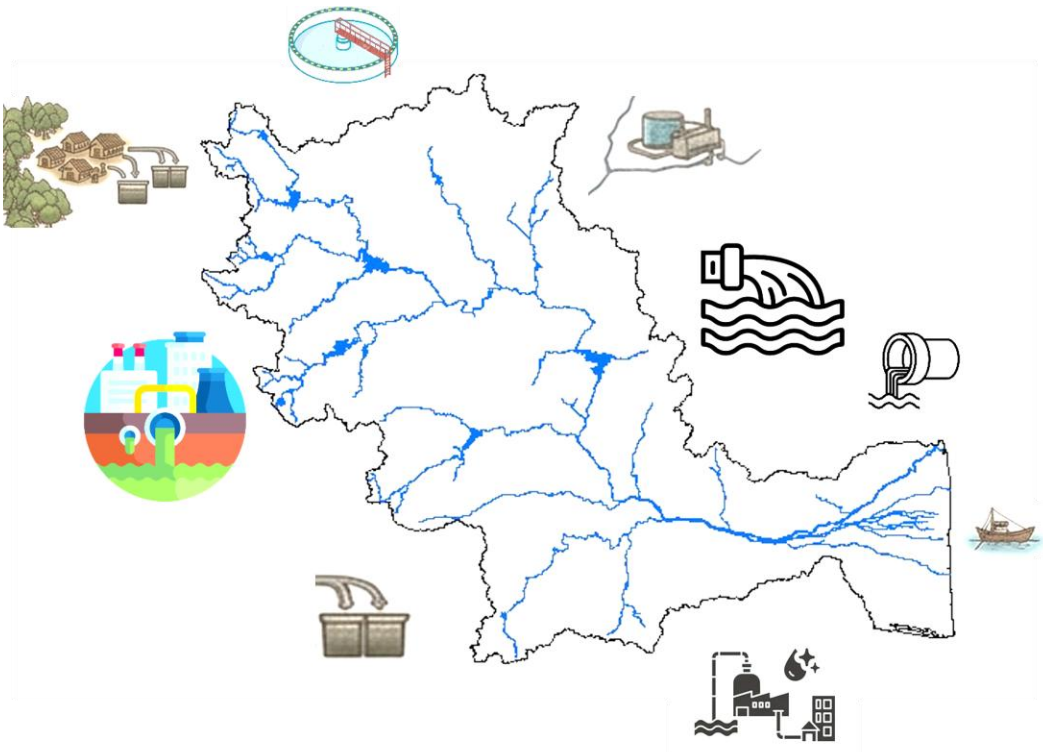
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development and Ganga Rejuvenation
Government of India

Nirmal Dhara

Management plan for domestic wastewater within delineated administrative and natural boundaries



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Cauvery River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development and Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Cauvery River Basin Management Studies (cCauvery)

The Centre for Cauvery River Basin Management Studies (cCauvery) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IISc Bengaluru and NIT Tiruchirappalli, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cCauvery is committed to restoring and conserving the Cauvery River Basin (CRB) and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.ccauvery.org

Centre for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by IISc Bengaluru (Lead Institute) and NIT Tiruchirappalli (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

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Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Centres for Cauvery River Basin
Management Studies (cCauvery)
IISc Bengaluru (Lead Institute), NIT Tiruchirappalli (Fellow Institute)

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Abbreviations and Acronyms

AL	Aerated Lagoon
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
APL	Above Poverty Line
ASP	Activated Sludge Process
BBMP	Bruhat Bengaluru Mahanagara Palike
BOD	Biochemical Oxygen Demand
BPL	Below Poverty Line
BWSSB	Bangalore Water Supply and Sewerage Board
cCauvery	Centre for Cauvery River Basin Management and Studies
cGanga	Centre for Ganga River Basin Management and Studies
CETP	Common Effluent Treatment Plant
CPCB	Central Pollution Control Board
CRB	Cauvery River Basin
DEWATS	Decentralized Wastewater Treatment Systems
EAP	Effluent Application Process
EASP	Extended Aeration Sludge Process
FAB	Fluidized Aerobic Bed
FAL	Facultative Aerated Lagoon
GIS	Geographic Information System
GRBMP	Ganga River Basin Management Plan
HRC	High Rate Clarifier
IHHL	Individual Household Latrine
IISc	Indian Institute of Science
IoT	Internet of Things
LPCD	Litres Per Capita per Day
MBBR	Moving Bed Biofilm Reactor
MBR	Membrane Bioreactor
MLD	Million Litres per Day
MSW	Municipal Solid Waste

NGO	Non-Governmental Organization
NITI	National Institution for Transforming India
NMCG	National Mission for Clean Ganga
NRCD	National River Conservation Directorate
NRCP	National River Conservation Plan
NRSC	National Remote Sensing Centre
ODF	Open Defecation Free
OP	Oxidation Pond
PPP	Public-Private Partnership
RDWSD	Rural Development and Water Supply Department
SBR	Sequencing Batch Reactor
SC	Scheduled Caste
SCADA	Supervisory Control and Data Acquisition
SCP	Special Component Plan
SDG	Sustainable Development Goal
SPCB	State Pollution Control Board
ST	Scheduled Tribe
STP	Sewage Treatment Plant
SW	Solid Waste
SWM	Solid Waste Management
TF	Trickling Filter
TNPCB	Tamil Nadu Pollution Control Board
TNUSSP	Tamil Nadu Urban Sanitation Support Programme
TPD	Tonnes per Day
TSP	Tribal Sub-Plan
ULB	Urban Local Body
UGSS	Underground Sewage System
UV	Ultraviolet
WHO	World Health Organization
WSP	Waste Stabilization Pond

WTP	Water Treatment Plant

Continuation of Abbreviations and Acronyms

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1. Introduction

The Cauvery River Basin (CRB), one of India's most significant inter-state basins, sustains over 40 million people across Karnataka, Tamil Nadu, Kerala, and Puducherry. Rapid urbanization, industrial growth, and population expansion have led to rising domestic water demand and concomitant wastewater generation. Unregulated discharge of untreated sewage has become a critical environmental and health concern, affecting the river's ecological integrity and water security for downstream communities.

Rapid urbanization, industrial expansion, population growth, and changing land-use patterns have significantly increased water demand throughout the basin. As urban centres continue to expand, the generation of domestic wastewater has increased substantially, placing considerable pressure on existing wastewater treatment infrastructure. In many parts of the basin, untreated or partially treated sewage is discharged directly into rivers, streams, lakes, and reservoirs, leading to deterioration of water quality and degradation of aquatic ecosystems. Such discharges contribute to elevated concentrations of organic pollutants, nutrients, pathogens, and suspended solids, which adversely affect ecosystem health and pose risks to public health and water security.

Wastewater pollution has emerged as a major environmental challenge in many river basins worldwide, particularly in developing countries where wastewater treatment facilities often lag behind urban growth. The discharge of untreated sewage not only degrades surface water quality but also affects groundwater resources, agricultural productivity, and biodiversity. In river systems such as the CRB, where water resources are extensively utilized for domestic and agricultural purposes, understanding the spatial distribution of wastewater generation and treatment capacity is essential for sustainable water resource management.

