Bridging Circular Economy and Water Sustainability: A CWQN-Based Comparative Study of Urban and Rural Systems in Konkan

Priyanka Deshmukh[1], Vinod Salunkhe [2], Vikas Nagve[3], Yogesh Bhalekar

[1] *Assistant Professor, Engineering Sciences & Humanities, Thakur College of Engineering and Technology, Maharashtra, India*
[2] *Assistant Professor, Engineering Sciences & Humanities, Thakur College of Engineering and Technology, Maharashtra, India*
[3] *Assistant Professor, Engineering Sciences & Humanities, Thakur College of Engineering and Technology, Maharashtra, India*
[4] *Assistant Professor, Engineering Sciences & Humanities, Thakur College of Engineering and Technology, Maharashtra, India*

ABSTRACT

This study examines how Circular Economy (CE) principles can strengthen water and waste management systems in the ecologically sensitive Konkan region of western India. The area faces increasing pressure from climate change, rapid urbanization, infrastructure gaps, and socio-spatial disparities that collectively degrade local water quality. To address these challenges, the research integrates secondary data, policy analysis, case studies, and a community perception survey conducted across rural and semi-urban locations such as Ratnagiri, Dapoli, and Chiplun.

A major contribution of this study is the development of the Circular Water-Quality Nexus (CWQN) model, a conceptual framework that connects climate stressors, waste flows, community behaviours, and key water quality indicators such as BOD, DO, and turbidity. The model illustrates how context-sensitive circular interventions—ranging from greywater recycling and decentralized treatment systems in urban areas to composting, rainwater harvesting, and community-led sanitation initiatives in rural settings can collectively reduce ecological pressures and improve local resilience.

Survey results reveal a notable awareness–practice gap: while residents demonstrate general understanding of waste segregation and water reuse, actual adoption remains limited due to infrastructural, behavioural, and informational barriers. Comparative analysis of urban and rural systems further highlights how CE strategies must be tailored to each setting's unique socio-environmental conditions.

Overall, the findings show that CE-driven water management, supported by participatory governance, digital monitoring, and locally relevant solutions, can offer a viable pathway for enhancing water sustainability in regions like Konkan. The study emphasizes that integrating community engagement with CE interventions is essential for building long-term environmental resilience and guiding future policy directions.

Keyword:- *Circular economy1, Water quality2, Waste management3, Climate change4, Konkan5, CWQN model6, Urban-rural systems7,etc.*

1. INTRODUCTION

The discussions on environmental issues and their associated problem has been approached by focusing on finding root issues rather than finding solutions to symptoms over the years. This is even more relevant when considering water management and waste. Such systems are very important for countries like India which have rapid urban development, susceptible rural areas, and the factors of climate change combined adds more pressure on freshwater resources. [1,2]

Water management traditionally has a linear approach extraction, usage, and getting rid of resources/ water. With irregular rainfall patterns, untreated waste, etc, this becomes increasingly more troublesome. It does not account for rising temperatures which makes this model daunting. These challenges are exacerbated in areas such as Konkan's

coast in western India where local communities access water for drinking and agricultural purposes. Rural gaps in infrastructure combined with the overburdened systems in the nearby city add to the challenge. [3,4]

Circular economy (CE) serves as a plausible alternative. CE unlike traditional methods help reserve resources by promoting its use and regeneration, eliminating waste and therefore garnishing needed attention. Within water and waste management circular economies enables practices such as composting as well as decentralised treatment alone can create a sustained environment in these areas.[5,6]

This paper draws on secondary data, policy analysis, and case studies to examine the current state of water and waste management in the region. It also proposes a conceptual model the Circular Water-Quality Nexus (CWQN) to explore the links between climate change, waste systems, and water quality, while highlighting ways local communities can lead circular, sustainable interventions.

By identifying gaps and showcasing technology-driven, inclusive solutions, this study adds to the growing efforts toward sustainable water governance grounded in both innovation and community action.

