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VARANASI NAGAR NIGAM

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THE COUNCIL

# City-level Action Plan for Reuse of Treated Water for Varanasi

## Under National Framework on Safe Reuse of Treated Water

## Prepared by: Council on Energy, Environment and Water

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# City-level Action Plan for Reuse of Treated Water for Varanasi

## Under National Framework on Safe Reuse of Treated Water

NMCG, VNN and CEEW

Report I July 2026

सी आर पाटील
C R Paatil

जल शक्ति मंत्री
भारत सरकार
Minister of Jal Shakti
Government of India

## FOREWORD

Water is at the heart of India's development journey. It sustains our people, agriculture, industries, cities and ecosystems. As India moves towards becoming a developed nation by 2047, the way we manage water today will determine the resilience and prosperity of generations to come. Our vision must therefore extend beyond conservation alone to creating a circular water economy in which every drop is valued, treated and reused wherever possible.

The Government of India's Water Vision @ 2047 calls for precisely such a transformation. It requires us to move away from a linear approach of extracting, using and discharging water, and towards a sustainable system in which treated water becomes a valuable resource. This transition is essential for reducing pressure on freshwater sources, improving water security and protecting our rivers from pollution.

The Namami Gange Programme, implemented by the National Mission for Clean Ganga, has emerged as one of the world's most comprehensive river rejuvenation programmes. Its approach goes beyond cleaning the Ganga. It brings together sewage treatment, industrial pollution abatement, biodiversity conservation, afforestation, riverfront development, public participation and knowledge-based governance within an integrated river-basin framework. As of July 2026, 218 sewerage infrastructure projects with a treatment capacity of 6,610 million litres per day have been sanctioned under the programme, demonstrating the scale of India's commitment to restoring the Ganga and its tributaries.

NMCG has developed a National Framework on Treated Wastewater Reuse emphasizing urban reuse, industrial applications, and ecological restoration. The framework has been developed after multi-stakeholder consultations and exploring best practices around the world. The main objectives for the Framework are to set the context, priorities and direction for SRTW, raise awareness of its importance and facilitate its implementation through support programs. The framework also mandates for state policies of SRTW aligned with National Framework.

Uttar Pradesh has drafted their reuse policy in accordance with the National Framework, the policies are sent to respective state governments for notification. On the similar lines Varanasi has developed the Treated Water Reuse Plan.

The Treated Water Reuse Plan for Varanasi exemplifies this vision, by providing a data-driven framework for the productive reuse of treated water, the plan can help reduce pressure on freshwater resources, improve the utilisation of sewage-treatment infrastructure and support sustainable urban growth. Its significance is particularly profound in Varanasi, where the life, culture and identity of the city are inseparably linked with Maa Ganga.

The Government of India's commitment to the Water Vision @ 2047 requires a paradigm shift towards a circular economy, ensuring that every drop is valued. The Treated Water Reuse Plan for Varanasi exemplifies this vision by providing a robust framework to safeguard our precious water resources while supporting urban growth and protecting our sacred rivers.

I congratulate the National Mission for Clean Ganga and all partners associated with this important initiative. I am confident that the lessons emerging from Varanasi will contribute to a larger national movement for water reuse, water security and sustainable river rejuvenation, taking us closer to the vision of a Viksit Bharat @ 2047.

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## FOREWORD

Varanasi is one of India's most revered cities—a place where history, spirituality and everyday life flow together with Maa Ganga. As the city grows and transforms, it also has the opportunity to become a model for sustainable urban water management.

Through the Namami Gange Programme, the National Mission for Clean Ganga (NMCG) has undertaken significant interventions to strengthen sewage treatment and prevent pollution from entering the Ganga. Varanasi has been an important focus of these efforts, with substantial investments in sewage-treatment infrastructure contributing to cleaner river systems and improved urban sanitation.

Recognizing the need to maximize the beneficial use of treated wastewater, the National Mission for Clean Ganga (NMCG) has prepared the National Framework on Safe Reuse of Treated Wastewater (SRTW). Developed through stakeholder engagement and informed by proven global practices, the Framework provides strategic guidance for expanding wastewater reuse across municipal, industrial, and ecological sectors. It also encourages States to formulate their own reuse policies in harmony with the national framework.

The Treated Water Reuse Plan for Varanasi takes this transformation a step further. It recognises that treated water should not be viewed as waste, but as a valuable resource. Its productive reuse can reduce dependence on freshwater and groundwater while meeting appropriate non-potable demands and improving the sustainability of urban water systems.

This approach is particularly relevant for Uttar Pradesh, which has the longest stretch of the Ganga among all States through which the river flows. The lessons from Varanasi can therefore provide a pathway for other cities across the State and the wider Ganga basin.

The Plan represents an important step towards sustainable urban water management, efficient resource utilisation and cleaner, healthier river systems. It brings together the timeless importance of Maa Ganga with the modern principles of circularity and responsible water use.

I compliment NMCG and all stakeholders involved in this initiative and hope that Varanasi will emerge as a leading example of how India's cities can grow sustainably while protecting their rivers for future generations.

**(Dr. Raj Bhushan Choudhary)**

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सत्यमेव जयते

## FOREWORD

India's rapid urbanisation is placing increasing pressure on freshwater resources and urban water systems. In this context, the transition from a linear model of water use to a circular water economy is both an environmental imperative and an economic necessity.

The policy challenge before us is to ensure that investments in sewage-treatment infrastructure deliver outcomes beyond treatment alone. Treated wastewater must increasingly be recognised as a dependable resource capable of substituting freshwater for suitable non-potable uses. Achieving this requires sound data, demand mapping, appropriate quality standards, viable conveyance systems and clear institutional accountability.

The National Mission for Clean Ganga (NMCG), through the Namami Gange Programme, has created a strong foundation for this transition by significantly strengthening sewage-treatment infrastructure and advancing an integrated river-basin management approach.

The National Mission for Clean Ganga (NMCG) has established a National Framework on Safe Reuse of Treated Wastewater (SRTW) to provide a roadmap for the effective reuse of treated wastewater in urban services, industrial operations, and environmental restoration. The Framework, shaped through broad consultations and international learning, aims to strengthen policy support, improve awareness, and enable adoption through coordinated implementation measures. It further recommends that States develop reuse policies aligned

The Treated Water Reuse Plan for Varanasi translates these principles into a practical, city-level framework. By connecting the availability of treated water with potential demand, it can help improve resource efficiency, reduce pressure on groundwater and freshwater sources, and protect river ecosystems.

Varanasi can serve as an important demonstration for other cities across the Ganga basin. The successful implementation of a treat-and-reuse model here can generate valuable lessons for wider replication and inform the development of scalable approaches to circular water management.

I commend NMCG and all partners associated with this initiative. The Varanasi Reuse Plan reinforces a fundamental policy principle for India's water future: treated water is not waste—it is a resource that must be managed responsibly, efficiently and sustainably.

**(V. L. Kantha Rao)**

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राष्ट्रीय स्वच्छ गंगा मिशन

Rajeev Kumar Mital, IAS
DIRECTOR GENERAL
NATIONAL MISSION FOR CLEAN GANGA

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GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES
RIVER DEVELOPMENT & GANGA REJUVENATION

## FOREWORD

The rejuvenation of the Ganga is ultimately measured by visible change on the ground—by sewage prevented from entering the river, treatment plants operating effectively, healthier river ecosystems and communities becoming active partners in protecting their rivers.

Under the Namami Gange Programme, the National Mission for Clean Ganga (NMCG) has worked to translate the vision of river rejuvenation into measurable action across the Ganga basin. Significant sewage-treatment infrastructure has been created, strengthening our ability to intercept and treat pollution before it reaches the river.

The next step is equally important: ensuring that treated water is productively reused wherever technically and economically feasible. Every litre of treated water that safely substitutes freshwater can reduce pressure on natural water sources, improve the value of investments made in sewage-treatment infrastructure and contribute to cleaner rivers.

To encourage the efficient and sustainable utilization of treated wastewater, the National Mission for Clean Ganga (NMCG) has issued the National Framework on Safe Reuse of Treated Wastewater (SRTW). The Framework, formulated through extensive consultations and informed by international experience, outlines the strategic approach for mainstreaming wastewater reuse across urban, industrial, and environmental sectors. It also guides States in preparing their own reuse policies consistent with the national vision.

Following this approach, Uttar Pradesh has prepared a State-level Treated Wastewater Reuse Policy, which is under consideration for notification. Building upon the same principles, Varanasi has also formulated a Treated Water Reuse Plan to promote the productive use of treated wastewater within the city.

The Treated Water Reuse Plan for Varanasi City provides a vital, data-driven framework for this transition. By connecting treated-water availability with potential demand, the Plan can help move urban wastewater management from a linear "use-and-discharge" model to a circular "treat-and-reuse" model.

For NMCG, this transition is integral to the holistic rejuvenation of the Ganga basin. Varanasi, with its deep civilisational connection to Maa Ganga and significant sewage-treatment infrastructure, provides an ideal setting to demonstrate this approach.

The real value of this Plan will lie in its implementation and scalability. It is essential that the treat-and-reuse model is progressively expanded across the Ganga basin, turning treated wastewater into a valuable resource for cities, communities and ecosystems.

I congratulate NMCG team, CEEW and all other stakeholders involved in this initiative and look forward to seeing Varanasi lead the way towards a more circular, water-secure and river-sensitive future.

**Dated : 10th July 2026** **(Rajeev Kumar Mital)**

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# About the Treated Used Water Reuse Plan

The *Treated Used Water Reuse Action Plan for Varanasi City* aims to maximise the safe reuse of treated used water (TUW), enabling a circular economy approach to used water management within Varanasi Nagar Nigam (VNN). The plan evaluates Varanasi's water scenario over time and outlines long-term strategies for efficient used water management in the city. It sets targets to improve sewerage network coverage, enhance treatment capacity utilisation, upgrade existing treatment infrastructure, and maximise the safe reuse of TUW in Varanasi.

We sincerely acknowledge the significant contributions of the expert team from the Council on Energy, Environment and Water (CEEW). The plan was formulated by Saiba Gupta, Kartikey Chaturvedi, Ayushi Kashyap, Trisha Ravindanath, Durgesh Kumar Singh, Abhishek Pal, and Nitin Bassi. We acknowledge the support of Chaitanya Raj during the development of the plan. We thank Zaid Khan, Programme Associate at CEEW, for reviewing the plan and providing valuable insights to strengthen it. Our appreciation extends to the Outreach team at CEEW for their support in editing, design, and publication.

We are grateful to the *National Mission for Clean Ganga* (NMCG), Ministry of Jal Shakti (MoJS), for providing the opportunity to develop this plan and supporting progress towards circular used water management in Ganga basin cities. We sincerely thank Shri Rajeev Kumar Mital, Director General (DG), NMCG; Shri Nalin Kumar Srivastava, Deputy Director General (DDG), NMCG; Shri Dheeraj Joshi, Director, NMCG, and Shri Himanshu Nagpal, Municipal Commissioner, VNN, for reviewing the plan and providing valuable feedback throughout its development. We thank NMCG, departmental officials at VNN, and associated agencies for their support in data collation, provision of ground-level insights, and constructive feedback that shaped the plan. Our appreciation goes to Amrendra Tiwari, Chief General Manager, Varanasi Smart City; Dr Santosh Kumar Tripathi, City Data Officer, Varanasi Smart City; Vinod Kumar Gupta, Additional Municipal Commissioner, VNN; O. P. Singh, Executive Engineer, Jal Kal Department; Kamal Singh, Executive Engineer, UP Jal Nigam (Urban); and Ashish Singh, Executive Engineer, UP Jal Nigam (Rural). We are also grateful to the farmer groups and Indian Institute of Technology Banaras Hindu University faculty consulted during the development of this plan for sharing their perspectives and insights.

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*As Varanasi experiences rapid urban expansion, reducing our reliance on groundwater and preventing the pollution of the Varuna, Assi, and Ganga rivers is our top priority. We are highly appreciative of CEEW's contribution in developing this city-specific Treated Used Water Reuse Plan, which provides Varanasi Nagar Nigam with actionable strategies to manage used water efficiently and mainstream its reuse."*

**Shri Himanshu Nagpal, IAS**
Municipal Commissioner
Varanasi Nagar Nigam

# Contents

Reuse of treated used water can be used
to rejuvenate waterbodies

# Executive summary

Ensuring water security amidst rapid urbanisation and population growth is becoming a critical challenge for Indian cities. Varanasi, one of India's oldest living cities and a critical urban centre along the Ganga River, faces similar challenges. Over the past five years, since 2021, the jurisdictional boundary of Varanasi Nagar Nigam (VNN) has expanded by over 78 per cent, and the city's population has nearly doubled. As a result, the existing water supply and used water (sewage) infrastructure is no longer adequate to meet this rising demand (VSCL 2017). Only 48 per cent of households (HHs) have a formal water supply, while only 38 per cent are connected to the centralised sewerage network (UP Jal Nigam (Rural) Varanasi 2025). Due to inadequate public water supply and used water infrastructure, the city faces the dual challenge of unrestricted groundwater extraction to meet water demand and surface water contamination from the discharge of untreated used water. Addressing this requires a shift from a 'linear' to a 'circular' treat-and-reuse approach to optimise freshwater use and improve the quality of local water sources. A hyper-local plan is therefore essential for managing used water and scaling up its reuse.

## Vision of the Reuse Plan

The *Treated Used Water (TUW) Reuse Plan for Varanasi City* has been developed by the Council on Energy, Environment and Water (CEEW) in association with the *National Mission for Clean Ganga* (NMCG) and VNN. It aims to maximise the treatment of used water and its safe reuse for non-potable purposes, thereby enabling a circular economy approach to used water management in the city. This has substantial potential to reduce the city's unsustainable reliance on groundwater, lower pollution loads from untreated sewage entering natural drainage systems, and directly support the rejuvenation of the local rivers, such as Varuna and Assi, which ultimately drain into the River Ganga.

The Reuse Plan sets three actionable targets for 2030 and 2040: expanding the sewerage network, improving the operational used-water treatment capacity, and maximising safe reuse by identifying suitable reuse avenues (Section 2). The 2047 targets include increasing sewerage network to 100 per cent, achieving full operational treatment capacity, and meeting the city's estimated TUW reuse potential, ensuring that no untreated sewage is discharged into the environment.

## Approach for developing the Reuse Plan

We followed a nine-step methodology to develop the Reuse Plan, building on an approach previously developed and applied in the city of Thane, Maharashtra (TMC and CEEW 2025). This methodology includes assessing Varanasi's water resources and setting long-term treatment and reuse targets, while accounting for current and projected water demand and planned urban development. It also identifies the roles and responsibilities of municipal departments, state agencies, and national institutions operating in Varanasi. The plan was developed in close collaboration with VNN and draws on over 25 consultations with VNN officials from 18 departments and non-government stakeholders such as farmers. Field visits were conducted to sewage treatment plant sites and agricultural fields where TUW is already being used by some farmers for irrigation.

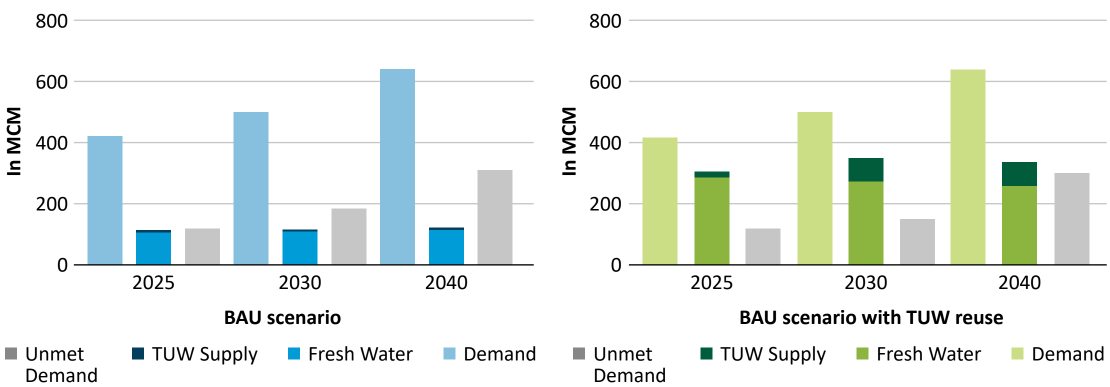
## Key findings

- **Groundwater levels:** Under a business-as-usual (BAU) scenario, groundwater levels are steadily declining, with the pre-monsoon groundwater depth declining at a rate of 68 mm per year during 2000–21. This trend is driven by unabated rates of extraction and evapotranspiration (~1,500 mm) that exceed the city's average annual rainfall (~850 mm).

- **Water quality:** Surface water quality monitoring at one of three monitoring stations indicates persistently high pollution levels across all five years of assessment (2019–23). Pollution levels are particularly high in locations where untreated sewage is discharged into the Varuna and Ganga rivers, with faecal coliform levels exceeding 47,400 MPN/100 ml. Groundwater quality, assessed at two monitoring stations, is also poor, with elevated nitrate, total hardness, and magnesium levels, rendering it unsuitable for drinking in four out of five assessment years.

- **Water balance:** The water balance assessment indicates that Varanasi is likely to face a widening gap between water demand and supply under future growth scenarios (Figures ES1(A–B)). Under BAU population growth (3 per cent), unmet water demand is projected to increase from 117 million litres per day (MLD) in 2025 to 310 MLD by 2040. Under a high population growth scenario (assuming 6 per cent growth), unmet demand is projected to reach 581 MLD by 2040. TUW reuse can partially bridge this gap, reducing unmet demand by 3 per cent (to 301 MLD) under the BAU scenario and by 12 per cent (to 509 MLD) under the high-growth scenario by 2040. While increasing supply through infrastructure development to divert additional surface water is one option to address the deficit, integrating reuse into water supply planning offers a complementary pathway.

