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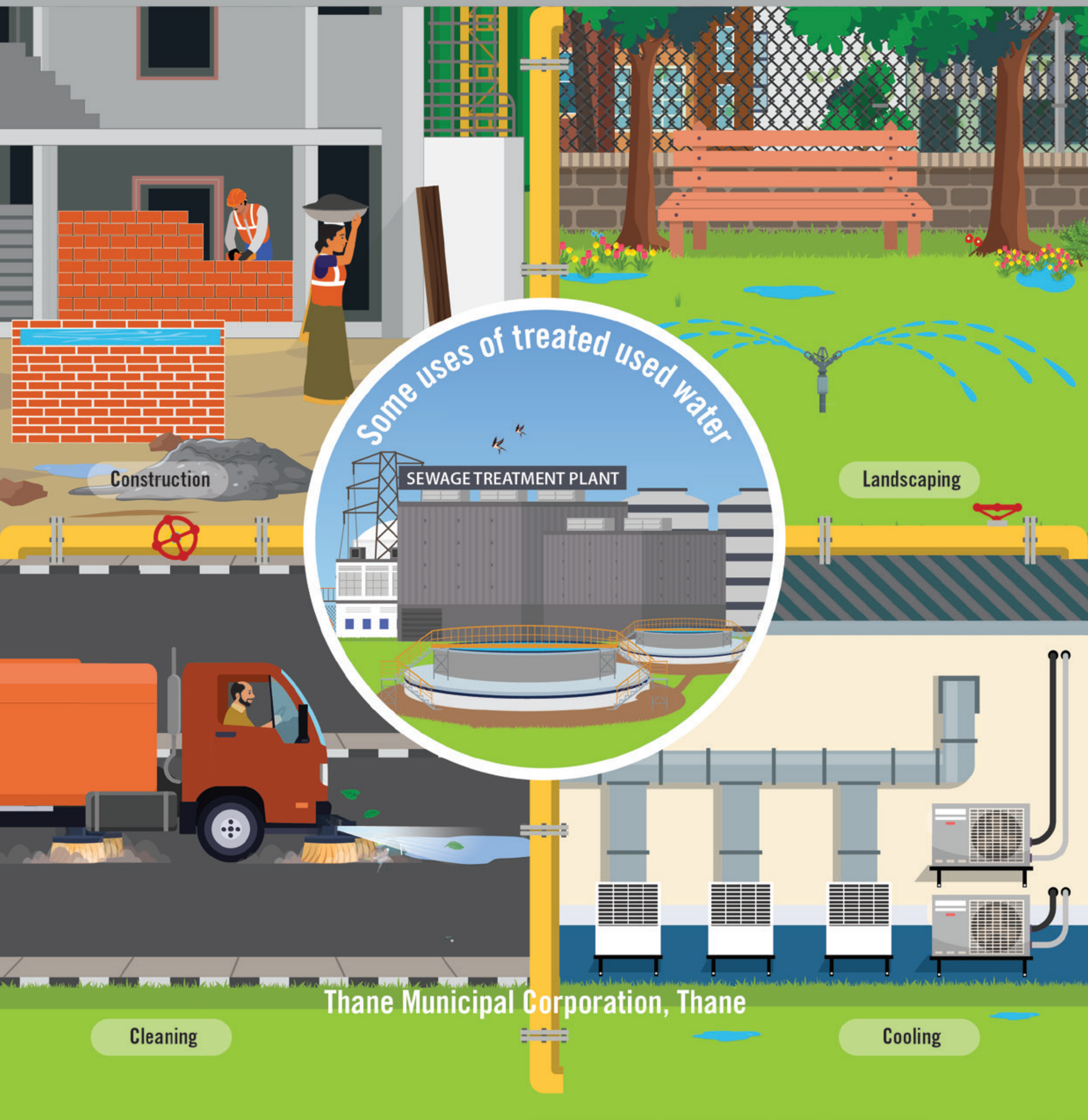
Treated Used Water Reuse Plan for Thane City



Thane Municipal Corporation, Thane

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Treated Used Water Reuse Plan for Thane City

January 2025

Thane Municipal Corporation, Thane

Reuse of treated used water for landscaping.

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FOREWORD

Ensuring water security is an imminent challenge in India. The issue is particularly acute in urban areas, which face heightened risks from increased climate-induced extreme events like droughts and floods. The lack of adequate water supply services to ensure year-round water availability compounds these risks, further increasing vulnerability. Therefore, to build water-resilient cities, there is a need to improve water use efficiency and explore alternative water sources. Reusing treated used water is one such alternative that can enable the sustainable use of water resources and abate water pollution.

The **'Treated Used Water (TUW) Reuse Plan for Thane City'** is a first-of-its-kind city-level plan that aims to strengthen used water treatment and maximise the safe reuse of TUW for non-potable purposes, enabling a circular economy approach to used water management. This will reduce the dependence on existing freshwater resources, optimise water use, and improve the water quality of local sources in Thane City.

More specifically, the Reuse Plan evaluates Thane's water and used water scenario over the years and devises long-term strategies for efficient used water management in the city. It sets targets for 2035 and 2046 for enhancing used water treatment capacity, its utilisation and reuse, thereby minimising the quantum of untreated used water and maximising the safe reuse of TUW.

Further, the Reuse Plan identifies the potential reuse avenues or users (such as industrial users, construction activities, landscaping, commercial cooling, etc.) of TUW within Thane City. It outlines a mechanism for allocating TUW to these users. It develops a sewage zone–wise implementation framework, with provisions for appropriate treatment technologies, recommended conveyance mechanisms, and financially feasible business models to implement reuse projects. Also, it identifies the nodal departments within the Thane Municipal Corporation that are responsible for the implementation.

Thane Municipal Corporation remains committed to addressing developmental challenges and reducing climatic risks for its people, infrastructure, and economy, making them resilient. I am confident that robust implementation, effective monitoring, and periodic revision of the **'Treated Used Water (TUW) Reuse Plan for Thane City'** will contribute significantly to making Thane a water-resilient city. The reuse plan will serve as a model for other cities in Maharashtra and elsewhere in the country to develop their treated used water reuse plans.

I extend my heartfelt gratitude to the leadership of Ms Sujata Saunik (IAS), Chief Secretary, Government of Maharashtra, for her vision for the city. Also, I would like to congratulate the officers of various Thane Municipal Corporation departments who supported the plan's development. I sincerely acknowledge the technical support of the Council on Energy, Environment and Water (CEEW), New Delhi, which led the development of this plan.

(Saurabh Rao)
Municipal Commissioner
Thane Municipal Corporation

About the Treated Used Water Reuse Plan for Thane City

The Treated Used Water (TUW) Reuse Plan for Thane City aims to maximise the safe reuse of TUW, enabling a circular economy approach to used water management in Thane Municipal Corporation (TMC). The plan evaluates Thane's water scenario over the years and devises long-term strategies for efficient used water management in the city. It considers used water as an important asset and essential component of water resources management. The Reuse Plan sets targets for 2035 and 2046 to enhance treatment capacity utilisation, upgrade existing treatment infrastructure, and maximise the safe reuse of TUW in Thane City.

We sincerely acknowledge the significant contributions of the expert team from the Council on Energy, Environment, and Water (CEEW). The plan was developed under the supervision of Mr Nitin Bassi, Team Lead of the Sustainable Water Programme at CEEW. It was formulated by Ms Saiba Gupta, Ms Ayushi Kashyap, and Mr Kartikey Chaturvedi, with the support of Mr Kushal Pratap Mall. We acknowledge the support of Dr Vishwas Chitale, Team Lead of the Climate Resilience Programme at CEEW in facilitating the development of this plan. We also acknowledge the support of Ms Sunita Patra and Mr Sonal Kumar in providing their knowledge and expertise.

We are grateful to Shri Rajeev Kumar Mital, Director General (DG), National Mission for Clean Ganga (NMCG), Ministry of Jal Shakti (MoJS), Shri Nalin Kumar Srivastava, Deputy DG NMCG, MoJS, other NMCG officials, and officers from various departments under TMC for reviewing the plan and providing their valuable feedback. We also thank Dr Thiruppugazh Venkatachalam for his guidance throughout the development of the plan and for providing valuable insights through his review.

Our heartfelt gratitude goes to the review and advisory committee for providing valuable feedback and reviews to enhance the robustness of the plan. The committee includes Ms Sujata Saunik, IAS (Chief Secretary, Maharashtra), Mr Saurabh Rao, IAS (Commissioner, Thane Municipal Corporation), Mr Prashant Rode (Additional commissioner, Thane Municipal Corporation), Mr Sandeep Malvi (Additional commissioner, Thane Municipal Corporation) and Ms Manisha Pradhan (Chief Environment Officer, Thane Municipal Corporation).

We thank department representatives at TMC, especially Mr Vikas Dhole, Deputy City Engineer (Water Supply Department), Mr Atul Kulkarni, Assistant Engineer (Water Supply Department), Mr Vivek Karande, Deputy City Engineer (Sewage Department), Mr Gunvant Zambre, Deputy City Engineer (Mechanical Department), Mr Kedar Patil, Senior Garden Superintendent (Parks and Garden Department), Mr Sunil Patil, Executive Engineer (Town Planning Department), Mr Bhalchandra Behere, Manager (Thane Municipal Transport Department), Mr Girish Zalke, Chief Fire Officer (Fire Department) and officials from the Maharashtra Pollution Control Board (MPCB) for their support in the collation of data, providing ground insights and valuable feedback throughout the development of the plan.

Lastly, we thank Premji Invest and MacArthur Foundation for funding CEEW's research and coordination associated with the TUW Reuse Plan for Thane City.

Contents

Reuse of treated used water for vehicle exterior and wheel washing at bus depots.

Executive summary

Water security is crucial for the sustainable growth and resilience of economies. Managing freshwater demand should be India's foremost priority in achieving water security, considering that 11 out of the 15 major river basins in the country will be water-stressed by 2025 (Bassi, Gupta, and Chaturvedi 2023). The situation is particularly severe in urban areas where scarce freshwater resources are unable to keep up with the growing water demand. Given the quantum of domestic used water generated in Indian cities, once safely treated and reused, it can serve as a highly valuable resource that can reduce the pressure on freshwater resources and improve the quality of rivers and aquifers. However, only 30 per cent of the domestic used water generated by Class I and II cities (population above 50,000) is treated (CPCB 2021). Further, the reuse of treated used water is very low, even in the major urban agglomerations in the country (Bassi, Gupta, and Chaturvedi 2023). Hence, it is essential to empower urban local bodies (ULBs) to formulate and adopt long-term reuse plans with clear targets for used water treatment and reuse – an element currently missing in Indian cities.

Vision of the Reuse Plan

The Treated Used Water (TUW) Reuse Plan for Thane City was developed by CEEW in association with the Thane Municipal Corporation (TMC). This first-of-its-kind plan aims to maximise the safe reuse of TUW, enabling a circular economy approach to used water management in TMC. It promotes TUW reuse for non-potable purposes and establishes reuse – specific quality standards to ensure its reusability. This will reduce the city's dependence on existing freshwater resources for non-potable purposes, optimise resource efficiency, and improve the water quality of local water sources in Thane City.

The Reuse Plan sets quantifiable targets for 2035 and 2046 for enhancing treatment capacity utilisation, upgrading existing treatment infrastructure – mainly treatment technologies – and maximising the safe reuse of TUW in Thane City. Local authorities must align their efforts and resources towards achieving these time-bound benchmarks.

Approach for developing the TMC Reuse Plan

We studied Thane's water and used water scenario over the years and devised long-term strategies for efficient used water management to create the TMC Reuse Plan. The plan considers used water as an important asset and an essential component of water resources management. The overall approach adopted to develop the plan is illustrated in Figure ES1. TMC officials were consulted throughout the development process, and over 20 consultations were carried out.

Figure ES1: Nine-step approach for developing the TMC Reuse Plan

1 **Analysis of groundwater and surface water resources scenario in TMC**
1. Analysis of depth to groundwater level (2000-2021)
2. Analysis of surface water (2019-2023) and groundwater quality (2018 and 2022)

2 **Estimation of city water balance**
Preparation of administrative ward-wise water deficit

3 **Evaluation of used water management in TMC**
1. Evaluation of current used water management using an assessment framework
2. Projection of used water generation and treatment capacity for the years 2035 and 2046

4 **Setting of Reuse plan targets**
City-level targets up to 2046

5 **Identification of TUW reuse avenues**
Defining suitable sectors and applications for the reuse of TUW

6 **Defining an allocation and conveyance mechanism for the reuse of TUW**
1. Estimating the water requirements of the identified reuse avenues
2. Defining allocation criteria for allocating TUW
3. Defining a rationale for recommended conveyance mechanism

7 **Defining sector-specific TUW quality standards and treatment levels**
1. Assessing the effluent water quality of existing STPs in TMC
2. Defining reuse-specific minimum TUW quality standards and treatment levels

8 **Financing of TUW reuse**
1. Financial requirements to maximise reuse: strengthening existing infrastructure, technology upgradation, conveyance mechanism
2. Funding provisions for used water management and reuse
3. Identifying business models for the identified reuse avenues
4. Pricing of TUW

9 **Development of an implementation framework**
1. Reuse-zone specific implementation framework
2. Setting up a monitoring committee
3. Framework for data sharing and management
4. Training needs assessment for institutional capacity building

Source: Authors' analysis

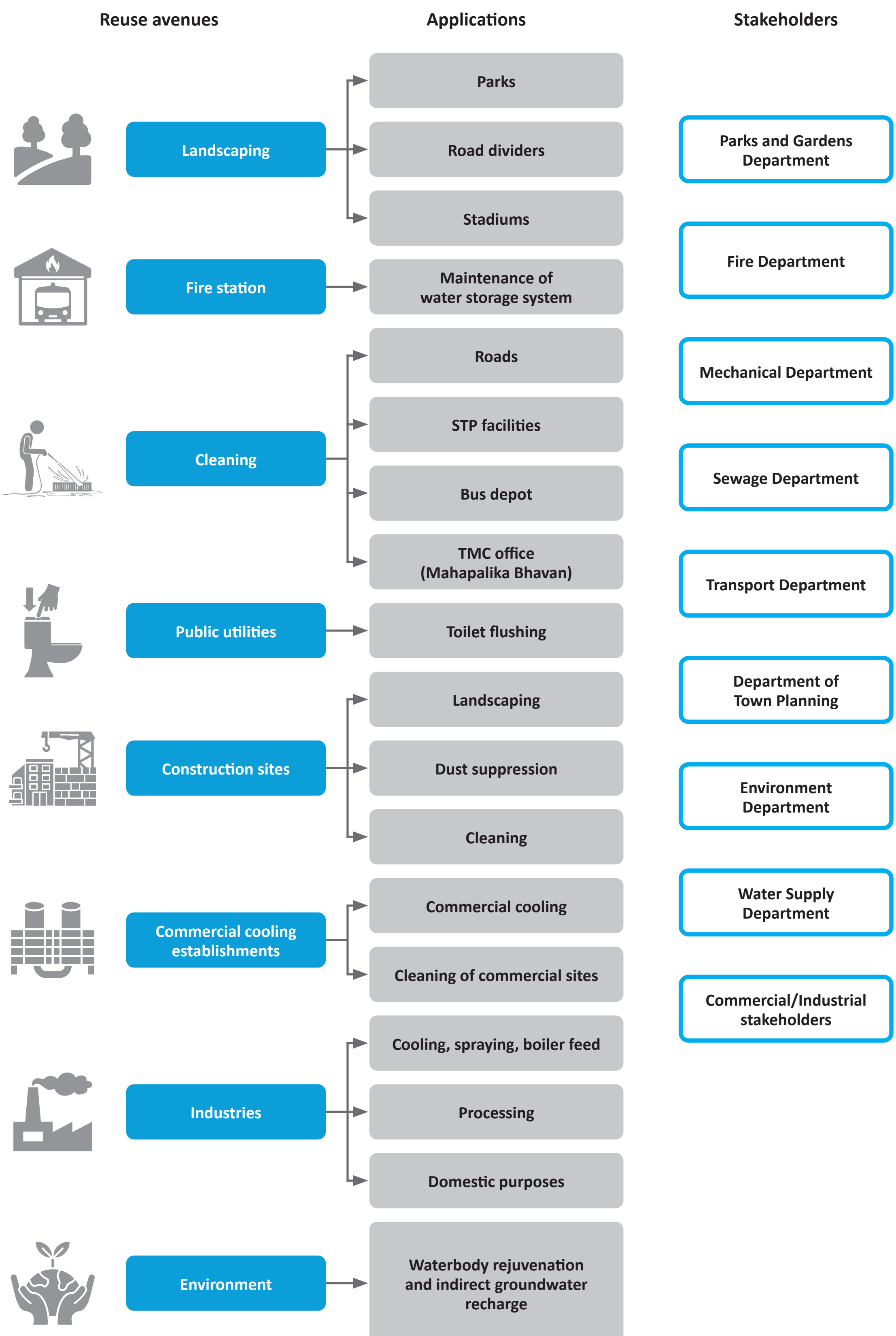
Key findings

- **Groundwater levels**: The pre-monsoon depth-to-groundwater level in TMC has declined at the rate of 10 cm per year due to increased groundwater extraction, despite increasing rainfall.
- **Water quality**: Three out of eight surface water monitoring stations in TMC were classified as polluted during the analysis period (2019–23). Average annual biological oxygen demand and average pre-monsoon seasonal faecal coliform (FC) levels in monitored *nullahs* (natural drains) were 46.94 mg/l and 3,495 counts/100 ml, respectively, which exceed acceptable standards for surface water, suggesting the discharge of untreated or partially treated sewage into surface water bodies. Additionally, the groundwater quality monitoring station in TMC reported that the groundwater was polluted in both assessment years (2018 and 2022). The annual groundwater quality index decreased from 130.55 in 2018 to 185.15 in 2022, with a higher groundwater quality index indicating lower water quality.
- **Water deficit**: The city's water balance analysis reveals a shortfall of 53 million litres per day (MLD) in the actual water supply for domestic and commercial uses from public sources.
- **Used water treatment and reuse**: Currently, 73 per cent of the used water generated in TMC is treated, out of which only about 5 per cent is reused. Strengthening used water management can reduce the city's dependence on freshwater to meet its growing water demand, prevent the misuse of groundwater resources, and improve the quality of local water sources.
- **TUW reuse potential**: We have identified eight reuse avenues in TMC as of 2024 that has potential to reuse 20 per cent of the total used water generated and 27 per cent of the available TUW.
- **Treatment quality requirements**: Presently, in TMC, all sewage treatment plants operate at the secondary level. If they can be updated to the tertiary level, the treated water will be able to fulfil over 70 per cent of the identified reuse potential.
- **Financial requirements**: The Net Present Value (NPV) of upgrading existing secondary treatment plants with tertiary treatment technology is INR 4.67 crore per MLD and setting up a new tertiary treatment plant is INR 6.37 crore per MLD. Thus, the upgradation cost is 31 per cent less than that of setting up a new tertiary treatment plant. This cost includes both capital and operation and maintenance (O&M) costs, which are annualised over 30 years.
- **TUW tariff**: TMC can recover the annual cost of tertiary technology upgradation by selling tertiary-level TUW to industrial and commercial users at a 30 per cent lower price than the existing freshwater prices for these sectors.

Action areas for TMC

The Reuse Plan has identified potential reuse avenues or users of TUW within Thane City, along with corresponding departments within TMC that oversee these areas (Figure ES2). Further details regarding the roles and responsibilities of the relevant departments in TMC are provided in Section 13.1 (Table 22b). The end use will determine the quantity of TUW required and the quality parameters that the TUW will need to meet, further influencing the design of treatment systems and, in particular, the treatment technologies required.

Figure ES2: Identified TUW reuse avenues and stakeholders in TMC

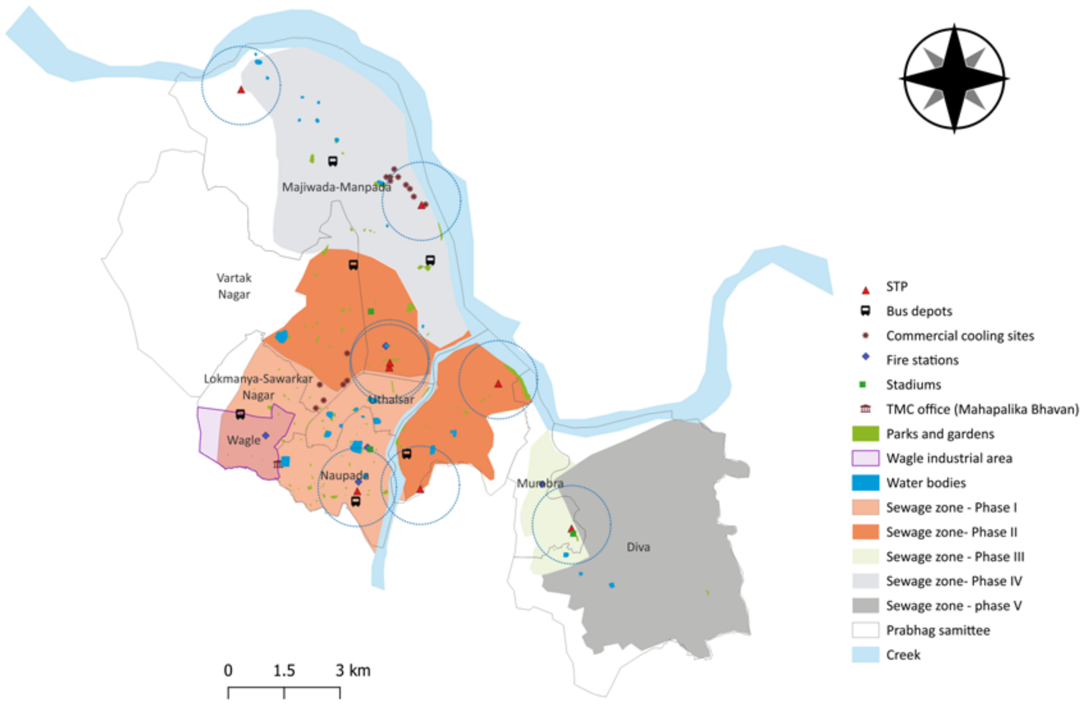


Source: Authors' analysis

Based on this, the plan recommends the following areas of action for effective TUW reuse planning and implementation:

- **Zone-wise planning**: The plan recommends zone-wise planning for TUW allocation, considering the installed treatment capacity (and actual treatment) of existing and planned treatment infrastructure and the estimated TUW requirements of the identified reuse avenues located within each zone. The allocation criteria will further determine the conveyance mechanism adopted from the point of treatment to the point of reuse. For this purpose, five reuse zones have been defined – corresponding to TMC-defined sewage zones – with the existing treatment infrastructure (point of treatment) and the reuse avenues (point of reuse) mapped spatially (Figure ES3) within each zone.

Figure ES3: Five demarcated sewage zones within TMC for zone-wise reuse planning

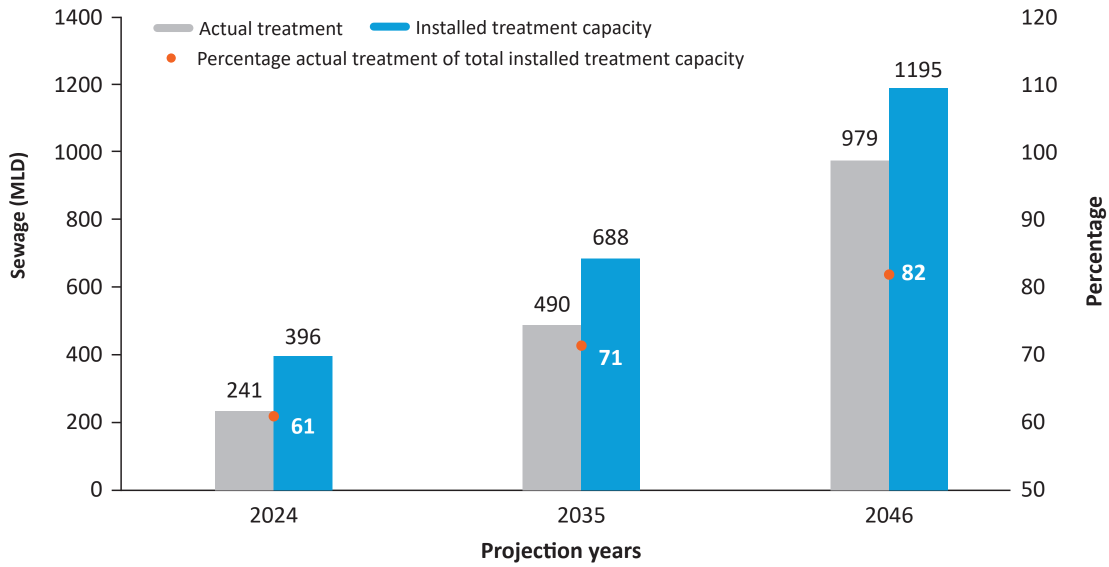


Source: Authors' analysis

- **Treatment capacity utilisation:** The existing used water treatment capacity in TMC needs to be strengthened in terms of the actual utilisation of the installed sewage treatment capacity. This highlights the importance of monitoring the O&M of installed infrastructure. The plan sets targets for actual treatment (as a percentage of projected installed treatment capacity) – 71 per cent by 2035 and 82 per cent by 2046 (Figure ES4). The 2046 actual treatment target accounts for 100 per cent of the projected used water generation. This is essential to ensure that there is no discharge of untreated or partially treated domestic used water into surface water bodies to prevent them from being polluted.

- **Priority for reuse:** The first phase of TUW reuse in TMC should focus on the reuse applications that require water that meets the quality standards of the currently available TUW. Hence, reuse applications that require secondary-level TUW will be the first priority users. These include applications such as landscaping, wheel washing, and road cleaning, which have an annual estimated water demand of 7,035 million litres. The plan recommends that 100 per cent of this water requirement be met by TUW.

Figure ES4: By 2046, no discharge of untreated domestic used water is targeted in TMC



Source: Authors' analysis based on data from TMC, Sewage Department

- **Diversity of reuse applications:** The existing treatment infrastructure in TMC needs to be upgraded to the tertiary level of treatment to realise the full TUW reuse potential. Also, any additional capacity should incorporate tertiary treatment technologies. This will increase and diversify reuse potential across different avenues – such as in industries, the construction sector, and commercial cooling – and hence build a market for reuse. Once the necessary infrastructure has been upgraded, the potential for TUW reuse will increase from 7,035 million litres per annum to 23,902 million litres per annum, with over 70 per cent of the current estimated reuse potential requiring tertiary-treated TUW.

- **Sustainable financing:** The reuse projects need to be financially sustainable, with risk sharing between TMC, end users and private stakeholders. The plan recommends business models that can be adopted by TMC to implement reuse projects – including used water treatment, conveyance, and reuse. The recommended business models include onsite value creation, reuse utility buyback, and investments by end users. Further, the price of the TUW should be set such that the revenues generated help reduce/recover the costs incurred by the TMC and thus contribute towards making reuse projects commercially viable and sustainable. However, the TUW price needs to be lower than that of the freshwater to encourage its reuse.

The TMC Reuse Plan has been developed as a long-term guiding document for sustainable used water management in Thane City. It aligns with national and state guidelines for domestic used water treatment and reuse. The national *Atal Mission for Rejuvenation and Urban Transformation* 2.0 targets meeting 20 per cent of municipal water demand through TUW by 2025-26. Additionally, Maharashtra's *Treated Water Reuse and Management 2023 (Draft) Policy* aims to replace 30 per cent of municipal freshwater use with TUW by 2025. The responsibility of implementing these policies lies with the ULBs, being the primary authorities for managing domestic used water in Indian cities. The TMC Reuse Plan provides a strategic framework and guidance to the ULB to strengthen used water management and implement TUW reuse projects within its jurisdiction. It sets city-specific targets that consider both the current and future water demand, factoring in the city's planned development. This plan can be used as a template and provide direction to other cities to develop standardised reuse plans across the state. This is a crucial step for mainstreaming a circular economy in urban used water management.

