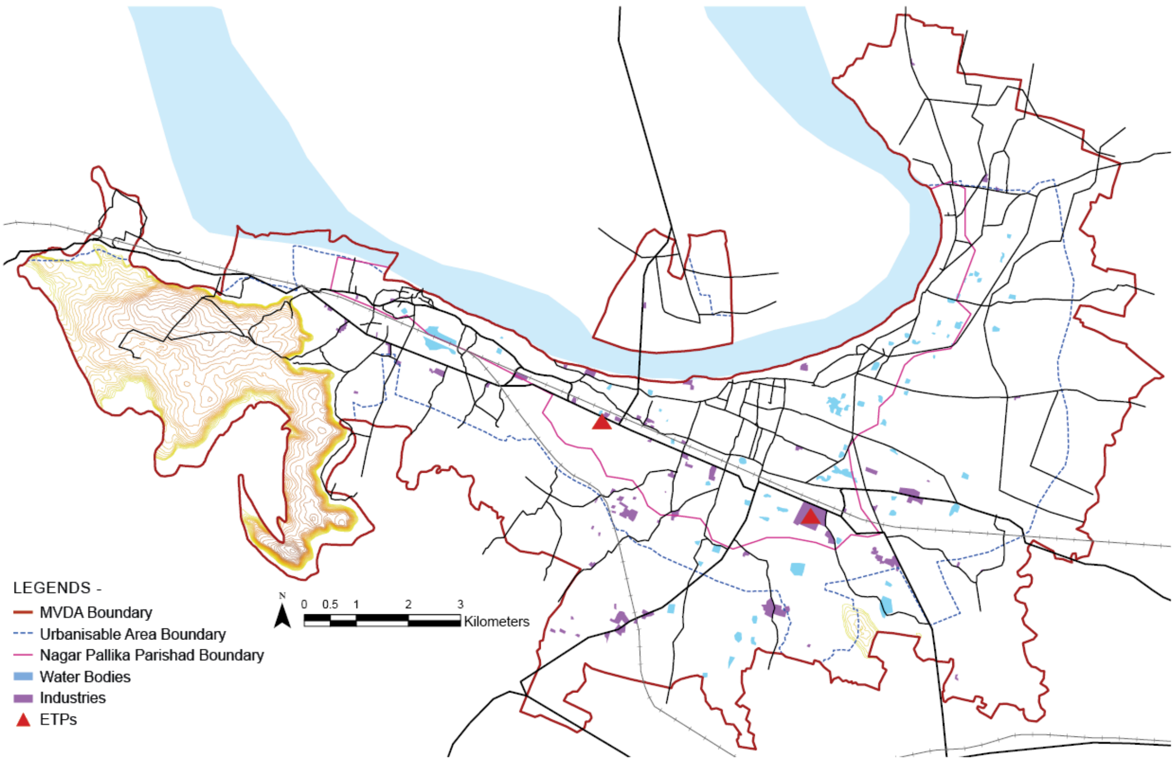


Figure 24: Location of Industries

3.7.1. Types Of Industries

The industrial composition of the site is predominantly led by the carpet industry, which accounts for 60% of the total industrial base. This is followed by the brassware industry, contributing 30%, while the remaining 10% is composed of other industries such as steel, cement, agro-based, and food processing industries.

3.7.2. Classification Based on Pollution Level

CATEGORY	DESCRIPTION	POLLUTION LEVEL
Red	Highly Polluting	Pollution Index ≥ 80
Orange	Moderately Polluting	55 ≤ Pollution Index < 80
Green	Low Polluting	25 ≤ Pollution Index < 55
White	Non Polluting	Pollution Index < 25

Figure 25: Industries Classification

Industries are classified into four categories—Red, Orange, Green, and White—based on their Pollution Index (PI), which is a measure of the environmental load an industry places on air, water, and land. The White category includes non-polluting industries with a PI of less than 25, Green industries are low polluting with a PI between 25 and 55, Orange industries are moderately polluting with a PI between 55 and 80, and Red industries are highly polluting with a PI of 80 or above. This classification system helps in regulating industrial activities by prioritizing environmental clearance and monitoring according to the pollution potential of each sector.

In the context of local industries, handloom and carpet weaving (without dyeing and bleaching) is classified under the White category, indicating it is non-polluting and environmentally sustainable. On the other hand, the manufacture of brassware utensils falls under the Green category, considered low polluting. Meanwhile, jute processing involving dyeing operations is categorized as an Orange industry, reflecting its moderate pollution potential due to chemical usage in dyeing processes. This classification highlights the need for targeted environmental management, promoting eco-friendly practices in traditional sectors while implementing stricter controls where moderate pollution is involved.

3.7.3. Effluent Treatment Plants

Neeman Carpets, Pathriya, Mirzapur

The Effluent Treatment Plant (ETP) at Neeman Carpets has an installed capacity of 15 KLD, out of which only 11 KLD is currently operational, reflecting underutilization of the system. Despite achieving basic treatment goals, only 1 KLD of treated water is reused, primarily for flushing, gardening, and car washing, which indicates a limited focus on resource recovery. The major share of treated water is still being disposed of into drains that ultimately connect to the Ganga, posing a potential threat of recontamination during transit. The sludge generated is around 200 grams per liter, which is responsibly transported to Kanpur for disposal, highlighting a relatively structured sludge management mechanism.

As per the outlet water quality parameters, the pH is 8.23, BOD is 11.8 mg/l, COD is 60.5 mg/l, and TSS is 8.5 mg/l. These figures suggest a moderate level of treatment, with BOD and COD values falling within permissible limits for non-potable reuse but potentially requiring further polishing if discharged near ecologically sensitive zones like the Ganga. While the ETP demonstrates partial success in wastewater treatment and reuse, it still lacks a robust reuse strategy and secure discharge mechanism. Scaling up reuse and preventing recontamination through closed-loop systems or dedicated reuse infrastructure could significantly enhance its environmental impact.

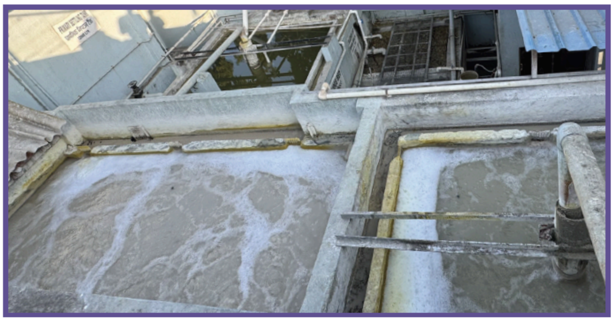



Figure 26: ETP at Neeman Carpets, Mirzapur

Jaipur Rugs, Rajapur, Mirzapur

The Effluent Treatment Plant at Jaipur Rugs in Rajapur has an installed capacity of 400 KLD, with an operational capacity of 350 KLD, indicating efficient utilization of the system. The plant follows a three-step treatment process designed to ensure effective wastewater management and enable water reuse, particularly for irrigation purposes.

1. Primary Treatment involves the use of lime and alum, which help in removing suspended solids and neutralizing the acidity of the wastewater.
2. In the Secondary Treatment, biological processes come into play, where bacteria decompose organic matter, and the water is further purified through sand and carbon filters to eliminate residual impurities.
3. The Tertiary Treatment stage refines the water quality to a level suitable for agricultural irrigation, after which the treated water is discharged into nearby fields for reuse, promoting sustainable water management practices in the region.

3.7.4. Issues

The carpet and dyeing industries in Mirzapur, including major players like Obeetee Carpets, Neeman Carpets, and Jaipur Rugs, are heavily dependent on groundwater drawn through borewells, leading to unregulated extraction and stress on local water resources. On average, 30 buckets (approximately 450–500 liters) of water are used per square yard during the rug washing process, which significantly contributes to water consumption. Despite being mandated to operate their own Effluent Treatment Plants (ETPs)—a rule these companies comply with—there remains a growing concern over the inefficient reuse of treated water and continued dependence on fresh groundwater, especially in a region already experiencing water scarcity.

While dyeing industries are officially classified under the "Orange" pollution category, indicating moderate pollution levels, their actual water discharge quality often reflects characteristics of the "Red" category, due to the presence of high chemical loads and untreated effluents in some instances. Notably, Obeetee Carpets pioneered industry-led wastewater management by establishing the first ETP in 1984, setting an important precedent. However, broader challenges persist, such as inadequate enforcement of reuse practices, lack of advanced treatment upgrades, and insufficient groundwater regulation. This points to a critical need for integrated water management policies, promotion of closed-loop recycling systems, and stricter monitoring to ensure environmental sustainability and long-term water security in the region.

3.8. Upstream - Downstream Water Quality

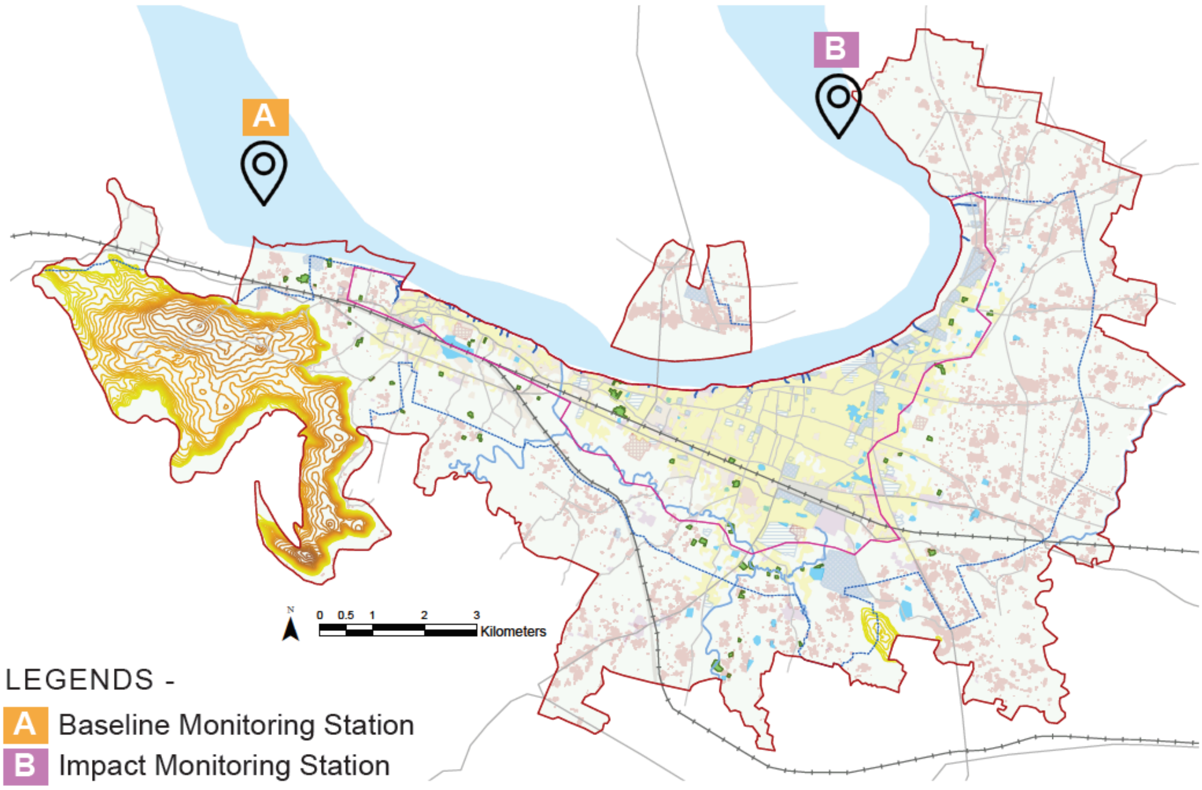


Figure 27: Location of Monitoring Stations

3.8.1. Dissolved Oxygen (D.O.) Level

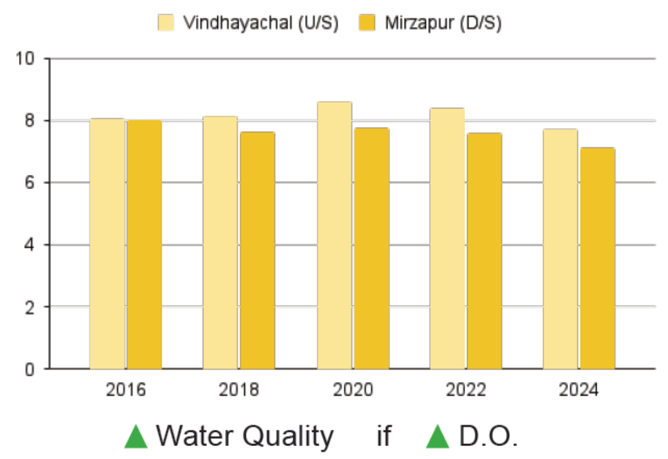


Figure 28: Dissolved Oxygen Level

The Dissolved Oxygen (DO) levels in the Ganga River at both upstream (U/S) and downstream (D/S) locations in Mirzapur have shown a gradual decline from 2016 to 2024, signaling a worsening water quality trend. DO is a critical parameter for assessing the health of a water body, as it directly influences the survival of aquatic organisms. A decline in DO levels typically points to an increase in organic pollution and reduced self-purification capacity of the river.

In particular, the sharp decrease in DO values at the downstream site of Mirzapur reflects the growing organic load and discharge of untreated or partially treated wastewater into the river. This is likely due to inputs from domestic sources, industrial effluents, and recontaminated treated water from open drains. Lower DO concentrations negatively impact aquatic biodiversity, leading to fish kills, reduced ecosystem resilience, and impaired riverine health. The data emphasizes the urgent need for better wastewater treatment, strict discharge regulations, and restoration efforts to improve the river's ecological balance and ensure long-term sustainability.

3.8.2. Biochemical Oxygen Demand (B.O.D.) Level

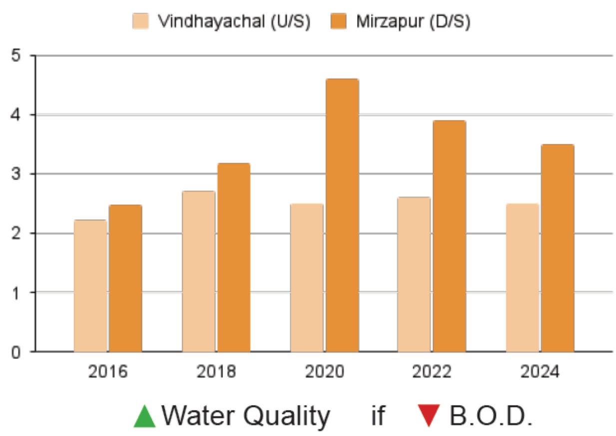


Figure 29: Biochemical Oxygen Demand Level

The Biochemical Oxygen Demand (BOD) levels at the downstream (D/S) location in Mirzapur peaked in 2020, indicating a period of high organic pollution and poor water quality in the Ganga River. However, with the commissioning of a new Sewage Treatment Plant (STP) shortly after, there has been a gradual decline in BOD levels from 2020 to 2024. This decline reflects a positive impact of improved wastewater treatment infrastructure, suggesting that the STP has played a role in reducing the organic load entering the river.

Despite this improvement, the BOD values still remain relatively high, especially downstream, which points to persistent pollution challenges such as incomplete treatment, illegal discharges, and recontamination from open drains. High BOD levels consume more dissolved oxygen (DO) from the water, which further degrades the aquatic ecosystem and river health. The trend indicates that while the new STP has made a difference, there is a need for stricter enforcement, better maintenance of sewer systems, and efforts to prevent untreated waste from mixing with treated effluents to achieve sustainable water quality improvements.

3.8.3. Faecal Coliform (F.C.) Level

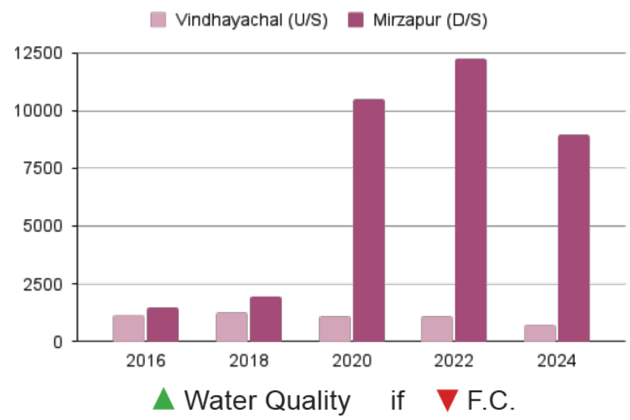


Figure 30: Faecal Coliform Level

The Fecal Coliform (FC) levels, a key indicator of sewage contamination, have been observed to be alarmingly high in the downstream (D/S) sections of the Ganga River in Mirzapur. This rise in FC levels signifies a serious deterioration in water quality, driven largely by the discharge of untreated or partially treated wastewater. While the upstream (U/S) areas have remained relatively stable, the surge in pollution load downstream points to localized contamination, especially from urban drains and household discharges that bypass treatment systems.

Although the commissioning of new Sewage Treatment Plants (STPs) has helped reduce overall pollution, the lack of complete drain coverage and open discharge points continues to compromise the gains made in wastewater management. Elevated FC levels not only signal poor sanitation practices but also pose direct health risks, contributing to the spread of waterborne diseases such as diarrhea, cholera, and dysentery. A sustainable improvement in river health demands not only infrastructural upgrades but also behavioral changes, strict enforcement of discharge norms, and full utilization and maintenance of existing STPs to ensure a long-term decrease in FC levels and a significant boost in overall water quality.

3.8.4. Total Coliform (T.C.) Level

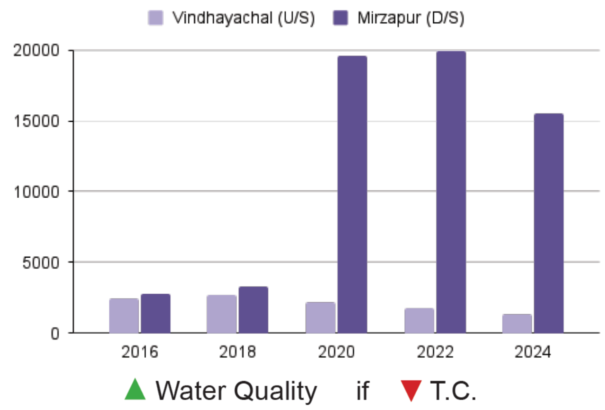


Figure 31: Total Coliform Level

The Total Coliform (TC) levels in the Ganga River around Mirzapur have shown a sharp rise between 2016 and 2022, reflecting a significant deterioration in water quality due to untreated sewage discharge and inadequate sanitation infrastructure. Although there was a slight decline in TC levels in 2024, the values still remain critically high, far exceeding the safe limits for domestic or recreational water use. This indicates that despite recent efforts such as the construction of new STPs, the impact on microbiological contamination has been limited.

However, a positive trend was observed in Vindhyachal, where TC levels declined, suggesting better upstream wastewater management or reduced contamination sources in that region. Nevertheless, persistently high TC levels downstream signal the continued presence of untreated sewage inflows, posing serious public health risks and threatening aquatic ecosystems. These findings highlight the urgent need for a holistic wastewater management strategy, including the tapping of all drains, behavioral change campaigns, regular water quality monitoring, and most importantly, reuse of treated water to prevent recontamination of cleaned water bodies.

3.8.5. Water Quality Assessment at Monitoring Stations (2024)

	PH	DO (mg/l)	BOD (mg/l)	FC (MPN/100ml)
Vindhayachal (U/S)	8.07 ✓	7.7 ✓	2.5 ✓	735 ✓
Mirzapur (D/S)	7.75 ✓	7.1 ✓	3.5 ✗	8945 ✗
Permissible Limit	6.5 - 8.5	> 5	<3	500-2500

Figure 32: Water Quality Parameters 2024

- Upstream (Vindhyachal) water quality is within permissible limits for all measured parameters.

- Downstream (Mirzapur) shows significant degradation in water quality, especially due to high BOD and FC levels, pointing to:
  - Untreated or partially treated sewage discharge
  - Lack of sanitation infrastructure in nearby settlements
  - Impact of human activities and insufficient wastewater treatment

3.8.6. Issues

- **Discharge of Untreated Wastewater from Drains into the Ganga River -**
  Numerous open drains directly discharge untreated domestic and industrial wastewater into the Ganga River. This occurs **despite the presence of multiple Sewage Treatment Plants (STPs)** in the region, indicating either **underutilization or inefficiency** of existing infrastructure. These untreated discharges significantly elevate the **organic and microbial pollution loads** in the river, especially downstream, leading to **environmental degradation and threats to aquatic ecosystems**.
- **Lack of Sewerage Connections Among Riverbank Households-**
  A substantial number of **households located along the riverbanks** lack proper sewerage infrastructure and connections to the municipal sewer system. Consequently, **wastewater from these households is disposed of directly into the river** without undergoing any form of treatment. This not only contributes to increased **faecal contamination** and **pathogen load**, but also poses **serious public health risks** for communities that rely on the river for domestic or agricultural purposes.
- **Downstream WQ Falls Below Class B Standards – Relegated to Class C -**
  Water quality analysis at **Mirzapur (D/S)** reveals **Biochemical Oxygen Demand (BOD) and Faecal Coliform (FC)** levels that exceed the permissible limits defined for **CPCB Class B water quality standards (outdoor bathing)**. As a result, the downstream water **does not qualify for Class B** and is more accurately categorized under **Class C**, which is intended for **drinking water sources with conventional treatment**. This shift in classification indicates that the **river water has become unsuitable for direct contact or recreational use**, reflecting **serious pollution levels** and degradation of water quality.

4. Proposal, Strategies and Recommendations

4.1. Treated Wastewater Reuse Action Plan

4.1.1. Procedure To Identify Potential Bulk Users

- Identify potential avenues for wastewater reuse.
- Calculate the water demand of each identified avenue.
- Determine the accessibility and location of potential bulk users.
- Assess the frequency of water requirements for each user.
- Define the required water quality standards based on usage.
- Identify suitable modes of wastewater conveyance.
- Establish safety protocols and appropriate methods for using treated wastewater.

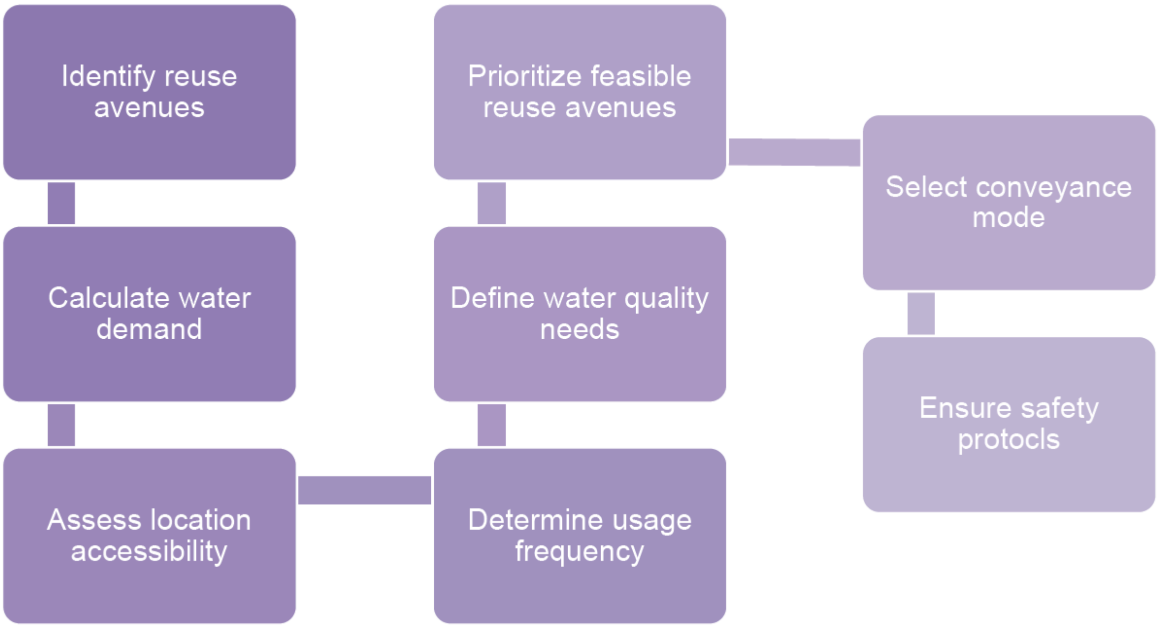


Figure 33: Procedure To Identify Potential Bulk Users

4.1.2. Potential Reuse Avenues For Treated Wastewater

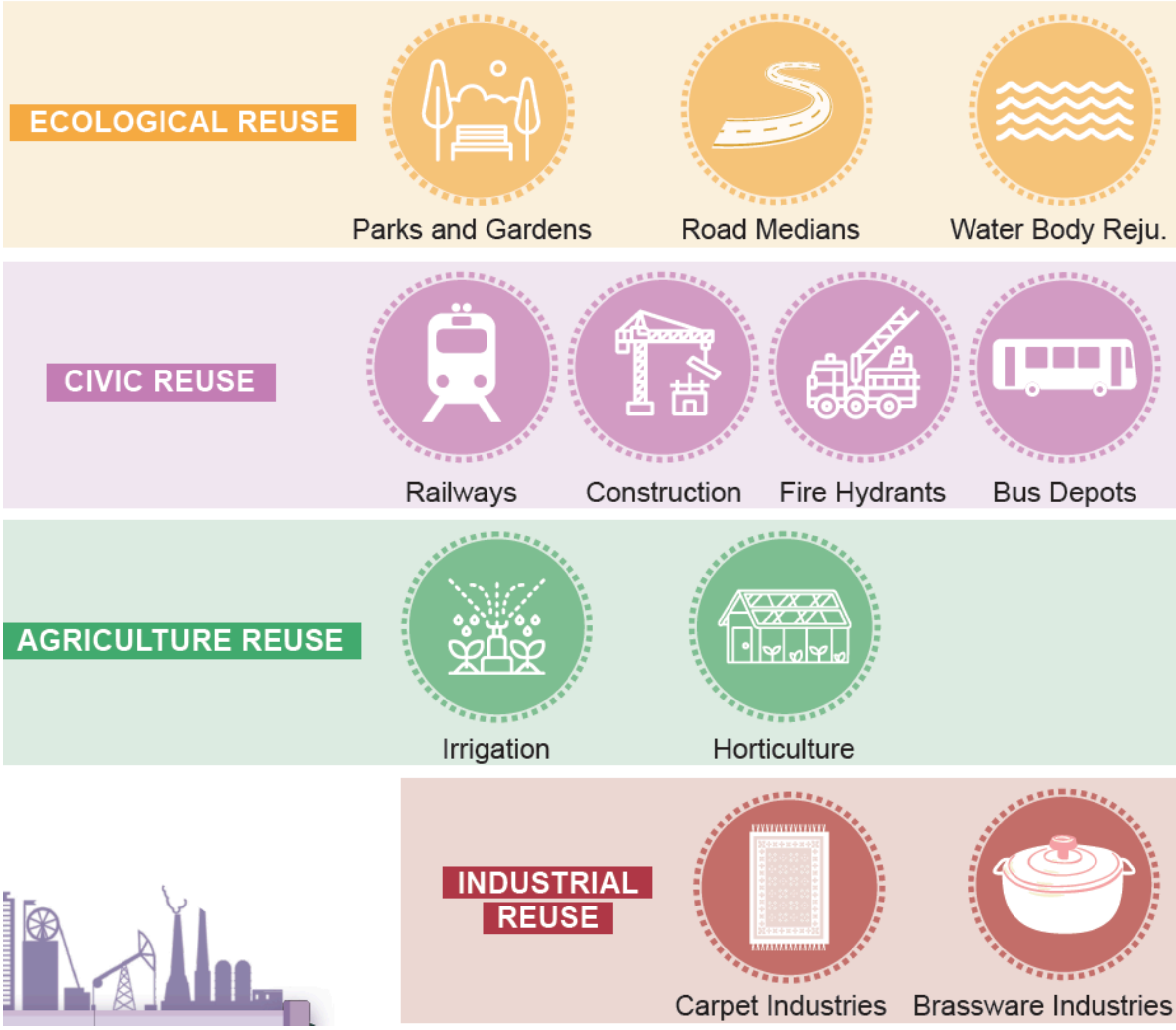


Figure 34: Possible reuse avenues

4.1.3. Identified Bulk Users in Accessible Radius of STP 1 And 4 - Pakka Pokhra

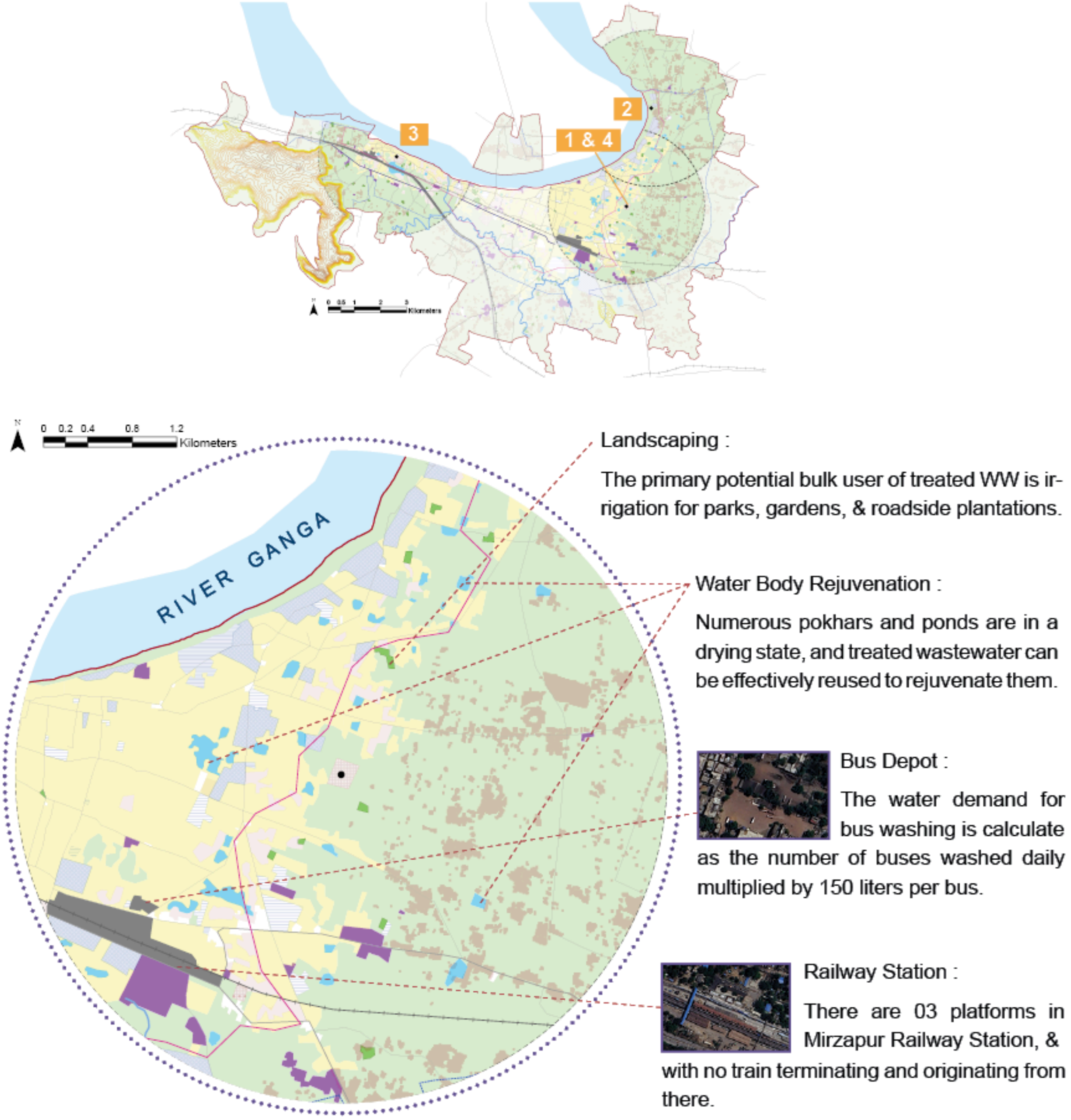


Figure 35: Identified Bulk Users in Accessible Radius of STP 1 And 4 - Pakka Pokhra

Landscaping

WD = total area (in sq m) * water required / sq m (2.5 L / sq m)

- Total Area = 61,265 sq m
- Water Demand = 153162.5 L or 0.15 ML

Railways

WD = water required to wash platform (5 liters / sqm)