**Figure ES1(A): Under the business-as-usual scenario, estimated reuse potential can meet 35% of unmet demand by 2040**

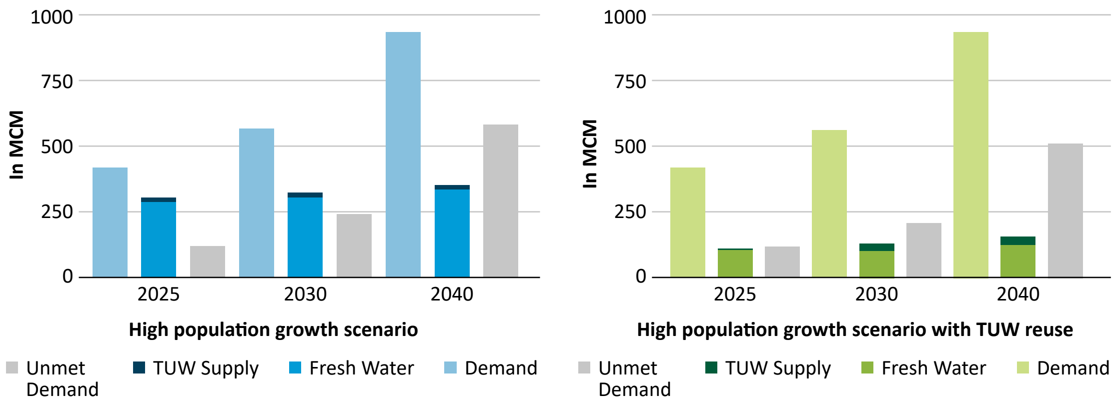



*Source: Authors' analysis based on data received from VNN line departments.*

- **Used water treatment and reuse:** As of 2025, the city generates nearly 465 MLD of sewage and has an installed treatment capacity of 422 MLD. However, actual treatment stands at only 354 MLD, and sewage treatment plants (STPs) remain underutilised due to limited sewerage network coverage (only 38 per cent of households are connected). As a result, untreated used water flows into 43 identified drains and subsequently discharges into the Varuna River.

- **TUW reuse potential:** At present, only around 3 per cent of TUW is being reused; however, there is potential to reuse up to 30 per cent of the currently available TUW in Varanasi. The plan identifies 12 reuse avenues in VNN (Figure ES2(a)) (Section 7), including agriculture (irrigation), Banaras Locomotive Works (BLW), railways, construction, industries, and landscaping (Figure

**Figure ES1(B): In the high population growth scenario, unmet water demand can be reduced by almost 13% or 72 MLD with TUW reuse**




*Source: Authors' analysis based on data received from VNN line departments.*

ES2(B). The quantified reuse potential is estimated at 108 MLD (range: 91–127 MLD), which can meet 35 per cent of unmet water demand by 2040. Agricultural irrigation emerges as a priority reuse avenue, accounting for the city's maximum reuse potential.

- **Treatment quality requirements:** Currently, all STPs operate at the secondary treatment level. To achieve fit-for-purpose quality standards (Annexure 6) of all specified parameters across the identified reuse avenues, post-treatment interventions are required to generate TUW that is safe for use in contact-based and environmentally sensitive applications such as irrigation, landscaping, cleaning, construction, toilet flushing, firefighting, and waterbody rejuvenation. Upgrading to tertiary treatment would enable TUW to meet 100 per cent of the estimated reuse potential.

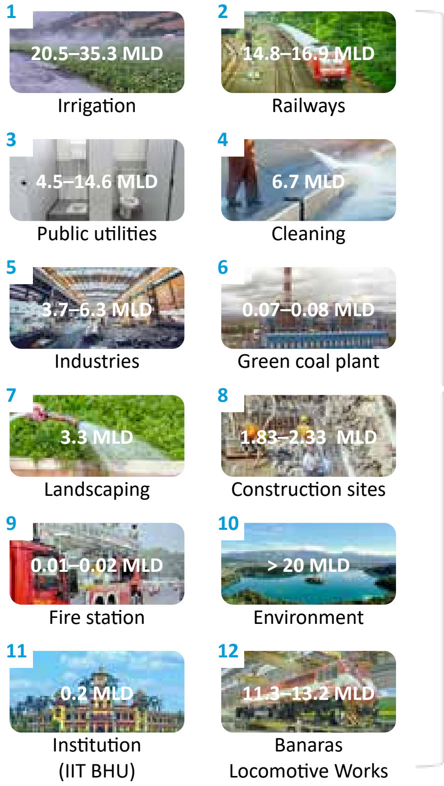
- **Financial requirements for strengthening used water treatment:** The life cycle cost of upgrading treatment technologies ranges from INR 0.9–3.1 crore per MLD for nature-based systems to INR 4.2–6.2 crore per MLD for filtration/media-based tertiary treatments.

- **TUW tariff:** By setting the TUW price at par with the current cost of groundwater extraction for revenue-generating sectors, including construction, coal plants, and industries, VNN could recover 77–93 per cent of the operational expenses required to upgrade 7 MLD of capacity to tertiary treatment for these sectors.

## Recommendations for effective TUW reuse planning and implementation

- **Institutionalise a city-level TUW reuse committee under the chairmanship of the commissioner, VNN:** A broad-based stakeholder committee should serve as the apex body at the city level for mainstreaming TUW reuse initiatives. Chaired by the municipal commissioner, Jal Nigam (Urban) would act as the nodal agency for facilitating, coordinating, and implementing the Reuse Plan in the city. The committee should include all relevant VNN departments (e.g. Jal Kal Vibhag, Jal Nigam, and the Tax Department), institutional end users (e.g. Engineering Department for parks and gardens, Public Works Department (PWD)/Setu Nigam/National Highways Authority of India (NHAI) for construction, and the Irrigation Department for agriculture), and community stakeholders, such as representatives from resident welfare associations (RWAs) and farmer producer organisations (FPOs).

## Figure ES2(A): Identified reuse avenues and relevant stakeholders in Varanasi Nagar Nigam




1 Irrigation Department

5 Industrial associations

6 National Thermal Power Corporation

2, 12 Railway departments (Northern, North-Eastern, Banaras Locomotive Works)

7 Engineering Department

3 Public Works Department

8, 10 Varanasi Development Authority

4, 8 Varanasi Nagar Nigam

4 Jal Nigam (Urban)

4 Jal Nigam (Rural)

8 National Highway Authority of India

8 Setu Nigam

9 Fire Department

4 UPSRTC

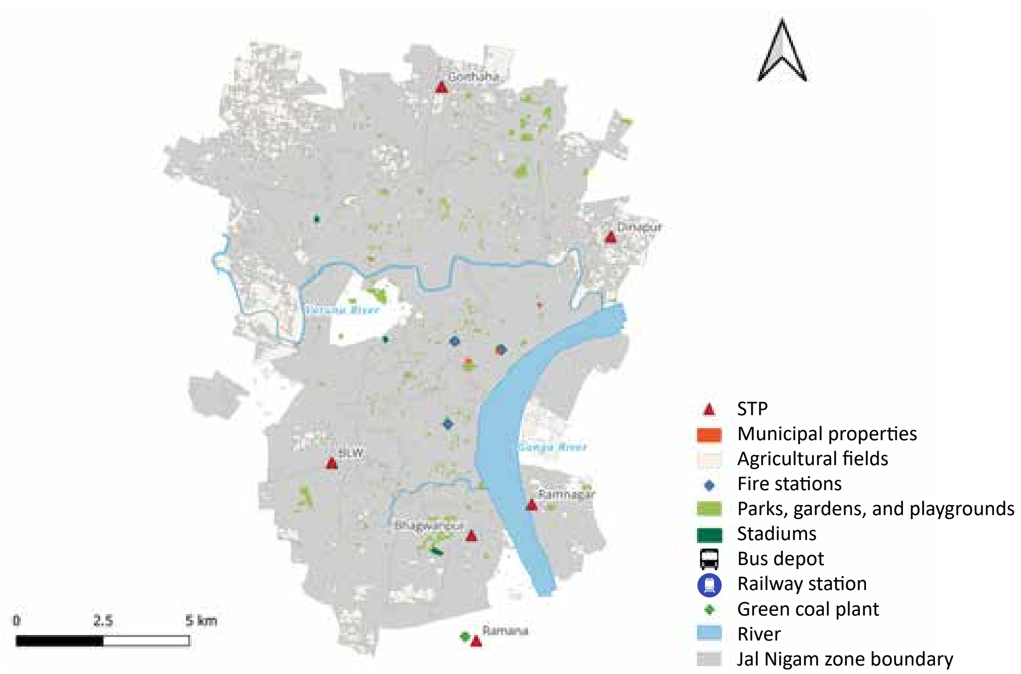
11 IIT BHU

**Jal Kal Vibhag**

*Source: Authors' analysis.*

Note: Jal Kal Vibhag to play a coordinating and facilitating role across all stakeholders.

## Figure ES2(B): Spatial distribution of identified reuse avenues in Varanasi Nagar Nigam




*Source: Authors' analysis.*

Note: Some reuse avenues, namely, industries, construction sites, cleaning, and public utilities, have not been spatially mapped.

- **Prioritise sewerage network expansion and strengthen intra-departmental coordination for time-bound implementation:** Jal Nigam (Urban) is undertaking sewerage network expansion, while Jal Nigam (Rural) is responsible for drain interception and diversion (I&D). Stronger coordination within Jal Nigam is required to ensure timely project completion and achieve the city-level targets outlined in the plan, namely, 60 per cent sewerage network coverage by 2030 and 100 per cent by 2040.

- **Strengthen and upgrade existing treatment infrastructure and deploy decentralised wastewater treatment systems (DEWATS) to promote reuse:** Priority STPs need to be partially upgraded based on the type of reuse avenue linked to the STP and the quantity of TUW required. For instance, Goithaha STP (for agriculture) and Ramnagar STP (for industrial reuse) need to be partially upgraded to tertiary and advanced treatment, respectively, to achieve fit-for-purpose quality standards. The plan recommends STP-specific interventions to improve operational efficiency and achieve these quality standards (Section 9.2, Table 6). The plan also suggests that Jal Nigam, in coordination with the Varanasi Development Authority (VDA), integrate DEWATS into master and zonal-level plans and prioritise implementation in central sewage zones (Districts 2B and 2C, and Problematic 18A), where supplying TUW through centralised STPs is not feasible and tapping drains provides a reliable inlet source.

- **Mandate end-user institutions to formulate strategies for mainstreaming TUW reuse in their respective sectors:** To enable effective uptake of TUW by end-user institutions, reuse provisions should be integrated into their project planning documents, aligned with the *State Urban Wastewater Treatment (Recycle, Reuse and Disposal) Policy* published in 2023 (RCUES 2023). Institutions such as PWD, NHAI, and Setu Nigam should incorporate mandatory TUW reuse clauses in tender documents and detailed project reports (DPRs) for their construction projects. Adoption can be incentivised by linking contractor incentives to higher TUW utilisation and by including TUW conveyance, on-site treatment (if required), and storage costs as reimbursable bill-of-quantities (BOQ) items for projects located beyond 10 km from the city boundary. For agricultural reuse, the irrigation department, in coordination with Jal Nigam, should develop water release schedules aligned with cropping calendars and gradually introduce a differential canal tariff system based on the area under irrigation via the canal and the cropping pattern.

- **Ensure sustainable financing and effective cost recovery for TUW reuse infrastructure:** Reuse projects must be financially sustainable, with risk-sharing among VNN, nodal departments, and private stakeholders. The plan recommends business models for VNN to implement reuse projects, including multi-stakeholder water swap models, Hybrid Annuity Model–Public–Private Partnership (HAM–PPP) with reuse, and direct end-user investments. Institutions such as PWD, NHAI, and Setu Nigam can leverage existing private-sector partnerships to develop PPP-based bulk supply agreements. Further, the TUW price should be sufficient to recover the urban local body's (ULB) costs of treatment and conveyance. For instance, by setting the tertiary TUW price at par with current freshwater costs for revenue-generating sectors, such as construction, coal plants, and industries, VNN could potentially recover 77–93 per cent of the operational expenses associated with technology upgrades necessary to meet sectoral water demand.

# 1. Introduction

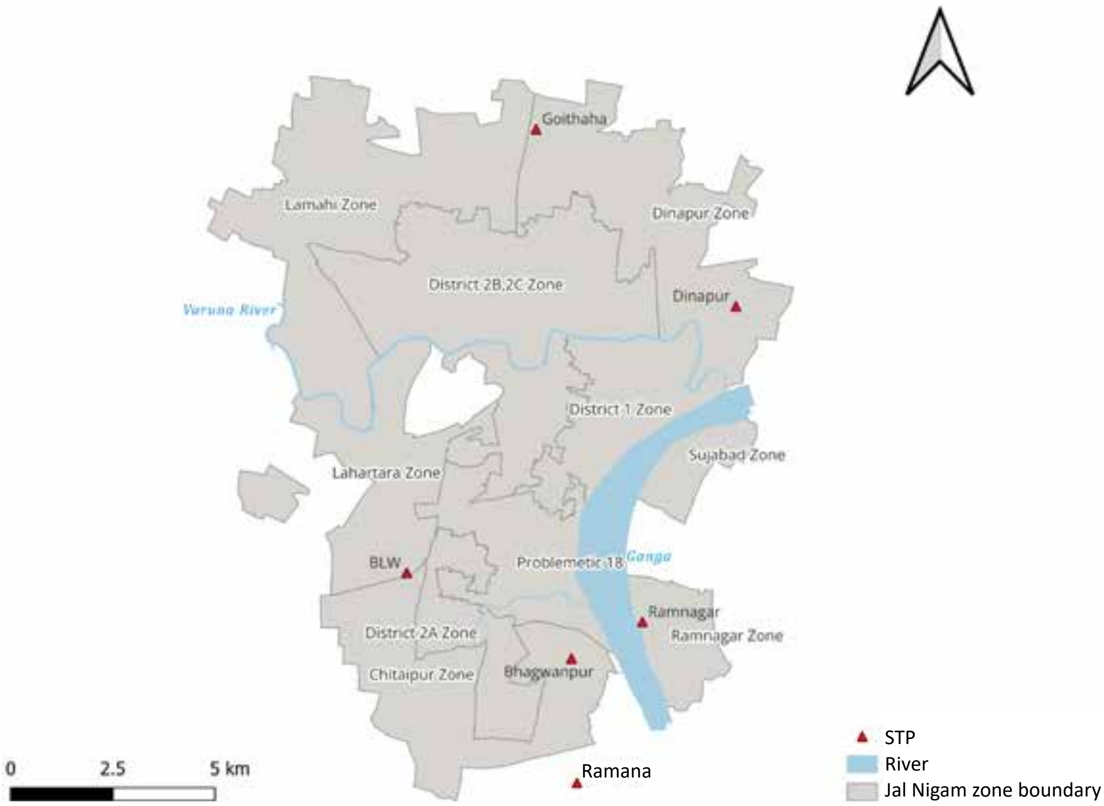
The *National Mission for Clean Ganga* (NMCG) – *Namami Gange Programme* – is an integrated conservation mission launched to achieve the dual objectives of effective pollution abatement and the conservation and rejuvenation of the Ganga River. As part of these efforts, the programme has focused on improving the health of river stretches in cities along the Ganga basin. Among these cities, Varanasi holds particular significance due to its strategic location along the river and its immense religious and cultural importance. As one of India's oldest living cities and a critical urban centre along the Ganga River, Varanasi is witnessing rapid urbanisation that has far outpaced its existing water supply and used water infrastructure.

The city has eight administrative zones – Adampur, Bhelupur, Dashashwamedh, Kotwali, Varunapur, Rishi Mandvi, Sarnath, and Ramnagar – governed by the Varanasi Nagar Nigam (VNN) (UP Jal Nigam (Rural) Varanasi 2025). In 2021, the area under the jurisdiction of VNN increased from 86 sq km to 146 sq km, representing an increase of more than 100 per cent (VSCL 2017). The city's population is 26 lakh, residing in 4.15 lakh households (HHs). Of these, only 48 per cent of households have water supply coverage, and only 38 per cent are connected to the centralised sewerage network (UP Jal Nigam (Rural) Varanasi 2025). Due to limited coverage of formal water supply and sewerage network, Varanasi's water resource management faces the dual challenge of unrestricted groundwater extraction to meet water demand and pollution of water bodies due to the release of untreated used water.

The VNN is divided into 10 sewage zones, and its geography is shaped by two tributaries – the Varuna and the Assi – which flow west to east before converging with the Ganga River (Figure 1). The city generates nearly 465 million litres per day (MLD) of domestic sewage and has an installed treatment capacity of 422 MLD through six sewage treatment plants (STPs) (Figure 2). However, actual treatment is only 354 MLD, indicating that STPs remain underutilised, either due to inadequate sewerage network coverage or operational challenges. As a result, untreated used water is discharged directly into open drains.

According to a drone-based survey conducted by VNN, 48 small and medium drains that discharge into the Varuna River have been identified. Of these, 43 are within the municipal limits of VNN, and 5 are in rural areas (UP Jal Nigam (Rural) Varanasi 2025b). Of these, 23 drains within VNN, with a cumulative discharge capacity of 110 MLD (UP Jal Nigam (Rural) Varanasi 2025b), are currently untapped and discharge directly into the Varuna River. The remaining 19 drains, with a cumulative discharge capacity of 105 MLD, are reported to be tapped but frequently overflow due to inadequate maintenance. Additionally, one drain – Narokhar drain – into which treated effluent from the 120 MLD Goithaha STP is discharged, is partially untapped (UP Jal Nigam (Rural) Varanasi 2025b).

**Figure 1: 10 sewage zones in Varanasi Nagar Nigam**




*Source: Authors' analysis using data from Varanasi Smart City Limited (VSCL).*

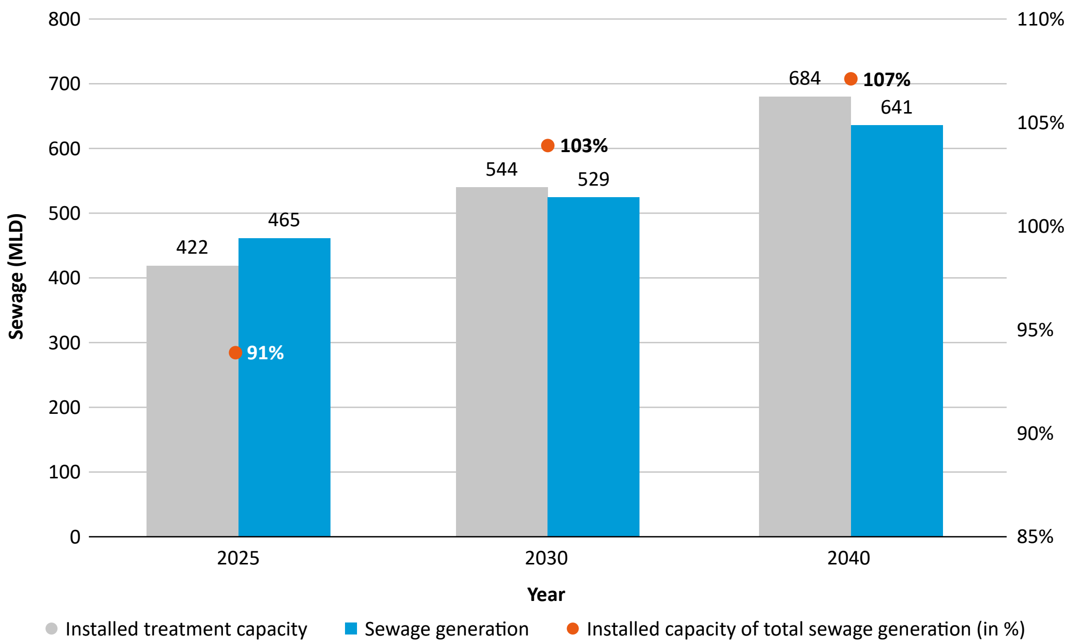
Thus, the Varuna River has become a perennial carrier of untreated sewage, which in turn degrades the water quality of the stretch of the Ganga River flowing through Varanasi. The Assi River faces similar challenges, including floodplain encroachment and the dumping of solid waste, effectively reducing it to a stagnant drain or *nullah*.