Effective domestic wastewater management is thus central to restoring the Cauvery's environmental flow and achieving Sustainable Development Goal (SDG 6.3), improving water quality by reducing pollution and promoting recycling and safe reuse. The report aims to develop a basin-scale strategic framework for domestic wastewater management in the CRB through assessment of existing infrastructure, identification of treatment gaps, promotion of wastewater reuse and resource recovery, and formulation of investment and policy recommendations for transitioning towards a circular water economy

- **Basin Characteristics**

Administrative and Natural Boundaries

The Cauvery basin extends over states of Tamil Nadu, Karnataka, Kerala and Union Territory of Puducherry draining an area of 81,155 Sq.km which is nearly 2.7% of the total geographical area of the country with a maximum length and width of about 560 km and 245 km. The basin's physiography is defined by the Western Ghats in the west, undulating plateaus in the central region, and deltaic plains in the east. Major sub-basins include Kabini, Hemavathi, Shimsha, Bhavani, Noyyal, and Amaravathi.

Demography and Urbanization

The basin hosts major cities such as Bengaluru, Mysuru, Mandya, Erode, Tiruchirappalli, Thanjavur, and Puducherry. Urban sprawl, inadequate sewerage networks, and outdated treatment systems are key challenges in maintaining water quality.

Hydrology and Drainage

Originating from the Talakaveri in the Western Ghats, the river flows ~800 km before discharging into the Bay of Bengal. With an average annual rainfall of ~1,200 mm, the basin exhibits significant seasonal variability in flow, leading to stress during lean periods.

2. Infrastructure Status

2.1. Existing WTPSs, STPs, Pumping Stations, Sewers

2.1.1. Water treatment plant

A water treatment plant (WTP) is a facility designed to treat raw water (from rivers, lakes, wells, or other natural sources) to make it suitable for human consumption, industrial use, and other purposes. The main goal of a WTP is to ensure that the water provided meets the required quality standards for safety and health, free from contaminants like pathogens, chemicals, and impurities. Water treatment processes can vary depending on the quality of the source water, but they typically involve several stages to purify the water. A brief description of WTP in the CRB) is given in Table 1, and spatial distribution is shown in Fig. 1.

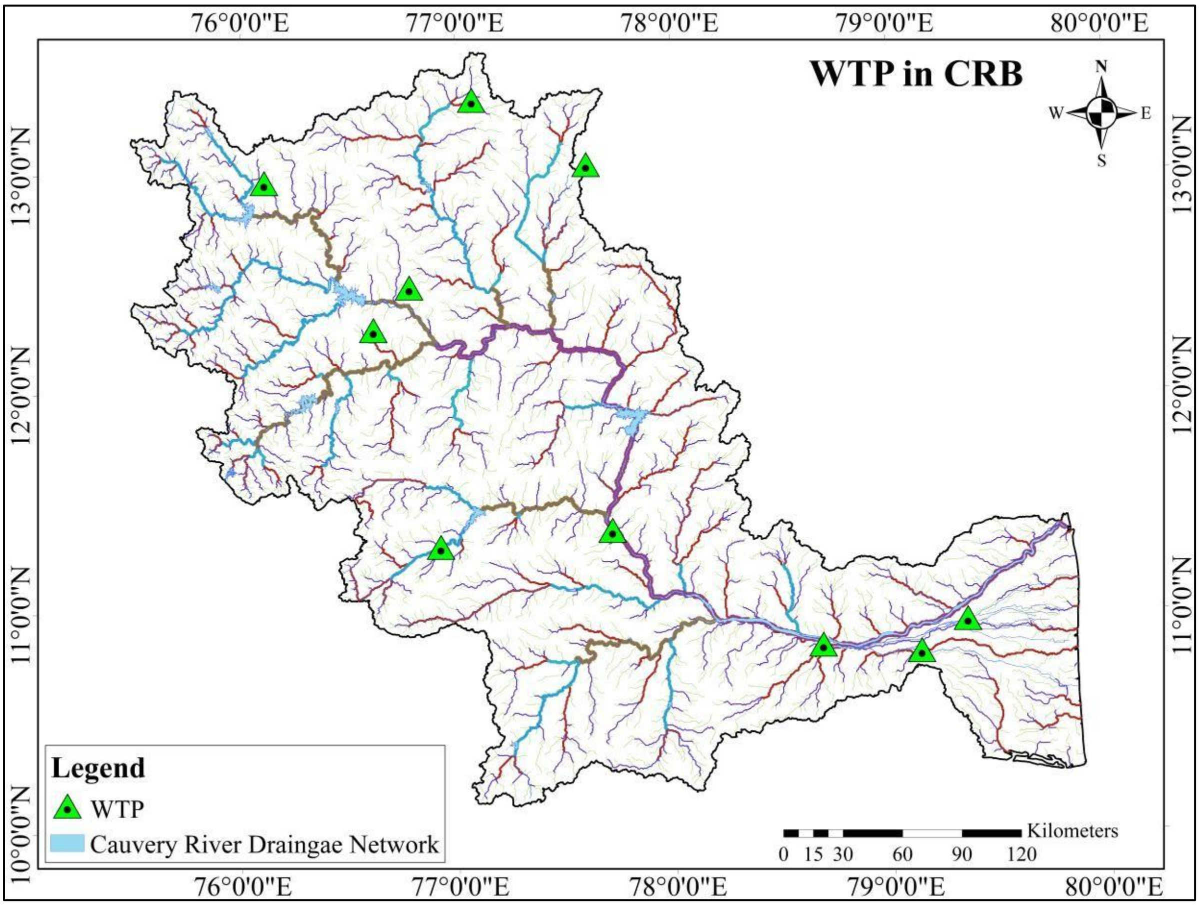

Fig. 1. Water treatment plants in the CRB

Table 1. Details of water treatment plants in the CRB

Sr. No.	Name of Town	WTP Capacity Installed (MLD)	WTP Capacity Water Treated (MLD)	Water Source	Type of Treatment	LPCD
1	Tiruchirappalli	88	88	Cauvery	Bleaching	118
2	Thanjavur	-	-	Vennar River and	Bleaching Powder	

				Coleroon River		
3	Kumbakonam	15	15	G/W	Liquid Chlorine	107.1
4	Erode	30	20	Cauvery River	Sedimentation, Filtration, Disinfection	132
5	Tiruppur	46	44	Bhavani River	Sedimentation, Filtration, Disinfection	125.2
6	Dindigul	10	10	Lake	Sedimentation, Filtration, Disinfection	50.9
7	Bengaluru	1350	1350	Cauvery River	Sedimentation, Filtration, Disinfection	150
8	Mysuru	175	175	Cauvery River	Sedimentation, Filtration, Disinfection	135
9	Mandya	70	70	Cauvery River	Sedimentation, Filtration, Disinfection	120
10	Hassan	40	40	Hemavathi River	Sedimentation, Filtration, Disinfection	110
11	Tumkuru	30	30	Hemavathi River	Sedimentation, Filtration, Disinfection	100

Source: CPCB

- **Sewerage and drainage network plan**

Pollution refers to the contamination of the environment with harmful substances that disrupt the natural balance of ecosystems and pose risks to the health of living organisms, including plants, animals, and human beings. River pollution has become a crucial environmental issue because of its significant impact on the major rivers in Tamil Nadu. The main sources of contamination in these rivers include Industrial discharges, sewage pollution, and poor waste management practices. Domestic wastewater is primarily organic but still has a high concentration of substances that can lead to serious environmental impacts. The release of this wastewater into open water bodies or groundwater can cause oxygen-depletion due to the chemical and biochemical reactions that occur when organic matter is broken down. This process depletes dissolved oxygen levels, which are critical for aquatic life, leading to Eutrophication.