1. Introduction

Ensuring water security has emerged as an imminent challenge, with per capita renewable freshwater resources diminishing steadily across the globe. India is no exception. The country has witnessed a steady decline in freshwater resources, with an almost 20 per cent decrease in annual per capita water availability over the last two decades (Mishra et al. 2023a). Various water–demand interventions to address freshwater shortages are being explored. However, maximising used water treatment and safe reuse is increasingly being recognised as a potential solution for mitigating water stress, especially in urban areas. Indian cities generate over 72,000 million litres of used water (domestic sewage) per day, of which only 28 per cent is treated (CPCB 2021). The remaining water is discharged into freshwater bodies such as rivers and lakes (Bassi, Gupta, and Chaturvedi 2023). This significantly contributes to water body pollution in India, especially in the stretches passing through urban areas. Given the quantum of used water generated in urban areas, it can be a highly valuable resource that can address the water supply and demand gap and improve the quality of rivers and aquifers when treated to the prescribed quality standard and reused.

1.1 Need for reuse planning

Although many Indian cities are implementing treated used water (TUW) reuse projects, the level of reuse is still very low overall, even in metropolitan cities. Out of the 503 urban local bodies (ULBs) assessed by a CEEW study, 414 do not reuse their TUW (Gupta et al. 2024). ULBs need to be empowered to formulate and adopt long-term reuse plans – with clear targets for used water treatment and reuse – since they are the paramount authorities responsible for domestic used water management. This first-of-a-kind TUW Reuse Plan has been developed for TMC to mainstream the circular economy approach. It focuses on strengthening treatment systems, upgrading treatment technologies, identifying context-specific reuse avenues and determining viable business models to implement reuse projects. Such a plan can provide direction to other cities for the development of uniform policies across the state.

1.2 Understanding used water – definitions and terminologies

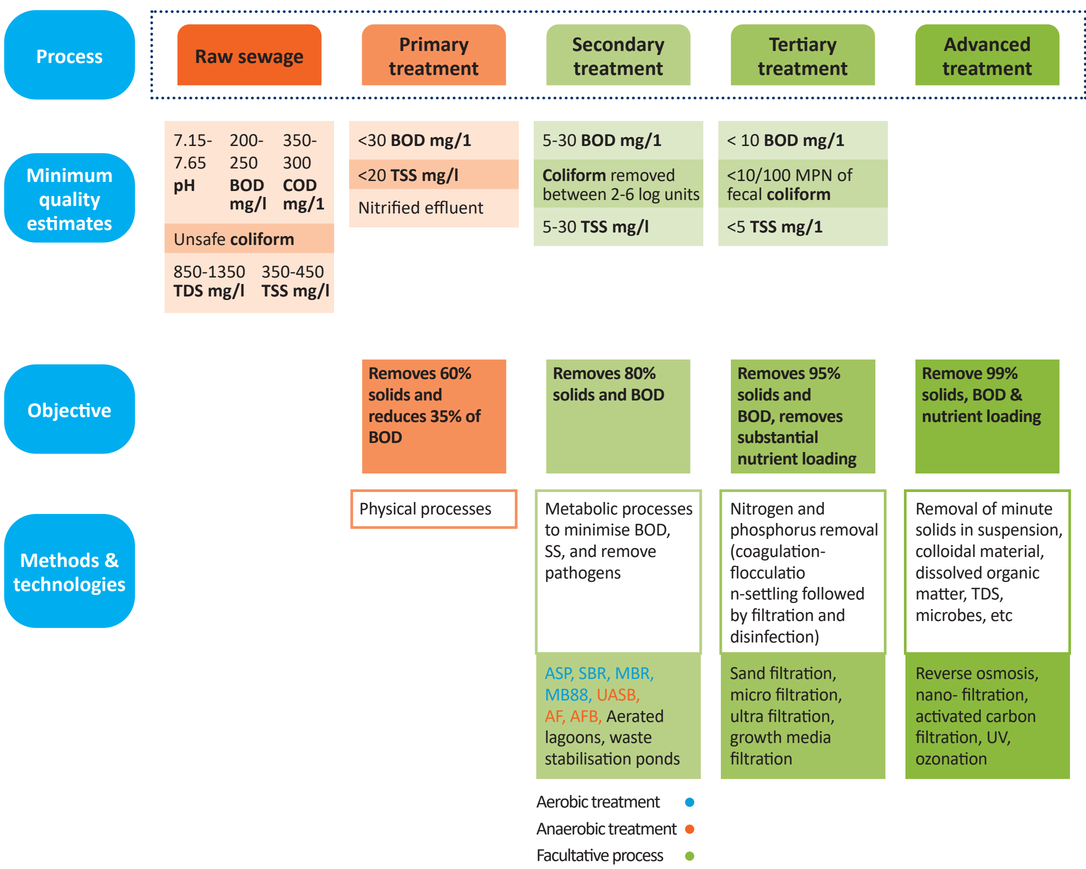
The National Framework on Safe Reuse of Treated Water (NF-SRTW) launched in 2023 by the *National Mission for Clean Ganga* (NMCG), defines used water as "a combination of one or more of: a) domestic effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing used water); b) water from commercial establishments and institutions, including hospitals; c) stormwater and other urban runoff; d) industrial effluents; and e) agricultural, horticultural and aquaculture effluents, either dissolved or as suspended matter."(NMCG 2022)

Domestic used water – commonly referred to as municipal wastewater – accounts for 50 to 80 per cent of the total volume of used water released into the environment (Hussain et al. 2019). The TUW Reuse Plan for TMC considers domestic used water collected and transported through a piped sewerage network to sewage treatment plants (STPs) operated and maintained by the TMC.

Used water treatment involves one or more processes of primary, secondary, tertiary, or advanced levels of treatment. Based on the level of treatment, TUW can be reused for different non-potable and potable purposes. This Plan promotes the reuse of TUW for non-potable uses, i.e., water not meant for human consumption.

At the first stage, or the primary treatment level, sewage undergoes physical treatment through screening and equalisation (Bassi, Gupta and Chaturvedi, 2023). This is followed by secondary treatment, wherein metabolic processes digest organic waste and minimise suspended solids. This is undertaken through aerobic, anaerobic, or combined (facultative) pathways. The secondary level may be followed by tertiary treatment to lessen nutrient load through chemical precipitation or semi-permeable membrane filtration (CPHEEO 2013). An advanced level of treatment, such as reverse osmosis (RO), is applied to produce industrial-grade TUW by removing turbidity, microbes, total dissolved solids (TDS), and minerals such as salt and lead. Used water treatment processes are elaborated on in Figure 1.

Figure 1: Used water treatment process and associated technologies



Source: Authors' analysis based on data from Minhas, Paramjit S., Jayanta K. Saha, M. L. Dotaniya, Abhijit Sarkar, and Madhumonti Saha. 2022. Wastewater Irrigation in India: Current Status, Impacts and Response Options. Science of the Total Environment

Note: ASP – Activated sludge process
SBR – Sequencing batch reactor
MBR – Membrane bioreactor
MBBR – Moving bed biofilm reactor
UASB – Upflow anaerobic sludge blanket
AF – Anaerobic filter
AFB – Anaerobic fluidized bed reactor

1.3 Existing governance on the reuse of treated used water in India and Maharashtra

Recognising used water management as an essential urban service, the Indian government has taken comprehensive steps to strengthen used water treatment, promoting TUW reuse and abating water pollution through various national missions and initiatives. Some of the important national missions and policies for mainstreaming used water management are as follows:

- **National Framework on Safe Reuse of Treated Water (NF-SRTW), 2023**
  The framework was developed as a set of directives to guide the updation and formulation of state-level reuse policies. It provides a three-tier institutional arrangement with the National Advisory Council at the apex level (NMCG 2022). Since water is a state subject, each state is required to formulate a state-level policy on SRTW suited to their respective context. At the local level, ULBs are encouraged to formulate a city reuse plan for treated water.

- The framework also identifies various central government schemes – such as the *Atal Mission for Rejuvenation and Urban Transformation* (AMRUT), *Swachh Bharat Mission* (SBM), and *Jal Jeevan Mission* (JJM) – as potential sources of funding that can supplement state budget allocations for project implementation. Further, it sets reuse targets based on the level of collection and treatment infrastructure. For example, in areas where STPs are operational and have sufficient capacity, the goal is to safely reuse 50 per cent of TUW by 2025 and 100 per cent by 2030 (NMCG 2022).

- **Atal Mission for Rejuvenation and Urban Transformation 2.0 (AMRUT 2.0)**
  AMRUT 2.0 emphasises improving sewage and septage management and mainstreaming the reuse of TUW in urban areas. Cities are required to prepare a city water action plan, which must include projects related to sewage and septage management and rejuvenation of water bodies (MoHUA 2021).

- The guidelines mandate the adoption of the public–private partnership (PPP) model for certain project categories. The mission has set ambitious targets of achieving 100 per cent coverage of sewerage network in 500 AMRUT cities, meeting 20 per cent of the water demand, and fulfilling 40 per cent of industrial water demand by the fiscal year 2025–26 (MoHUA 2021).

- **Swachh Bharat Mission 2.0 (SBM 2.0)**
  SBM 2.0 focuses on the systematic collection, safe transportation, and effective treatment of used water, along with promoting the reuse of treated water for various non-potable purposes. The mission targets recycling and reusing at least 20 per cent of TUW (SBM-U 2021). The SBM management information system – a centralised database – has been established to track the progress of ongoing projects backed by a third-party audit to assess and evaluate the mission's outcomes.

- **Urban river management plans (URMP)**
  The NMCG mandates that all river cities (within the Ganga basin), which are also classified as class I – with a population greater than a lakh – should have a city-specific URMP in place. URMPs focus on regulating activities within floodplains, abating river pollution, rejuvenating water bodies and wetlands in the city, and promoting the reuse of TUW (NMCG and NIUA 2020). Funding for preparing URMPs can be channelled through various sources such as national missions like AMRUT, the *Smart Cities Mission*, grants to ULBs from state/central commissions, and corporate social responsibility (CSR) funding.

Before the NF-SRTW and parallel to these national initiatives, 12 Indian states already had a dedicated policy on SRTW, either approved or at an advanced stage of drafting (NMCG 2022).

These states included Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Punjab, Rajasthan, and West Bengal, with Maharashtra and Uttar Pradesh having draft policies in place. Most states provided targets to improve the collection of sewage and its treatment and reuse within a defined time frame based on city size and the status of existing infrastructure. For instance, Haryana aims to achieve 100 per cent reuse by 2030 (GoH 2019), while Karnataka aims to achieve 50 per cent by 2030 (GoK 2016). Reuse priorities tend to vary across different state policies. Some states prescribe mandatory usage of TUW for industrial estates while others focus on TUW in agriculture only. In most states, ULBs are mandated to prepare city-level reuse plans with targets ranging from 20 to 25 per cent for the use of TUW.

1.4 State profile in used water management

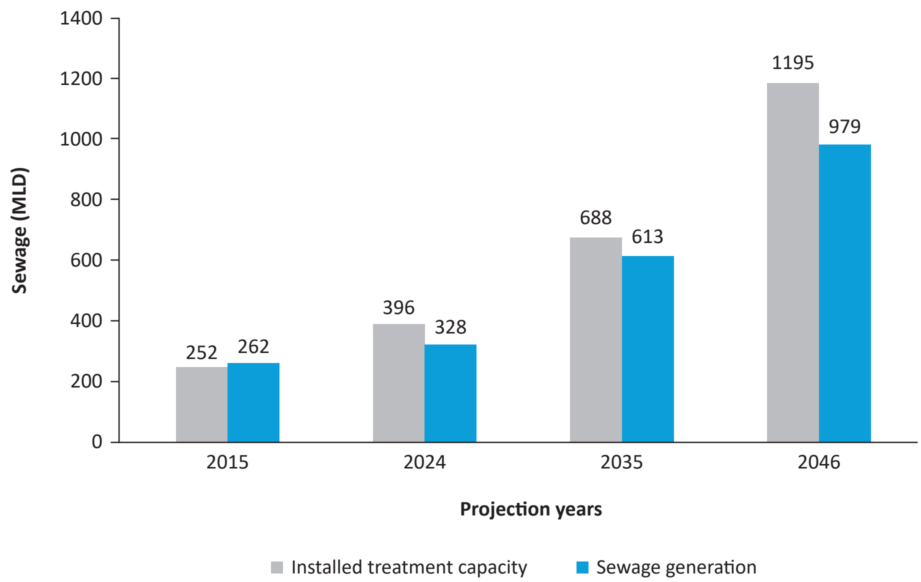
Among the Indian states, Maharashtra has the highest domestic used water generation of 9,107 million litres per day (MLD) (Mishra et al. 2023b). Out of the 9,107 MLD of sewage generated, 47 per cent gets treated to varying degrees (Mishra et al. 2023b), of which 17 per cent is reused for cooling thermal power plants (TPPs) and auxiliary purposes such as gardening and horticulture (CEPT 2023). Further, Maharashtra's *Treated Water Reuse and Management 2023 (Draft) Policy* sets a municipal-level target to replace 30 per cent of freshwater use with TUW by 2025. The policy highlights the following possible uses of TUW: in large commercial and institutional units and for construction activities, landscaping, and washing of roads/public premises. The state also prioritises effective water resource management through other state-level instruments such as government orders on bulk water tariffs, the *State Water Policy 2019*, and sectoral plans and guidelines (refer to Annexure 1).

2. Profile of Thane Municipal Corporation

Thane City falls within the sub-district of Thane and covers an area of approximately 128.23 sq. km. It is governed by the TMC, which exercises jurisdiction over the towns of Kalwa, Mumbra, and the central city of Thane. TMC is subdivided into 9 *prabhag samitees* (administrative wards) and 33 electoral wards. As per TMC, Thane City's population currently stands at 30,67,216.

Thane City's sewerage network covers 77 per cent of the city's area through underground piped networks and has a collection efficiency of 73 per cent. The city generates approximately 328 million litres per day (MLD) of domestic used water (Figure 2). There are 8 STPs within the TMC jurisdiction, with a total installed sewage treatment capacity of 318 MLD. Additionally, the total decentralised sewage treatment capacity installed in residential areas in the city is 78 MLD. The actual sewage treatment (utilised installed treatment capacity) is 241 MLD – both centralised and decentralised – which accounts for about 73 per cent of the used water generation. Of this, only 12 MLD is currently being reused for jetting vehicles, gardening, and cleaning within sewage treatment facilities.

Figure 2: Installed treatment capacity is estimated to triple from 2024 to 2046



Source: Authors' analysis based on data from TMC, Sewage Department

Treated used water reuse for road cleaning.

3. Vision

The proposed plan aims to maximise the safe reuse of TUW, enabling a circular economy approach to used water management in TMC. This will reduce the city's dependence on existing freshwater resources for non-potable purposes, optimise resource efficiency, and improve the water quality of local sources in Thane City. There are a total of 35 lakes within the jurisdiction of TMC.

The plan's vision echoes the vision of the NF-SRTW, which aims to achieve "widespread and safe reuse of treated used water in India that reduces the pressure on scarce freshwater resources, reduces pollution of the environment and risks to public health, and achieves socio-economic benefits by adopting a sustainable circular economy approach." (NMCG 2022)

Local authorities can align their efforts and resources towards achieving this vision by establishing achievable and time-bound benchmarks. For this purpose, the Reuse Plan sets three targets for Thane City in 2035 and 2046 (Table 1).

The first target concerns actual treatment, which is envisioned to increase from 61 per cent of installed treatment capacity in 2024 to 71 per cent by 2035 and 82 per cent by 2046. The actual treatment target for 2035 will account for 80 per cent of used water generation, while the 2046 target will account for 100 per cent of used water generation, ensuring that no untreated used water is discharged into the environment.

The second target for TUW reuse is based on the estimated current and future reuse potential of all identified reuse avenues in the city (Section 10, Table 6a–b). The current reuse potential accounts for 27 per cent of the actual treatment, as of 2024. For 2035 and 2046, respectively, the TUW reuse levels required to achieve the future reuse potential are 16 and 9 per cent of the projected actual treatment.

The third target, which concerns establishing tertiary treatment capacity, is a subset of the second target: 11 and 6 per cent of the projected actual treatment by 2035 and 2046, respectively, are required at the tertiary level to meet the corresponding TUW reuse targets.

Table 1: City-level targets under the TMC Reuse Plan

S. No	City-level target	Indicator	2035	2046
1.	Actual treatment	Actual treatment as a percentage of installed treatment capacity	**71**	**82**
2.	Reuse of TUW	Percentage of available secondary and tertiary TUW (based on actual treatment) reused for non-potable uses	**16**	**9**
3.	Used water treated to tertiary level	Tertiary treatment capacity as a percentage of total actual treatment	**11**	**6**

Source: Authors' analysis based on data from TMC, Mechanical and Sewage Department

Reuse of treated used water for construction activity.

4. Approach for developing the TUW Reuse Plan

The Reuse Plan evaluates Thane's water resources scenario over the years and devises long-term strategies for efficient used water management in the city. It considers used water management as essential to water resource management in the city. The overall approach adopted for the development of the plan is illustrated in ES Figure 1. This section elaborates on each component of the approach (Sections 4.1–4.8). Over 20 consultations were conducted with TMC officials while developing the plan (Figure 3).

Figure 3: Consultation workshops and meetings with TMC officials

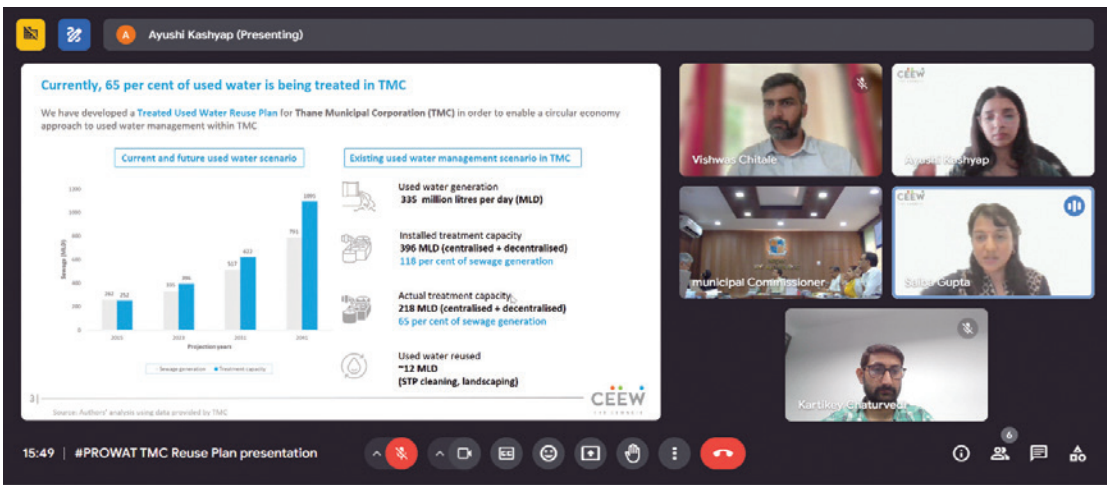
a) CEEW team presenting to the Commissioner of TMC

b) Consultation with various line departments within TMC

c) CEEW team briefing TMC officials about the training and assistance needs assessment exercise

d) CEEW team visiting the Kopri STP for consultations with engineers

e) CEEW team presenting the TUW Reuse Plan (Draft) to the TMC Commissioner for review and feedback



Images: CEEW

Thane City's growing population and expanding economic activities have significantly increased water demand across various sectors. To address this growing water demand sustainably and realise the potential of using TUW to meet some of the non-potable demand, it is essential to map existing water resources both in terms of quantity and quality. In the following section, we estimate depth-to-groundwater levels over the last 20 years and seasonal variations in the water quality of groundwater and surface water sources over a period of 5 years.

4.1.1 Trend analysis of depth-to-groundwater levels in TMC over the last 20 years

The trend analysis of depth-to-groundwater levels was carried out for a 20–year period from 2000 to 2021, focusing on three distinct scenarios in Thane City. **Scenario 1 examined trends in the average depth-to-groundwater level overlaid with the city's average annual rainfall.**

Scenario 2 and Scenario 3 analysed pre- and post-monsoon groundwater depth trends, linking them with average annual rainfall and average rainfall during the monsoon months over the years, respectively.

The depth-to-groundwater level data was accessed from the India–Water Resource Information System (WRIS) (2022). Data on average annual groundwater depth (in metres) and pre- and post-monsoon groundwater depth (in metres) were accessed from the India–WRIS portal for Thane district. The analysis considered the groundwater datasets of the monitoring station installed within Thane's city limits. The rainfall analysis was carried out using daily rainfall data for Thane district from the Indian Meteorological Department (IMD).

4.1.2 Assessment of water quality of groundwater and surface water sources in TMC

Understanding the water quality status of major water bodies is crucial for assessing the overall health of a city's freshwater resources. We assessed the water quality of TMC's surface water bodies and groundwater using a water quality index (WQI). It is a single-value indicator that is used to represent the overall quality of a water body based on observations of multiple parameters (Bassi and Kumar 2016). The methodology used to compute the WQI was introduced by the National Sanitation Foundation (NSF), USA (Brown et al. 1970). The general NSF formula for the calculation of WQI is given as:

$$NSFWQI = \sum_{i=1}^{p} WiIi \qquad \text{.....Equation A1}$$

Where,

P = Number of parameters
Wi = Weight assigned to each parameter
Ii = Sub-index value of each parameter

Based on their WQI value, water bodies are classified into different categories and best-use classes. In India, the NSF–WQI methodology has been adopted and modified by the Central Pollution Control Board (CPCB) (TERI 2024), and the same has been followed for the WQI analysis of water bodies in TMC over a period of five years (2019–2023). The MPCB monitors water quality under the *National and State Water Monitoring Programme* (MPCB 2014) and disseminates information on the state's water quality status to comply with the Water (Prevention and Control of Pollution) Act, 1974. The surface and groundwater WQI are calculated and reported periodically as part of this exercise. The detailed methodology used for assessing surface water and groundwater quality is presented in Annexure 2.

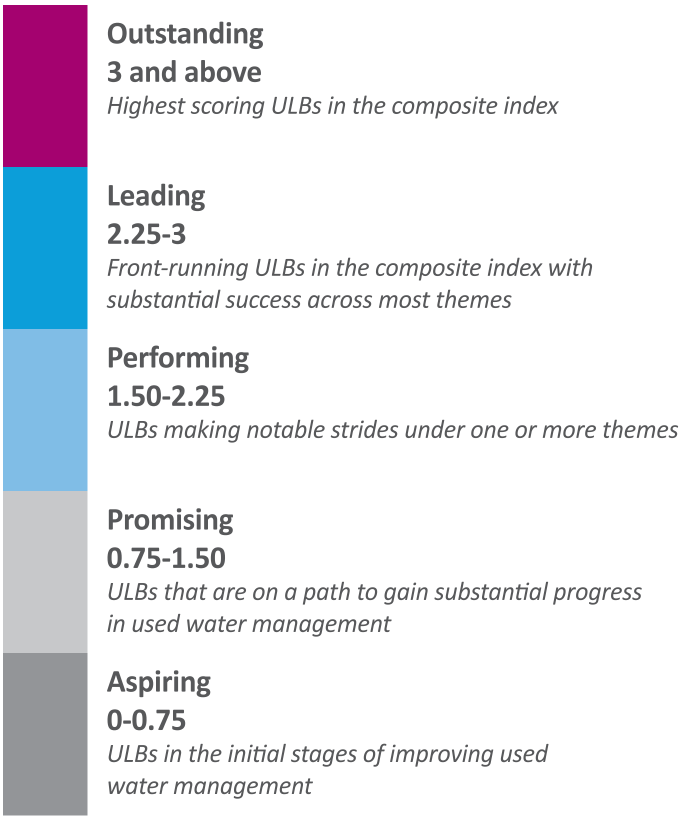
4.2 Estimation of the city water balance

Estimating a city's water balance is the process of accounting for the total water supply and demand within a city's jurisdictional boundaries and assessing the difference between the two. It is an essential process for estimating the deficit or surplus between the water demand and supply. The analysis helps inform relevant institutional and policy interventions to meet the city's water requirements judiciously. To undertake this exercise for TMC, aspects of the urban water cycle, including different water supply sources (i.e., surface water and groundwater resources), water demand, non-revenue water, and used water generation were considered. The water deficit or surplus is calculated considering the water supply and demand for domestic and commercial uses. The details are provided in Annexure 3.

4.3 Evaluation of used water management in TMC

Proper used water management is crucial for augmenting the reuse of TUW in a city. CEEW's Municipal Used Water Management (MUWM) framework is a comprehensive assessment tool that assesses a ULB's overall performance in used water management (Gupta et al. 2024). The framework is based on the UN Water Global Acceleration Framework (UN-W 2020) and follows a TPI (themes–parameters–indicators) approach. It covers five themes – finance, infrastructure, efficiency, governance, and data and information – and has 25 parameters, each with one or more indicators used to quantify a ULB's performance in aspects of used water management (Figure 4). This index has been applied to 503 ULBs in India and was used for TMC as well.

Figure 4: Award categories of the MUWM index



Source: Gupta, Saiba, Kartikey Chaturvedi, Ayushi Kashyap, and Nitin Bassi. 2024. Enabling Circular Economy in Used Water Management in India: A Municipal Index for Assessing Urban Local Bodies' Performance. New Delhi: Council on Energy, Environment and Water

4.4 Identification of TUW reuse avenues

Potential users (reuse avenues and applications) of TUW in Thane City were identified through consultations with TMC officials. For instance, landscaping was identified as one of the reuse avenues. This included the irrigation of municipal parks, gardens, road dividers, and stadiums using TUW.

4.5 Defining an allocation and conveyance mechanism for the reuse of TUW

The water demand of the identified reuse avenues was estimated to define an allocation mechanism for the available TUW. This estimation was carried out for TUW applications within each reuse avenue and the aggregated estimate for the city. The methodology adopted for estimating the TUW requirements or reuse potential is given in Annexure 4. The current (2024) reuse potential accounts for the existing scenario in the city, and the future reuse potential (2046) accounts for developments planned under the *Draft Revised Development Plan Thane 2026–2046*. Based on existing sewage zones in TMC, reuse zones were defined taking into account their location and the treatment infrastructure available within them.

4.6 Defining sector-specific TUW quality standards and treatment levels

This section discusses the approach used to assess the effluent water quality of existing STPs, and define minimum TUW quality standards along with the required treatment levels for the identified reuse avenues.

4.6.1 Assessment of effluent water quality of existing STPs in TMC

TMC has eight operational secondary-level STPs. The Mechanical Department of TMC monitors the influent and effluent water quality of STPs monthly. The water quality parameters monitored are pH, BOD, chemical oxygen demand (COD), TDS, oil and grease, total suspended solids (TSS), total coliform (TC), faecal coliform (FC), ammonia, and total nitrogen.

Using the latest available datasets for the months between April 2023 and January 2024, the STPs' effluent water quality parameter ranges were assessed against the effluent discharge standards prescribed by MPCB, which are in line with the 2019 Nation Green Tribunal's (NGT) directions (MPCB 2022; NGT 2019). Further, the average water quality achieved by STPs was compared to the performance standards of treatment technologies at the secondary treatment level (Tare et al. 2010).

4.6.2 Defining the minimum TUW quality standards and the required treatment levels for the identified reuse avenues

Defining TUW quality standards for specific reuse purposes is essential to reduce the health and safety risks associated with reuse. The Ministry of Housing and Urban Affairs (MoHUA) recommends certain norms for the reuse of TUW for specified purposes (MoHUA 2023). These guidelines – along with the MPCB discharge norms – inform the minimum quality standards for reuse within the identified sectors. It is to be noted that the recommendations only specify minimum quality standards. Higher quality levels can be targeted depending on reuse requirements.