Following section deals with the literature review;

2. LITERATURE REVIEW

The existing body of literature on circular economy (CE) and water management demonstrates that sustainable water governance requires understanding the interconnected challenges faced by both urban and rural systems. Scholars consistently highlight that rapid urbanization, growing waste generation, climate-induced pressures, and infrastructural disparities all shape how circular practices emerge and operate across different contexts. Urban regions primarily grapple with pollution loads, outdated sewage networks, and dense populations, while rural areas struggle with limited technical capacities and reliance on natural water sources. At the same time, climate variability intensifies vulnerabilities in both settings, pushing communities to adopt adaptive and resource-efficient interventions. The literature also underscores the importance of policy frameworks, community participation, and measurable indicators to ensure that CE strategies are not only implemented but sustained. Together, these insights form the foundation for a structured review of how CE principles have been applied across urban and rural environments, how waste and water dynamics influence circular transitions, and how governance and monitoring mechanisms support the shift toward resilient water systems.

2.1 Circular Economy in Urban and Rural Water Systems

As regions grow, both urban and rural areas put pressure on their water systems. Cities, which are already struggling with industrialization and overcrowded populations, have aged infrastructure and waterways filled with pollutants. On the other hand, rural areas do not have enough resources to erect systems capable of recycling waste water and upholding environmental standards.

OECD 2020 has proposed that strategies such as stormwater management, recovering nutrients, and treating water on a smaller scale are nifty approaches for dealing with the environmental impacts of pollution. In urban areas, these methods are being incorporated into city designs through closed loop systems and regenerative infrastructure that enhance resilience [1, 7].

In rural regions, strategies must be simple to understand and integrate in order to achieve acceptable participation from the public. Rodrigo-Ilarri et al (2021) are a case in point showcasing how small-scale practices like biofertilizer production, treating greywater, and recovering solid waste at the community level in rural Colombia improved water standards and local employment opportunities [6]. These case studies from different contexts emphasize the need for adaptation and that sustainability is context specific.

2.2 Urban Waste, Water Quality, and Circular Practices

The pollution of water is greatly attributed to the solid and liquid waste from urban areas, especially considering that towns experience flooding and heavy rainfall more often as a result of climate change. These processes could reduce waste, given a circular approach was implemented in their management, it would make a difference.

Encouraging results are highlighted in the studies: As an example, circular practices for Haris et al. (2024), sewage systems like recycling, composting, and biogas recovery systems, reduce landfill waste, in addition to containing sewage pollutants[8]. Additionally, the so-called 'green' infrastructure permeable pavements, green roofs and other forms of sustainable drainage systems not only better manage stormwater but actually reduce contamination [9].

Furthermore, changing behavioural patterns on the side of the citizens is as valuable as an improvement of the different services and infrastructures. In the focus of Marjanović et al. (2024) lies in sustainability, comprising the culture of less water usage, adequate waste separation, and circularity promoting actions on the ground like so fostered [10].

2.3 Circular Solutions for Climate-Stressed Communities

Both in the urban slum and in the rural settlement, the population is increasingly experiencing the extremes. Being exposed to the higher range temperature, alongside the alteration of the water's chemical composition, and the more frequent climate shocks present threats to the fragile state of the water infrastructure that is already existing.[8]
Community circular initiatives are emerging as powerful community-led initiatives. As highlighted Ceddia et al. (2024) for such undertakings voluntary sanitation, local water monitoring, and small scale participatory action are all examples of community driven water corrective actions. [11] These grassroots approaches are particularly valuable in climate-sensitive regions, where centralized infrastructure is often too slow or costly to deploy.