In eutrophic conditions, excessive nutrients like nitrogen and phosphorus fuel the rapid growth of algae, which further reduces oxygen levels and disrupts aquatic ecosystems. They harm the aquatic life of the receiving water and affect humans through the f ood chain. Sewage from residential and commercial buildings that frequently don't have enough underground sewer connections runs directly into the rivers, further degrading the water quality. Sewage treatment plants that aren't working properly make the problem even worse. Using contaminated water for irrigation reduces the fertility of the land, creating new difficulties for agriculture. The considerable amount of solid residue generated by the CETP needs adequate treatment and reclamation before ending up in the environment as solid waste.

- **Sewerage system mapping**

Sewerage system mapping in Karnataka and Tamil Nadu is crucial for efficient urban planning, sanitation management, and environmental protection. Both states have undertaken initiatives to map their sewer networks using GIS and modern surveying techniques. In Karnataka, cities like Bengaluru have implemented digital mapping to track underground drainage systems, aiding in reducing waterlogging and improving maintenance. Tamil Nadu, particularly in Chennai, has also adopted GIS-based mapping to manage stormwater drains and prevent urban flooding. These efforts help authorities monitor sewage flow, detect leaks, and enhance wastewater treatment, ultimately improving public health and water quality. However, challenges such as aging infrastructure, unauthorized sewage connections, and rapid urbanization necessitate continuous updates and technological advancements in sewerage system mapping.

The Underground Sewage System (UGSS) covers the Tiruchirappalli Corporation and 2 Town

Panchayats (Fig. 2). The corporation is covered by UGSS through old schemes. The total sewage generated from Tiruchirappalli Corporation, Municipalities, Town Panchayat and Villages is 118 MLD, 5 MLD, 5 MLD and 19 MLD. 71% of the Tiruchirappalli Corporation area is covered by a sewer network. 54% of Manachanallur and S.Kannanoor Town Panchayat area is covered through sewer network (Directorate of Town and Country Planning).

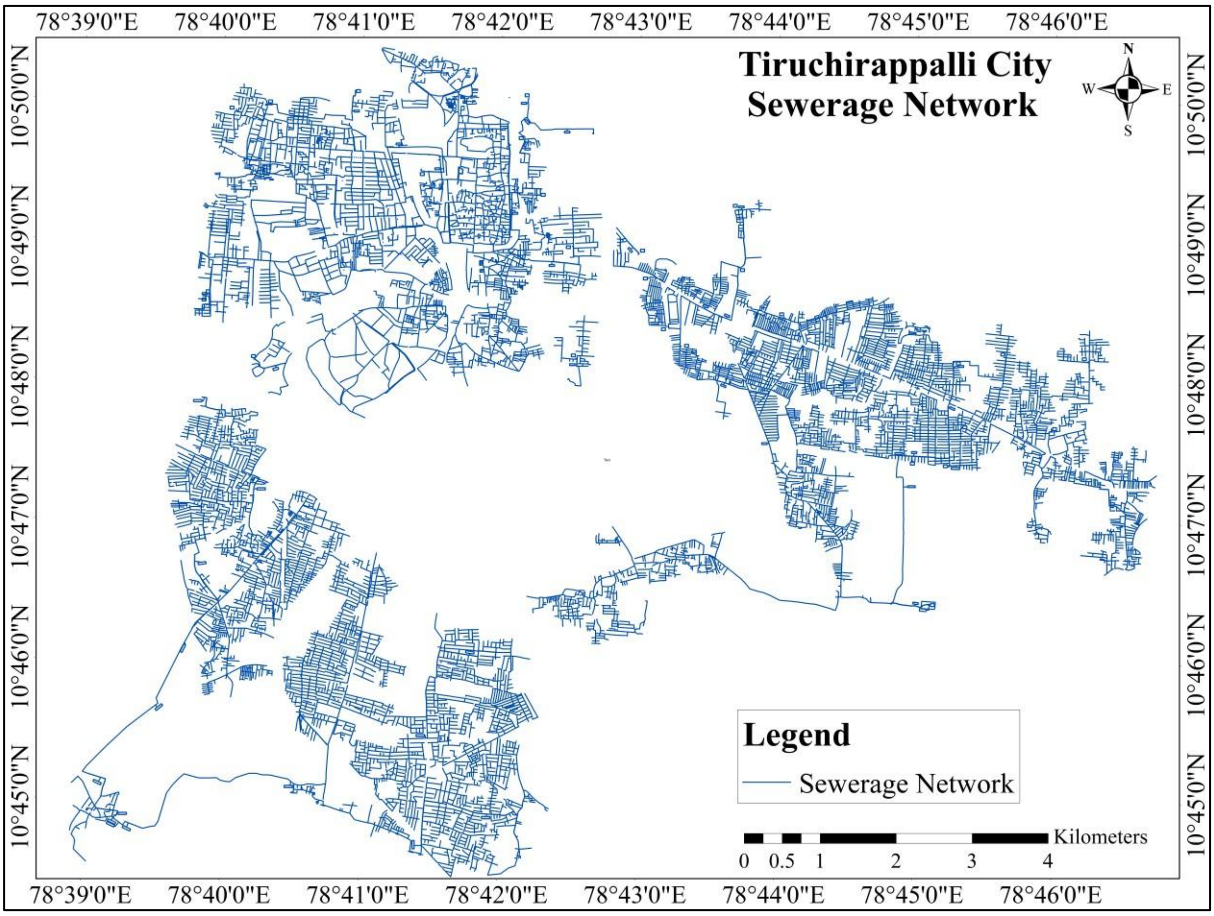

Fig. 2. Sewerage network map of Tiruchirappalli city, Tamil Nadu

(Source: Tiruchirappalli City Municipal Corporation**)**

Stormwater drainage

Storm water is that portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a storm water drainage system into a defined surface water body, or a constructed infiltration facility. Storm water management is the control and use of storm water runoff. It includes planning for runoff, maintaining storm water systems, and regulating the collection, storage, and movement of storm water. Storm water management should also factor in drainage in the design of cities and housing developments. The drainage system should best preserve or mimic the natural hydrologic cycle and fit within the capacity of the existing infrastructure.

Bruhat Bengaluru Mahanagara Palike (BBMP) spread over an area of 741 sq km is demarcated into eight zones. As per the records of the Chief Engineer, Storm Water Drains, BBMP has a total drain network (primary and secondary drains only) of 842 km. However, as per the master plan of drains also prepared by BBMP, the total length of drains was 856.74 km which includes the length of drains that are outside the jurisdiction of BBMP but are considered for hydraulic analysis purposes only. BBMP did not have on records the length of the tertiary drains under its jurisdiction. Even the drainage network map of BBMP has no mention/sketch of the tertiary drains.

- **Wastewater treatment facilities**

Effective wastewater treatment within the CRB is crucial to maintain water quality and support the diverse needs of the population. In Karnataka, the BWSSB is responsible for managing sewage disposal and water supply in Bengaluru. The city operates several STPs to treat wastewater before its release or reuse. These facilities are essential for mitigating pollution in the Cauvery River, as untreated sewage can significantly degrade water quality. In Tamil Nadu, cities like Erode and Tiruchirappalli have established STPs to manage urban wastewater. These plants are designed to handle the sewage generated by the urban population, ensuring that the treated effluent meets environmental standards before being discharged into the river system.

Additionally, community-based initiatives like Cauvery Calling aim to restore the river basin's health by promoting agroforestry among farmers. By planting trees, these projects enhance soil health, increase water retention, and reduce runoff, thereby improving the overall water quality in the basin. Collectively, these efforts in establishing and maintaining wastewater treatment facilities, along with community engagement in sustainable practices, are pivotal in preserving the ecological balance of the CRB. The details of various STPs (Fig. 3) installed in CRB are summarized in Table 2.