- Total Area = 22,378.79 sq m
- Water Demand = 111894 L or 0.11 ML

4.1.4. Identified Bulk Users in Accessible Radius of STP 2 - Bisunderpur

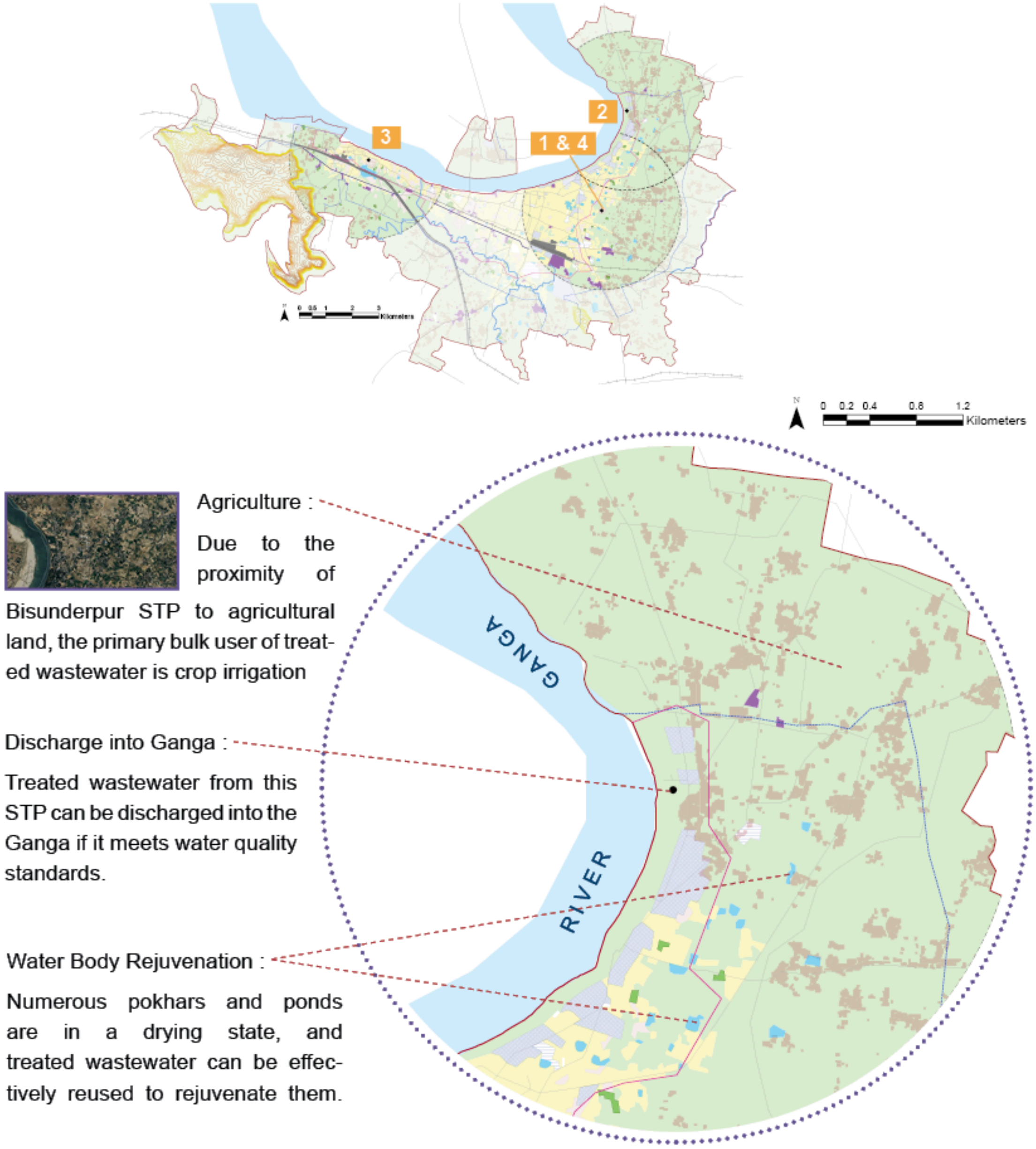


Figure 36: Identified Bulk Users in Accessible Radius of STP 2 - Bisunderpur

Water Body

WD = calculate the volume of water body

4.1.5. Identified Bulk Users in Accessible Radius of STP 3 - Vindhyachal

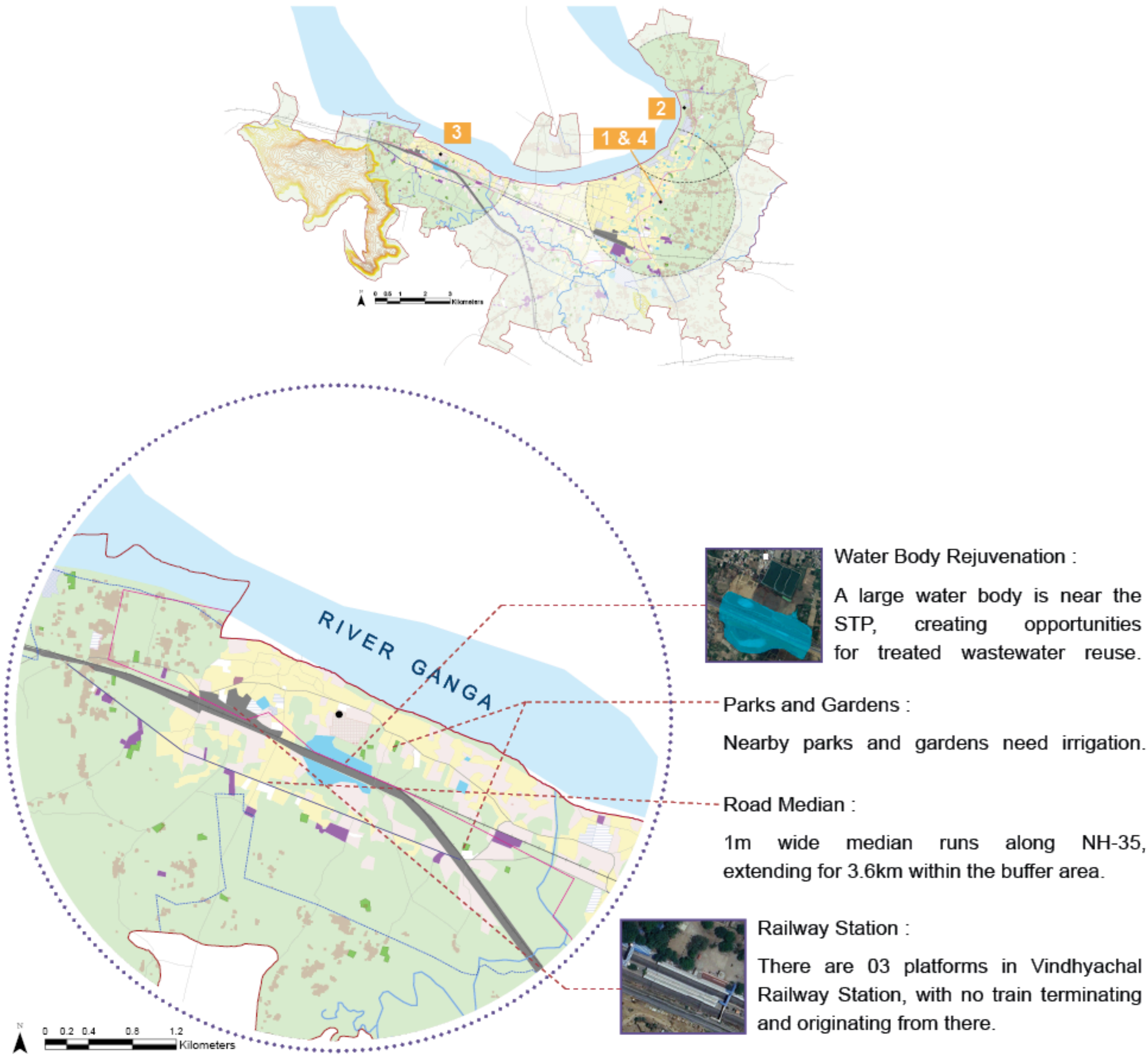


Figure 37: Identified Bulk Users in Accessible Radius of STP 3 - Vindhyachal

Landscaping

WD = total area (in sq m) * water required / sq m (2.5 L / sq m)

- Total Area = 87,960 sq m
    - Parks and Gardens = 84,294 sq m
    - Road Median (1 m thick) = 3,666 sq m
- Water Demand = 153162.5 L or 0.15 ML

Railways

WD = water required to wash platform (5 liters / sqm)

- Total Area = 12,663.84 sq m
- Water Demand = 63319 L or 0.06 ML

4.1.6. Recommendations & Strategies For Potential Reuse Avenues For Treated Wastewater

Construction

Strategies

- ULBs should make it mandatory for large construction projects to use treated wastewater, reducing dependence on freshwater sources.
- During project approvals, water demand should be assessed and a specific quantity of treated wastewater should be enforced for reuse.
- Treated wastewater should be supplied to construction sites via tankers at a minimal or subsidized cost to make it economically viable.
- Treated wastewater can be safely used for concrete mixing, curing, dust suppression, soil compaction, and road construction, as long as it meets BIS standards.
- To promote adoption, ULBs can offer incentives like reduced fees, tax rebates, or fast-track approvals for projects that use treated wastewater.

Indian Case Example

- **Delhi Metro Rail Corporation (DMRC):** Used treated wastewater for concrete mixing and curing, significantly reducing potable water consumption in metro construction.
- **Pune Municipal Corporation:** Enforced mandatory use of treated wastewater for construction activities, supplying water through tankers at a subsidized rate.

Safety Protocols

- **Water Quality Compliance:** Ensure wastewater meets BIS/CPHEEO standards for non-potable use.

- **Storage & Handling:** Store wastewater in designated tanks to prevent contamination and odors.
- **Prevent Cross-Contamination:** Use separate pipelines and equipment for freshwater and treated wastewater.
- **Regular Monitoring:** Conduct periodic quality checks to maintain safe usage standards.

Agriculture

Strategies

- Promote treated wastewater reuse under Pradhan Mantri Krishi Sinchayi Yojana.
- Farmers can be charged ₹5 per 1,000L of treated WW to ensure affordability while covering OC.
- Early adopters of wastewater reuse can receive financial incentives or reduced water tariffs.
- The Ojhala Nadi can be used as a natural irrigation canal for transporting treated wastewater to agricultural fields.
- Encourage WW irrigation for non-edible crops, fodder, and floriculture to minimize health risks.
- Collaborate with private entities to develop WW irrigation projects.

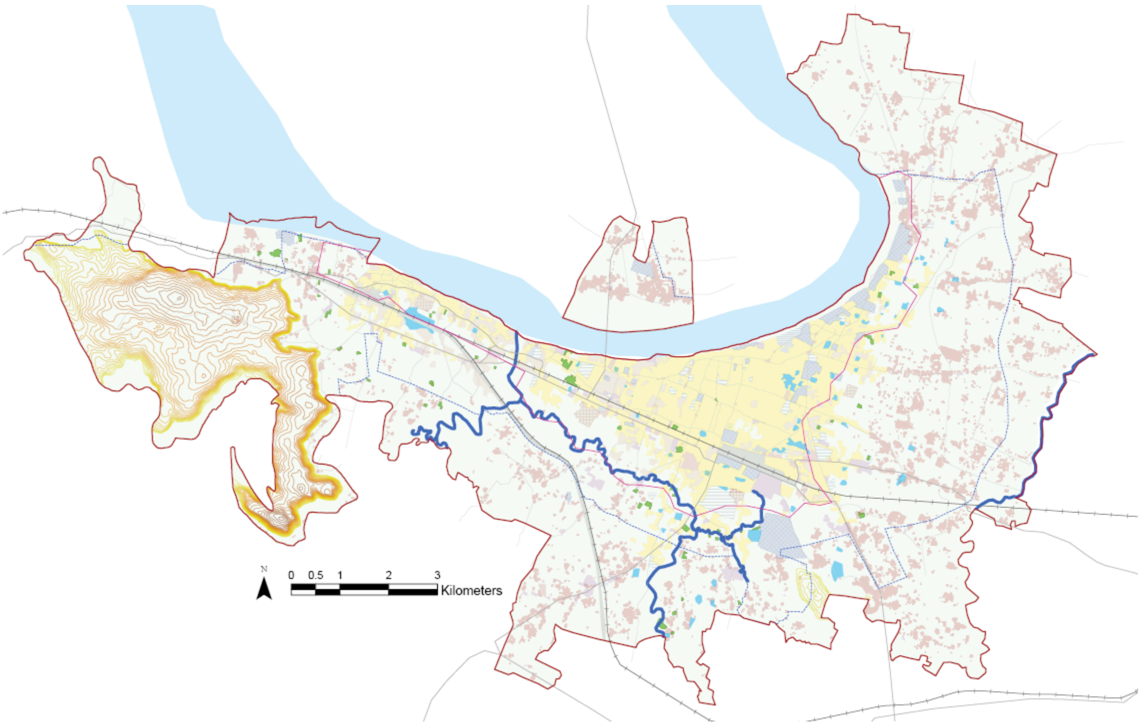


Figure 38: Location of Ojhala Nadi

Safety Protocols

Subsurface drip irrigation is ideal for using treated wastewater because it applies water directly to the root zone beneath the soil, avoiding contact with leaves, fruits, or humans. This minimizes health risks, prevents odor and pathogen exposure, reduces evaporation losses, and ensures efficient, safe irrigation—especially for parks, gardens, and non-edible crops.

Industries

Strategies

- Industries should be restricted from extracting groundwater.
- On-Site reuse of ETP-treated wastewater for dyeing, cooling, and cleaning instead of discharge.
- Additional water needs should be met from nearby STPs.
- Strict monitoring & enforcement for compliance.
- Industries adopting wastewater reuse should receive benefits like tax rebates or lower industrial water tariffs.

Indian Case Example

- **Tiruppur, Tamil Nadu:**
    - The textile industry **reuses treated wastewater** for dyeing and finishing, reducing dependence on fresh water.
    - **Common Effluent Treatment Plants (CETPs)** are installed for collective wastewater treatment.
- **Nagpur, Maharashtra:**
    - Industries purchase **treated wastewater from Bhandewadi STP**, reducing groundwater extraction.
    - **PPP models** ensure financial sustainability and efficient wastewater reuse.

Safety Protocols

- **Water Quality Compliance:** Ensure treated wastewater meets required BIS and CPCB standards for industrial applications.
- **Regular Monitoring:** Conduct routine testing of treated wastewater for heavy metals, toxins, and pathogens.

- **Proper Disposal of Sludge:** Sludge generated during treatment should be safely managed to prevent environmental hazards.
- **Efficient Storage & Distribution:** Treated wastewater should be stored in leak-proof tanks and transported through a regulated supply system.

Fire Hydrant

Water Demand

Q = 100 √P, where Q is water required in cubic meters & P is population in thousands

- Population = 2,94,782
- Water Demand = 29,47,820 L or 2.95 ML

Strategies

- Treated WW can be safely reused for non-potable firefighting purposes, for refilling fire tenders.
- Since the fire station is near the Pakka Pokhra STP, treated wastewater can be easily supplied via tanker trucks or piped network.

Landscaping (parks, gardens and road medians)

Water Demand (for areas outside buffer area of any STP)

WD = total area (in sq m) * water required / sq m (2.5 L / sq m)

- Total Area = 2,30,205 m
  - Parks and Gardens = 2,26,550 sq m
  - Road Median (1 m thick) = 3,655 sq m
- Water Demand = 5,75,512 L or 0.57 ML

Frequency

Landscaping should be watered daily using treated WW.

Mode of Conveyance

Water tanker trucks should be used for watering it.

Strategies

- **Sprinkler Systems**: Encourage mechanized watering (sprinklers, drip irrigation) to reduce human contact and water wastage.
- **Early Morning Watering**: Schedule irrigation during early hours to minimize public exposure and maximize efficiency.
- **Community Participation**: Involve RWAs and park committees in monitoring and managing wastewater reuse.

Safety Protocols

- Avoid direct human contact during reuse.
- Use mechanized irrigation methods like sprinklers, or drip irrigation.
- Schedule reuse during early morning or late evening to minimize public exposure.

Railways

Frequency and Mode of Conveyance

Treated WW should be supplied daily via water tankers.

Safety Protocols

- Implement a color-coded or labeled pipeline system to prevent cross - contamination with potable water supplies.
- Conduct it during non-peak hours to reduce public exposure.

Water Body Rejuvenation

Mode of Conveyance

- Transported primarily through pipelines or dedicated canals.

Safety Protocols

- Ensure treated WW meets environmental standards before discharge.
- Allow treated wastewater to percolate into aquifers through recharge groundwater.

Strategies

- Allow treated WW to flow into degraded water bodies to support ecological rejuvenation, & maintain base flow.

Indian Case Example

- **Nagpur, Maharashtra:**
    - ULB uses treated wastewater to recharge lakes and for industrial reuse, reducing stress on freshwater sources while improving urban water bodies.

4.2. Desired Wastewater Flows

This diagram illustrates a circular approach to wastewater management, connecting wastewater generation, treatment, reuse, and resource recovery. Domestic and industrial wastewater from point sources is sent through sewer connections to Sewage Treatment Plants (STPs) or Industrial Treatment Plants (ETPs). Non-point source pollution like urban and agricultural runoff also enters the system. After treatment, the water is either reused or safely discharged.

Treated wastewater is reused in various sectors such as landscaping, construction, bus depots, and railways. Excess treated water helps rejuvenate water bodies, which can later be pumped, treated again, and supplied for domestic use—closing the water loop.

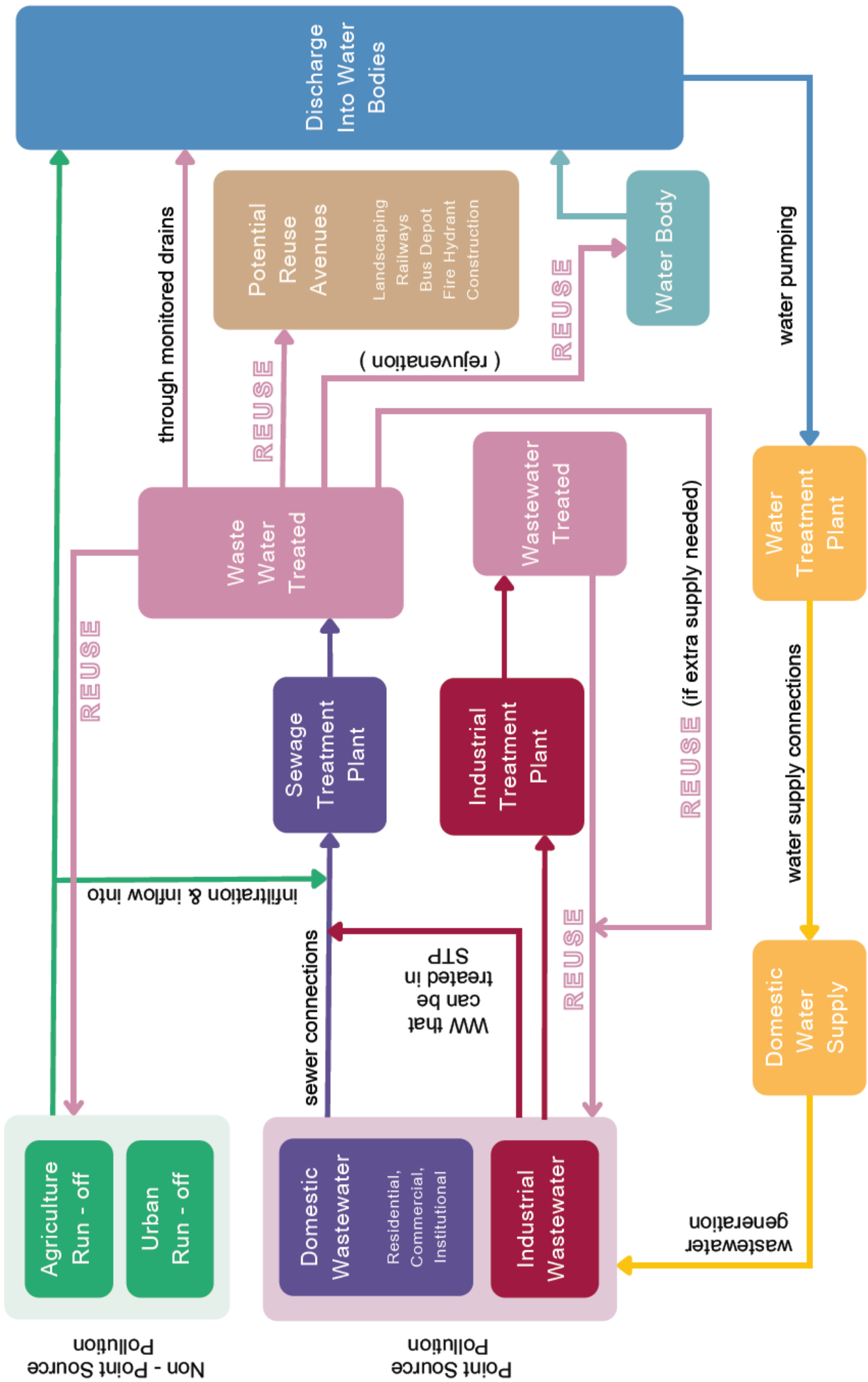


Figure 39: Desired Wastewater Flows

4.3. Natural Treatment For Drains

4.3.1. Hotspot Areas

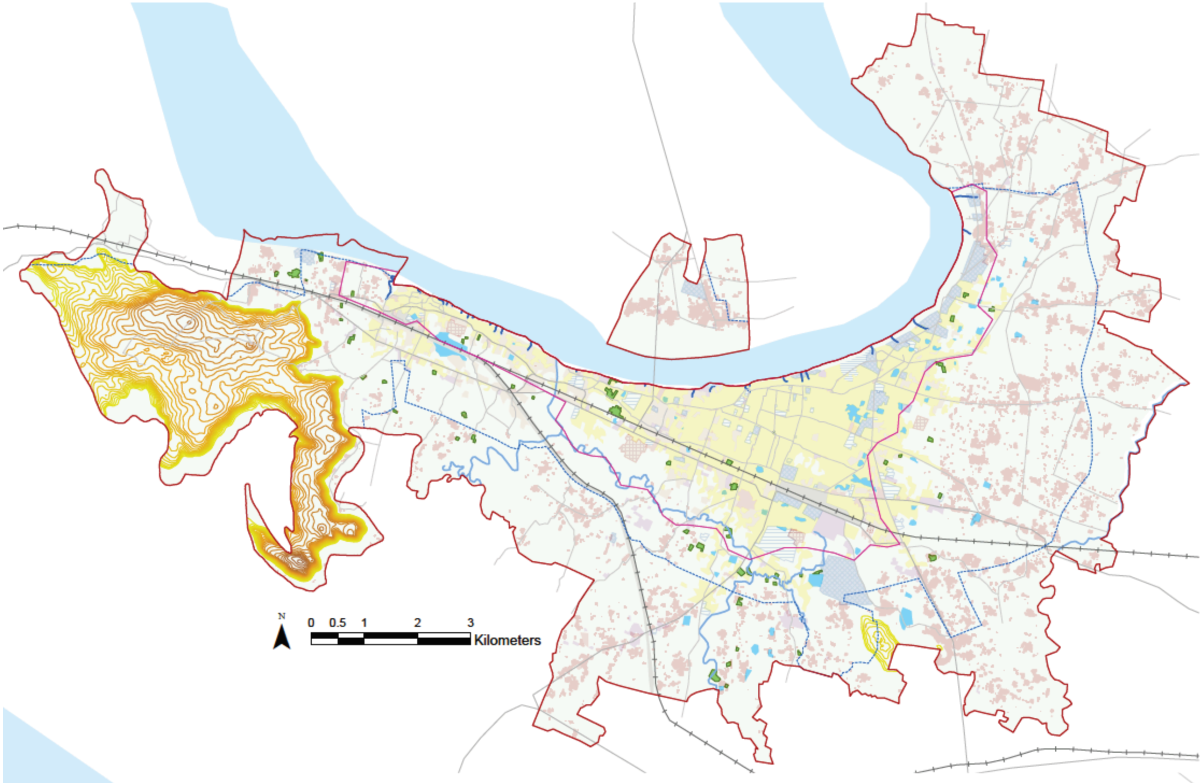


Figure 40: Location of drains

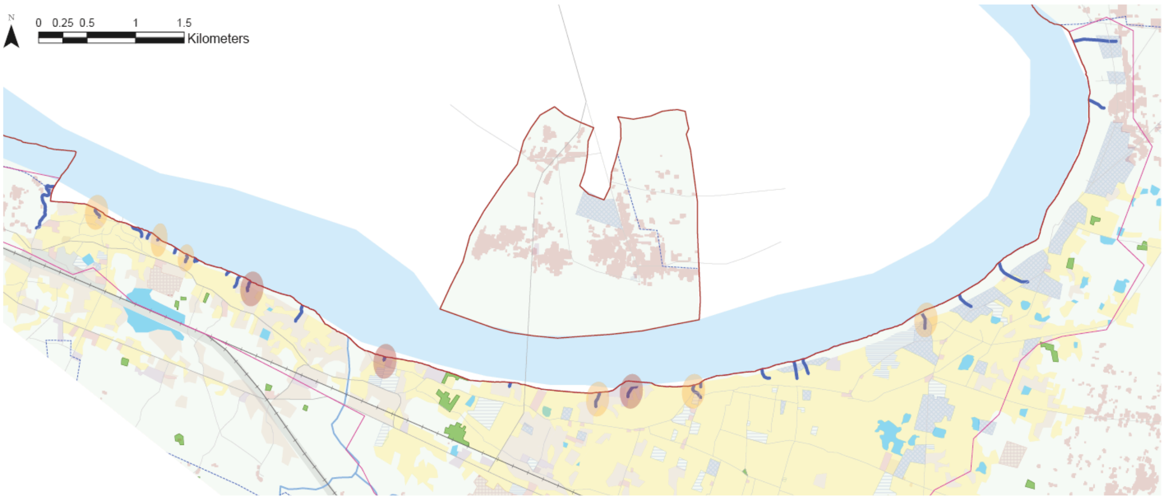


Figure 41: Hotspot areas of most polluted drains

Drains

1. Malhaya Drain
2. Balughat Kaccha Drain
3. Parasuram Drain

4. Chorawa Drain
5. Lift Canal Drain
6. Public Club Drain
7. Khandawa Drain
8. Balaji Drain
9. Kachahari Drain

4.3.2. Bioremediation

Bioremediation is a nature-based technique that uses microorganisms, plants, or enzymes to break down or neutralize pollutants in wastewater flowing through drains.

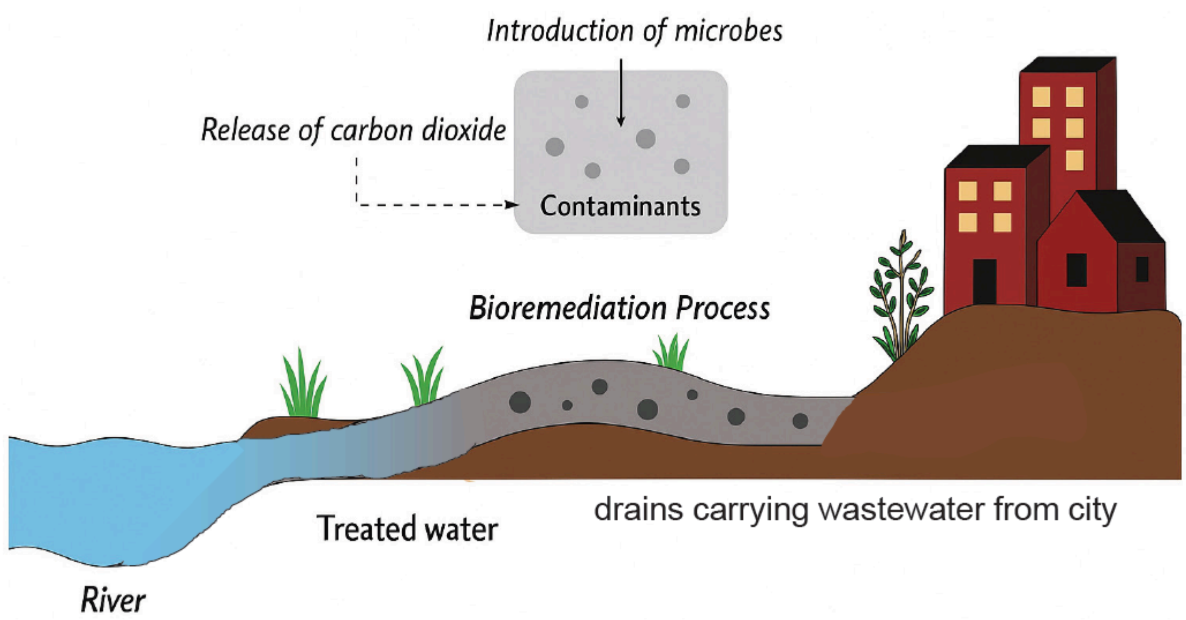


Figure 42: Process of Bioremediation (Source : Jyoti Verma , NIUA)

4.3.3. How It Works

1. Introduce microbes (bacteria or fungi) into the drain.
2. Microbes break down organic waste and nutrients like nitrogen and phosphorus.
3. Pollutants convert into harmless by-products like carbon dioxide, water, and biomass.
4. Plant aquatic vegetation in drains to boost natural treatment.

4.3.4. Advantages

- Cost effective due to low O & M cost.
- Suitable for drains with low to moderate pollutant loads.
- On-site process, minimizing excavation and environmental disruption.

4.4. Sewage Treatment Plant

4.4.1. Infrastructure Upgradation

- **Mandate Full-Capacity Operation:** Introduce a local/state-level regulation that requires all operational STPs to function at ≥ 85% capacity utilization based on actual wastewater inflow data.
- **Penalty for Underperformance**: Impose penalties or notices for consistent underutilization (e.g., <60% usage for more than 6 months) without technical justification.

4.4.2. Aligning Pakka Pokhra With Cpcb 2017

- **Mandatory Upgrade to CPCB 2017 Norms:** Enforce statutory compliance requiring the STP to align with CPCB 2017 discharge standards, replacing the outdated 1986 norms.

4.4.3. Stopping Re - Pollution

- The open outlet drain should be converted into a covered or piped system to avoid illegal discharges by households.
- Enforcement measures and penalties should be introduced for unauthorized waste disposal.

4.5. Circular Economy

4.5.1. Sludge to Biofertilizer (Agricultural Use)

- Treat and convert sewage sludge into nutrient-rich compost or organic manure.
- Distribute the processed sludge to farmers at minimal or no cost through municipal partnerships.

4.5.2. Energy Recovery from Sludge (Biogas)

- Generate biogas from sludge using anaerobic digestion.
- Use biogas to power STP operations.

5. Annexure

5.1. Systematic Literature Review

GUARDING THE RIVER GANGES: MIRZAPUR'S COMPREHENSIVE PLAN FOR SUSTAINABLE WASTEWATER MANAGEMENT AND REUSE										
S. No.	**Title**	**Author**	**Year**	**Journal**	**Publisher**	**Research Focus**	**Methods & Tools**	**Findings**	**Research Gap**	**References**
1	A Case Study on Sewage Treatment Plant (STP), Delawas, Jaipur	Rahul Sharma, Pritesh Agrawal	2017	International Journal of Engineering Science and Computing	PEARL MEDIA PUBLICATIONS PVT LTD	This paper aims at investigating sustainable wastewater reuse and the case study chosen is the Delawas Sewage Treatment Plant (STP) Jaipur, India. It encompasses safety, perception and possibility of conversion into energy, in its efforts of minimizing the environmental footprint and enhancing the utilization of resources.	The work uses observations of the STP processes such as wastewater treatment and biogas production at the research site. Questionnaires are used to collect the public perception on the use of treated water reuse, while chemical analysis and records on the plant performance are used to obtain the technical information.	The Delawas STP works effectively with the help of activated sludge process and generate biogas and nutrient rich sludge. Treated water is sometimes used for irrigation but there is no proper reuse systems or disinfection. Horticulture and industrial usage are more acceptable than the food crops by the public.	Some of these gaps are; Poor public perception of treated water as safe and useful, lack of tertiary treatment such as tertiary treatment processes, and lack of structures for systematic reuse. Thirdly, there is a lack of sufficient legal and regulatory instruments to support safe and efficient water reuse.	Sharma, R., & Agrawal, P. (2017). A case study on sewage treatment plant (STP), Delawas, Jaipur. Int. J. Eng. Sci. Comput, 7(5). https://www.irjet.net/archives/V7/i7/IRJET-V7I7491.pdf
2	A circular economy approach for sustainable water reuses in India: policies, practices and future prospects	Divya Dubey, Saroj Kumar, Venkatesh Dutta	2024	Environmental Sustainability	Springer	The research is dedicated to solving India's critical problems of freshwater scarcity by fostering circular reuse of water through high-end wastewater treatment methods. This review looks at challenges including deficiency in facilities, poor resource mobilization and efficient policies, and restrictions in policy reforms to advance the use of wastewater reuse.	Using a literature review, case studies and policy analyses approach, the study aims at identifying a range of challenges and opportunities of wastewater treatment and reuse in India. This work utilizes stakeholder analysis, legal requirements, and performance reviews of treatment technologies for developing implications.	Some challenges include; lack of treatment structures, policy uncertainties, low demand in the market, and consumer's reluctance to consume treated water. Government policies, tertiary treatment technology and public private partnership have emerged as best practice strategies for Cost effective wastewater reuse in industrial and agricultural sectors as exposed by case studies.	They found that there are no integrated national standards for water reuse, poor public awareness and lack of use of modern, low cost treatment technologies. The authors urge more research on interesting topics in operational scalability of decentralised systems, and ways to increase public acceptance of reclaimed water for sustainability.	Dubey, D., Kumar, S., & Dutta, V. (2024). A circular economy approach for sustainable water reuses in India: policies, practices and future prospects. Environmental Sustainability. https://doi.org/10.1007/s42398-024-00321-z
3	A Review of Wastewater Pollution by Diuron: From Its Origin to Treatments for Safe Reuse	Cristian Yoel Quintero-Castañeda, Claire Tendero, Thibaut Triquet, Oscar H. Moreno-Torres, María Margarita Sierra-Carrillo and Caroline Andriantsiferana	2024	Water	MDPI	The present study looks into water reuse of wastewater after the removal of micropollutants using different treatment technologies for combating water scarcity at the global level with especial reference to pesticide diuron. It looks at the possibility of using AOPs to manufacture water of good quality suitable for reuse from WWTP effluents.	In the study, a systematic review of wastewater reuse around the world is conducted with emphasis on diuron as an example of the emerging organic contaminant. It assesses the effectiveness of traditional and innovative treatment processes such as photocatalysis with TiO_2 from lab and pilot test data.	The utilizing of WRRF has a lot of advantages, such as minimum abstraction of natural water, diminished pollution, and water and resources regeneration. Micropollutants such as diuron can only be partially eliminated by conventional processes in the WWTPs requiring special treatments. Laboratory studies have demonstrated that photocatalysis using TiO_2 is very effective in the degradation of diuron, but further work has to be done to bring these processes on an industrial scale. As the regulations for safe pesticides remain lax Asia and Latin America, the contamination risks rise as overall usage in the farming processes rises.	The study reveals the absence of industrial-scale, cost effective methods for advanced treatment of micropollutants such as diuron in the effluent from the WWTPs. On the other hand, laboratory scale results look encouraging, but, pilot scale and large scale come across with technical and economical hurdles. Also, lax policies regarding the use of pesticides in the developing countries compound the effects of water pollution hence the importance of standardization of policies as well enhancement of technology.	Quintero-Castañeda, C. Y., Tendero, C., Triquet, T., Moreno-Torres, O. H., Sierra-Carrillo, M. M., & Andriantsiferana, C. (2024). A Review of Wastewater Pollution by Diuron: From Its Origin to Treatments for Safe Reuse. Water, 16(23), 3524. https://doi.org/10.3390/w16233524
4	A study on Sewage Treatment and Disposal in Delhi	Shreya Gupta, SK Singh, Vishal Gandhi	June 2018	International Journal of Advance Research and Innovation	GLA University	The study explores the present status of running sewage treatment plants (STPs) in Delhi with respect to its capacity, technologies and shortcoming in managing the aspect of wastewater. It discusses problems associated with untreated sewage discharge, lack of capacity, and management of the existing structures as well as introducing ideas like Vermifiltration technology.	Extensive primary field research includes 35 online STP case studies in Delhi besides, visits to significant plants including Okhla STP. Information was gathered concerning location, availability of treatment capacities, technological approaches implemented and efficiency on treatment and reuse. Comprehensive comparison of the treatment technologies and the novel solutions including Vermifiltration was also discussed.	Delhi produces 3909 MLD of sewage out of this only 2940.66 MLD is treated and 1268.34 MLD is still not treated. Some of the operational STPs use the conventional treatment processes such as ASP- but vermifiltration, another innovation being introduced in this research, has the advantage of providing effective multi-stage treatment process and pathogen removal.	While the existing STPs are technologically developed, there is inadequate management as well as optimization of the facilities. Further, weak implementation and replication of such modern and eco-friendly technologies such as Vermifiltration also prevent Delhi from truly closing the sewage treatment gap. Growing attention must be paid to such aspects as cheap and distributed structures and upgraded management approaches.	Gupta, S., Singh, S. & Gandhi, V. (2018) A study on sewage treatment and disposal in Delhi. International Journal of Advance Research and Innovation, 6(2), 88–91. https://ijari.org/assets/papers/6/2/IJARI-CV-18-06-104.pdf
5	A Study on the Sewage Disposal on Water Quality of Harmu River in Ranchi City, Jharkhand, India	Arvind Kumar Rai, Biswajit Paul, Nawal Kishor	2012	International Journal of Plant, Animal and Environmental Sciences		This work aims at comparing the physical and chemical properties of the Harmu River water in Ranchi City, Jharkhand, in order to establish the effects of the disposing off sewage and urban wastes on water quality. Among the parameters measured there is pH, electrical conductivity, total dissolved solids, suspended solids, hardness, alkalinity, chloride, and dissolved oxygen.	Water samples were collected from three sites along the Harmu River during morning hours (9:00 a.m. to 11:30 a.m.). Analytical techniques described in APHA (1985) were used for determination of some water quality parameters prepared from AR grade chemicals and double distilled water.	The study established major declines in water quality in the Harmu River. Concentration levels of parameters such as pH, TDS, hardness and dissolved oxygen were determined to have exceeded WHO recommended standards. Such sources of pollution as direct discharge of sewage, dumping of urban wastes, and absence of vegetation along the river banks were pointed out. DO levels were at very low levels, meaning that aquatic life was at-risk and water usability downstream was severely compromised.	It is also important to note, that although the study presented, established both direct and indirect physico-chemical effects, the variations in biological pollutants and the potential variation in water quality between the two seasons was not explored. Third, there is scarce knowledge on rehabilitation measures or approaches regarding sustainable River management as a way of checking pollution.	Paul, B., Rai, A. K., & Kishor, N. (n.d.). A STUDY ON THE SEWAGE DISPOSAL ON WATER QUALITY OF HARMU RIVER IN RANCHI CITY JHARKHAND, INDIA. https://www.researchgate.net/publication/260349990