There is an urgent need to expand water supply network coverage to reduce dependence on groundwater to meet domestic demand, strengthen sewerage infrastructure to improve the utilisation of treatment capacity, and ensure the time-bound implementation of drain interception and diversion projects to improve surface water quality.

The VNN has prepared an action plan for sewage management in the catchments of the Varuna, Ganga, and Assi rivers. Under this plan, sewage zones have been reconfigured to include newly incorporated areas, and efforts are underway to expand sewerage network coverage and treatment capacity. However, these measures must be integrated within a long-term, city-level *Treated Used Water* (TUW) *Reuse Plan* framework to achieve sustained impact.

Varanasi requires a reuse planning framework that embeds circularity in used water management through a well-planned sequence of interventions. This includes expanding sewerage networks, upgrading existing centralised treatment plants to meet reuse-specific quality standards and improve operational treatment capacity, developing decentralised wastewater treatment systems (DEWATS) for identified reuse avenues (Districts 2B and 2C, and Problematic 18A), and maximising reuse for non-potable purposes.

## Figure 2: Sewage generation in the city is expected to rise by 38% by 2040




*Source: Authors' analysis based on data from VNN (Jal Nigam).*

# 2. Vision

This plan aims to maximise the reuse of domestic TUW in VNN, thereby supporting the mainstreaming of a circular economy approach to used water management in the city. It seeks to address the unsustainable reliance on groundwater, optimise the use of treatment infrastructure, and improve the quality of local water sources, thereby enhancing urban resilience. For this purpose, it establishes quantitative targets for 2030 and 2040 (Table 1), aligning with Jal Nigam's treatment capacity targets.

The first target is to expand sewerage network coverage from the current 38 per cent to 60 per cent by 2030 and 100 per cent by 2040, ensuring that sewage is efficiently collected from households (HHs) across the city and transported for treatment.

The second target is to achieve 80 per cent and 100 per cent operational treatment (as a share of installed capacity) by 2030 and 2040, respectively (Table 1). Together, these targets can ensure that no untreated sewage is discharged into the environment by 2040.

The third target focuses on increasing the reuse of TUW for non-potable purposes in the city. It targets the reuse of up to 15 per cent and 20 per cent of available TUW by 2030 and 2040, respectively.

**Table 1: City-level targets under the Reuse Plan for Varanasi City**

| City-level target | Indicator | 2030 | 2040 |
|---|---|---|---|
| Sewerage network expansion | Number of HHs connected to the sewerage network as a percentage of total HHs | **60%** | **100%** |
| Operational treatment | Operational treatment as a percentage of installed treatment capacity | **80%** | **100%** |
| Reuse of TUW | Percentage of available TUW reused for non-potable uses | **15%** | **20%** |

*Source: Authors' analysis based on data from VNN (Jal Nigam and Jal Kal).*

# 3. Approach for developing the Treated Used Water Reuse Plan

The Reuse Plan assesses Varanasi's water resource scenario over time and outlines mid- and long-term strategies for implementing TUW reuse in the city. The stepwise approach begins with a holistic assessment of the city's water resources, including the quality of surface and groundwater, the city's water balance, and the status of water management, as well as the identification of potential avenues for TUW reuse. This baseline assessment is followed by setting quantifiable reuse targets, estimating reuse potential across identified sectors, and aligning with quality standards to ensure safe reuse.

The final focus of the plan is on implementation, including estimating financial requirements and delineating dedicated reuse zones. This involves detailed zone-wise planning and the deployment of institution-led actions, supported by a framework for continuous monitoring and capacity building to ensure the plan's long-term viability.

The approach also integrates DEWATS to complement the existing centralised sewage treatment system and recommends strategic capacity upgrades to systematically divert treated effluent away from local rivers for non-potable applications. The overall approach to developing the plan is detailed in Annexures 2–7. To ensure the holistic development of the plan, all relevant stakeholders, including VNN officials, state departments, and end-user groups, were involved in over 25 consultations (Figure 2).

**Figure 2: Consultation exercise and progress meetings with Varanasi Nagar Nigam officials**

*a) CEEW team presenting to the commissioner of Varanasi Nagar Nigam*

*b) CEEW team's visit to the Banaras Locomotive Works sewage treatment plant of 12 MLD capacity*

*c) CEEW team's visit to the Ramana Sewage Treatment Plant of 50 MLD capacity*

*Images: CEEW*

# 4. Groundwater and surface water scenario in VNN

In this section, we analyse depth-to-groundwater levels in Varanasi over a 20-year period (2000–21), along with seasonal variations in groundwater and surface water quality over five years (2019–23). The analysis considers three scenarios: Scenario 1 examines trends in average depth-to-groundwater levels alongside the city's average annual rainfall, while Scenarios 2 and 3 analyse pre- and post-monsoon groundwater depth trends in relation to monsoon rainfall. A detailed analysis is presented in Annexure 2.

## 4.1. Depth to groundwater level

Annual rainfall in Varanasi over 2000–21 shows a declining trend (approximately 6.5 mm per year), although this trend is statistically insignificant. Rainfall also exhibits high inter—annual variability, ranging from 400 to 1,300 mm over this period. Monsoon rainfall accounts for roughly 90 per cent of the city's annual rainfall. Post-monsoon depth to groundwater level is moderately correlated ($r = -0.38$) with monsoon rainfall (Figure 3b), indicating that higher rainfall generally has a positive effect on groundwater levels. However, time series analysis of groundwater depth relative to rainfall shows a decline in groundwater levels across all scenarios (Figure 3(a–b)). Although statistically insignificant, the steepest decline (68 mm per year) is observed during the pre-monsoon period. Further, the evapotranspiration rate in the region (~1,500 mm) exceeds the average annual rainfall (Raju et al. 2024), placing additional pressure on the city's freshwater resources.

Apart from declining rainfall in the region, unabated groundwater extraction to sustain urban growth, growing population density, and agricultural activities have contributed to groundwater depletion in the city (Raju et al. 2024; Dey et al. 2020). The region is characterised by a multi-tier aquifer system, with the first aquifer extending to 150–160 metres below ground level (mbgl) and a second, deeper layer characterised by permeable sand, separated by a thick clay layer (Raju et al. 2024). The shallow, unconfined aquifers in the region are tapped through dug and tube wells to meet the city's growing water demand. Under a business-as-usual (BAU) scenario, in the absence of alternative water supply augmentation, the city's groundwater resources are projected to decline further. In certain areas of the city, especially near the ghats along the Ganga River, groundwater depletion is contributing to land subsidence. If current trends persist, the continued reduction in storage recovery during the post-monsoon period may lead to a permanent loss of groundwater.

**Figure 3 (A): Varanasi's annual groundwater depth is declining at a rate of 40 mm per year**

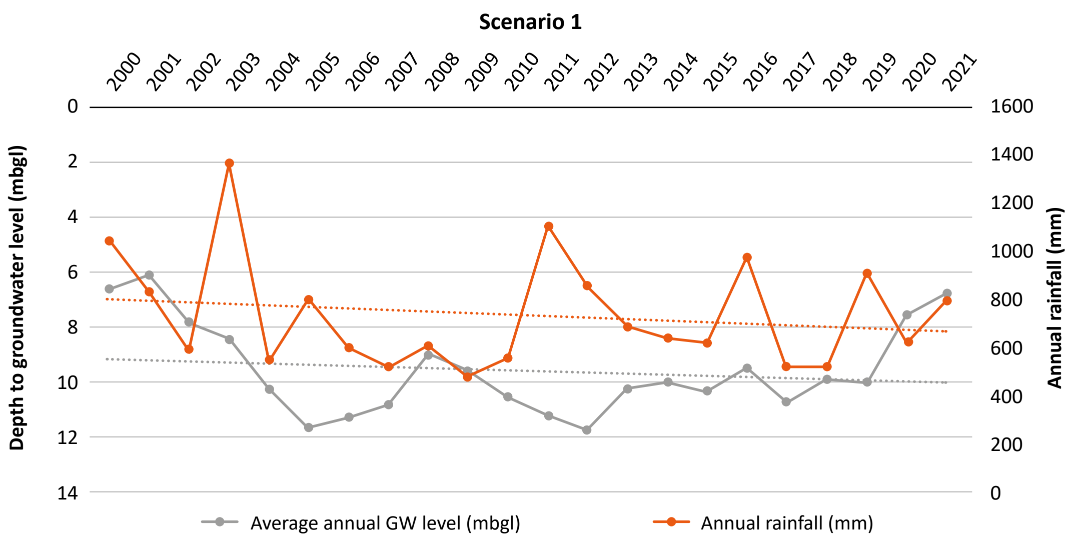
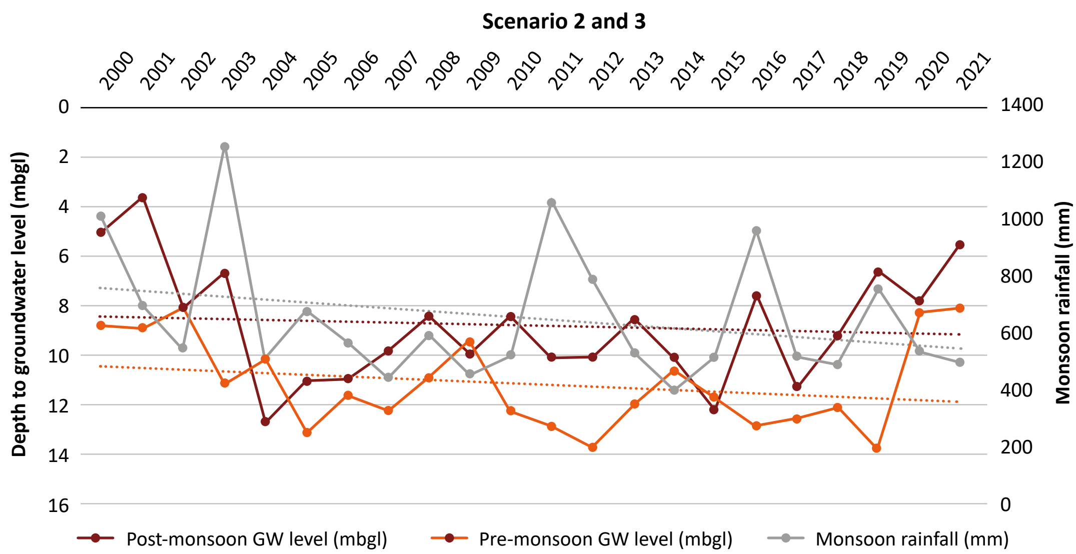



**Figure 3 (B): Varanasi's pre-monsoon groundwater depth is declining at a rate of 68 mm per year**




*Source: Authors' analysis using data from India–WRIS (Water Resource Information System). n.d. "Groundwater Behaviour." Ministry of Jal Shakti, Government of India. indiawris.gov.in/wris/#/groundWater and IMD (India Meteorological Department). 2023. "District-Wise Rainfall Distribution (Daily and Cumulative)." Ministry of Earth Sciences, Government of India.*

## 4.2. Water quality of groundwater and surface water sources

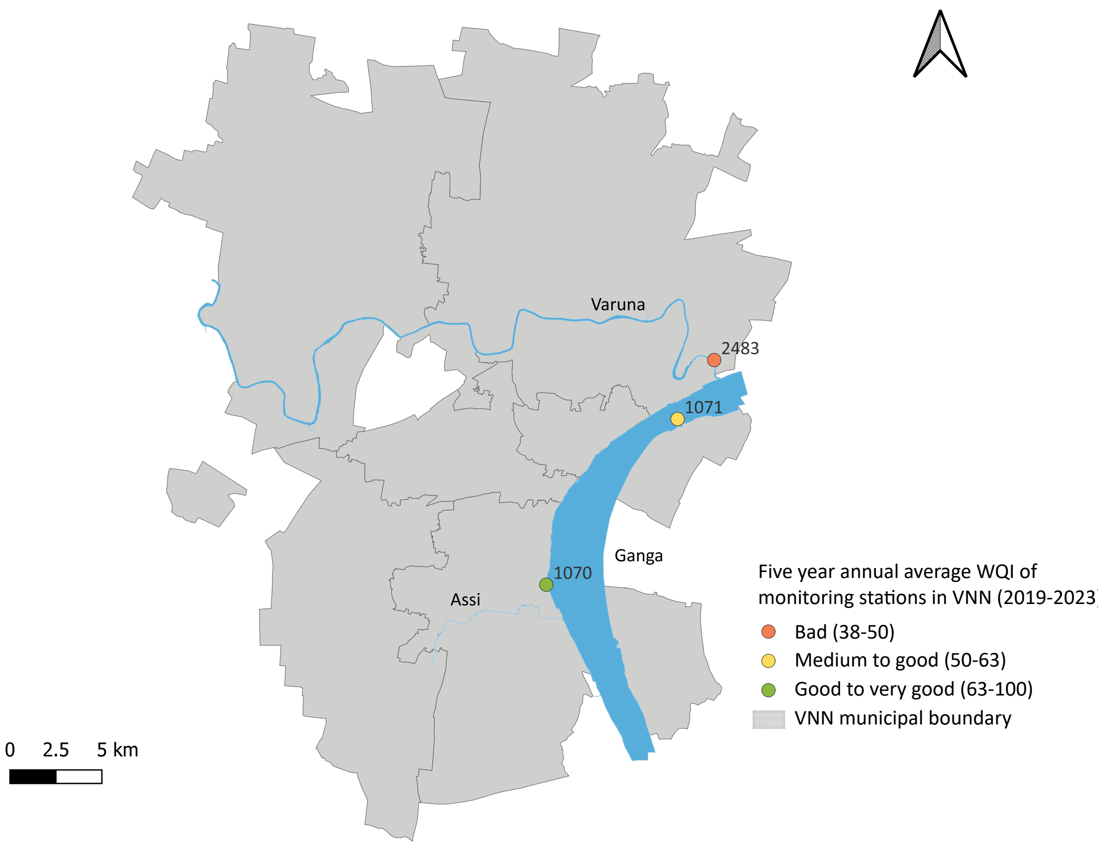
The water quality index (WQI) has been computed to assess the quality of freshwater resources in VNN over a five–year period (2019–23). This section describes the status of surface water and groundwater quality.

- **Surface water quality**

Surface water quality analysis using data from three surface water monitoring stations (1070, 1071, and 2483) under the *National Water Quality Monitoring Programme* reveals that the five-year annual average WQI ranges from 40.8 to 66.5 (bad to medium water quality). While an overall improvement in water quality is observed during 2019–23 (Figure 5), monitoring station 2483, situated at the confluence of the River Varuna and the Ganga River, is categorised as bad across five years of assessment.

Parameters substantially exceeding the limits set by the *Environmental (Protection) Rules, 1986,* include faecal coliform, with annual averages of 12,790 ± 2,566 MPN/100 ml at station 1071 and 47,400 ± 38,801 MPN/100 ml at station 2483, against the guideline of 2,500 MPN/100 ml. Additionally, station 2483 records biological oxygen demand (BOD) levels above 3 mg/L and dissolved oxygen below 5 mg/L in four out of five years. The poor water quality at this location is likely due to the discharge of untreated sewage through drains entering the Varuna and subsequently the Ganga (Figure 4).

**Figure 4: The monitoring station at the confluence of the Varuna and the Ganga displays bad quality**

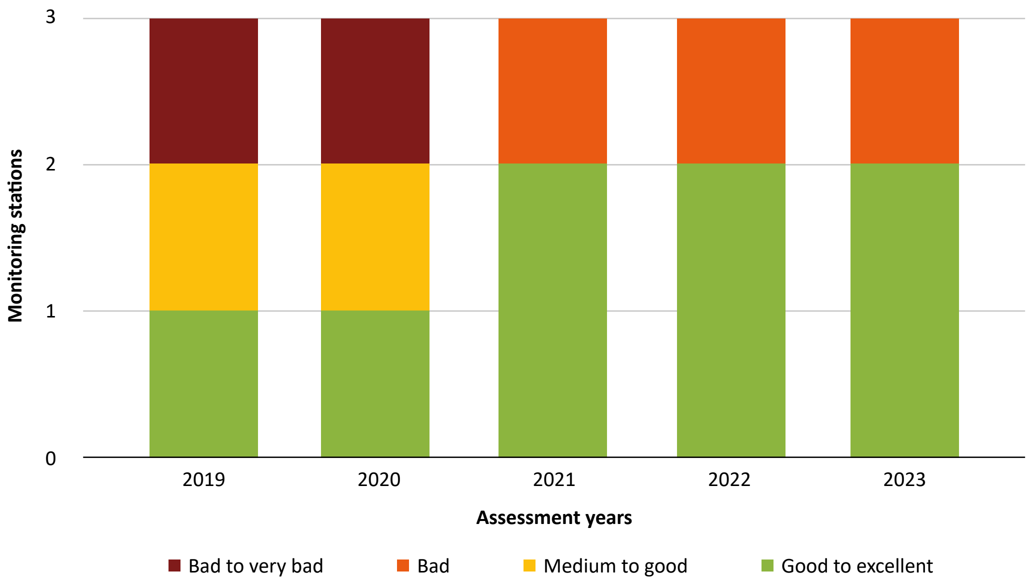



*Source: Authors' analysis using data from Central Pollution Control Board (CPCB) 2019, 2020, 2021, 2022, and 2023.*

- **Groundwater quality**

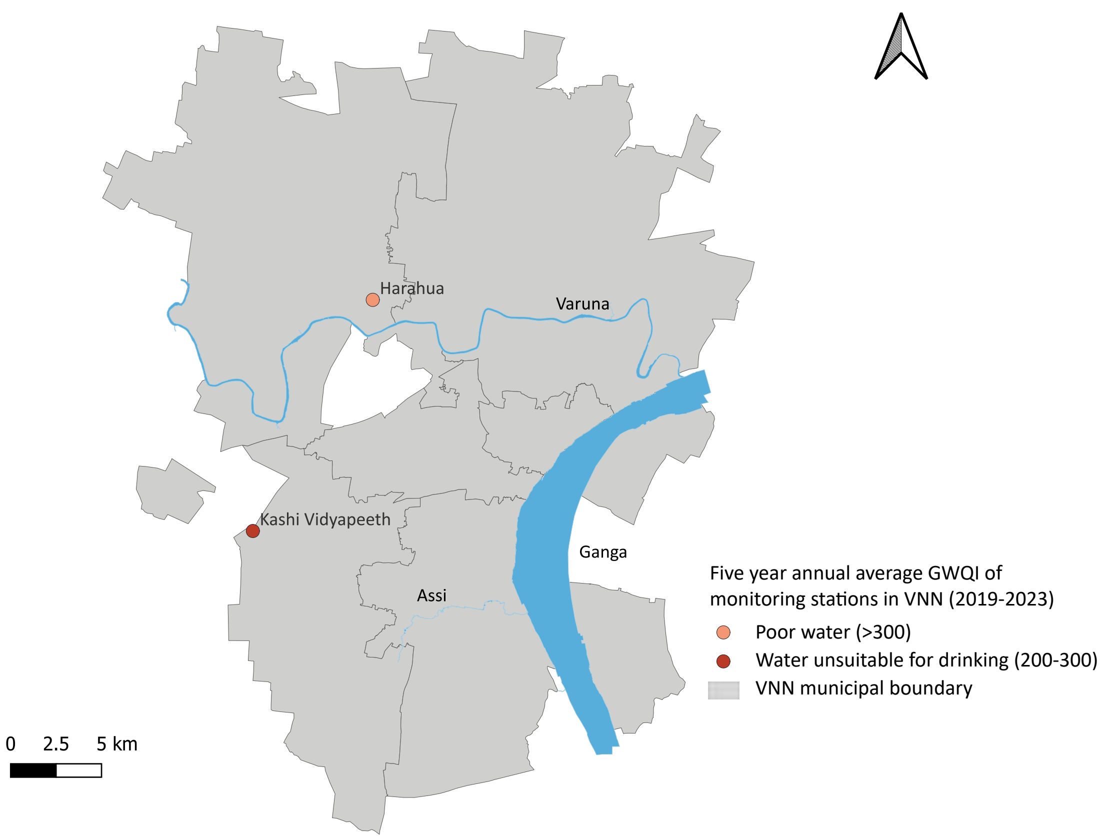
The annual average groundwater quality index (GWQI) assessed at two monitoring stations in Harahua (135) and Kashi Vidyapeeth (335) indicates consistently poor water quality during 2019–23 (Figures 6 and 7). The GWQI at the Kashi Vidyapeeth station classifies the water as unsuitable for drinking in four of the five assessment years (2020, 2021, 2022, and 2023).