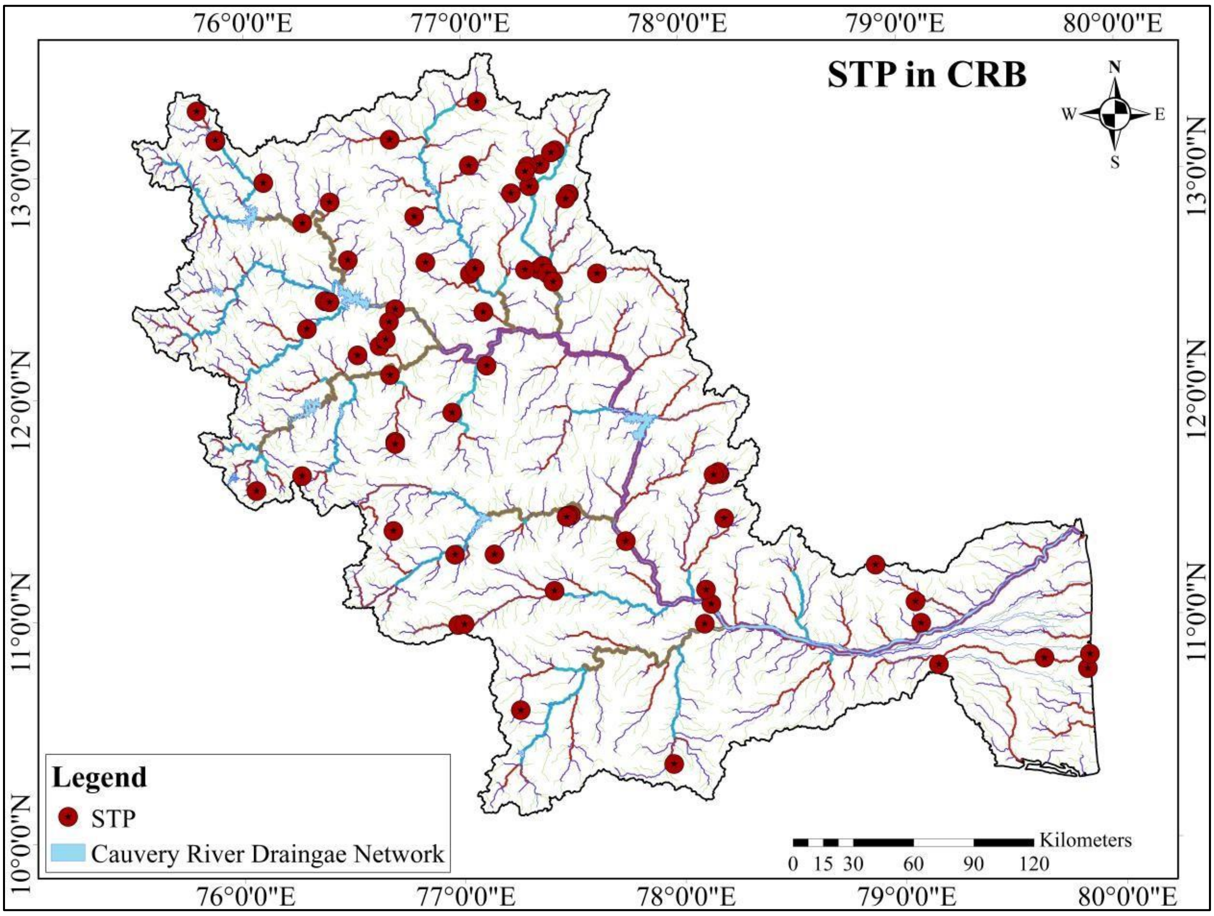

Fig. 3. Sewage treatment plants in the CRB

Table 2. Summary of various STPs installed in the CRB

Sr. No.	Location	STP Installed Capacity (MLD)	STP capacity utilization (MLD)	Technology
1	Bangalore Urban	15	15	MBBR
2	Bangalore Urban	218	190	ASP
3	Bangalore Urban	30	30	EAP
4	Bangalore Urban	1.5	1.5	ASP and UV method

5	Bangalore Urban	4	4	MBR
6	Bangalore Urban	10	8	ASP
7	Bangalore Urban	15	13	SBR
8	Bangalore Urban	5	3.5	SBR
9	Bangalore Urban	75	75	ASP
10	Bangalore Urban	120	70	2 stage TF
11	Bangalore Urban	60	10	HRC
12	Bangalore Urban	1	1	ASP
13	Bangalore Urban	5	5	SBR
14	Bangalore Urban	2	1.8	SBR
15	Bangalore Urban	20	10.814	SBR
16	Bangalore Urban	20	8.484	EAP
17	Bangalore Urban	20	20	UAS
18	Bangalore Urban	40	30	SBR
19	Bangalore Urban	60	60	ASP
20	Bangalore Urban	60	40	ASP
21	Bangalore Urban	20	20	SBR
22	Bangalore Urban	20	10	SBR
23	Chamarajanagar	9	5	FAL
24	Kanakapura	6.29	4	WSP

25	Magadi	3.7	1.5	WSP
26	Kollegal	9	5	EAT
27	Gundlupet	2.5	1.5	WSP
28	Gundlupet	1.5	1	WSP
29	Chikmagalur	20	6	MBBR
30	Belur	2.4	2.4	WSP
31	Belur	0.3	0.3	WSP
32	C.R Patna	4.6	4.6	WSP
33	Hassan	10	10	WSP
34	H. N Pura	3	3	OP
35	Maddur	3.5	3.5	WSP
36	Mandya	9.62	7.5	OP
37	Mandya	8.9	7.5	WSP
38	SR Patna	2.27	2.27	WSP
39	SR Patna	1.63	1.63	WSP
40	Nagamangala	3	1	WSP
41	Malavalli	5.65	0.5	WSP
42	K.R Pet	5	2	WSP
43	Mysore	60	39	FAL
44	Mysore	67.5	51	FAL

45	Mysore	30	15	FAL
46	Nanjangud	7	2.35	AL
47	Bannur	2.5	0.5	WSP
48	Hunsur	3.9	3.9	AL
49	K.R.Nagar	1.45	1.45	WSP
50	K.R.Nagar	2.5	2.5	WSP
51	K.R.Nagar	1.44	1.44	WSP
52	Tumkur	25	18	AL
53	Turuvekere	1.95	0	UASB
54	Udupi	12.5	5	FAL
55	Coimbatore	70	35	SBR
56	Coimbatore	60	6	SBR
57	Dindigul	13.65	3	ASP
58	Thanjavur	28.05	14.15	ASP
59	Tiruppur	15	8.5	EASP
60	Erode	50.55	27	MBBR
61	Salem	13	11	ASP
62	Salem	6	5	MBBR
63	Salem	35	8	FAB
64	Salem	44	1	FAB

65	Karur	15	5.63	EAP
66	Namakkal	5	5	ASP
67	Mettur STP-1	0.823	0.354	ASP
68	Mettur STP-2	0.924	0.314	ASP
69	Mettur STP-3	5.452	2.834	ASP
70	Kumbakonam	17	12.5	ASP
71	Nagapattinam	9.63	4.4	ASP
72	Nagapattinam	2.69	1.1	EASP
73	Tiruvarur	6.92	4.1	ASP
74	Ariyalur	4.16	1.5	ASP
75	Perambalur	4.2	3.6	ASP
76	Udhagamandalam	5	4	WSP
77	Udumalaipet	7.81	4	ASP
78	Rasipuram	6.96	3.3	ASP
79	Sathyamangalam	4.08	0.5	ASP
80	Mettupalayam	8.65	-	ASP
81	WAYANAD	0.14	0.05	FAB
82	WAYANAD	0.01	0.01	SBR
83	WAYANAD	UC	UC	-

Source: NMCG

AL: Aerated Lagoon, ASP: Activated Sludge Process, TF: Trickling Filter, EAP: Effluent

Application Process, EA: Extended Aeration, EASP: Extended Aeration Sludge Process, FAB: Fluidized Aerobic Bed, FAL: Facultative Aerated Lagoon, HRC: High Rate Clarifier, MBBR: Moving Bed Biofilm Reactor, MBR: Membrane Bioreactor, OP: Oxidation Pond, , SBR: Sequencing Batch Reactor, TF: Trickling Filter, UASB: Up-flow Anaerobic Sludge Blanket, UC: Under Construction, UV: Ultra Violet, WSP: Waste Stabilization Pond.