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6	Acceptance of on-site wastewater treatment and reuse in Bengaluru, India: The role of perceived costs, risks, and benefits	Josianne Kollmann, Shreya Nath, Sneha Singh, Sahana Balasubramanian, Eva Reynaert, Eberhard Morgenroth, Nadja Contzen	June 2023	Science of the Total Environment	Elsevier	This study examines the acceptance of on-site wastewater treatment systems in Bengaluru, India, focusing on perceived costs, risks, and benefits as predictors of acceptance. The research compares mandated users and non-users of on-site systems to identify key factors influencing their perspectives and potential adoption behavior.	An online survey was conducted between November 2021 and February 2022, targeting Bengaluru residents. Participants were divided into two groups: mandated users and non-users. The survey included sociodemographic questions, multiple-choice quizzes on system knowledge, and a series of rating scales for perceived costs, risks, and benefits. Statistical analyses, including Mann-Whitney U tests, correlation analyses, and regression analyses, were used to assess the data.	Both users and non-users perceived costs, risks, and benefits of on-site systems as similarly high, but only perceived benefits—such as environmental pollution reduction, user image improvement, and financial benefits for the city—significantly predicted acceptance. Differences in subjective relevance of these benefits were observed, with mandated users valuing personal image more and non-users emphasizing city-wide financial benefits. Costs and risks did not significantly hinder acceptance, and acceptance was generally high among both groups.	The study is limited by its focus on English-speaking, educated participants, excluding those of lower socioeconomic status, which restricts generalizability. It also lacks causal evidence due to its cross-sectional design. Future research could explore longitudinal effects, examine diverse demographic groups, and investigate acceptance in other geographic or policy contexts to provide a broader understanding of on-site system adoption.	Kollmann, J., Nath, S., Singh, S., Balasubramanian, S., Reynaert, E., Morgenroth, E., & Contzen, N. (2023). Acceptance of on-site wastewater treatment and reuse in Bengaluru, India: The role of perceived costs, risks, and benefits. The Science of the Total Environment, 895, 165042. https://doi.org/10.1016/j.scitotenv.2023.165042
7	Addressing water stress through wastewater reuse: Complexities and challenges in Bangalore, India	Priyanka Jamwal, Bejoy K Thomas, Sharachchandra Lele and Veena Srinivasan	May 2014	Resilient Cities 2014	ICLEI	The study explores wastewater treatment and reuse (WWRU) as a strategy to mitigate water stress in urban centers, focusing on Bangalore, India. It examines the efficiency of current treatment systems, debates centralized versus decentralized treatment scales, and investigates the downstream impacts of untreated wastewater on agriculture and inter-state river water-sharing commitments. The research emphasizes the need for a basin-scale perspective to address technical, institutional, and socio-environmental challenges of WWRU.	The study integrates primary data from wastewater treatment systems in Bangalore with analysis of debates on treatment scale and downstream usage impacts. It draws on findings from the "Adapting to Climate Change in Urbanizing Watersheds" project and related studies funded by international and national organizations. Qualitative and quantitative assessments, alongside stakeholder analysis, were employed to investigate technical efficiencies, institutional roles, and socio-environmental effects.	The sewage treatment plant on the Vrishabhavathy River was found to be inefficient, with no significant improvement in water quality. Centralized treatment systems dominate, but decentralized systems may offer cost-effective alternatives. Untreated wastewater supports downstream agriculture but poses health risks, while upstream recycling can reduce water availability for irrigation, affecting livelihoods. Basin-scale challenges, such as inter-state water-sharing obligations, complicate WWRU implementation. Effective WWRU requires integration of techno-institutional frameworks, stakeholder coordination, and attention to hydrological and socio-economic impacts.	The study highlights limited exploration of hydrological links between upstream recycling and downstream use. There is a lack of research on socio-technical reconfigurations and environmental flow requirements needed for WWRU implementation. Additionally, institutional fragmentation and inadequate stakeholder engagement remain underexplored barriers to achieving effective and sustainable WWRU solutions.	Jamwal, P., Thomas, B. K., Lele, S., & Srinivasan, V. (2014). Addressing water stress through wastewater reuse: Complexities and challenges in Bangalore, India. In COREView & ePrints@ATREE, Proceedings of the Resilient Cities 2014 Congress [Conference-proceeding]. http://resilient-cities.iclei.org/
8	Advanced Technologies of Water and Wastewater Treatment	Athanasia K. Tolkou and George Z. Kyzas	2024	Environments	MDPI	To this extent, this research aims at exploring advanced water and wastewater treatment technologies because of natural water contamination and to encourage water reuse. These are areas of the treatment of new pollutants including heavy metals, pharmaceuticals, micro-plastics, and pesticides, as well as agricultural and industrial water re-use.	Several treatment technologies were reviewed, including; biological treatment, membrane processes, adsorption, coagulation/ion exchange, advanced oxidation and integration of two or more processes. Laboratory tests were conducted using batch and continuous reactors, analysis of fixed and first order decay constants,, BioWin, and EPANET modeling, and pilot scale studies for assessing treatment efficacy, contaminant removal, and system performance optimality.	Significant progress was noted in biology of additive emissions control for livestock waste, systems of photocatalytic water disinfection, constructed wetlands for grey water and industrial effluents treatment. Research showed that advanced centralized and decentralised wastewater technologies are suitable for small communities and new materials such as Mg-Si-La@AC for heavy metal elimination. Major advancement was achieved in using bacterial and yeast strains to degrade micro plastic and in fact and phosphorus recovery from wastewaters.	Some limitations still exist as follows which encompass difficulties in up-scaling the laboratory data for industrial usability, ineffectiveness in the treatment technology of the composite pollutants, and weak regulatory standards in Asia and Africa. The problem is a scarcity of research on real-world applications and long-term profitability and sustainability of advanced systems. More research has to be directed towards advanced oxidation processes, and advanced oxidation processes integrated systems, for efficient and economical water treatment.	Tolkou, A. K., & Kyzas, G. Z. (2024). Advanced Technologies of Water and Wastewater Treatment. Environments, 11(12), 270. https://doi.org/10.3390/environments11120270
9	Analysing the co-benefits: case of municipal sewage management at Surat, India	Manmohan Kapshe, Paulose N. Kuriakose, Garima Srivastava, Akhilesh Surjan	2013	Cleaner Production	Elsevier	The study concentrates on providing solution to climate change mitigation and environmental sustainability through smart urban wastewater management. In particular, it assesses methane capture and electricity generation from STPs in Surat, India. The study also demonstrates the direct and ancillary benefits of such projects, including reduction in greenhouse gas emission, generation of clean energy, production of organic manure, and mitigation of water pollution.	The study uses a case study methodology to capture and examine the methane recovery systems in selected STPs in Surat. Quantitative data thus covers the initial and final CO2 equivalent emissions, electricity generated, and organic manure produced. Data collection includes organisational field visits, interviews with SMC-sourced records, and observation. Water quality changes are measured in terms of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) which are the environmental parameters.	Surat's sewage treatment plants lowered the emission of CO2 equivalents by 80,000 tonnes per annum by capturing methane and generating 1.5–2.5 million kilowatt-hours of electricity. They also generate 3,000-5,000 tonnes of organic manure per annum which the organization earns INR 2.5 million through. The project reduced COD and BOD levels, the amount of pollution, and generated employment while enhancing the health of the public.	The work also shows that there is inadequate incorporation of wastewater treatment into national climate policies, hindering replication and scale-up of effective models. There is also lack of quantitative measurement of social returns over the long-term which include better health and economic returns. More studies are required to: analyse policy mechanisms and funding sources, and to examine the suitability of using treated wastewater for recharging aquifers and for irrigation.	Kapshe, M., Kuriakose, P. N., Srivastava, G., & Surjan, A. (2013). Analysing the co-benefits: case of municipal sewage management at Surat, India. Journal of Cleaner Production, 58, 51–60. https://doi.org/10.1016/j.jclepro.2013.07.035

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10	Assessment of water-use efficiency for enhancing urban wastewater reuse – a case of Bhopal, India	Mrunmayi Wadwekar and Manmohan Kapshe	2024	Water Policy	IWA	The study explores the potential of wastewater reuse in urban areas, particularly focusing on Bhopal, India. It evaluates the sufficiency and efficiency of urban water use while promoting treated wastewater as an alternative resource. The research aims to address gaps in policy for urban wastewater reuse, emphasizing the circular economy principles to make water use sustainable and efficient.	The research uses the Urban Water Metabolism Framework to assess water-use efficiency, incorporating spatial and temporal data. Performance indicators evaluate water supply, demand, and wastewater generation within and outside urban boundaries. Methods include precipitation analysis, watershed mapping, and spatial identification of potential treated wastewater users. Data was gathered through literature review, spatial analysis, and performance evaluation tools.	The study finds that Bhopal has sufficient water supply but relies heavily on external sources. Wastewater reuse for non-potable purposes, like irrigation, toilet flushing, and municipal cleaning, is feasible and sustainable. However, wastewater treatment capacity is limited, and reuse systems are underdeveloped. Promoting decentralized wastewater treatment and integrating treated water into urban systems can reduce dependence on external water sources and improve resource efficiency.	Current policies lack emphasis on urban wastewater reuse, focusing mainly on agricultural and industrial applications. There is limited public awareness, inadequate infrastructure for decentralized systems, and a lack of spatial data on wastewater generation and reuse. The study highlights the need for holistic, flexible policies and improved data collection to address these gaps and enhance water resource management.	Wadwekar, M., & Kapshe, M. (2024). Assessment of water-use efficiency for enhancing urban wastewater reuse: a case study in Bhopal, India. Water Policy, 26 (10), 1020–1038. https://doi.org/10.2166/wp.2024.162
11	Challenges and Opportunities in Enabling Circular Economy for Sustainable Wastewater Treatment	Hema Jha and Brajesh Kumar Dubey	2024	Biological and Hybrid Wastewater Treatment Technology	Springer	This research is concerned with the use of WWT as a part of the circular economy to recover energy, water, and resources for sustainability concerns. It looks at the place of WWT in the provision of energy autonomy and resources, and its relation to SDGs. Literature review assesses opportunities and challenges of circular economy business model, and tools for transitioning WWT.	The study uses both a literature review and case study methodology to explore circular economy strategies in WWT. It applies the concepts of sustainability assessment tools like life cycle assessment (LCA) for the assessment of environmental and economical effects of different WWT technologies. Other possibilities and more sophisticated potential methods for resource recovery are also considered with a focus on anaerobic processes and, microalgae-based solutions.	The study shows that WWT has the possibility to generate energy self-sufficiency, resource recovery and minimize the negative effects on the environment. Some of the successful examples include biogas recovery, nutrient recycles and other technologies such as membrane bioreactor (MBR). There are, however, problems still in infrastructure, policy, cost, and acceptance. Least 63% of the wastewater is collected and 52% is treated globally, which reveals the shortfall in terms of circularity.	The study brings out some of the research gaps in the real-world application of circular WWT system especially at the local level. Some of these are; implementing new technologies on existing structures, handling new contaminants, and regulatory issues and public perception. Less focus is paid to the systematic approaches that include decentralised structures, sustainability instruments, and policy co-governance for integrated resource management.	Jha, H., & Dubey, B. K. (2024). Challenges and Opportunities in Enabling Circular Economy for Sustainable Wastewater Treatment. In Earth and environmental sciences library (pp. 483–507). https://doi.org/10.1007/978-3-031-63046-0_20
12	Challenges for Circular Economy under the EU 2020/741 Wastewater Reuse Regulation	Julio Berbel, Enrique Mesa-Pérez, and Pedro Simón	2023	Global Challenges	Wiley-VCH GmbH	In the context of the circular economy, this research aims to assess the new opportunities and risks brought by the EU Regulation 2020/741 regarding the use of wastewater for agriculture in irrigation. It is to provide insights into the effects of the regulation upon various stakeholders in the water treatment value chain, to determine the existing barriers for the processes of governance, social acceptance, and technologies also to identify how the regulation contributes to the augmentation of reuse of wastewater and solution of water scarcity problems.	To assess current status of wastewater reuse in agriculture, academic and policy literatures were both reviewed through a systematic approach. This study also assessed case, survey and EU policy data on the opportunities and constraints with the Regulation 2020/741. It was found that some important areas like the governance structures, risk management and stakeholder communications were emphasized.	The new regulation safeguards the usage of water reuse for agriculture as a key element of the circular economy in the EU and beyond by establishing standardization. It requires that the management has to come up with risk management plans, increases the interface between the stakeholders and the projects, and encourages the advancement in reclamation technology. On the challenges to adoption of the services they are expensive particularly for farmers, has little influence on water scarcity and high rate of social rejection. For the regulation to succeed, there is need for improved governance, financial incentives for the farmers and localisation.	Still, there is surprisingly little empirical assessment of the Regulation 2020/741 and its real-world consequences, including the efficiency of the proposed measures for farmers and consequences for downstream ecosystems. However, the need for specific governance frameworks at the river basin level and the longstanding perception of the public towardsreuse of reclaimed water in agriculture have not been adequately addressed. Additional studies are required to evaluate the effect of implementation and its efficiency on different contexts to get an understanding of its applicability across Europe.	Challenges for Circular Economy under the EU 2020/741 Wastewater Reuse Regulation. (2023). In Global Challenges. https://doi.org/10.1002/gch2.202200232
13	Economic Indicators in Water and Wastewater Sector Contributing to a Circular Economy (CE)	Marzena Smol and Renata Koneczna	2021	Resources	MDPI	The objective of the study is to identify a number of economic indicators to assess the CE transition in the water and wastewater sector. The proposed indicators track important CE actions such as minimizing, recycling, recovering, reusing, and landfilling. The focus is made on evaluating microeconomic impacts and the economic efficiency in the sector, as well as matching with the EU's CE goals and sustainable water management activities.	The research uses a systematic literature review on desk research with international and European documents, official statistics, and peer-reviewed articles. Data was collected using keywords to search for the indicators from databases such as Eurostat, OECD, and MDPI. This was followed by consultation with industry practitioners and academics to review and confirm the economic indicators for the water and wastewater industry.	The study suggests the list of 41 general and specific economic CE indicators classified by the categories of the cash flow statement and corresponded to the CE actions. These indicators help in the assessment of CE related activities such as water reuse, energy recovery and material recycling. They allow water and wastewater organizations to track CE transformation, enhance resource utilization, and facilitate policy and business choices.	Currently, there are no CE indicators specific to the economic characteristics of the water and wastewater industry. There is no tool that can assess the microeconomic performance of CE transformation comprehensively. Future studies should explore the use of these indicators in different organizations and improvement of them to meet new CE tasks and technologies.	Smol, M., & Koneczna, R. (2021). Economic Indicators in Water and Wastewater Sector Contributing to a Circular Economy (CE). Resources, 10(12), 129. https://doi.org/10.3390/resources10120129
14	Environmental Indicators for Assessment of Circular Economy (CE) Implementation in the Water and Wastewater Sector	Marzena Smol, Alfonso Mejia, Massimo Gastaldi, Idiano D'Adamo	2024	Business Strategy and the Environment	Wiley Online Library	This paper has the primary objective of proposing a framework of environmental indicators to evaluate CE advancement in the water and wastewater sector. These indicators cover aspects like minimisation, utilisation, conversion and regeneration, retrieval and renewed thinking in the usage of resources, which assist to measure and manage the change process of the sector towards circular economy.	The study adopts the systematics literature review approach following the PRISMA protocol to synthesize 83 documents from scientific, policy, and sector sources. Step 2 involved sourcing the opinion of various professionals in the development of CE indicators unique to the water and wastewater sector, which formed the basis of the monitoring framework developed for these organizations.	The study presents a comprehensive set of CE indicators across six areas: Source: Developed based on the literature review reduction (such as water and wastewater generation reduction), reclamation (such as pollutants removal), reuse (for instance, water reuse for nonpotable purposes), recycling (for instance, potable water recycling), recovery (for instance, energy recovery), and rethink (for instance, CE technologies, business models). These indicators can be used to monitor change and to help in policy making for the CE change in the sector.	Since current CE frameworks do not have specific sector-specific indicators for the water and wastewater sector, this study seeks to recommend specific indicators that can be used to evaluate the implementation of CE in the sector. Future research should further develop these indicators particularly for the economic and social dimensions as new CE solutions are developed.	Smol, M., Mejia, A., Gastaldi, M., & D'Adamo, I. (2024). Environmental Indicators for Assessment of Circular Economy (CE) Implementation in the Water and Wastewater Sector. Business Strategy and the Environment. https://doi.org/10.1002/bse.4090

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15	Governance Arrangements for Water Reuse: Assessing Emerging Trends for Inter-Municipal Cooperation through a Literature Review	Fayaz Riazi, Teresa Fidélis and Filipe Teles	2022	Water	MDPI	This paper looks at the appropriateness of Inter-Municipal Cooperation (IMC) governance structure in enabling environmentally sustainable transition to Water Circular Economy (WCE). It emphasises the manner in which IMC handles governance issues, optimises the delivery of services, and evaluates social, economic and environmental effects of WCE implementation. The study also examines the possibility of improving the efficiency of IMC in addressing the coordination of the stakeholders, the problem of policy integration, and the rational use of land use in water resources management.	This paper will use a systematic literature review approach where three databases of scientific articles are developed and their contents analyzed. These databases are based on IMC, IMC & Water and IMC & Circular Economy (CE). Articles were selected based on citation frequency and recency, with qualitative classification into three dimensions: lgovernance, services delivery, and measuring effectiveness. It has been made clear that the organization of the topic as sections allowed for the thorough discussion of the aspects under consideration and the identification of the gaps in the knowledge base connected to them.	This paper concludes that IMC is useful in improving fragmented water governance since it brings together the stakeholders, common purpose, and transboundary conflict resolution as advanced by IMC. It sustains the economical utilization of land for water reuse structure and delivers enhanced service provision through size-related efficiencies. Nonetheless, the findings of this research have implications for WCE only and future research should extend the analysis to examine the cost and effectiveness of IMC and its implications for social, economic and ecological wellbeing.	The research therefore stresses the lack of empirical examination of the practical application of IMC for WCE adoption. Previous research primarily covers the aspects of governance and efficiency, while there is a scarcity of comprehensive case-based evaluations concerning social, economical and environmental impacts. Future quantitative studies should expand upon the results obtained in this research by assessing IMC's viability in actual environments of WCE and by establishing the ideal way of IMC application.	Riazi, F., Fidélis, T., & Teles, F. (2022). Governance Arrangements for Water Reuse: Assessing Emerging Trends for Inter-Municipal Cooperation through a Literature Review. Water, 14(18), 2789. https://doi.org/10.3390/w14182789
16	Greywater reuse as a key enabler for improving urban wastewater management	Arjen Van de Walle, Minseok Kim, Md Kawser Alam, Xiaofei Wang, DiWu, Smruti Ranjan Dash, Korneel Rabaey, Jeonghwan Kim	2023	Environmental Science and Ecotechnology	Elsevier	The present study aims at the identification of sustainable strategies in greywater management especially in the aspect of treatment and re-use in the urban regions. It focuses on decentralized systems of greywater treatment and emphasizes the need to use appropriate technologies and approaches to respond to issues such as climate change, urbanization, population increase.	This research employs a systematic literature review to gather and assess data from existing research on aspects of greywater characteristics, treatment technologies, and reuse practices. It assesses biological, chemical, and physical treatment systems, sample applications, and new technologies in greywater reuse.	Greywater is a significant part of household wastewater and therefore it has high potential for reuse. The main methods of treatment include biofilm technologies and membrane bioreactors (MBR) and physicochemical methods: membrane filtration and ultraviolet disinfection. However, some of the challenges that are associated with implementation of greywater include the following; Quality of greywater, Legal frameworks in the country , Perception . Appropriate technology such as energy efficient and decentralized systems have the potential of enhancing localized water management.	Despite the growing interest in greywater treatment and reuse, there is a lack of recent and systematic review of the subject. Further studies should concentrate on systems integration, variability of greywater, legal aspects, acceptation of greywater by the public, and solution adaption to different urban contexts.	Van De Walle, A., Kim, M., Alam, M. K., Wang, X., Wu, D., Dash, S. R., Rabaey, K., & Jeonghwan Kim. (2023). Greywater reuse as a key enabler for improving urban wastewater management. In Environmental Science and Ecotechnology [Journal-article]. https://doi.org/10.1016/j.ese.2023.100277
17	Innovative Approaches for Sustainable Wastewater Resource Management	Ay¸se Ulusoy, Atılgan Atılgan, Roman Rolbiecki, Barbara Jagosz and Stanisław Rolbiecki	2024	Agriculture	MDPI	This research focuses on efficient management of wastewater to cope with the water shortages and pollution. It focuses on the new treatment technologies that can be used to recover resources as well as minimize energy consumptions as well as carbon emissions. Areas of interest are biology, physical chemistry, and membrane technologies, oxidation methods, and wastewater recycling and reuse as per circular economy principles.	The methods adopted in the research include reverse osmosis, ultra filtration, ozonation, photocatalysis and nanotechnology based filtration. It incorporates energy recovery systems, resource recovery methods as well as circular economy strategies. AI tools, the concept of machine learning, and simulation models are applied for the process improvement and monitoring.	Advanced oxidation processes, biological treatment integrated with membrane processes, and nanotechnologies are innovative technologies that have shown high removal efficiency of pollutants and resources recovery. Case studies in the agricultural sector, industrial use and drinking water production demonstrate how demand for water, energy and carbon footprints can be minimized. Higher recognition and incorporation of AI systems also contribute to the adoption as well as the performance levels.	There remains significant barriers to extending sustainable WW technologies, making them affordable, and conforming with wastewater treatment compliance. Lack of information on actual field uses and their effects slows down scale-up. More investigations are required to enhance the integrated systems and apply them in various contexts of the environment as well as the industries.	Tolkou, A. K., & Kyzas, G. Z. (2024). Advanced Technologies of Water and Wastewater Treatment. Environments, 11(12), 270. https://doi.org/10.3390/environments11120270
18	Institutional arrangements for water reuse: assessing challenges for the transition to water circularity	Fayaz Riazi, Teresa Fidélis, Manuel Victor Matosb, Maria Carolina Sousab, Filipe Teles and Peter Roebeling	2023	Water Policy	IWA	This paper explores the policy instruments required for the delivery of water reuse in the shift to a WCE. It stresses out the management issues related to new water loops, including differences in water quality, risks and their connections, new users and obligations. The paper evaluates the possibilities for, as well as risks and challenges to, effective institutional adaptation to WRR schemes, through case studies of Spain, Italy, Croatia, and Israel.	This research use Ostrom's Institutional Analysis and Development (IAD) framework to categorize governing systems. Questionnaires were distributed to the stakeholders including the municipalities, water utilities and river basin authorities. The IAD framework was integrated together with regulatory factors to compare and contrast institutional design features such as risks, control, penalties and options. The research incorporated consulting advice and regulatory reports to define institutional voids and motivators.	The study suggests that institutional supports must be instituted as key drivers and enablers of the outreach and adoption of technologies in water reuse. And these include role delineation, fair sharing of risks and rewards, monitoring and controlling for adverse effects for any conflict that may arise within the trial. However, in several case studies including; Almendralejo-Spain & Eilat-Israel, the models of governance are often stiff and uncongenial. Some of the strategies mentioned in the study is enhancing governance through cooperative policies, risk acknowledgment, equitable cost sharing and building stakeholder relations, combined with the reduction of cost of water reuse.	The study identifies limitations in governance readiness for adopting new water loops, including inadequate policy frameworks, insufficient flexibility in regulations, and low public awareness. It also points to gaps in addressing long-term risks, such as compliance, spatial considerations for water storage, and societal acceptance. Future research should focus on refining institutional frameworks to address these challenges and ensuring robust governance for sustainable water reuse adoption.	Riazi, F., Fidélis, T., Matos, M. V., Sousa, M. C., Teles, F., & Roebeling, P. (2023). Institutional arrangements for water reuse: assessing challenges for the transition to water circularity. Water Policy, 25(3), 218–236. https://doi.org/10.2166/wp.2023.155

GUARDING THE RIVER GANGES: MIRZAPUR'S COMPREHENSIVE PLAN FOR SUSTAINABLE WASTEWATER MANAGEMENT AND REUSE

S. No.	Title	Author	Year	Journal	Publisher	Research Focus	Methods & Tools	Findings	Research Gap	References
19	Integrated, Decentralized Wastewater Management for Resource Recovery in Rural and Peri-Urban Areas	Andrea G. Capodaglio	2017	Resources	MDPI	In this study, sustainability issues are considered through decentralized wastewater management systems. AEP focus on the onsite wastewater management, recycling and reuse of water, nutrients and energy within the farm. The goal of this investigation is to understand how decentralization can improve water management, support the circular economy and respond to global challenges including water deficits, lack of sanitation, and environmental concerns.	The research used literature review and case analysis for the assessment of decentralized wastewater treatment systems. In order to compare decentralized and centralized systems, tools such as life cycle assessment (LCA) are employed. Feasibility and scale factors of technological options and sustainability aspects such as reuse locally, energy recovery and cost implications are assessed.	Decentralized systems have advantages in terms of sustainability from environmental point of view, costs of infrastructure and ability to address local requirements. They are less sensitive to climate events and contribute to resource restoration, for example, water for irrigation and nutrients for soil replenishment. The study reveals the potential of decentralized systems to achieve cost savings; up to 60% on collection and treatment compared to centralized systems mainly in rural and peri-urban areas. But transition entails dealing with operation, maintenance, and governance issues.	The research also highlights some of the challenges that organizations encounter in adopting decentralization models at large. The major difficulties are rooted in the opposition of existing practice, the absence of an integrated approach, and the scarcity of advanced technologies for resource management. There are a limited number of examples which can guide decision-making comprehensively, taking into account local socio-economic conditions, and climate change adaptation. More research is required to develop common practices of decentralised measures and implement them into a wider context of water management.	Capodaglio, A. G. (2017). Integrated, Decentralized Wastewater Management for Resource Recovery in Rural and Peri-Urban Areas. Resources, 6(2), 22. https://doi.org/10.3390/resources6020022
20	Life cycle assessment of wastewater reuse alternatives in urban water system	Rajhans Negi , Munish K. Chandel	2024	Resources, Conservation & Recycling	Elsevier	The research is concerned with the assessment of environmental consequences of various WwR scenarios in UWSs using LCA. It analyses indirect reuse, direct reuse, non-potable reuse and hybrid reuse in order to identify which is environmentally the most effective. The research questions are as follows: The purpose of the research is to determine best approaches to wastewater reuse that have least effects on the environment and at the same time meeting the water deficit in urban centers. Since all the reuse scenarios are evaluated for their entire life cycle, this research offers significant information for the creation of sustainable urban water system, particularly in arid areas.	This research adopts LCA under the CML-IA baseline to compare the environmental effects across different reuse scenarios. It employs open LCA software, ecoinvent database and data from actual water and wastewater organizations to develop life cycle assessments. The effects are derived from the construction phase and the use phase of the building, with respect to electricity consumption, resource utilization, and emissions.	The study reveals that if septic tanks are replaced by full wastewater treatment (BS*) there is a reduction of the chemical oxygen demand/ eutrophication potential but at the same time there is an increase in other impacts. Based on the impacts assessment of the reuse strategies, centralized NPR has the lowest impact and, therefore, is the most sustainable strategy. New treatment technologies for direct potable reuse and hybrid systems have higher overall environmental impacts, primarily due to energy.	Thus, this research addresses important knowledge gaps with regards to environmental effects in developing UWSs where there might be incomprehensive wastewater treatment and sparse data. It underlines the deficit of research on wastewater reuse in the context of developing economies, as well as the necessity of investigating the effects of the construction stages and resource consumption in UWSs with full-scale wastewater treatment facilities.	Negi, R., & Chandel, M. K. (2024). Life cycle assessment of wastewater reuse alternatives in urban water system. Resources Conservation and Recycling, 204, 107469. https://doi.org/10.1016/j.resconrec.2024.107469
21	Parameters of Successful Wastewater Reuse in Urban India	Kelly D. Alley, Nutan Maurya and Sukanya Das	2018	Indian Politics & Policy	Policy Studies Organisation	This study focuses on wastewater recycling in India, particularly on identifying success parameters in decentralized wastewater treatment systems. The research investigates the roles of government agencies, public-private partnerships, and private enterprises in developing functional and sustainable recycling projects to address water scarcity. It emphasizes human dimensions such as institutional, policy, economic, and leadership factors over technological performance.	The study employs a qualitative methodology, utilizing focus groups, structured interviews, and participant observation across 40 sites over three years. Snowball sampling was used to identify knowledgeable individuals and successful projects. Key informant interviews with officials, project monitors, NGOs, and researchers supplemented the data. Analysis involved reviewing government records, research reports, feasibility studies, and regulatory frameworks to derive patterns across projects.	The study identifies leadership, water pricing, availability, regulations, and business savings as key success factors for wastewater recycling projects. Successful cases, like IIT-M Chennai and Renaissance Hotel Mumbai, demonstrate that closed-loop systems reduce water dependency and operational costs. Regulatory pushes, such as NGT mandates, drive adoption, while decentralized management enhances functionality. However, the focus remains on human and institutional dynamics over technological efficiency.	The study does not extensively explore technological adequacy or efficiency in wastewater treatment systems, focusing more on human and institutional dynamics. Additionally, there is limited discussion on replicability for small-scale or peri-urban systems and user acceptance in unregulated or informal sectors. Quantitative analysis of cost-benefit outcomes and long-term environmental impacts remains underexplored.	Alley, K. D., Maurya, N., & Das, S. (2018). Parameters of Successful Wastewater Reuse in Urban India. In Indian Politics & Policy. https://doi.org/10.18278/inpp.1.2.4
22	Problems and Perspectives of the Urban Sewage System: A Geographical Review	Vidhyatai Patil and Avinash Kadam	March 2019	Research Review International Journal of Multidisciplinary	Research Review Publication	Geographical analysis and issues relating to sewage systems in the context of urban regions form the subject matter of the research. It also discusses how urbanization, population density and poor urban design cause enormous strain on current sewer systems which results in blockages, overflows and pollution. This paper seeks to establish the most important geographical characteristics, users' behavior and technical issues leading to the inefficiency of sewage systems in the urban areas.	The research mainly employs literature review method involving analyzing the existing research articles, papers, government reports, and other relevant and reputable sources. The research method also involves analyzing data from global organizations including WHO and UNWWD besides evaluating case studies from different global urban centers. Techniques for this research include comparison method, thematic classification of urban sewage problems, and assessment of the data on the capacities of sewage treatment and urban development.	This study reveals several challenges affecting urban sewage systems such as; Overload due to rapid urbanization, unplanned city growth and poor sewage infrastructure. Lack of public awareness on proper waste disposal is also among the reasons that lead to blockages within the system; there is also poor maintenance, old age infrastructure and last but not the least economic constraints. Most cities across the globe, especially in developing countries, release raw sewage into water bodies, which causes a lot of harm to the environment and poses health hazards.	It is therefore necessary to conduct more studies on the effects of poorly treated sewage on health and the environment. Moreover, there remains uncertainty about how successful public awareness raising campaigns are and how the use of smart technologies in sewage systems is effective. There is also a lack of understanding of how geographical factors affect sewage systems, further research on urban governance and policy impact.	Patil, V., & Kadam, A. (2022). Problems and Perspectives of the Urban Sewage System: A Geographical Review. Res Rev Int J Multidiscip, 4(3), 2815-9. https://rb.gy/9g8u70