2.4 Governance and Policy: Laying the Groundwork for Circularity

Adaptable frameworks, governance models, and policies are necessary for implementing circulatory systems in water management. OECD's 2020 report and Van Den Berghe et al.'s 2024 release articulate how local regulations need to be more flexible and tailored to the local context while also calling for improved coordination and integration between different levels of government and sectors [1, 9].
The integration of waste recovery and water reuse in smart city plans marks the beginning of the efforts in India. Unfortunately, progress is inconsistent. Numerous cities, along with rural areas, still confront limited public interest, insufficient funding, and problematic policies. Singhvi et al. (2025) stress that developing public comprehension of circular practices through educational incentives and community-driven activities is fundamental for adoption acceleration [7].

2.5 Metrics and Monitoring: Measuring What Matters

Tracking the effectiveness of implementing circular strategies is equally important. According to Muñoz and Navia (2021), methodologies such as material flow analysis (MFA), lifecycle assessment (LCA), and water foot-printing can be used to measure impact from pollution reduction to efficiency improvement [12].
MFA and LCA are relatively simple to attain. Restoring reliable data and establishing accessible monitoring platforms as a new standard would help both urban and rural areas pinpoint effective systems and identify those requiring improvement.
To sum up, the distinct approaches of both urban and rural settings to the controlled watersheds, showcases the need for a more encompassing solution in circular economies relating to water and waste management. This spans from grassroots initiatives to policy changes, encouraging performance-driven collaborative efforts to alter water management in a hotter world.

3. METHODOLOGY

This study undertakes conceptual and analytical methods to investigate the application of Circular Economy (CE) principles to wastewater issues in the Konkan region of western India which is vulnerable to climate change impacts. This approach attempts to balance the theoretical and practical layers of the problem by integrating literature reviews alongside community-level comparative case studies and perception-based primary data gathering.

3.1 The Konkan Region

The region of Konkan includes the coastline of the state of Maharashtra, the state of Goa, and Karnataka. There is strong justification for selection of this region for the research because of its ecological diversity, socio-economic complexity and an integrated urban-rural setting. While urban centers such as Thane and some parts of Mumbai are under severe strain of infrastructure and wastewater overloading, rural regions such as Ratnagiri, Dapoli, and Sindhudurg are facing lack of sanitation infrastructure and increasing vulnerability to climate impacts on water resources including flooding, seasonal drought, and pollutant runoff. [1,3]
The region is also home to ecologically significant rivers like the Ulhas, Vaitarna, Savitri, and Vashishti, which are essential to agriculture, domestic use, and industry. However, studies and government reports MPCB, 2020–2023 highlight rising Biochemical Oxygen Demand (BOD), nutrient loading, and declining dissolved oxygen (DO) levels particularly in peri-urban and agricultural runoff zones pointing to a critical need for circular and community-responsive water management strategies.

3.2 Survey Design and Implementation

To understand local perspectives and practices regarding CE particularly in the domains of water reuse, sanitation, and waste management a community survey was conducted with a sample size of 150 respondents. Participants were selected from rural and semi-urban locations such as Ratnagiri, Dapoli, and Chiplun, using a mix of offline (paper-based) and online (Google Forms) survey tools.
The sample included a demographically diverse group comprising homemakers, farmers, small business owners, students, and teachers. While this sample provides rich qualitative insights, its modest size and purposive nature imply that results should be interpreted with caution regarding statistical generalizability.
The survey focused on four thematic areas:
Awareness of Circular Economy Concepts

•Are respondents familiar with the term "Circular Economy"?
•Do they understand water reuse or waste-to-resource initiatives?
Current Practices
•Is household waste segregated?
•Is greywater reused for non-potable purposes?
•Are composting or biogas techniques used?
Barriers to Adoption
•What limits the adoption of CE practices? (e.g., lack of infrastructure, awareness, interest)
•Willingness to Participate
•Are people open to participating in community-led water or waste programs?