- **Sanitation plan**

Sanitation planning refers to the strategic process of ensuring safe, equitable, and sustainable sanitation services, including waste collection, transportation, treatment, and disposal. A sanitation plan (Fig. 4) aims to identify, assess, and mitigate risks related to public health and the environment by establishing systems that provide clean water, adequate waste management, and proper sanitation. This plan involves a holistic approach to managing sanitation systems across urban and rural areas, with an emphasis on health, hygiene, environmental sustainability, and social equity. Sanitation planning is a preventive risk management approach that identifies the risks associated with waste management, focusing on the entire sanitation service chain:

- Waste collection and transportation
- Waste treatment and disposal
- Water and wastewater treatment
- Reuse and resource recovery (e.g., composting, biogas production)

Fig. 4. Workflow of sanitation plan

The plan involves local authorities, government bodies, NGOs, communities, and private sector participants, working together to ensure effective waste management and sanitation. In India, with its large population, rapid urbanization, and rural-urban disparities, sanitation is a critical issue. Managing sanitation systems is essential for public health, reducing disease burden, and protecting the environment.

Open defecation has been a common issue especially in rural India. Historically, it wasn't considered a shame or looked at from a sanitary perspective. Over the past few decades, Karnataka has seen the implementation of various sanitation projects under centrally sponsored schemes, externally aided programs and Government of Karnataka sponsored programs such as Nirmal Grama Yojana, Swachh Grama Yojana, etc. According to the Baseline Survey of 2012, out of 70.32 lakh rural households in Karnataka, 35% households had toilets, while the majority 65% were without toilets. To achieve the desired goal of accelerating sanitation coverage across rural India, "Swachh Bharat Mission" was launched on 2nd October 2014 by the Government of India. From 2nd October 2014 to 19th November 2018, 48 lakh Individual Household Latrines (IHHLs) were constructed across the state (RDWSD).

- **Public toilets**

Under this scheme, every BPL household, SC / ST households belonging to restricted APL sector, small and micro families, landless families, differently abled families and household headed by women can construct individual toilets with a subsidy of Rs.12000/- which consists of Rs.7200/- from central government and Rs.4800/- from state government. The SC/ST family can get a benefit of Rs.15000/- where the state government provides an additional Rs.3000/- under SCP/TSP. Focus is also given for the construction of Community Toilets wherever needed (Fig. 5).

Fig. 5. Public toilets

(Source: RDWSD)

Sustainability of Open Defecation Free (ODF) status is the main objective of SBMG Phase-2. Central Ministry of Jal Shakti has instructed to construct community toilets (Fig. 6) if there is no availability of space to build individual toilets, and where there are maximum of 35 households. In the state, 905 community toilets are in use (as of August 2020), and the construction of 1862 community sanitary complexes are in progress. SBM (G) compensates up to 70% of the total fund and the remaining 30% can be covered under the 15th finance commission.

Fig. 6. Community toilets

(Source: RDWSD)

In Tamil Nadu, the responsibility for maintaining public toilets (Fig. 7) in districts outside of Chennai lies primarily with the local urban bodies (ULBs), which include municipal corporations, municipalities, and town panchayats. Each of these entities is tasked with planning, constructing, operating, and maintaining public sanitation facilities within their respective jurisdictions.

- **Local Urban Bodies:** Each district's municipal corporation or municipality is responsible for the upkeep of public toilets. This includes cities like Coimbatore, Madurai, Tiruchirappalli, and others where local bodies manage the sanitation facilities.
- **Public Health Department:** The Public Health Department at the local level also plays a role in overseeing sanitation standards and ensuring that public toilets meet hygiene requirements.
- **Private Partnerships:** In some cases, local bodies may outsource maintenance to private

contractors to improve service efficiency. However, this has sometimes led to challenges regarding the quality of maintenance, as highlighted by public complaints in various districts.

- **Swachh Bharat Mission:** The central government initiative encourages ULBs to enhance public sanitation facilities, and it provides guidelines for effective management of public and community toilets. This mission emphasizes the importance of adequate maintenance and cleanliness to combat open defecation and improve overall public health.

The maintenance of public toilets in Tamil Nadu's districts is primarily managed by local urban bodies, with support from state health departments and potential private sector involvement.

Fig. 7. Public toilets in Tiruchirappalli

(**Source:** TNUSSP)

- **Waste management**

Solid waste generation in an inevitable consequence of rapid urbanization, population explosion, changing lifestyle and modernization. SWM is efficient collection, transportation, processing, recycling and disposal and monitoring of waste and its impact on environment. SWM is one of the major challenges all over the world and in India. About 72 million Tons of SW is generated in the country, of which 43 million Tons are collected and only 12 million Tons of waste is scientifically treated. Balance quantity of 31 million Tons is dumped in landfills without any treatment. Un-scientific landfilling of municipal solid waste (MSW) generates huge quantity of leachate, which contaminates water. Most of the ULBs adopt landfilling as the option for disposal of SW, which is linked to water contamination, generation of greenhouse gases beside odour nuisance.

- **Objectives of waste management**
- **Environmental Protection:** Prevent pollution of air, water, and soil by ensuring proper waste treatment and disposal.
- **Public Health:** Minimize the risk of disease transmission by managing waste in sanitary ways.
- **Resource Conservation:** Promote recycling and reusing waste materials to conserve natural resources.
- **Energy Recovery:** Harness energy from waste materials through processes like incineration or anaerobic digestion.
- **Compliance with Regulations:** Adhere to environmental laws and waste management standards set by governments and international organizations.
- **Waste generation in the CRB**

The data reveals considerable variability in MSW generation across districts within the same state, underscoring the influence of population density, economic activity, and urbanization levels (Fig. 8) (Waste management in Karnataka: Realities and opportunities). For instance, Bengaluru Urban district in Karnataka records the highest MSW generation at 4,593 tons per day (TPD), reflecting its status as a major metropolitan hub. In contrast, districts such as Chamarajanagar generate significantly lower quantities, around 75 TPD, due to their rural and less densely populated nature. In Tamil Nadu, Coimbatore (990 TPD), as one of Tamil Nadu's major urban and industrial hubs, it generates high MSW due to its dense population, thriving IT and textile industries, and urban sprawl. Smaller districts like Ariyalur (14 TPD) generate less waste due to their rural nature, smaller populations, and lack of extensive industrialization.