S. No.	Title	Author	Year	Journal	Publisher	Research Focus	Methods & Tools	Findings	Research Gap	References
23	Reuse of Treated Wastewater	Elena Galkina and Olesya Vasyutina	2018	IOP Conference Series: Materials Science and Engineering (MSE)	IOP	This paper aims at exploring the use of water that is recycled from a particular phase in a cycle to another phase through different sectors such as agricultural, civil, and industrial. The study focuses on the need to treat water to make wastewater reusable, the implications of such practices in water scarce regions.	The study employs a literature review analysis to evaluate different treatment processes and technologies to wastewater reuse including pre-treatment, sedimentation, biological treatment and final disinfection. Case studies of specific wastewater reuse systems employed in industrial, agricultural, and domestic applications are also presented. Further, the study investigates other natural treatment options such as constructed wetlands and bioponds.	The study concludes that treated wastewater can play a very important role of reducing freshwater consumption especially in areas where water is scarce. This outlines different uses of reused water such as on agriculture, industries and domestic purposes like, flushing the toilet, washing car among others. The issues that should be solved include the choice of treatment methods that correspond to the sanitary and environmental requirements for water and the variability of the quality requirements for various uses.	At present, there are few specific studies on the long term effects of the environmental and health consequences of reuse of wastewater especially in the agricultural sector. Furthermore, there is limited information on the cost and productivity of natural treatment processes such as constructed wetlands and bioponds. The state of the local conditions and the composition of the wastewater determining the most suitable reuse methods also needs to be better understood.	Galkina, E., & Vasyutina, O. (2018). Reuse of treated wastewater. IOP Conference Series: Materials Science and Engineering, 365(2). https://doi.org/10.1088/1757-899X/365/2/022047
24	Reuse of Treated Wastewater	Elena Galkina and Olesya Vasyutina	2018	IOP Conference Series: Materials Science and Engineering (MSE)	IOP	The paper is centred on the use of water that has passed through a treatment process as a sustainable solution in water scarce areas. It explores the use of recycled water for municipal, industrial, domestic purposes, and discusses issues of environmental concern such as safety, sanitation and legal requirements. Also, treatment technologies are discussed, and the suitability of these technologies with specific activities such as farming and industry is also explained.	The research uses a literature review of the existing technologies and processes of WWTPs as well as primary, secondary, and tertiary like nitrification, denitrification, and UV disinfection. It also includes natural treatment systems and constructed wetlands and biological ponds and dual system where potable water and reused water are separated. The feasibility of each approach is discussed with regard to the existing regulatory frameworks and implementation case studies.	Reclaimed water can help decrease the use of fresh water for civil, industrial and agricultural purposes. Technologies such as dual systems and natural treatment methods make re-use safe and cheaper hence enhancing the use of resources. The other two sustainable approaches are rainwater harvesting and recycling, which the authors maintain can supply up to 50% of domestic water demand in some situations. But it requires appropriate treatment to fulfill sanitary and environmental requirements mainly in the case of human touch applications.	The research does not provide a detailed comparison of the pros and cons of various approaches to adopt wastewater reuse systems at different industries and geographical locations. It also entails limited information concerning the long term ecological consequences of the reuse of water alongside public acceptability. Subsequent research can examine integration with new technologies and application of effective practices for expanding wastewater reuse in various geographical and economic conditions.	Galkina, E., & Vasyutina, O. (2018). Reuse of treated wastewater. IOP Conference Series: Materials Science and Engineering, 365(2). https://doi.org/10.1088/1757-899X/365/2/022047
25	Sewage Treatment and Management in Goa, India: A Case Study	A. Singh, A. Kazmi, M. Starkl, I. Bawa, P. Khale, V. Patil, I. Nimkar, M. Naik	2015	Exposure and Health	Springer	In this study, the existing situation of sewage treatment plants (STPs) in Goa, India is investigated with a particular interest in the opportunities for STP capacity enhancement and the utilization of treated wastewater. This paper discusses the rationale for water management in a state that is largely dependent on tourism, and assesses the preparedness of current STPs to address the need of the populace and tourists.	The empirical data collected for the study are secondary in nature and have been collected from CPCB, PWD Goa, SIDCGL, and field visits to four municipal STPs. It is a technical, social, financial, and managerial case study. Physical, chemical, and microbial characteristics of water samples are determined from different STPs. STP mapping and its distribution and correlation with population and drainage networks in Goa is done in the ArcGIS application.	The study identifies that Goa has a total of 177 STPs, out of which majority of 170 are operated by private hotels and residential societies. These plants have different capacities and the gap in terms of treatment capacity needed to treat sewage is very large. The treatment technologies used are the Sequential Batch Reactor (SBR), Extended Aeration and the Activated Sludge Process. However, the treated wastewater is poorly reused contrary to the need it has in various sectors like agriculture, aesthetic, industrial etc.	The study reveals a general absence of proper wastewater reuse practices in the Goa's STPs. More studies should be conducted to identify efficient and innovative ideas to treat water in STPs; particularly, private and small-scale STPs. Furthermore, little has been done toward ascertaining the applicability of TWW reuse in states such as Goa that relies extensively on tourism where water quality is a major consideration. The use of GIS for future sewage flow estimate and infrastructure planning is also need further research.	Singh, A., Kazmi, A., Starkl, M., Bawa, I., Khale, P., Patil, V., Nimkar, I., & Naik, M. (2015). Sewage Treatment and Management in Goa, India: A Case Study. Exposure and Health, 8(1), 67–77. https://doi.org/10.1007/s12403-015-0183-5
26	Sustainable Development of Water Resources Based on Wastewater Reuse and Upgrading of Sewage Treatment Plants in Developing Countries: A Case Study of Jammu and Kashmir, India	Bashir Ahmad Pandit, Musaib Ul Zaman, Rohitashw Kumar, Tariq Sofi	ebruary 202	International Journal for Research in Applied Science & Engineering Technology (IJRASET)		This research focuses on sustainable development of water resources through wastewater recycling, particularly in regions like Jammu & Kashmir (J&K), India. It investigates efficient wastewater collection, treatment, and reuse strategies to mitigate water scarcity, highlighting the need for policy reforms and public awareness to treat wastewater as a valuable resource.	The study employs a qualitative approach, reviewing existing literature, policies, and case studies on wastewater reuse. It examines regulatory frameworks, public acceptance, and environmental impacts while considering technical, cultural, and economic factors influencing project success. Tools include data analysis, stakeholder surveys, and comparative assessments of regional and global wastewater management practices.	The research identifies key success factors, including regulatory support, public awareness, advanced treatment technologies, and sustainable project funding. In J&K, limited wastewater reuse stems from mismanagement and inadequate treatment facilities. Successful projects demonstrate reduced water stress, improved agricultural irrigation, and enhanced environmental outcomes.	There is a lack of region-specific studies on cost-effective wastewater treatment technologies, operator training, and socio-cultural barriers in J&K. Additionally, research on long-term performance evaluation of wastewater recycling systems and adaptive policy frameworks is limited. Future studies should address these gaps with a focus on localized solutions and integrated water resource management.	Pandit, B. A., Zaman, M. U., Kumar, R., Sofi, T. A., & Khan, S. (2023). Sustainable Development of Water Resources Based on Wastewater Reuse and Upgrading of Sewage Treatment Plants in Developing Countries: A Case Study of Jammu and Kashmir, India. International Journal for Research in Applied Science and Engineering Technology, 11(2), 389–397. https://doi.org/10.22214/ijraset.2023.49045
27	Sustainable Urban Wastewater Management and Reuse in Asia	Absar Kazmi Hiroaki Furumai	2005	International Review for Environmental Strategies: The Environmentally Sustainable City	IGES	Examining some of the range of new and established technologies and methods that can help Asian cities and periurban areas to minimize the burden and maximize the potential benefits of urban wastewater.	Case Studies of Asiam Countries	Wastewater management and treatment techniques for metropolitan, medium scale cities and small cities Watershed approach while planning wastewater management in urban areas. (example: Tokyo)	There's a gap in providing specific insights into the challenges and opportunities associated with implementing these technologies in diverse Asian contexts, considering factors such as governance, infrastructure, and socio-economic conditions.	Kazmi, A., & Furumai, H. (2005). International Review for Environmental Strategies Special Feature on the Environmentally Sustainable City Sustainable Urban Wastewater Management and Reuse in Asia (Vol. 5, Issue 2). https://www.iges.or.jp/en/publication_documents/pub/peer/en/1180/IRES_vol.5-2_425.pdf

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S. No.	**Title**	**Author**	**Year**	**Journal**	**Publisher**	**Research Focus**	**Methods & Tools**	**Findings**	**Research Gap**	**References**
28	The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline	Khaled Obaideen, Nabila Shehata, Enas Taha Sayed, Mohammad Ali Abdelkareem, Mohamed S. Mahmoud, A.G. Olabi	2022	Energy Nexus	Elsevier	This research aims to determine how wastewater management contributes towards the implementation of the United Nations Sustainable Development Goals. It focuses on the role of Wastewater treatment plants in supporting 11 of the 17 Sustainable Development Goals including water and sanitation, health, energy, economy, and environment. The research also discusses crosslinkages between SDG 6 and other Sustainable Development Goals to understand the role of wastewater management in sustainable development.	The research employs a systematic assessment approach in establishing the role of wastewater treatment in SDGs achievement. They include; Life Cycle Assessment (LCA), Environmental Impact Quantification (EIQ), Water Footprint (WF). Furthermore, the energy nexus concept is applied to analyze the interaction between water and energy networks. Guidelines and indicators for improvement have been developed to contribute toward the improvement of the sustainability performance of wastewater facilities.	The study reveals that wastewater treatment is associated with the fulfilment of 11 SDGs: directly and indirectly through its impacts on SDG 1 (no poverty), SDG 2 (zero hunger), SDG 3 (good health and well-being), and SDG 6 (clean water and sanitation) as well as indirectly influencing SDG 7 (affordable and clean energy), SDG 8 (decent work and economic growth It reveals the opportunities afforded by wastewater treatment as a resource for recovery, biogas production, minimization of water scarcity, and promotion of public health. Some limitations were also discussed regarding implementation and evaluation of SDG goals from the wastewater perspective, and future research needs to develop global-level indicators and the integration of policymakers and stakeholders.	Many previous works address SDG 6 or particular technologies in the context of wastewater management, and do not consider the impacts on a set of SDGs. Surprisingly, little has been achieved in the formulation of extensive global indices that would help in evaluating the role of wastewater treatment to sustainable development. It is for these reasons that the research calls for the development of interdisciplinary and integrated approaches and frameworks for evaluating the coordinated effects of WWT on the SDGs.	Obaideen, K., Shehata, N., Sayed, E. T., Abdelkareem, M. A., Mahmoud, M. S., & Olabi, A. G. (2022). The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline. Energy Nexus, 7, Article 100112. https://doi.org/10.1016/j.nexus.2022.100112
29	The Treatment of Wastewater, Recycling and Reuse - Past, Present, and in the Future	Jyotsana Maura, Suchita Atreya, Anfal Arshi	2023	International Journal of Science and Research (IJSR)	World Wide Journals	The study is based on the topic: Wastewater Treatment, Recycling, and Reuse as a Solution to Water Scarcity and Environmental Pollution. This paper provides historical development of wastewater management, current technologies in management and future trends on water management. The focus is on the innovation in water treatment, water resources, small-scale systems, and coupling of intelligent systems to the improvement of water quality and accessibility.	In analyzing the wastewater management practices, the chapter adopts a historical and technological review approach. It explains primary, secondary and tertiary processes and conventional and advanced approaches. Technologies like membrane bioreactors, artificial wetlands, enhanced oxidation processes, internet of things, artificial intelligence are presented with respect to their ability to enhance treatment efficiency and facilitate water reuse.	The paper also explains the enhanced development of wastewater management through the assessment of various wastewater management systems and structures from a primitive age to the current world. Advanced technologies have made it possible to remove pollutants, and recover resources, make recycling and reuse possible. Future trend focuses on the application of artificial intelligence, use of decentralised systems and energy neutral treatment for the sustainable management of water. Concerning the factors that facilitate the management of challenges like emerging contaminants and climate change, public awareness and international cooperation are highlighted.	Despite such developments, however, the existing technologies lack some ways of managing new pollutants such as microplastics and pharmaceuticals. Few researches have provided a framework on how decentralized systems could be interfaced with smart technologies for large-scale application. Other areas of research interest include public participation and global policy frameworks in improving wastewater recycling and reuse. Further, the focus on approaches to make treatment systems energy neutral also requires consideration.	Maura, J., Atreya, S., Arshi, A., & Defence Institute of Bio-Energy Research (DIBER), DRDO, Haldwani, Nainital-263139, India. (2023). The Treatment of Wastewater, Recycling and Reuse - Past, Present, and in the Future. In International Journal of Science and Research (IJSR) (Vol. 12, Issue 11). https://dx.doi.org/10.21275/SR231013064713210
30	Treatment of Gray Water for Reusing in Non-potable Purpose to Conserve Water in India	Sonali Manna	2018	International Journal of Applied Environmental Sciences	Research India Publications	The research primarily addresses the issue of water scarcity in India, emphasizing the conservation of fresh water through the treatment and reuse of gray water. It investigates the potential of gray water reuse as a sustainable alternative for non-potable purposes such as toilet flushing, garden irrigation, and household cleaning. The study aims to evaluate the feasibility, efficiency, and environmental impact of gray water reuse systems in residential and public settings.	The study employs a statistical analysis of domestic water consumption, gray water generation, and treated water production across various household and community setups. It reviews existing gray water treatment technologies, including physical, chemical, biological, and natural methods, and compares their effectiveness. Additionally, the research examines regulatory frameworks like the WHO guidelines and CPCB standards to assess the suitability of gray water reuse in India.	The findings reveal that treated gray water can significantly reduce the demand for fresh water in domestic settings. Light gray water reuse alone can meet up to 35% of non-potable water needs, while treated mixed gray water can provide an additional 20–25% for purposes like ground recharge and landscaping. The study underscores the economic and environmental benefits of gray water treatment, suggesting it as a viable alternative to reduce water consumption in water-scarce regions.	Despite its potential, the study highlights gaps in the adoption of gray water reuse systems in India. The lack of comprehensive policies, enforcement mechanisms, and public awareness limits the widespread implementation of these systems. Additionally, there is limited research on the long-term environmental impacts, such as soil contamination from micro-pollutants, and on cost-effective technologies tailored to India's socio-economic context. Addressing these gaps is crucial for promoting gray water reuse as a sustainable water conservation strategy.	Manna, S.. Treatment of Gray Water for Reusing in Non-potable Purpose to Conserve Water in India. International Journal of Applied Environmental Sciences, 2018, 13(8): 703-716. https://www.ripublication.com/ijaes18/ijaesv13n8_01.pdf
31	Treatment of Gray Water for Reusing in Non-potable Purpose to Conserve Water in India	Sonali Manna	2018	International Journal of Applied Environmental Sciences	Research India Publications	The paper is developed to discuss the management and recycling of grey water to ease the shortage of fresh water in India. It looks at the properties of gray water, suitable technologies for its treatment, and possible uses in water reuse for purposes other than drinking to minimize fresh water usage.	The research used a review-based approach that incorporates statistical analysis of water consumption and gray water generation as well as an assessment of the treatment technologies. It is the process where physical, chemical, and biological, and natural operations in either single or integrated processes, are employed to achieve treated water for non-portable uses. Quality standards are mentioned from WHO and CPCB as a guide to the current guidelines.	The research also finds that treated grey water from residential buildings can meet as much as 35% of the non-portable domestic water demand. Light gray water needs less treatment and yields adequate water for domestic utilization and mixed gray water treatment produces excess water for uses like ground recharging and watering of lawns. The country, especially urban and water-deficit regions of India, could save fresh water in large measure by 'recycling' gray water.	The use of gray water treatment systems is not very popular in India and there is little awareness, and legal compliance as well. For the impact of long-term pollution by substances such as sodium and micro-pollutants on the soil and ecosystems, there is a lack of research. Also, the performance, affordability, and applicability of gray water treatment technologies for various residential and industrial uses require further research.	Manna, S. & Research India Publications. (2018). Treatment of Gray Water for Reusing in Non-potable Purpose to Conserve Water in India. In International Journal of Applied Environmental Sciences (Vol. 13, Issue 8, pp. 703–716). http://www.ripublication.com

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S. No.	**Title**	**Author**	**Year**	**Journal**	**Publisher**	**Research Focus**	**Methods & Tools**	**Findings**	**Research Gap**	**References**
32	Wastewater and sludge reuse: selected case studies across the globe	Petros Kokkinosa, Jose R. Comia Jr., Serena Caucci, Hiroshan Hettiarachchi, Florencio C. Ballesteros Jr., Gideon Orond, Miquel Salgot, Ioannis K. Kalavrouziotis	2022	Desalination and Water Treatment	Desalination Publications	This paper explores the utilisation of wastewater and sewage sludge in circular economy context as valuable resources. It focuses on possibilities of wastewater reuse in irrigation, industries and cities and the usage of sludge for energy and farming needs. The practice comparison of the study involves case studies from Greece, Israel, Perú, Philippines, and Spain.	The study adopts a descriptive research methodology on the treatment of wastewater and sludge, reuse policies, economic factors, acceptance, and limitations of the selected countries. It also contains examples of nanotechnology application for water improvement in Israel, like the descriptions of ultrafiltration (UF) and reverse osmosis (RO) membranes.	The research also reveals vast opportunities for using the wastewater and sludge in the identified target countries. Some of the key success stories involve agricultural and energy reuse in the Philippines, agricultural reuse all over Spain and nanotechnology in water reuse in Isreal. All countries in the regions identified above present further potential to expand the circular economy approach in wastewater and sludge management.	The study establishes the lack of complete regulations, the lack of public support, and the lack of uniform reuse practice. This information shows a demand for a comprehensive strategy that considers technological, political, financial, and societal aspects in order to promote the large-scale use of the technology. Lack of data and variability in the collected information across different countries also become a problem for generalization on an international level and stress the need for standardized structures and protocols.	Wastewater and sludge reuse: selected case studies across the globe. (2022). Desalination and Water Treatment, 65–79. https://doi.org/10.5004/dwt.2022.28183
33	Wastewater infrastructure for sustainable cities: assessment based on UN sustainable development goals (SDGs)	H. M. K. Delanka-Pedige , S. P. Munasinghe-Arachchige , I. S. A. Abeysiriwardana-Arachchige & N. Nirmalakhandan	2020	International Journal of Sustainable Development & World Ecology	Taylor and Francis Group	The paper looks into infrastructure of wastewater, in relation to sustainable cities within the United Nations Sustainable Development Goals (SDGs), specifically SDG #11 (sustainable cities and communities) and SDG #6 (clean water and sanitation). It evaluates five key attributes: water recycling, pathogen destruction, energy consumption/recovery, biofertilizer recovery, and emission control. In the research, the sustainability of the new algal-based STaRR system is compared with the traditionally used activated sludge-based systems.	The evaluation framework of sustainability was defined with 36 measurable factors within five attributes based on nine interconnected SDGs. Information was gathered from the literature and from experimental findings. Therefore, the study aimed at comparing the performance of the STaRR system to activated sludge-based systems by establishing performance measures on energy efficiency, resources, microbial degradation, and greenhouse gas.	The findings of this research revealed that the sustainability performance of the STaRR system was higher than the comparator group in 29 of the 36 measured parameters. These are enhanced nutrient retention, improved pathogen elimination, increased energy utilization and reduced emission of green house gases. The system also demonstrated high possibilities in biofertilizer production and water recycling that corresponded to SDG goals. While the STaRR system needs chemical changes for the best performance, it has more environmental advantages than the normal systems.	Previous research on wastewater infrastructure has mainly relied on subjective measures, whereas a quantitative analysis of sustainability characteristics connected to the goals of the SDGs is scarce. Consequently, this research underscores the importance of increasing the use of combined, quantitative approaches to assess new emergent technologies such as the STaRR system. Some of the issues that need to be overcome include; the scaling up of technologies, cost associated with wastewater treatment, and the enhancement of the relevant legislation.	H. M. K. Delanka-Pedige , S. P. Munasinghe-Arachchige , I. S. A. Abeysiriwardana-Arachchige & N. Nirmalakhandan (2020): Wastewater infrastructure for sustainable cities: assessment based on UN sustainable development goals (SDGs), International Journal of Sustainable Development & World Ecology. https://doi.org/10.1080/13504509.2020.1795006
34	Wastewater Reuse in the EU and Southern European Countries: Policies, Barriers and Good Practices	Jurgita Malinauskaite, Bertrand Delpech, Luca Montorsi, Matteo Venturelli, Wolfgang Gernjak, Morgan Abily, Tadej Stepišnik Perdih, Eleni Nyktari and Hussam Jouhara	2024	Sustainability	MDPI	This paper investigates the opportunities for the reuse of reclaimed wastewater in the EU with focuses on legislation for the implementation of circular water solutions. To fill this gap, the study identifies gaps and possibilities in EU policies, with a concentration on agriculture and industry, as well as practices and issues in southern European nations like Italy, Greece, and Spain.	This research uses a systematic literature review of EU legal documents, legislations, policies, and national strategies. This study uses an analysis of Italian, Greek, and Spanish experiential cases in order to establish the possibilities and challenges for wastewater reuse. Evaluation also takes into account socio-economic, technical and legislative barriers to the acceptance of reclaimed water.	The research highlights the untapped potential of wastewater reuse in the EU, with only 3% of urban wastewater currently reused. Barriers include fragmented regulations, high monitoring costs, and varying standards across member states. Positive developments include the new EU Water Reuse Regulation for agriculture and national efforts in Southern Europe. Circular water reuse has significant environmental and economic benefits, including reduced water scarcity, energy efficiency, and greenhouse gas emissions.	A precise legislation and generalized EU standards for the reuse of wastewater and more specifically industrial reuse do not exist. Present day policies are generally relevant to agriculture more than industrial water reuse. Subsequent research should focus on the evaluation of why certain range of actors have a bottleneck effect, the regulation of reuse to match various industries, and how implementation of circular re-use solutions can be better integrated to increase reuse across different fields. Further, there is limited research regarding the socio cultural factors that affect the acceptance of products in the public domain.	Malinauskaite, J., Delpech, B., Montorsi, L., Venturelli, M., Gernjak, W., Abily, M., Perdih, T. S., Nyktari, E., & Jouhara, H. (2024). Wastewater Reuse in the EU and Southern European Countries: Policies, Barriers and Good Practices. Sustainability, 16 (24), 11277. https://doi.org/10.3390/su162411277
35	Wastewater Treatment and Reuse: Sustainability Options	Seetharam Chittoor Jhansi, Santosh Kumar Mishra	2013	Consilience: The Journal of Sustainable Development	Columbia University	The study is relevant to the global water crisis by assessing sustainable wastewater treatment and reuse technologies especially in urban cities of developing countries. It focuses on retrofitting existing, discharge-oriented wastewater systems to sustainable, cyclic systems. The research focuses on technologies for water, nutrients and energy recycling as well as minimizing the impact on the environment and public health and supporting agriculture.	This paper focuses on different decentralised and environmentally friendly wastewater treatment technologies such as lagoons, anaerobic digesters and SAT systems. A comparative assessment of their performance, ability to integrate with local conditions, and resource recovery opportunities is made. This study uses case studies of other countries, previous experiences in implementing the policy, and the costs and benefits of the policy.	In decentralized systems, including anaerobic digesters and SAT technologies, there is a high potential for sustainable wastewater treatment in the urban environment. These systems are capable of adopting the socio-economic and environmental status of the locality, enable the recycling of resources such as water, energy, and nutrients and minimize dependence on central structures. In this context, SAT systems are shown to have effective pathogen removal, enhance groundwater recharge and overcome cultural barriers to water reuse.	However, difficulties in the implementation of decentralized systems are insufficient institutional environment, low recognition, and deficiency of funds. More work is required to fine-tune these system at various climate, socio-economic contexts and at large scale. Furthermore, specific policies and specific community engagement approaches are necessary to ensure implementation.	Chittoor Jhansi, S., & Mishra, S. K. (2013). Wastewater Treatment and Reuse: Sustainability Options. Consilience: The Journal of Sustainable Development. Columbia University. https://doi.org/10.7916/D8JQ10Q1

GUARDING THE RIVER GANGES: MIRZAPUR'S COMPREHENSIVE PLAN FOR SUSTAINABLE WASTEWATER MANAGEMENT AND REUSE										
S. No.	**Title**	**Author**	**Year**	**Journal**	**Publisher**	**Research Focus**	**Methods & Tools**	**Findings**	**Research Gap**	**References**
36	Wastewater Treatment and Water Reuse in Spain. Current Situation and Perspectives	Antonio Jodar-Abellan, María Inmaculada López-Ortiz and Joaquín Melgarejo-Moreno	2019	Water 2019	MDPI	This research highlights the critical role of wastewater treatment and reuse in addressing water scarcity, especially in regions like Spain, where water shortages are a structural issue. The study focuses on the environmental, social, and economic advantages of wastewater reuse and its alignment with European Union directives. It delves into the strategies for improving water management through sustainable reuse practices, emphasizing Spain's advancements and the regulatory frameworks that guide these efforts.	The study utilizes diverse methods and tools to achieve its objectives. It relies on data collection from national authorities, private companies, and international reports to analyze water usage and reuse trends. Geographical Information System (GIS)-based tools are employed to map water inputs and demands across Spain. Additionally, the research conducts a comprehensive policy analysis, examining historical and current water management initiatives, such as the National Plan of Sanitation and Water Treatment (PNSD). Comparative analyses are also carried out to assess wastewater reuse rates, costs, and technologies against global benchmarks.	Spain has emerged as a leader in wastewater reuse in Europe, with a substantial proportion of reclaimed water being utilized in agriculture, urban irrigation, and industrial processes. This practice has led to significant environmental benefits, such as reducing aquifer overexploitation and restoring ecosystems like the Albufera natural park. Economically, reclaimed water proves to be more cost-effective than desalination and interbasin transfers due to its lower energy requirements. The study also highlights the impact of EU directives, which have driven improvements in wastewater treatment coverage, although challenges persist in ensuring compliance with tertiary treatment requirements, particularly in larger municipalities.	Despite progress, gaps remain in adopting advanced, energy-efficient wastewater treatment technologies and enforcing compliance with EU directives, especially in urban areas. Financing mechanisms, such as improved sanitation taxes and equitable pricing, are needed to ensure cost recovery. Mandatory reuse practices and integration of high-quality infrastructure in water-scarce regions are also lacking. The research highlights the potential of wastewater reuse as a sustainable solution to water scarcity, emphasizing coordinated efforts in technology, policy, and economic models to enhance its impact.`	Jodar-Abellan, A., López-Ortiz, M. I., & Melgarejo-Moreno, J. (2019). Wastewater Treatment and Water Reuse in Spain: Current Situation and Perspectives. Water, 11(8), 1551. https://doi.org/10.3390/w11081551
37	Wastewater Treatment Using Constructed Wetland: Current Trends and Future Potential	Ikrema Hassan, Saidur R. Chowdhury, Perdana K. Prihartato and Shaikh A Razzak	2021	Processes	MDPI	This paper reviews the use of Constructed Wetlands (CW) for wastewater treatment, and looks at its advantages to the environment, how it works to remove pollutants and recent advancement. This applies to both municipal, industrial, agricultural, and stormwater wastewater types, while highlighting how CW can be applied to solve problems such as nutrient pollution or climate change.	The study entails a review of literature, case study, experimentation and theoretical models of CW systems in different geographical locations. The research also analyses the materials that are used in CWs such as plants, substrates, and microorganisms together with remediation processes. The findings of the CW design, performance indices, and trends are synthesized to find new directions for future development.	Constructed wetlands are developed to mimic the natural processes in removing/degrading contaminants in wastewater It is environment friendly method as CWs are a home for native and migratory wildlife and create a balance between the land development and the need for green cover	While the review emphasizes the benefits of Constructed Wetlands (CWs), there's a gap in providing detailed insights into specific challenges associated with different types of CWs and potential opportunities for improvement. Also, Where CWs have been applied, there are research limitations in the interactions between microplastics, pollutants such as POPs (persistent organic pollutants), and CW plants.	Hassan, I., Chowdhury, S. R., Prihartato, P. K., & Razzak, S. A. (2021). Wastewater Treatment Using Constructed Wetland: Current Trends and Future Potential. Processes, 9(11), 1917. https://doi.org/10.3390/pr9111917
38	Water Reclamation and Reuse in Singapore	Yue Choong Kog	2020	Journal of Environmental Engineering	ASCE Library	The paper explores the factors that led to the development of Water Reclamation and Reuse Singapore, with an emphasis on NEWater. It focuses on how Singapore has been managing its severe water stress through sustainable sources of water supply and new technologies such as membrane technology and the public acceptance of water conservation measures.	The research is based on a historical survey of Singapore's water management policies from colonialism to the present. It uses information relating to rainfall, population, technological development, and governmental treaties. The study employs cases of NEWater deployment and also comparisons with other water supply options such as desalination and local catchments.	The study shows the impact of NEWater which provides 40% of the water consumed in Singapore and plans to provide 50% by 2030 and 85% by 2060. Some of the benefits of reclaimed water include; enhanced water security, Climate resilience and efficiency of land by cutting on the storage required. Social awareness addr essed stigmas regarding the consumption of wastewater, while demand management greatly decreased water consumption rates.	The research does not examine the applicability of Singapore's water reclamation model to other countries with different socio-economic and physical environments. Further, it fails to provide an elaborated assessment of the cost-benefit comparison of NEWater vis-a-vis other technologies like advanced desalination or other future innovative water recycling technologies.	Kog, Y. C. (2020). Water Reclamation and Reuse in Singapore. Journal of Environmental Engineering, 146 (4). https://doi.org/10.1061/(asce)ee.1943-7870.0001675

5.2. Expert Opinion Survey Questionnaire

Wastewater

Wastewater, the byproduct of anthropogenic activities, contains various pollutants detrimental to both human health and the environment. Effective management and treatment of wastewater are imperative to mitigate contamination risks and ensure the sustainable use of water resources. I am conducting a survey to assess the current state of wastewater management in urban India for my research project. This survey aims to identify challenges, explore potential solutions for reuse, and enhance the efficiency of existing systems. Your participation is invaluable in shaping strategies for a cleaner and more sustainable future.

* Indicates required question

1. Name: *

2. Designation: *

3. What's the primary cause of water scarcity in urban areas? *

Tick all that apply.

- [ ] Over-Extraction of Groundwater
- [ ] Pollution of Existing Water Sources
- [ ] Poor Water Management Practices
- [ ] Inefficient Wastewater Treatment
- [ ] Policy and Governance Issues

4. What are the biggest challenges in implementation of wastewater management solutions in urban areas? *

Tick all that apply.

- [ ] Infrastructure Limitations
- [ ] Funding limitations
- [ ] Technological limitations
- [ ] Lack of public awareness/support
- [ ] Policy and regulatory hurdles
- [ ] Other:

5. Rate the efficiency of sewage treatment plants in ensuring the safety and quality of reused water *

Mark only one oval per row.

	Highly effective	Moderately effective	Neutral	Moderately ineffective	Highly ineffective
Tier - I Cities	( )	( )	( )	( )	( )
Tier - II Cities	( )	( )	( )	( )	( )
Tier - III Cities	( )	( )	( )	( )	( )

6. Rate the effectiveness of wastewater management policies and regulations : *

Mark only one oval.

- ( ) Highly effective
- ( ) Moderately effective
- ( ) Neutral
- ( ) Moderately ineffective
- ( ) Highly ineffective

7. How would you describe the public's perception of wastewater management issues? *

Mark only one oval.

- Unconcerened
- Uninformed
- Concerned but disengaged
- Actively engaged and supportive
- Highly critical and demanding

8. How open is the society to the idea of reusing treated sewage for non-potable purposes? *

Mark only one oval.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very resistant

9. Which measure do you think is most effective in preventing the discharge of untreated sewage in open drains? *

Tick all that apply.

- [ ] Strict enforcement of regulations
- [ ] Community education and awareness programs
- [ ] Improved infrastructure for sewage collection and treatment
- [ ] Penalties for non-compliance
- [ ] Other: ____________

10. Rate the effectiveness of following solutions: *

Mark only one oval per row.

	Highly effective	Effective	Ineffective	Highly Ineffective	Not Sure
Decentralised STP	◯	◯	◯	◯	◯
Constructed Wetland	◯	◯	◯	◯	◯

11. Which stakeholder group do you think should play a more active role in addressing wastewater management issues? *

Tick all that apply.

- [ ] Government agencies
- [ ] NGOs and civil society organisations
- [ ] Private sector entities
- [ ] Local communities
- [ ] All of the above

12. What areas of research and development do you believe require further attention to advance wastewater reuse technologies and practices? *

5.3. Questionnaire for Administrative Officials

Questions to be asked during interview

1. Water source for various sectors (industrial, residential, commercial)?
2. Ward wise data available on wastewater generation, collection and treatment
3. Sewage network map? (according to AMRUT - 39.6% is covered)
4. What is the breakdown of wastewater sources (industrial, residential, commercial)?
5. Which all stakeholders are involved and their roles during the wastewater management process?
6. What are the key challenges faced by the municipal body in collecting, transporting and treating wastewater in Mirzapur?
7. If wastewater is collected but disposed of untreated, what happens?
8. How are septic tanks cleaned and where is waste disposed, treated or reused?
9. What is the primary method of sludge disposal in Mirzapur or where is it used?
10. Is treated wastewater currently being reused in Mirzapur? If yes, could you specify the locations, purposes, and approximate quantities being reused?