3.3 Secondary Data Sources and Literature Review

To complement the survey, secondary data were collected from:
•Maharashtra Pollution Control Board (MPCB) reports (2020–2023) on BOD, DO, pH, and turbidity levels in regional water bodies. [14]
•Municipal and district sanitation plans, which revealed that only 65–70% of wastewater in Mumbai is effectively treated. [15]
•National documents like the Jal Jeevan Mission and Maharashtra State Water Policy (2020) helped contextualize governance challenges and institutional priorities. [16]
Academic sources were drawn from journals such as Sustainability, Water Policy, and Environmental Science & Policy, focusing on:
•CE implementation in Indian and global contexts
•Urban-rural differences in water-waste dynamics
•Decentralized solutions like DEWATS and composting toilets
•Role of ICT in community-level monitoring and engagement

3.4 Analytical Framework

To organize and interpret findings, a multi-step analytical process was employed:
1. Thematic Literature Synthesis
•Relevant literature was coded to extract recurring themes such as:
•Infrastructure and policy gaps.
•Success of decentralized and community-driven interventions.
•Regional disparities in water access and waste treatment.
•Themes were organized by urban and rural relevance, aligning with the literature review's comparative structure.

For instance, urban areas emphasized overburdened sewage systems, while rural areas highlighted greywater treatment and informal waste disposal practices.
2. Comparative Case Profiling
•Two representative case profiles were developed:
•Urban: The Mumbai Metropolitan Region (MMR), with infrastructure-intensive but strained wastewater systems
•Rural: Villages in Ratnagiri and Sindhudurg, with informal sanitation practices and emerging community-led initiatives

This comparison allowed us to analyze context-specific challenges and potential CE responses across contrasting settings.

3.5 The Circular Water-Quality Nexus (CWQN) Model

To guide the integration of data and insights, the study proposes a conceptual framework the Circular Water-Quality Nexus (CWQN) Model which visualizes the interactions between climatic stressors, waste management strategies, and community-based circular interventions. [6,11]
Model Structure:
Layer 1: Drivers
•Climate-related stress (e.g., extreme rainfall, rising temperatures)
•Human-induced pressures (e.g., industrial runoff, waste mismanagement)
Layer 2: Stress Indicators
•Elevated BOD and turbidity
•Reduced DO and water pH balance
•Contamination from fertilizers and pathogens
Layer 3: Circular Interventions

•Urban Solutions: Green roofs, SuDS, greywater recycling
•Rural Solutions: Compost toilets, rainwater harvesting, DEWATS
•Interventions are context-driven, factoring in available resources, local capacity, and climatic risk

Layer 4: Outcomes and Feedback
•Improved water quality metrics (e.g., DO ↑, BOD ↓)
•Reduced untreated waste discharge
•Increased community awareness and participation
•Feedback mechanisms for policy and behaviour adjustment [9,12]

The CWQN model serves as a decision-making tool that connects CE strategies to real-world performance outcomes, particularly in regions under climate stress. It is grounded in systems-thinking and aligns with recent scholarly frameworks on resilient water governance and circular planning [1,6,11]. Following fig 1 shows Circular Water-Quality Nexus (CWQN) Model.

Circular Water-Quality Nexus (CWQN) Model

Fig 1. The CWQN Model

4. RESULTS: COMPARATIVE ANALYSIS OF URBAN AND RURAL CE PRACTICES

This part integrates results from the literature-based comparative analyses and the primary survey data. The insights are interpreted using the Circular Water Quality Nexus (CWQN) model, which was created for this research to assess the intersection of climate stressors, waste management, community behaviours, and resulting water quality outcomes.

4.1 Comparative Insights: Urban vs. Rural Circular Economy Practices

This analysis draws upon field observations, secondary data, and documented CE interventions in both urban Mumbai and rural Konkan villages. It supports the first research objective: to compare urban and rural applications of CE practices impacting water quality.

Urban Context: Mumbai Metropolitan Region
•Wastewater Generation: Roughly 2,100 MLD is generated daily; only ~1,200 MLD is effectively treated despite higher installed capacity. [2]
•Circular Practices: Select wards are piloting Decentralized Wastewater Treatment Systems (DEWATS) and reusing treated water in industries and landscaping.
•Challenges: Land scarcity, high capital costs, and public hesitancy in reusing treated water.