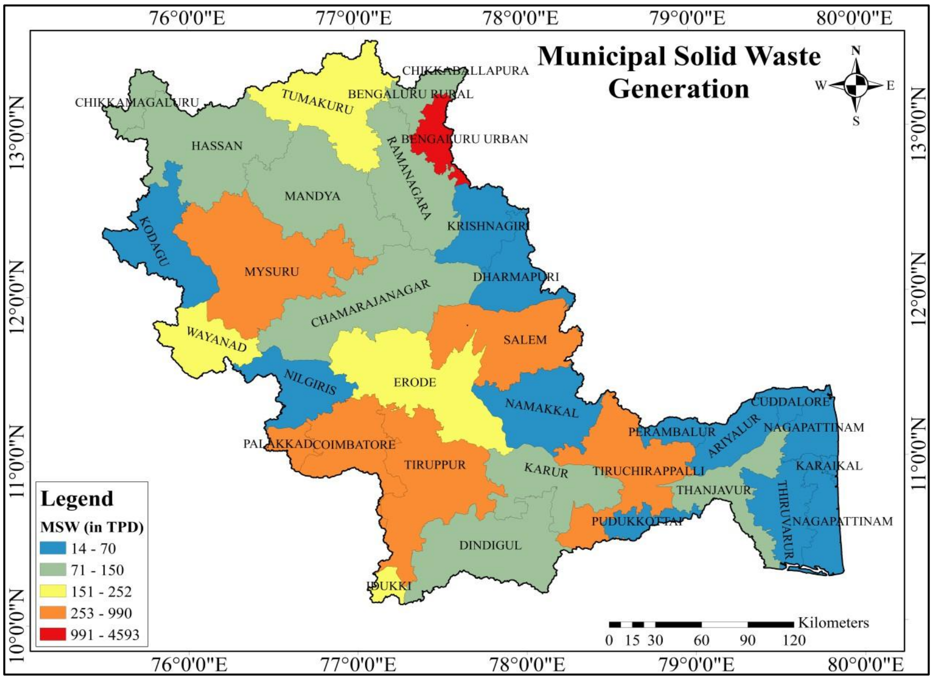

Fig. 8. Municipal solid waste generation map of the CRB

District-wise analysis of municipal solid waste generation highlights the pressing need for tailored waste management strategies. Urban centres with high waste generation require immediate interventions to prevent environmental and public health crises, while rural districts need support to establish efficient waste processing systems. Policymakers, municipal authorities, and citizens must collaborate to build a sustainable framework for managing solid waste effectively. By adopting innovative practices and fostering a culture of responsibility, districts can transition towards a cleaner, more sustainable future.

- **Government initiatives for solid waste management**

In the context of the CRB, which is one of the most important river systems in southern India, waste management plays a critical role in preserving the health of the river and the surrounding environment. The river basin is vital for drinking water supply, agriculture, industry, and the livelihoods of millions of people. However, pollution, particularly from industrial, agricultural, and domestic waste, threatens the quality of water and overall ecosystem health in the region. The various government initiatives taken for waste management are described below:

a) Swachh Bharat Mission

The central government's cleanliness mission, aimed at improving waste management practices across urban and rural areas, is being implemented in different districts under the CRB. The mission emphasizes clean cities, waste segregation, and the elimination of open defecation.

b) State Policy on Solid Waste Management

The state government has adopted a comprehensive policy that sets goals for reducing waste generation, promoting segregation, recycling, and composting, and minimizing the impact of waste on the environment.

c) Public Awareness Campaigns

NGOs, local bodies, and the state government are also involved in running awareness campaigns to encourage waste segregation, reduce plastic use, and promote recycling.

- **Efforts and challenges in effective solid waste management**

While there are waste treatment plants in some urban areas, they are often insufficient or underperforming due to outdated technology or lack of proper maintenance. In some places, sewage continues to be discharged untreated into the Cauvery. Several government and non-governmental organizations have been working to reduce pollution in the Cauvery, such as the Cauvery Calling initiative by the Isha Foundation, which focuses on reforestation and watershed management. However, more targeted efforts are required to address the root causes of industrial, domestic, and agricultural waste.

Urban centres within the CRB collectively generate approximately 5,663 MLD of domestic wastewater, while the installed treatment capacity is only 3,312 MLD, resulting in a substantial treatment gap of nearly 42%. Furthermore, only about two-thirds of the existing treatment plants operate at design efficiency due to inadequate maintenance, high energy costs, and limited reuse infrastructure. This highlights that the challenge is not only infrastructural deficiency but also operational inefficiency and underutilization of existing systems.

Table 3: State-wise wastewater generation, treatment capacity, treatment gap, and major contributing urban centres within the CRB.

State / UT	Wastewater Generated (MLD)	Treatment Capacity (MLD)	Gap (%)	Key Cities / Contributors
Karnataka	2 531	1 464	42	Bengaluru, Mysuru, Mandya

Tamil Nadu	2 723	1 651	39	Erode, Tiruchirappalli, Thanjavur
Kerala	255	117	54	Wayanad, Palakkad
Puducherry	154	80	48	Lawspet, Karaikal

(Data source: NITI Aayog 2022, pp. 35-50; CPCB 2023)

Karnataka (Upper Basin)

Karnataka, particularly Bengaluru, represents the largest contributor to wastewater generation in the basin. Bengaluru alone produces nearly 1,500 MLD of sewage, treated through approximately 33 STPs operated by the Bangalore Water Supply and Sewerage Board (BWSSB). Although nearly 80% of installed capacity is operational, inefficiencies in sewer connectivity and inflow management result in underutilization of treatment infrastructure. While treated wastewater is increasingly reused for construction, landscaping, and industrial cooling, a significant fraction continues to be discharged into the Vrishabhavathi and Arkavathi tributaries, contributing to downstream pollution.

Tamil Nadu (Middle & Lower Basin)

Tamil Nadu accounts for the highest wastewater generation within the CRB (~2,700 MLD) and faces a treatment gap of about 39%. Urban centres such as Erode, Tiruchirappalli, and Thanjavur contribute significantly to pollutant loads entering the Cauvery mainstream. The state has taken progressive steps through the Tamil Nadu Treated Wastewater Reuse Policy (2020), which mandates a minimum reuse target of 20%, thereby linking wastewater management with resource recovery. However, infrastructure gaps and uneven sewerage coverage continue to limit effective treatment.

Kerala (Western Fringe of Basin)

Kerala contributes roughly 255 MLD yet treats less than half. ULBs depend largely on septic tanks and soak pits, leading to diffuse contamination of shallow aquifers. The Suchitwa Mission and AMRUT 2.0 are piloting decentralized treatment units and wetlands, particularly in Wayanad and Palakkad districts.

Puducherry (Cauvery Delta)

Puducherry generates approximately 154 MLD of wastewater, with a treatment capacity of about 80 MLD, resulting in a gap of nearly 48%. Existing STPs at Lawspet and Karuvadikuppam, operated by the Public Works Department, support partial reuse for irrigation of parks and green belts. However, limited sewerage coverage, land constraints, and inadequate infrastructure continue to hinder effective wastewater management.

3. Wastewater Demand-Capacity Gap and Infrastructure Deficiencies

A pronounced mismatch between wastewater generation and treatment capacity remains one of the most critical challenges in urban water management across India and within river basin systems such as the CRB. At the national scale, urban centres generate approximately 61,754 MLD of sewage, while the installed treatment capacity is only about 22,963 MLD, representing nearly 37% treatment coverage. This indicates that a significant proportion of wastewater remains untreated or partially treated, contributing to widespread environmental degradation and public health risks. (Central Pollution Control Board (CPCB), 2022-23, "Urban Wastewater Scenario in India")

The demand-capacity gap is not merely a reflection of inadequate infrastructure but is deeply rooted in systemic inefficiencies across the wastewater management chain, including collection, conveyance, treatment, and reuse. Even in regions where treatment infrastructure exists, operational inefficiencies and incomplete network coverage prevent optimal utilization of available capacity.