    OR

    Information on existing projects that utilize treated wastewater for various purposes (e.g., irrigation, industrial processes, landscaping). Location and scale of these reuse initiatives.
11. How is treated wastewater transported for reuse purposes?
12. What specific regulations and standards are there that govern the use of treated wastewater (for agriculture, industrial, construction, landscaping, public place cleaning) ?
13. Are there any cases of water borne disease in past years due to water pollution?
14. Agriculture patterns follow? What is their source of water? How wastewater is disposed of and treated related to agriculture?

15. Types of industries? Their water demand? Amount of wastewater generated? How is it disposed of and treated?
16. List of CETPs / ETPs available in Mirzapur (by industries)
17. How does the city currently manage untreated wastewater that flows into the Ganga ?
18. How are the financial and technical gaps in wastewater treatment and reuse projects being addressed?
19. How does the city monitor and enforce compliance with environmental regulations regarding wastewater discharge?
20. What percentage of the city's budget is currently allocated to wastewater management?

5.4. Presentation Sheets

NEED FOR WASTEWATER MANAGEMENT

Water is the elixir for human life, sustainable development, and ecosystem health, yet the world faces growing challenges related to water scarcity and pollution.


Source : Canva

Wastewater is used water from any combination of domestic, industrial, commercial or agricultural activities, surface runoff / stormwater, and sewer flow.

The right to water entitles everyone to have access to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic use. Still, at least 1.8 billion people globally use drinking water sources contaminated with faecal matter.

In India, approximately 72% of the urban wastewater is left untreated and is often discharged directly into rivers, lakes, or groundwater.

There are 14 major rivers, 55 minor rivers, and hundreds of smaller streams receive millions of litres of untreated sewage, industrial effluents, and agricultural runoff daily, posing severe risks to both surface and groundwater quality.


Source : Canva

Addressing these challenges requires a shift toward a circular approach in water resource management, emphasising the reuse and recycling of water to bridge the existing gap in wastewater treatment and synchronise future treatment capacity needs.

Source : Multiple Sources

AIM

To develop a **comprehensive strategy for wastewater management,** focusing on reducing river pollution and fostering a circular water strategy through reducing and reuse practices.

OBJECTIVES

To review the existing scenarios, practices and policies of wastewater management, at study area level.

To identify the gaps in wastewater generation, collection and treatment, with a focus on challenges in infrastructure and mangerial aspects of wastewater management.

To assess the feasibility of reusing treated wastewater for ecological, industrial, agricultural, and civic uses through mapping the potential bulk user.

To develop a sustainable comprehensive framework for wastewater management, fostering a circular economy.

WHY MIRZAPUR ?

- The city is located along the Ganga River, one of India's holiest rivers, which is heavily polluted by untreated wastewater, industrial waste, agricultural runoff, etc.
- There are many untapped drains like Khajuri Nalain Mirzapur which discharge untreated wastewater into the Ganga.
- Existing STPs and infrastructure is insufficient to treat wastewater generation and to serve projected population.
- Industrial hub with water-intensive carpet industries, offering potential for treated wastewater reuse.
- Frequent riverbank flooding worsens wastewater management and pollution.

SCOPE AND LIMITATIONS

Findings will be focused on Mirzapur, providing insights tailored to its specific challenges.

The study focuses solely on liquid waste, excluding solid waste at all stages of the wastewater management process.

While the Ganga faces multiple pollution challenges, this study concentrates only on wastewater-related issues in the Mirzapur stretch.

The study is limited to point source pollution (domestic and industrial wastewater), while excluding non-point sources (agricultural and stormwater runoff).

METHODOLOGY

- Literature Review
  - Existing Research Paper, Journals, Articles etc.
  - Study Current Policies, Guidelines and SDG 2030 agenda
  - Study the Wastewater Generation and Treatment Scenario in India.
- Formulation and Conceptualization of the Need of Study.
- Identification of Site
- Research Design
  - Aim
  - Objective
  - Scope & Limitation
- Data Collection
  - Primary Data Collection
    - Household Survey
    - Observatory Survey
    - Stakeholder Interview
  - Secondary Data Collection
    - Demography
    - Landuse Data
    - Water Supply Data
    - Wastewater Data
    - Bulk Users Data (Social Infrastructure like - Green Spaces, Railway Station, Industril and Agriculture Profile)
  - Remote Sensing and GIS Data Collection
    - Digital Elevation Modelling (contour, aspect, slope, etc.)
    - Hydrology Mapping (drainage system, water flow and accumulation, streams and watershed)
- Data Analysis and Spatial Mapping
  - Demand and Supply Gap Analysis
  - Water Quality and Pollution Mapping
  - Cost - Benefit Analysis (for reusing wastewater)
  - Identification of Bulk Users in Accessible Radius
- Proposals
  - Comprehensive Wastewater Management Plan
  - Recommendations and Strategies

GUARDING THE RIVER GANGES : MIRZAPUR'S COMPREHENSIVE PLAN FOR SUSTAINABLE WASTEWATER MANAGEMENT AND REUSE

Planning Thesis Project
Bachelor of Planning
(2021- 2025)

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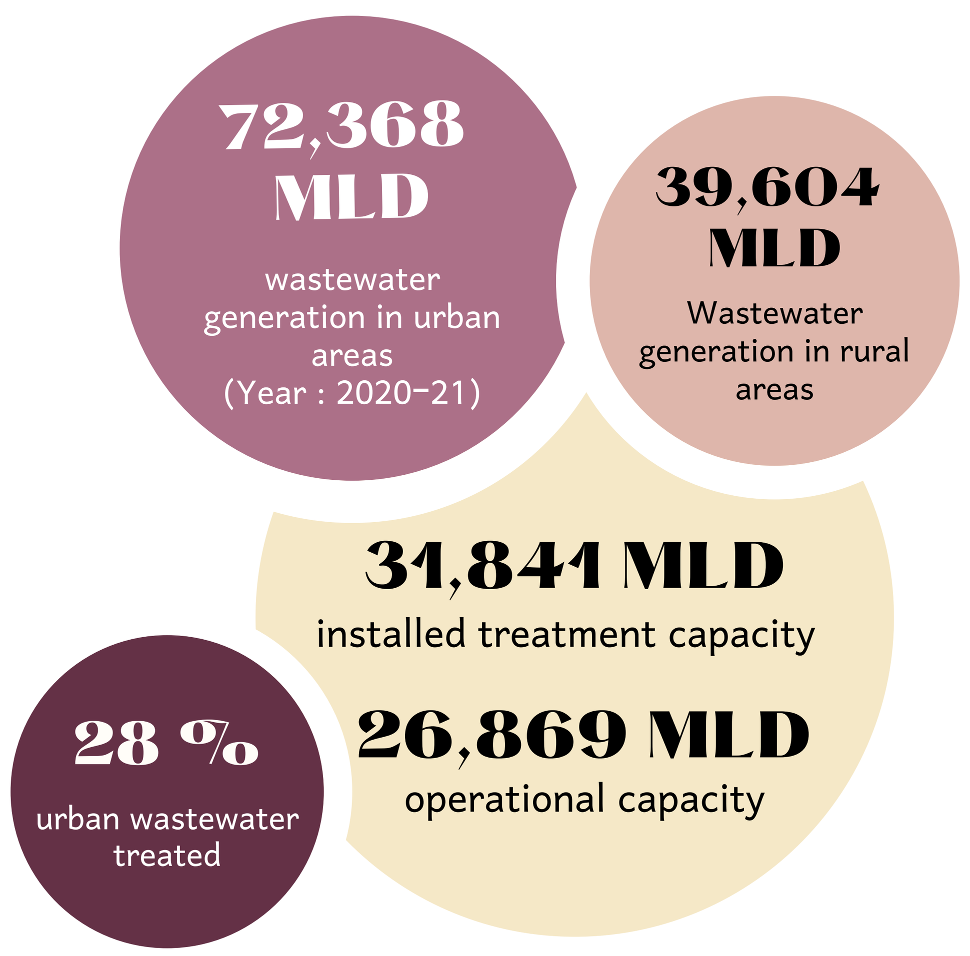
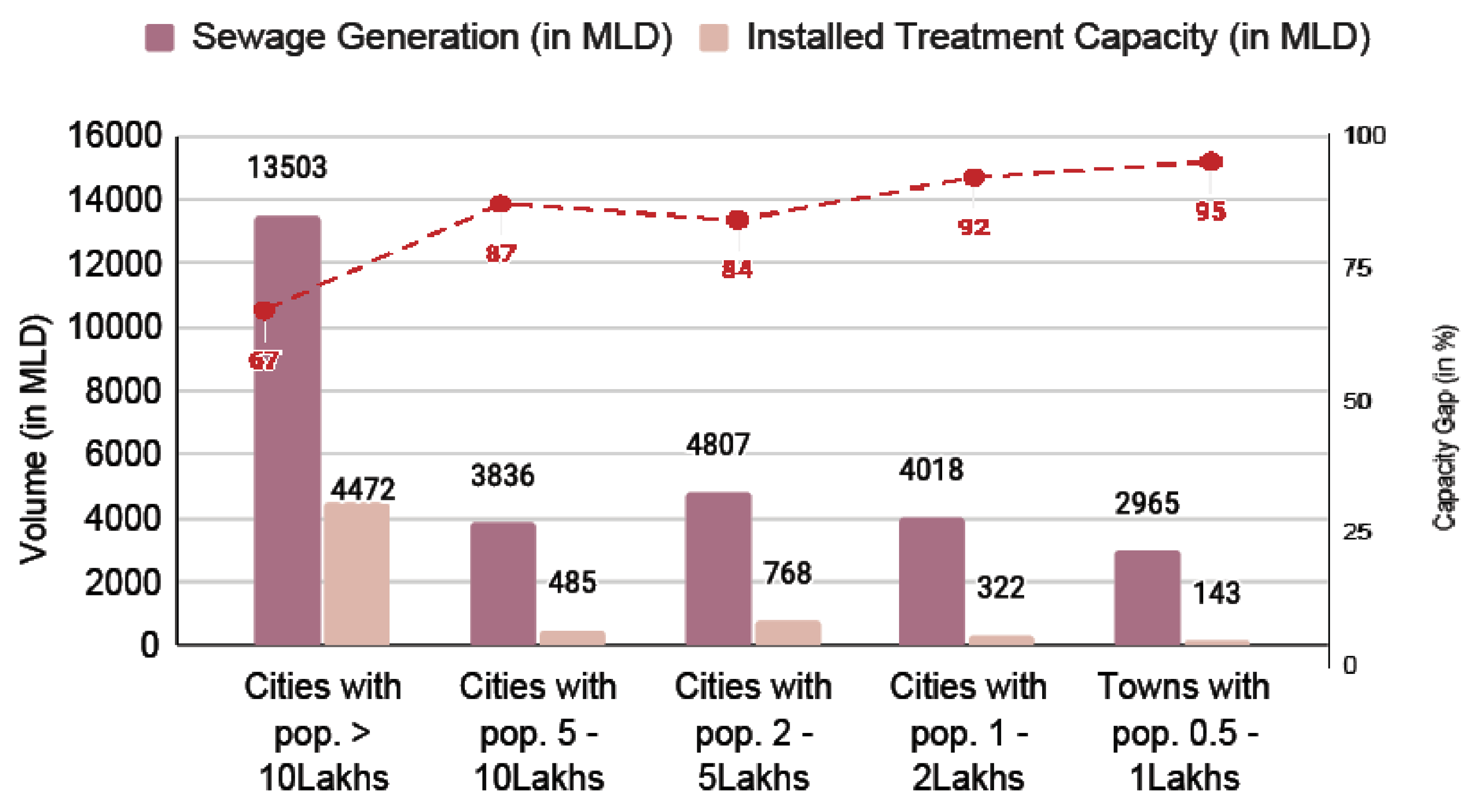
WASTEWATER SCENARIO

- Globally, around **60% of household wastewater** is discharged into the environment without adequate treatment in countries representing **80% of the world's population.**
- **Asia** is the largest contributor, accounting for **42% of global wastewater.**



- The CPCB 2021 report reveals India generates an estimated 72,368 MLD of urban wastewater, but only **28% of this is treated, leaving 72% of the wastewater untreated** and likely to be discharged into rivers, lakes, groundwater.

Source : CPCB, 2021



- Smaller towns are often more neglected in wastewater management, with Class-II towns facing a 95% treatment capacity gap compared to 67% in larger cities like Delhi.
- Despite their smaller size, these towns contribute significantly to wastewater generation, highlighting the need to prioritize their treatment infrastructure.
- India's water demand is set to double its supply in the coming decades, making wastewater treatment and reuse essential for the future.

POLICY AND LEGAL REGULATION FRAMEWORKS

1977 – The Water (Prevention & Control of Pollution) Cess Act
funded Central and State Boards through industrial water taxes and offered a 25% cess rebate to incentivize wastewater treatment.

1978 – The National Water Quality Monitoring Programme of India
advises central and State governments on prevention, control, abatement of water pollution and sets standards on water quality in streams and wells.

1986 – The Environment (Protection) Act
empowers the Central Government to set sewage and effluent standards, enforce compliance, & embeds the "polluter pays principle" in Indian policy.

1985 - 1993 – Ganga Action Plan (GAP-I 1985, GAP-II 1993) and The National River Conservation Plan
initiative began with cleaning the Ganga and major tributaries like Yamuna and Gomti, later expanding to other rivers.

2006 – The National Environment Policy
addresses water pollution by promoting wastewater recycling, treatment, and reuse through urban action plans and regulations.

2008 – National Urban Sanitation Policy
focuses on sanitary and safe disposal of human waste and recommends recycle and reuse.

2008 – The National Water Mission
promotes the recycling of wastewater for meeting water needs of urban areas.

2012 – National Water Policy
incentivises decentralised sewage treatment plants, recycling and reuse of treated water through planned tariff systems, and subsidized treatment of industrial effluents.

2013 – The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act
prohibits manual sewer cleaning, eliminates insanitary latrines, and rehabilitates scavengers in alternative jobs.

2014 – Swachh Bharat Mission
reduced open defecation through toilet construction, minimizing untreated waste in water bodies, improving sanitation, and promoting STPs for effective urban wastewater management.

2015 – Namami Gange Program
sanctioned 161 projects to create/rehabilitate 5,501 MLD STP capacity and 5,134 km sewer network. So far, 92 projects completed, delivering 1,643 MLD STP capacity and 4,156 km network.

2015 – Atal Mission for Rejuvenation and Urban Transformation (AMRUT)
enhanced sewage management by expanding sewer connections and STP capacity, improving urban sewage disposal, environmental cleanliness, and public health.

2015 – The National Guidelines on Zero Liquid Discharge
developed by CPCB for industrial sectors highlights the zero effluent discharge.

2016 – National Building Code
emphasizes the reuse of treated sewage and sullage in commercial or residential multi-storeyed complexes for flushing of toilets, horticulture and fire-fighting purposes.

2017 – National Faecal Sludge and Septage Management Policy
focuses to achieve 100% access to safe sanitation, achieve integrated urban sanitation, safe disposal of faecal waste and mandates strict environmental discharge standards

2019 – Uttar Pradesh State Septage Management Policy
aims to manage and treat wastewater from septic tanks, reducing pollution in water bodies by ensuring proper treatment before disposal, thus improving sewage management.

2020 – Uttar Pradesh State Water Policy
emphasizes improved wastewater treatment, reuse, and septage management to reduce pollution in water bodies, focusing on proper sewage systems, especially in urban areas.

2021 – National Framework on the Safe Reuse of Treated Water
envisions widespread, safe reuse to ease freshwater scarcity, reduce pollution, protect public health, and promote a sustainable circular economy.

LITERATURE REVIEW

POLICY AND GOVERNANCE

- Many STPs in India **do not meet regulatory standards**, and enforcement actions are often limited, with **more than half of the violations left unaddressed** (CPCB, 2020).
- The **shortage of staff** in scientific, technical, and administrative roles ranges between **37.6% - 52.3%**, making it difficult for institutions to function effectively.
- WWT can generate energy through biogas recovery and nutrient recycling, but **infrastructure, policy, and cost challenges** persist.
- The **cost** of water reuse services, **social resistance**, & lack of clear **governance structures hinder** the transition to a circular model.

CIRCULAR ECONOMY

- The **use of biogas from wastewater, organic manure generation, and phosphorus recovery** can enhance CE but requires better policy and investment support.
- **3 Million ha** of land can be **fertilised** annually with the sludge from treated wastewater, & **reduces the need for fertilisers by 40%.**
- By 2050, the **freshwater abstraction by industries will be 10.1%**. All these factors make a strong case for a circular economy pathway in the wastewater sector.
- A paradigm shift from "**use and throw**" to a "**use, treat, and reuse**" approach is required.

WASTEWATER REUSE

- **Rainwater harvesting and recycling** could supply up to **50% of domestic water demand** in some regions.
- Through the utilisation of **110 major cities' 80%** untreated wastewater, nation could meet **75%** of its anticipated **industrial water needs by 2030.**
- **Drip irrigation** using treated wastewater can **reduce freshwater demand by 30-40%.**
- CEEW estimates suggest that by 2050, over **96,000 million litres per day** of treated used water (TUW) will be **available for reuse** in India.

WASTEWATER TREATMENT

- **Decentralized systems and AI-driven systems** enhance efficiency and sustainability.
- Technologies like dual systems and **natural treatments enhance safe reuse.**
- Localized treatment can **reduce costs** and promote resource regeneration.
- More research is required to **reduce the resource requirement** associated with using advanced technologies.
- Decentralised systems are currently popular, they are **detached from governance, regulatory, and political complexities.**

EXPERTS INSIGHT

Experts highlight the need for decentralized, eco-friendly wastewater treatment, standardized emerging technologies, and IoT integration. They stress public participation, skill development, and local initiatives to raise awareness. Key focus areas include resource recovery, low-cost natural treatments, and linking wastewater management to climate resilience.

WASTEWATER AND SDGs

Wastewater Management supports **5 out of 17 SDGs** directly and 6 / 17 SDGs indirectly -

3 Good Health and Well-being	3.3	Reduces waterborne diseases
	3.9	Prevents water pollution-related illnesses
9 Industry, Innovation and Infrastructure	9.4	Encourages industrial WW use
6 Clean Water and Sanitation	6.1	Protects drinking water sources
	6.3	Promotes WWT & reuse
	6.4	Supports water conservation
11 Sustainable Cities and Communities	11.6	Reduces urban water pollution
12 Responsible Consumption and Production	12.2	Enhances water sustainability
	12.4	Prevents hazardous discharge
	12.5	Promotes wastewater recycling

BEST PRACTICES

NATIONAL : PUNE, MAHARASHTRA

Pune is reusing a large volume of treated wastewater for multiple purposes, serving as a model for other cities.

CHALLENGES

- The current water supplied is approximately **1,250 million litres per day** (MLD)
- Total sewage generation: **850 MLD**.
- Effective treatment capacity: **477 MLD**.
- 50% of untreated sewage is discharged into the **Mula-Mutha River**.
- The polluted waters of the Mula-Mutha rivers eventually merge into the Bhima River, adding to the overall flow into the **Krishna River.**

SOLUTIONS

- **Mandatory STPs for housing schemes** with over 150 tenements.
- Non-compliance **penalties** based on STP capacity.
- Construction sites must use treated greywater for **construction activities**.
- Pune **reuses 400 MLD** of treated wastewater from the Mula-Mutha River, supplying it to farmland via the Agriculture Department.
- Treated water utilized for **construction, road cleaning, and industrial cooling.**
- Daily use for **gardening and landscaping projects**.
- Encourages **freshwater conservation** and reduces groundwater depletion.
- Promotes **circular water use**, alleviating pressure on water sources.

Source : Multiple Sources

INTERNATIONAL : SINGAPORE

" Achieving a Diversified, Secure Water Supply "
Singapore is considered a best practice for wastewater management primarily because it is 100% sewered to collect all used water.

CHALLENGES

- 4.4 million people live on a 700 km² island.
- **High population density** contributes to water scarcity.
- **Increased water demand** due to population and economic growth.
- Faces water stress due to **limited land for rainwater storage.**
- Over-abstraction of groundwater worsens shortages.
- Disputes over **water import pricing** with Malaysia.

SOLUTIONS

- It launched a **water reclamation program for self-sufficiency**.
- By 2060, **water demand** is predicted to nearly **double**.
- The core element of the ***closing the loop*** philosophy is the **Four National Taps.**
- NEWater and desalination will meet up to **85%** of 2060 demand.

Water from Local Catchment	Imported Water from Johor, Malaysia	NEWater (Reclaimed Water)	Desalinated Water From Sea
30% (combined)		40%	30%

4 NATIONAL TAPS OF SINGAPORE

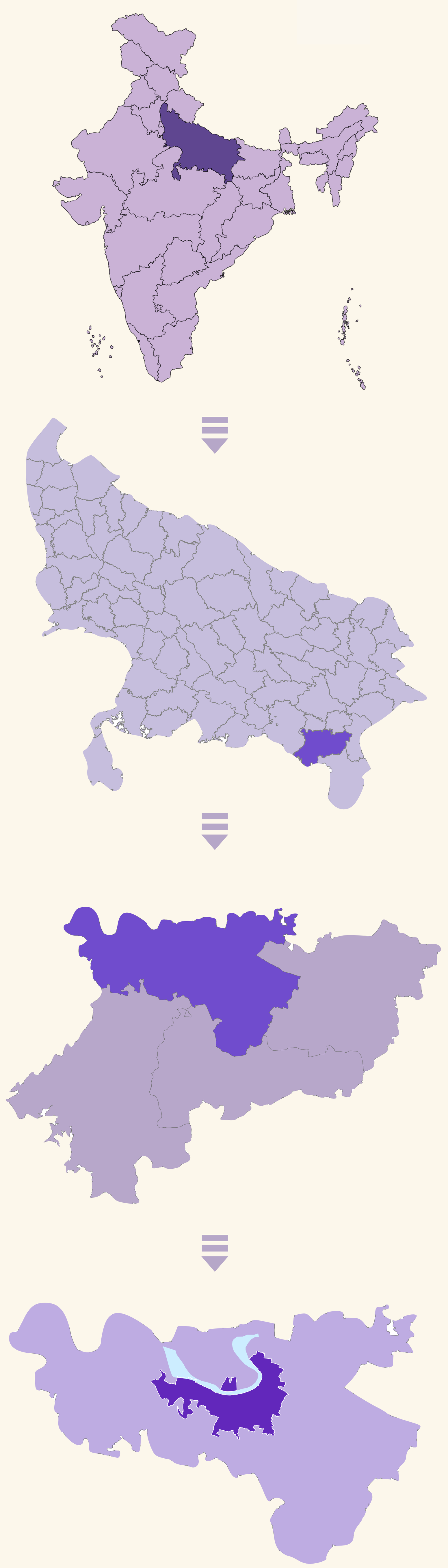
GUARDING THE RIVER GANGES : MIRZAPUR'S COMPREHENSIVE PLAN FOR SUSTAINABLE WASTEWATER MANAGEMENT AND REUSE

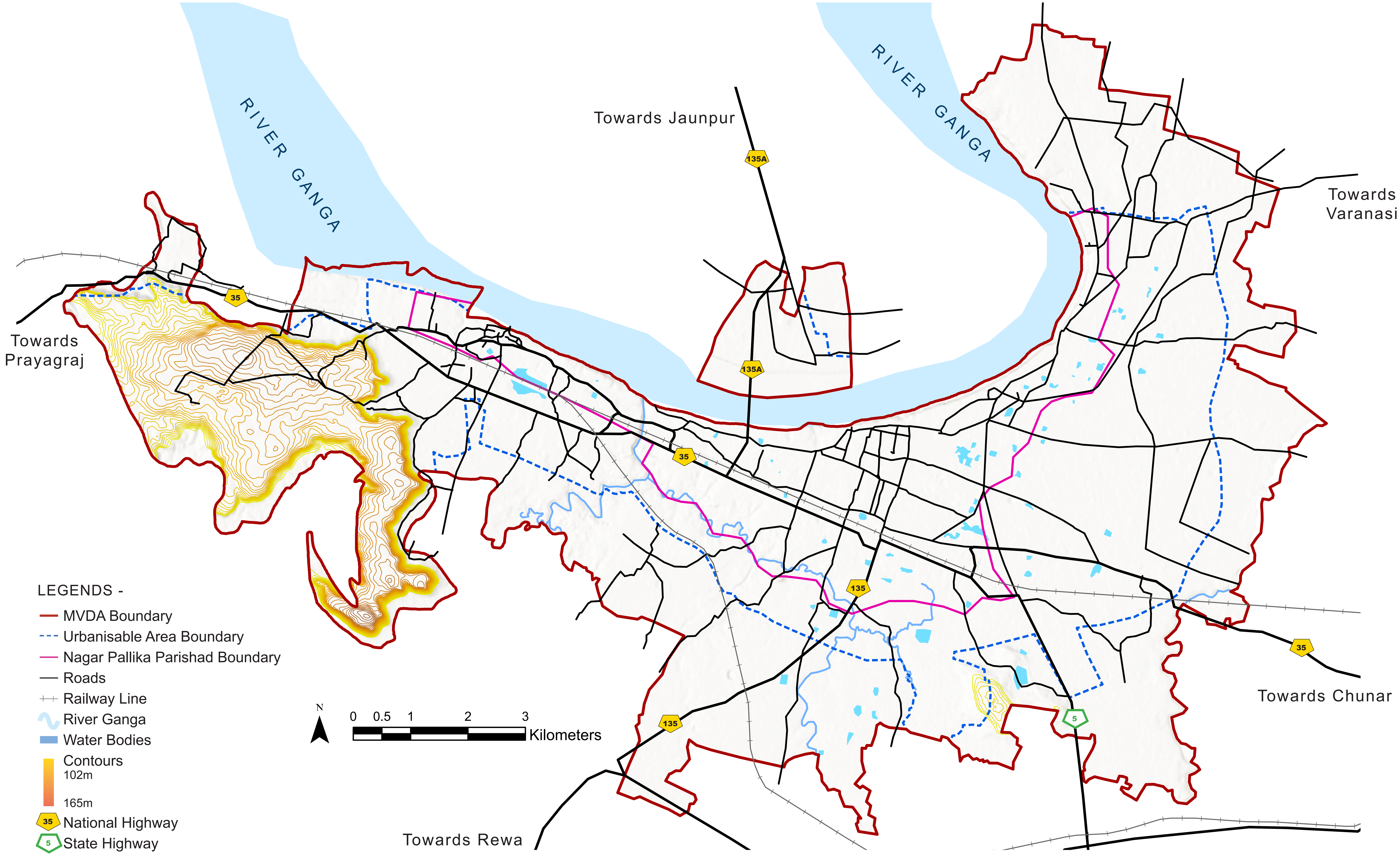
Planning Thesis Project
Bachelor of Planning
(2021- 2025)

Charu Middha
A4134921003

National Institute of Urban Affairs

BASEMAP & SITE CONTEXT



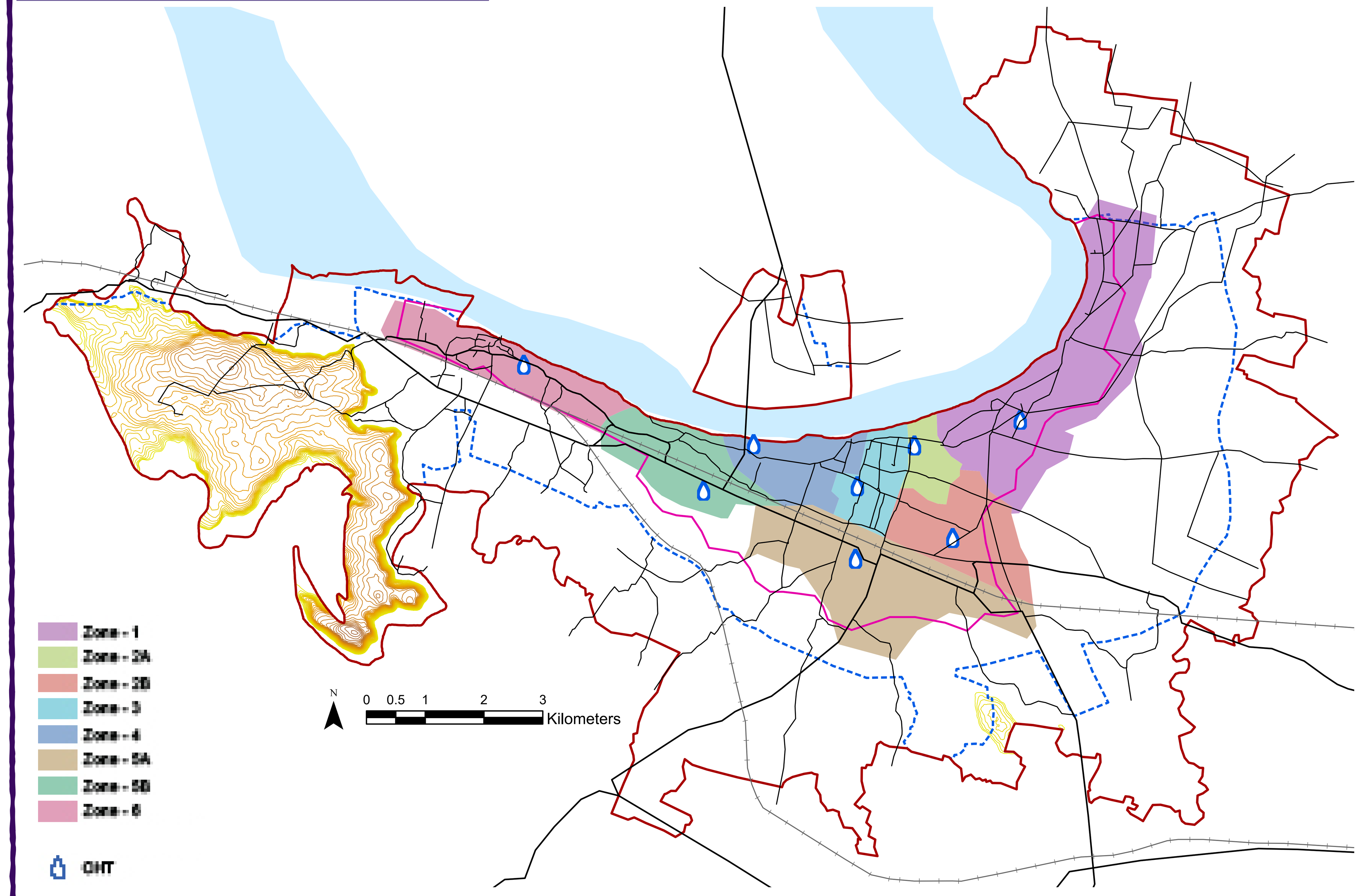


Area (MVDA) 114.85 km²	Area (UA) 83.2 km²	Area (NPP) 38.85 km²	68 Revenue Villages	Known for Carpet Industries	Temperature 7°C - 36.8 °C
Pop. (2011) 3,53,547	Pop. (2011) 2,46,920	Pop. (2011) 2,34,871	38 Municipal Wards	Surrounded by Vindhya Range	Rainfall 978 mm

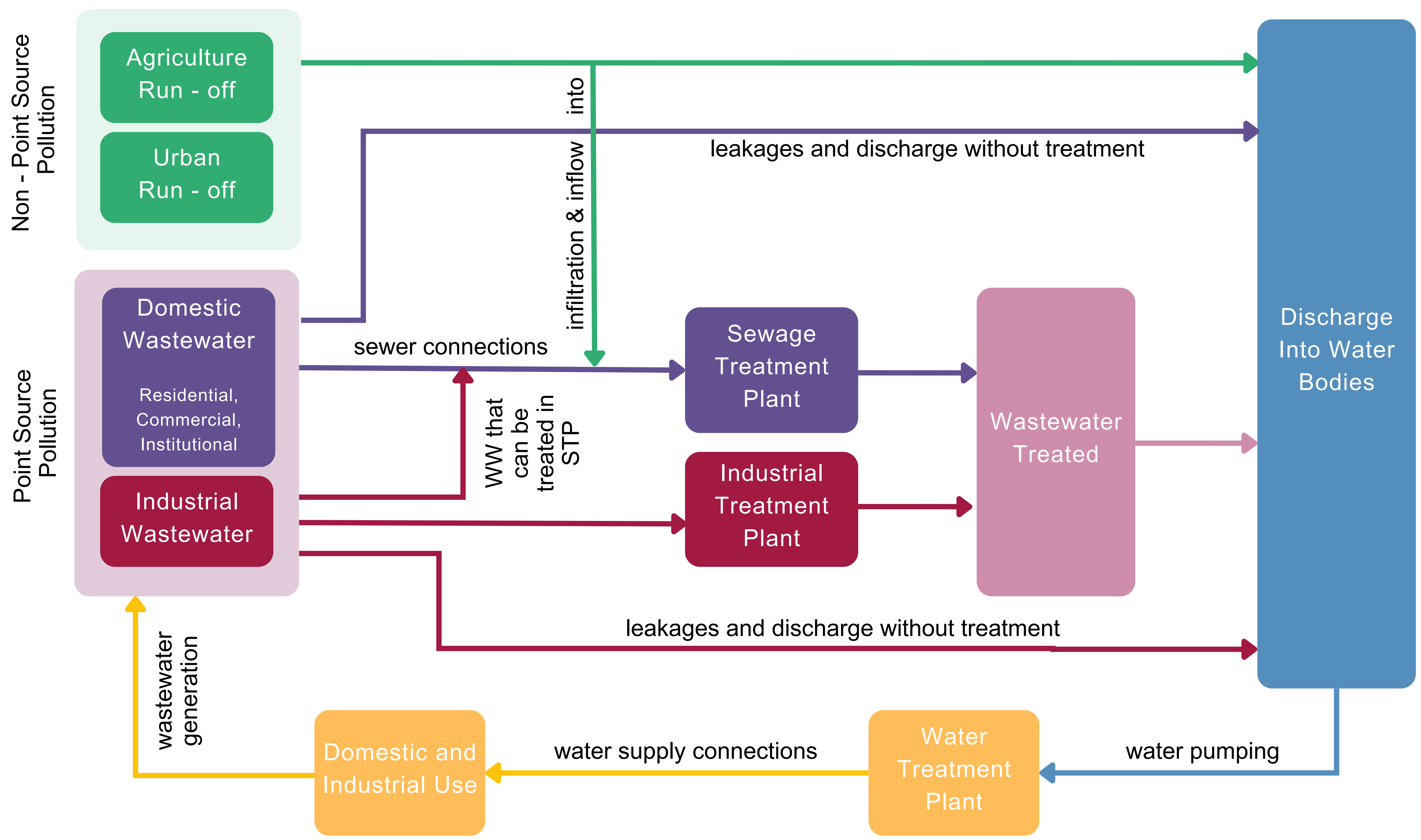
LANDUSE MAP

RIVER GANGA
RIVER GANGA
Towards Jaunpur
Towards Varanasi
Towards Prayagraj
Towards Chunar
Towards Rewa
Residential - 12.48 %
Commercial - 0.5 %
Industrial - 1.06 %
Public - Semi Public - 1.85 %
Educational - 0.85 %
Healthcare - 0.16 %
Public Utilities - 0.29 %
Vacant Land - 2.69 %
Green Spaces - 0.34 %
Waterbody - 0.84 %
Railways - 1.24 %
Rural Area - 49.83 %
Agriculture - 27.82 %
N
0 0.5 1 2 3
Kilometers
LEGENDS -
Water Body
Industrial
Commercial
Residential
Educational
Healthcare
Public Utilities
Green Spaces
Public - Semi Public
Vacant Land
Railway
Agriculture