Rural Context: Konkan Villages
•Waste Profile: Lower per capita waste (~0.3–0.6 kg/day), mostly organic in nature. [17]
•CE Practices: Villages are using community composting and rainwater harvesting, enhancing both water retention and soil health.
•Challenges: Technical know-how, lack of sustained funding, and limited awareness impede scalability.

Following Table no 1 shows the comparative matrix of urban vs rural CE implementation.

Table no 1. Comparative Matrix: Urban vs. Rural CE Implementation

Aspect	Urban Areas (Mumbai)	Rural Areas (Konkan Villages)
Wastewater Volume	High (~2,100 MLD)	Low
Treatment Infrastructure	Advanced but underutilized	Minimal or community-based
CE Practices	Decentralized Wastewater Treatment System (DEWATS), wastewater reuse	Composting, rainwater harvesting
Challenges	Infrastructure costs, public perception	Technical expertise, funding, awareness
Opportunities	Industrial reuse, policy support	Community engagement, low-cost solutions

4.2 Case Study Insights: Global and Local Reflections

Aligned with the second research objective to contextualize CE strategies globally case studies illustrate how diverse regions have adapted circular practices to restore water ecosystems.

Urban Inspiration: Thames and Los Angeles Rivers

•UK's Thames River: Once considered biologically dead, the river now boasts over 125 species of fish, thanks to CE-aligned works like the Thames Tideway Tunnel, which also intercepts combined sewer overflows. [18]

•Los Angeles River (USA): Faced with urban runoff and industrial waste, LA introduced green infrastructure and constructed wetlands, restoring ecosystem balance. [19]

These cities show how policy, investment, and community design can reverse water degradation lessons relevant to Navi Mumbai and Thane, where DEWATS and blue-green infrastructure can replicate such outcomes.

Rural Inspiration: Ganges Basin and Rural Colombia

•Ganges Villages (India): Small-scale CE projects bio-toilets, composting, local sanitation drives have reduced BOD levels and promoted behavioural change. [20]

•Rural Colombia: Villages use eco-toilets, rainwater harvesting, and greywater reuse, resulting in nutrient recovery and groundwater protection. [6]

These examples align with the needs of Konkan villages, reinforcing the CWQN model's emphasis on community-led, low-cost, and culturally embedded CE solutions.

4.3 Survey-Based Insights: The Awareness-Practice Divide

The third research objective to examine CE awareness and behaviour was addressed through a primary survey across Konkan's urban and rural populations.

Key Survey Findings:

•78% of respondents were aware of waste segregation, but only 42% practiced it regularly.

•Water reuse awareness was at 55%, while only 27% reported practicing it.

•The majority showed willingness to adopt CE practices if supportive infrastructure or local programs were available.

Following fig 2 shows a clear gap exists between what people know and what they do highlighting a key focus area for future CE policy and education efforts.