As mentioned in Section 1, treatment levels are classified into primary, secondary, tertiary, and advanced levels of treatment based on the treatment process and the quality of effluent produced. Based on the water quality achieved after each treatment, this section recommends the subsequent level of treatment required for each application within every reuse sector. Expert and stakeholder consultations were also undertaken to inform the recommendations. A precautionary approach was adopted to ensure maximum safety in reuse applications.

4.7 Defining financing provisions for TUW reuse

The methodology used to estimate the financing required to strengthen the existing treatment infrastructure and establish a conveyance mechanism for reuse is presented in Annexure 5. It also discusses the funding provisions of existing national missions, along with reuse-specific business models. Further, it delves into the pricing of TUW based on the level of treatment and intended end use, which is essential for generating demand and creating a market for its uptake. The pricing structure considers the potential for cost recovery through tariffs imposed on revenue-generating sectors such as commercial establishments and industries. This estimation accounts for the costs associated with upgrading some of the existing technology to the targeted tertiary treatment capacity – as a percentage of total actual treatment – by 2046 (refer to Section 3). Three different scenarios have been developed for commercial establishments and industries to evaluate the tariffs necessary for TMC to recover treatment costs. Scenario 1 assumes that both the TUW and freshwater is sold at the same price for commercial and industrial purposes in TMC. Scenario 2 considers the price at which tertiary-level TUW is being sold to commercial and industrial users in Pimpri–Chinchwad Municipal Corporation, i.e., at a rate 30 per cent less than that of freshwater. Scenario 3 considers a TUW price that is 20 per cent lesser than freshwater in TMC. This can ensure that TMC recovers the cost of treatment technology upgradation.

4.8 Developing an implementation framework

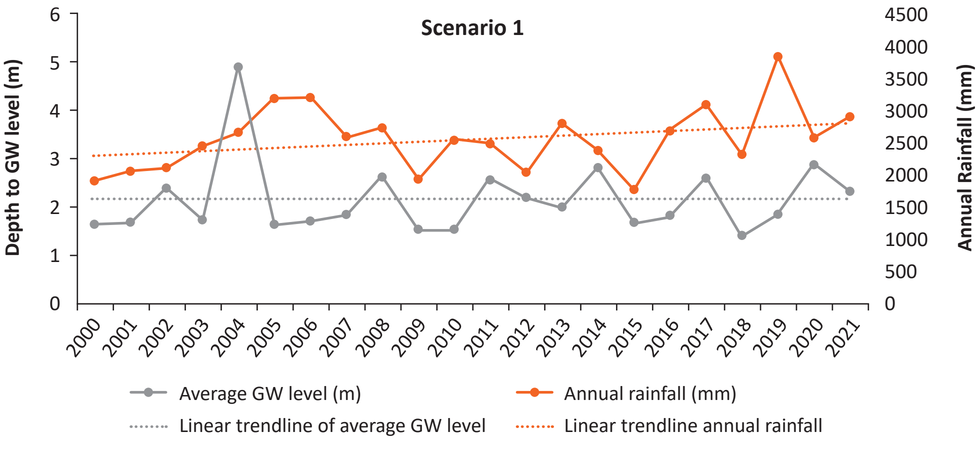
The Reuse Plan's implementation framework lays out the standard operating procedures for the identified reuse avenues (and applications), which are organised reuse-zone-wise (details provided in Annexure 6). Further, it defines the roles and responsibilities of nodal departments with respect to the recommended intervention areas. It also defines the role of the monitoring committee, recommended to be set up as the nodal monitoring agency at the ULB level. This section also evaluates the knowledge gaps and capacity-building needs of relevant departments in the TMC for the successful implementation of the Reuse Plan (details provided in Annexure 7).

5. Trend analysis of depth-to-groundwater level in TMC

All three scenarios (refer to Section 4.1.1) highlight the declining depth-to-groundwater levels in Thane City despite increasing rainfall over 20 years (2000–21). A negative correlation (Figure 5) between groundwater levels and rainfall has also been observed. Since 2000, the minimum (1,789.58 mm) and maximum (3,864.08 mm) annual rainfall occurred in 2015 and 2019 respectively. The corresponding average annual groundwater levels were observed to be 1.67 m and 1.84 m, respectively. This negative correlation was observed even in pre- and post-monsoon groundwater levels, which are generally expected to be directly influenced by the amount of rainfall. Despite the increasing trend in rainfall, groundwater levels during the pre- and post-monsoon months witnessed a decline of 10 cm (Figure 6) and 2 cm (Figure 7), respectively, over the last 20 years.

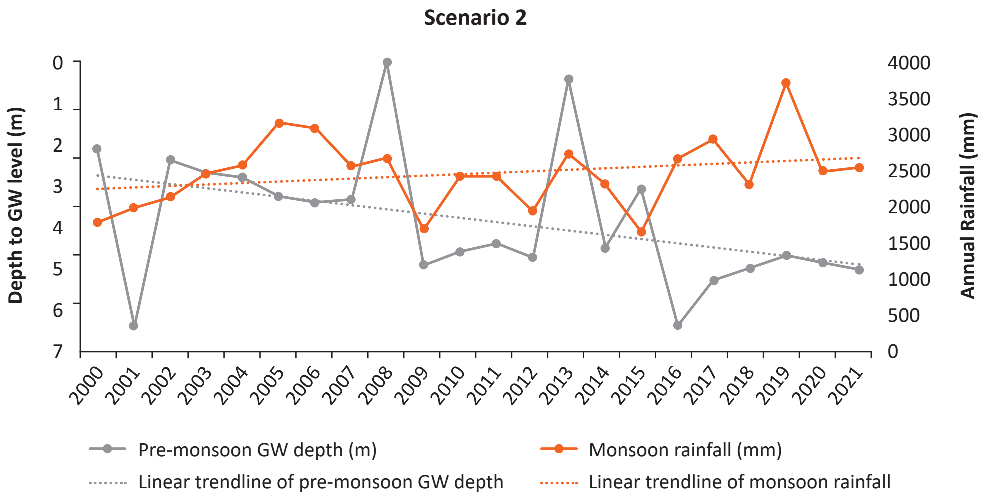
The declining trend in pre-monsoon groundwater levels in TMC – despite the increase in rainfall – can be attributed to the rapid rise in groundwater extraction, which has outpaced the natural recharge rate. In recent years, Thane City has witnessed a sharp increase in water demand from various sectors. In the absence of regulation, groundwater has become the primary source to meet this demand. To arrest the declining trend in groundwater levels and its rapid extraction, there is an urgent need to mainstream the reuse of TUW as a viable alternative to meet the rising water demand. However, initiatives to mainstream the reuse of TUW must be backed by robust and stringent groundwater regulations for its effective implementation and wider acceptance.

Figure 5: An inverse relationship between rainfall received and average annual groundwater level has been observed in the past 20 years



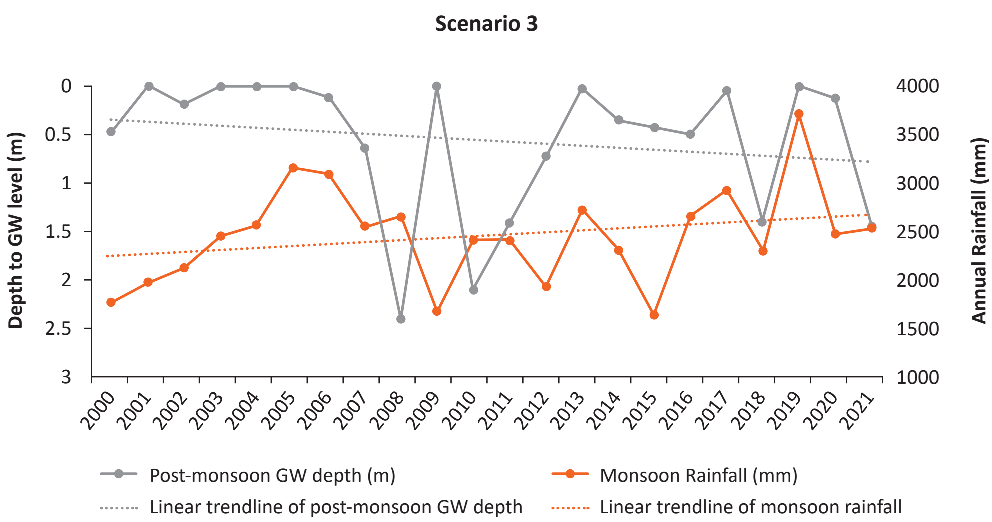
Source: Authors' analysis using data from India–WRIS. 2022. Groundwater Behaviour. India–Water Resource Information System, Department of Water Resources, RD & GR, Ministry of Jal Shakti, Government of India, and IMD. 2021. District-wise Rainfall Distribution (Daily and Cumulative). India Meterological Department, Ministry of Earth Sciences, Government of India

Figure 6: Pre-monsoon groundwater depth is declining at the rate of 10 cm per year



Source: Authors' analysis using data from India–WRIS. 2022. Groundwater Behaviour. India–Water Resource Information System, Department of Water Resources, RD & GR, Ministry of Jal Shakti, Government of India, and IMD. 2021. District-wise Rainfall Distribution (Daily and Cumulative). India Meterological Department, Ministry of Earth Sciences, Government of India

Figure 7: Post-monsoon groundwater depth is declining at the rate of 2 cm per year



Source: Authors' analysis using data from India–WRIS. 2022. Groundwater Behaviour. *India–Water Resource Information System, Department of Water Resources, RD & GR, Ministry of Jal Shakti, Government of India, and IMD. 2021. District-wise Rainfall Distribution (Daily and Cumulative). India Meterological Department, Ministry of Earth Sciences, Government of India*

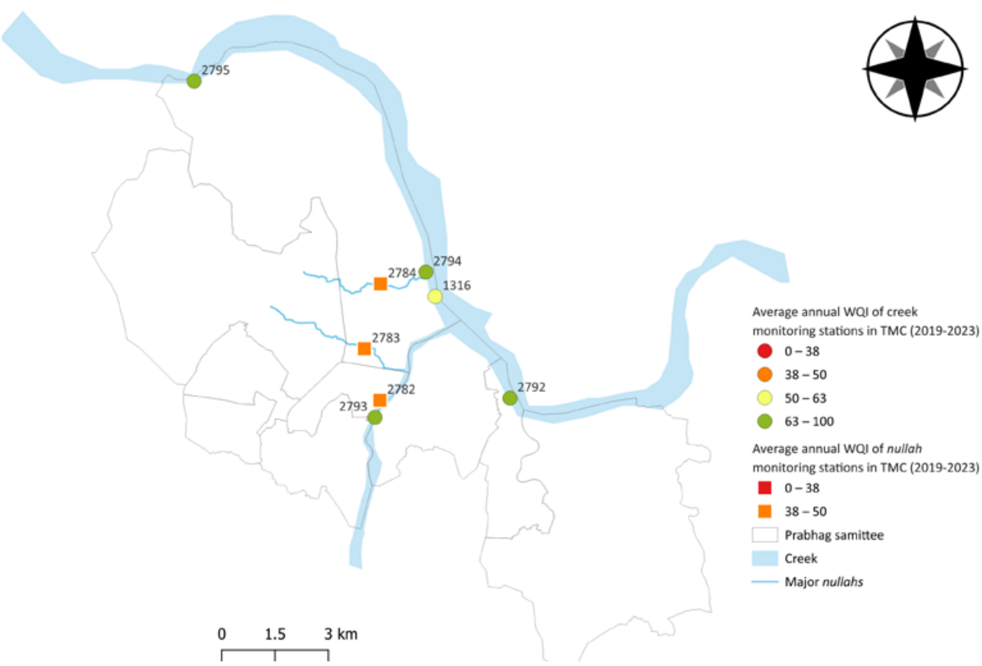
6. Water quality of groundwater and surface water sources in TMC

The WQI has been computed to assess the quality of freshwater resources in TMC over a five-year period (2019–2023). The water quality of surface water and groundwater bodies is described below.

6.1 Surface water quality

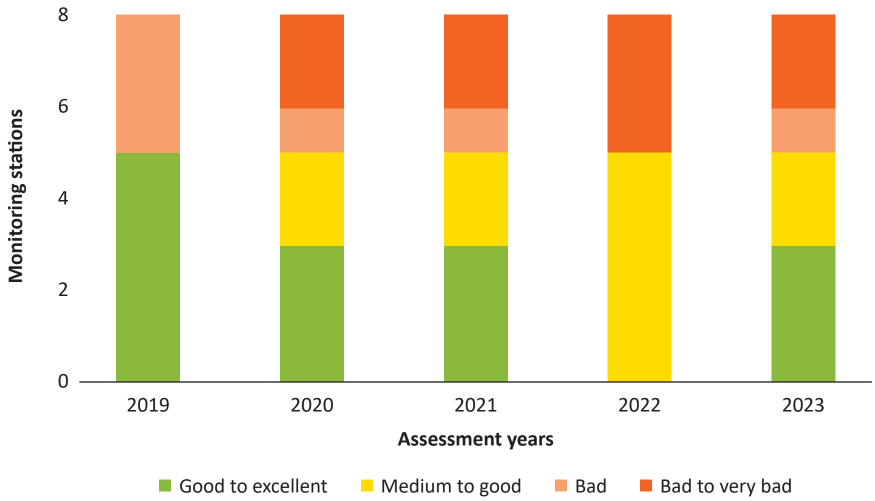
Water quality analysis of surface water bodies in TMC using data from eight surface water monitoring stations, reveals that the annual average WQI of three *nullahs* falls in the poor category in all the assessment years. Their five-year annual average WQI ranges between 38–41 (Figure 8). Annually, more than 50 per cent of the samples collected from these three monitoring stations – numbered 2782, 2783, and 2784 – have been observed to be polluted (TERI 2019, 2020, 2022, 2023, 2024). The five-year annual average WQI of monitoring stations along the creek ranges between 60–67, indicating a non-polluted status (Figure 8). The distribution of WQI across the WQI scale (Table A2) over five years is illustrated in Figure 9.

Figure 8: WQI of the three nullahs being monitored in TMC falls in the poor category between 2019–2023



Source: Authors' analysis using data from MPCB. 2014. Water Quality Monitoring Network in Maharashtra. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

Figure 9: Three out of eight monitoring stations in TMC remain polluted across all assessment years (2019–2023)



Source: Authors' analysis using data from MPCB. 2014. Water Quality Monitoring Network in Maharashtra. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

The seasonal analysis of surface water quality is presented in Annexure 8.

6.2 Groundwater quality

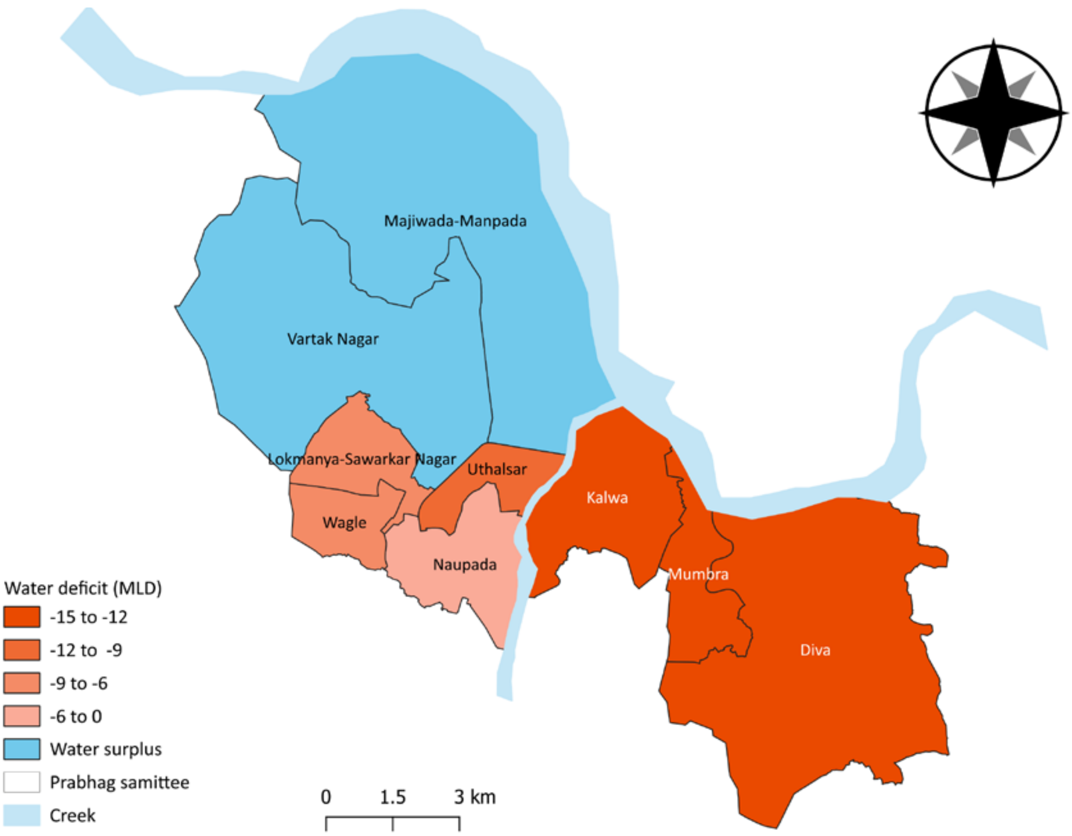
The Bhaindarpada groundwater monitoring station's WQI was classified as poor or lying under polluted status in both assessment years of 2018 and 2022. The annual groundwater quality index decreased from 130.55 in 2018 to 185.15 in 2022, with a higher groundwater quality index indicating lower water quality.

Several geogenic and anthropogenic factors may affect groundwater quality, namely the topography, geology, the nature of the aquifer, extensive extraction, and pollution of water resources (Ravi, Srinivasa, and Krupavathi 2024; Abanyie et al. 2023). Although all the assessed water quality parameters currently fall within acceptable limits, eight of the nine measured parameters showed elevated levels during the period of assessment (2018–2022). Notably, between 2018 and 2022, concentrations of nitrate, fluoride, and TDS doubled from 9 mg/l, 0.12 mg/l, and 223 mg/l to 25 mg/l, 0.36 mg/l, and 404 mg/l, respectively. The increasing levels of TDS and nitrogen may be attributed to the infiltration of water contaminated by industrial or municipal effluent and unlined drainage or sewerage pipes (Ravi, Srinivasa, and Krupavathi 2024; Sunitha and Muralidhara 2022). If the current rate of water quality deterioration continues, groundwater in Thane City may become unsuitable for human consumption.

7. City water balance

The results of the water balance exercise indicate a 53 MLD deficit in the actual water supply for domestic and commercial uses in TMC (Table 2) as compared to the water demand. The most significant water deficit was recorded in Mumbra (-15 MLD), Kalwa (-14 MLD) and Diva (-12 MLD), followed by Uthalsar (-11 MLD), Lokmanya Nagar (-7 MLD), Wagle (-6 MLD) and Naupada–Kopari (-2 MLD) administrative wards. The Majiwada–Manpada and Vartak Nagar administrative wards have a positive water balance (Figure 10).

Figure 10: Seven out of nine administrative wards in TMC show water deficit



Source: Authors' analysis based on data from TMC, Water Supply Department

The current water supply capacity in administrative wards reporting a deficit is inadequate to fulfil the required domestic and commercial demand. A high NRW share of 30 per cent exaggerates the gap between the water supply and demand. Non-revenue water (NRW) in TMC is higher than the Central Public Health and Environmental Engineering Organisation (CPHEEO) benchmark of 20

Table 2: Administrative ward-wise water deficit in TMC

S. No.	Administrative ward	Actual water supply (surface water supply + groundwater supply - non-revenue water)	Total water demand (domestic + commercial demand)	Water deficit (actual water supply - total water demand)
		in MLD		
1.	Majiwada–Manpada	76	68	9
2.	Vartak Nagar	40	36	4
3.	Lokmanya Nagar	34	41	-7
4.	Wagle	32	38	-6
5.	Naupada–Kopari	48	50	-2
6.	Uthalsar	40	51	-11
7.	Kalwa	45	59	-14
8.	Mumbra	45	60	-15
9.	Diva	46	58	-12
Total		**407**	**460**	**-53**

Source: Authors' analysis using data provided by TMC, Water Supply Department

per cent set under the Service-Level Benchmarking Framework for ULBs (Ministry of Housing and Urban Affairs 2008).

If the current rate of population growth continues, the population of TMC will more than double by 2046 compared to the city's current population in 2024 (Table A7). The water supply must be augmented to bridge the existing water deficit and meet the growing demand. We assume that informal sources such as private bore wells meet the current water deficit. As previously discussed (Section 5), the groundwater level in TMC is witnessing a steady decline due to rapid extraction. An increase in demand will thus increase the pressure on groundwater resources, causing over-abstraction and further depletion.

The city currently generates 328 MLD of domestic used water (Table A7). The total installed treatment capacity is 396 MLD; however, only 241 MLD is presently in use. Therefore, 39 per cent of the used water remains untreated. Of the total TUW, about 12 MLD is being reused for municipal uses. The remaining treated and untreated used water is discharged into surface drains. The effect on water quality is evidenced by the polluted status of surface *nullahs* (Section 6.1) and deteriorating groundwater quality (Section 6.2). Maximising used water treatment and safe reuse can help close the gap between supply and demand in two ways. One is through indirect groundwater recharge using TUW, and second, by using TUW directly for non-potable purposes. Hence, strengthening used water management can reduce the city's dependence on freshwater to meet its growing water demand, prevent the misuse of groundwater resources, and improve the quality of local sources of water. Table 3 shows the current and targeted levels of TUW reuse (Section 3), which can indirectly address TMC's water deficit.

Table 3: Projected water demand and water deficit vis-a-vis the population from 2015 to 2046

Year	2015	2024	2035	2046
Population	21,82,868	30,67,216	51,08,811	81,55,126
Total water demand (MLD)	327	460	766	1,223
Water deficit (MLD)	38	53	80	120
Current and future TUW reuse potential (MLD)	–	65 (currently only 12 MLD is reused)	77	88

Source: Authors' analysis using data provided by TMC, Water Supply Department

8. Used water management in TMC

TMC is categorised as a leading ULB with a composite index score of 2.83 out of 5 under the MUWM index (Table 4). Its performance in overall used water management is better than 98 per cent of the ULBs assessed. TMC is performing exceptionally well in the finance theme across all three parameters – investment in sewage and septage management, cost recovery in used water management, and efficiency of sewage charge collection. However, given its current infrastructural capacity and operational efficiency levels, it can treat only 73 per cent of the total used water generated. Further, only 5 per cent of the used water received for treatment is currently being reused. There is a need to instrumentalise financial resources to strengthen the structural and non-structural infrastructure required to achieve the maximum treatment and reuse of used water. The strengths, weaknesses, opportunities, and threats within all five assessment themes of the MUWM index are presented in Annexure 9.

Table 4: The composite index score and theme scores of TMC using the MUWM framework

Theme	Scores	Maximum	Category
Finance	2.83	3.00	Outstanding
Infrastructure	4.22	6.00	Leading
Efficiency	3.29	6.00	Performing
Governance	3.04	7.00	Performing
Data and information	0.71	3.00	Promising
Composite index score	**2.83**	**5.00**	**Leading**

Source: Authors' analysis using data from Gupta, Saiba, Kartikey Chaturvedi, Ayushi Kashyap, and Nitin Bassi. 2024. Enabling Circular Economy in Used Water Management in India: A Municipal Index for Assessing Urban Local Bodies' Performance

Reuse of treated used water for fire-fighting.

9. Identified TUW reuse avenues in TMC

The *Maharashtra State Water Policy 2019* obligates ULBs to make the entire quantity of generated sewage under their jurisdiction available for reuse after treating it to the standards prescribed by the MPCB. Both the NF-SRTW and the *Maharashtra State Water Policy* promote the reuse of TUW for non-potable uses. 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 in the city, TUW availability, and level of treatment.

Such demand-profiling at the ULB level helps identify the different local reuse contexts that exist in a ULB. The quality parameters that the TUW needs to meet is set based on the identified users, further influencing the design of treatment systems in terms of the treatment technologies adopted. Such an approach can ensure the feasibility of reuse projects. In cases where treatment systems are yet to be set up, they can be located close to sources of demand. This will bring down conveyance costs, making reuse viable.

Based on the present situation in Thane City and consultations with relevant TMC departments (ES Figure 2), certain avenues and applications have been identified for reusing TUW in TMC (Table 5). This can reduce the pressure on existing freshwater resources and improve TMC's water environment.

Table 5: Identified TUW reuse avenues in TMC

S.No	Reuse avenue	Applications	Provisions
1.	Landscaping	Parks	Irrigation requirements of municipal parks, gardens, road dividers, and stadiums can be met through TUW.
		Road dividers	
		Stadiums	
2.	Cleaning	Bus depots (vehicle and wheel washing)	TUW of specified quality can be used to clean buses (wheels & exteriors) and roads, cleaning requirements within STP facilities, and TMC office.
		Roads	
		STP facilities	
		TMC office (Mahapalika Bhavan)	
3.	Construction sites	Landscaping	TUW can be used during construction activities to suppress dust and clean aggregate, concrete batching plants, machinery, roads, vehicles. It can also be used for landscaping on construction sites.
		Dust suppression	
		Cleaning (aggregate, concrete batching plants, vehicles)	

S.No	Reuse avenue	Applications	Provisions
4.	Fire stations	Maintaining water storage systems for firefighting	TUW treated to specified quality standards can be used in fire hydrant systems.
5.	Industries	Industrial cooling, spraying in mine pits, boiler feed	Manufacturing industrial units can use TUW of specified quality for cooling and cleaning purposes and as process water.
		Processing where water gets polluted and pollutants are not easily biodegradable	
		Processing where water gets polluted and pollutants are easily biodegradable	
		Domestic purposes (cleaning requirements)	
6.	Commercial establishments (malls, offices)	Commercial cooling	Commercial water chillers can use TUW of specified quality for their cooling requirements and for cleaning within commercial establishments' premises.
		Commercial establishments cleaning	
7.	Public utilities	Toilet flushing	TUW of specified quality can be used for flushing in public toilets.
8.	Waterbody rejuvenation and indirect groundwater recharge	Discharge into surface water bodies such as creeks and lakes	Used water should be treated before it can be discharged into surface water bodies in the city. This is a significant reuse avenue that can rejuvenate urban water bodies and indirectly recharge groundwater.

Source: Authors' analysis

10. Allocation and conveyance mechanism for the reuse of TUW

To define an allocation mechanism for the available TUW, the water demand of the identified reuse avenues needs to be estimated. This can ensure optimal allocation of TUW (Section 9) according to the users' specific requirements. Based on the methodology defined in Annexure 4, the current estimated reuse potential for the city ranges from 59 to 72 MLD, with an average of 65 MLD or 23,725 million litres per annum (Table 6a). This accounts for 27 per cent of the current actual treatment in TMC. Additionally, the discharge of TUW that meets specific quality standards into surface water bodies (Section 11.2) is a significant aspect of used water management, as ensuring that no untreated used water is discharged into water bodies is essential for preventing them from being polluted.

Based on the *Draft Revised Development Plan Thane 2026–2046*, the TUW water requirement for selected reuse avenues has been projected for the year 2046. The plan prioritises urban renewal as a flagship scheme, demarcating 46 areas across all ward committees that will undergo substantial redevelopment and construction activities. Thus, the construction sector is expected to be a significant reuse avenue in the upcoming years, and its water requirement is expected to rise from 1.9 MLD in 2024 (Table 6a) to 7.8 MLD by 2046 (Table 7). Similarly, with an increase in green cover, the TUW requirement for parks and gardens is projected to increase from 2.25 MLD in 2024 to 5.36 MLD by 2046 (Table 6b). The development plan underlines the importance of bus-based public transportation to promote sustainable mobility, stating that the bus fleet will be increased from 474 in 2024 to 666 by 2046. This will further increase water requirements by more than 1 lakh litres per day by 2046. Taking into account these additional water requirements, the TUW reuse potential is estimated to be 88 MLD (average of 79 and 97 MLD) by 2046 (Table 6b). Thus, the potential to reuse TUW is bound to increase in the upcoming years.