**Figure 5: Surface water monitoring stations show a gradual improvement in water quality during 2019–23**




*Source: Authors' analysis using data from Central Pollution Control Board (CPCB) 2019, 2020, 2021, 2022, and 2023.*

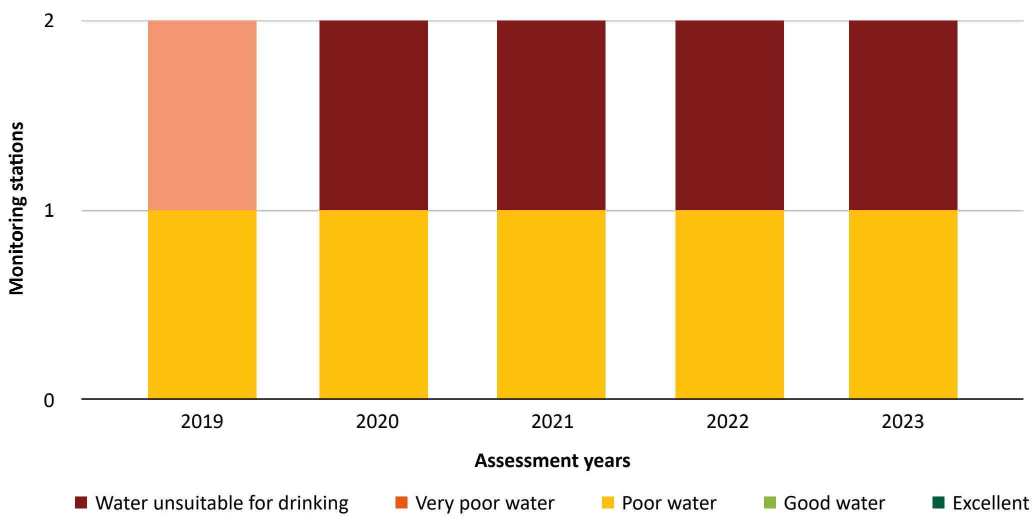
**Figure 6: Groundwater monitoring stations in Varanasi display poor groundwater quality**




*Source: Authors' analysis using data from CGWB (Central Groundwater Board). 2023. "Ground Water Quality." Ministry of Jal Shakti, Government of India.*

Parameters such as total hardness (>300 mg/L), magnesium (>30 mg/L), and nitrate (>45 mg/L) exceed the acceptable limits specified in BIS 10500 at Kashi Vidyapeeth. Further, a strong positive correlation exists between electrical conductivity and nitrate (r = 0.59), suggesting a higher proportion of nitrate ions in groundwater and the influence of anthropogenic factors, such as excess fertiliser use in agriculture or leakage from sewerage or septic systems, contributing to groundwater contamination. The findings align with previous studies that attribute high nitrate levels in groundwater to human activities, including inadequate sewerage network coverage, leakage from septic tanks, improper solid waste disposal, agricultural practices, irrigation using untreated used water, and agricultural and industrial runoff in Varanasi (Ahamad et al. 2018; Raju et al. 2009).

**Figure 7: The monitoring station in Kashi Vidyapeeth reported water quality unsuitable for drinking for four consecutive years**



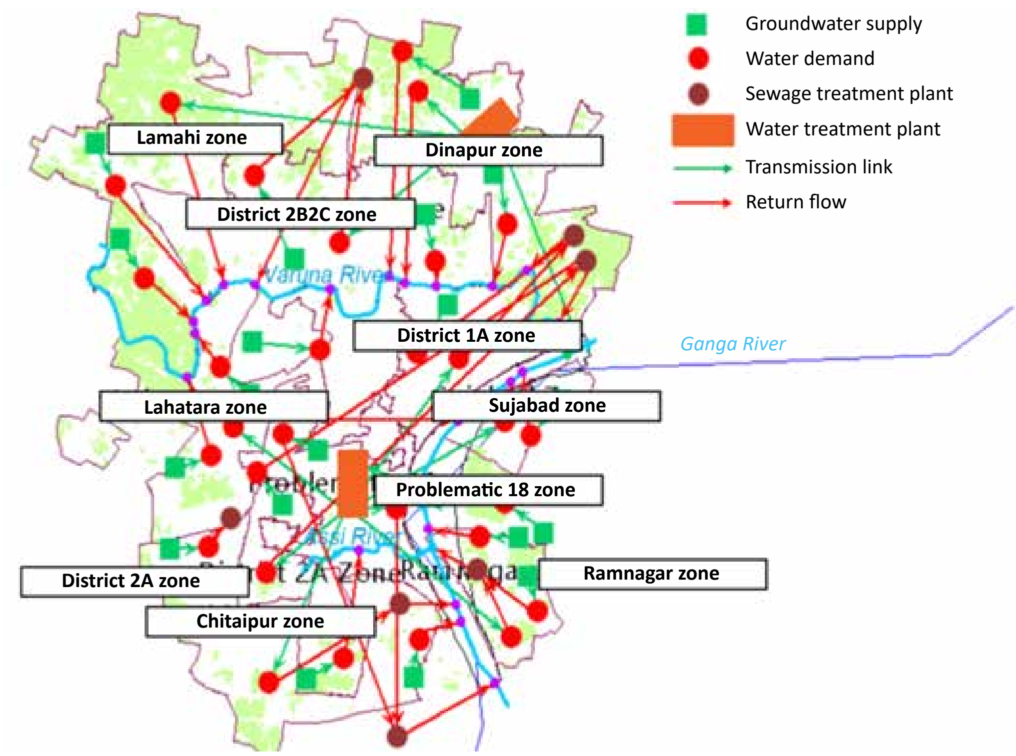

*Source: Authors' analysis using data from CGWB (Central Groundwater Board). 2023. "Ground Water Quality." Ministry of Jal Shakti, Government of India.*

# 5. City water balance

The city water balance for VNN was prepared using the Water Evaluation and Adaptation Planning (WEAP) model developed by the Stockholm Environment Institute (SEI) (SEI 2023). The model was configured for the period 2025–2040 to simulate the dynamics of water demand, supply, used water generation, and treatment within the VNN boundary (Figure 8; Annexure 3). The results of the water balance modelling highlight a widening gap between water demand and supply under both BAU and high-population-growth scenarios. Under the BAU scenario (assuming 3 per cent annual population growth), unmet demand increases from 117 MLD in 2025 to 184 MLD in 2030 and 310 MLD by 2040. With TUW reuse based on the reuse targets outlined in Section 2, the deficit is reduced to 149 MLD in 2030 and 301 MLD in 2040 (Figure ES2(a)). Under the high population growth scenario (assuming 6 per cent annual growth), the supply gap widens further, with unmet demand increasing to 241 MLD in 2030 and 581 MLD by 2040 (Figure ES2(b)). With TUW reuse interventions, unmet demand decreases to 205 MLD in 2030 and 509 MLD in 2040.

Scaling up TUW reuse can therefore play a critical role in partially bridging the demand–supply gap and strengthening urban water security.

**Figure 8: WEAP model configuration for Varanasi Nagar Nigam**




*Source: Authors' analysis using data received from VNN (Jal Nigam and Jal Kal).*

# 6. Used water management in Varanasi Nagar Nigam

Varanasi Nagar Nigam is categorised as an outstanding ULB, with a composite index score of 3.18 out of 5 using the Municipal Used Water Management (MUWM) framework (Gupta et al. 2024), among 463 Tier 1 and Tier 2 cities in the Ganga basin (Table 2). The ULB has also secured the highest score in three out of five themes – finance, governance, and data and information – highlighting strong institutional capacity, financial planning, and data-driven decision-making. These strengths can be leveraged to accelerate TUW reuse planning by enabling effective stakeholder coordination, designing sustainable financing models for reuse infrastructure, and supporting data-driven planning and monitoring of reuse interventions. The analysis of the MUWM index's assessment themes is presented in Annexure 4.

**Table 2: The composite index score and theme scores of Varanasi Nagar Nigam using the Municipal Used Water Management framework**

| Theme | Scores | Maximum | Category |
|---|---|---|---|
| Finance | 3.04 | 4 | Leading |
| Infrastructure | 3.11 | 6 | Performing |
| Efficiency | 3.03 | 6 | Performing |
| Governance | 5.02 | 7 | Leading |
| Data and information | 2.99 | 4 | Leading |
| **Composite index score** | **3.18** | **5** | **Outstanding** |

*Source: Authors' analysis.*

# 7. Identified TUW reuse avenues in VNN

The *Urban Wastewater Treatment (Recycle, Reuse, and Disposal) Policy,* developed by the Regional Centre for Urban and Environment Studies (RCUES), Lucknow, and the Urban Development Department, Government of Uttar Pradesh (RCUES 2023), outlines a vision to promote TUW as an economic resource and maximise its use, thereby reducing the dependency on freshwater. The policy provides guidelines for improving the collection and reuse of TUW, identifies priority areas for the Government of Uttar Pradesh, and sets service-level benchmarks.

To maximise reuse, it is essential to identify suitable sectors or user categories for the safe reuse of TUW based on the presence of bulk water users, TUW availability, and the level of treatment. Based on the current situation in Varanasi and consultations with relevant VNN departments (Figure ES3(a)), 12 reuse avenues and their respective applications for non-potable TUW reuse in VNN have been identified (Table 3).

**Table 3: Identified reuse avenues and treated used water quantity requirements in Varanasi Nagar Nigam**

| Reuse avenue | Applications | Reuse quantity requirements (MLD) | | Specification |
|---|---|---|---|---|
| | | Minimum | Maximum | |
| Irrigation | Irrigation of horticulture, rice, and wheat | 20.51 | 35.51 | TUW can meet the irrigation requirements of agricultural areas along the periphery of VNN. |
| Waterbody rejuvenation | Maintenance of city waterbodies | - | - | TUW can rejuvenate urban water bodies and maintain river flows. |
| | Minimum Environmental- flow (e-flow) in the Assi River | 20.00 | 20.00 | |
| Public utilities | Toilet flushing | 4.52 | 14.58 | TUW of specified quality can be used for storage tanks in public toilets. |
| Banaras Locomotive Works (BLW) | Irrigation | 2.57 | 4.28 | The reuse of TUW of specified water quality can meet non-potable water requirements within the railway production unit located in the city. |
| | Filling ponds | 0.28 | 0.28 | |
| | Flushing + vehicle washing (domestic) | 0.42 | 0.42 | |
| | Industrial operations | 5.51 | 5.51 | |
| | Cooling tower | 2.27 | 2.27 | |
| | Locomotive cleaning stations | 0.27 | 0.41 | |

| Reuse avenue | Applications | Reuse quantity requirements (MLD) | | Specification |
|---|---|---|---|---|
| | | Minimum | Maximum | |
| Cleaning | Bus depot (vehicle exterior and wheel washing) | 0.01 | 0.02 | TUW of specified quality can be used to clean buses (wheels and exteriors) and for cleaning requirements within STP facilities and municipal properties. |
| | STP facilities | 6.50 | 6.50 | |
| | Municipal properties | 0.12 | 0.12 | |
| Industries | Process-based application | 3.72 | 6.27 | TUW of specified quality can be used by manufacturing industrial units as process water. |
| Railways | Washing of platforms, coaches, terminal tracks, and pits | 2.92 | 2.92 | TUW of specified quality can be used to fulfil various non-potable water requirements at railway stations in the city. |
| | Toilet flushing | 0.88 | 1.17 | |
| | Landscaping and irrigation | 0.02 | 0.02 | |
| Landscaping | Parks | 2.74 | 2.74 | TUW can meet the watering requirements of municipal parks, gardens, road dividers, and stadiums. |
| | Road dividers | 0.44 | 0.44 | |
| | Stadiums | 0.14 | 0.14 | |
| Construction sites<br><br>(municipal sites, National Highway Authority of India (NHAI), Public Works Department (PWD), Setu Nigam) | Cleaning (aggregate, concrete batching plants, and vehicles) | 1.83 | 2.33 | Secondary TUW can be used for landscaping on construction sites, as well as for clean aggregate, concrete batching plants, machinery, roads, and vehicles. A higher quality of TUW can be used during construction activities to suppress dust. |
| | Dust suppression | | | |
| | Landscaping | | | |
| Coal plant | Process-based application | 0.07 | 0.08 | TUW of specified quality can be supplied to the city's green coal plant to meet process-based water requirements. |
| Fire station | Maintenance of the water storage system for firefighting | 0.01 | 0.02 | TUW treated to specified quality standards can be used in fire hydrant systems. |
| Institutional (IIT Banaras Hindu University campus) | Landscaping | 0.216 | 0.216 | TUW can be supplied to the IIT-BHU campus to meet their non-potable water needs (e.g. toilet flushing, cleaning, landscaping). |
| | Cleaning | | | |
| | Toilet flushing | | | |
| Total reuse potential (MLD) | | 75.96 | 106.24 | |
| **Total reuse potential (MLD) including 20% conveyance loss** | | **91.15** | **127.49** | |

Tertiary treatment        Advanced treatment

*Source: Authors' analysis using data received from VNN (as cited in Annexure 5).*

# 8. Allocation mechanism for the reuse of treated used water

Allocation for the available TUW is determined based on the estimated water demand across the identified reuse avenues. This approach enables optimal allocation of TUW to the identified users based on their respective requirements. Based on the methodology defined (Annexure 5), the total quantified reuse potential of the city ranges between 91 and 127 MLD, averaging at 108 MLD (Table 3). The quantified reuse potential is equivalent to 30 per cent of the city's current operational used water treatment capacity. Fulfilling the estimated reuse potential across the 12 reuse avenues would ensure the reuse of 19 per cent and 17 per cent of available TUW by 2030 and 2040, respectively. While the 2030 potential (19 per cent) exceeds the 15 per cent target, the 2040 potential (17 per cent) falls 3 percentage points short of the 20 per cent target, necessitating the identification of new avenues or expansion of existing potential over the long term to achieve the desired target.

For ease of implementation, TUW allocation will be undertaken zone-wise in phases, taking into account the sewerage network, the installed and operational capacities of existing and planned treatment infrastructure, and the TUW requirements of identified reuse avenues within the zones.

Six reuse zones – defined based on the city's existing sewage zones (Figure 1) – have been identified for this purpose. For zone-wise planning, treatment infrastructure within each zone has been spatially mapped along with the identified reuse avenues (Section 11). Based on the extent of treatment infrastructure and treatment levels, as well as the spatial distribution of reuse avenues, the zone-wise planning recommends augmenting infrastructure and developing conveyance mechanisms to efficiently fulfil the city's identified reuse potential.

The allocation priorities for TUW reuse in VNN are based on a defined set of criteria comprising six indicators, which determine the feasibility of reuse across identified avenues (Table 4). It should be noted that this is a relative assessment – certain reuse avenues may fulfil one or more criteria but not be classified as a priority use compared with other uses.

## Table 4: Criteria for treated used water allocation for Varanasi Nagar Nigam

| Reuse avenue | Institution | Used water treatment level required | Quantity of TUW required | Frequency of TUW required | Distance from STP | Spatial distribution | End user/ institutional readiness |
|---|---|---|---|---|---|---|---|
| | | Whether the water quality required aligns with the available quality of TUW | Whether a minimum of 1 MLD of TUW is required | Whether a regular supply of water is required | Whether the end user lies within 1–2 km of the nearest STP | Whether the reuse avenue is predominantly present in clusters across the city | Whether the end user/ nodal agency exhibits willingness to pay for TUW or showcases institutional readiness to adopt TUW reuse |
| **BLW** | BLW | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Cleaning** | UPSTRTC | × | × | ✓ | × | × | × |
| | Jal Nigam | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| | VNN | × | × | ✓ | × | × | ✓ |
| **Coal plants** | NTPC–MBL | × | × | ✓ | ✓ | ✓ | ✓ |
| **Construction sites Commercial establishments Fire stations** | NHAI | × | ✓ | ✓ | × | ✓ | ✓ |
| | PWD | × | × | ✓ | × | ✓ | ✓ |
| | Setu Nigam | × | × | ✓ | × | ✓ | ✓ |
| | VDA | × | × | ✓ | × | ✓ | ✓ |
| **Fire stations** | Fire services | × | × | ✓ | × | × | × |
| **Industries** | Private users | × | ✓ | ✓ | × | ✓ | * |
| **Institutional (IIT-BHU campus)** | IIT-BHU | × | × | ✓ | ✓ | ✓ | ✓ |
| **Irrigation** | Irrigation Department | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Landscaping** | Engineering Department | × | ✓ | ✓ | × | × | ✓ |
| **Public utilities** | Sanitation department | × | ✓ | ✓ | × | × | × |
| **Railways** | Northern Railways | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| | North-Eastern Railways | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Waterbody rejuvenation** | VDA | × | * | ✓ | × | × | ✓ |

× Does not meet allocation criteria ✓ Meets allocation criteria

*Source: Authors' analysis based on data from VNN.*

Note: UPSRTC – Uttar Pradesh State Road Transport Corporation; NTPC–MBL –National Thermal Power Corporation–Macawber Beekay; NHAI – National Highway Authority of India; PWD – Public Works Department; VDA – Varanasi Development Authority.