WATER SUPPLY ZONES



EXISTING WASTEWATER FLOWS



SOURCES OF WATER

Piped Supply (treated) - **65.67%**

Handpump **20.63%**

Piped Supply (untreated) - **6.88%**

Tubewell **5.32%**

Well **1.50%**

Source : Master Plan 2031

STAKEHOLDER INVOLVED AND THEIR ROLES

Private and Public

Residential Areas
Commercial Facilities
Institutional Facilities
Industrial Areas

Nagar Pallika Parishad Mirzapur & Uttar Pradesh Jal Nigam

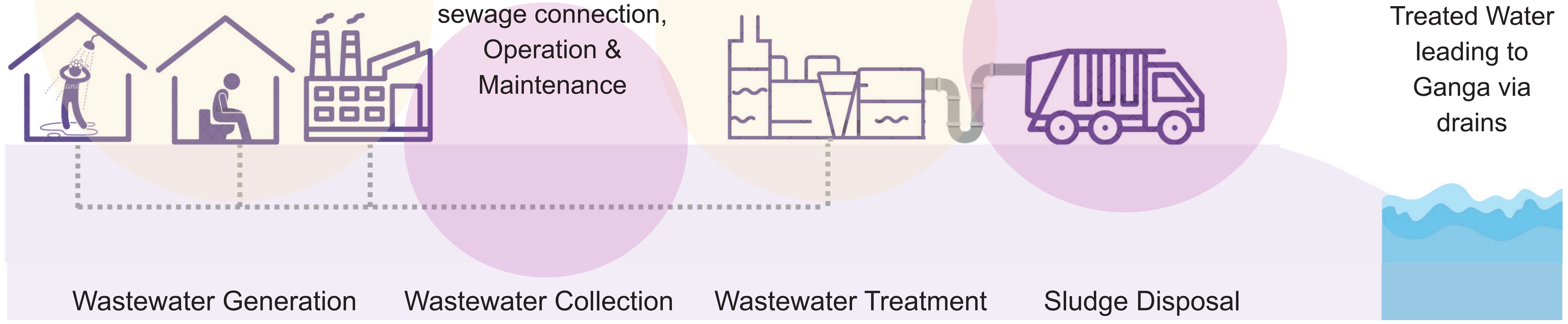
Laying of pipes for sewage connection, Operation & Maintenance

Mirzapur Ghazipur STP Pvt Ltd & UPJN

Construction, O&M : MG STP Pvt Ltd
Overseeing : UPJN

Uttar Pradesh Jal Nigam

Collection of sludge from STPs, Transporting it through trucks to empty land



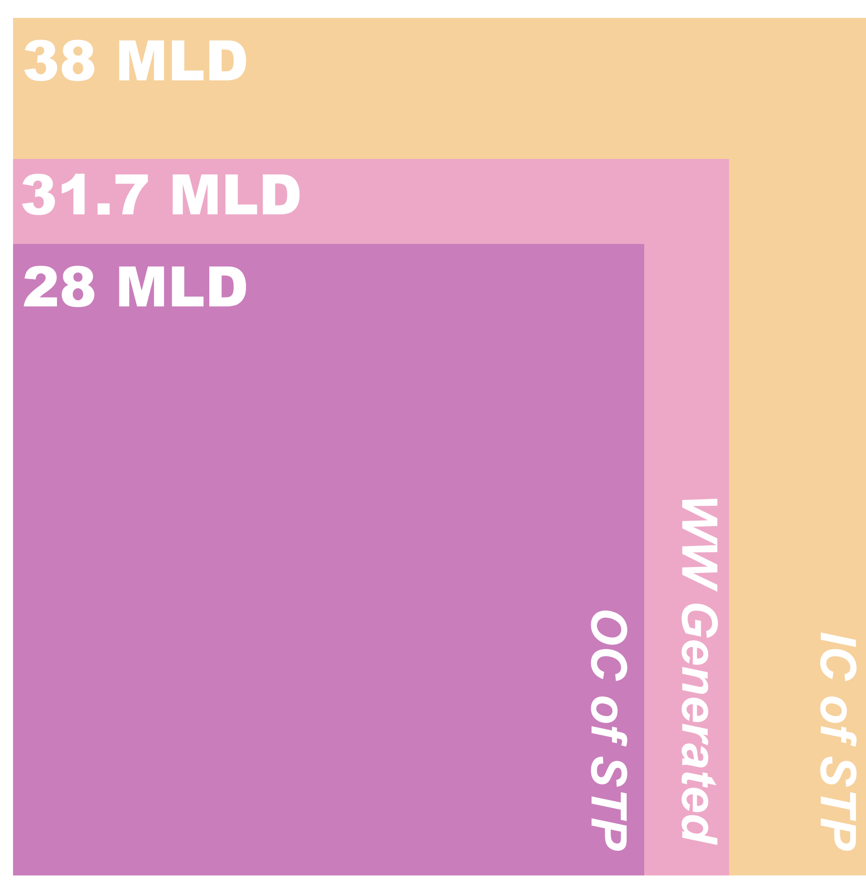
WASTEWATER SCENARIO

Population of MVDA (2025) - 4,41,222

Pop. of Urban Area	Pop. of Revenue Villages
2,94,782	1,46,440
Water Consumption pop. * 135 LPCD	Water Consumption pop. * 55 LPCD
39.7 MLD	8.05 MLD

Wastewater Treated
88 %

Wastewater Reused
0 %



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DRAIN MAP

Balughat Kaccha Drain

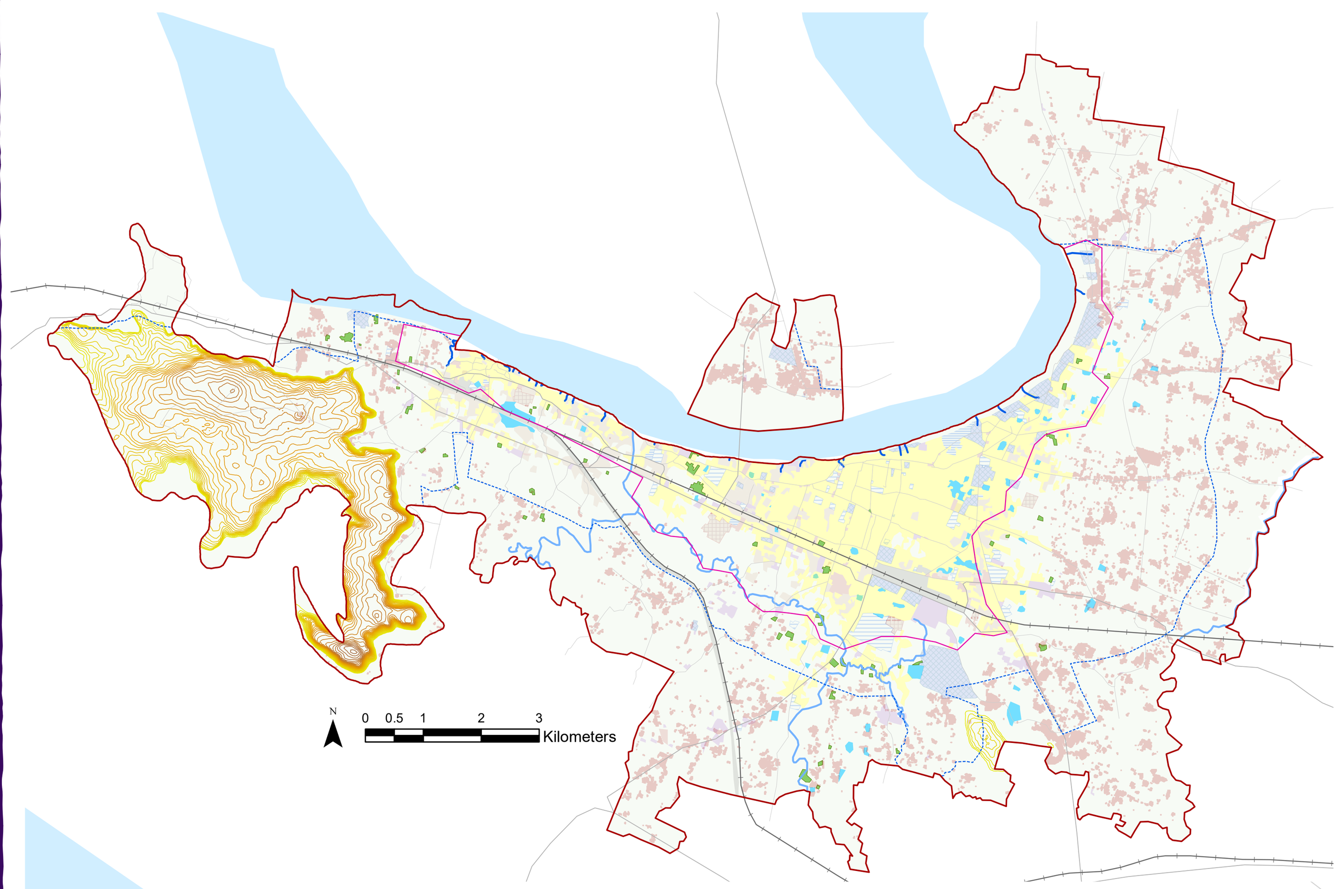
Malhaya Drain

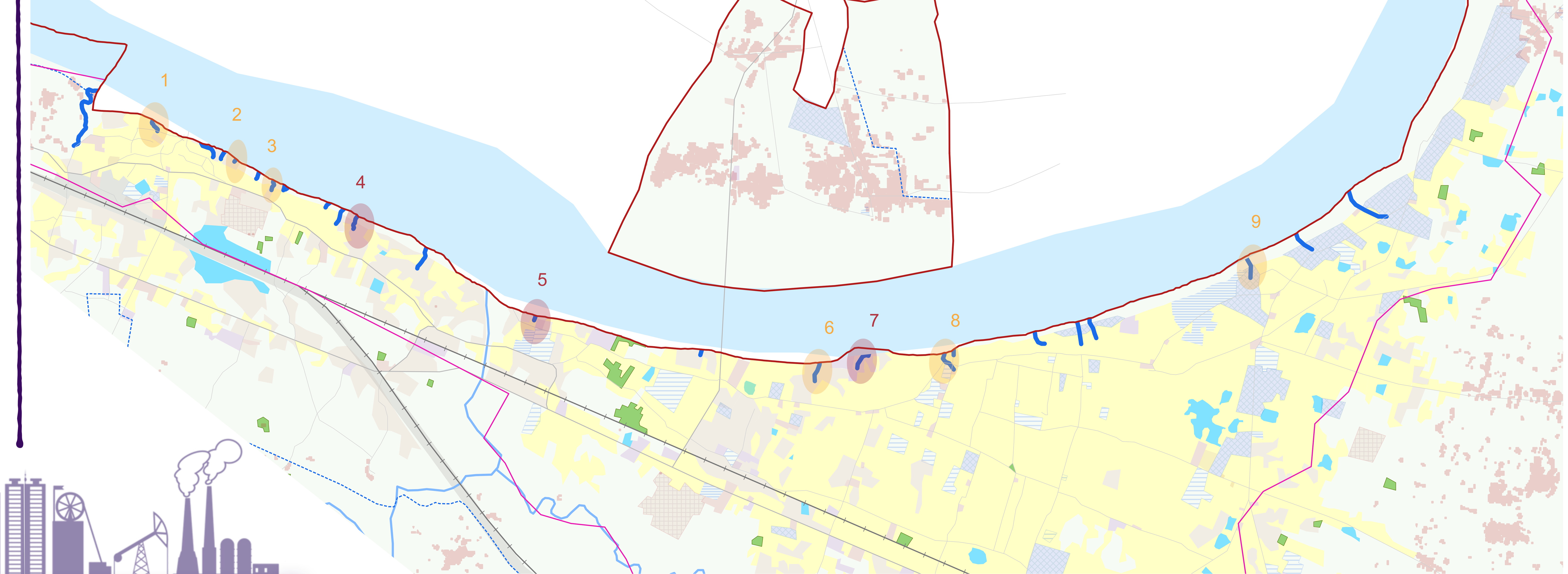
Balaji Temple Drain

Oliyar Drain

Public Club Drain

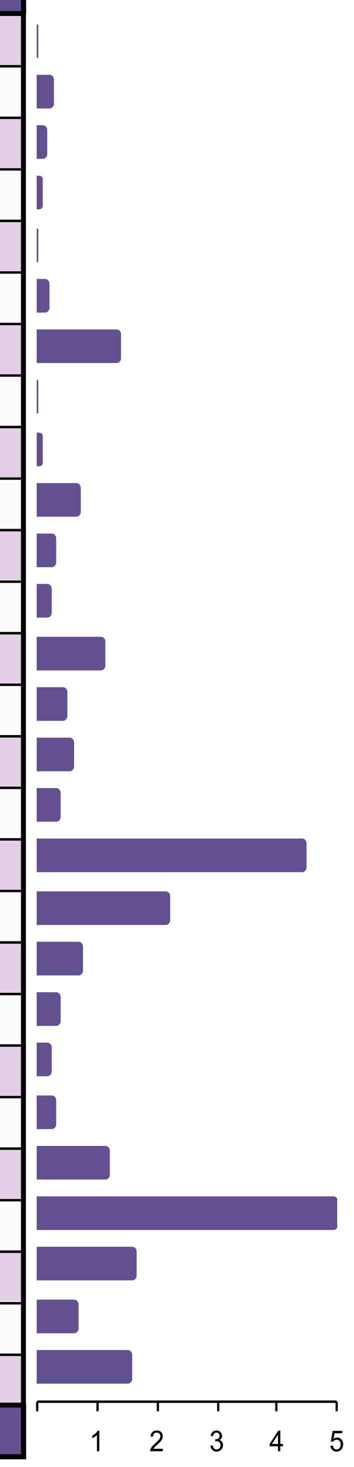
Parasuram Drain



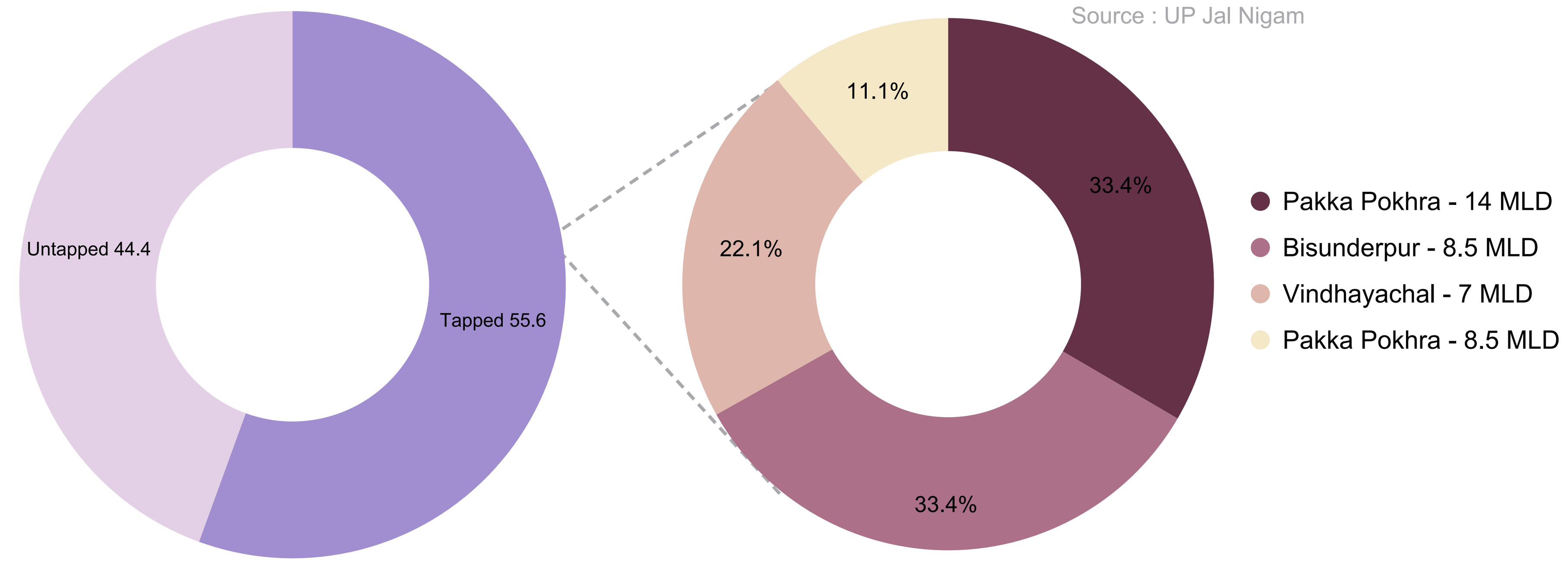


DRAINS DISCHARGING INTO GANGA

S.No	Area	Drain Name	Drain Type	BOD (mg/l)	Discharge (MLD)
1	Vindhyachal	Shivpur Drain	Untapped	-	0.03
2	Vindhyachal	Malhaya Drain	Untapped	34	0.27
3	Vindhyachal	Balughat Pakka Drain	Tapped	-	0.17
4	Vindhyachal	Balughat Drain	Untapped	-	0.09
5	Vindhyachal	Balughat Kaccha Drain	Untapped	41.4	0.01
6	Vindhyachal	Gudara Drain	Tapped	-	0.2
7	Vindhyachal	Parasuram Drain	Tapped	55.7	1.39
8	Vindhyachal	Diwan Ghat New Drain	Untapped	-	0.02
9	Vindhyachal	Diwan Ghat Old Drain	Tapped	-	0.1
10	Vindhyachal	Patengra Drain	Untapped	19	0.74
11	Vindhyachal	Dargah Sharif Drain	Untapped	-	0.32
12	Mirzapur	Chorawa Drain	Untapped	155	0.25
13	Mirzapur	Basvariya Drain	Untapped	6	1.13
14	Mirzapur	Lift Canal Drain	Tapped	110	0.5
15	Mirzapur	Public Club Drain	Tapped	35.4	0.6
16	Mirzapur	District Judge Drain	Tapped	-	0.4
17	Mirzapur	Khandawa Drain	Tapped	100	4.5
18	Mirzapur	Balaji Drain	Untapped	38	2.2
19	Mirzapur	Narghat Drain	Tapped	-	0.78
20	Mirzapur	Badali Drain	Tapped	-	0.39
21	Mirzapur	Sundar Ghat Drain	Tapped	-	0.24
22	Mirzapur	Oliyar Drain	Tapped	-	0.31
23	Mirzapur	Kachahari Drain	Tapped	35.4	1.2
24	Mirzapur	Ghoreshahid Drain	Untapped	24.8	5
25	Mirzapur	Morchghar Drain	Tapped	24.6	1.64
26	Mirzapur	Hanuman Ghat Drain	Untapped	30.4	0.68
27	Mirzapur	Bisundarpur Drain	Tapped	20.4	1.58
		Total Discharge in MLD			24.74



Source : UP Jal Nigam



Khandawa Drain

Diwan Ghat New Drain

The cumulative discharge from all drains into the Ganga is 24.74 MLD. This is a significant pollution load affecting the river ecosystem.

Untapped drains should be prioritized, treatment capacity improved, and stricter wastewater management policies enforced to reduce pollution.

STP 1 - PAKKA POKHRA

- Location : Pakka Pokhra
- Zones Covered : Zone 1, 2, 3, 4 and 5
- Installed Capacity : 14 MLD
- Operational Capacity : 14 MLD
- Treatment Technology : UASB
- Treated Water Reused : 0 MLD
- Sludge Generated : 35 kg / MLD
- Disposal Of Sludge : sent to Kanpur
- Outlet Water Quality Parameters :

pH 7.89 | BOD 16.4 mg/l | COD 111.4 mg/l | TSS 30.7 mg/l

Drains Tapped :

- Badali Drain
- Kachahari Drain
- Khandawa Drain
- Narghat Drain
- Oliyar Drain
- Sundar Ghat Drain

ISSUES

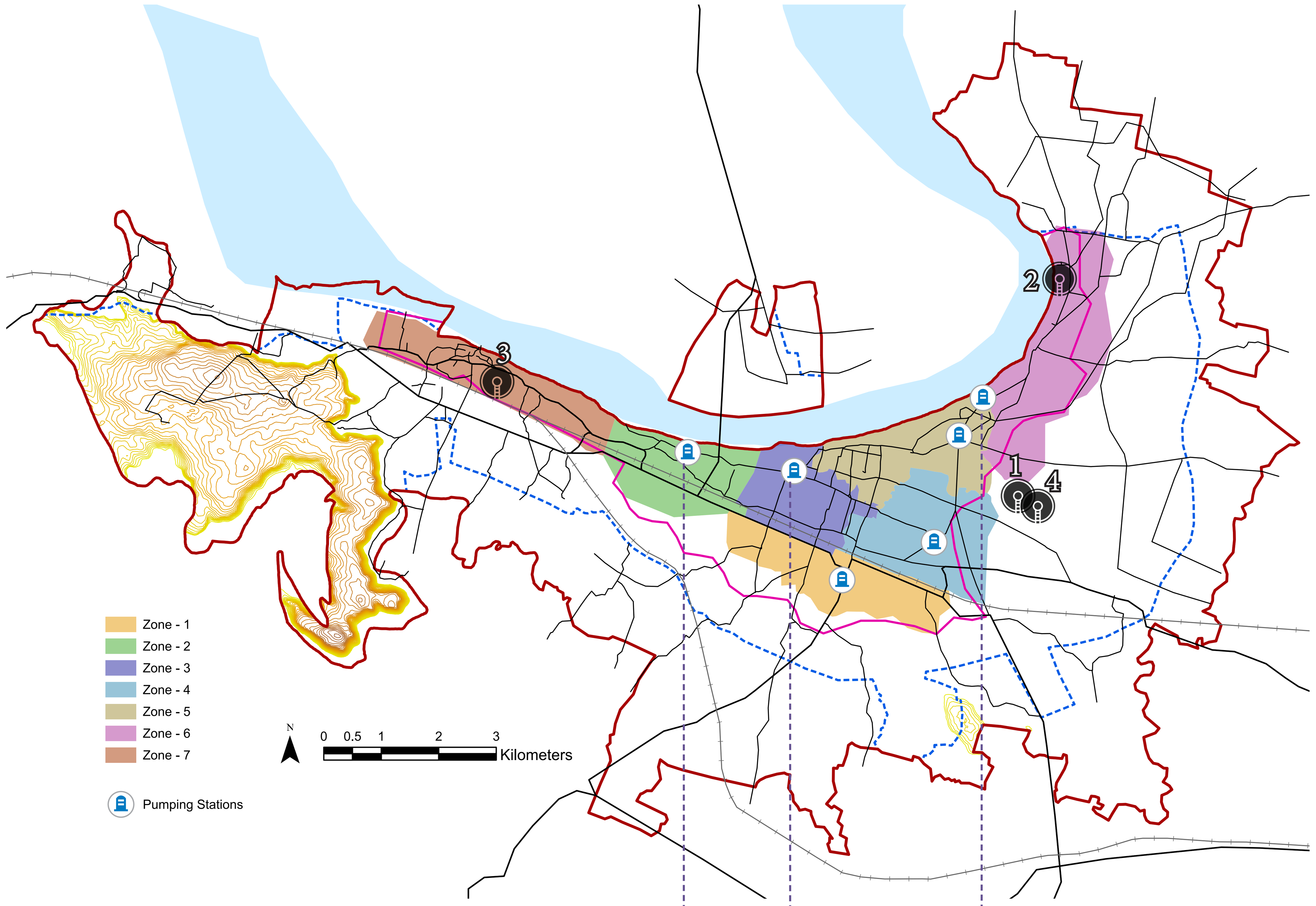
Year of Establishment: **1992**

Environmental Standards Followed: **CPCB, 1986** instead of the latest **CPCB, 2017** guidelines.

Compliance with Standards:
- CPCB 1986 Guidelines: **Meets all 4** discharge standards
- CPCB 2017 Guidelines: Meets only **1 out of 4** standards (COD exceeds the acceptable limit).

Treated water discharged into an open drain, which merges with **Goreshahid Drain** and flows into the Ganga River.

Households dispose waste into the treated water drain, **causing recontamination and increasing Ganga pollution.**



Zone - 2	Zone - 3	Zone - 6
Intermediate Pumping Station	Main Pumping Station	Intermediate Pumping Station
Quantity - 2.49 MLD	Quantity - 8.50 MLD	Quantity - 5.05 MLD


Outlet Water Chamber after Treatment


Inlet WW Chamber from Households


Open Outlet Drain from STP


Primary Process of Treatment

STP 2 - BISUNDERPUR

- Location : Bisunderpur
- Zones Covered : Zone 6
- Installed Capacity : 8.5 MLD
- Operational Capacity : 4 MLD
- Treatment Technology : SBR
- Treated Water Reused : 0 MLD
- Sludge Generated : 55-60 kg / MLD
- Disposal Of Sludge : sent to Kanpur
- Outlet Water Quality Parameters :

pH 7.57 | BOD 7.0 mg/l | COD 32.4 mg/l | TSS 8.1 mg/l

Drains Tapped :

- Bisunderpur Drain
- District Judge Drain
- Irrigation Colony Drain
- Lift Canal Drain
- Morcha Ghar Drain
- Public Club Drain

ISSUES

Installed capacity is **8.5 MLD**, but operational capacity is only **4 MLD**, indicating **underutilization** of the plant.

Compliance with Standards:
- CPCB 2017 Guidelines: **Meets all 4** discharge standards

Despite suitable treated water quality, **0 MLD is reused**, missing opportunities for irrigation, industry, or urban use.


Transportation of Sludge

Treated water is discharged into drains, where **households and industries** add waste water, leading to potential contamination before reaching River Ganga.

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STP 3 - VINDHAYACHAL

- Location : Vindhayachal
- Zones Covered : Zone 7
- Installed Capacity : 7 MLD
- Operational Capacity : 4 MLD
- Treatment Technology : SBR
- Treated Water Reused : 0 MLD
- Sludge Generated : 75-80 kg / MLD
- Disposal Of Sludge : in WS Pond
- Outlet Water Quality Parameters :

pH	BOD	COD	TSS
7.39	7.2 mg/l	36 mg/l	8.9 mg/l

Drains Tapped :

- Balughat Pakka Drain
- Diwan Ghat Old Drain
- Gudara Drain
- Parasuram Drain

ISSUES

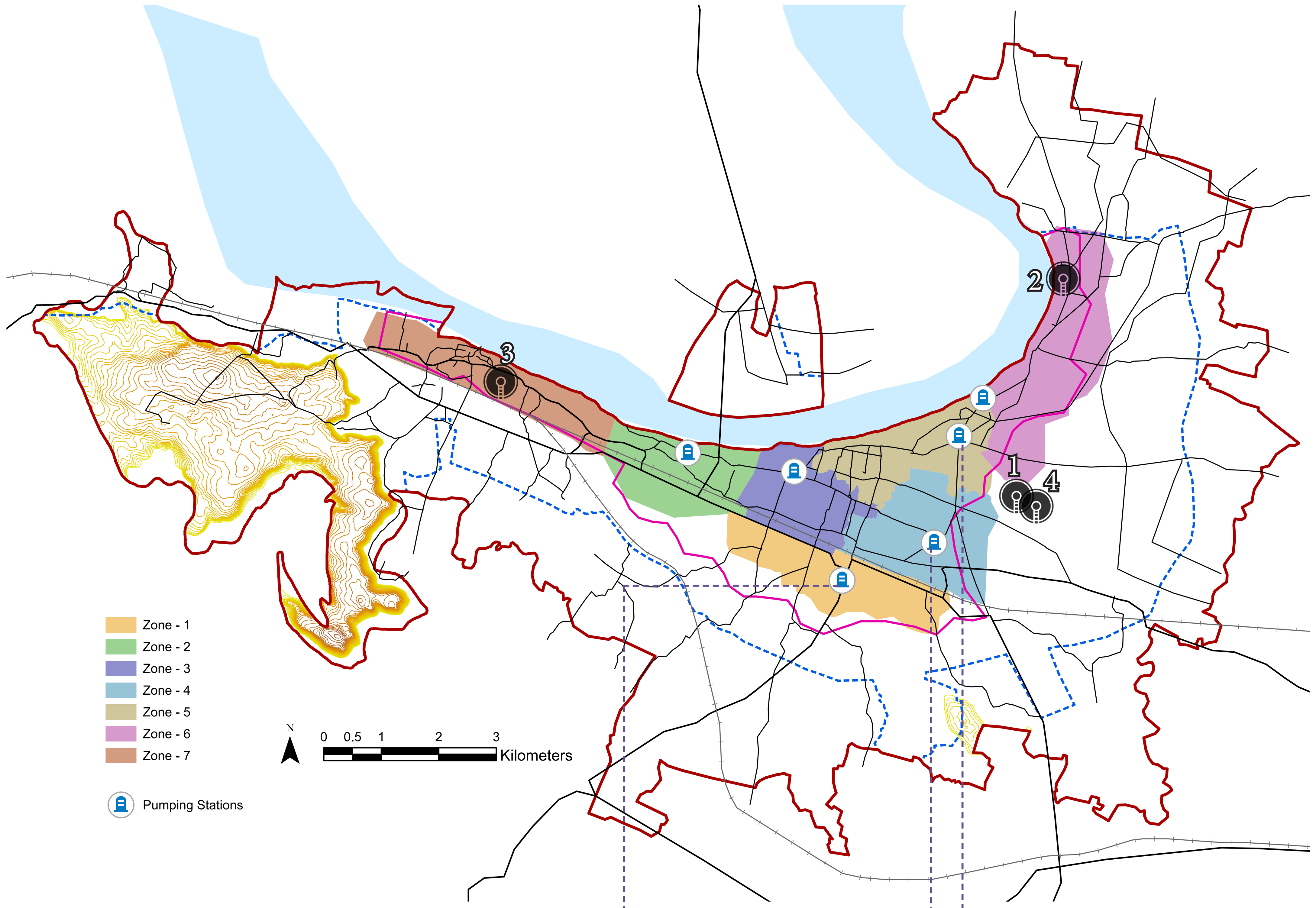
Installed capacity is **7 MLD**, but operational capacity is only **4 MLD**, indicating **underutilization** of the plant.

Compliance with Standards:
- CPCB 2017 Guidelines: **Meets all 4** discharge standards

Previously, the STP used **nature-based wastewater treatment (WSP)** but recently **switched to SBR technology.**

Treated water is discharged into Diwan Ghat Drain & Parasuram Drain, polluted by HH waste.


Waste Stabilisation Pond for Treatment



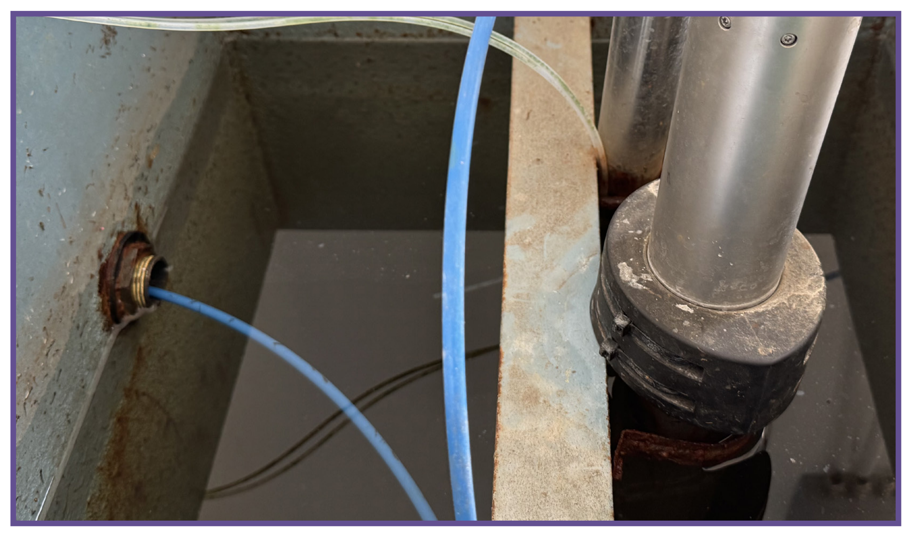
Zone - 1
Intermediate Pumping Station
Quantity - 2.49 MLD

Zone - 4
Main Pumping Station
Quantity - 5.96 MLD

Zone - 5
Intermediate Pumping Station
Quantity - 14.0 MLD


Outlet Water Chamber after Treatment


Outlet Drain of Vindhayachal STP


Outlet Water Chamber after Treatment


Aeration Process During Treatment

STP 4 - PAKKA POKHRA

- Location : Pakka Pokhra
- Zones Covered : Zone 1, 2, 3, 4 and 5
- Installed Capacity : 8.5 MLD
- Operational Capacity : 6 MLD
- Treatment Technology : SBR
- Treated Water Reused : 0 MLD
- Sludge Generated : 41.6 kg / MLD
- Disposal Of Sludge : sent to Kanpur
- Outlet Water Quality Parameters :

pH	BOD	COD	TSS
8.13	6.0 mg/l	29.7 mg/l	11 mg/l

Drains Tapped :

- Barahmilliah Drain
- Konia Drain

ISSUES

Installed capacity is **8.5 MLD**, but operational capacity is only **6 MLD**, indicating **underutilization** of the plant.