Table 6: Treated used water quantity requirement estimates for the identified reuse avenues

a) Current TUW quantity requirements (2024)

S.No.	Reuse avenues	TUW quantity requirements (MLD)			
		Applications	TMC estimates	Min. TUW (MLD)	Max. TUW (MLD)
1.	Landscaping	Parks	Total area = 8,99,325 sq. m. Water requirement = 2.5 litres per day per sq. m.	2.25	2.25
		Road dividers	Total area = 1,11,448 sq. m. Water requirement = 2.5 litres per day per sq. m.	0.28	0.28

S.No.	Reuse avenues	TUW quantity requirements (MLD)			
		Applications	TMC estimates	Min. TUW (MLD)	Max. TUW (MLD)
		Stadiums (secondary treatment)	Data provided during consultation	0.073	0.18
2.	Cleaning	Bus depot (vehicle exterior & wheel washing) (tertiary treatment)	Number of buses = 474 Water requirement range per bus = 150–400 litres per day	0.07	0.19
		Roads (secondary treatment)	Total road area = 5.27 million sq. m. Water requirement = 0.28 litre per sq. m. per day.	1.48	1.48
		STP facilities (secondary treatment)	Data provided during consultation	11.80	11.80
		TMC office (Mahapalika Bhavan) (tertiary treatment)	TMC office area = 17,140 sq. m. Water requirement = 1 litre per sq. m. per day	0.02	0.02
3.	Construction sites	Landscaping (secondary treatment) Dust suppression (tertiary treatment) Cleaning (aggregate, concrete batching plants, vehicles) (tertiary treatment)	Total area under construction = 4,70,31, 728 sq. ft. Water requirement range per sq. ft. = 0.037–0.044 litres per day	1.76	2.09
4.	Fire stations	Maintaining water storage system for firefighting (tertiary treatment)	Total storage capacity = 2,62,000 litres Refills per year = 24	0.02	0.03
5.	Industries	Industrial cooling, spraying in mine pits, boiler feed (tertiary treatment) Processing where water gets polluted and pollutants are not easily biodegradable (tertiary treatment) Processing whereby water gets polluted and pollutants are easily biodegradable (tertiary treatment) Domestic purposes (cleaning) (tertiary treatment)	Data accessed through MPCB portal	6.70	6.70
6.	Commercial cooling establish-ments (malls, offices)	Commercial cooling (tertiary treatment)	Total refrigeration capacity = 21,475 tonnes of refrigeration Total make-up water requirement range = 240–633.84 litres per day	3.61	9.53
		Cleaning of commercial sites (malls, hospitals, offices) (tertiary treatment)	Total commercial area = 7,68,613 sq. m. Water requirement = 1 litre per sq. m. per day	0.77	0.77
7.	Public utilities	Toilet flushing (tertiary treatment)	Data provided during consultations	20.00	25.00
Total estimate reuse potential (MLD)				49	60
Total estimate reuse potential (MLD) assuming water loss of 20% (i)				**59**	**72**

Secondary treatment   Tertiary treatment

Source: Authors' analysis based on data from different sources mentioned in Annexure 4

b) Future TUW reuse quantity requirements (2046)

S.No.	Reuse avenues	Additional TUW quantity requirements (MLD)		
		Activities	Min. TUW (MLD)	Max. TUW (MLD)
1.	Landscaping	Parks & gardens Stadium	8	8
2.	Cleaning	Bus depot	0.03	0.08
3.	Construction sites	Landscaping Dust suppression Cleaning (aggregate, concrete batching plants, vehicles)	7	8
4.	Fire stations	Maintaining water storage system for firefighting	0.02	0.04
5.	Commercial cooling establishments (malls, offices)	Commercial cooling	2	4
Total estimate of increase in reuse potential (MLD)			17	20
Total estimate of increase in reuse potential (MLD) assuming water loss of 20% (ii)			**20**	**24**
Total estimate reuse potential for 2046 (i + ii)			**79**	**97**

Secondary treatment   Tertiary treatment

Source: Authors' analysis based on data from sources mentioned in Annexure 4

For ease of implementation, the TUW can be allocated zone-wise, considering the installed treatment capacity (and actual treatment) of existing and planned treatment infrastructure, and the TUW requirements of reuse avenues located within the zones. Five reuse zones – corresponding to TMC's sewage zones – have been defined within the city. Existing treatment infrastructure (point of treatment) and reuse avenues (point of reuse) are mapped spatially (ES Figure 3) within each zone. Defining reuse zones will enable zone-wise planning for water allocation and developing infrastructure for used water treatment and conveyance – from the point of treatment to the point of reuse.

The allocation priorities for the reuse of TUW in Thane City are based on the following criteria.

- **Used water treatment level required**: Reuse avenues that meet the quality standards of existing treatment infrastructure in TMC will be prioritised. The currently available TUW in TMC can help meet this water demand, thereby reducing the consumption of freshwater resources. Hence, reuse avenues that can use secondary-level TUW will be priority users. These include landscaping, wheel washing, road cleaning, etc.

- **Quantity of TUW required**: Reuse avenues with a minimum water demand of 1 MLD will be prioritised. Irrigation of road dividers and stadiums, washing requirements at bus depots, and maintenance of water storage systems for firefighting are identified as low-priority users of TUW.

- **Frequency of TUW required**: Reuse avenues with regular water supply requirements will be prioritised. This includes parks, since they require irrigation every alternate day.

- **Distance from STP**: The ease of conveying TUW from the point of treatment to the point of reuse is governed by the distance of the reuse avenue from the closest STP. Reuse avenues within a 0.75–1.25 km radius of STPs will be prioritised (ES Figure 3). A radius of 1 km from the STP is considered a short distance, with many reuse avenues falling within the range of 0.75–1.25 km.

- **Spatial distribution**: Another essential aspect to be taken into account for allocation and conveyance of TUW is the spatial distribution of reuse avenues within the city. Reuse avenues located in clusters will be prioritised. For instance, commercial cooling sites (malls, offices, and hospitals located on Ghodbunder Road) and construction sites located in clusters will be prioritised.

Table 7 applies these criteria to the identified reuse avenues to derive the potential priority uses for TUW, based on the current scenario. It is to be noted that this is a relative assessment – certain reuse avenues may fulfil one or more criteria and yet not be classified as a priority use relative to other uses.

Table 7: Criteria for TUW allocation

<table>
<tr><th rowspan="2">S.No.</th><th rowspan="2">Reuse avenue</th><th rowspan="2">Application</th><th>Used water treatment level required</th><th>Quantity of TUW required</th><th>Frequency of TUW required</th><th>Distance from STP</th><th>Spatial distribution</th></tr>
<tr><th>Water quality required aligns with available TUW quality</th><th>Min. 1 MLD TUW required per day</th><th>Regular water supply required</th><th>End user lies within 0.75–1.25 km of STP</th><th>Reuse avenue is predominantly present in clusters across the city</th></tr>
<tr><td rowspan="3">1.</td><td rowspan="3">Landscaping</td><td>Parks</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>×</td></tr>
<tr><td>Road dividers</td><td>✓</td><td>×</td><td>✓</td><td>×</td><td>×</td></tr>
<tr><td>Stadiums</td><td>✓</td><td>×</td><td>✓</td><td>✓</td><td>×</td></tr>
<tr><td rowspan="3">2.</td><td rowspan="3">Cleaning</td><td>Bus depots (Vehicle exterior and wheel washing)</td><td>×</td><td>×</td><td>✓</td><td>×</td><td>×</td></tr>
<tr><td>Roads</td><td>✓</td><td>✓</td><td>✓</td><td>*</td><td>×</td></tr>
<tr><td>STP facilities</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td rowspan="3">3.</td><td rowspan="3">Construction sites</td><td>Landscaping</td><td rowspan="3">×</td><td rowspan="3">✓</td><td rowspan="3">✓</td><td rowspan="3">*</td><td rowspan="3">✓</td></tr>
<tr><td>Dust suppression</td></tr>
<tr><td>Washing (aggregate, vehicles)</td></tr>
<tr><td>4.</td><td>Fire stations</td><td>Maintaining water storage system</td><td>×</td><td>×</td><td>×</td><td>✓</td><td>×</td></tr>
<tr><td rowspan="4">5.</td><td rowspan="4">Industries</td><td>Landscaping</td><td rowspan="4">×</td><td rowspan="4">✓</td><td rowspan="4">✓</td><td rowspan="4">*</td><td rowspan="4">×</td></tr>
<tr><td>Cleaning and industrial floor washing</td></tr>
<tr><td>Vehicle washing</td></tr>
<tr><td>Manufacturing and processing</td></tr>
</table>

S.No.	Reuse avenue	Application	Used water treatment level required	Quantity of TUW required	Frequency of TUW required	Distance from STP	Spatial distribution
6.	Commercial establish-ments (malls, offices)	Cooling water	×	✓	✓	×	✓
7.	Public utilities	Toilet flushing	×	✓	✓	*	*
8.	Environment	Waterbody rejuvenation and indirect groundwater recharge	×	✓	×	×	×

Source: Authors' analysis using data from TMC
** indicates non-applicability or absence of relevant information to make an inference*

The following considerations should also be considered for TUW allocation planning.

- **Willingness to pay**: Users willing to share the cost incurred in conveying the TUW will be prioritised. These can include bulk private users such as industries, commercial users (malls and offices), and private developers (construction sector).
- **Unavailability of TUW**: New infrastructure for collecting and treating used water will need to be developed in areas where TUW is unavailable. In TMC, sewage zone phase V, in Diva ward, is under development. Hence, a sewerage network will need to be developed for existing developments in this area. Further, any new developments here should construct a decentralised sewage treatment system with dual piping.

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

1. Cleaning requirements in STP facilities
2. Landscaping within parks and gardens
3. Cooling water requirements in commercial establishments
4. Identified applications within industries
5. Identified applications within construction sites
6. Landscaping within stadiums
7. Cleaning roads
8. Toilet flushing in public utilities
9. Cleaning commercial establishments
10. Landscaping within road dividers

These priority areas have been identified based on the city's current scenario. They can be redefined to align with planned future development. For instance, under the *Urban Renewal Scheme (Draft Revised Development Plan Thane 2026–2046)*, many parts of TMC are expected to undergo large-scale redevelopment. This will shift focus to the construction sector (Table 6b), requiring TUW allocation to meet the rising water demand. Further, the above allocation criteria (Table 7) have been used to recommend feasible conveyance mechanisms for TUW from the point of treatment to the point of reuse (Table 8). While these criteria inform the preferred mode of conveyance, this is subject to individual case considerations (Section 13.1).

Table 8: Rationale for the recommended conveyance mechanism

S. No.	Conveyance mechanism	Used water treatment level required	Quantity of TUW required	Frequency of TUW required	Distance from STP	Spatial distribution
1.	Tankers	Tankers can be used to convey currently available secondary treated water in lower volumes	Transporting higher water volumes in tankers requires more trips, resulting in higher costs and emissions per unit of water transported	Regular TUW supply in tankers will require more fuel per unit of water transported, making it an environmentally unsustainable option	Generally, tankers are not a preferred option for longer distances due to higher costs and environmental externalities linked to fuel consumption	Leveraging road network connectivity, tankers can transport TUW to spatially scattered reuse avenues
2.	Pipelines	Pipelines are a preferred conveyance mode when a higher level of treatment is required. A piped network would ensure continuous supply in both centralised and decentralised tertiary treatment units	Pipelines are an environment-friendly and cost-effective solution for conveyance when a higher water volume is required	Laying a pipeline distribution network is a one-time investment to establish a mode of conveyance for regular TUW supply	Laying pipelines is preferred for longer distances because they are more cost-effective than tankers	Land-use constraints may limit the construction of new infrastructure such as pipeline distribution. Pipelines are preferred where reuse avenues are present in clusters.

Source: Authors' analysis based on Verma, Jyoti, Rahul Sachdeva, Mehak Aggarwal, Victor R. Shinde, Dheeraj Joshi, Sumit Chakraborty, Ashwini Dubey, Nitin Bassi, Saiba Gupta, Kartikey Chaturvedi, and Ayushi Kashyap. 2024. Toolkit for Preparing City Action Plans for Reuse of Treated Used Water. New Delhi: National Institute of Urban Affairs, National Mission for Clean Ganga, and Council on Energy, Environment and Water, and Ramaiah, Manish, Ram Avtar, and Pankaj Kumar. 2022. Treated Wastewater Use for Maintenance of Urban Green Spaces for Enhancing Regulatory Ecosystem Services and Securing Groundwater. Hydrology 9(10): 180

11. Sector-specific TUW quality standards and treatment levels

Maintaining the prescribed quality standards and defining reuse-specific TUW standards is essential for the safe reuse of TUW. First, the TUW discharged must comply with surface water discharge standards, and second, it must meet fit-for-purpose quality standards recommended by national and state agencies. This minimises risks to public health and the environment. The current water quality of the TUW generated in TMC, and the quality standards required for safe reuse within each identified reuse avenue, is discussed below.

11.1 Effluent water quality of existing STPs in TMC

Table 9 presents the average effluent water quality of existing STPs in TMC against MPCB-prescribed effluent discharge standards (MPCB 2022; NGT 2019). The effluent quality produced falls within the prescribed limits for most parameters except BOD. In the period of analysis, the average BOD content of the effluent produced from STPs in Kopari (23 mg/l), Hiranandani (20.8 mg/l), and Everest World (10.8 mg/l) breached the prescribed discharge limit.

Table 9: Prescribed STP discharge standards and the effluent water quality of existing STPs in TMC

S. No.	Parameter	MPCB standards	Recorded range of parameter value
1.	pH	6.5–9.0	7.1–7.3
2.	BOD (mg/l)	10	7.6–23
3.	COD (mg/l)	50	26–42
4.	TSS (mg/l)	20	13–23
5.	Ammonia (Nh4–N) (mg/l)	5	0.5–1.4
6.	Total nitrogen (mg/l)	10	1–3.2
7.	FC (MPN/100 ml)	100	Present
8.	Oil and grease (mg/l)	–	5.5–9.2

Parameter breaches the technology-specific performance standard

Source: Authors' analysis using data from MPCB. 2022. Consent to 1st Operate for 5 Nos of STP & Renewal of Consent to Operate for 9 Nos of STP's at Different Location in Thane Region. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

The existing STPs at TMC undertake secondary-level treatment using two types of treatment technologies. Kopari, Mumbra, Hiranandani, and Nagla Bunder have deployed the sequential batch reactor (SBR) technology, while the Vitava, Everest World, Lodha, and Kharegaon plants use the moving bed biofilm reactor (MBBR) technology. Currently, STPs installed with SBR technology are less efficient than plants using MBBR technology (Table 10). The performance of each technology is measured and compared in terms of effluent TSS and BOD removal (Tare et al. 2010).

Table 10: Performance comparison of current treatment efficiency of installed treatment technologies

S. No.	STP	Assessment parameter of performance	
		TSS removal	BOD removal
	SBR	Standard: <10mg/l	Standard: <10mg/l
1.	Kopari	8	23
2.	Mumbra	15.4	10
3.	Hiranandani	9.2	20.8
4.	Nagla Bunder	14.43	7.6
	MBBR	Standard: <30 mg/l	Standard: <30 mg/l
5.	Vitava	13.1	9.6
6.	Everest World	22.8	10.9
7.	Lodha	12.75	9.9

Parameter breaches the technology-specific performance standard

Source: Authors' analysis based on data from Tare, Vinod, Purnendu Bose, Subrata Hait, Ligy Philip, A. A. Kazmi, Indu Mehrotra, A. K. Nema, Atul Mittal, and Arun Kumar. 2010. Sewage Treatment in Class I Towns: Recommendations and Guidelines. New Delhi: Ministry of Jal Shakti, Government of India, and TMC, Mechanical Department

Note: Kharegaon plant has not been commissioned as of 2023.

11.2 Reuse-specific TUW quality standards and required treatment levels

As per the CPHEEO and MPCB guidelines, the minimum water quality standards and treatment levels for reusing TUW in the identified reuse sectors are presented in Annexure 10.

Overall, all the STPs in TMC currently treat sewage up to the secondary level of treatment. In order to achieve fit-for-purpose quality standards and maximise reuse in bus depots, fire stations, construction sites, commercial cooling establishments, industries, public utilities, and for waterbody rejuvenation, the tertiary level of treatment is required. For activities that can reuse TUW treated to the secondary level, the level of the highlighted parameters (Annexure 10) – namely BOD and coliform – must comply with the desired treatment level before use. Further, this treatment must be followed by disinfection to eliminate bacteria and microbial pathogens. Regular monitoring of effluent quality is required to ensure strict adherence to quality standards. While the given recommendations adopt a precautionary approach, higher treatment standards can be targeted to meet specific user requirements.

Tertiary level of treatment is required to maximise the extent of reuse in TMC, with about 71 per cent (46 MLD or 16,866 million litres per annum) of the current estimated reuse potential (Table 6a) requiring tertiary-treated TUW (Annexure 10). Since the construction and commercial sectors are expected to emerge as key demand areas in the city's planned development, the tertiary-treated TUW requirement continues to be predominant. In 2046, it is expected to account for 67 per cent (59 MLD or 21,626 million litres per annum) of the estimated reuse potential (Table 6b).

12. Financing of TUW reuse

This section discusses the financial requirements for strengthening the existing treatment infrastructure and establishing conveyance mechanisms for TUW. It also discusses funding provisions in existing national missions and recommends business models. Finally, it highlights pricing models for TUW, which are essential for generating demand for non-conventional products.

12.1 Financing requirements for strengthening the existing treatment capacity and upgrading the existing treatment infrastructure

As elaborated in Section 2, TMC's installed secondary treatment capacity is 318 MLD (centralised). To maximise the reuse potential, TMC must install adequate tertiary treatment capacity to achieve the desired water quality standards for reuse (Section 11). This can be achieved by installing a new tertiary STP or retrofitting existing i.e. secondary STPs with tertiary or advanced technologies. This section provides the financial requirements for undertaking capacity strengthening and technology upgradation.

12.1.1 Installation of new STP

Table 11 presents the estimated net present value (NPV) per MLD, which includes the capital and O&M costs over a 30-year period for establishing a new secondary- and tertiary-level STP with the two technologies currently in use in TMC. According to the analysis, the cost of establishing a new tertiary STP is, on average, 3.5 times the cost of establishing a secondary STP.

Table 11: NPV of the new STP per MLD (in INR crore)

	SBR	MBBR
Secondary STP	1.67	1.95
Tertiary STP	6.01	6.73

Source: Authors' analysis based on data from Tare, Vinod, Purnendu Bose, Subrata Hait, Ligy Philip, A. A. Kazmi, Indu Mehrotra, A. K. Nema, Atul Mittal, and Arun Kumar. 2010. Sewage Treatment in Class I Towns: Recommendations and Guidelines. New Delhi: Ministry of Jal Shakti, Government of India, and TMC, Mechanical Department

12.1.2 Technology upgradation

Alternatively, current secondary STPs can be partially or completely upgraded to tertiary STPs by retrofitting existing SBR or MBBR infrastructure with new tertiary treatment technologies. The NPV of technology upgradation is INR 4.34 crore per MLD in the case of an SBR plant, and INR 4.78 crore per MLD in the case of an MBBR plant (Table 12). Table 12 also presents the capital and O&M costs of upgradation. The additional O&M costs in the case of an MBBR plant are higher due to the associated chemical costs (Tare et al. 2010).

Table 12: NPV and its constituent capital and O&M cost of technology upgradation per MLD

NPV (including both capital and O&M) of technology upgradation per MLD (in INR crore)		
	SBR	**MBBR**
Secondary treatment	1.67	1.95
Tertiary upgradation cost	4.34	4.78
Capital cost of technology upgradation per MLD (in INR crore)		
	SBR	**MBBR**
Secondary treatment	0.68	0.89
Tertiary upgradation cost	4.20	4.20
Annualised O&M cost of technology upgradation per MLD (in INR crore)		
	SBR	**MBBR**
Secondary treatment	0.09	0.10
Tertiary upgradation cost	0.04	0.08

Source: Authors' analysis based on data from Tare, Vinod, Purnendu Bose, Subrata Hait, Ligy Philip, A. A. Kazmi, Indu Mehrotra, A. K. Nema, Atul Mittal, and Arun Kumar. 2010. Sewage Treatment in Class I Towns: Recommendations and Guidelines. New Delhi: Ministry of Jal Shakti, Government of India, and TMC, Mechanical Department

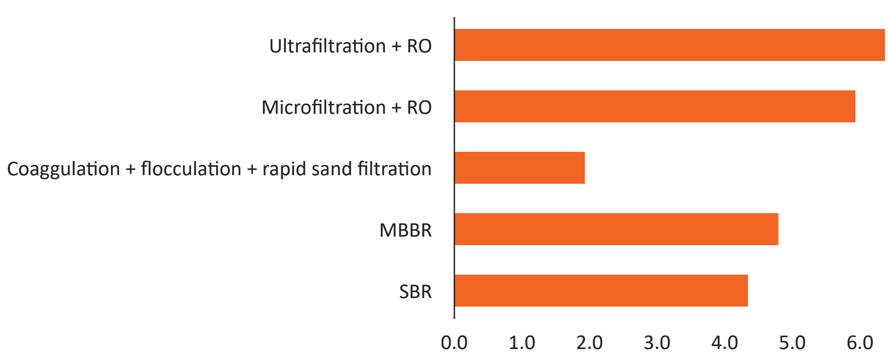
12.1.3 Technology upgradation under different scenarios

Figure 11 presents the NPV with its constituent capital and O&M costs for three different technological combinations (Srivastava and Singh 2022). As described in Section 1 (Figure 1), sand filtration is a tertiary treatment technology that removes suspended solids to produce TUW suitable for reuse in toilet flushing and other activities with the same quality requirements post-disinfection. Microfiltration (MF) and ultrafiltration (UF) produce low-grade industrial water suitable for cooling. In contrast, RO is an advanced treatment technology that produces high-grade industrial water suitable for most industrial processes (NMCG 2022).

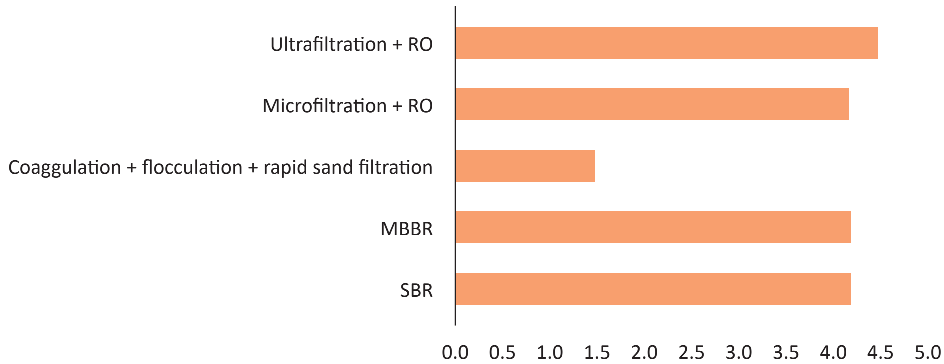
The NPV of upgrading to these technological combinations ranges from INR 1.94–6.36 crore (Figures 11). Upgrading to these treatment technologies in combination or in silos can potentially bridge the gap between the current TUW quality status and the minimum water quality required for the identified reuse avenues under the Reuse Plan. The next section elaborates on the existing and potential funding provisions required to strengthen and upgrade infrastructure capacity.

Figure 11: Cost estimates of using different technology combinations per MLD (in INR crore)

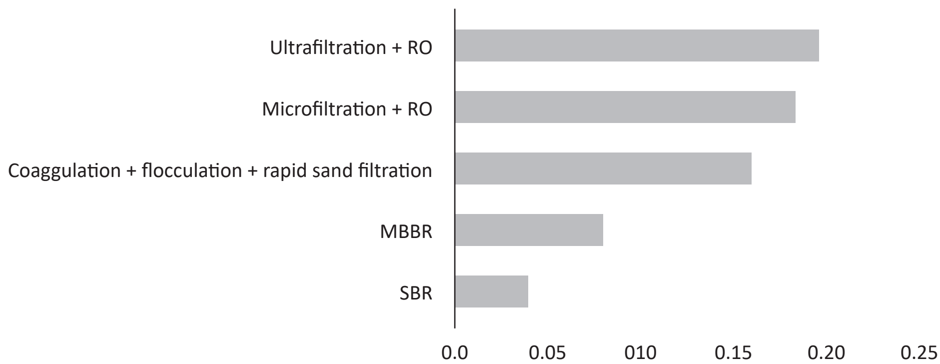
a) NPV (total) of different technology upgradation



b) Total capital cost of different technology upgradation



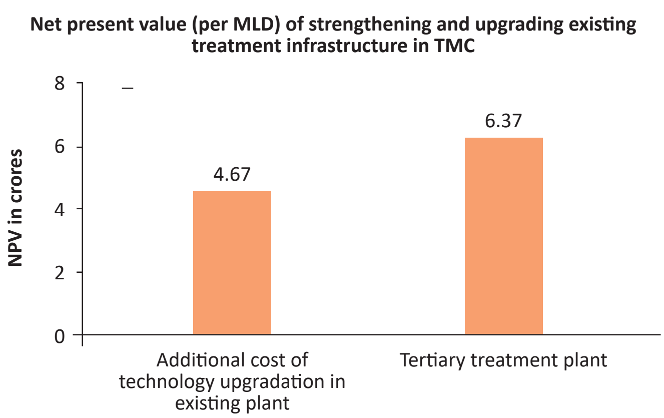
c) Annualised O&M cost of different technology upgradation



Source: Authors' analysis based on Srivastava, R. R., and Prakash K. Singh. 2022. Reuse-Focused Selection of Appropriate Technologies for Municipal Wastewater Treatment: A Multicriteria Approach. International Journal of Environmental Science and Technology 19(12): 12505–12522, and Tare, Vinod, Purnendu Bose, Subrata Hait, Ligy Philip, A. A. Kazmi, Indu Mehrotra, A. K. Nema, Atul Mittal, and Arun Kumar. 2010. Sewage Treatment in Class I Towns: Recommendations and Guidelines. New Delhi: Ministry of Jal Shakti, Government of India, and TMC, Mechanical Department

From the analysis, we can conclude that the average cost per MLD of upgradation is 2.5 times the cost of establishing a secondary STP (Table 11, 12, and Figures 11 a–c). However, technology upgradation requires significantly less investment than establishing a new tertiary STP (Figure 12). This considers both capital and O&M costs annualised over 30 years. Therefore, this approach is a more feasible alternative in the short term as it minimises the need to stretch financial and non-financial resources by utilising the existing infrastructure capacity to meet quality requirements.

Figure 12: Technology upgradation costs 31 per cent less than installing a new tertiary STP



Source: Authors' analysis based on data from Tare, Vinod, Purnendu Bose, Subrata Hait, Ligy Philip, A. A. Kazmi, Indu Mehrotra, A. K. Nema, Atul Mittal, and Arun Kumar. 2010. Sewage Treatment in Class I Towns: Recommendations and Guidelines. New Delhi: Ministry of Jal Shakti, Government of India

12.1.4 Financial requirements of establishing conveyance mechanism for TUW

Financial estimates for conveying TUW are given in Table 13 (approach is given in Annexure 5). Depending on the nature of the end user and the mode of conveyance, costs can vary. Pipeline networks require a high initial investment for laying the necessary infrastructure but have a long lifecycle of at least 20 years. Tankers, in contrast, maybe less reliable due to availability concerns and losses during transportation. They also have a higher operational cost due to fuel consumption.