### Priority areas for TUW allocation

Based on these criteria, the following applications within the identified reuse avenues have emerged as priority areas for TUW allocation:

1. Irrigation undertaken by the irrigation department
2. Identified applications within the railway sector (Northern and North-Eastern Railways)
3. Identified applications within the BLW campus
4. Institutional purposes within the IIT-BHU campus
5. Construction activities undertaken by NHAI
6. Construction activities undertaken by PWD
7. Construction activities undertaken by Setu Nigam
8. Construction activities undertaken by VDA
9. Landscaping undertaken by the engineering department
10. Identified applications within industries

These priority areas have been identified based on the city's current development patterns. They may be refined to align with future development plans. Within the assessed criteria, institutional readiness emerges as an important consideration in VNN, influencing the social acceptability and economic feasibility of TUW reuse.

# 9. Sector-specific TUW quality standards and treatment levels

The TUW discharged must first comply with surface water discharge standards and subsequently meet fit-for-purpose quality standards for reuse, as recommended by national and state agencies. This ensures minimal risk to public health and the environment. The current water quality of TUW generated in VNN and the quality standards required for safe reuse across the identified reuse avenues are discussed in this section.

**Table 5: Recommended discharge standards and effluent water quality of existing sewage treatment plants in Varanasi Nagar Nigam**

| | Ph | | BOD (mg/L) | | COD (mg/L) | |
|---|---|---|---|---|---|---|
| | Influent (Inf) | Effluent (Eff) | Influent (Inf) | Effluent (Eff) | Influent (Inf) | Effluent (Eff) |
| CPHEEO 2024 | 6.5–9 | | 10 | | 50 | |
| Dinapur | 7.7 | 7.5 | 112.5 | 23.0 | 244.6 | 50.5 |
| Goithaha | 7.2 | 7.3 | 118.7 | 6.5 | 247.2 | 21.2 |
| Ramana | 7.2 | 7.6 | 120.8 | 9.5 | 281.2 | 41.5 |
| Bhagwanpur | 7.6 | 7.1 | 66.0 | 12.3 | 238.3 | 66.2 |
| BLW | | 5-9 | | <30 | | <50 |
| Ramnagar | 5.8 | 7.1 | 104.2 | 7.0 | 229.4 | 37.1 |

Parameters exceeding discharge guidelines    Data missing

*Source: Authors' analysis using data from VNN (Jal Nigam) and CPCB (Central Pollution Control Board). 2024. "Guidelines for Reuse of Treated Sewage in Reference to Item of Circular Economy." Ministry of Environment, Forest and Climate Change.*

## 9.1. Effluent water quality of existing STPs in VNN

The existing STPs in VNN undertake secondary-level treatment using the activated sludge process (ASP), the sequential batch reactor (SBR) method, or the anaerobic–anoxic–aerobic (A2O) method.

Compared with the performance standards set for conventional technologies (ASP and SBR), the STPs installed in Varanasi are operating efficiently (Tare et al. 2010). However, as per the latest national guidelines issued by the Central Public Health and Environmental Engineering Organisation (CPHEEO) on effluent quality, STPs located in Dinapur, BLW, and Bhagwanpur require improvements to reduce levels of biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), faecal coliform (FC), total nitrogen (TN), and phosphorus in effluent discharge (CPCB 2024) (Table 5).

Accordingly, Jal Nigam should prioritise improving the operational efficiency of existing treatment infrastructure to ensure consistent compliance with minimum discharge standards (Section 11).

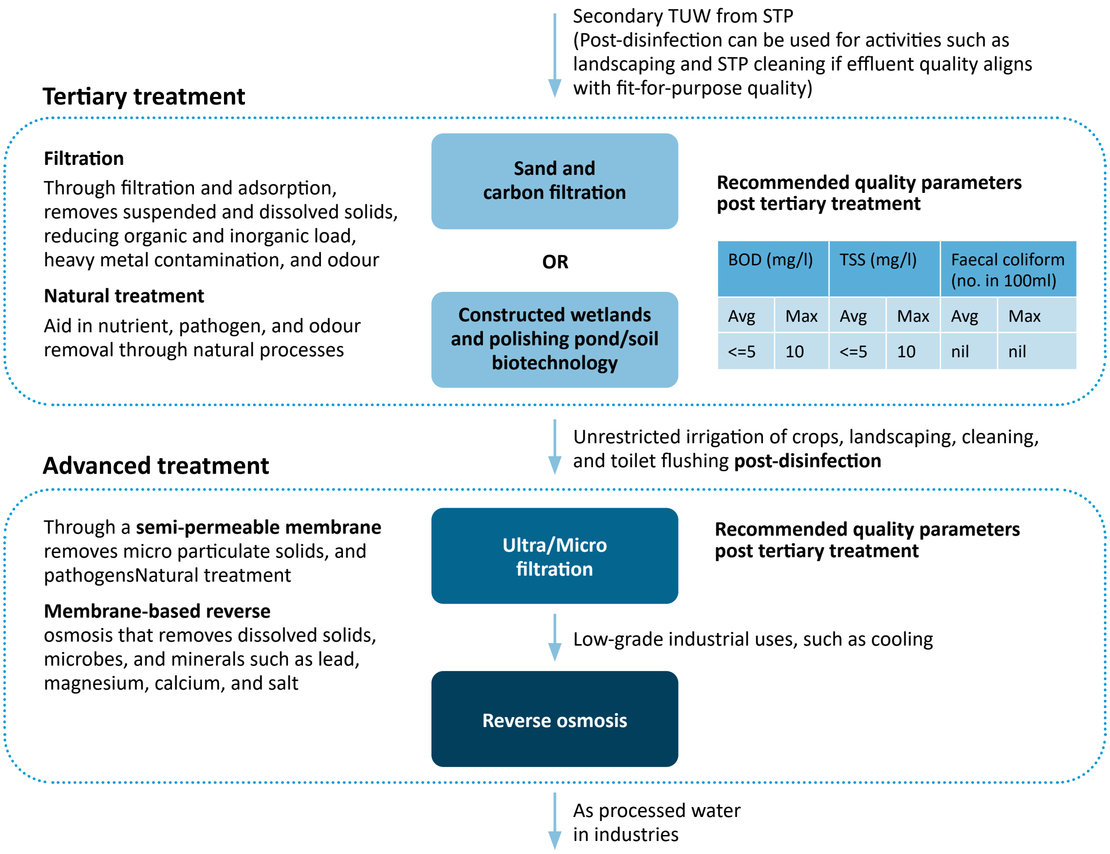
| TSS (mg/L) | | FC (MPN/100ml) | | TN (mg/L) | | Phosphorus (mg/L) | |
|---|---|---|---|---|---|---|---|
| Influent (Inf) | Effluent (Eff) | Influent (Inf) | Effluent (Eff) | Influent (Inf) | Effluent (Eff) | Influent (Inf) | Effluent (Eff) |
| 20 | | Desirable 100 MPN/100ml/ Permissible 230 MPN/100 ml | | 10 | | 10 | |
| 225.2 | 34.9 | 68466666.7 | 749.7 | - | - | - | - |
| 197.1 | 6.6 | - | | 35.0 | 7.0 | 4.0 | 1.0 |
| 261.4 | 11.8 | - | 59.5 | 35.1 | 7.7 | 4.2 | 1.3 |
| 93.0 | 15.9 | 669.0 | 0.3 | | | | |
| | <100 | | | | | | |
| 217.4 | 7.6 | - | 72.1 | 72.3 | 6.9 | 3.6 | 1.3 |

## 9.2. Reuse-specific treated used water quality standards and required treatment levels

All STPs in VNN currently provide secondary-level treatment for sewage. Analysis of current effluent quality against CPHEEO guidelines for fit-for-purpose reuse (Annexure 6) reveals consistent breaches of critical parameters, including BOD, TSS, and FC, necessitating additional treatment interventions to ensure public health protection and environmental safety. This approach is aligned with the precautionary principle and follows national and state guidelines for TUW reuse (CPCB 2024; RCUES 2023).

Figure 9 illustrates a sequence of technological interventions required to achieve safe TUW quality for reuse across different sectoral applications. This framework provides baseline treatment recommendations while recognising that specific end-use requirements may necessitate higher treatment standards. Regular effluent quality monitoring, user feedback, and periodic review of reuse outcomes should inform improvements to treatment processes and quality targets, ensuring the plan remains responsive to evolving standards.

### Figure 9: Secondary treated used water from STPs needs post-treatment interventions to be fit-for-purpose for reuse




*Source: Authors' analysis based on Mishra et al. 2023; CPHEEO 2013; NMCG 2022; Azis et al. 2021, and consultation with VNN officials.*

In the case of contact-based reuse avenues or environmentally sensitive activities, such as irrigation, landscaping, cleaning, construction, toilet flushing, firefighting, and waterbody rejuvenation, which require meeting specific quality levels with reduced organic, inorganic, and pathogen loads, tertiary treatment in the form of additional filtration through structural/artificial or natural systems is recommended. This step can reliably reduce these parameters to target levels (BOD <10 mg/L; TSS <10 mg/L). The choice between structural and natural systems should be guided by site-specific factors, including land availability, operational capacity, and cost considerations (Section 10). Natural systems offer the dual benefit of nutrient polishing and lower operational complexity, making them particularly suitable for peri-urban reuse sites such as irrigation.

Agriculture is a high-priority reuse avenue in Varanasi, where parameters such as nutrients, heavy metals, and emerging contaminants must be monitored and reported to safeguard soil health, crop physiology, and agricultural productivity and ensure the safe and acceptable reuse of TUW for agricultural purposes (Annexure 6). While TUW is rich in nutrients such as nitrogen (N), phosphorus (P), and potassium (K), these must be maintained within permissible limits to prevent soil salinity, toxicity, and physiological harm to crops. For agricultural reuse, TUW quality must comply with national guidelines for parameters, including but not limited to boron (mg/L), sulphate (mg/L), chlorides (mg/L), sodium (per cent), and alpha and beta emitters (CPCB 2024).

For industrial reuse, advanced treatment such as ultrafiltration or microfiltration may be required to ensure TUW is suitable for specific industrial and commercial processes. Reverse osmosis (RO) should be considered only for applications requiring stringent water quality standards, such as in the pulp and paper and textile industries.

Table 6 proposes STP-specific interventions in Varanasi to achieve minimum fit-for-purpose quality standards for priority reuse avenues.

**Table 6: Recommended interventions for sewage treatment plants in Varanasi Nagar Nigam to meet fit-for-purpose quality guidelines**

| STP | Operational challenges | Priority reuse avenue | Proposed interventions | Minimum quality requirements* | Nodal agency |
|---|---|---|---|---|---|
| Dinapur (140 MLD) | Average BOD, TSS, and FC levels are above the permissible limit of effluent discharge | Agriculture | • Optimisation of plant operations to reduce BOD, TSS, and FC levels in secondary treated effluent.<br>• Optimum utilisation of the biogas recovery facility within the STP premises.<br>• Partial treatment upgradation up to fit-for-purpose standards for agriculture using natural (constructed wetlands) or sand-/carbon-filtration methods (Annexure 6)<br>• Regular monitoring and reporting of additional quality parameters, namely, oil and grease, TN, P, and suspended solids (sodium, chlorine, boron) | BOD = <6 mg/L<br>TDS = 2,100 mg/L<br>Oil and grease = nil<br>Minimum residual chlorine = nil<br>Coliform = nil<br>Thermotolerant coliform = </=10 – 100 number/100 ml | Jal Nigam (Urban) |

| STP | Operational challenges | Priority reuse avenue | Proposed interventions | Minimum quality requirements* | Nodal agency |
|---|---|---|---|---|---|
| Goithaha | • The STP reportedly faces power outages, affecting operational efficiency<br>• Excess sludge generation reported downstream of effluent discharge | | • Optimisation of plant operations to ensure continuous treatment of effluent and reduction of sludge generation (e.g. through ozonation) in secondary treated effluent<br>• Partial treatment upgradation up to fit-for-purpose standards for agriculture using natural (constructed wetlands) or sand/carbon filtration methods (Annexure 6)<br>• Regular monitoring and reporting of additional quality parameters, namely, oil and grease, suspended solids (sodium, sulphate, chlorine, boron) | | |
| Ramana | Overload of plant capacity observed | Reuse for environmental activities to maintain e-flows in the Assi River and supply to the green coal plant | • Ensure influent quantity as per STP capacity to maintain efficiency in treatment<br>• Regular monitoring and reporting of additional quality parameters, namely, oil and grease, minimum residual chlorine, and turbidity | BOD = >=6 mg/L<br>TDS = 2,100 mg/L<br>Turbidity = <2<br>Oil and grease = nil<br>Minimum residual chlorine = 0.5<br>Coliform = nil | Jal Nigam (Rural) |
| Bhagwanpur | Average BOD and COD levels are above the permissible limit of effluent discharge | Institutional reuse (IIT-BHU campus) for landscaping, toilet flushing, and cleaning | • Optimisation of plant operations to reduce BOD and COD<br>• Increasing aeration intensity to maintain DO levels to lower BOD<br>• Passing the STP effluent through a constructed wetland or reed bed to filter the BOD/COD further<br>• Treatment upgradation to treat up to fit-for-purpose standards for institutional use | BOD = >=6 mg/L<br>TDS = 2,100 mg/L<br>Turbidity = <2<br>Oil and grease = nil<br>Minimum residual chlorine = nil<br>Coliform = nil | |
| Ramnagar | No operational challenge observed | Industrial reuse | • Treatment upgradation to treat up to fit-for-purpose standard for industrial reuse | BOD = >=10 mg/L<br>COD = 50 mg/L<br>TSS = <5 mg/L<br>Turbidity = <2<br>Oil and grease = nil | |

| STP | Operational challenges | Priority reuse avenue | Proposed interventions | Minimum quality requirements* | Nodal agency |
|---|---|---|---|---|---|
| | | | | Minimum residual chlorine = 1<br>Coliform = 10<br>Oil and grease = nil<br><br>Other parameters as specified industry-wise (Annexure 6) | |
| BLW | Average BOD and TSS levels are above the permissible limit | Reuse within the BLW campus for filling ponds, flushing, vehicle washing (domestic), industrial operations, cooling, and tower and locomotive cleaning stations | • Optimisation of plant operations to reduce BOD and TSS<br>• Passing the STP effluent through a constructed wetland or reed bed to filter the BOD and TSS further<br>• Partial treatment upgradation to treat up to the fit-for-purpose standard for industrial operations | Industrial purposes:<br>BOD = <=10 mg/L<br>COD = 50 mg/L<br>TDS = 2,100 mg/L<br>TSS = <5 mg/L<br>Turbidity = <2<br>Oil and grease = nil<br>Minimum residual chlorine = 1<br>Coliform = 10 (MPN/100 ml)<br><br>Other activities:<br>BOD = <=6 mg/L<br>TDS = 2,100 mg/L<br>Turbidity = <2<br>Oil and grease = nil<br>Minimum residual chlorine = nil<br>Coliform = nil | BLW |

*Source: Authors' analysis based on data from VNN, end-user groups, CPCB 2024, and Mishra et al. 2023.*
*Listed values represent critical parameters.*

Used water treatment to the desired levels must be followed by disinfection to eliminate bacteria and microbial pathogens in all cases. Strict adherence to fit-for-purpose quality standards must be substantiated with monitoring of effluent quality. There is also a need to report additional parameters, such as oil and grease levels, as their presence in TUW can limit its reuse several identified reuse avenues.

# 10. Financing treated used water reuse

This section discusses the financial requirements to strengthen the existing sewage collection and treatment infrastructure and to establish conveyance mechanisms for TUW in Varanasi. It also highlights pricing mechanisms for TUW in identified revenue-generating sectors that can enable cost recovery and generate demand for TUW. Finally, we enumerate some innovative financial instruments to diversify funding sources available to the ULB for financing used water treatment and TUW reuse projects. The methodology underpinning the estimates presented in this section is detailed in Annexure 7.

## 10.1. Financial requirements

Financial resources are required to expand the city's sewerage network, increase installed treatment capacity, implement technological upgrades to improve TUW quality for reuse, and develop conveyance mechanisms to supply TUW to end users. Table 7 highlights the additional financial requirements needed to achieve the Reuse Plan targets (Section 2), in addition to VNN's planned projects to expand used water treatment infrastructure. Tertiary treatment can be undertaken either at STP sites or at end-user facilities. The life cycle cost (LCC) per MLD of treatment upgradation varies depending on the technology adopted (Figure 10 (a–c) and Figure 11(a –c)).