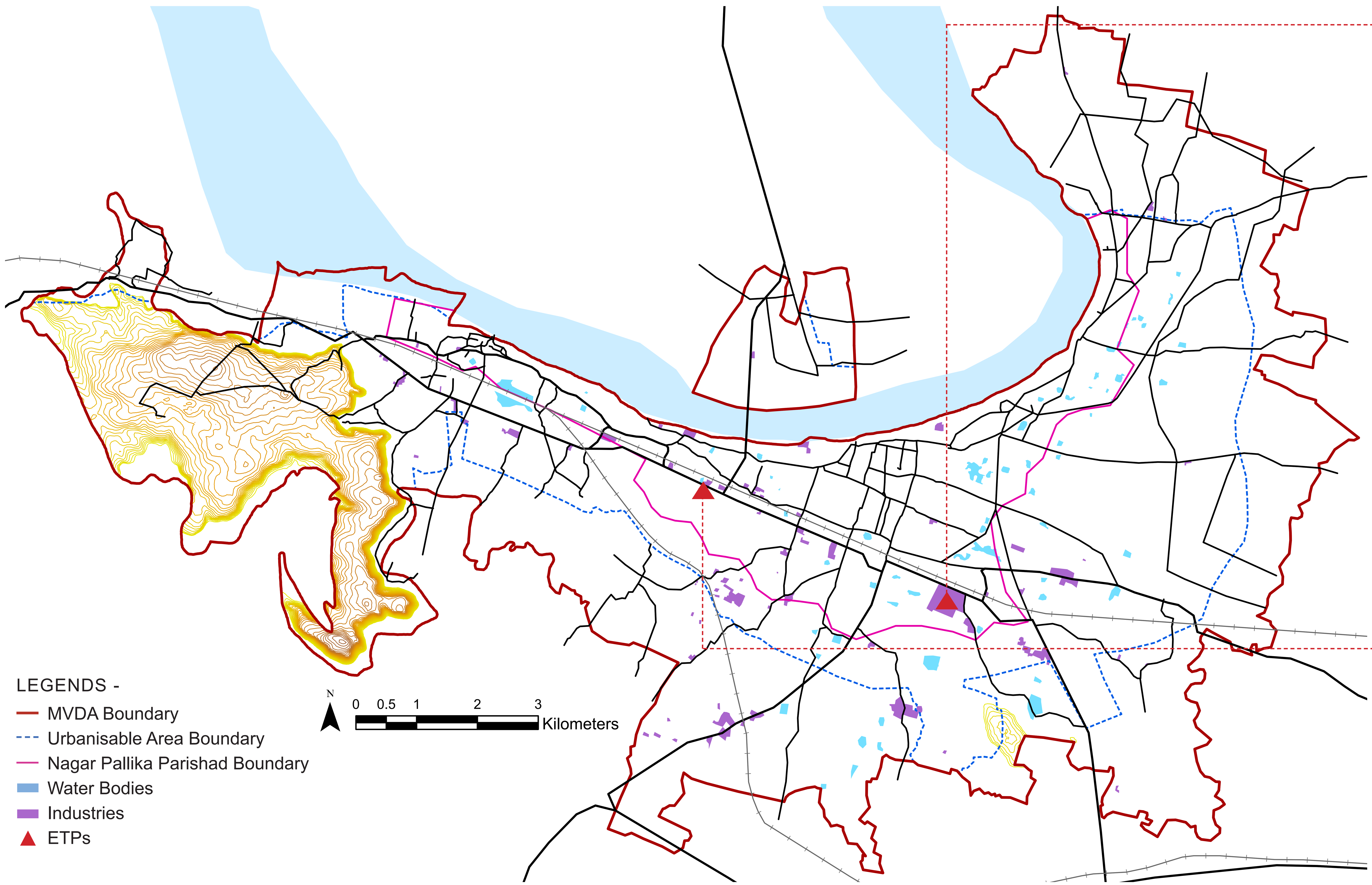
Compliance with Standards:
- CPCB 2017 Guidelines: **Meets all 4** discharge standards

Sludge is dumped in open areas, causing pollution and health risks, requiring better management.


Treated WW Flowing Back to Ganga

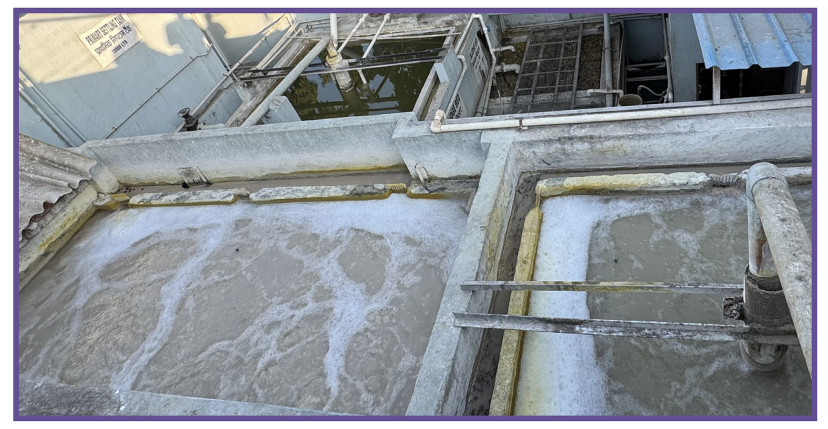
Pakka Pokhra has two STPs—**the 14 MLD STP** follows 1986 standards, resulting in **lower treated water quality compared to the 8.5 MLD STP**, which follows 2017 guidelines.

LOCATION OF INDUSTRIES



EFFLUENT TREATMENT PLANTS

NEEMAN CARPETS, PATHRIYA, MIRZAPUR



Installed Capacity : 15 KLD

Operational Capacity : 11 KLD

Treated Water Reuse : 1 KLD

Reuse Avenues : Flusing, Gardening, Car Washing

Disposal of Treated Water : Drains connecting to Ganga

Sludge Generated & Disposal : 200gm / L & sent to Kanpur

Outlet Water Q. Parameters :

- pH: 8.23
- BOD: 11.8 mg/l
- COD: 60.5 mg/l
- TSS: 8.5 mg/l

JAIPUR RUGS, RAJAPUR, MIRZAPUR

Installed Capacity : 400 KLD

Operational Capacity : 350 KLD

3 - Step Treatment Process :

Primary	Secondary	Teritary
Lime-alum to remove suspended particles & neutralize acidity.	Bacteria break down waste. Sand & carbon filter impurities.	Water is made fit for irrigation and released into fields.

TYPES OF INDUSTRIES

I II III

I - Carpet Industries **60%**
II - Brassware Industries **30%**
III - Other Industries **10%**
(Steel, Cement, Agro, Food)

CLASSIFICATION OF INDUSTRIES BASED ON POLLUTION

CATEGORY	DESCRIPTION	POLLUTION LEVEL
Red	Highly Polluting	Pollution Index ≥ 80
Orange	Moderately Polluting	55 ≤ Pollution Index < 80
Green	Low Polluting	25 ≤ Pollution Index < 55
White	Non Polluting	Pollution Index < 25

- Handloom / Carpet Weaving (without dying and bleaching operation) - *WHITE INDUSTRY*
- Manufacturing of utensils from Brassware - ***GREEN INDUSTRY***
- Jute processing (with dyeing) - ***ORANGE INDUSTRY***

CARPET INDUSTRY: WATER USE AND POLLUTION

Industries rely solely on **groundwater via borewells**, leading to uncontrolled extraction.

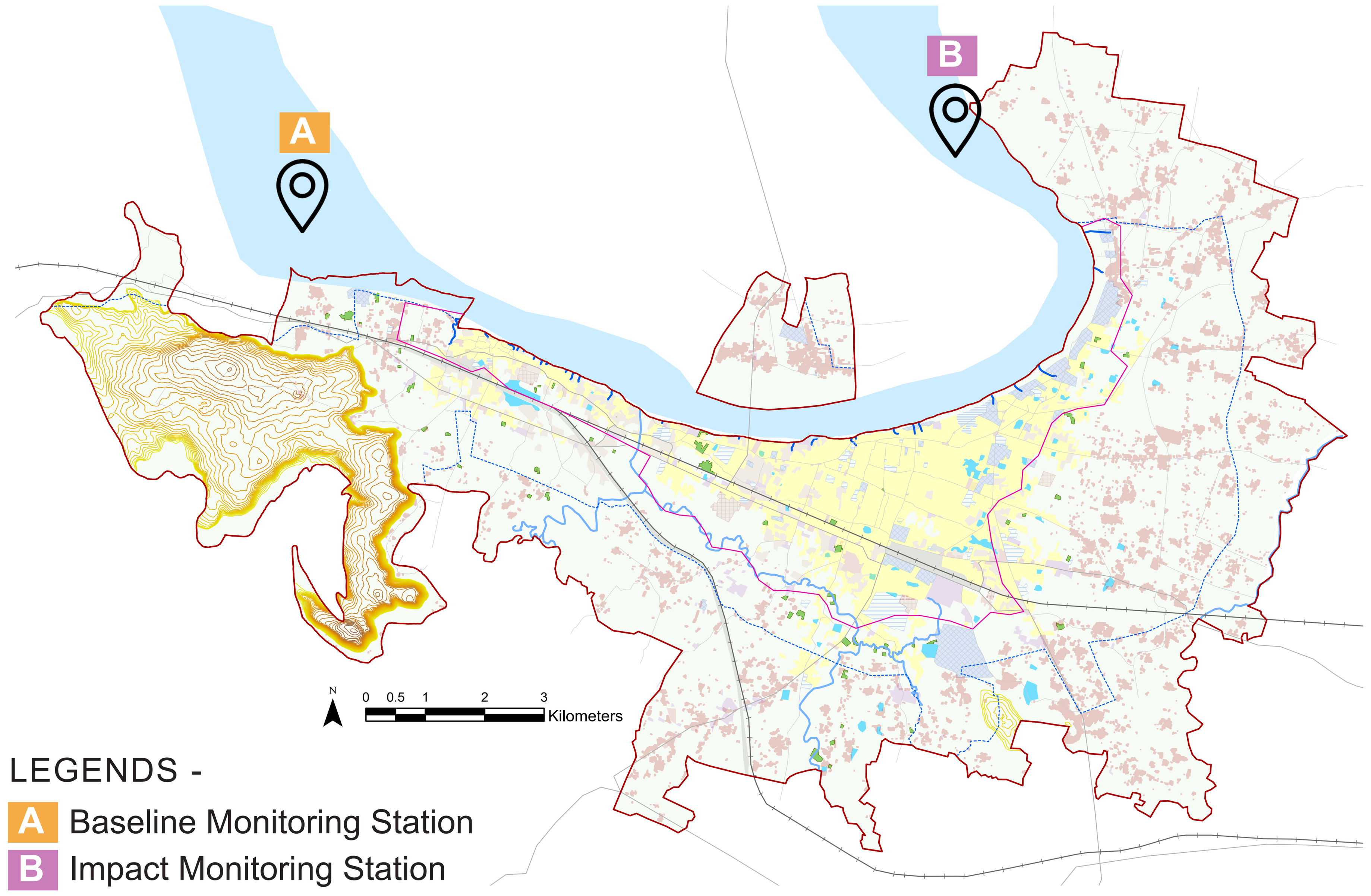
30 buckets (450 - 500L) of water are used **per square yard** for washing rugs.

The three major industries—Obeetee Carpets, Neeman Carpets, and Jaipur Rugs—are **compulsorily required to** have their own **ETPs**.

Obeetee Carpets established the **first ETP** in the industry in 1984.

Although dyeing industries fall under the **"orange" pollution category**, their **water discharge pollution index is classified as "red"**.

UPSTREAM - DOWNSTREAM



LEGENDS -
A Baseline Monitoring Station
B Impact Monitoring Station

WATER QUALITY ASSESSMENT AT MONITORING STATIONS (2024)

	PH	DO (mg/l)	BOD (mg/l)	FC (MPN/100ml)
Vindhayachal (U/S)	8.07 ✓	7.7 ✓	2.5 ✓	735 ✓
Mirzapur (D/S)	7.75 ✓	7.1 ✓	3.5 ✗	8945 ✗
Permissible Limit	6.5 - 8.5	> 5	<3	500-2500

Source : UPPCB

Upstream (Vindhyachal) water quality is within permissible limits for all measured parameters.

Downstream (Mirzapur) shows significant degradation in water quality, especially due to high BOD and FC levels, pointing to:

- Untreated or partially treated sewage discharge
- Lack of sanitation infrastructure in nearby settlements
- Impact of human activities and insufficient wastewater treatment

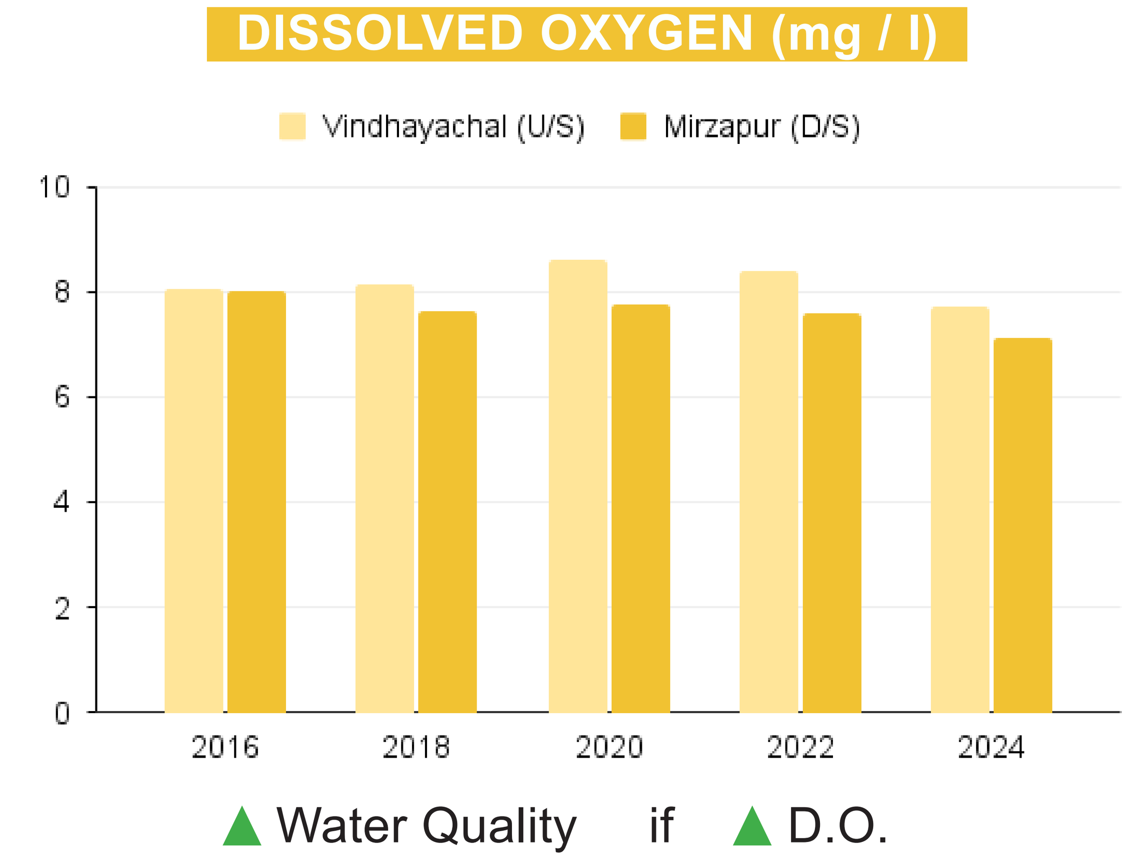
ISSUES

Drains merging with the Ganga bring untreated wastewater, increasing pollution despite the presence of multiple STPs.

Households near riverbanks lack sewerage connections, leading to direct wastewater disposal into the river without treatment.

The downstream water quality at Mirzapur (D/S) fails to meet the required standards for Class B, thus it lies in category of Class C due to high BOD and FC levels, making it unfit for many purposes.

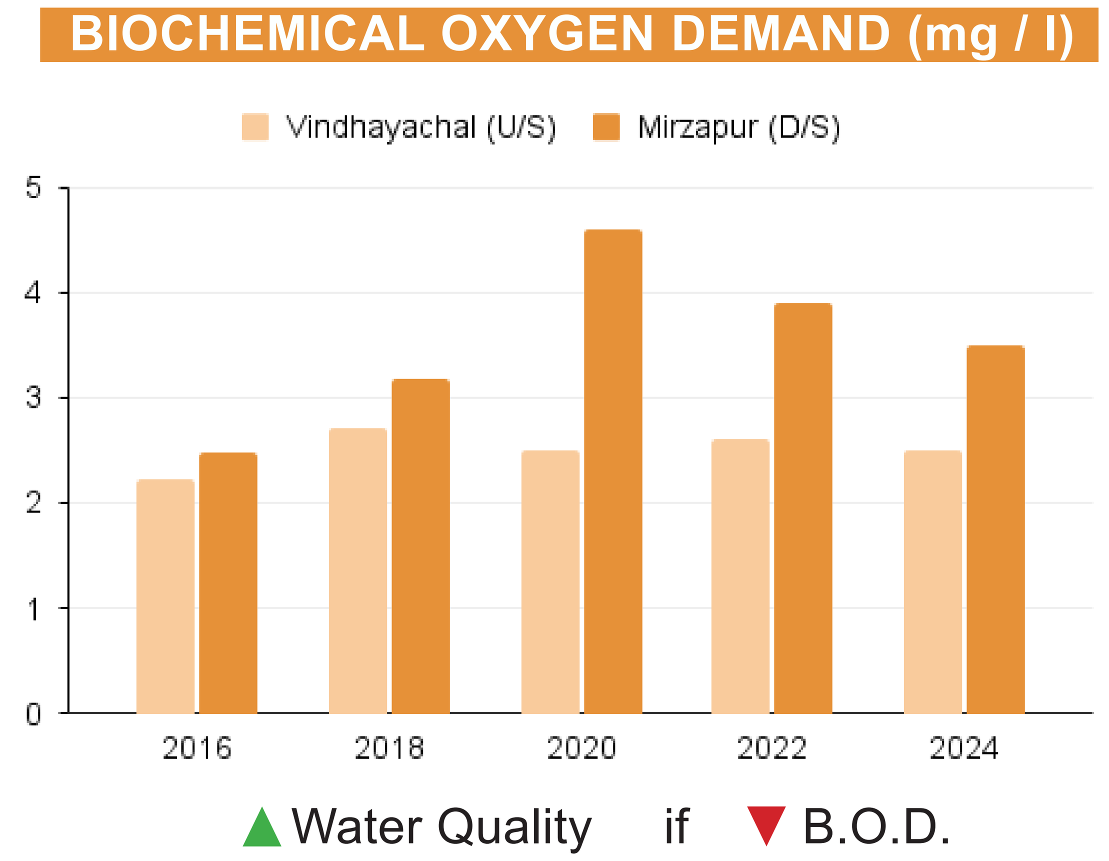
WATER QUALITY TRENDS



The DO levels show a **declining trend** at both U/S and D/S from 2016 to 2024.

The significant DO decline at Mirzapur shows rising pollution & organic **load downstream.**

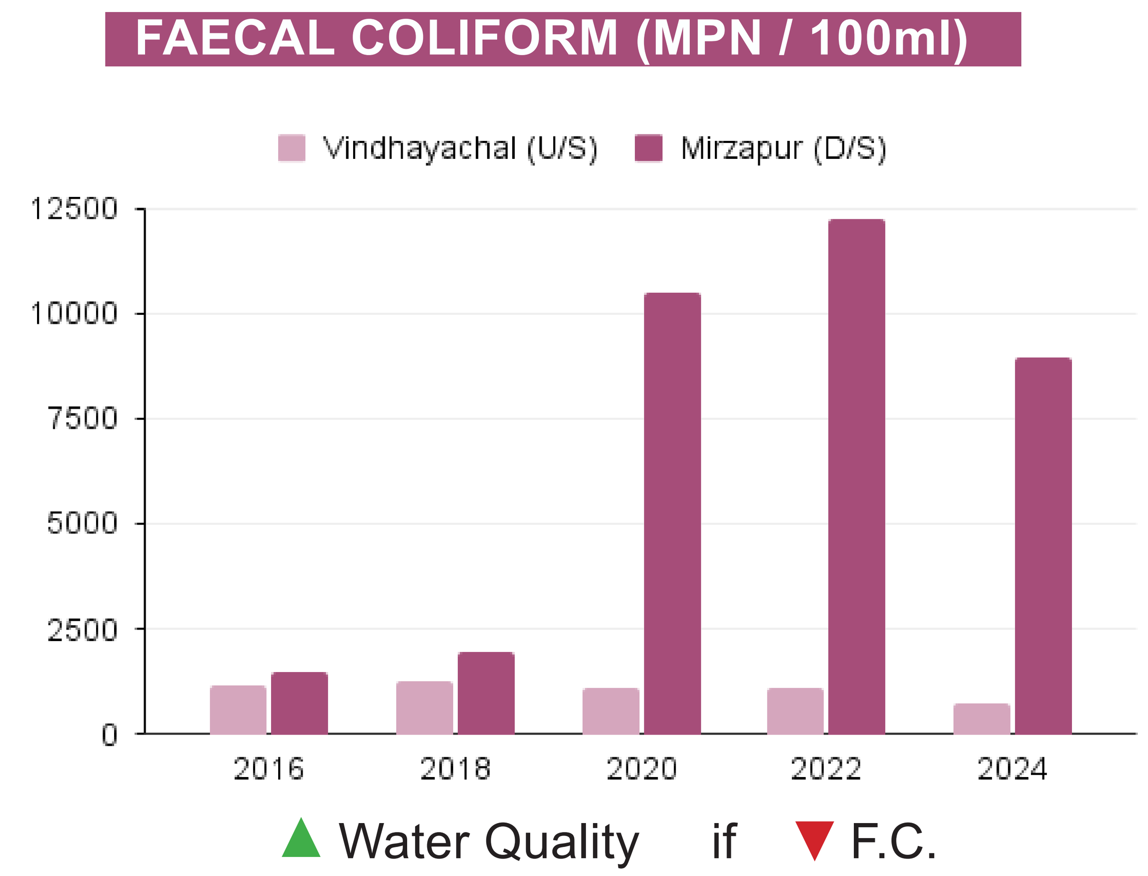
Lower DO levels indicate deteriorating water quality, which can **affect aquatic life.**



BOD at D/S **peaked in 2020**, then declined to 2024 due to a new STP.

Despite improvement, **BOD remains high**, indicating, increasing pollution downstream.

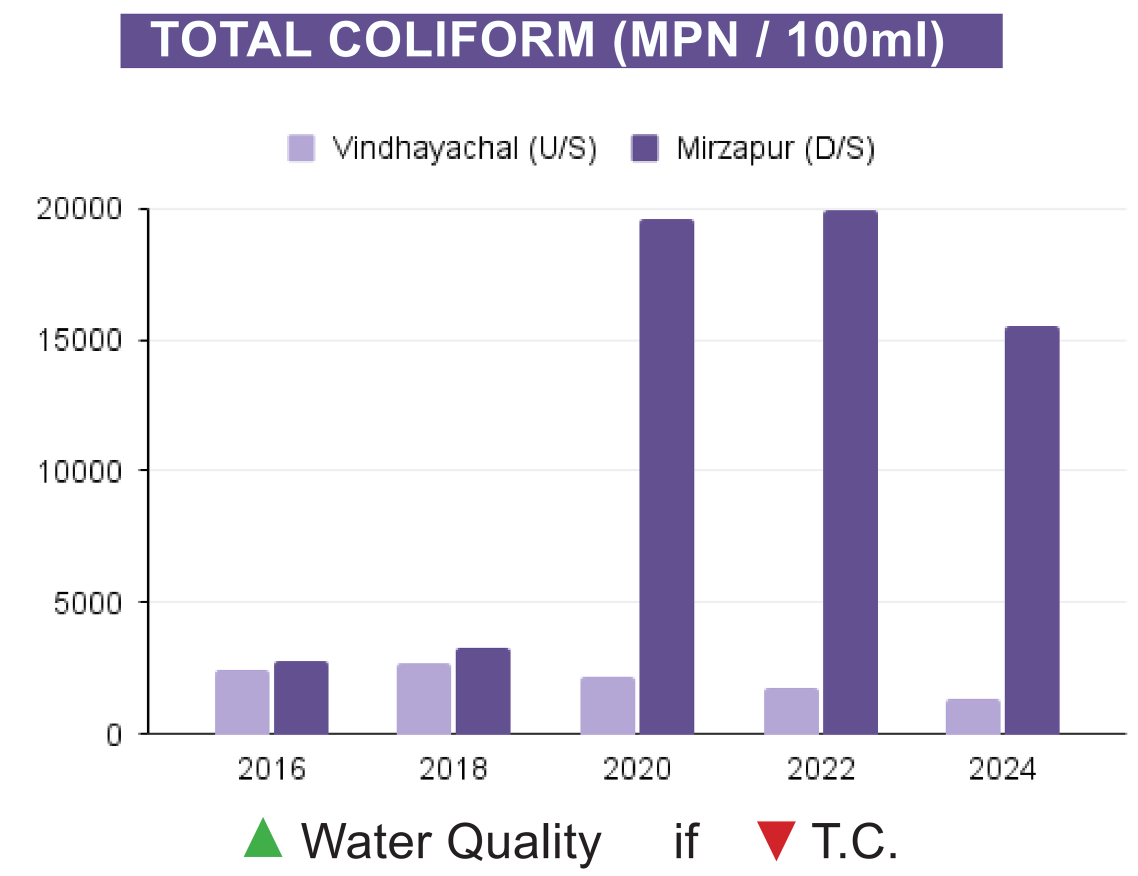
High BOD reduces DO, leading to **poor water quality and increased pollution.**



Pollution load at **D/S surged**, showing WQ deterioration, while **U/S remained stable.**

New STPs reduced pollution, but **untreated drains continue to pollute** the river.

High FC indicates sewage contamination, **causing waterborne diseases** & poor water quality.



TC levels **rose sharply** in 2016 - 22, slightly **dropping in 2024** but still critically high.

Coliform levels at **Vindhyachal declined**, indicating **improved upstream** water quality.

High TC levels suggest untreated sewage discharge, **making water unsafe for drinking and harming aquatic ecosystems.**

Source : UPPCB

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PROCEDURE TO IDENTIFY POTENTIAL BULK USERS

- Identify reuse avenues
- Calculate water demand
- Assess location accessibility
- Determine usage frequency
- Define water quality needs
- Prioritize feasible reuse avenues
- Select conveyance mode
- Ensure safety protocols

Source : NIUA_ Toolkit for Preparing City Action Plans for Reuse of Treated Used Water

POTENTIAL REUSE AVENUES FOR TREATED WASTEWATER

ECOLOGICAL REUSE: Parks and Gardens, Road Medians, Water Body Reju.

CIVIC REUSE: Railways, Construction, Fire Hydrants, Bus Depots

AGRICULTURE REUSE: Irrigation, Horticulture

INDUSTRIAL REUSE: Carpet Industries, Brassware Industries

Source : NIUA_ Toolkit for Preparing City Action Plans for Reuse of Treated Used Water

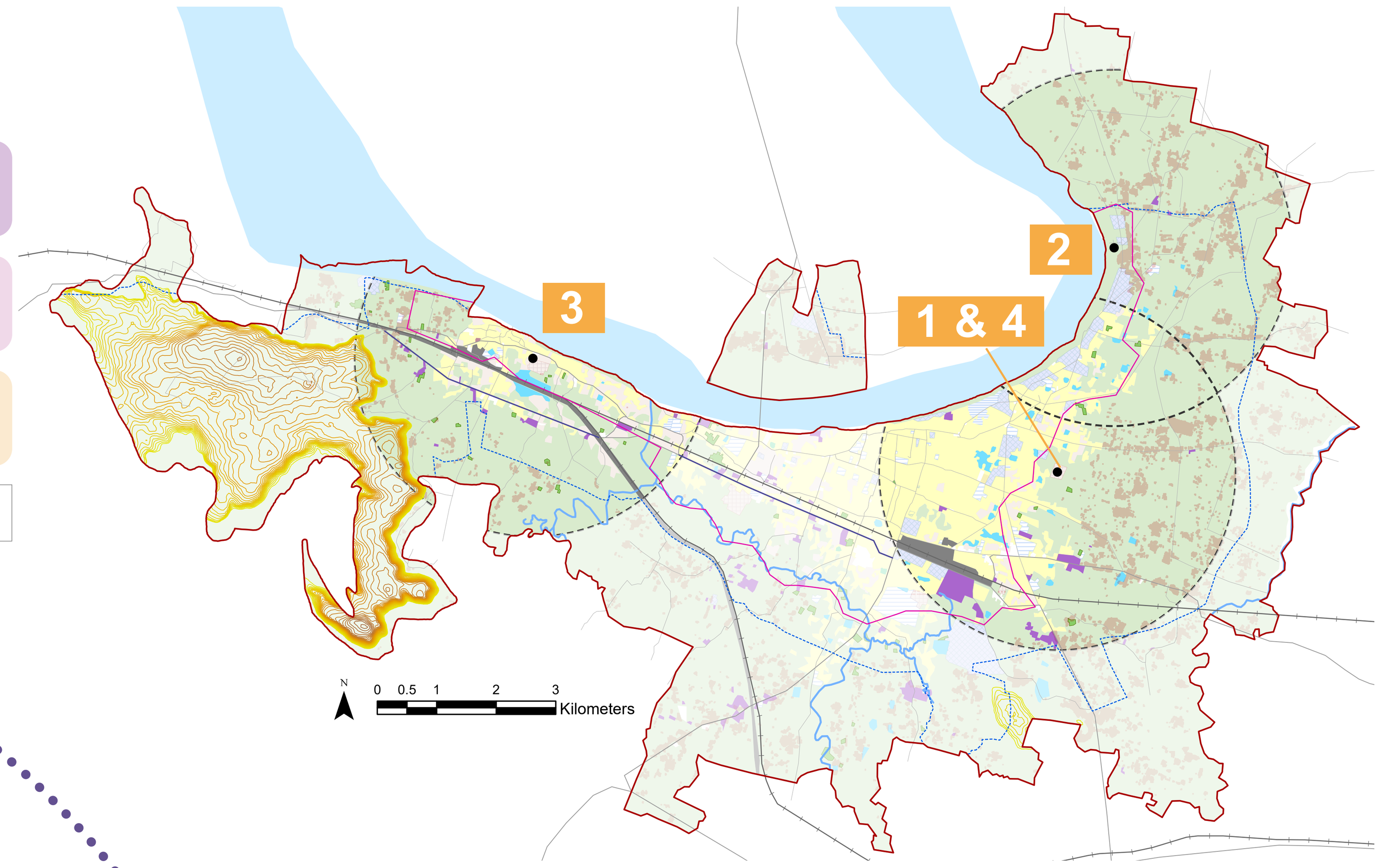
STP 3 - VINDHAYACHAL

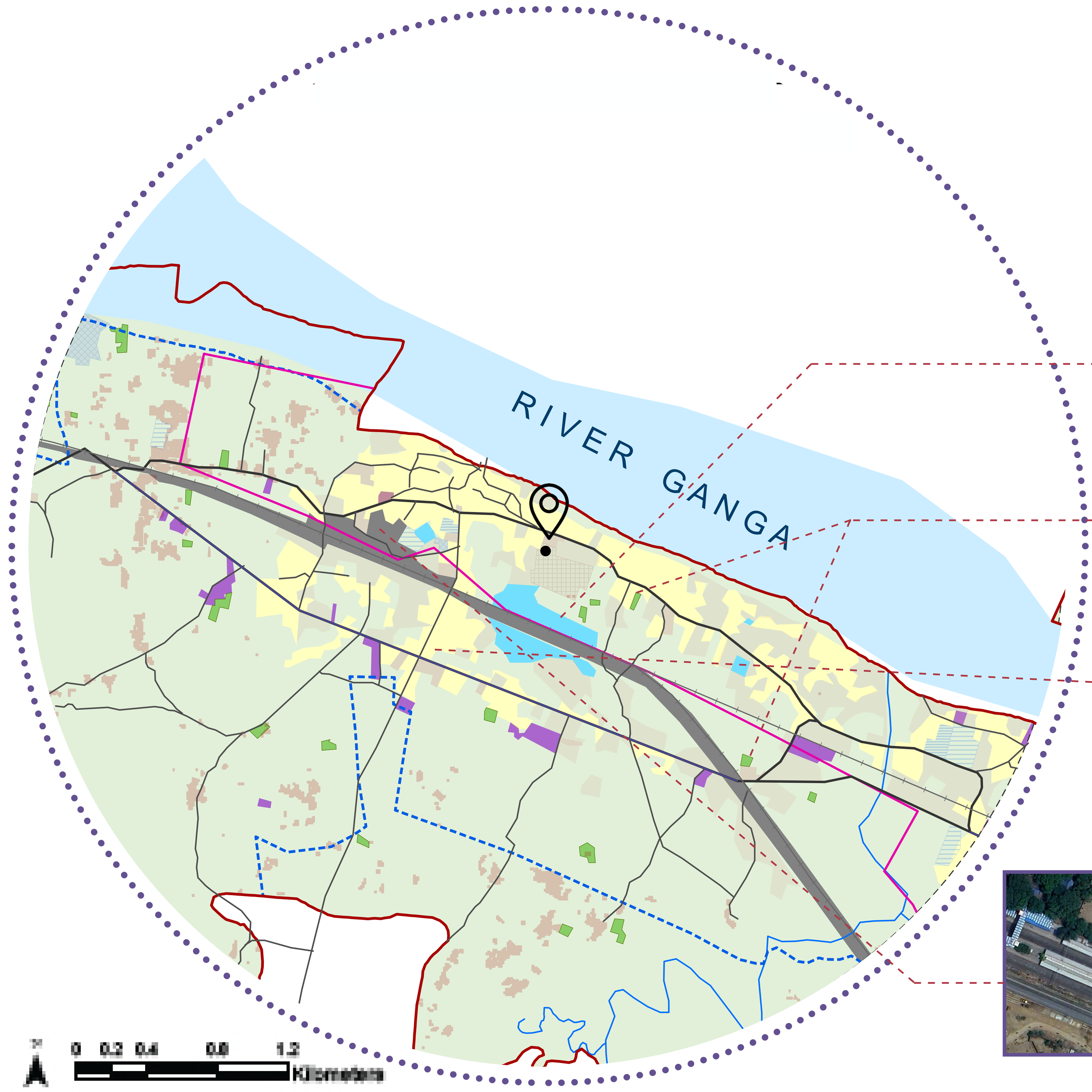
Installed Capacity : 7 MLD

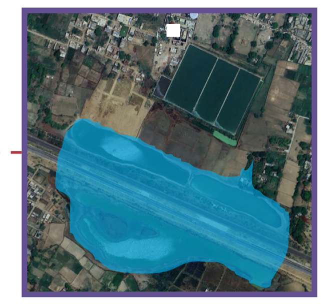
Operational Capacity : 4 MLD

Outlet Water Quality Parameters :

pH	7.39	BOD	7.2 mg/l	COD	36 mg/l	TSS	8.9 mg/l







Water Body Rejuvenation :

A large water body is near the STP, creating opportunities for treated wastewater reuse.