Table 13: Cost comparison of conveyance mechanisms: tanker versus pipeline

S.No.	Variable	Tanker		Pipeline	
		Cost estimate	Source	Cost estimate	Source
1.	Fixed cost	INR 1,100 per tanker per day	TMC	INR 15–30 lakh/km	Ramaiah, Avtar, and Kumar (2022); Municipal Council Chhatarpur (2016)
Additional variable costs					
2.	Fuel	INR 450 per day	CWS, CRDF, and CEPT (2022); Ramaiah, Avtar, and Kumar (2022)	–	
3.	Storage tank	INR 42,756	Ramaiah, Avtar, and Kumar (2022)	INR 42,756	Ramaiah, Avtar, and Kumar (2022)
4.	Motor	INR 24,000	Ramaiah, Avtar, and Kumar (2022)	INR 1,47,130	Ramaiah, Avtar, and Kumar (2022)
5.	Labour wage	INR 12,000–15,000	CWS, CRDF, and CEPT (2022); Ramaiah, Avtar, and Kumar (2022)	INR 15,000	Ramaiah, Avtar, and Kumar (2022)

Source: Authors' analysis using data from listed sources

12.2 Funding provisions for used water management and reuse

Ongoing programmes of the Indian government which can fund TUW projects include AMRUT 2.0, SBM 2.0, *Smart City Mission*, and JJM (NMCG 2022). Additionally, we recommend incorporating TUW projects into all state-level programmes so that budgetary resources can be allocated to improve used water management at ULBs. Avenues to create special-purpose vehicles for managing sewage, financing treatment, and distribution infrastructure can also be explored. ULBs should also explore appropriate business models based on PPPs to implement TUW projects (Section 12.3). This will ensure effective risk sharing, distributed responsibility, and optimum utilisation of scarce financial resources. Moreover, ULBs can explore private-sector financing and sub-sovereign and non-sovereign funding from external funding agencies.

Incentives for implementing treated water recycling and reuse projects are offered under certain schemes such as AMRUT 2.0 and SBM 2.0. The fund allocation and fund-sharing arrangements for schemes applicable to TMC are mentioned in Table 14.

Table 14: Fund allocation and fund-sharing arrangements of national schemes for TUW projects

S. No.	Scheme	Provisions at national level			State share for project implementation in TMC		
		Targets	Fund allocation	Fund sharing arrange-ment (centre: state)	State share as a percentage of CAPEX cost	Incentive	State share in percentage for TUW recycle and reuse projects
1.	AMRUT 2.0	100% coverage of sewerage/ septage management in 500 AMRUT cities by 2025–26 20% of city water demand should be met by recycled water	Total indicative outlay is INR 2,99,000 crore, including central share of INR 76,760 crore over 5 years	25:75 (except for projects under PPP mode)	25	10	35
2.	SBM 2.0	50% of all statutory towns with < 1 lakh population will become water+ certified ULBs are targeted to recycle & reuse at least 20% of TUW	Total indicative outlay dedicated to used water management is INR 96,153 crore for over 5 years	50:50 share (for ULBs with > 1 lakh population)	35	10	45

Source: Authors' compilation using data from MoHUA. 2021. Atal Mission for Rejuvenation and Urban Transformation 2.0 (AMRUT 2.0 Making Cities Water Secure): Operational Guidelines. New Delhi: Ministry of Housing and Urban Affairs, Government of India, and SBM-U. 2021. Swachh Bharat Mission (Urban 2.0) – Operational Guidelines. Delhi: Ministry of Housing and Urban Affairs, Government of India

Note: In calculating indicative outlay, project funds dedicated to solid waste management and sanitation have been excluded.

These schemes have specific funding provisions for used water management. However, certain other programmes' funds can also contribute towards TMC's effort to develop financially viable reuse projects. The following programmes and their outlays are listed in Table 15.

Table 15: Financial outlay and funding arrangements of national schemes to mainstream used water management

S.No.	Schemes/Programmes	Financial outlay & arrangements
1.	Jal Jeevan Mission	Total estimated cost under JJM is INR 3.6 lakh crore. The fund-sharing pattern between the centre and the state is 90:10 for the Himalayan (Uttarakhand, Himachal Pradesh) and the Northeastern states, 100:0 for UTs, and 50:50 for the rest of the states.
2.	15th Finance Commission	The 15th Finance Commission has allocated INR 1.5 lakh crore in grants to ULBs for the next 5 years, comprising 100% outcome funding of INR 26,000 crore for million-plus urban agglomerations tied to water and sanitation.

Source: Authors' analysis using data from JJM. 2019. Operational Guidelines for the Implementation of Jal Jeevan Mission. New Delhi: Department of Drinking Water and Sanitation, Ministry of Jal Shakti, Government of India, and XV FC. 2020. Fifteenth Finance Commission. New Delhi: Government of India

12.3 Business models

In addition to conventional funding mechanisms, exploring innovative financing tools for TUW reuse projects can be highly beneficial. For instance, the Maharashtra government is exploring tradeable reuse certificates that use a cap-and-trade mechanism to promote TUW reuse. *The National Green Credit Programme* provides credits for voluntarily adopting environment-friendly practices such as used water treatment and reuse. The private sector can also be approached to invest in TUW projects under their CSR obligations. For instance, Hindustan Zinc Limited (HZL) contributed to Udaipur's water management by establishing a 60 MLD STP as part of its CSR obligation. The TUW from this plant is mainly reused in HZL's industries.

Adoption of innovative business models is crucial for effective implementation. The hybrid annuity model (HAM) introduced by NMCG encourages private-sector investment in used water treatment infrastructure. The government's payback mechanism is linked to the plant's performance in terms of adherence to pre-defined key performance indicators. Similarly, appropriate business models specific to reuse avenues must be explored for sustainable implementation. Some reuse-specific business models that TMC can adopt have been discussed in Annexure 11.

12.4 Pricing of TUW

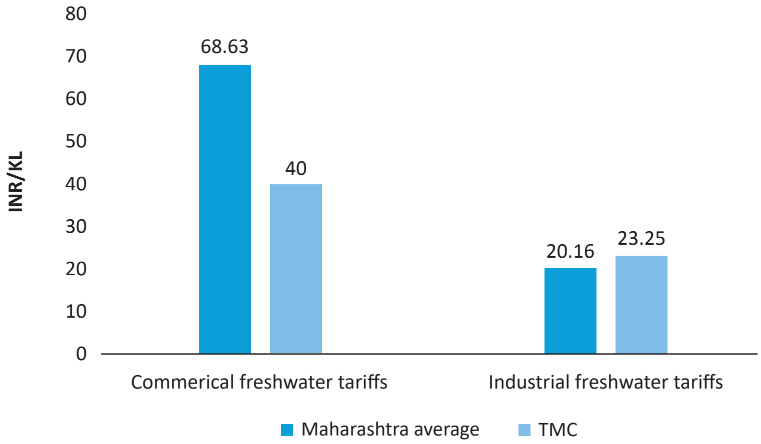
Pricing principles tend to be a deciding factor for generating demand, especially for non-conventional products (Bassi et al. 2022). To develop a market for the reuse TUW, we recommend considering the following when deciding its tariff.

- **Price of freshwater**: The price of TUW per unit should be lower than that of freshwater per unit for the same usage. For instance, TUW should be priced below INR 40 per kilolitre (KL) and INR 25–40 per KL for commercial and industrial uses, respectively, in TMC. Further, freshwater tariffs should be reviewed. A comparison of freshwater tariffs in TMC and other cities in Maharashtra shows that, on average, TMC's commercial freshwater tariff is lower than that of other cities (Figure 13).
- **Level of treatment**: The price of the TUW will also depend on the level of treatment, with tertiary TUW priced higher than secondary TUW.
- **User's paying abilities**: The price of TUW should be determined based on the target stakeholders' capacity to pay. Further, in case the TUW quality required by the end user differs from the quality supplied by TMC, then the end user (private developer, MIDC/industrial association, etc.) can meet the cost of upgrading the infrastructure to meet the quality norms pursuant to an agreement/MoU between the two parties.

An effective pricing mechanism for TUW will help reduce/recover the used water treatment costs incurred by the ULB and thus contribute towards making reuse projects commercially viable and sustainable. As per the *Maharashtra State Water Policy 2019*, the Maharashtra Water Resources Regulatory Authority (MWRRA) is responsible for tariff determination. Hence, a uniform pricing mechanism should be developed by TMC in conjunction with the MWRRA based on the principle of cost recovery. The pricing mechanism should consider the following factors (as estimated in Section 12.1).

- Lifecycle cost assessment of STPs (based on a 30-year design period) in TMC
- O&M costs of STPs in TMC
- Upgradation costs of existing STPs and/or the cost of setting up a new tertiary treatment plant
- The nodal authority (Section 13.2) should review suitable price variations and escalations after two years of operation, which may vary on a case-to-case basis

Figure 13: Commercial freshwater tariffs in TMC are lower than the average tariff in other cities in Maharashtra

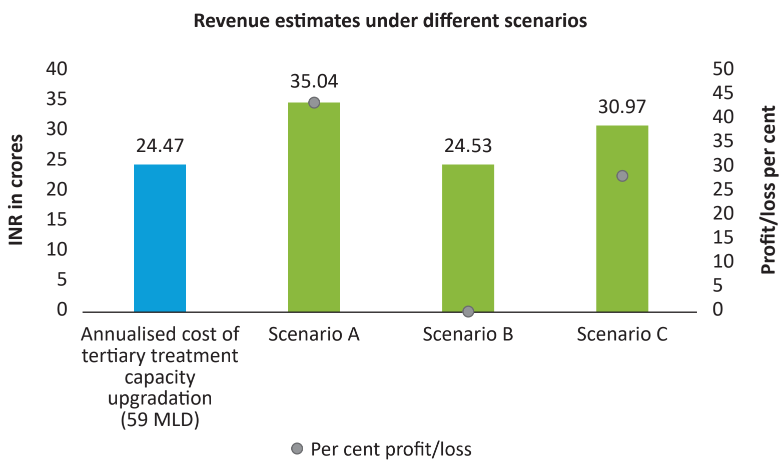


Source: Authors' analysis based on data from MJP. 2023a. Water Tariff Rates. Mumbai: Maharashtra Jeevan Pradhikaran, Government of Maharashtra, MJP. 2023b. Water Tariff. Mumbai: Maharashtra Jeevan Pradhikaran, Government of Maharashtra, and TMC, Water Supply Department

Note: 13 Maharashtra cities and 28 industrial zones were considered to calculate Maharashtra's average commercial and industrial tariffs, respectively.

The TUW tariffs collected from private users, including the commercial sector and industries, can generate revenue for TMC. Both these sectors primarily require tertiary-level treated used water (TTUW) for their identified applications (Section 11.2). To recover the estimated annualised cost of technology upgradation needed to establish a tertiary treatment capacity of 59 MLD (Table 16), TUW tariffs need to be 30 per cent less than existing freshwater prices in TMC. Hence, the minimum industrial tariff for TTUW needs to be around INR 16.27 per KL, and the commercial tariff is INR 28 per KL (Figure 14, Scenario B). Further, if the industrial TTUW tariff is set at INR 18.5 per KL and the commercial TTUW tariff at INR 36 per KL – i.e., at 20 per cent less than existing freshwater prices – TMC will not only be able to recover the annual cost of technology upgradation but also gain a substantial profit of 26.5 per cent (Figure 14, Scenario C).

Figure 14: TMC can recover the cost of technology upgradation by selling TUW to industries and commercial users at a 30% lesser price than that of freshwater



Source: Authors' analysis using data from Kulkarni, Sanjay. 2020. Project Information Memorandum (PIM) for Recycle and Reuse of Treated Wastewater. Presentation given at Recycle and Reuse of Treated Wastewater in Pimpri–Chinchwad Municipal Corporation Pre-Proposal Conference cum Webinar, Maharashtra, and TMC, Water Supply Department

Table 16: Scenario analysis of TTUW pricing in TMC (in INR crore)

Targeted tertiary treatment capacity (2046)	Total cost of tertiary upgradation (capital cost + O&M cost) for 30 years	Annualised NPV/cost of tertiary upgradation	Revenue-generating reuse avenues	Estimated potential of TUW reuse (MLD)	Potential of TUW reuse (KL/annum)	Scenario A: TTUW price same as freshwater prices in TMC		Scenario B: Min. TTUW price for treatment cost recovery by TMC		Scenario C: TTUW price 20% lesser than freshwater prices in TMC	
						Rate of TTUW (INR/KL)*	Revenue/annum	Rate of TTUW (INR/KL)*	Revenue/annum	Rate of TTUW (INR/KL)*	Revenue/annum
59	275.53	24.47	Industry	7	24,45,500	23.25	5.69	16.27	3.98	18.5	4.55
			Commercial (construction sector & commercial cooling)	20	73,38,325	40	29.35	28	20.55	36	26.42
			Total	**27**	**97,83,825**	–	**35.04**	–	**24.53**	–	**30.97**

Source: Authors' analysis using data from Kulkarni, Sanjay. 2020. Project Information Memorandum (PIM) for Recycle and Reuse of Treated Wastewater. Presentation given at Recycle and Reuse of Treated Wastewater in Pimpri–Chinchwad Municipal Corporation Pre-Proposal Conference cum Webinar, Maharashtra, and TMC

Incentives are also an essential component of an overall pricing strategy. They play an important role in generating TUW demand and encourage private-sector participation. Incentives can be tailored to specific business models adopted for a particular reuse avenue (Table 17), while broader incentives at the state level can further improve the viability of TUW projects.

Table 17: Incentives are the driving force behind the adoption of appropriate business models

S. No.	Business model	Possible incentives at the ULB level
1.	Onsite value-creation model	ULBs can give land on lease if the installation is to be done outside ULBs may provide an assured market for TUW purchase
2.	Reuse utility buyback model	ULBs may provide land within STP premises or lease land if the installation is to be done outside Buyback guarantee for reclaimed water ULBs can provide electricity rebates for plant operations and TUW conveyance
3.	Investment by end user	ULBs can cover the conveyance costs of supplying secondary treated water (STW) from the STP to the end user ULBs can set minimal volumetric charges for STW
4.	End user build-operate-transfer PPP model	ULBs can partially cover the capital costs incurred to construct secondary and tertiary treatment plants

Existing incentive mechanisms

A bouquet of incentives provided at different levels can cumulatively play a critical role in scaling up TUW reuse projects. Incentives in the form of indirect tax exemption on purchases and manufacturing of equipment for TUW reuse projects can enhance their financial viability. For instance, Government of India exempts treatment equipment and pipes for TUW conveyance purchased for industrial purposes (CECO 2004) from GST and TUW reuse projects financed by external organisations from customs duty (DoR 2008). Operational incentives also play an important role in facilitating private-sector participation. For instance, the Rajasthan government exempts payment of 50% of electricity duty for seven years on TUW reuse projects and 50% of entry tax on capital goods brought into local areas before commencing commercial production, on investment of INR 1 crore or more (GoR 2016).

Incremental rebates in TUW pricing linked to volumetric consumption by end users can help further reduce freshwater consumption and increase the uptake of treated water. For instance, Maharashtra's Draft Policy on Treated Water Reuse and Management provides an incremental rebate in TUW rates for industrial users based on their monthly treated water consumption. For example, for monthly consumption up to 300 cubic metres, there is rebate of 2.5 per cent on the standard TUW rate. For 301–450 cubic metres, the rebate is 5 per cent.

Source: Authors' analysis based on information from NMCG. 2022. National Framework on Safe Reuse of Treated Water. New Delhi: Ministry of Jal Shakti, Government of India

13. Implementation framework

The implementation framework for the Reuse Plan is based on reuse zone–wise planning (Section 4.8). It provides a standard operating procedure for the identified reuse avenues within each reuse zone. The available reuse avenues have been mapped out and the reuse potential estimated for each reuse zone. Further training needs assessment has been undertaken for the effective implementation of the reuse plan. These are elaborated in the following sub-sections.

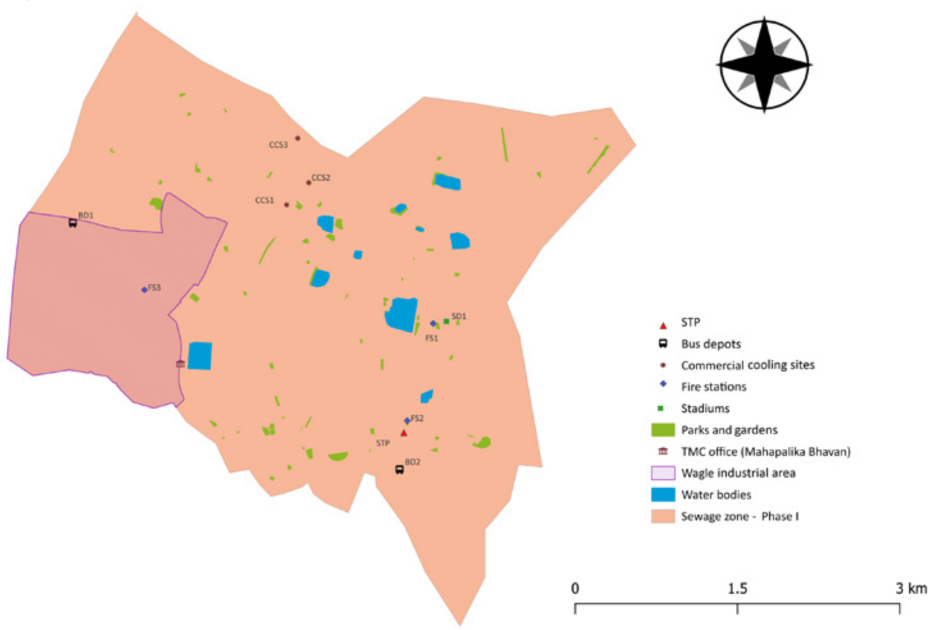
13.1 Reuse-zone-specific implementation framework

A framework has been developed for each reuse zone. This includes the water quantity and quality requirement for each TUW reuse application unit along with the appropriate conveyance mechanism and recommended business model for its effective operationalisation. The framework also identifies the nodal departments within TMC for each reuse avenue.

13.1.1 Reuse zone 1

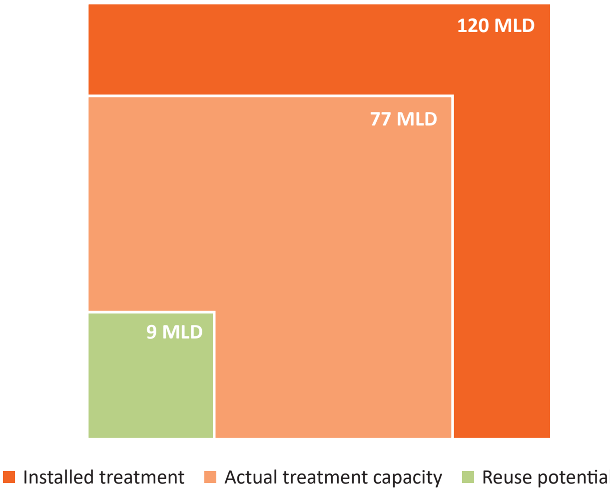
A diverse set of reuse avenues have been identified in zone 1 (Figure 15), with the total reuse potential estimated to be 9 MLD (Figure 16). Industries corner a significant share of the reuse potential (Table 18). The quality of water required by industries depends on their nature and type of operation, and therefore, it is essential to further process the TUW supplied by TMC to achieve the desired level. Thus, investment by end–user (Table 18) is one of the appropriate business models for industries.

Figure 15: Identified reuse avenues in reuse zone 1



Source: Authors' analysis based on data from TMC line departments

Figure 16: The current reuse potential is 12 per cent of the actual treatment in zone 1



Source: Authors' analysis based on data from TMC line departments

Table 18: Implementation framework matrix for reuse zone 1 with the suggested conveyance mechanisms and business models

S. No.	Reuse avenue	Application	Reuse site	Total water requirement (MLD)		Treatment quality required	Conveyance mode	Business model	TMC departments involved
1.	Cleaning	Floor cleaning	TMC office (Mahapalika Bhavan)	0.02	0.02	Secondary	Pipeline	Onsite value creation	Sewage department Administration section within TMC
2.	Land-scaping	Stadium	Dadoji Konddev	0.05	0.15	Secondary	Pipeline	Onsite value creation	Sewage department Stadium department
		Parks & gardens	Parks & gardens	0.60	0.63	Secondary	Tanker	Onsite value creation	Sewage department Parks and gardens department
3.	Cleaning	Bus depot (vehicle exterior & wheel washing)	Kanhaiya nagar	0.02	0.03	Tertiary	Pipeline	Reuse utility buyback model	Sewage department Transport department
			Wagle	0.01	0.05		Tanker	Investment by end–user	
4.	Fire stations	Maintaining water storage system	Jawahar Bagh	0.004	0.006	Tertiary	Tanker	Investment by end user	Sewage department Fire department
			Kopari	0.004	0.006				
			Wagle estate	0.004	0.006				

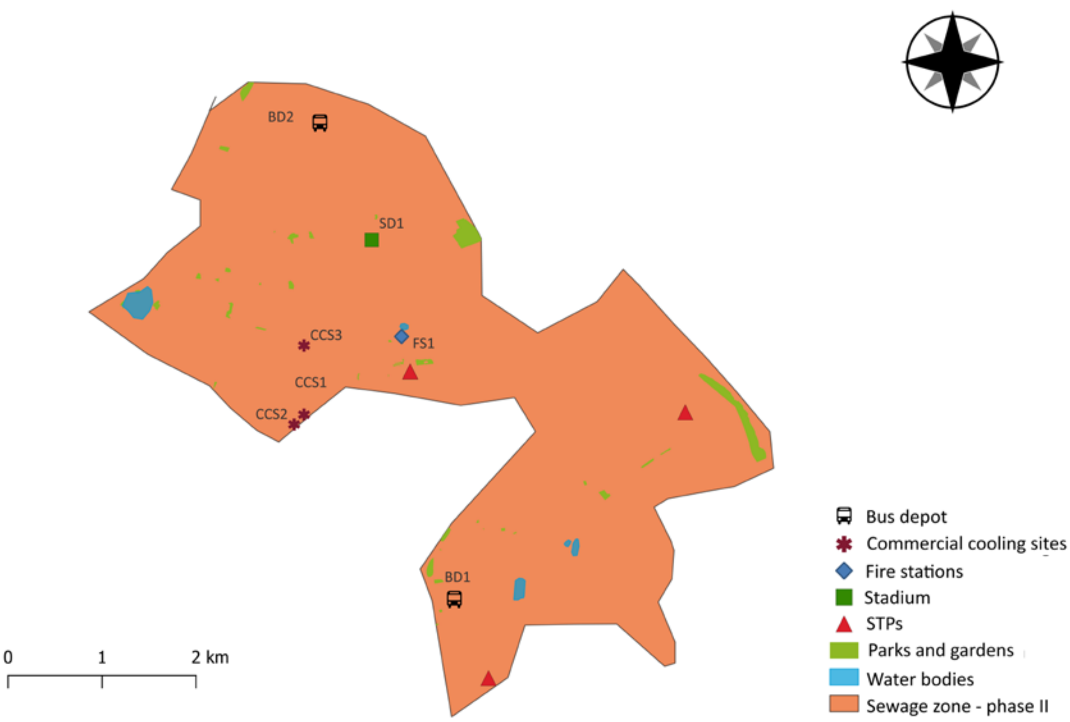
S. No.	Reuse avenue	Application	Reuse site	Total water requirement (MLD)		Treatment quality required	Conve-yance mode	Business model	TMC departments involved
5.	Industries	Processing and cooling requirements		6.70	6.70	Tertiary	Pipeline	Investment by end user Build-operate-transfer end user PPP model	Sewage department MIDC Industrial entities
6.	Comm-ercial establish-ments	Cooling water and cleaning	Raymond company	0.30	0.78	Tertiary	Pipeline	Investment by end user Close loop or zero discharge model	Sewage department Town planning department Commercial establishments
			Cadbury company	0.29	0.76				
			Korum mall	0.31	0.78				

Source: Authors' analysis based on Sections 10 and 12.3

13.1.2 Reuse zone 2

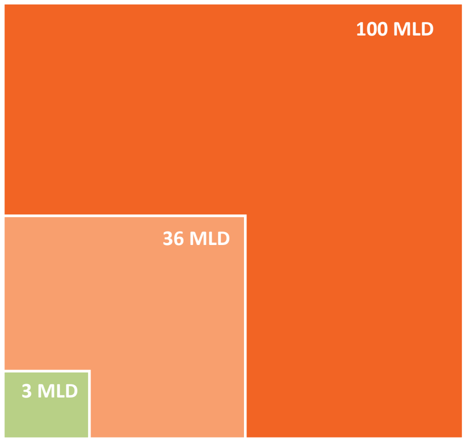
The identified reuse avenues have been mapped out across the zone (Figure 17) and the reuse potential has been estimated to be around 3 MLD (Figure 18). Appropriate business models for each reuse application have been recommended along with suggested conveyance mechanisms (Table 19).

Figure 17: Identified reuse avenues in reuse zone 2



Source: Authors' analysis

Figure 18: The reuse potential is 8 per cent of the actual treatment in zone 2



■ Installed treatment ■ Actual treatment capacity ■ Reuse potential

Source: Authors' analysis based on data from TMC line departments

Table 19: Implementation framework matrix for reuse zone 2 with the suggested conveyance mechanism and business models

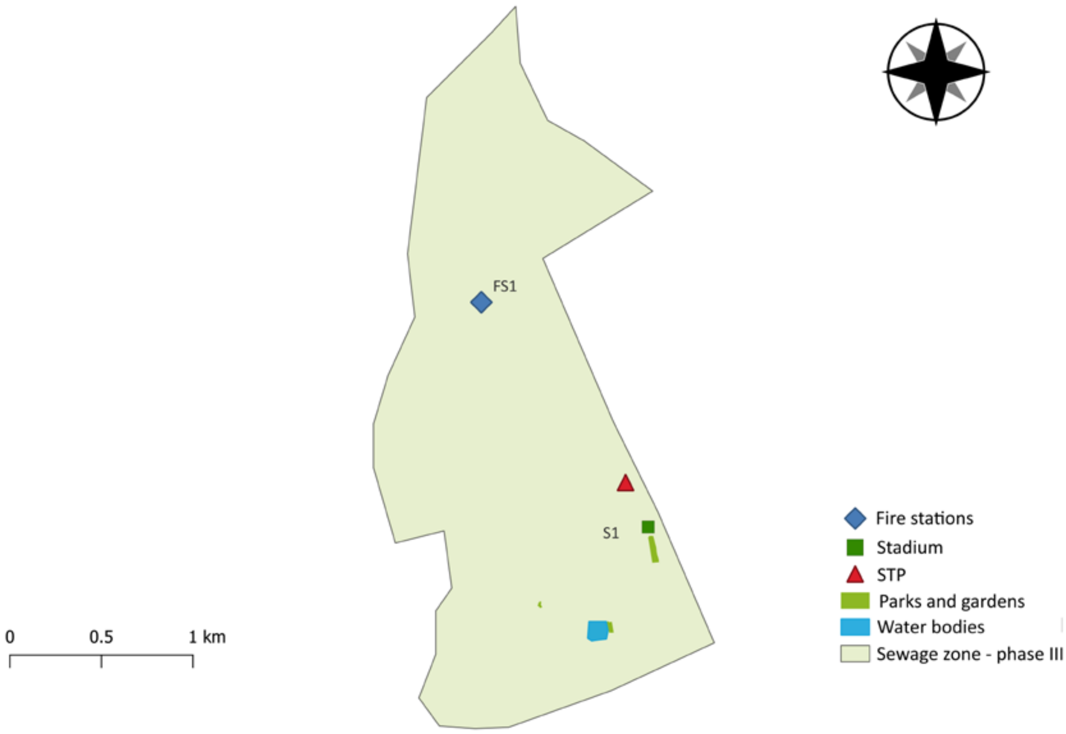
S. No.	Reuse avenue	Application	Reuse site	Total water requirement (MLD)		Quality required	Convey-ance mode	Business model	TMC departments involved
1.	Land-scaping	Stadium	Sharad chandraji Pawar mini stadium	0.008	0.010	Secondary	Tanker	Onsite value creation	Sewage department Stadium department
		Parks and gardens	Parks and gardens	1.19	1.25	Secondary	Tanker	Onsite value creation	Sewage department Parks and gardens department
2.	Cleaning	Bus depot (vehicle exterior and wheel washing)	Kalwa			Tertiary	Pipeline	Reuse utility buyback model	Sewage department Transport department
			Mulla Baug	0.005	0.01		Tanker	Investment by end user	
3.	Fire stations	Maintaining water storage system	Balkum fire brigade	0.004	0.006	Tertiary	Tanker	Investment by end user	Sewage department Fire department
4.	Comm-ercial establish-ments	Cooling water and cleaning	TCS	0.33	0.81	Tertiary	Pipeline	1. Investment by end user 2. Close loop or zero discharge model	Sewage department Town planning department Commercial establishments
			Jupiter hospital	0.31	0.79				
			Viviana mall	0.34	0.82				

Source: Authors' analysis based on Sections 10 and 12.3

13.1.3 Reuse zone 3

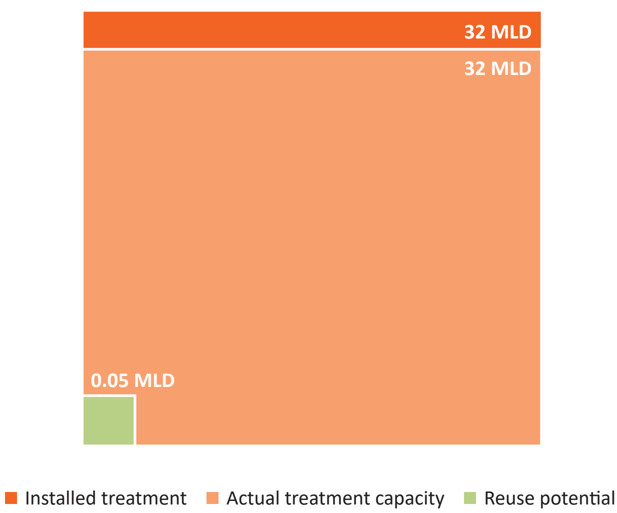
In this reuse zone, used water treatment infrastructure is limited but more efficient than in the other zones. Actual treatment matches with the total installed capacity (Figure 20). We have identified landscaping and fire stations (Figure 19) as reuse avenues in this zone. Based on the nature of reuse avenues (Section 10), we recommend tankers as the major conveyance mechanism (Table 20).