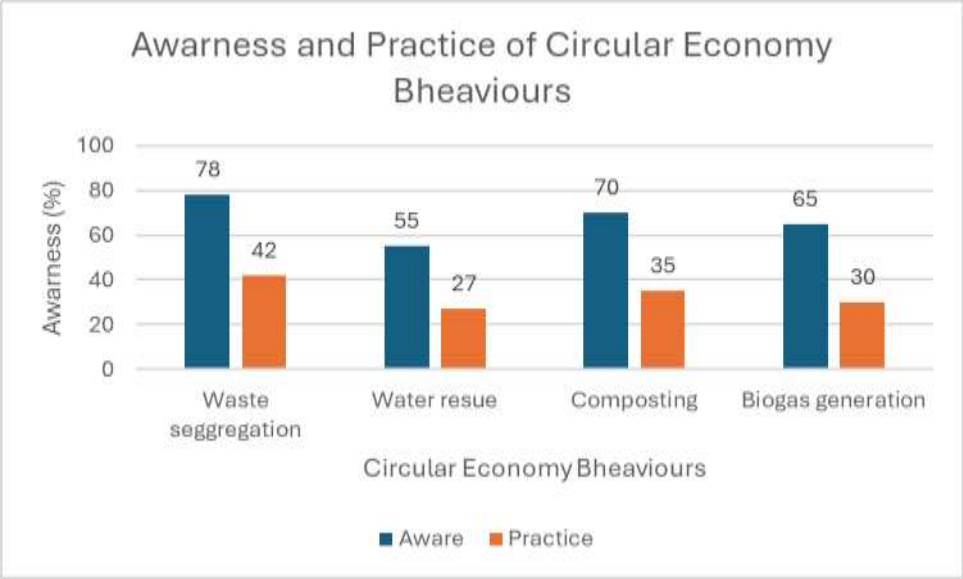

Fig 2. Awareness vs. Practice in CE Behaviours

4.4 Insights from the CWQN Model Application

By applying the CWQN model, several patterns became clear across both geographies:

•Climate stressors, such as intense rainfall and rising heat, intensify water pollution by overwhelming natural and built systems.

•Localized circular interventions like bio-sanitization in villages and greywater systems in peri-urban colonies are most effective when scaled in alignment with local capacities.

•Community participation is pivotal: Villages that engaged in CE programs showed visible improvements in water clarity, odour, and biodiversity, supported by secondary water quality assessments [14].

4.5 Emerging Enablers and Policy Linkages

Recent national programs support the CE transition:

•Jal Shakti Abhiyan and AMRUT 2.0 have begun integrating CE tools like water reuse incentives and rural-urban water connectivity.

•Digital water monitoring using IoT-based sensors and open dashboards is empowering local bodies to make real-time decisions.[12]

These enablers bridge the systemic gaps identified in the CWQN model and offer a roadmap for mainstreaming CE in policy and practice.

Through a mix of field data, case studies, and survey insights, the study validates the CWQN model as a useful analytical lens for understanding how circular economy principles can be tailored for context-sensitive water management. The urban-rural contrast shows that while solutions may differ in scale and complexity, the underlying drivers and human behaviours remain intertwined.

5. CONCLUSION

India's environmentally sensitive regions such as the Konkan belt are increasingly straining for water resources due to erratic changing climates, inadequate waste management, and poor infrastructural planning. This research examines the extent to which circular economy (CE) principles could practically and sustainably remediate these problems in both urban and rural settings.

Employing the CWQN model, the research was able to demonstrate with substantial confidence that climate stressors, community behaviour, and the corresponding-deterioration of water quality are interlinked. While there is a marked distinction between urban centers like Mumbai and rural outposts like Ratnagiri, both urgently need to shift from linear to circular approaches.

The research noted that circular approaches, whether DEWATS in cities or composting and raisin farming in rural areas, have proven to be more effective and support healthier ecosystems when driven by community engagement, local relevance, and policy support.

Key Takeaways:

•Context matters: Urban areas benefit from tech-enabled, policy-backed systems (e.g., greywater reuse, DEWATS), while rural communities thrive with low-cost, community-led practices like composting and bio-toilets.

•Bridging the awareness-practice gap is crucial. Survey results show high CE awareness but low adoption underscoring the need for participatory programs, behavioural nudges, and infrastructure support.
•Technology is an enabler, not a substitute: Tools like IoT sensors and AI-based waste tracking amplify impact, but must be paired with education and localized planning.
In alignment with national missions like Jal Jeevan, AMRUT 2.0, and Swachh Bharat, and global goals like SDG 6, 11, and 13, this study reaffirms that circular water strategies are more than infrastructure upgrades they are pathways to resilient, inclusive, and climate-smart development in regions like Konkan.