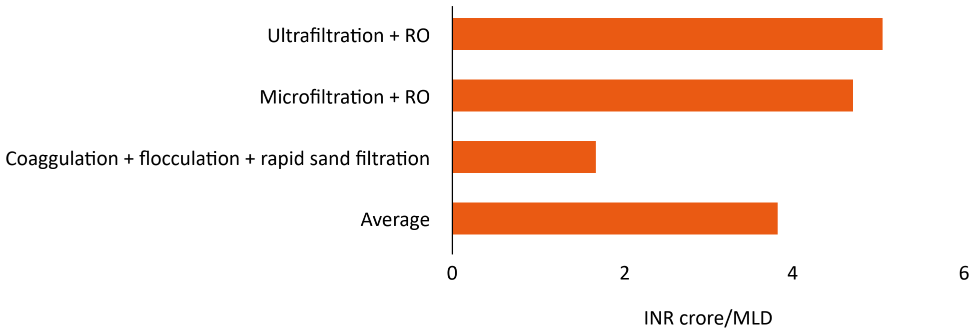
### Table 7: Financial requirements to meet treated used water reuse targets

| Sewerage network expansion | Conveyance mechanism (excluding variable costs) | | Life cycle cost of technology upgradation | |
|---|---|---|---|---|
| INR 3.3 crore/km | Tankers | Pipelines | Structural interventions | Nature-based treatments |
| | INR 50/KL | INR 15–30 lakhs/ km | INR 4.2–6.2 crore/ MLD | INR 0.9–3.1 crore/MLD |

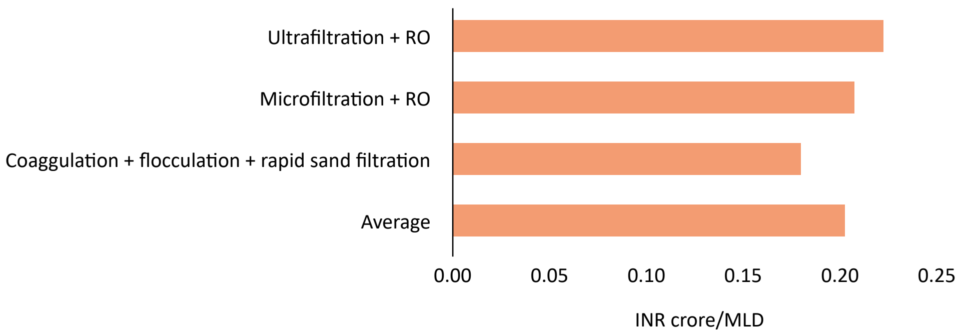
*Source: Authors' analysis based on data from VNN; Ramaiah et al. 2022; Municipal Council Chhatarpur 2016; Srivastava and Singh 2022; Tare et al. 2010, and CEEW and TMC 2024.*

### Figure 10 (A–C): The total life cycle cost of structural infrastructure interventions for tertiary upgradation can average at INR 5.7 crore/MLD

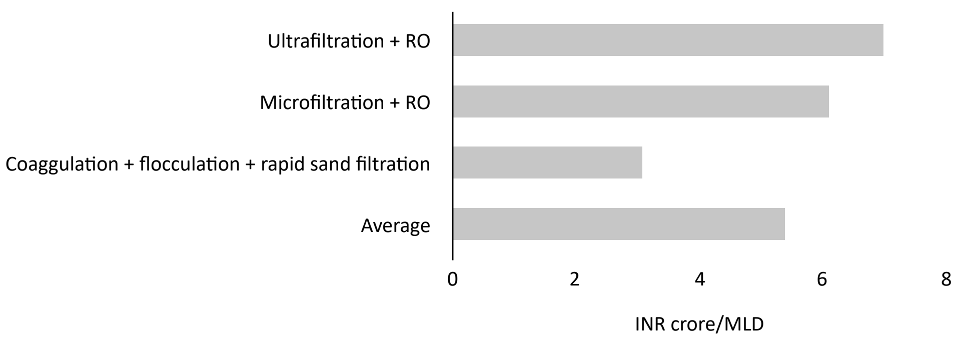
**A) Capital cost per MLD**




**B) Annualised O&M cost per MLD**



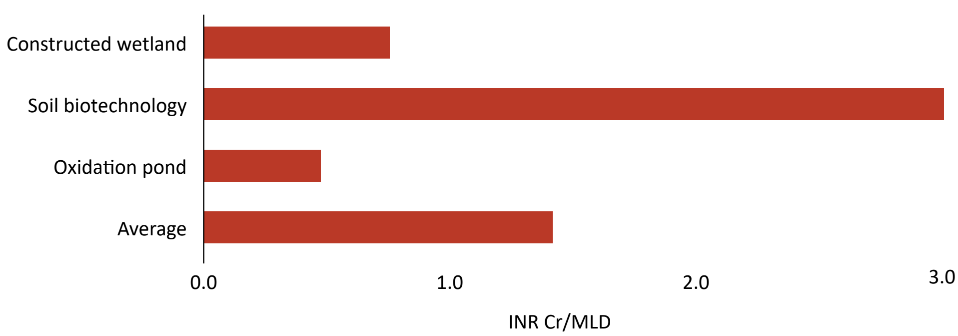

**C) LCC per MLD (total cost)**



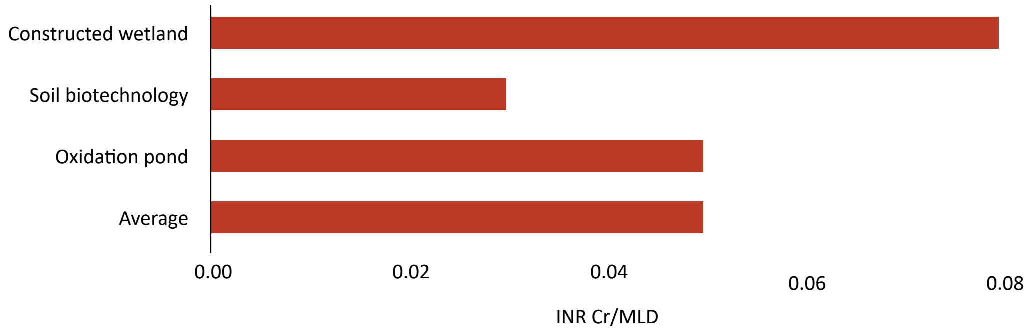

*Source: Authors' analysis based on Srivastava and Singh 2022; Tare et al. 2010, and CEEW and TMC 2024.*

### Figure 11 (A–C): The total life cycle cost of nature-based solutions for tertiary upgradation can average at INR 1.8 crore/MLD

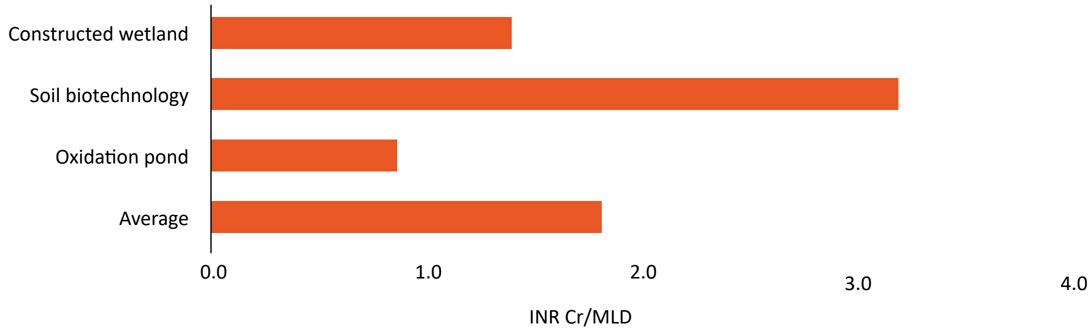
**A) Capital cost per MLD**



**B) Annualised O&M cost per MLD**




**C) LCC per MLD (total cost)**




*Source: : Authors' analysis based on Centre for Science and Environment. 2012. "Case Studies on Decentralised Wastewater Treatment and Reuse." Centre for Science and Environment.*

## 10.2. Pricing treated used water

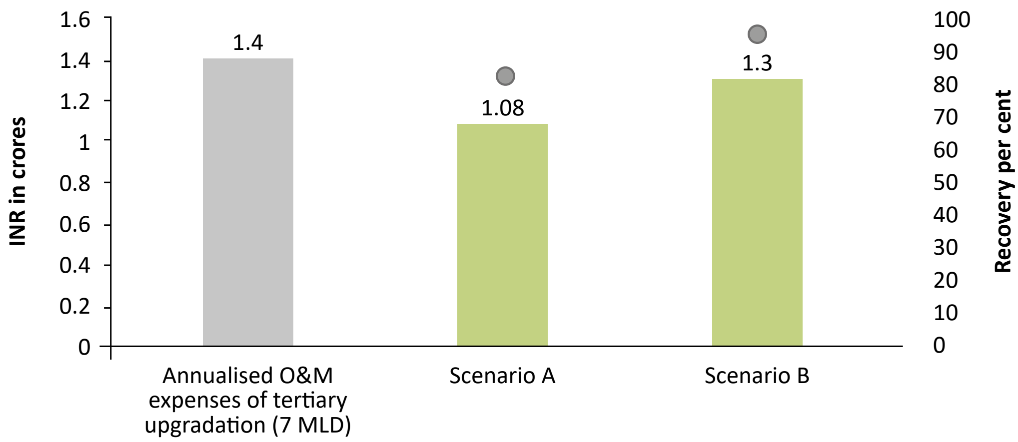
Establishing pricing principles to generate demand and support cost recovery for water utilities is crucial to sustaining a market for TUW. In line with national guidelines on the *Safe Reuse of Treated Used Water* (NMCG 2022) and the *State Urban Wastewater Treatment Policy* (RCUES 2023), the following factors must be considered while determining tariffs:

- **Price of freshwater:** The price of TUW per unit should be lower than that of freshwater per unit for the same usage to generate demand. This includes user costs associated with both municipal water supply and groundwater abstraction.
- **Level of treatment:** The price of TUW will depend on the level of treatment and the type of technology deployed, with tertiary TUW priced higher than secondary TUW.
- **Users' ability to pay:** TUW pricing should reflect the target stakeholders' capacity to pay. Due to their higher paying capacity, the construction sector, the green coal plant, and industries are among the identified tariff-generating reuse avenues in VNN.

Effective pricing of TUW can support the recovery of ULB used water treatment costs, reduce reliance on state and central budgetary support, and enhance the commercial and financial viability of reuse projects. Currently, central fiscal transfers constitute the primary source of income for Jal Nigam, with expenditure partially met through annual sewerage charges collected as part of property tax. As per the Uttar Pradesh state policy, Jal Nigam or the local authority is responsible for pricing TUW appropriately, and the collected tariff must be used for the operation and maintenance (O&M) of STPs

Figure 12 displays two scenarios for revenue generation from tertiary treated used water (TTUW), with the TTUW price set at par with the current minimum and maximum freshwater costs incurred by the identified revenue-generating reuse avenues of construction, coal plants, and industries. Assuming water requirements in these avenues are met through groundwater abstraction, the current unit cost of freshwater is estimated to range from 2 to 5 INR/KL (refer to Annexure 5 for the methodology). Scenario 1 assumes the groundwater abstraction rate applicable to government projects in the construction sector, while Scenario 2 assumes the rate applicable to non-government projects. At these rates, the identified sectors have the potential to cover 77–93 per cent of the operational expenses required to upgrade 7 MLD of treatment capacity to the tertiary level.

**Figure 12: Revenue generating sectors have the potential to recover 77 to 93 per cent of the operational expenses for upgrading 7 MLD of capacity to tertiary treatment**

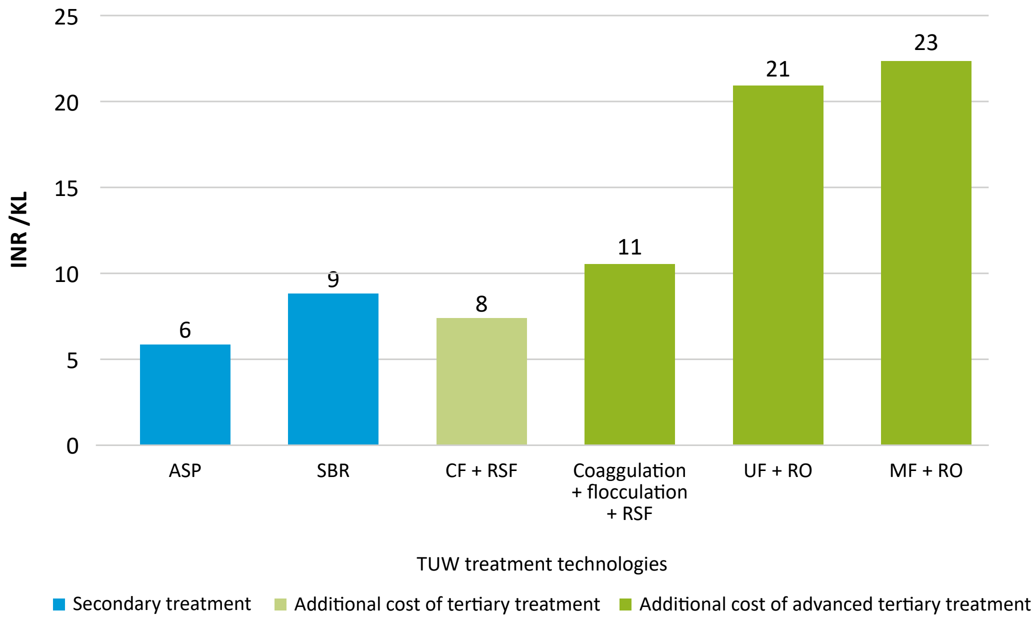



*Source: Authors' analysis based on data from CGWA. 2025. "Ground Water Abstraction Charges 2025-26." CGWA Compliance. Ground Water Abstraction Charges 2025-26, and consultations with PWD and VNN officials.*

The availability of freshwater at low rates in VNN is a limiting factor for pricing TUW and enabling cost recovery. As a countermeasure:

- First, the TUW pricing mechanism must be supplemented with groundwater regulations, such as restricting the use of freshwater for high-priority and/or revenue-generating reuse applications, such as railways, construction, and industries. In addition, water utilities (Jal Kal and the irrigation department) can gradually implement or increase freshwater pricing to make tertiary upgradation and TUW use economically viable (discussed in Section 11.3).
- Second, as per the State Urban Wastewater Treatment (Recycle, Reuse, and Disposal) Policy (RCUES 2023), the pricing mechanism must be reviewed every five years to progressively align with the per-unit treatment cost for each technology (Figure 13).

**Figure 13: Technology-wise, per-unit cost of used water treatment for hard infrastructure interventions**




*Source: CEEW analysis based on data from RCUES 2023; Srivastava and Singh 2022; Tare et al. 2010, and CEEW and TMC 2024.*

Note: ASP – Activated Sludge Process
SBR – Sequential Batch Process
CF – Carbon Filtration
RSF – Rapid Sand Filtration
MF – Microfiltration
UF – Ultrafiltration

## 10.3. Financial instruments

The economic viability of TUW reuse can be enhanced by diversifying Jal Nigam's revenue sources by mainstreaming innovative financial instruments. Through a combination of instruments, such as bond issuance, credit schemes, user incentives and charges, and private investment, the ULB can recover the costs incurred from different end users, contributing to the eventual success of TUW's circular economy in VNN. Table A8 proposes a variety of financial instruments that can be leveraged, the success of many of which relies on structured collaboration and sustained partnerships between identified stakeholders (Annexure 7).

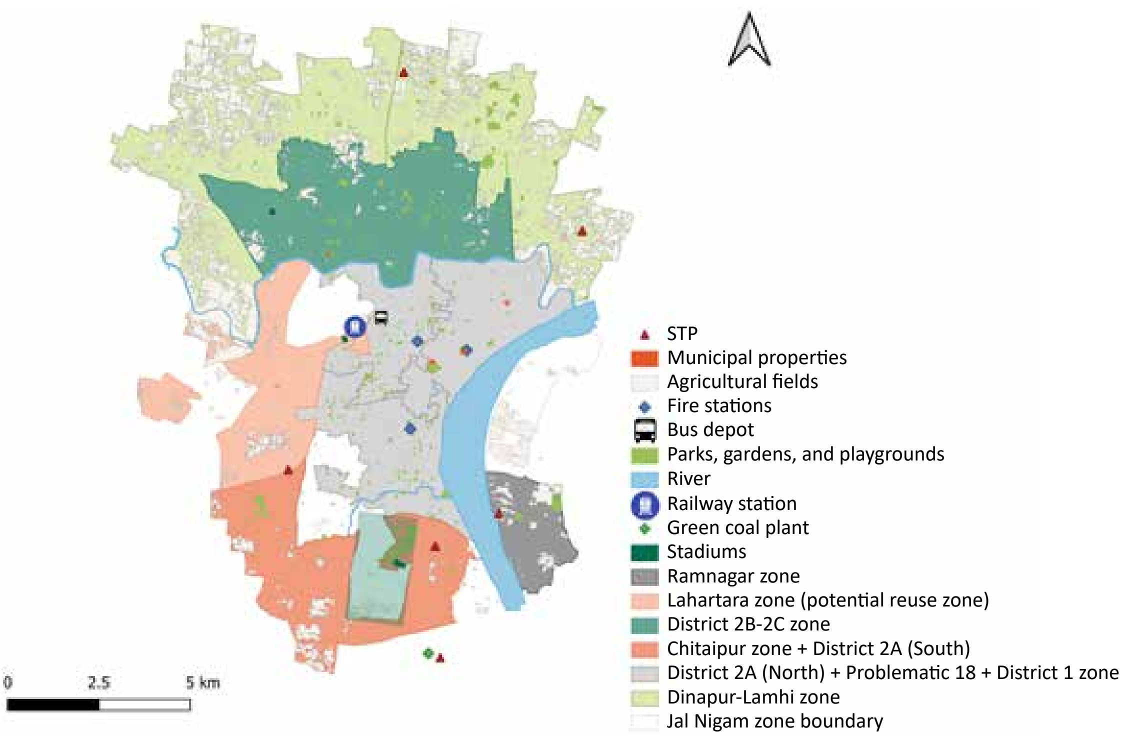
# 11. Implementation framework

The implementation framework is designed in a twofold manner. First, it adopts a reuse zone-wise planning approach, outlining standard operating procedures for identified reuse avenues within each zone (Figure 14). Reuse zones have been delineated from VNN's existing sewage zones based on the feasibility of supplying TUW from centralised STPs or proposed DEWATS to identified reuse avenues, with buffer areas of 1–2 km considered for conveyance planning. For each reuse zone, reuse avenues have been mapped and the corresponding reuse potential estimated.

Second, the framework provides an institutional plan. Under this, a detailed action plan assigns clear roles and responsibilities to specific institutions across action areas (Table 20), enabling accountability for mainstreaming TUW reuse within respective sectors.

The rationale for this plan is to strengthen implementation and ensure institutional accountability for TUW reuse across sectors. For instance, the Irrigation Department has been tasked with TUW reuse in the agricultural sector. The action plan recommends entering into water resource-sharing agreements with Jal Nigam and developing water release schedules aligned with cropping calendars.

**Figure 14: Six reuse zones identified for implementation of the Treated Used Water Reuse Plan in Varanasi Nagar Nigam**




*Source: Authors' analysis.*

## 11.1. Reuse - zone-specific implementation framework

An implementation framework has been developed for each reuse zone. This includes water quantity and quality requirements for each reuse avenue, appropriate conveyance mechanisms, and recommended business models for effective operationalisation. The framework also identifies the nodal departments within VNN for each reuse avenue. Details are provided in Annexure 8.