Figure 19: Identified reuse avenues in reuse zone 3



Source: Authors' analysis

Figure 20: The utilisation capacity of treatment infrastructure in reuse zone 3 is 100 per cent



Source: Authors' analysis based on data from TMC line departments

Table 20: Implementation framework matrix for reuse zone 3 with the suggested conveyance mechanisms and business models

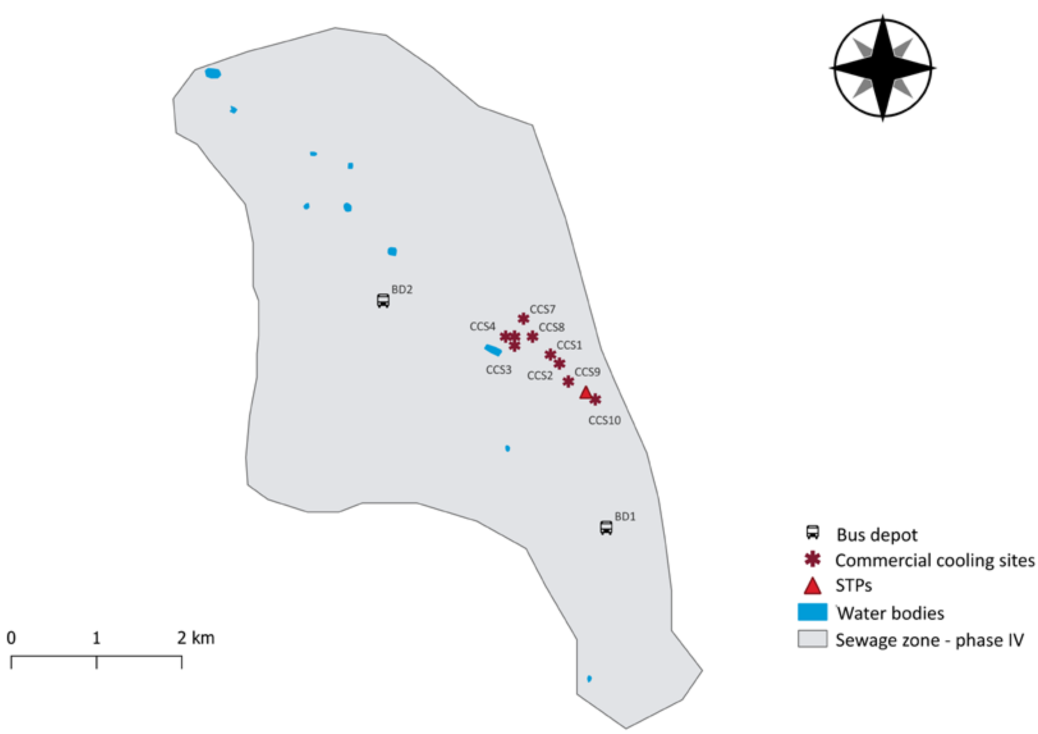
S. No.	Reuse avenue	Application	Reuse site	Total water requirement (MLD)		Quality required	Convey-ance mode	Business model	TMC departments involved
1.	Land-scaping	Stadium	Kausa (Mumbra)	0.015	0.020	Secondary	Tanker	Onsite value creation	Sewage department Stadium department
		Parks and gardens	Parks and gardens	0.029	0.029	Secondary	Tanker	Onsite value creation	Sewage department Parks and gardens department
2.	Fire stations	Mainta-ining water storage system	Mumbra fire brigade	0.004	0.006	Tertiary	Tanker	Investment by end user	Sewage department Fire department

Source: Authors' analysis based on Sections 10 and 12.3

13.1.4 Reuse zone 4

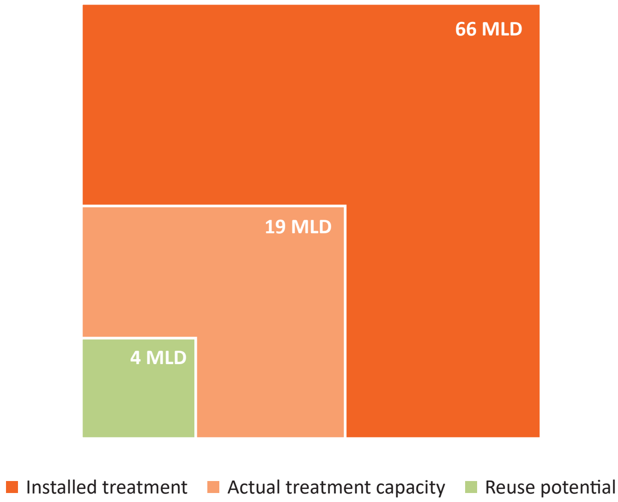
Commercial establishments are the predominant reuse avenue in reuse zone 4 (Figure 21). This zone's reuse potential is more than 20 per cent with respect to the actual treatment (Figure 22). Considering the major reuse avenues in this zone, we recommend pipelines (Table 21) as the major distribution source of TUW.

Figure 21: Identified reuse avenues in reuse zone 4



Source: Authors' analysis

Figure 22: Zone 4's reuse potential is 23 per cent of actual treatment



Source: Authors' analysis based on data provided by TMC line departments

Table 21: Implementation framework matrix for reuse zone 4 with the suggested conveyance mechanisms and business models

S. No.	Reuse avenue	Application	Reuse site	Total water requirement (MLD)		Quality required	Conveyance mode	Business model	TMC departments involved
1.	Landscaping	Parks and gardens	Parks and gardens	0.323	0.417	Secondary	Tanker	Onsite value creation	1. Sewage department 2. Parks and gardens department
2.	Cleaning	Bus depot (vehicle exterior and wheel washing)	Kasarwadavali	0.036	0.10	Tertiary	Tanker	Reuse utility buyback model	1. Sewage department 2. Transport department
3.	Commercial establishments	Cooling water and cleaning	TCS 2	0.26	0.57	Tertiary	Pipeline	1. Investment by end user 2. Close loop or zero discharge model	1. Sewage department 2. Town planning department 3. Commercial establishments
			Waste facility	0.19	0.50				
			TCS 1	0.35	0.66				
			Bayer corporate office	0.23	0.54				
			Upcoming hotel building	0.20	0.51				
			Business hub 1	0.19	0.50				
			Business hub 2	0.31	0.62				
			IT building 1	0.22	0.53				
			IT building 2	0.27	0.58				
			IT building 3	0.27	0.58				

Source: Authors' analysis based on Sections 10 and 12.3

13.1.5 Reuse zone 5

During consultations with TMC's Sewerage Department, we learned that reuse zone 5's sewerage network is still under development. So far, no STPs has been installed. We believe there is an opportunity to develop a more robust reuse plan for Greenfield, since the installation, quantity, and quality of STPs and the conveyance mode can be integrated into the zone's land-use planning.

Based on the reuse-zone-wise implementation framework, we suggest the following priority action areas for TMC in terms of short, medium, and long-term interventions (Table 22a). Further, we have highlighted the roles and responsibilities of relevant TMC departments in the stakeholder responsibility matrix (Table 22b).

Table 22a: Short, medium, and long-term interventions for TMC

Sr. No.	Nature of intervention	Intervention	Reuse Zone 1	Reuse Zone 2	Reuse Zone 3	Reuse Zone 4	Reuse Zone 5
1.	Short term (target year 2027)	Strengthen existing treatment capacity by enhancing actual utilisation of installed STPs	✓	✓	✗	✓	✗
		Build the institutional capacity of the identified departments within TMC	✓	✓	✓	✓	✓
		Prioritise reuse applications that require secondary-level TUW	✓	✓	✓	✓	✗
		Set up a multi-stakeholder monitoring committee for M&E of the TUW Reuse Plan under the Thane municipal commissioner	✓	✓	✓	✓	✓
2.	Medium-term (target year 2035)	Upgrade the existing (and planned) treatment infrastructure to the tertiary level	✓	✓	✓	✓	✗
		Reuse TUW in private-sector applications such as the construction sector, commercial establishments, and industries	✓	✓	✓	✓	✗
		Adopt reuse avenue–specific business models for the effective implementation of reuse projects	✓	✓	✓	✓	✗
		Develop a tariff structure based on the cost recovery principle for secondary and tertiary TUW	✓	✓	✓	✓	✗
3.	Long term (target year 2046)	Develop new infrastructure (centralised and decentralised) for collection and treatment of used water	✗	✗	✗	✗	✓

Source: Authors' analysis

Table 22b: Stakeholder responsibility matrix

Department-wise stakeholder responsibility matrix for TUW Reuse Plan implementation									
Interventions	**MIDC**	**Parks & gardens**	**Water**	**Mechanical**	**Sewage**	**Transport**	**Fire**	**Town planning**	**Environment**
Plan and schedule installation of sewage treatment infrastructure	×	×	×	×	○	×	×	✓	✓
Strengthen existing treatment capacity by enhancing actual utilisation of installed STPs	×	×	×	○	✓	×	×	×	×
Ensure the sewage treatment infrastructure meets the desired TUW quality standards through third-party monitoring	×	×	×	✓	✓	×	×	×	○
Build the institutional capacity of the identified departments within TMC	✓	✓	✓	✓	✓	✓	✓	✓	○
Prioritise reuse applications that require secondary-level TUW	×	✓	×	✓	✓	×	×	×	○
Set up a multi-stakeholder monitoring committee for M&E of the TUW Reuse Plan under the Thane municipal commissioner	✓	✓	✓	✓	✓	✓	✓	✓	○
Upgrade existing (and planned) treatment infrastructure to the tertiary level of treatment	×	×	×	✓	○	×	×	×	✓

Department-wise stakeholder responsibility matrix for TUW Reuse Plan implementation									
Interventions	**MIDC**	**Parks & gardens**	**Water**	**Mechanical**	**Sewage**	**Transport**	**Fire**	**Town planning**	**Environment**
Reuse TUW in private-sector applications such as the construction sector, commercial establishments, and industries	✓	×	×	✓	✓	×	×	✓	○
Adopt reuse avenue–specific business models for the effective implementation of reuse projects	✓	✓	×	×	✓	✓	✓	✓	○
*Develop a tariff structure based on the cost recovery principle for secondary and tertiary TUW	×	×	✓	✓	✓	×	×	×	○
Develop new infrastructure (centralised and decentralised) for the collection and treatment of used water	×	×	×	×	✓	×	×	×	○
Enhance community participation and awareness among current or potential users of TUW through **IEC activities	✓	✓	✓	✓	✓	✓	✓	✓	○

Source: Authors' analysis

Note: The MWRRA is responsible for deciding a tariff structure for TUW in consultation with relevant TMC departments.

**IEC refers to Information, Education and Communication*

○ *Nodal department*
✓ *Relevant department*
× *Not relevant*

13.2 Setting up a monitoring committee

We recommend setting up a multi-stakeholder monitoring committee in TMC under the Thane municipal commissioner. Acting as the nodal authority, it will have members from all

The relevant departments identified for TUW reuse within TMC (ES Figure 3) – MWRRA, MPCB, and Maharashtra Industrial Development Corporation (MIDC). The committee will ensure inter-departmental and inter-agency coordination for successfully implementing the TUW Reuse Plan. It will be responsible for monitoring the progress of used water treatment capacity utilisation, treatment infrastructure upgradation and/or the development of tertiary treatment infrastructure, implementation of TUW reuse projects, TUW pricing, and PPPs.

The committee's chairperson will be empowered to co-opt additional members, such as representatives of resident welfare associations (RWA), industrial associations, private developers, ward committees, and civil society. Further, IEC activities – i.e., behaviour change campaigns – will be developed for a) generating public awareness and promoting acceptance of safe TUW reuse and b) propagating rainwater harvesting and recharging techniques.

13.3 Framework for data sharing and management

Access to updated and reliable information at the municipal level is essential for efficient monitoring and evaluation of the Reuse Plan. The MUWM framework (Section 4.3) can be used to develop a baseline database at the ULB level (Figure 23) that is updated regularly under the monitoring committee's supervision.

Figure 23: Framework for data sharing and management for used water management

	S. no.	Parameters	Indicators
Finance	1.	Investment in sewage & septage management	5-year consolidated investment in sewage & septage management as a % of consolidated investment at the ULB level for municipal services (2015-20)
Finance	2.	Cost recovery in used water management	Annual used water revenues recovered as a % of TUW expenses incurred by the ULB
Finance	3.	Efficiency in collection of sewage charges	Annual used water revenues collected as a % of total operating revenues billed by the ULB
Infrastructure	1.	Sewage network coverage	Total number of properties/households connected to sewage network as a % of total number of properties/households in the ULB
Infrastructure	2.	Collection efficiency of sewage network	Quantity of used water collected at the intake of the treatment plant as a % of the total quantity of used water generated
Infrastructure	3.	Used water treatment capacity installed	Installed treatment capacity as a % of total used water generation at the ULB level
Infrastructure	4.	Existence of separate sewage & drainage networks	Whether there are separate sewage & drainage networks in the ULB
Infrastructure	5.	Storm water drainage network coverage	Length of drainage network as a % of total road length in the ULB
Infrastructure	6.	Status of polluted river stretches at the state level	Whether the number of polluted river stretches (BOD >3 mg/L) have increased, remained constant, or decreased between the assessment years (2022 & 2018)

	S. no.	Parameters	Indicators
Efficiency	1.	Used water treatment capacity utilisation	Actual treatment capacity as a % of installed treatment capacity in the ULB
	2.	Reuse of TUW	Quantity of TUW that is being reused in different sectors for non-potable purposes as a % of actual treatment in the ULB
	3.	Energy efficiency	Annual energy consumption of treatment plants per MLD of actual used water treatment in the ULB
	4.	Quality of TUW	% of STPs that comply with CPCB standards of the total STPs in the ULB
	5.	Energy cost incurred	Annual energy consumption per MLD of actual treatment in the ULB multiplied by cost per unit of energy
	6.	Level of GHG emissions/carbon intensity	Per capita annual GHG emissions from used water treatment & discharge at the state level
Governance	1.	Publication of performance reports	Whether service-level performance reports are published by the ULB regularly
	2.	Availability of updated city master plan	Whether an updated city master plan is available
	3.	Addressing used water management in the city master plan	Whether the master plan mentions quantitative sewage-related targets
			Whether sewage-related key performance indicators are mentioned as part of the monitoring & evaluation of the city master plan
	4.	Availability of sewage plan	Whether a sewage plan is available for the ULB
	5.	Presence of PPP to manage used water treatment &/or reuse	Whether PPP models are being used for undertaking projects related to used water treatment &/or reuse at the ULB level
	6.	Adequacy of ULB staff	Number of ULB staff per 1000 population
	7.	Presence of a dedicated municipal cadre	Whether the municipal cadre/personnel system at the state level is classified under separate personnel, unified personnel, or integrated personnel systems
Data & information	1.	Availability of MIS portal	Whether a MIS portal is available for publishing data at ULB level
	2.	Grievance redressal mechanism	Whether a grievance redressal mechanism related to sewage management is present at the ULB level/state level
			The total number of sewage-related complaints redressed within 24 hours of receipt of complaints, as a % of the total number of sewage related complaints received in the given time period at the ULB level
	3.	Readability of city master plans	Whether the city master plan is available in the local language & any official language (English or Hindi)

Source: Gupta, Saiba, Kartikey Chaturvedi, Ayushi Kashyap, and Nitin Bassi. 2024. Enabling Circular Economy in Used Water Management in India: A Municipal Index for Assessing Urban Local Bodies' Performance. New Delhi: Council on Energy, Environment and Water

13.4 Training and Assistance Needs Assessment (TANA) for institutional capacity building

The main objective of the Training and Assistance Needs Assessment (TANA) is to identify knowledge gaps and determine training needs of ULB officials in TMC

Table 23: Perceived roles and responsibilities of TMC departments with respect to used water management

S. No.	Department	Sewerage network connections & collection	Planning & scheduling sewage treatment infrastructure installation	Legal aspects & compliance of sewage treatment infrastructure	Technical & engineering aspects of used water treatment	Financial aspects of used water management	Tendering & procurement for sewage treatment infrastructure	Field supervision/ inspection of sewage treatment infrastructure	Training & capacity building of ground functionaries	Inter-departmental coordination	Public complaint redressal for sewage management	Enhancing community participation & awareness among current/ potential TUW users	No perceivable involvement in used water management	Potential TUW users
1.	Environment Dept.	■			■			■		■	■	■		
2.	Fire Dept.												■	
3.	Mechanical Dept.				■									
4.	Parks & gardens Dept.									■				■
5.	Sewage Dept.	■	■				■				■			
6.	Town planning Dept.									■				
7.	Transport Dept.									■				■
8.	Water supply Dept.									■				

Source: Authors' analysis using data collected from primary survey

13.4.1 Stakeholder mapping and perceived roles and responsibilities

The identified stakeholders include line departments within TMC that are responsible for managing used water or are potential end users of TUW. We have identified departments and summarised their perceived responsibilities with respect to used water management in the responsibility matrix (Table 23). This mapping aids in understanding how used water management is executed within TMC and in identifying potential gaps in service delivery. For instance, 'legal aspects and compliance of sewage treatment infrastructure,' 'financial aspects of used water management,' and 'training & capacity building of ground functionaries' currently lack well-defined roles within TMC's structure.

13.4.2 Level of understanding of evaluated parameters

We have listed parameters where survey respondents recorded the lowest level of understanding in Table 24. In our analysis, we found that less than one-third of the respondents demonstrated a technical understanding of treatment technologies, national and state policies or guidelines on used water treatment and reuse, cost recovery mechanisms, conveyance mechanisms for TUW reuse, and the roles and responsibilities of relevant stakeholders in ensuring safe reuse.

Table 24: Identified knowledge gaps within each theme

S. No.	Theme	Identified knowledge gaps
1.	Used water treatment technologies	Technical and engineering aspects of treatment technologies (infrastructure, capex/opex, O&M)
2.	Used water policies and legislative frameworks in India	Water (Prevention and Control of Pollution) Act, 1974
		Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013
		NGT Quality Guidelines, 2021
		CPHEEO Manual on Sewerage and Sewage Treatment Systems, 2013
		National Urban Sanitation Policy, 2008
		Maharashtra State Water Policy, 2019
		Maharashtra Sewage Treatment and Reuse Policy, 2017
		Action Plan for Utilisation of Treated Sewage, 2019 (MPCB)
		National Framework on Safe Reuse of Treated Water, 2022
3.	Governance structure	Roles & responsibilities of other relevant stakeholders like SPCBs*, private sector, NGOs, and RWAs for safe TUW reuse
4.	Reuse of TUW	Feasible conveyance mechanisms for TUW to reuse point
5.	Financial aspects of wastewater treatment and reuse	Business models
		Used water pricing

Source: Authors' analysis using data collected from primary survey
**SPCB refers to State Pollution Control Board*

13.4.3 Training and assistance needs assessment (TANA)

We have summarised the training and assistance needs of TMC officials in Table 25 based on our analysis of the survey (Annexure 7) responses. They are listed in descending order of priority. These needs align with the knowledge gaps identified in the previous section. High-priority areas for training include all aspects of used water treatment such as technologies, policies, legislative frameworks, advantages of reuse, different TUW application avenues, the roles and responsibilities of various stakeholders involved in enabling reuse, and finally, financing reuse projects.

Table 25: Training needs of TMC officials on used water management and reuse (high to low priority)

S. No.	Theme	Identified training needs		
		High priority	Moderate priority	Low priority
1.	Used water treatment	Associated risks of untreated used water discharge Used water treatment capacity Used water treatment levels TUW quality standards	M&E to ensure proper STP operations	
2.	Used water treatment technologies	Types of used water treatment technologies Technical and engineering aspects of treatment technologies		
3.	Used water policies and legislative frameworks	Policies and legislative frameworks		
4.	Governance structure	Roles and responsibilities of other relevant stakeholders like SPCBs, private sector, NGOs, and RWAs for safe TUW reuse	Overall mandate and responsibilities of respective departments for used water treatment and reuse Inter-departmental coordination for data sharing and used water management in TMC	
5.	TUW reuse	Advantages of TUW reuse TUW reuse avenues	Feasible TUW conveyance mechanisms to reuse point Current levels of TUW reuse in TMC	
6.	Financial aspects of used water treatment & reuse	Funding sources Cost of used water treatment and reuse Business models Pricing used water		

S. No.	Theme	Identified training needs		
		High priority	**Moderate priority**	**Low priority**
7.	Community engagement	IEC programmes for developing awareness and building acceptance		
8.	Current water ad used water management scenario			Water supply Water deficit TMC's sewerage network non-revenue water Used water generation in TMC

Source: Authors' analysis using data collected from primary survey

We have also mapped the training needs to the relevant department (Annexure 12). This can be helpful in designing department-specific training modules under future capacity building initiatives. Our analysis shows that used water treatment, associated technologies, and policies and legislative frameworks are the most common themes under department-specific training needs.

14. Conclusion

The TMC Reuse Plan has been developed as a long-term guiding document for sustainable used water management in Thane City. It aligns with national and state guidelines for domestic used water treatment and reuse. The national Atal Mission for Rejuvenation and Urban Transformation 2.0 targets meeting 20 per cent of municipal water demand through TUW by 2025-26. Additionally, Maharashtra's Treated Water Reuse and Management 2023 (Draft) Policy aims to replace 30 per cent of municipal freshwater use with TUW by 2025. The responsibility of implementing these policies lies with the ULBs, being the primary authorities for managing domestic used water in Indian cities. The TMC Reuse Plan provides a strategic framework and guidance to the ULB to strengthen used water management and implement TUW reuse projects within its jurisdiction. It sets city-specific targets that consider both the current and future water demand, factoring in the city's planned development. This plan can be used as a template and provide direction to other cities to develop standardised reuse plans across the state. This is a crucial step for mainstreaming a circular economy in urban used water management.

Acronyms

AMRUT	:	*Atal Mission for Rejuvenation and Urban Transformation*
BIS	:	Bureau of Indian Standards
BOD	:	Biological Oxygen Demand
CEEW	:	Council on Energy, Environment, and Water
CEPT	:	Centre for Environmental Planning and Technology
CGWB	:	Central Ground Water Board
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
CPHEEO	:	Central Public Health and Environmental Engineering Organisation
CSR	:	Corporate social responsibility
CWS	:	Center for Water and Sanitation
DO	:	Dissolved Oxygen
DoWR, RD, & GR	:	Department of Water Resources, River Development, and Ganga Rejuvenation
FC	:	Faecal Coliform
GoH	:	Government of Haryana
GoK	:	Government of Karnataka
GoM	:	Government of Maharashtra
GoR	:	Government of Rajasthan
IIT	:	Indian Institute of Technology
IMD	:	India Meteorological Department
JJM	:	*Jal Jeevan Mission*
KL	:	Kilolitres
Lpcd	:	Litres per capita per day
M&E	:	Monitoring and Evaluation
MF	:	Microfiltration
MIDC	:	Maharashtra Industrial Development Corporation
MIS	:	Management Information System
MLD	:	Million Litres per Day
MoHUA	:	Ministry of Housing and Urban Affairs

MPCB : Maharashtra Pollution Control Board

MUWM : Municipal Used Water Management

MWRRA : Maharashtra Water Resources Regulatory Authority

NF-SRTW : National Framework for Sage Reuse of Treated Water

NGT : Nation Green Tribunal

NIUA : National Institute of Urban Affairs

NMCG : *National Mission for Clean Ganga*

NPV : Net Present Value

O&M : Operations and Maintenance

PPP : Public–Private Partnership

RO : Reverse Osmosis

RWA : Resident Welfare Association

SBM : *Swachh Bharat Mission*

SBM-U : *Swachh Bharat Mission (Urban)*

SPCB : State Pollution Control Board

STP : Sewage Treatment Plant

TC : Total Coliform

TDS : Total Dissolved Solids

TERI : The Energy Resource Institute

TMC : Thane Municipal Corporation

TPP : Thermal Power Plant

TSS : Total Suspended Solids

TUW : Treated Used Water

TTUW : Tertiary Treated Used Water

UF : Ultrafiltration

ULB : Urban Local Body

WQI : Water Quality Index

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Annexures

ANNEXURE 1:

Analysis of Maharashtra's state level instruments promoting the reuse of TUW

S. No.	Policies	Objectives	Reuse priority	Technology	Financing Mechanism	Institutional arrangement	Targets
1.	State Water Treatment and Recycling Policy (SWTRP), 2017	To mainstream the safe reuse of treated water in the state	Thermal power plants (within 50 km of STP) MIDC (within 50 km of STP) Railway or other bulk buyers Agriculture	Focus on the adoption of innovative treatment technologies developed by IIT/NEERI	Funding shall be raised through central and state government schemes or PPP model	ULBs to recycle and reuse water. The Water Resources Department to cancel the freshwater supply for the establishment that uses TUW.	Special areas in the state shall be identified for priority imple - mentation based on scarcity, pollution levels and sewerage network coverage in an area.
2.	Maharashtra State Water Policy, 2019 (WRD 2019)	To overcome overall water stress in the state and its associated risk, the policy provides for maximising total utilizable water and supple menting the freshwater sources by exploring the options for reuse of Treated Water	Thermal power plants		Responsibility for tariff determination is entrusted with Maharashtra Water Resource Regulatory Authority (MWRRA).	Establishment of an autonomous research center for water policy evaluation and advice Creation of a "Centre of Excellence" for the water sector with global collaboration Promotion of research and technology advancements in the water sector with adequate funding and expert panel oversight	A minimum 30 % of the recycled water shall be reused to reduce the freshwater demand by 2024.
3.	Action Plan for utilisation of treated sewage, 2019 (MPCB 2019)	Mandates the reuse of treated water for certain classes of users	Thermal power plants Industrial units Construction activities. Non–potable municipal usage Irrigation			Local bodies are encouraged to reuse TUW for various purposes such as in thermal power plants.	Infrastructure projects are mandated to recycle 60% of treated sewage for secondary use by providing dual pipelines.
4.	Bulk water tariff order, 2022 (WRD 2022)	To develop uniform criteria for determining the TUW tariff			Development of a differential tariff system for different users Exploring innovative financing such as treated water reuse certificates		

Source: Authors' analysis using listed schemes

ANNEXURE 2:

The detailed methodology for the assessment of surface water and groundwater quality index

Surface water quality index

As per CPCB, four parameters – pH, DO, BOD, and FC – are considered for the calculation of the surface WQI demonstrated in Equation A1 (Section 4.1.2). The respective weights – specified by CPCB – and sub-index formulas for each parameter are given in Table A1.