6. REFERENCES

[1]. OECD. (2020). *The circular economy in cities and regions: Synthesis report*. Organisation for Economic Co-operation and Development.

[2]. Centre for Science and Environment (CSE). (2021). *State of India's environment: In figures*. New Delhi: CSE.

[3]. Council on Energy, Environment and Water (CEEW). (2020). *Towards Circularity in Used Water Management in India*.

[4]. Maharashtra Pollution Control Board (MPCB). (2021). *Water Quality Report 2020–21*.

[5]. Ellen MacArthur Foundation. (2013). *Towards the circular economy: Economic and business rationale for an accelerated* transition. Ellen MacArthur Foundation.

[6]. Rodrigo-Ilarri, J., et al. (2021). Decentralized wastewater treatment in rural Colombia: A sustainable solution for water reuse and sanitation. *Sustainability*, 13(7), 3816. https://doi.org/10.3390/su13073816

[7]. Singhvi, A., Athanassiadis, A., & Binder, C. R. (2025). Configurations for circularity? A scoping review of urban planning approaches in the circular economy literature. *Urban Research & Practice*. Advance online publication. https://doi.org/10.1080/17535069.2025.2465961

[8]. Haris, N. I. N., Osman Al Edrus, S. S., Abdul Raof, N., Wondi, M. H., Khan, W. R., Sien, L. S., Ilyas, R. A., Norrrahim, M. N. F., & Sawatdeenarunat, C. (2024). Toward low-carbon cities: A review of circular economy integration in urban waste management and its impact on carbon emissions. *WIREs Energy and Environment, 13*(5), e535. https://doi.org/10.1002/wene.535

[9]. Van den Berghe, K., et al. (2024). *Policy recommendations for urban and regional circular economy*. In *Regional Studies Policy Impact Books* (Vol. 6, No. 1, pp. 99–108).

[10]. Marjanović, S., et al. (2024). Transition to Circular Economy in Urban Areas with Focus on Lifestyles. *Discover Sustainability*.

[11]. Ceddia, A. R., et al. (2024). Exploring the Nexus between Circular Economy and Communities. *Frontiers in Sustainable Cities*, 6, 1404279

[12]. Muñoz, E., & Navia, R. (2021). Circular Economy in Urban Systems: How to Measure Impact? *Waste Management & Research*, 39(10), 1121–1130.

[13]. Britannica. (n.d.). *Konkan*. Retrieved from https://www.britannica.com/place/Konkan

[14]. Maharashtra Pollution Control Board (MPCB). (2021). *Water Quality Report 2020–21*, Government of Maharashtra.

[15]. Municipal Corporation of Greater Mumbai (MCGM). (2022). *Environmental Status Report*, Government of Maharashtra.

[16]. Maharashtra State Water Policy-Water Resource Department 2019- (Government Resolution No-Water Policy-2019/C.R. 21/17/WR (P) dated 5th Dept 2019)

[17]. Status of Municipal Solid Waste: Generation Collection Treatment and Disposal in Class I cities, CPCB April 2000.

[18]. Environment Agency UK. (2020). *Thames River Basin Management Plan – Progress Update*.

[19]. Li, H., Pomeroy, C. A., & Sample, D. J. (2019). Stormwater runoff and sustainable drainage systems in Los Angeles. *Journal of Hydrology*, 569, 535–546. https://doi.org/10.1016/j.jhydrol.2018.12.007

[20]. Mishra, A., Sinha, R., & Tare, V. (2017). Mitigating pollution in the Ganga River through participatory management and decentralised systems. *Environmental Science & Policy*, 76, 51–61. https://doi.org/10.1016/j.envsci.2017.06.005

[21]. World Bank. (2021). *Water in circular economy and resilience (WICER): The case of Chennai, India*. World Bank Group. https://openknowledge.worldbank.org/handle/10986/35659

[22]. United Nations. (n.d.). *The 17 Sustainable Development Goals*. Retrieved from https://sdgs.un.org/goals