State-level data further illustrates the magnitude of this issue. For example, in Tamil Nadu, the estimated sewage generation is approximately 3,786 MLD, whereas the available treatment capacity is about 1,634 MLD, resulting in a deficit of nearly 1,400 MLD. Moreover, actual utilization of installed capacity is significantly lower than the design capacity, with only around 985 MLD being effectively treated, highlighting inefficiencies in infrastructure usage.

(Tamil Nadu Pollution Control Board (TNPCB), 2021, "Monthly Progress Report on Polluted River Stretches")

3.1. Drivers of Demand-Capacity Gap

- **Incomplete Sewerage Network Coverage**

A major contributor to the demand-capacity gap is the lack of comprehensive sewerage networks, particularly in peri-urban and rapidly urbanizing regions. In many cities, wastewater generated in residential and commercial areas does not reach treatment plants due to fragmented or non-existent sewer systems. Instead, it is discharged directly into open drains, lakes, and river tributaries. This results in a situation where even adequately designed treatment facilities receive insufficient inflows, leading to underutilization.

Decentralized wastewater disposal practices, such as septic tanks and soak pits, are widely prevalent in smaller towns and rural-urban transition zones. While these systems provide localized solutions, they often lack proper sludge management and monitoring mechanisms, resulting in diffuse groundwater contamination and environmental risks.

- **Underutilization of Existing Treatment Infrastructure**

Despite the presence of numerous STPs, many operate below their designed capacity. Evidence from Tamil Nadu indicates that although 71 STPs are operational, the actual treatment achieved is considerably lower than installed capacity. (TNPCB, 2021)

This underutilization can be attributed to:

Poor sewer connectivity

Inflow variability

Mismatch between design capacity and actual wastewater generation patterns

Delayed commissioning of associated infrastructure

As a result, significant capital investments in wastewater infrastructure do not translate into proportional environmental benefits, leading to inefficiencies in resource allocation.

- **Operational and Maintenance Inefficiencies**

Operational inefficiencies represent another critical dimension of the infrastructure gap. National assessments indicate that a large proportion of STPs do not function at optimal efficiency and often fail to meet prescribed discharge standards. (CPCB, 2022-23)

Key factors contributing to poor performance include:

High energy consumption and unreliable power supply

Limited technical expertise at the ULB level

Inadequate monitoring and compliance mechanisms

Irregular maintenance and aging infrastructure

These challenges reduce treatment efficiency and increase lifecycle costs, further widening the effective demand-capacity gap.

- **Inadequate Conveyance and Pumping Infrastructure**

Efficient wastewater management depends not only on treatment capacity but also on the ability to transport wastewater from source to treatment facilities. In many urban areas, pumping stations and conveyance systems are either insufficient or poorly maintained. This leads to frequent overflows, bypassing of treatment systems, and localized flooding, especially during peak flow conditions.

Topographical constraints, urban congestion, and unplanned development further complicate the expansion and maintenance of sewer networks, particularly in older cities and densely populated regions.

- **Limited Integration of Reuse Infrastructure**

Another critical factor contributing to inefficiencies in wastewater management is the lack of a well-developed reuse ecosystem. While treated wastewater represents a valuable resource for non-potable applications such as agriculture, industrial cooling, and landscaping, the absence of tertiary treatment systems, storage facilities, and distribution networks limits its effective utilization.

National policy assessments emphasize that insufficient incentives and infrastructure for reuse reduce the motivation for efficient wastewater treatment and recovery.

(NITI Aayog, 2023, "Reuse of Treated Wastewater in Urban/Peri-Urban Agriculture in India")

As a result, even treated wastewater is often discharged into natural water bodies instead of being reused, undermining the principles of circular water economy.

- **Institutional and Governance Constraints**

Wastewater management in India involves multiple agencies, including ULBs, State Pollution Control Boards (SPCBs), and parastatal organizations. However,

fragmented institutional responsibilities, limited coordination, and inadequate capacity often hinder effective implementation.

National-level reports highlight that while regulatory frameworks exist, enforcement remains inconsistent, and institutional capacity constraints limit the effectiveness of wastewater management strategies. (CPCB, 2022-23)

3.2. Implications of the Demand-Capacity Gap

The cumulative effect of these infrastructure deficiencies is the widespread discharge of untreated or partially treated wastewater into natural water systems. This has several critical implications:

Water Quality Degradation: Elevated levels of Biochemical Oxygen Demand (BOD), nutrients, and pathogens in rivers and lakes

Public Health Risks: Increased incidence of waterborne diseases due to contamination of drinking water sources

Ecosystem Damage: Loss of aquatic biodiversity and degradation of riverine ecosystems

Water Resource Stress: Reduced availability of clean freshwater resources, particularly in water-scarce regions

Furthermore, the lack of efficient wastewater management undermines efforts toward sustainable urban development and climate resilience.

- **Synthesis**

The demand–capacity gap in wastewater management is not solely a consequence of insufficient treatment infrastructure but is the result of a complex interplay of technical, operational, and institutional challenges. While expanding treatment capacity remains important, it must be complemented by:

Strengthening sewerage networks

Improving operational efficiency of existing STPs

Enhancing institutional coordination and capacity

Promoting reuse and resource recovery

A shift toward an integrated and systems-based approach is essential to bridge the existing gap and ensure sustainable wastewater management across basin and national scales.

4. Identified Models for the Cauvery River Basin

The CRB, spanning Karnataka, Tamil Nadu, Kerala, and Puducherry, exhibits significant spatial variability in wastewater generation, infrastructure availability, and reuse potential. Rapid urbanization in cities such as Bengaluru, Mysuru, Erode, and Tiruchirappalli has resulted in high wastewater generation, while rural and peri-urban regions continue to rely on decentralized and often unregulated sanitation systems. In this context, a uniform wastewater management approach is neither feasible nor effective. Instead, a hybrid and adaptive framework is required, integrating centralized, decentralized, and nature-based treatment models tailored to basin-specific conditions.

The identified models aim to address three key challenges: (i) bridging the treatment capacity gap, (ii) improving operational efficiency of existing infrastructure, and (iii) promoting reuse as a resource recovery strategy. These models are categorized into urban and rural solutions, reflecting the distinct socio-economic, infrastructural, and hydrological conditions across the basin.

a. Solutions for Urban Areas

Urban centres in the CRB contribute the majority of wastewater generation and are characterized by dense populations, established sewer networks (though often incomplete), and relatively higher financial and institutional capacity. However, these cities face challenges such as underutilized treatment plants, aging infrastructure, and limited reuse integration. The following models are proposed:

- **Centralized STP Optimization and Upgradation Model**

Most major cities in the basin already possess STPs, but their performance is often constrained by operational inefficiencies, poor maintenance, and mismatched inflows. Instead of focusing solely on building new infrastructure, priority should be given to optimizing existing capacity. This includes:

Retrofitting conventional systems (e.g., Activated Sludge Process) with advanced technologies such as Sequential Batch Reactors (SBR) and Moving Bed Biofilm Reactors (MBBR)

Improving energy efficiency through automation and process control

Ensuring consistent inflow through improved sewer connectivity

This model enhances cost-effectiveness, as upgrading existing infrastructure is often more economical than constructing new plants.