Table A1: Surface WQI parameter weights and sub-index calculation formulas

S. No.	Water quality parameter	Weights (CPCB)	Sub-index	
			Range	Formula
1.	DO (% saturation)	0.31	0–40	0.18 + 0.66 X % Saturation DO
			40–100	(–13.55) + 1.17 X % Saturation DO
			100–140	163.34 – 0.62 X % Saturation DO
2.	FC (counts/100 ml)	0.28	1–103	97.2 – 26.6 X log FC
			103–105	42.33 – 7.75 X log FC
			>105	2
3.	pH	0.22	02–05	16.1 + 7.35 X (pH)
			05–7.3	(–142.67) + 33.5 X (pH)
			7.3–10	316.96 – 29.85 X (pH)
			10–12	96.17 – 8.0 X (pH)
			<2, >12	0
4.	BOD (mg/l)	0.19	0–10	96.67 – 7 X (BOD)
			10–30	38.9 – 1.23 X (BOD)
			>30	2

Source: TERI. 2024. Water Quality Status of Maharashtra 2023–24. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

Surface WQI lies on a scale of 0–100, with a high index value corresponding to better water quality. Based on their WQI value, MPCB has assigned a pollution status to water bodies as given in Table A2.

Table A2: Surface WQI scale and categorisation

WQI	Classification	Class by CPCB	Status
100–63	Good to excellent	A	Non-polluted
63–50	Medium to good	B	Non-polluted
50–38	Bad	C	Polluted
38 and less	Bad to very bad	D, E	Heavily polluted

Source: TERI. 2024. Water Quality Status of Maharashtra 2023–24. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

Eight surface monitoring stations lie within TMC's administrative boundary, of which three monitor the water quality of *nullahs* (station code 2782, 2783, 2784) and five monitor the water quality of Thane creeks (station code 2792, 2793, 2794, 2795, 1316) (MPCB 2024a). We used the monthly WQI reported by MPCB for each monitoring station to analyse the five-year (2019–2023) seasonal and annual average WQI. For seasonal analysis, we grouped the monthly WQI into four seasons – pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November), and winter (December–February).

Groundwater quality index

We calculated the groundwater WQI using nine parameters – pH, total hardness, calcium, magnesium, chloride, total dissolved solids, fluoride, manganese, nitrate, and sulphate. The weightage of each parameter is based on its relative importance to the drinking water quality (TERI 2024). The weights range between one and five, with five corresponding to a high degree of relative harmfulness when present in water, as specified in Table A4. The assigned weights are then converted to a 0–1 scale to arrive at the relative weights using the following formula:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi}$$ …..Equation A2

Where,
Wi = relative weight
wi = parameter weight
n = number of parameters

Next, we calculated a quality rating for each parameter by dividing its concentration in the water sample by its respective quality standard according to the guidelines published by the Bureau of Indian Standards (BIS) (Table A3). We multiplied the results obtained by 100. Finally, we multiplied the quality rating by the individual relative weight to arrive at the sub-index values of each parameter (Equation A3).

$$qi = (Ci/Si) \times 100$$ …..Equation A3

Where,
qi = quality rating
Ci = concentration of each chemical parameter in each water sample in mg/L
Si = Indian drinking water standard for each chemical parameter in mg/L according to BIS 10500 guidelines

Table A3: Groundwater WQI parameter quality standards and weights

S. No	Parameters	Drinking water quality standards		Weights	
		Acceptable limits	Permissible limits	Weight (wi)	Relative weight (Wi)
1.	pH	6.5–8.5	No relaxation	4	0.13333
2.	Total hardness	300	600	2	0.6667
3.	Calcium	75	300	2	0.6667
4.	Magnesium	30	No relaxation	2	0.6667
5.	Chloride	250	1000	3	0.1
6.	Total dissolved solids	500	2000	4	0.1333

S. No	Parameters	Drinking water quality standards		Weights	
		Acceptable limits	Permissible limits	Weight (wi)	Relative weight (Wi)
7.	Fluoride	1	1.5	4	0.1333
8.	Nitrate	45	No relaxation	5	0.16667
9.	Sulphate	200	400	4	0.1333
				Total = 30	**Total = 1**

Source: TERI. 2024. Water Quality Status of Maharashtra 2023–24. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

The final WQI value is computed by summating all nine sub-index values, resulting in an index on a scale of 0 to 300. A lower index value corresponds to better groundwater quality and vice versa. The groundwater WQI classification comprises five categories based on the suitability of the respective water sample for drinking water use (Table A4).

Table A4: Groundwater WQI categorisation

WQI	Classification
<50	Excellent
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking

Source: TERI. 2024. Water Quality Status of Maharashtra 2023–24. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

TMC has two groundwater monitoring stations (Bhayandarpada and Yeoor) in its administrative boundary. Based on data availability, we calculated Bhayandarpada's annual groundwater WQI (monitored during the pre-monsoon season) using CGWB data hosted on the India–WRIS portal for the assessment years 2018 and 2022.

ANNEXURE 3:

Estimation of domestic and commercial water supply

We calculated the total water supply by adding the total surface and groundwater resources extracted within TMC (Table A5). Surface water is imported from water reservoirs (Bhatsa and Barvi dams in Thane district) located outside the TMC boundary. The total surface water supply displayed – for domestic and commercial use – is as provided by the TMC's water supply department.

We derived the total groundwater supply or extraction estimate by apportioning the total groundwater extraction in Thane taluka by area as reported in CGWB, Report on Dynamic Groundwater Resources in Maharashtra and TMC . Next, we estimated the ward-wise water supply for domestic and commercial use by proportioning the surface and groundwater water supply between all wards based on population.

Finally, we derived the actual water supply by considering the total losses in the water supply system or the total non-revenue water (NRW), which is assumed to be 30 per cent of the total water supply (as per TMC).

S. No.	Ward	Total population	Population proportion	Domestic surface water supply	NRW	Ground water extraction for domestic uses	Actual water supply (surface water supply + ground water supply – NRW)
		by number	population/ total population	MLD			
1.	Majiwada–Manpada	4,50,564	14.69	110	34	0.15	76
2.	Vartak Nagar	2,37,837	7.75	58	18	0.08	40
3.	Lokmanya Nagar	2,74,210	8.94	49	15	0.09	34
4.	Wagle	2,53,264	8.26	46	14	0.08	32
5.	Naupada–Kopari	3,31,004	10.79	70	23	0.11	48
6.	Uthalsar	3,41,906	11.15	58	18	0.11	40
7.	Kalwa	3,96,567	12.93	65	20	0.13	45
8.	Mumbra	3,97,864	12.97	64	19	0.13	45
9.	Diva	3,84,000	12.52	65	20	0.13	46
	Total	**30,67,216**	**1.00**	**585**	**179**	**1**	**407**

Source: Authors' analysis using data from CGWB. 2022. Report on the Dynamic Groundwater Resources in Maharashtra. Thiruvananthapuram: Department of Drinking Water and Sanitation, Ministry of Jal Shakti, and TMC, Water Supply Department

Estimation of domestic and commercial water demand

As per the urban water supply norms set by CPHEEO, the water supply in metropolitan cities – with a population above 10 lakh – is targeted at 150 litres per capita per day (lpcd) (CPHEEO 2023). We approximated the ward-wise water demand for TMC using this norm. Of the total water use, 135 and 15 lpcd are proportioned for domestic and commercial use, respectively, as per TMC (Table A6). We derived the water deficit by subtracting the total water demand from the actual supply. Further, taking the current percentage share of water deficit across all years and projected populations, we made future projections of water deficit for the years 2035 and 2046.

Table A6: Administrative ward-wise water demand in TMC

S. No.	Ward	Calculated domestic demand (135 lpcd)	Calculated commercial demand (15 lpcd)
1.	Majiwada–Manpada	61	7
2.	Vartak Nagar	32	4
3.	Lokmanya Nagar	37	4
4.	Wagle	34	4
5.	Naupada–Kopari	45	5
6.	Uthalsar	46	5
7.	Kalwa	54	6
8.	Mumbra	54	6
9.	Diva	52	6
	Total	**414**	**46**

Source: Authors' analysis using data provided by TMC, Water Supply Department

Estimation of used water generation and treatment

The total domestic sewage generation is assumed to be 80 per cent of the water supply (CPCB 2021). Using this assumption, we estimated the current used water generation in TMC using the water supply in 2024. We estimated the projected used water generation for the years 2035 and 2046 based on the projected water demand, assuming water demand is equal to supply. Details about the city's sewage infrastructure is provided by TMC (Table A7).

Table A7: Current and future used water generation and installed treatment capacity in TMC

Year	2015	2024	2035	2046
Used water generation (MLD)	262	328	613	979
Installed treatment capacity (MLD)	252	396	688	1195

Source: Authors' analysis using data provided by TMC, Sewage Department

ANNEXURE 4:

Estimation of the water requirements of the identified reuse avenue

a) Estimation of current reuse quantity requirements (2024)

S. No.	Reuse avenues	Reuse quantity requirements (MLD)		
		Subcategories	Methodology for estimated TUW	Source
1.	**Landscaping**	Parks	**Formula** Water requirement (in MLD) = (Total area under parks and garden/road dividers (in sq.m) * Water requirement (in liter) per sq.m per day)/10^6 **Note:** • Application under parks includes areas under parks, gardens, and urban forests. **Assumption** • Water required = 5 liters per sq.m (applied once in two days)	TMC
		Road dividers		TMC
		Stadiums	**Formula** Water requirement (in MLD) = (Total area under parks and garden/road dividers (in sq.m) * Water requirement (in liter) per sq.m per day)/10^6 **Note:** • Application of water supplied includes irrigation, sprinkling shops • The water requirements for stadiums were provided during the consultation.	TMC
2.	**Cleaning**	Bus Depot (Vehicle exterior and wheel washing)	**Formula** Water requirement (in MLD) = (No. of buses * Water requirement (per bus per day))/10^6	CIJ n.d
		Roads	**Formula** Water requirement (in MLD) = (Total area of road network (in sq.m) * Water requirement (in liter) per sq.m per day)/10^6 **Assumption** Water required for road cleaning = 1 litre per sq.m (applied twice a week)	CSIR–NEERI 2019 & TMC
		STP facilities	Water requirement for cleaning STP facilities per day in MLD as provided by concerned authority	TMC

S. No.	Reuse avenues	Reuse quantity requirements (MLD)		
		Subcategories	Methodology for estimated TUW	Source
		TMC office (Mahapalika Bhavan)	**Formula** Water requirement (in MLD) = (Total floor area of TMC office (in sq.m) * Water requirement (in liter) per sq.m per day)/10^6 **Assumption** Water required for cleaning of TMC office = 1 litre per sq.m (applied daily)	CSIR–NEERI 2019 & TMC
3.	**Construction sites**	Landscaping	**Formula:** Water requirement (in MLD) = (Area under construction (in sq. ft) * Water requirement (in per sq. ft per day))/10^6 **Assumption** • Water requirement range = 67.5 liters per sq. ft – 80 liters per sq. ft • The duration of the project is considered to be 60 months.	Expert consultation
		Dust suppression		
		Cleaning (aggregate, concrete batching plants, and vehicles)		
4.	**Fire station**	Maintenance of water storage system for firefighting	**Formula:** Water requirement (MLD) = (Total storage capacity in million litres x refills per year)/365 **Assumption** The maximum water estimated takes into account one major fire event per year, which requires approximately 20 times the water storage capacity of the fire department	TMC
5.	**Industries**	Industrial cooling, spraying in mine pits, and boiler feed	**Formula:** Water demand for industries (in MLD) = (100 per cent of total non-domestic demand of industries + 20 per cent of domestic purposes demand in industries within TMC) **Note:** Water demand is derived for individual industry (green and red/orange categories) from their consent forms uploaded at the MPCB portal	MPCB 2024b, MoHUA 2021
		Processing whereby water gets polluted and pollutants are not easily biodegradable		
		Processing whereby water gets polluted and pollutants are easily biodegradable		
		Domestic purposes (cleaning requirements)		
6.	**Commercial cooling establishments (malls, offices, etc.)**	commercial cooling	**Formula** Water requirement (in MLD) =(Refrigeration capacity (in TR) x Working hours (24 hrs) x Consumption of makeup water (in litres per hour) x load factor)/ 10^6. **Note:** Consumption of makeup water includes evaporation in cooling tower, wind blow and leakage	(Ashcroft et al. 2018)

S. No.	Reuse avenues	Reuse quantity requirements (MLD)		
		Subcategories	Methodology for estimated TUW	Source
		Cleaning of commercial establishments	**Formula** Water requirement (in MLD) = (Total floor area of commercial establishments (in sq.m) * Water requirement (in liter) per sq.m per day)/10^6 **Assumption** Water required for cleaning of commercial establishment = 1 litre per sq.m (applied daily)	CSIR–NEERI 2019
7.	**Public Utilities**	Toilet flushing	**Formula** Water requirement (in MLD) = (Water required in each flush (in litres) * No. of flush per day) /10^6 **Note** The data for public utilities was provided by TMC.	TMC

Source: Authors' analysis using data from listed sources

b) Estimation of future reuse quantity requirements (2046)

S. No.	Reuse avenue	Sub-categories	Provision in TMC Development Plan (2026-2046)	Methodology for estimated TUW
1.	**Landscaping**	Parks and Garden	• New 62 garden sites of 51.18 Ha have been proposed. • A Botanical Garden with an area of 23.51 Ha has been proposed. • A total of 19 park sites of 119 Ha have been proposed • An urban park site of an area of 20.73 Ha has been proposed.	This includes the areas under parks, gardens, botanical gardens, and urban forests proposed in the development plan. **Formula** Water requirement (in MLD) = (Total area under parks and garden (in sq.m) * Water requirement (in litre) per sq.m per day)/10^6
		Stadiums	• New 63 playground sites of 46.69 Ha have been proposed. • New 7 sports complexes of 25.79 ha have been proposed. • New 24 recreational grounds of 21.95 ha have been proposed.	This includes the area under playgrounds, sports complexes, and recreational grounds. **Formula** Water requirement (in MLD) = (Total area under parks and garden (in sq.m) * Water requirement (in litre) per sq.m per day)/10^6
2.	**Construction**	Landscaping Dust suppression Cleaning (aggregate, concrete batching plants, and vehicles)	• Urban Renewal Plans for 46 areas covering an area of 1599.5 Ha has been proposed • Total area of 174 Ha for metro car shed and allied purpose has been proposed.	This includes the area proposed for redevelopment under the urban renewal scheme and the area that is to be brought under construction for metro development. **Formula:** Water requirement (in MLD) = (Area under construction (in sq.ft) * Water requirement (in per sq.ft per day))/10^6 **Assumption:** Duration for project is 60 months.

S. No.	Reuse avenue	Sub-categories	Provision in TMC Development Plan (2026-2046)	Methodology for estimated TUW
3.	**Commercial establishments (malls, offices etc.)**	Commercial cooling	• A growth centre of approximately 30.44 Ha has been proposed.	The activities in the growth centers will involve IT-enabled services, private and public offices, commercial establishments. **Formula:** Water requirement (in MLD) = (Refrigeration capacity (in TR) x Working hours (24 hrs) x Consumption of makeup water (in litres per hour) x load factor)/ 10^6. **Assumption:** • Considering growth centre to undergo district cooling. • The refrigeration capacity taken for the proposed growth center is based on the standards of the GIFT city, Gujarat. • 62 million sq.ft of area requires 1,80,000 TR.
4.	**Cleaning**	Bus Depot (Vehicle exterior and wheel washing)	• The proposal to add 192 new buses in the fleet.	**Formula** Water requirement (in MLD) = (No. of buses * Water requirement (per bus per day))/10^6
5.	**Fire station**	Maintenance of water storage system for firefighting	• A total of 13 sites having a total area of 8.54 Ha, are proposed for fire brigade stations.	**Formula** Water requirement (in MLD) = (Total storage capacity (in million litres) * Refills per year)/365

Source: Authors' analysis using data from TMC. 2024. Draft Revised Development Plan Thane 2026–2046. Thane: Town Planning Department, Thane Municipal Corporation

ANNEXURE 5:

Estimating financing requirements for strengthening existing treatment capacity and upgrading existing treatment infrastructure to maximise reuse

The Reuse Plan's viability depends on the strength of the treatment capacity and the upgradation of existing treatment infrastructure. There is a need to establish tertiary treatment capacity to achieve the desirable water quality for reuse within the identified sectors. We have estimated the financial requirements for setting up a new tertiary treatment plant and carrying out technological upgradation through a lifecycle cost assessment. We have considered the capital cost – including the cost of land, annualised O&M, and electricity – to calculate the total cost using the NPV approach for a lifecycle of 30 years.

Annualised O&M is derived from the formula (Bassi et al. 2022):

$$\text{Anualised cost} = \frac{\text{NPV x R}}{1-(1+R)^{-n}} \qquad \text{..................Equation A4}$$

Where,

NPV = net present value of the asset capital cost and O&M

R = discount rate (assumed to be 8 per cent)

n = lifecycle of the asset (30 years)

The capital and O&M costs of secondary sewage treatment plants has been provided by TMC. We sourced the capital and O&M costs of a tertiary treatment plant from TMC and NMCG, respectively (Tare et al. 2010). Further, we have also estimated the financial requirements for upgrading to different technology combinations. Subject to data availability, the following combinations of tertiary and advanced technologies have been discussed (Srivastava and Singh 2022):

a. Coagulation + flocculation + rapid sand filters
b. UF + RO
c. MF + RO

Strengthening the infrastructure for increasing TUW reuse also involves establishing necessary conveyance mechanisms. In this section, we compare the estimated financial requirements for operating a fleet and a pipeline network. We estimated the cost of deploying tankers on a per-trip basis. The approach used to estimate the conveyance cost is mentioned in Table A8.

Table A8: Estimation of financial requirements for establishing a TUW conveyance mechanism

S. No.	Variable	Tanker		Pipeline	
		Approach	Source	Approach	Source
1.	Fixed cost	Given amount is assumed to be the cost of renting a tanker of capacity 10,000 l for 1 day	TMC	Range of one-time capital cost for a design period of min. 20 years is assumed based on reviewed literature	Ramaiah, Avtar, and Kumar (2022); Municipal Council Chhatarpur (2016)
	Additional variable costs				
2.	Fuel cost	Assumptions: km travelled per day = 45 diesel = INR 90/l Tanker average = 8–10 km/l	CWS, CRDF, and CEPT (2022); Ramaiah, Avtar, and Kumar (2022)	–	
3.	Storage tank	Cost of building storage tanks (5,000 l capacity) for storing water provided by tankers or pipeline			Ramaiah, Avtar, and Kumar (2022)
4.	Motor	One-time capital cost for installing 10 HP motor for pumping treated used water into tankers	Ramaiah, Avtar, and Kumar (2022)	One-time capital cost for installing 75 HP motor for pumping treated used water into pipeline	Ramaiah, Avtar, and Kumar (2022)
5.	Labour wage	Monthly wages for drivers & assistants	CWS, CRDF, and CEPT (2022); Ramaiah, Avtar, and Kumar (2022)	Monthly wages for electricians & technicians	Ramaiah, Avtar, and Kumar (2022)

Source: Authors' analysis using the listed sources

Funding provisions for used water management and reuse in existing national missions

We analysed national programmes to assess fund allocation and fund-sharing arrangements between the centre and state, along with the incentives available at the ULB level to implement reuse projects. For some schemes, financial outlay and fund-sharing arrangements between the centre and state are detailed separately. Innovative financing mechanisms can also be explored to generate additional funding for TUW reuse projects. The NF–SRTW also mentions certain viable business models and administrative and financial arrangements involving public–private players to ensure the viability of TUW reuse projects.

Recommended business models for the identified reuse avenues

Public–private partnerships are essential for risk sharing and responsibility allocation to manage TUW reuse projects effectively. We recommend reuse avenue–specific business models and have highlighted the roles and responsibilities of ULBs, end users, and private developers in each model. We have also mentioned examples of successfully implemented cases.

Pricing of TUW

The NF-SRTW states that the ULB shall be responsible for developing a pricing mechanism for TUW where "the pricing of TUW shall, at the minimum, aim to recover the additional operating costs incurred for treating used water to applicable reuse standards and its delivery to the end user." (NMCG 2022). Hence, we have developed pricing criteria for TUW such that the TMC can recover costs, ensuring the financial sustainability of used water treatment and reuse.

ANNEXURE 6:

Developing a standard operating procedure for identified reuse avenues

The objective behind developing a standard operating procedure (SOP) was to standardise the implementation framework at the sub-local level according to the identified reuse avenue in each zone. The SOP includes 1) mapping of sewerage network of the city, 2) estimation of the area covered by each sewerage zone and location of STPs, 3) development of reuse zones as a functional area for reusing of TUW available in that zone, 4) mapping out identified reuse avenues in the zone and estimation of their TUW requirement, 5) formulation of detailed implementation framework outlining the quantity and quality requirement for each identified reuse application along with appropriate business models and conveyance mechanisms, and 6) identification of relevant departments responsible for each reuse avenue.

The data for the sewerage network, STP locations, parks and gardens, bus depots, and fire stations was provided by TMC. Coordinates for other identified reuse avenues were obtained via Google Earth, and the mapping of reuse zones was conducted using GIS tools. However, public utilities, road length, and construction sites within the reuse zones could not be mapped, and their reuse potential has also not been estimated (section 13) due to the unavailability of zone-wise data. Additionally, the estimated reuse potential may be higher, as commercial establishments with high water demand for cooling purposes were identified from secondary literature.

ANNEXURE 7:

Conducting a training needs assessment for institutional capacity building

A Training and Assistance Needs Assessment (TANA) was carried out to 1) understand the roles and responsibilities of each department with respect to treated used water reuse planning and management, 2) understand the existing knowledge of TMC officials working under various line departments concerning used water management and reuse, and 3) assess the training needs of TMC officials with respect to used water management and reuse. The identified training and assistance needs can inform the formulation of a tailored capacity–building and training program for TMC officials in used water management and reuse.

The TANA was undertaken by firstly mapping stakeholders within relevant departments of TMC to undertake the exercise. Next, a structured questionnaire was prepared to collect insights on existing knowledge gaps and needs and expectations from a training program in identified themes (Table A9). Each theme had one or more parameters to undertake a quantitative and qualitative assessment. 13 responses were collected from mid–to senior–level officials from 8 departments in TMC. Finally, an assessment of knowledge gaps and training needs was carried out on the basis of responses collected.

Table A9: Questionnaire for undertaking the training and assistance needs assessment

a) Basic information

1.	Name				
2.	Gender				
3.	Contact number				
4.	Department				
5.	Designation				
6.	Years of experience	1–5 years	5–10 years	10–15 years	above 15 years
7.	Reporting under				
8.	Number of reportees	Permanent staff			Contractual staff

Job role and responsibilities w.r.t. used water management

a) How relevant are your responsibilities/department for used water management?
   - Very relevant
   - Somewhat relevant
   - Not relevant

b) Which aspects of used water management are you or your department involved in?

   Sewerage network connections and collection
   - Planning & scheduling for installation of sewage treatment infrastructure
   - Legal aspects and compliance of sewage treatment infrastructure
   - Technical & engineering aspects of used water treatment (operation and maintenance of sewage treatment plants, quality assurance of treated used water)
   - Financial aspects of used water management (expenditures/budgeting, revenues/billing from sewage connections)
   - Tendering and procurement for sewage treatment infrastructure
   - Field supervision/inspection of sewage treatment infrastructure
   - Training & capacity building of ground functionaries
   - Inter–departmental coordination
   - Public complaint redressal for sewage management
   - Enhancing community participation and awareness among current or potential users of treated used water
   - No perceivable involvement in used water management
   - Any other (please specify)

b) Awareness about used water management in TMC

Sr. No.	Parameters	Relevance w.r.t. job role (1 to 5)	Level of understanding			Is training needed?		Any specific expectations from training
			Good	Fair	Poor	Yes	No	
1. Current water and used water management scenario in TMC								
a.	Water supply (water supply sources, quantity of water supplied, supply network and storage)							
i.	Type and status of surface water supply sources							
ii.	Type and status of groundwater sources							
b.	Water deficit (demand–supply gap)							
c.	Non–revenue water (NRW percentage, causes of water loss, remedial action against water loss)							
d.	Used water generation (current and future generation, sources, mode of discharge)							
e.	Sewerage network (network coverage, efficiency, sewage zones)							
2. Used water treatment process								
a.	Used water treatment capacity (installed treatment vs actual treatment)							
b.	Used water treatment levels (primary, secondary, tertiary, advanced)							
c.	Treated Used Water (TUW) quality standards (water quality parameters measured, treated used water quality standards for surface water discharge and reuse–specific standards)							
d.	Monitoring and evaluation to ensure proper STP operations (operating and maintenance standards, quality guidelines)							
e.	Associated risks of untreated used water discharge (public health and safety, environmental risks)							
3. Used water treatment technologies								
a.	Types of used water treatment technologies (technology selection criteria, quality standards, technology upgradation requirements)							

Sr. No.	Parameters	Relevance w.r.t. job role (1 to 5)	Level of understanding			Is training needed?		Any specific expectations from training
			Good	Fair	Poor	Yes	No	
b.	Technical and engineering aspects of treatment technologies (Infrastructure, capacity, capex/opex, O&M, etc.)							
4. Used water policies and legislative frameworks in India								
a.	Environment (Protection) Act, 1986							
b.	Water (Prevention and Control of Pollution) Act, 1974							
c.	National Environmental Policy, 2006							
d.	National Urban Sanitation Policy, 2008							
e.	Prohibition of Employment as Manual Scavengers and Their Rehabilitation Act, 2013							
f.	Framework for municipal functions (Municipal act, Service rules, Building bye–laws, Municipal Bye–laws, etc.)							
g.	CPHEEO manual on Sewerage and Sewage Treatment Systems, 2013							
h.	NGT quality guidelines, 2021							
i.	Maharashtra State Water Policy, 2019							
j.	Maharashtra Sewage Treatment and Reuse Policy, 2017							
k.	Action Plan for utilisation of treated sewage, 2019 (MPCB)							
l.	National Framework on Safe Reuse of Treated Water, 2022							
m.	Swachh Bharat Mission, 2014							
n.	Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0), 2021							
o.	Smart Cities Mission, 2015							
5. Governance structure								
a.	Overall mandate and responsibilities of respective departments for used water treatment and safe reuse/disposal							
b.	Inter–departmental coordination for data sharing and management for used water management in TMC							

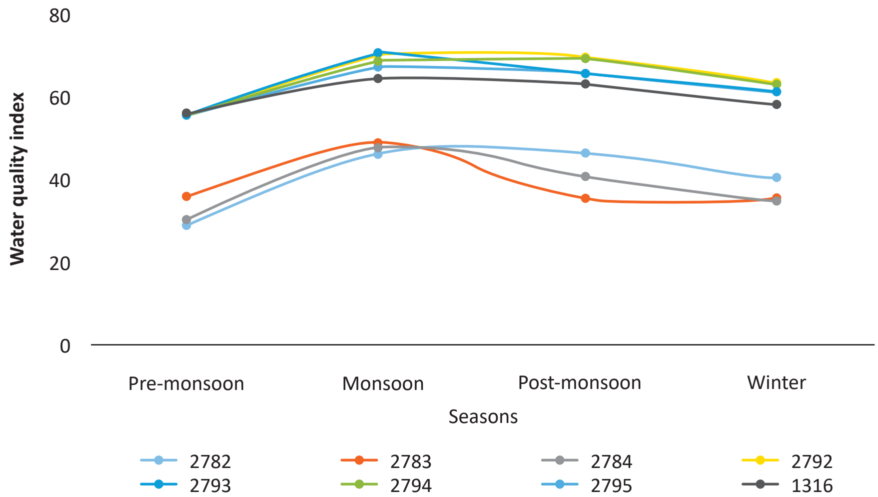
Sr. No.	Parameters	Relevance w.r.t. job role (1 to 5)	Level of understanding			Is training needed?		Any specific expectations from training
			Good	Fair	Poor	Yes	No	
c.	Roles and Responsibilities of other relevant stakeholders like SPCBs, private sector, NGOs, and RWAs for safe reuse of TUW							
6. Reuse of treated used water								
a.	Awareness of the advantages associated with the reuse of TUW							
b.	TUW reuse avenues (landscaping, construction, cleaning, cooling, industrial purposes)							
c.	Current levels of reuse of TUW in TMC							
d.	Feasible conveyance mechanisms for TUW to the point of reuse							
7. Financial aspects of wastewater treatment and reuse								
a.	Sources to access funds (National missions, CSR funds, municipal bonds, etc.)							
b.	Cost of used water treatment and reuse (capital cost, operations and maintenance, technology upgradation cost, conveyance cost)							
c.	Cost recovery mechanisms							
i.	Business models (e.g., Hybrid Annuity Model, Build Operate Transfer, Public Private Partnership, etc.)							
ii.	Pricing of used water (relative pricing to freshwater)							
8. Community engagement								
a.	Information, education, and communication programs for developing awareness and building acceptance towards safe reuse of treated used water							

ANNEXURE 8:

Seasonal surface water quality

Surface water quality varies seasonally, primarily due to fluctuations in water inflow driven by rainfall patterns. Generally, water quality improves during the monsoon season – benefiting from the dilatory effect of runoff generated from rainfall – and deteriorates during the pre-monsoon period, when the runoff reduces and largely consists of base flow. This pattern is evident across all monitoring stations in Thane. As shown in Figure A1, the lowest water quality across all monitoring stations is observed during the pre-monsoon months of March to May. We have represented seasonal WQI spatially in Figure A2.