- ### Dinapur–Lamhi zone

The Dinapur–Lamhi zone comprises areas newly incorporated into the VNN administrative boundary (Figure 15). Previously classified as peri-urban areas, this zone has agriculture as the primary reuse avenue, with additional potential for landscaping (Table 8). This zone comprises Goithaha and Dinapur STPs. Based on the feasibility of TUW conveyance from treatment to reuse locations, the identified irrigation reuse avenue has been divided into four clusters (Annexure 9).

### Table 8: Identified reuse avenue in the Dinapur–Lamhi zone

| Reuse avenue | Reuse application |
|---|---|
| Landscaping | Parks and gardens |
| Agriculture | Peri-urban irrigation |
| Cleaning | STP facilities |

*Source: Authors' analysis.*

### Figure 15: Agriculture is a major reuse avenue identified in the Dinapur–Lamhi zone


*Source: Authors' analysis based on the data received from VNN line departments.*

- **District 2B–2C zone**

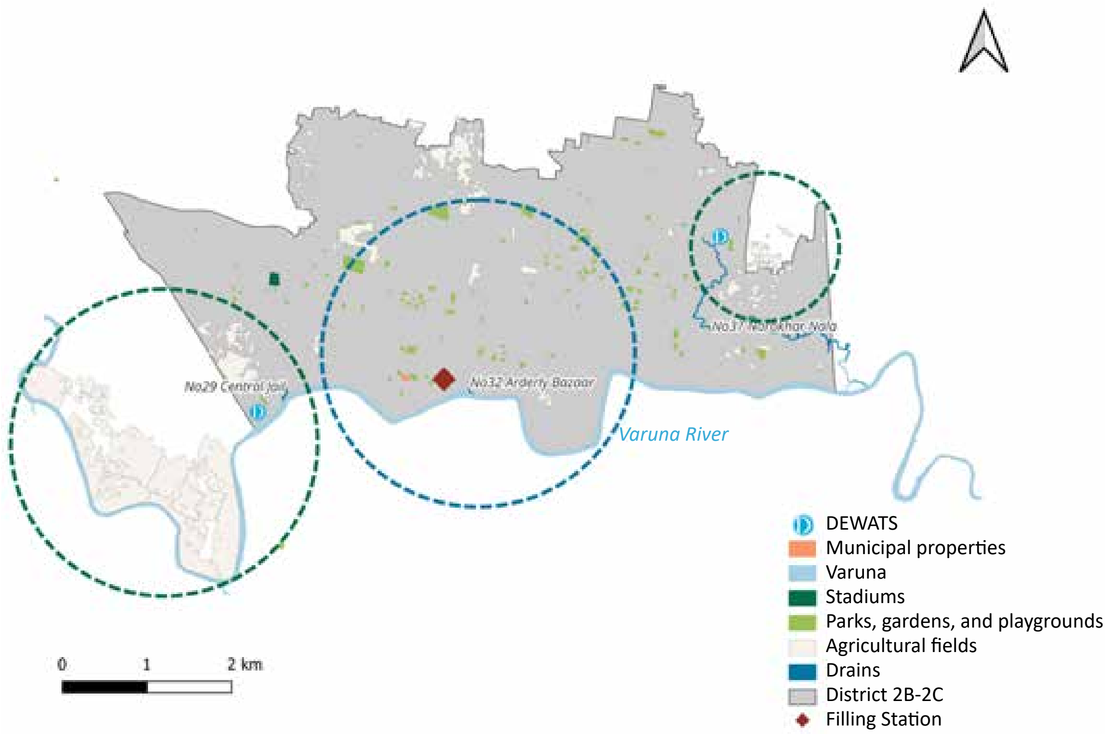
The 2B–2C zone lies within the trans-Varuna region, with the Varuna River forming its southern boundary (Figure 16). Multiple reuse avenues have been identified in this zone, including agriculture, parks and gardens, and municipal properties (Table 9). However, supplying TUW from the existing centralised STP is challenging due to the large distance involved. Therefore, DEWATS (Annexure 9), with inlets from identified drains, is critical for supplying TUW for identified reuse applications in the zone.

**Table 9: Identified reuse avenues in the District 2B–2C zone**

| Reuse avenue | Reuse application |
|---|---|
| Landscaping | Parks and gardens |
| | Stadiums |
| Agriculture | Irrigation |
| Cleaning | Municipal properties |

*Source: Authors' analysis.*

**Figure 16: Scaling up decentralised wastewater systems is essential for mainstreaming treated used water reuse in the District 2B–2C zone**




*Source: Authors' analysis based on the data received from VNN line departments.*

- **District 2A (North) + Problematic 18 + District 1 zone**

This reuse zone has been carved out of three sewage zones involving District 2A, Problematic 18, and District 1 (Figure 17). It lies within the cis-Varuna region, with the Varuna River forming its northern boundary. Among all reuse zones, this zone has the most reuse avenues, including landscaping, cleaning, railways, and fire stations (Table 10). However, supplying TUW from the existing centralised STP is challenging due to the large distance involved. Therefore, a bus depot has been proposed as a site for DEWATS, along with a filling station with an inlet from the Teliya

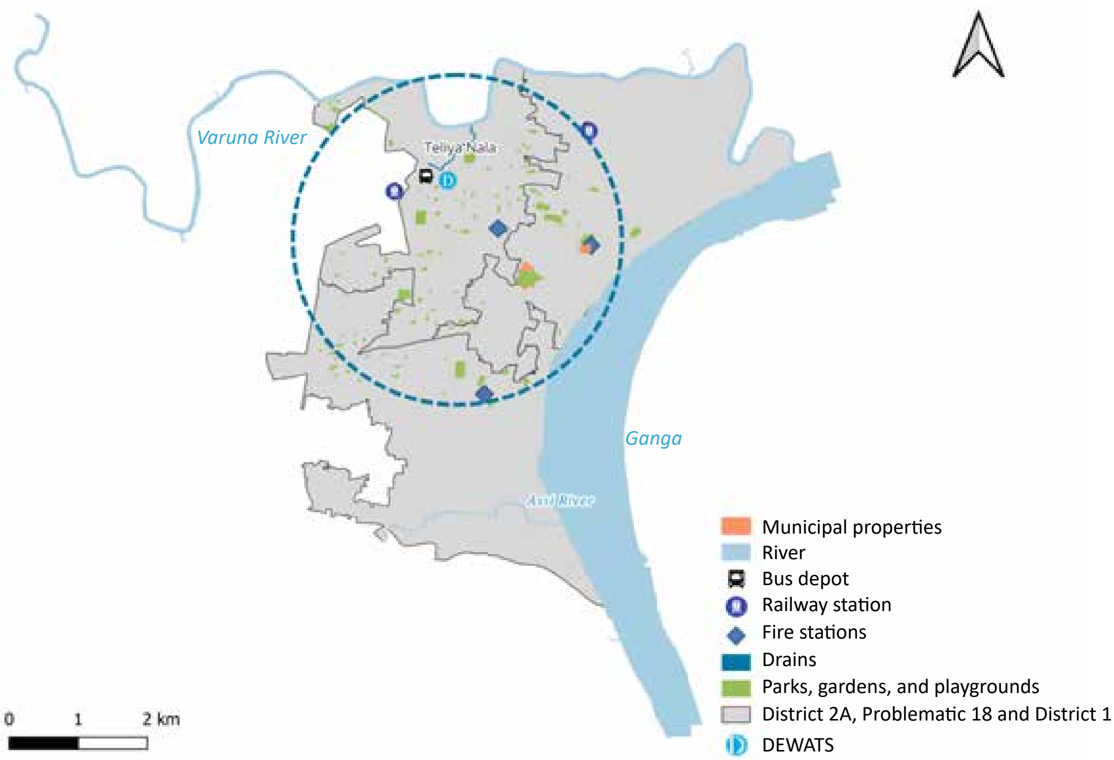
Bagh *nullah* (Figure 16). A serviceable buffer is created for the reuse zone to ensure the feasibility of supplying TUW for various identified reuse avenues (Annexure 9).

### Table 10: Identified reuse avenues in District 2A (North), Problematic 18, and District 1

| Reuse avenue | Reuse application |
|---|---|
| Landscaping | Parks and gardens |
| | Stadiums |
| Cleaning | Bus depots |
| | Municipal properties |
| Railways | Washing of platforms, coaches, terminal tracks, and pits |
| | Toilet flushing |
| | Landscaping and irrigation |
| Fire stations | Maintenance of the water storage system for firefighting |

*Source: Authors' analysis.*

### Figure 17: District 2A (North), Problematic 18, and District 1 have the most identified reuse avenues




*Source: Authors' analysis based on the data received from VNN line departments.*

- **Lahartara zone (potential reuse zone)**

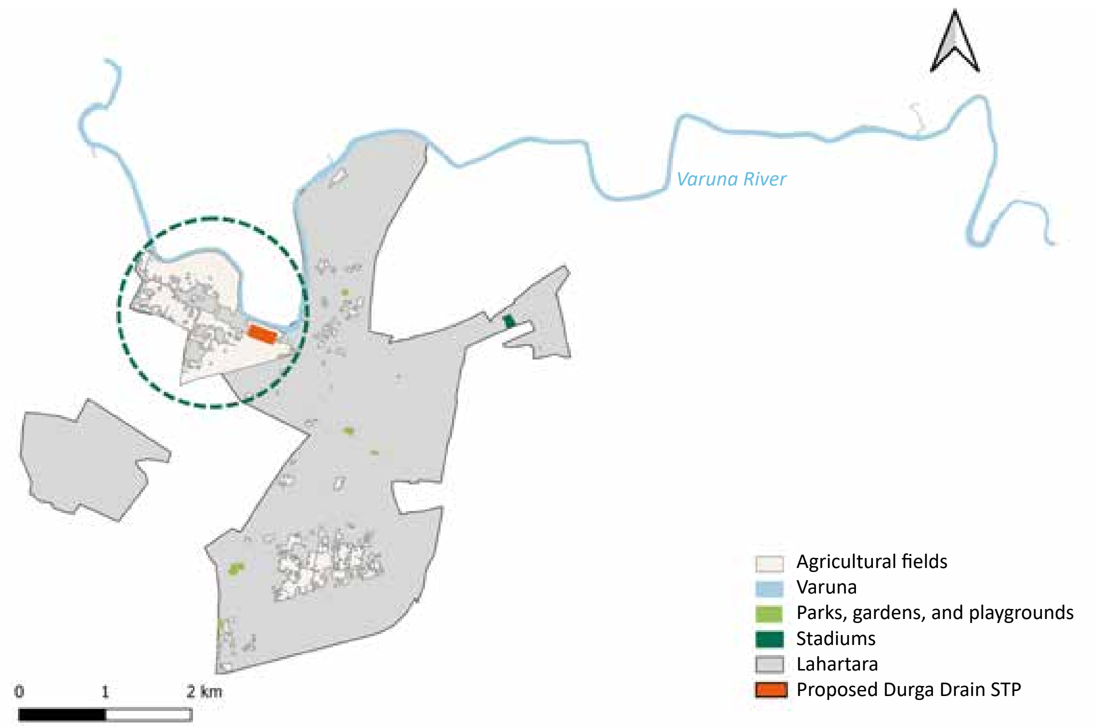
This sewage zone has been classified as a potential reuse zone, which, after the proposed Lahota STP or Durga drain STP is set up (Figure 18), will have significant potential for agricultural reuse. The establishment of the Lahota STP is part of VNN's drain interception project (Section 1), in which some drains, including the Durga drain, will be tapped and diverted to the proposed STP. The agriculture cluster has been identified in this zone (Annexure 9), representing a major avenue for reuse in addition to landscaping (Table 11).

### Table 11: Identified reuse avenue in Lahartara zone

| Reuse avenue | Reuse application |
|---|---|
| Landscaping | Parks, gardens, and playgrounds |
| | Stadiums |
| Agriculture | Irrigation |

*Source: Authors' analysis.*

### Figure 18: With the establishment of the Lahota sewage treatment plant, the Lahartara zone will have significant potential for agricultural reuse




*Source: Authors' analysis based on the data received from VNN line departments.*

- **Chitaipur zone + District 2A (South) zone**

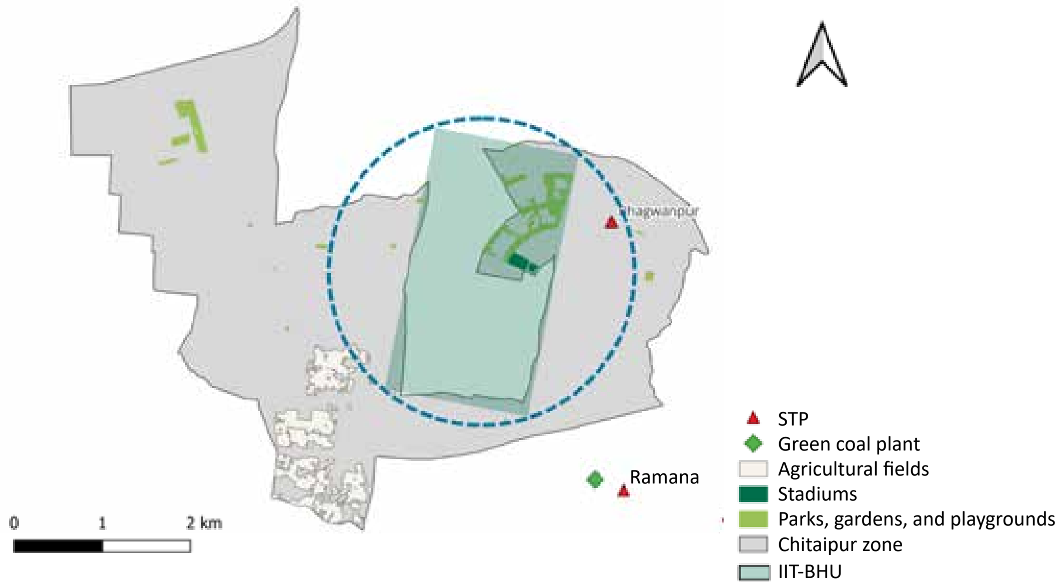
This reuse zone has been carved out of two sewage zones, Chitaipur and District 2A (South) (Figure 19). In this zone, Bhagwanpur STP and Ramna STP will serve as sources of TUW for various reuse avenues. The major reuse avenue in this zone is institutional reuse at the Indian Institute of Technology – BHU (IIT-BHU) (Table 12), which will receive TUW from Bhagwanpur STP and the green coal plant, which already receives TUW from Ramna STP (Annexure 9) (Figure 19).

### Table 12: Identified reuse avenue in Chitaipur zone and District 2A (South)

| Reuse avenue | Reuse application |
|---|---|
| Institutional | Landscaping |
| | Toilet flushing |
| | Cleaning |
| Green coal plant | Process-based applications |
| Cleaning | STP facilities |

*Source: Authors' analysis.*

**Figure 19: Institutional and industrial are important reuse avenues in the Chaitipur zone and District 2A (South)**




*Source: Authors' analysis based on data received from VNN line departments.*

### Ramnagar zone

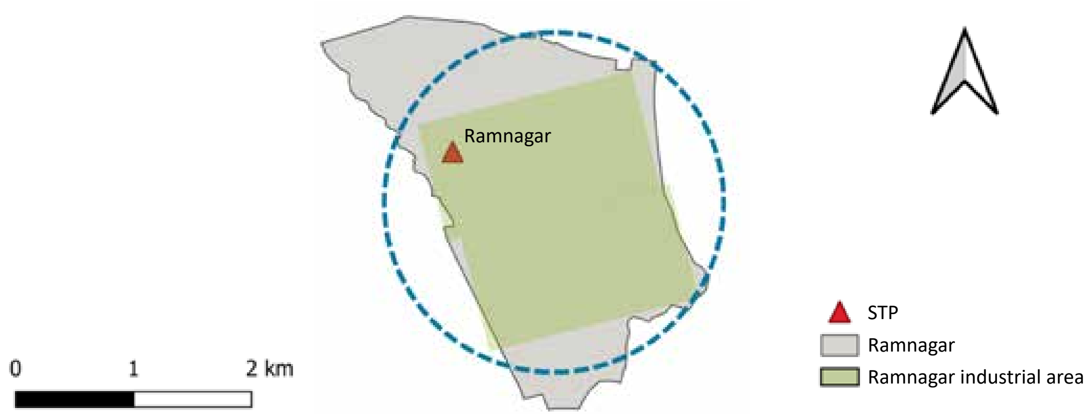
Ramnagar zone has been identified as an industrial reuse zone, with the Ramnagar STP serving as the source of TUW supply (Table 13 and Figure 20). The STP is strategically located and has significant potential to meet industrial water demand while also playing a crucial role in abating pollution in the Ganga River by treating domestic discharge generated by industries (Annexure 9).

**Table 13: Identified reuse avenues in Ramnagar zone**

| Reuse avenue | Reuse application |
|---|---|
| Industrial | Industrial cooling, spraying in mine pits, and boiler feed |
| | Processing whereby water gets polluted and pollutants are not easily biodegradable |
| | Processing whereby water gets polluted and pollutants are easily biodegradable |

*Source: Authors' analysis.*

**Figure 20: Dedicated industrial reuse zone in Varanasi Nagar Nigam**




*Source: Authors' analysis based on data received from VNN line departments.*

## 11.2. Institutional plan

The plan maps the relevant institutions responsible for administering the priority reuse avenue as identified in Section 8. It conducts a diagnostic assessment of these institutions by evaluating their strengths, weaknesses, and opportunities (Table 14) from the perspective of integrating TUW reuse into their projects. Based on this assessment, an institution-specific action plan is proposed across five action areas: governance, infrastructure, efficiency, pricing, and financing (Table 15).