Parks and Gardens :

Nearby parks and gardens need irrigation.

Road Median :

1m wide median runs along NH-35, extending for 3.6km within the buffer area.

Railway Station :

There are 03 platforms in Vindhyachal Railway Station, with no train terminating and originating from there.

LANDSCAPING (parks, gardens, road medians)

*WD = total area (in sq m) * water required / sq m (2.5 L / sq m)*

Area -

Parks and Gardens = 84,294 sq m

Road Median (1 m thick) = 3,666 sq m

Water Demand -

WD = 87,960 sq m * 2.5 L / sq m

WD = 219900 L or 0.22 ML

Water Quality

pH = ✓
BOD = ✓
COD = ✓
TSS = ✓

Frequency -

Landscaping should be watered **daily** using treated WW.

Mode of Conveyance -

Water tanker trucks should be used for watering it.

WATER BODY

WD = calculate the volume of water body

Water Quality -

pH = 6.5 - 8.5 ✓ COD = 50 mg / l ✓

BOD = 10 mg / l ✓ TSS = 20 mg / l ✓

RAILWAYS

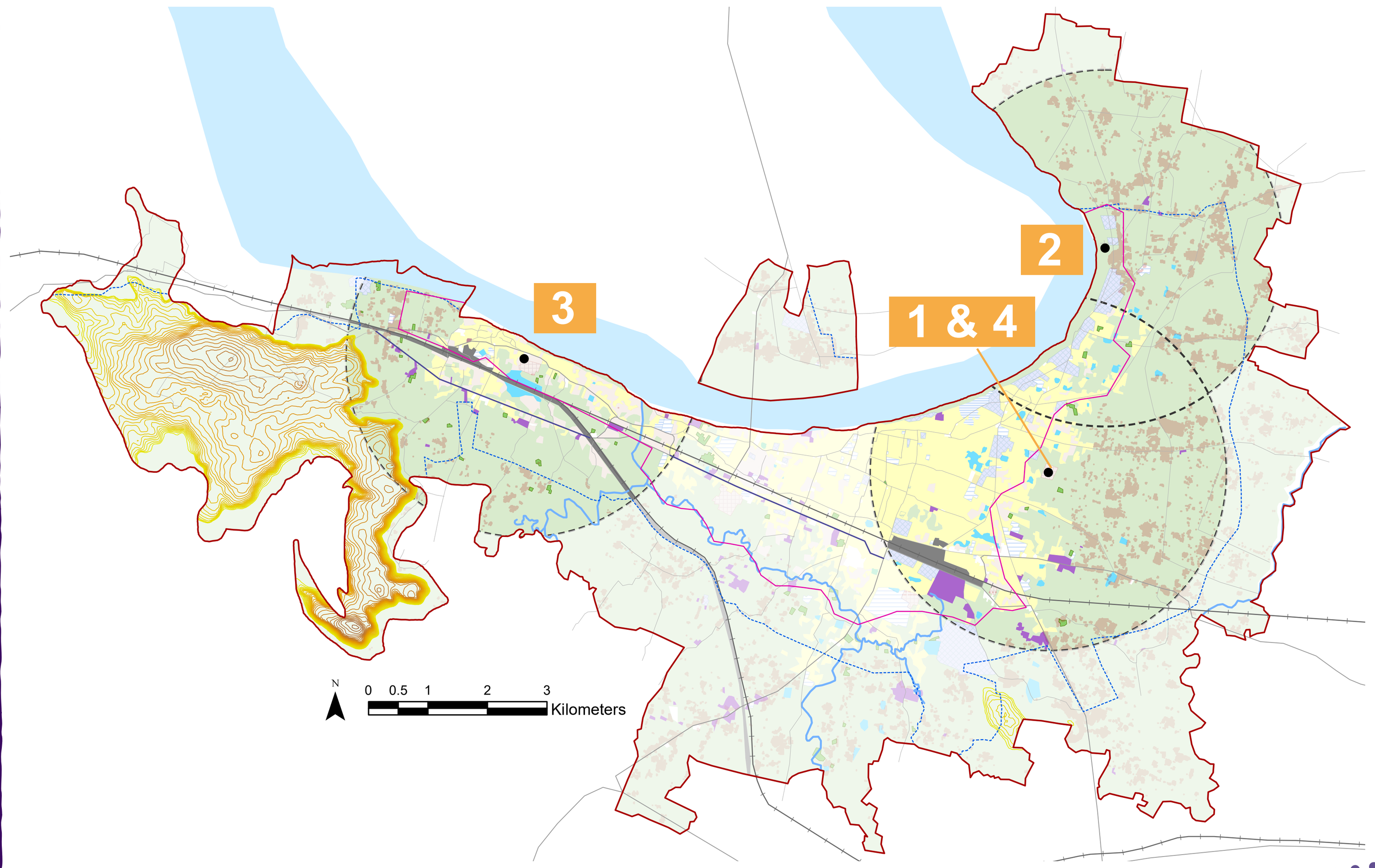
WD = water required to wash platform (5 liters / sqm)

Area -

Platform = 12,663.84 sq m ; **WD = 63319 L or 0.06 ML**

Frequency and Mode of Conveyance -

Treated WW should be supplied daily via water tankers.



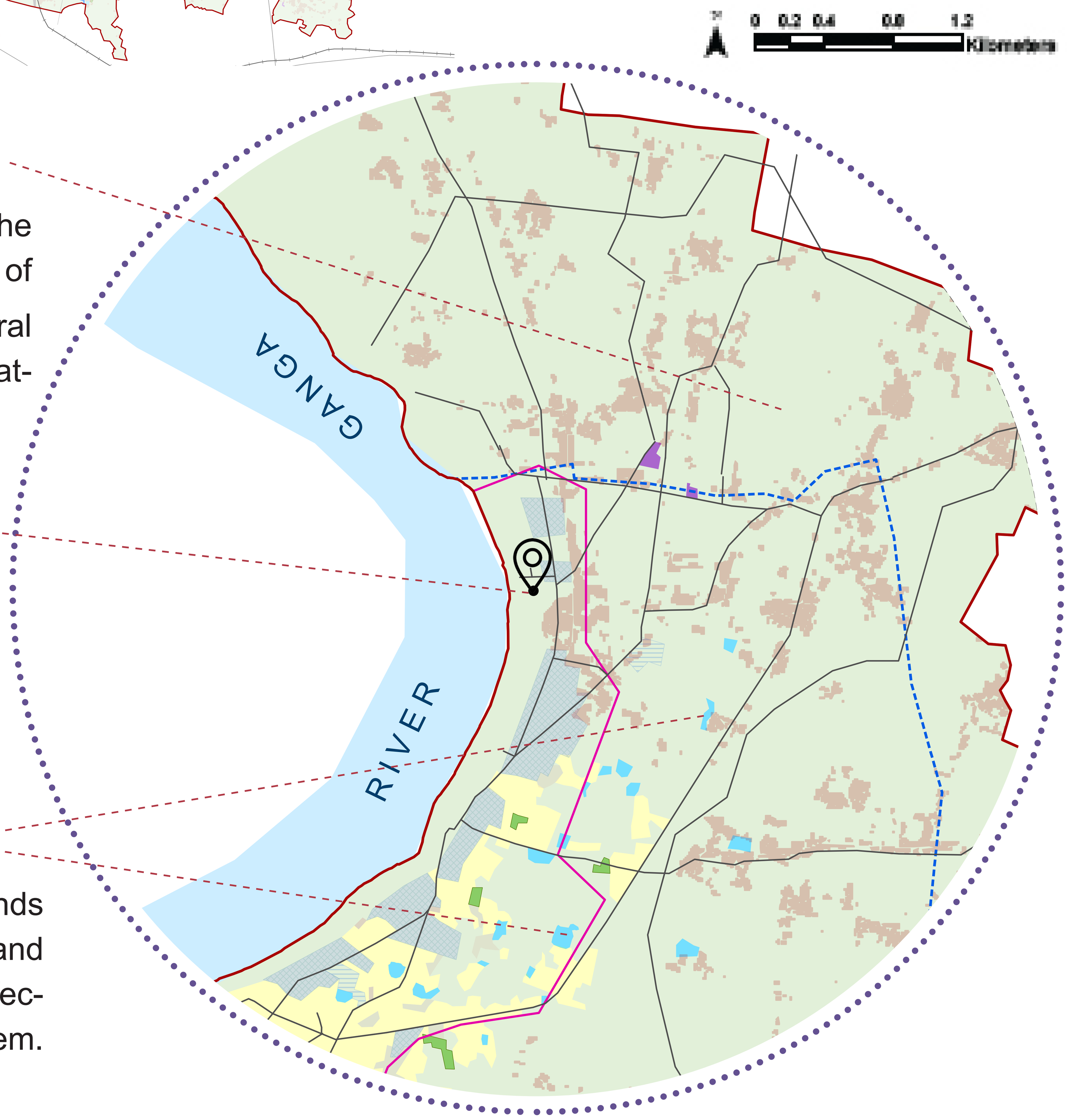
STP 2 - BISUNDERPUR

Installed Capacity : 8.5 MLD

Operational Capacity : 4 MLD

Outlet W.Quality Parameters

pH	7.57
BOD	7.0 mg / l
COD	32.4 mg / l
TSS	8.1 mg / l



Agriculture :

Due to the proximity of Bisunderpur STP to agricultural land, the primary bulk user of treated wastewater is crop irrigation

Discharge into Ganga :

Treated wastewater from this STP can be discharged into the Ganga if it meets water quality standards.

Water Body Rejuvenation :

Numerous pokhars and ponds are in a drying state, and treated wastewater can be effectively reused to rejuvenate them.

STP 1 and 4 - PAKKA POKHRA

Installed Capacity : 14 MLD

Operational Capacity : 14 MLD

Outlet Water Quality Parameters :

pH	7.89	COD	111.4 mg / l
BOD	16.4 mg / l	TSS	30.7 mg / l

Installed Capacity : 8.5 MLD

Operational Capacity : 6 MLD

Outlet Water Quality Parameters :

pH	8.13	COD	29.7 mg / l
BOD	6.0 mg / l	TSS	11 mg / l

Fire Staion

Landscaping :

The primary potential bulk user of treated WW is irrigation for parks, gardens, & roadside plantations.

Water Body Rejuvenation :

Numerous pokhars and ponds are in a drying state, and treated wastewater can be effectively reused to rejuvenate them.

Bus Depot :

The water demand for bus washing is calculate as the number of buses washed daily multiplied by 150 liters per bus.

Railway Station :

There are 03 platforms in Mirzapur Railway Station, & with no train terminating and originating from there.

AGRICULTURE

Agriculture is a viable reuse avenue as it meets all required water quality standards.

WATER BODY

Mode of Conveyance -

Transported primarily through **pipelines or dedicated canals.**

Safety Protocols -

- Ensure treated wastewater meets environmental standards before discharge.
- Facilitate the percolation of treated wastewater into aquifers to support groundwater recharge.

LANDSCAPING (parks, gardens, medians)

Total Area -

TA = 61,265 sq m

Water Demand -

WD = 153162.5 L or 0.15 ML

Safety Protocols -

- Avoid direct human contact during reuse.
- Use mechanized irrigation methods like sprinklers, or drip irrigation.
- Schedule reuse during early morning or late evening to minimize public exposure.

RAILWAYS

Area -

Platform = 22,378.79 sq m ; **WD = 111894 L or 0.11 ML**

Safety Protocols -

- Implement a color-coded or labeled pipeline system to prevent cross - contamination with potable water supplies.
- Conduct it during non-peak hours to reduce public exposure.

WATER BODY

Mode of Conveyance -

Transported primarily through **pipelines or dedicated canals.**

RECOMMENDATIONS & STRATEGIES FOR POTENTIAL REUSE AVENUES FOR TREATED WASTEWATER

CONSTRUCTION

STRATEGIES

- ULBs should **mandate treated wastewater use** in large construction projects.
- **Assess water demand** during project approval and enforce wastewater reuse.
- **Supply** treated wastewater **via tankers** at minimal cost.
- Use in concrete mixing, curing, dust suppression, soil compaction, and road construction while meeting BIS standards.
- Offer **incentives like reduced charges or fast-track approvals** for wastewater reuse.

INDIAN CASE EXAMPLE

 # Delhi Metro Rail Corporation: Used treated wastewater for concrete mixing & curing, significantly reducing potable water consumption in metro construction.

 # Pune Municipal Corporation: Enforced mandatory use of treated wastewater for construction activities, supplying water through tankers at a subsidized rate.

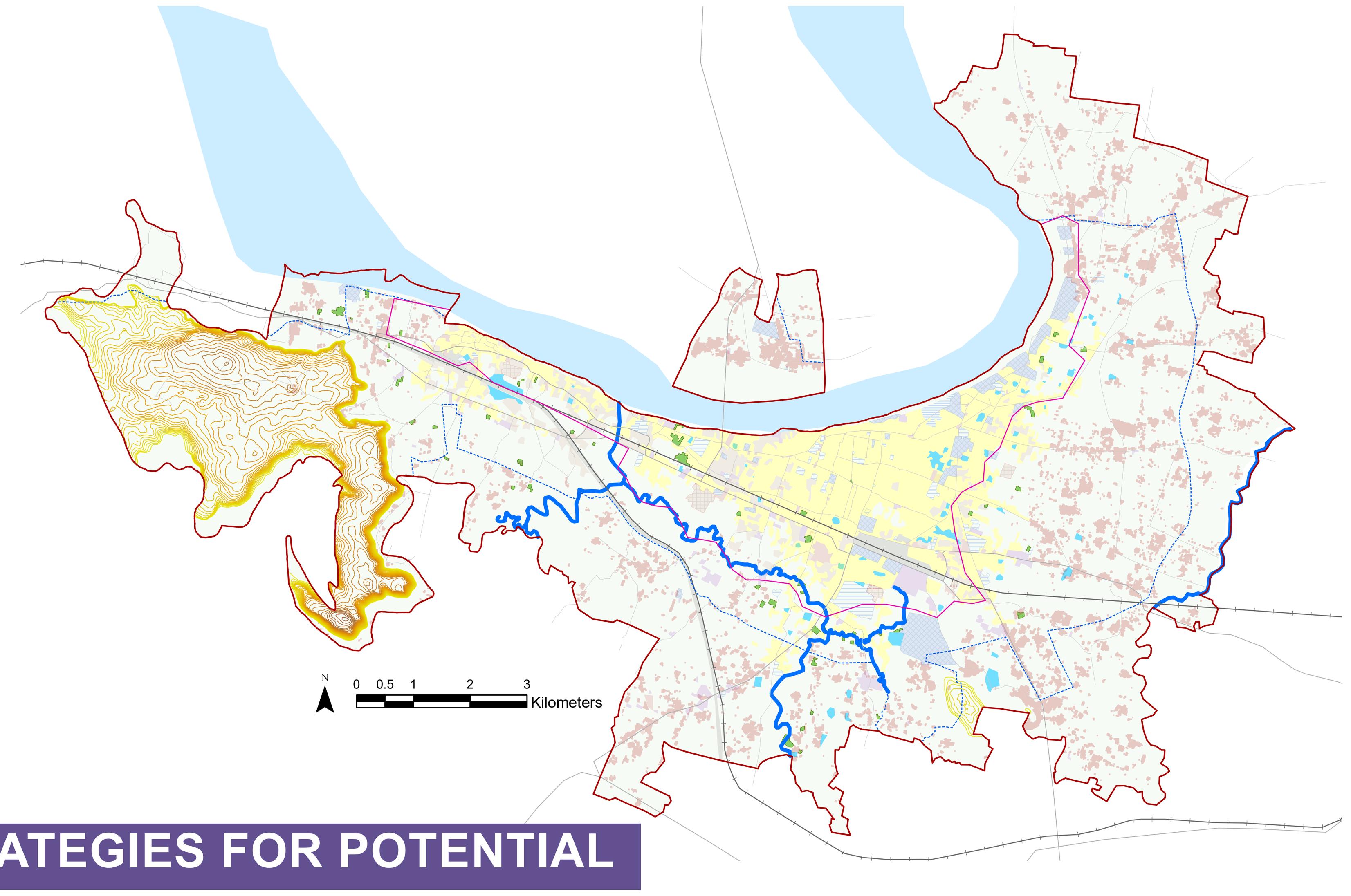
SAFETY PROTOCOLS

WATER QUALITY COMPLIANCE	STORAGE & HANDLING	PREVENT CONTAMINATION	REGULAR MONITORING
Ensure wastewater meets BIS/CPHEEO standards for non-potable use.	Store wastewater in designated tanks to prevent odors and contamination.	Use separate pipeline and equipment for freshwater and treated WW.	Conduct periodic quality checks to maintain safe usage standards.

AGRICULTURE

STRATEGIES

- Promote treated wastewater reuse under **Pradhan Mantri Krishi Sinchayi Yojana.**
- Farmers can be charged **₹5 per 1,000L** of treated WW to ensure affordability while covering OC.
- **Early adopters** of wastewater reuse can receive **financial incentives or reduced water tariffs.**
- The **Ojhala Nadi** can be used as a **natural irrigation canal** for transporting treated wastewater to agricultural fields.
- Encourage WW irrigation for **non-edible crops**, fodder, and floriculture **to minimize health risks.**
- **Collaborate with private entities** to develop WW irrigation projects.



SAFETY PROTOCOLS

For irrigation using treated WW, subsurface drip irrigation is considered a safe & efficient method, minimizing contact between the water and crops or humans.

FIRE HYDRANT

STRATEGIES

Q = 100 √P, where Q is water required in cubic meters & P is population in thousands

Population (2025) - 2,94,782 Water Demand = **29,47,820 L or 2.95 ML**

- Treated WW can be safely reused for **non-potable firefighting purposes**, for refilling fire tenders.
- Since the fire station is near the Pakka Pokhra STP, treated wastewater can be easily **supplied via tanker trucks or piped network.**

INDUSTRY

STRATEGIES

- Industries should be **restricted from extracting groundwater.**
- **On-Site reuse** of ETP-treated wastewater for dyeing, cooling, and cleaning instead of discharge.
- Additional water needs should be met from **nearby STPs.**
- Strict monitoring & enforcement for compliance.
- Industries adopting wastewater reuse should receive **benefits like tax rebates or lower industrial water tariffs.**

INDIAN CASE EXAMPLE

 # Tiruppur, Tamil Nadu: The textile industry uses treated wastewater for dyeing and finishing, reducing groundwater extraction.

 # Nagpur, Maharashtra: Industries purchase treated wastewater from Bhandewadi STP, reducing freshwater consumption.

SAFETY PROTOCOLS

- **Water Quality Compliance:** Ensure treated wastewater meets required **BIS and CPCB** standards for industrial applications.
- **Regular Monitoring:** Conduct **routine testing** of treated wastewater for heavy metals, toxins, and pathogens.
- **Proper Disposal of Sludge:** Sludge generated during treatment should be **safely managed** to prevent environmental hazards.
- **Efficient Storage & Distribution:** Treated wastewater should be stored in **leak-proof tanks** and transported through a regulated supply system.

LANDSCAPING

*WD = total area (in sq m) * water required / sq m (2.5 L / sq m)*

Total Area (for areas outside buffer area of any STP) -
Total Area = 2,26,550 + 3,655 sq m
= 2,30,205 sq m
Water Demand -
WD = 2,30,205 * 2.5 = 5,75,512 L or 0.57 ML

STRATEGIES

- Encourage **mechanized watering** to reduce human contact.
- **Involve** RWAs & park **committees** in monitoring and managing wastewater reuse.

WATER BODY REJUVENATION

STRATEGIES

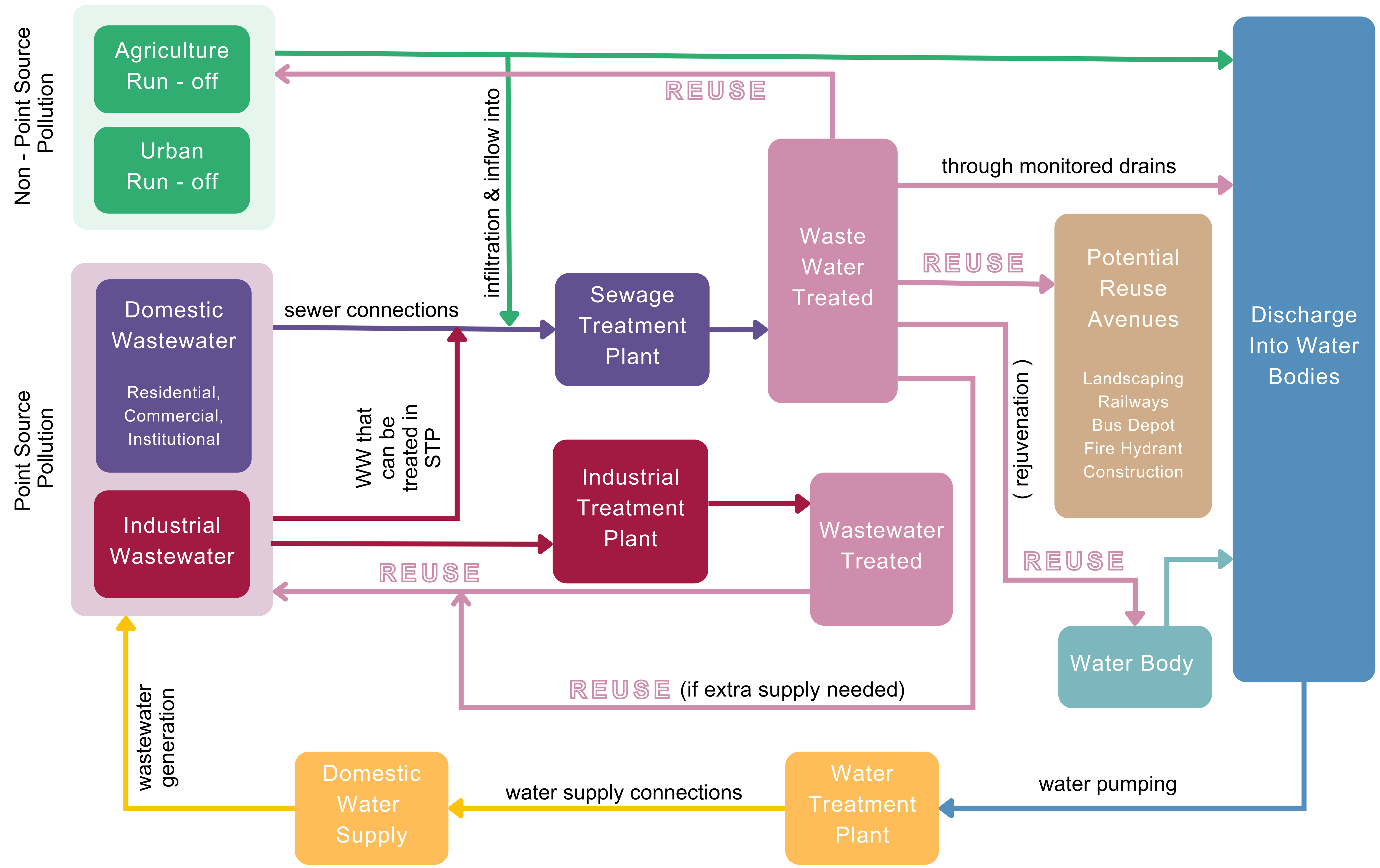
Allow treated WW to flow into degraded water bodies to support ecological rejuvenation, & maintain base flow.

INDIAN CASE EXAMPLE

 # Nagpur, Maharashtra:
ULB uses treated wastewater to recharge lakes and for industrial reuse, reducing stress on freshwater sources while improving urban water bodies.

Charu Middha
A4134921003
National Institute of Urban Affairs

DESIRED WASTEWATER FLOWS



SEWAGE TREATMENT PLANT

INFRASTRUCTURE UPGRADATION

- Local-level regulation that requires all operational STPs to **function at ≥ 85% capacity utilization.**
- Impose **penalties or notices** for consistent underutilization (e.g., <60% usage for more than 6 months).

ALIGNING PAKKA POKHRA WITH CPCB 2017

- Enforce **statutory compliance** requiring the STP to **align with CPCB 2017** discharge standards, replacing the outdated 1986 norms.

STOPPING RE - POLLUTION

- Convert open outlet drains into **covered/piped systems** to prevent discharges.
- Implement **penalties** for unauthorized waste dumping.

CIRCULAR ECONOMY

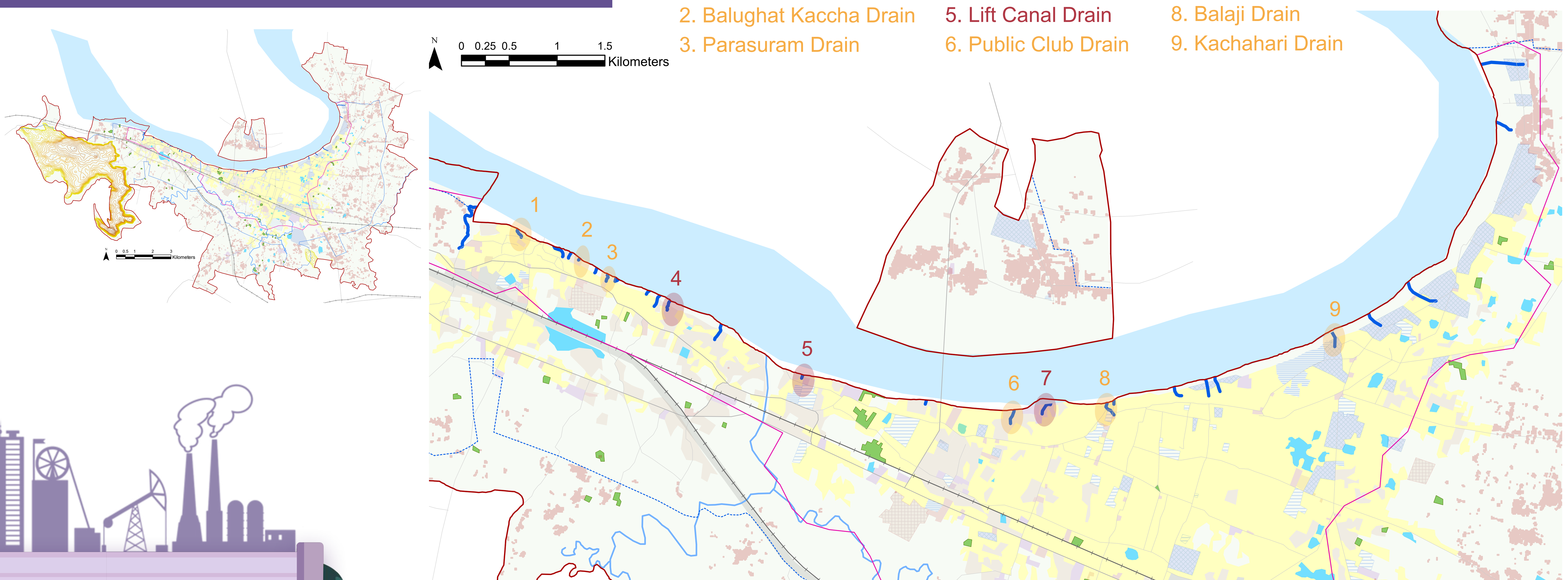
Sludge to Biofertilizer (Agricultural Use)

- Treat and convert sewage sludge into **nutrient-rich compost** or **organic manure**.
- Distribute the processed sludge to farmers at minimal or no cost through municipal partnerships.

Energy Recovery from Sludge (Biogas)

- **Generate biogas** from sludge using anaerobic digestion.
- **Use biogas** to power STP operations.

NATURAL TREATMENT FOR DRAINS



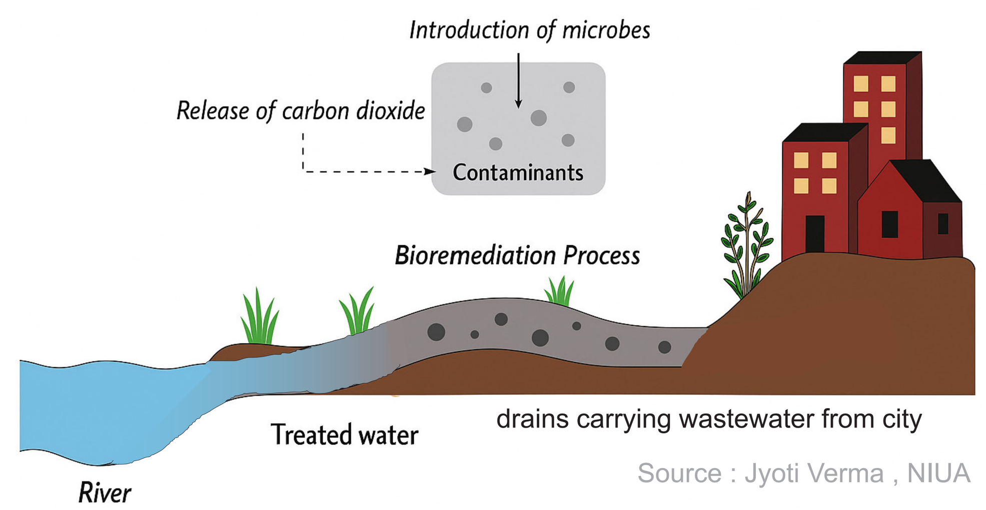
Bioremediation is a nature-based technique that uses microorganisms, plants, or enzymes **to neutralize pollutants** in wastewater flowing through drains.

How it works -

1. Introduce microbes (bacteria or fungi) into the drain.
2. Microbes break down organic waste and nutrients like nitrogen and phosphorus.
3. Pollutants convert into harmless by-products like carbon dioxide, water, and biomass.
4. Plant aquatic vegetation in drains to boost natural treatment.

Advantages -

- **Cost effective** due to low O & M cost.
- Suitable for drains with **low to moderate pollutant loads.**
- **On-site process**, minimizing excavation and environmental disruption.



Source : Jyoti Verma , NIUA

5.5. Weekly Progress Reports

5.6. Certificates

Gmail **ADITYA BHARADWAJ <aadity2k2@gmail.com>**

Congratulations for selection to STC S-5 Competition_NIUA-NMCG,

Student Thesis Competitition <stc@niua.org> Mon, 30 Dec at 4:36 PM
To: <aadity2k2@gmail.com>, <charumiddha15@gmail.com>
Cc: Director . NIUA <director@niua.org>, <skumar48@amity.edu>, <lkhurana@amity.edu>, Shreya Khurana <shreya@niua.org>, <sahu.sharanya@gmail.com>

Dear **Adiya**, dear **Charu,**

Congratulations once again on getting selected for the **'Student Thesis Competition' (STC) on 'Re-imagining the Urban Rivers,' Season-5 (2024-25)** by the National Institute of Urban Affairs (NIUA) and the National Mission of Clean Ganga (NMCG).

We also extend our **heartfelt congratulations to you, your HoD, your guides, faculties, and parents for their valuable support in your achievement**.

We are delighted to welcome you towards an enriching journey ; encompassing workshops, learning sessions and **meaningful engagement with mentors from NIUA and NMCG**. STC 5 holds a special significance for us as **we have finally gone global this year.**

The **STC team will be initiating formal communication with you and your respective institutions** starting from the **FIRST WEEK of January 2025**, to facilitate the competition proceedings.

Once again, felicitations for your accomplishment and we wish you all the best for a highly successful and productive STC S-5.

We also take the opportunity to wish you and your family a **very prosperous and successful New Year 2025**.

For further queries or assistance, feel free to reach out to us at +91 88606 10579 (Ms. Shreya Khurana, STC Team -NIUA)

Thanks and Regards

STC TEAM

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image.png

AMITY UNIVERSITY
UTTAR PRADESH

AMITY INSTITUTE OF PUBLIC POLICY
International Conference on Public Policy 2025

ICoPP'25

"Rethinking Public Service Delivery: Advancing Policy, Delivery and Impact"

27th FEBRUARY 2025

CERTIFICATE OF PARTICIPATION

This is to certify that Mr. / Ms./ Dr./ Prof./ Charu Middha

from Amity School of Architecture & Planning

has presented a paper titled Exploring Policy Gaps & Infrastructure Needs in Small Cities: A case of Urban Wastewater Crisis in Mirzapur during the International Conference on Public Policy (ICoPP'2025) held on 27th February 2025 at Amity University Uttar Pradesh, Noida.

Dr. Bidisha Banerji
Chair, ICoPP'25
Associate Professor and Deputy Director
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Dr. Yogendra Singh
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Co-Patron, ICoPP'25
Vice Chancellor, AUUP

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Dr. Bidisha Banerji Chair, ICoPP'25 Associate Professor and Deputy Director Amity Institute of Public Policy, AUUP	**Dr. Yogendra Singh** Chief Mentor, ICoPP'25 HOI (Actg.) Amity Institute of Public Policy, AUUP	**Prof.(Dr.) Balvinder Shukla** Co-Patron, ICoPP'25 Vice Chancellor, AUUP

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