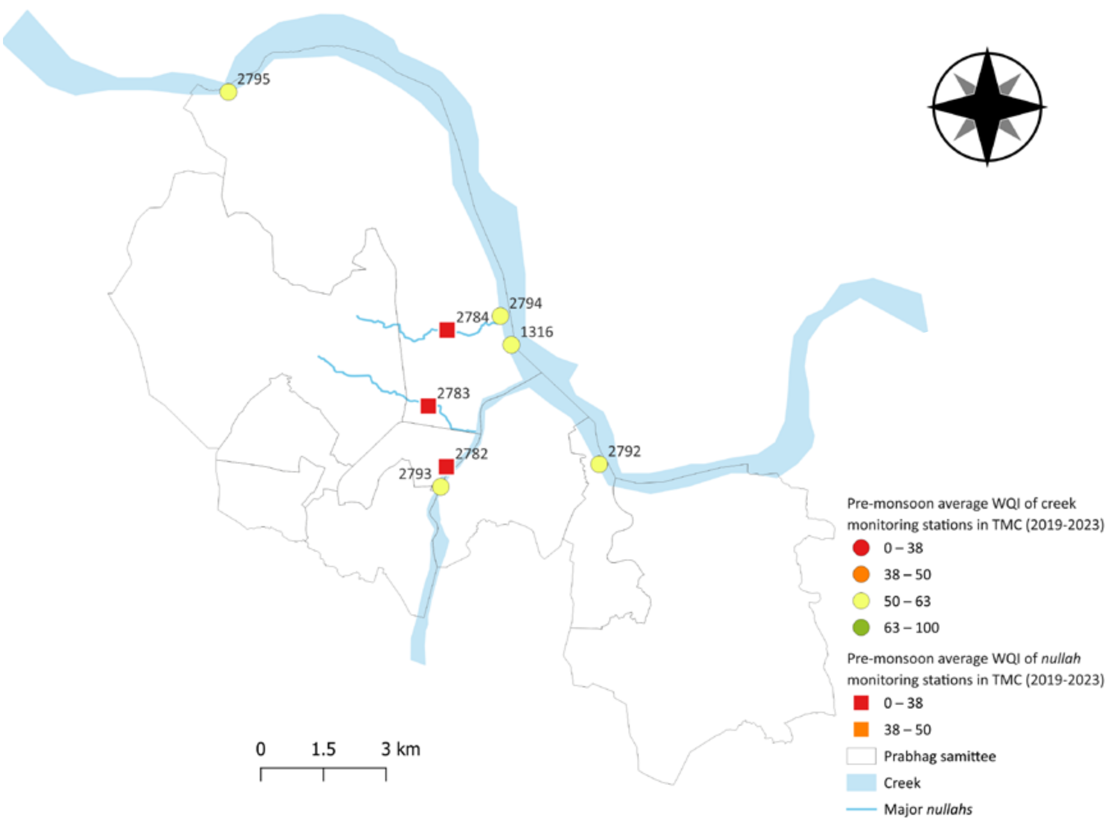
Figure A1: Highest value of the WQI is recorded during the monsoons for all monitoring stations



Source: Authors' analysis using data from MPCB. 2014. Water Quality Monitoring Network in Maharashtra. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

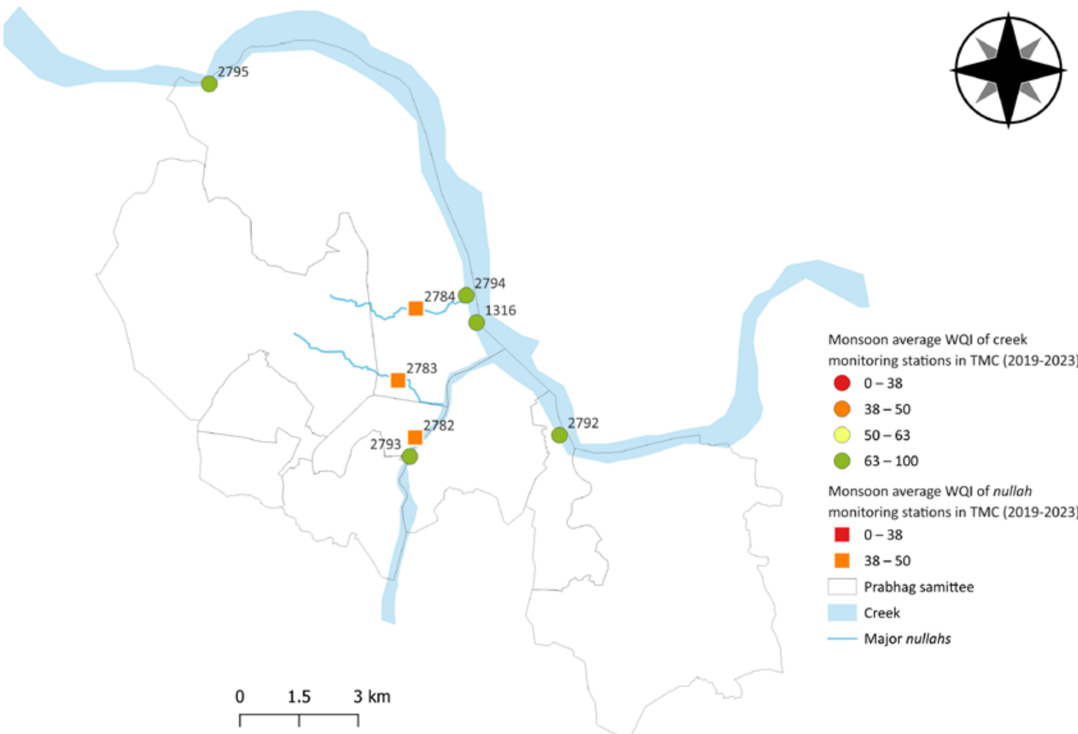
Figure A2: Five-year (2019–2023) seasonal average WQI for TMC: (a) pre-monsoon, (b) monsoon, (c) post-monsoon, (d) winter

(a) Pre-monsoon

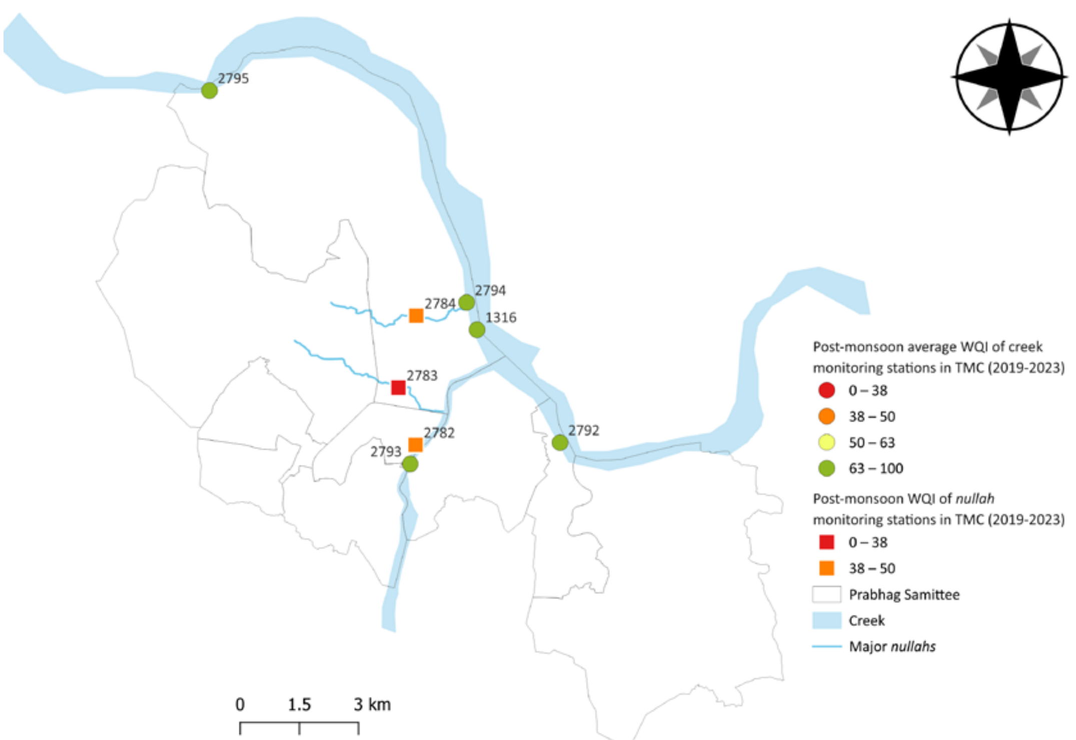


Source: Authors' analysis using data from MPCB. 2014. Water Quality Monitoring Network in Maharashtra. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

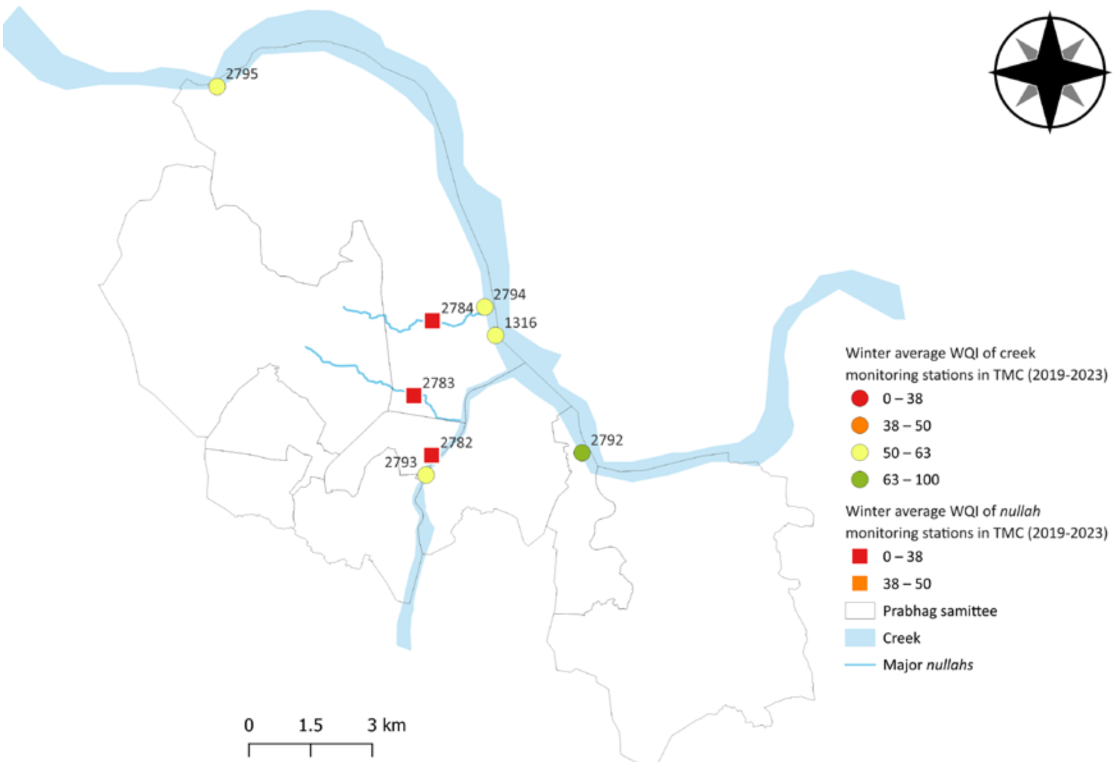
(b) Monsoon



(c) Post-monsoon



(d) Winter



Source: Authors' analysis using data from MPCB. 2014. Water Quality Monitoring Network in Maharashtra. Mumbai: Maharashtra Pollution Control Board, Government of Maharashtra

We found that, in the analysis period, BOD and FC levels in monitored *nullahs* frequently exceeded acceptable standards for surface water discharge. Mean BOD concentrations in *nullahs* exceeded 30 mg/l in all seasons except the monsoons, while FC levels surpassed the permissible limit of 2,500 MPN/100 ml (Bassi et al. 2016) during the pre-monsoons. We also found undesirable BOD values in creek water samples, with 13.87 mg/l in the pre-monsoon season and 10.49 mg/l in winter. BOD levels above 10 mg/l make the water unsuitable for domestic or municipal uses, such as outdoor bathing, landscaping, and vehicle washing. Additionally, BOD levels above 6 mg/l indicate a risk of pollutant accumulation and reduced DO, which can harm aquatic ecosystems (CPCB, n.d.). We observed that DO levels in *nullahs* were below the 4 mg/l threshold required for fish culture and wildlife propagation. In the creek, pre-monsoon and winter DO levels were above 4 mg/l, but was found unfavourable for use as drinking water and outdoor bathing, which require DO levels of 5–6 mg/l. Elevated BOD and FC concentrations, along with reduced DO levels, are likely caused by untreated sewage discharge into surface water bodies and contamination from biological sources.

Expanding the drainage and sewerage network coverage in Thane and keeping them separate can prevent intermixing of sewage and stormwater and mitigate water pollution challenges. Additionally, improving the efficiency of used water treatment facilities to handle the entire volume of sewage generated – along with maximising the reuse of treated water – can significantly reduce the pollution load entering surface water bodies.

ANNEXURE 9:

Strengths, weaknesses, opportunities and threats in used water management in TMC

S. No	Themes	Strengths	Weaknesses	Opportunities & Threats
1.	Infrastructure	TMC performs well in the theme of *Infrastructure* owing to a high installed treatment capacity 120 per cent of sewage generation. It also above average sewage network coverage of 77 per cent.	The city's drainage network coverage stands at 38 per cent.	Due to infrastructural limitations, 87 MLD of sewage remains untreated in Thane. The used water treatment infrastructure should be equipped to handle the current and future rates of sewage generation efficiently. A well-connected and functioning stormwater drainage network is necessary to reduce undue pressure on sewage infrastructure and occurrences of urban flooding.
2.	Efficiency	TMC scores well in terms of energy efficiency. The STPs have a lower power consumption per MLD of actual used water treatment, compared to other evaluated ULBs. Consequently, the energy cost incurred in the used water treatment process is also low, thus also increasing operational cost efficiency.	Used water treatment capacity utilisation is at 61 per cent of the installed treatment capacity. Reuse of treated used water is only five per cent of the total used water received for treatment.	Energy efficiency must be complemented with an increase in used water treatment capacity utilisation to achieve complete treatment of generated used water in the city. Further, the reuse of treated used water should be prioritised for maximising resource recovery in used water management.
3.	Governance	TMC has formulated a Sewage plan as per municipal sources. The city has also been divided into sewage zones that can ensure administration of used water management and reuse interventions.	The latest City Draft Development Plan does not prioritise the reuse of TUW within its objectives (TMC 2024).	A city's Master Plan is an important planning instrument that guides the long–term development of a city. The availability and accessibility of an updated city Master Plan is essential to integrate the existing Sewage Plan and reuse planning with the city's long–term development.
4.	Finance	TMC is the best–performing ULB in the *Finance* theme, with a high score in all the assessing parameters. Under the AMRUT scheme, 87 per cent of the total investment under municipal services is allotted for sewage and septage management (MoHUA 2017). TMC also reports a full cost recovery and efficiency in collecting sewage charges.		A high score in the Finance theme signals *financial* security in the used water management sector, which can be leveraged to prioritise and build capacity for the reuse of treated used water in the ULB.

S. No	Themes	Strengths	Weaknesses	Opportunities & Threats
5.	Data and information		TMC scores the lowest in the theme of *Data and Information,* with a score of 0.71 out of 3 The ULB lacks a dedicated Management Information System (MIS) portal to report performance data on urban services such as sewage management.	The development of a data sharing and management system using the MUWM framework can be useful for establishing a baseline database. This is important to generate awareness about treated used water as a resource and to inform new or existing policies on reuse.

Source: Authors' analysis

ANNEXURE 10:

Minimum water quality requirements and required treatment levels of TUW for identified reuse avenues

S. No.	Reuse Avenues	Applications	Ph	BOD (mg/L)	COD (mg/L)	TDS =mg/L	Oil and grease =mg/L	TSS =mg/L	Turbidity	Minimum residual Chlorine	Coliform	Nitrogen	Phosphorus	Source	Remarks
1.	Landscaping	Parks	6.5– 8.5	<=6–10 (<=6 preferred)	AA	2100	10	AA	AA	nil	nil	AA	AA	MoHUA 2023	The levels of trace compounds and suspended solids (e.g., Sodium, chlorine should be regularly monitored to maintain good plant and soil health)
		Road dividers	6.5– 8.5	<=6–10 (<=6 preferred)	AA	2100	10	AA	AA	nil	nil	AA	AA	MoHUA 2023	
		Stadium	6.5– 8.5	<=6–10 (<=6 preferred)	AA	2100	10	AA	AA	nil	nil	AA	AA	MoHUA 2023	
2.	Cleaning	Bus Depot (Vehicle exterior and wheel washing)	6.5– 8.5	<=6	AA	2100	nil	AA	<2	1	nil	10	1	MoHUA 2023	Tertiary treated water is recommended to prevent corrosion of metal used in vehicle exteriors
		Roads	6.5 – 9	10	50	–	–	20	–		100	10	–	MPCB 2022	
		STP facilities	6.5 – 9	10	50	–	–	20	–		100	10	–	MPCB 2022	
		TMC office (Mahapalika Bhavan)	6.5 – 9	10	50	–	–	20	–		100	10	–	MPCB 2022	Tertiary treated water is recommended for reuse applications with contact risk
3.	Construction sites	Landscaping	6.5– 8.5	<=6–10 (<=6 preferred)	AA	2100	10	AA	AA	nil	nil	10	1	MoHUA 2023	Tertiary treated water is recommended for reuse applications with contact
		Dust suppression:	6.5 – 9	10	50	–	–	20	–		100	10	–	MPCB 2022	
		Cleaning (aggregate, concrete batching plants, and vehicles)	6.5 – 9	10	50	–	–	20	–		100	10	–	MPCB 2022	risk and to prevent corrosion of metal in batching plants and vehicle exteriors

S. No.	Reuse Avenues	Applications	Ph	BOD (mg/L)	COD (mg/L)	TDS =mg/L	Oil and grease =mg/L	TSS =mg/L	Turbidity	Minimum residual Chlorine	Coliform	Nitrogen	Phosphorus	Source	Remarks
4.	Fire station	Maintenance of water storage system for firefighting	6.5– 8.5	10	AA	2100	nil	AA	<2	1	nil	10	1	MoHUA 2023	recommended for reuse applications with contact risk and to prevent corrosion of metal used in fire hydrants In make–up water: Chlorides = less than 175 mg/1 Ammonia= no appreciable amount Caustic alkinity = absent Methyl orange alkanity= less than 200 In re–circulating water: Silica = Less than 150 mg/1 Phosphates and sulphates = Not to exceed solubility levels in circulating water Alkul Benzene Sulfonate (ABS) Foam not to persist more than 1 minute after 10 seconds of vigorous shaking of re–circulating water Tertiary treated water is recommended for reuse applications with contact risk
5.	Commercial cooling establish-ments	Cooling water	6.8– 7	Less than 5	–	500–3000	nil	–		–	nil	–	*	MoHUA 2023	
		Cleaning of commercial establish-ments	6.5 – 9	10	50	–	–	20	–		100	10	–	MPCB 2022	
6.	Industries	Industrial cooling, spraying in mine pits, and boiler feed	6.8– 7	Less than 5	–	500–3000	nil	–		–	nil	–	*	MoHUA 2023	The minimum quality standards for manufacturing and processing industries is assumed to be the water quality achieved post tertiary treatment (NMCG 2011). Industry–wise water quality requirements (in mg/l) are given below (MoHUA 2023):
		Processing whereby water gets polluted and pollutants are not easily biodegredable	6.5–8.5	<=6	AA	2100	nil	AA	<2	1	nil			MoHUA 2023	

S. No.	Reuse Avenues	Applications	Ph	BOD (mg/L)	COD (mg/L)	TDS =mg/L	Oil and grease =mg/L	TSS =mg/L	Turbidity	Minimum residual Chlorine	Coliform	Nitrogen	Phosphorus	Source	Remarks
		Processing whereby water gets polluted and pollutants are easily biodegredable	–	<10				<5			10		<0.5	NMCG 2011, MoHUA 2023	
		Domestic purposes (cleaning requirements)	6.5 – 9	10	50	–	–	20	–		100	10	–	MPCB 2022	
7.	Public utilities	flushing toilets	6.5– 8.5	<=6	AA	2100	10	AA	<2	1	nil			MoHUA 2023	Tertiary treated water is recommended beyond the minimum quality standards for reuse applications with contact risk
8.	Environ-ment	Water body rejuvenation	6.5– 8.5	10	AA	2100	nil	AA	<2	0.5	nil			MoHUA 2023	Tertiary treated water is recommended beyond the minimum quality standards to maintain high quality of groundwater in the case of indirect recharge from rejuvenated water bodies (DJB 2016, Tyagi and Goyal 2024)

Source: Authors' analysis using listed sources

ANNEXURE 11:

Reuse specific business models will ensure economies of scale and long-term sustainability

S. No	Reuse avenue	Business model	Implementation mechanism	Case study
1.	Landscaping	On–site value creation model	Role of ULB Supports private entities in providing the land. Allow access to city used water drains Provide buy-back guarantee for TUW Role of private developer Cover cost of building and maintaining supply chain: Laying pipelines from the nearest used water source to the plant. Capital cost for construction of treatment plant Operation and maintenance cost for contractual period	Garden STPs under New Delhi Municipal Corporation (Alley, Maurya, and Das 2018)
2.	Cleaning	Reuse utility buy back model	Role of ULBs Provide land for the construction of treatment plant. Provide access to sewage Enforce contract terms and ensure quality compliance Provide buyback guarantee for reclaimed water. Role of private developers Invest in building treatment and conveyance infrastructure. O&M cost for contractual period Transfer of assets to ULBs after the contractual period	Keshevpur bus depot (Alley, Maurya, and Das 2018)
3.	Construction sites	Investment by end–user	Case 1: If water supplied and required is secondary treated. Role of ULBs Supply secondary treated water (STW) and charges minimal volumetric charge for STW. Role of end–user Invest in conveyance mains to bring STW to its premises. Case 2: If water supplied is secondary and required is tertiary treated. Role of ULBs Supply secondary treated water (STW) and charges minimal volumetric charge for STW. ULB covers the conveyance cost from STP to end–user premises Role of end–user Responsible for establishing and operating the tertiary treatment plants	DMRC batching plant at Sarita Vihar depot (For Case 2) (Field Visit)

S. No	Reuse avenue	Business model	Implementation mechanism	Case study
4.	Fire station	Investment by end–user	Role of ULBs Supply secondary treated water (STW) and charges minimal volumetric charge for STW ULB covers the conveyance cost from STP to end–user premises Role of end–user Responsible for establishing and operating the tertiary treatment plants	
	Industries	Investment by end–user	Role of ULBs Supply secondary treated water (STW) and charges minimal volumetric charge for STW ULB covers the conveyance cost from STP to end–user premises Role of end–user Responsible for establishing and operating the tertiary treatment plants	Chennai Petroleum Corporation Ltd. and CMWSSB agreement on reuse of TUW. (World Bank 2021)
		Build–Operate–Transfer end user PPP model	Role of ULBs Provide raw used water Cover a part of capital cost incurred for construction of secondary and tertiary treatment. Role of end–user Enter into agreement with EPC contractor and O&M operator for establishing conveyance mechanism from STPs to the premises and O&M of treatment plants Provide NMC with raw water charges fees	MahaGenCo and Nagpur Municipal Corporation agreement on “Construction and Operating Agreement of Treatment and Transmission Facilities for Reclaimed Water Usage (MPCB 2020)
5.	Commercial establishments (malls, offices, etc.)	Investment by end–user	Role of ULBs Supply secondary treated water (STW) and charges minimal volumetric charge for STW ULBs covers the conveyance cost from STP to end-user premises Role of end-user Responsible for establishing and operating the tertiary treatment plants	
		Close loop or zero discharge model	In this model, entities invest in the installation and commissioning of used water treatment plants, treat their locally produced used water, and reuse it for different reuse avenues locally. Thus, entities become producers as well as consumers	IIT Madras – net zero discharge. Renaissance hotel, Mumbai. (Alley, Maurya, and Das 2018)

Source: Authors’ analysis using listed sources

ANNEXURE 12:

Department–specific training needs in used water management and reuse

S. No.	Themes	Training needs							
		Env Dept	Fire Dept	Mechanical Dept	Parks and Gardens Dept	Sewage Dept	Town Planning Dept	Transport Dept	Water supply Dept
1	Current water and used water management scenario in TMC	Low	Moderate	Moderate	Low	Moderate	Low	Low	Low
2	Used water treatment	High	High	High	Low	High	Low	Low	High
3	Used water treatment technologies	High	High	High	No training needs	High	Low	Low	High
4	Used water policies and legislative frameworks in India	High	High	High	No training needs	High	Low	Low	High
5	Governance structure	High	Moderate	High	No training needs	Moderate	Low	Low	High
6	Reuse of treated used water	High	Low	High	No training needs	High	Low	No training needs	High
7	Financial aspects of wastewater treatment and reuse	High	No training needs	High	No training needs	High	Low	No training needs	High
8	Community engagement	High	No training needs	High	No training needs	High	Low	No training needs	High

Source: Authors' analysis using data collected from primary survey

- No training needs
- Low
- Moderate
- High

Notes

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