### Table 14: Action areas for mainstreaming TUW reuse in institution-led projects

| S. No. | Action areas | Action points |
|---|---|---|
| 1. | Governance | • Analysing existing policies and guidelines at the union, state, local, and institution-specific levels for mainstreaming TUW reuse.<br>• Mandating relevant institutional coordination for mainstreaming TUW reuse in institutional projects. |
| 2. | Infrastructure | • Proposing institution-specific infrastructure intervention required for mainstreaming TUW reuse. |
| 3. | Efficiency | • Designing interventions that maximise TUW reuse in the sector. This can include process-based approaches, behavioural change, outreach, and communication. |
| 4. | Pricing | • Determining the pricing principles that can be incorporated in the project implementation, which can make the reuse of TUW a viable option in the long term. |
| 5. | Financing | • Reworking of the existing financial model of the institution to incorporate TUW reuse as a viable source for water supply. |

*Source: Authors' analysis.*

### Table 15: Diagnostic assessment of institutions to evaluate their readiness for mainstreaming the reuse of treated used water

| Institution | Strength | Weakness | Opportunity |
|---|---|---|---|
| **Irrigation Department** | • Established conveyance infrastructure for supplying TUW.<br>• Policy support at the union level and the state level through the *National Framework on Safe Reuse of Treated Used Water* and the UP *Urban Wastewater Treatment (Recycle Reuse and Disposal) Policy,* respectively.<br>• TUW as a viable source of an alternate water supply during the kharif season, especially for tail-end farmers dependent on the Bhapatpur canal for irrigation.<br>• Departmental willingness to reuse TUW. | • Insufficient quality of TUW at the current level of treatment; heavy metal contamination.<br>• Trust deficit among farmers, leading to reluctance in using TUW for irrigation.<br>• Lack of coordination between Jal Nigam and the irrigation department regarding the sharing of TUW and the scheduling of its release.<br>• Lack of water quality and quantity monitoring.<br>• Lack of a viable financial mechanism for cost recovery.<br>• Absence of any user charges for utilising canal water for irrigation purposes. | • Reduction in fertiliser inputs due to nutrient content in TUW.<br>• Cost savings in the form of fewer inputs (energy, fertilisers). |

| Institution | Strength | Weakness | Opportunity |
|---|---|---|---|
| **Engineering Department** | • Existing conveyance mechanism in the form of tankers in place.<br>• Departmental willingness. | • Lack of standardisation in water supply estimation.<br>• End-user reluctance among private users.<br>• Low scope of cost recovery.<br>• Conveyance of TUW for landscaping due to the scattered nature of the reuse avenue.<br>• Institutional coordination with Jal Nigam for *nullah* tapping. | • Opportunity to scale DEWATS.<br>• Nature-based DEWATS solutions can meet both water quality and quantity requirements while enhancing water-use and energy-use efficiency.<br>• It can also result in departmental cost savings by lowering the need for groundwater extraction.<br>• Tapping of existing *nullah* infrastructure can act as an influent source for DEWAT systems. |
| **Fire Department** | • Regular water requirement to meet water storage needs. | • Low water requirement.<br>• Insufficient quality of TUW at the current level of treatment. | • Reduced dependency on groundwater. |
| **Jal Nigam** | • Existence of a favourable politico-administrative ecosystem for prioritising the development of sewerage infrastructure.<br>• Resource (financial and land requirements) availability to undertake capital expenditure for tertiary upgrades.<br>• Existence of a private-sector partnership to improve operational efficiency.<br>• Existing infrastructure for bio-gas recovery in some treatment plants, such as Dinapur. | • Due to limited sewerage network coverage, most sewage flows through open *nullahs*.<br>• Due to inefficient O&M practices, the effluent quality from several STPs does not align with reuse-specific guidelines.<br>• Burdened with extensive responsibilities, including the development of capital infrastructure as well as O&M of the entire used water management supply chain.<br>• Dependence on Jal Kal for fund disbursement. | • Design and expansion of sewerage infrastructure can be aligned with population growth projections of 2040.<br>• Improvement of effluent water quality by undertaking further treatment.<br>• Position tself as a central agency for the mainstreaming of TUW reuse in Varanasi city.<br>• Central role in setting up a differential tariff system for TUW reuse.<br>Opportunity to generate additional revenue through the sale of TUW. |
| **PWD/ NHAI/Setu Nigam** | • High project cost translates to adequate financial resources to allocate to TUW.<br>• Existing engagement with private players can be leveraged to enter into a viable PPP model for mainstreaming TUW in construction activities (e.g. HAM model for NMCG used for the construction of STPs). | • Higher cost of conveyance owing to high water requirement.<br>• Being a facilitator agency, institutional coordination between multiple agencies is a challenge.<br>• Higher water quality requirement. | • High water requirement.<br>• Cost savings in the form of fewer inputs (freshwater, energy).<br>• Policy mandate for the use of TUW in construction activities.<br>• Existing private-sector engagements. |

| Institution | Strength | Weakness | Opportunity |
|---|---|---|---|
| **VDA** | • Tender documents issued for ecological rejuvenation and enhancement of ponds also include five years of O&M, which would support the VDA in ensuring the long-term ecological integrity of the wetland ecosystem.<br>• UP building bylaws mandate the use of TUW construction activities (Housing and Urban Planning Department n.d.) after complying with all the required parameters for water use. | • User groups lack the technological know-how of DEWAT installation. | • Opportunity to scale DEWATS, including nature-based-solutions approaches in parks, water bodies, etc.<br>• Reduced dependence on groundwater resources.<br>• Incorporation of TUW reuse within master planning documents. |

*Source: Authors' analysis based on stakeholder consultations (Irrigation Department, Engineering, Jal Nigam, NHAI, PWD, Setu Nigam, and VDA)*

## 11.3. Detailed action plan for relevant departments

The detailed action plan outlines the activities to be undertaken by the relevant institution (Tables 16–20) across each action area to mainstream TUW reuse in the specific reuse avenue.

### Action Plan for Jal Nigam

Jal Nigam is a central department for mainstreaming TUW reuse across different reuse avenues in Varanasi city. It needs to work in close coordination with the proposed TUW cell at the district level and guide the VNN Municipal Commissioner's Office in operationalising the Reuse Plan (Table 16).

**Table 16: Detailed action plan for Jal Nigam to mainstream the reuse of treated used water across different sectors**

| Relevant departments | Governance | Infrastructure | Efficiency | Pricing | Financing |
|---|---|---|---|---|---|
| VNN Municipal Commissioner's Office<br>Jal Kal<br>Tax Department | Institutionalise a broad-based ULB-level TUW reuse committee under the chairmanship of the Hon'ble Commissioner VNN, to coordinate with the Treated Wastewater Cell (TWC) at the district level. This will be headed by the chief engineer (mentioned in the *Urban Wastewater Treatment (Recycle, Reuse, and Disposal) Policy* of Uttar Pradesh). | Prioritise partial upgradation of priority STPs of Goithaha (for irrigation) and Ramnagar (for industrial reuse) (Section 11.1) to tertiary treatment level, adopting sand and carbon filtration or NbS and UF + RO, respectively (Section 9.2).<br>Prepare and execute a dedicated O&M plan for all STPs to improve operational efficiency and meet effluent quality standards. | Improve operational efficiency of all STPs to achieve fit–for–purpose quality standards of all specified parameters in identified reuse avenues. For instance, Dinapur, BLW, and Bhagwanpur are yet to achieve fit- for-purpose standards for landscaping and agriculture reuse avenues. | Under the direction of the TUW reuse committee, formulate a differential tariff structure for TUW reuse, with Jal Nigam and Jal Kal playing a central role. | Ring-fence revenue from TUW sales for the following purposes:<br>• O&M of STPs<br>• O&M of sewerage network by Jal Nigam (Urban)<br>• O&M of *nullah* interceptor by Jal Nigam (Rural) |

| Relevant departments | Governance | Infrastructure | Efficiency | Pricing | Financing |
|---|---|---|---|---|---|
| | Jal Nigam (Urban) Varanasi can act as a facilitator and coordinating agency for the implementation of the Reuse Plan. Annexure 10 presents a case study on interdepartmental coordination that enables TUW reuse through short-, medium-, and long-term actions. | Plan and prioritise the installation of bio-gas recovery systems in all STPs to gradually reduce their operational energy demand. | Ensure effective dissemination and wider outreach of STP performance, especially among end users, to build transparency and trust. | | |
| | Periodically conduct the city's water balance assessment under the direction of the TUW reuse committee.<br>Review priority areas for TUW allocation at regular intervals to meet the reuse potential targets for 2030 and 2040.<br>The TUW reuse committee may consider the findings and recommendations of this Reuse Plan as a baseline to guide interventions to mainstream the reuse of TUW. | Institutionalise inter-departmental coordination to align the planning of sewerage network expansion and the *nullah* interception project, ensuring effective collection of TUW and time-bound completion of the projects.<br>(at present, the sewerage network plan is being undertaken by Jal Nigam (Urban) and the *nullah* interception by Jal Nigam (Rural)<br>Prioritise the deployment of nature-based DEWATS in the city's central sewage zones, such as District 2B–2C and Problematic 18 (North), where supplying TUW from centralised STPs is challenging but offers scope for *nullah* tapping. | Act as the enforcement authority to ensure compliance with reuse-specific water quality standards across all STPs. | | Revise existing PPP contracts to include tertiary upgradation and enter a reuse utility buy-back model for the deployment of DEWATS. |

*Source: Authors' analysis based on the consultations with VNN line departments.*

### Action plan for the irrigation department

Agriculture has been identified as one of the major avenues for TUW reuse for irrigation purposes. During an on-ground consultation, officials from the irrigation department acknowledged that, if supplied at an optimum quality standard, TUW can play a vital role in meeting irrigation demand during the kharif season, especially for the tail-end farmers in the canal command area (Table 17).

**Table 17: Detailed action plan for the irrigation department to mainstream the reuse of treated used water in the agricultural reuse avenue**

| Relevant departments | Governance | Infrastructure | Efficiency | Pricing | Financing |
|---|---|---|---|---|---|
| VNN Municipal Commissioner's Office<br>Irrigation department<br>Jal Nigam<br>Jal Kal<br>Farmer Producer Organisation (if exists)/ Impacted farmer groups in the Bharatpur canal area. | Leverage the ULB-level TUW reuse committee to oversee TUW use in agriculture, involving all relevant stakeholders, including farmers' representatives.<br>The committee should meet at least twice before each cropping season to:<br>- Resolve any coordination gaps<br>• Discuss the TUW requirement for the upcoming season<br>• Resolve farmers' grievances regarding effluent quality<br>• Table monthly performance reports of the relevant STP and conduct validation on the ground | Install field-level monitoring stations at critical points, such as the STP outfall point in the canal, to increase transparency and rebuild farmers' trust. | Prioritise TUW reuse during the kharif season. | Gradually reintroduce the differential canal tariff system based on the area irrigated through the canal and the cropping pattern. | Formulate a TUW seasonal impact matrix based on:<br>1. Percentage increase in Proposed irrigated area<br>2. Input cost reduction (energy and fertiliser usage)<br>3. Extent of reduction in groundwater extraction<br>4. Productivity increase |
| | Develop a water-release schedule that aligns with the cropping calendar. | | Develop an effective IEC campaign that highlights the tangible impact it creates, both through increased PIR and reduced GW extraction. | | Based on the results of the seasonal impact matrix results, enter into a resource transfer agreement with Jal Nigam. |

*Source: Authors' analysis based on the consultations with VNN line departments.*

### Action plan for VDA

Varanasi Development Authority is the nodal urban development authority for VNN. It has been included as a priority institution as it is responsible for ecological rejuvenation and enhancement of major ponds in Varanasi (Table 18).

**Table 18: Detailed action plan for Varanasi Development Authority to mainstream reuse of treated used water for the rejuvenation of water bodies**

| Relevant departments | Governance | Infrastructure | Efficiency | Pricing | Financing |
|---|---|---|---|---|---|
| VNN Municipal Commissioner's Office<br>Jal Kal<br>Jal Nigam | In coordination with Jal Nigam, incorporate mainstreaming TUW reuse using centralised treatment infrastructure and DEWATS into master plans and zonal-level plans. | Support VNN in developing tender documents to mainstream DEWATS in central sewage zones (Districts 2B and 2C, and Problematic 18A) through *nullah* tapping, particularly for landscaping. | Along with pond rejuvenation, mandate the reuse of TUW in tender documents for all VDA-maintained parks, construction activities, and roadside plantations. | Introduce an incentive mechanism for agencies deploying the on-site TUW reuse system, such as expedited approvals, permit grants, and rebates on electricity bills. | As carried out in urban pond rejuvenation, mandate the deployment of DEWATS in tender documents for the development and ecological rejuvenation of blue-green infrastructure. |
| | Designate buffers in and around urban ponds to regulate development activities. | In coordination with Jal Nigam, develop a retrofitting plan for the old city (District 1) and identify the scope for mainstreaming TUW reuse and the feasibility of deploying DEWATS. | | Mandate metering of borewells and the levy of groundwater use charges beyond a certain volumetric consumption standard for construction activities. | Mandate that private developers install and operate DEWATS as part of statutory environmental compliance.<br>Direct developers to ring-fence a portion of maintenance charges for DEWATS O&M in a separate escrow account. |

*Source: Authors' analysis based on the consultations with VNN line departments.*

### Action plan for the engineering department

The engineering department is designated as a priority institution responsible for maintaining the majority of parks and gardens (Table 19) within the VNN boundary.

**Table 19: Detailed action plan for the engineering department to mainstream the reuse of treated used water for landscaping purposes**

| Relevant departments | Governance | Infrastructure | Efficiency | Pricing | Financing |
|---|---|---|---|---|---|
| VNN Municipal Commissioner's office<br>Jal Kal<br>Jal Nigam<br>Forest Department<br>Technology provider (for installation of DEWATS) | Prepare a well-structured plan to scale up nature-based DEWATS and strategically tap *nullah* flows as influent for DEWATS. The plan should align with TUW's reuse strategy and complement the existing sewerage infrastructure. | Site selection for DEWATS should involve proximity to the targeted *nullah*, whose flow will serve as the influent to the DEWAT, and installation within the closest available park. | In coordination with the forest department, identify suitable native species for plantation and develop an irrigation calendar to determine precise water requirements. | Prioritise the mainstreaming of TUW reuse in serviceable buffers and reduce departmental costs associated with energy and fertiliser consumption. | Identify appropriate business models with effective risk-sharing arrangements.<br>Suggested models: Reuse utility buy-back model, on-site value creation. |
| | Leverage the existing TUW reuse committee for effective coordination and speedy approval for the deployment of DEWATS at the identified location. | Develop a serviceable buffer (1.5–2 km radius) around the DEWATS and use the existing tanker fleet to supply TUW from DEWATS to smaller, scattered parks. | Quantify the efficiency gains in terms of reduction in groundwater extraction, energy requirement, and fertiliser inputs to make a case for mainstreaming TUW reuse. | | |

*Source: Authors' analysis based on the consultations with VNN line departments.*

### Action plan for PWD, NHAI, and Setu Nigam

This action plan brings together three institutions responsible for implementing high-value infrastructure projects both within and beyond the boundaries of Varanasi city, potentially extending to the district level. These institutions are designated as priority institutions because several of their project sites may fall within the limits specified by the *Urban Wastewater Treatment (Recycle, Reuse, and Disposal) policy* of Uttar Pradesh.

Each institution identified here administers construction-sector reuse avenues under the Reuse Plan (Table 20), although the nature of their project varies. For instance, PWD is responsible for building buildings and roads, NHAI for roads and highways, and Setu Nigam for bridges.

**Table 20: Detailed action plan for PWD Department, NHAI, and Setu Nigam for mainstreaming reuse of TUW in the construction sector**

| Relevant departments | Governance | Infrastructure | Efficiency | Pricing | Financing |
|---|---|---|---|---|---|
| VNN Municipal Commissioner's office<br>Jal Nigam<br>Jal Kal<br>Private player Technology providers<br>Relevant institution for which the project is being developed (for instance, PWD is undertaking two projects for the medical department and the Uttar Pradesh police department | Include a mandatory clause in tender documents and DPRs requiring the reuse of TUW, subject to an assessment of its availability within a 10 km radius (as per the Uttar Pradesh reuse policy) or through *nullah* tapping, if required. | Develop a serviceable buffer (around 10 km) and designate TUW filling stations for bulk water users. | Standardise water quality norms and list activities that mandate the reuse of TUW to precisely assess water requirements. | Certify and provide targeted incentives to contractors for achieving a high replacement rate of fresh water with TUW. | Leverage existing private-sector partnerships to develop PPP-based bulk supply agreements. |
| | Leverage the existing TUW reuse committee as a one- stop centre for coordination and approval. | Set up on-site storage tanks and chlorination units within the batching plant. | | | If the project site is within 10 km of the municipal boundary, then equal cost-sharing for conveyance, on-site treatment (if required), and storage of TUW between PWD and the private player.<br>If the project site is > 10 km, then TUW conveyance, on-site treatment (if required), and storage costs shall be included in a reimbursable bill-of-quantities (BOQ) item. |

*Source: Authors' analysis based on the consultations with VNN line departments.*

# 12. Conclusion

The *Treated Used Water Reuse Plan* serves as a strategic, comprehensive, long-term guiding framework for sustainable used water management in Varanasi. It aligns with national and state guidelines on domestic used water treatment, reuse, and river conservation, including the *Namami Gange Programme* under the NMCG and the Uttar Pradesh *Urban Wastewater Treatment (Recycle, Reuse, and Disposal) Policy*. The VNN, as the primary ULB responsible for managing domestic used water in the city, will play a central role in implementing these interventions. The Reuse Plan provides a strategic framework to strengthen used water management and implement TUW reuse projects within its jurisdiction. It establishes city-specific targets that account for both current and projected water demand, as well as planned infrastructure development. The plan also offers a replicable approach that can guide similar initiatives in other cities across the Ganga basin.

# Acronyms

| | |
|---|---|
| **BAU** | business as usual |
| **BLW** | Banaras Locomotive Works |
| **BOD** | biological oxygen demand |
| **BOQ** | bill of quantities |
| **CGWB** | Central Groundwater Board |
| **COD** | chemical oxygen demand |
| **CPCB** | Central Pollution Control Board |
| **CPHEEO** | Central Public Health and Environmental Engineering Organisation |
| **DEWATS** | decentralised wastewater treatment systems |
| **FC** | faecal coliform |
| **FPO** | farmer producer organisation |
| **GWQI** | groundwater quality index |
| **HAM** | hybrid annuity model |
| **HH** | household |
| **I&D** | interception and diversion |
| **IMD** | India Meteorological Department |
| **KL** | kilolitre |
| **MLD** | million litres per day |
| **MPN** | most probable number |
| **MUWM** | municipal used water management |
| **NHAI** | National Highways Authority of India |
| **NMCG** | National Mission for Clean Ganga |
| **NPV** | net present value |
| **NTPC–MBL** | National Thermal Power Corporation–Macawber Beekay |
| **O&M** | operation and maintenance |
| **PPP** | public–private partnership |
| **PWD** | public works department |
| **RCUES** | Regional Centre for Urban and Environmental Studies |
| **RWA** | resident welfare association |

| | |
|---|---|
| **SEI** | Stockholm Environment Institute |
| **STP** | sewage treatment plant |
| **TN** | total nitrogen |
| **TSS** | total suspended solids |
| **TTUW** | tertiary treated used water |
| **TUW** | treated used water |
| **TWC** | treated wastewater cell |
| **ULB** | urban local body |
| **UPSRTC** | Uttar Pradesh State Road Transport Corporation |
| **VDA** | Varanasi Development Authority |
| **VNN** | Varanasi Nagar Nigam |
| **WEAP** | water evaluation and adaptation planning |
| **WQI** | water quality index |

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# Notes

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