- **Circular Water Economy and Reuse Model**

Urban wastewater should be viewed as a resource rather than waste. This model promotes the reuse of treated wastewater for:

Industrial cooling and processing

Construction activities

Urban landscaping and lake rejuvenation

The implementation of dual pipeline systems (separate potable and non-potable supply networks) is critical for scaling reuse. This reduces dependence on freshwater sources and supports sustainable urban water management. Cities like Bengaluru have already initiated partial reuse systems, which can be expanded basin-wide.

- **Decentralized Urban Treatment (Cluster-Based Model)**

In rapidly expanding peri-urban areas and unsewered zones, centralized systems are often ineffective due to high infrastructure costs and delays in network expansion. A cluster-based decentralized approach is more suitable, involving:

Installation of DEWATS at apartment complexes, institutions, and industrial clusters

Local reuse of treated water for non-potable purposes

This model reduces the burden on centralized STPs and improves treatment coverage in areas where sewer networks are incomplete.

- **Smart Wastewater Management Model**

Digital technologies can significantly improve the efficiency and governance of wastewater systems. This model includes:

SCADA-based monitoring of STP performance

IoT sensors for real-time water quality assessment

GIS-based mapping of sewer networks and treatment facilities

Such systems enable data-driven decision-making, reduce operational failures, and improve compliance with environmental standards.

- **Public-Private Partnership (PPP) Model**

Given the high capital and operational costs associated with wastewater infrastructure, PPP models can play a crucial role in improving service delivery. Under this model:

Private entities are involved in STP design, operation, and maintenance

Performance-based contracts ensure accountability

Financial risks are shared between public and private sectors

This approach enhances efficiency, ensures long-term sustainability, and reduces the burden on government agencies.

b. Solutions for Rural Areas

Rural and peri-urban regions of the CRB are characterized by dispersed settlements, limited financial resources, and absence of centralized sewer networks. Wastewater management in these areas must therefore rely on low-cost, decentralized, and community-driven approaches.

DEWATS

DEWATS are particularly suitable for rural settings due to their:

Low energy requirements

Minimal operational complexity

Ability to function without continuous power supply

These systems typically include sedimentation tanks, anaerobic reactors, and planted gravel filters. They are ideal for treating wastewater at the village or cluster level and can be scaled based on population size.

Nature-Based Treatment Systems

Nature-based solutions provide an environmentally sustainable and cost-effective alternative to conventional treatment systems. These include:

Constructed wetlands

Waste stabilization ponds

Phytoremediation systems

Such systems utilize natural processes involving vegetation, soil, and microbial activity to treat wastewater. They are particularly effective in rural areas where land availability is not a major constraint.

- **Greywater Management and Reuse Model**

In rural households, a significant portion of wastewater is greywater (from kitchens, bathrooms, and washing). This model focuses on:

Household-level greywater treatment units

Direct reuse for irrigation and gardening

This reduces pressure on freshwater resources and minimizes wastewater discharge into the environment.

- **Community-Based Wastewater Management Model**

Sustainable wastewater management in rural areas requires strong community participation. This model involves:

Village-level treatment systems managed by Panchayats

Capacity building and awareness programs

Local monitoring and maintenance

Community ownership ensures long-term sustainability and reduces dependency on external agencies.

- **Agriculture Reuse and Nutrient Recovery Model**

Treated wastewater can be effectively utilized for agricultural irrigation, particularly in water-scarce regions of the basin. This model offers:

Supplementary irrigation water

Nutrient-rich input (nitrogen and phosphorus), reducing fertilizer demand

This approach supports both water security and agricultural productivity, making it highly relevant for rural economies.

- **Integrated Basin-Level Perspective**

The implementation of these models should not be viewed in isolation but as part of an integrated basin-scale strategy. Urban areas should focus on efficiency, reuse, and technological advancement, while rural areas should prioritize decentralization, low-cost solutions, and community participation. The transition towards a circular water economy, where wastewater is treated, reused, and reintegrated into the system, is essential for ensuring long-term sustainability.

5. **Resource Recovery Plan**

Wastewater in the CRB should no longer be treated solely as a disposal problem but as a strategic resource that can contribute to water security, agricultural productivity, and energy sustainability. With increasing pressures from urbanization, climate variability, and competing water demands, the basin requires a transition from conventional wastewater treatment approaches toward an integrated resource recovery framework. Such an approach emphasizes the recovery of treated water, nutrients, energy, and useful by-products, thereby enabling a circular economy and reducing the environmental burden on the river system.

The recovery and reuse of treated wastewater form the cornerstone of this framework. Urban centres across the basin generate substantial volumes of wastewater, much of which remains underutilized even after treatment. By redirecting treated effluent toward non-potable applications such as industrial cooling, construction, landscaping, and ecological restoration of lakes and wetlands, cities can significantly reduce their dependence on freshwater withdrawals from the Cauvery River. The development of dual water distribution systems, which separate potable and non-potable supplies, is essential to scale up reuse practices. In this context, setting progressive reuse targets and ensuring reliable distribution infrastructure will be critical to mainstreaming treated wastewater as a dependable alternative resource.

Beyond water reuse, wastewater also contains valuable nutrients, particularly nitrogen and phosphorus, which can be recovered and utilized in agriculture. In the CRB, where agriculture remains a major water consumer, the use of treated wastewater for irrigation offers dual benefits of water supply and nutrient enrichment. Sludge generated from treatment plants can be processed into bio-fertilizers or soil conditioners, thereby reducing reliance on chemical fertilizers and supporting sustainable farming practices. Technologies such as struvite precipitation further enable the recovery of phosphorus, which is a finite and economically important resource. The integration of nutrient recovery into wastewater management systems thus provides both environmental and economic advantages at the basin scale.

Energy recovery represents another important dimension of the resource recovery plan. Wastewater treatment plants, particularly in large urban centres, have the potential to function as energy-generating systems through the anaerobic digestion of sludge. This process produces biogas, which can be used for electricity generation or heating, thereby reducing the operational energy requirements of treatment facilities. Over time, such systems can move toward energy-neutral or even energy-positive operations, enhancing the financial sustainability of wastewater infrastructure. In a basin like the Cauvery, where energy demand and costs are rising, this approach offers a significant opportunity to improve the efficiency of urban water management systems.

Effective sludge and biosolids management is equally important in ensuring a comprehensive recovery framework. Instead of being disposed of as waste, sludge can be treated and converted into compost, biochar, or other useful products. This not only reduces the burden on landfills but also contributes to soil health and carbon sequestration. However, it is essential to establish clear guidelines for safe handling, treatment, and application to avoid potential environmental and health risks associated with contaminants.

The role of industries in resource recovery is also critical, as they represent both major water users and potential partners in reuse initiatives. By linking wastewater treatment plants with industrial clusters through dedicated reuse networks, treated water can be supplied as a reliable input for industrial processes. Policies mandating or incentivizing the use of treated wastewater in industries can significantly accelerate the adoption of reuse practices and reduce freshwater extraction. This approach aligns with broader goals of sustainable industrial development and water conservation within the basin.

In rural and peri-urban areas, resource recovery must be adapted to local conditions, emphasizing low-cost, decentralized, and nature-based solutions. Greywater reuse at the household or community level can provide a valuable source of irrigation water, while systems such as constructed wetlands and stabilization ponds can facilitate both treatment and nutrient recovery. These approaches are particularly suitable for dispersed settlements where centralized infrastructure is not feasible. Community participation and local governance structures play a vital role in ensuring the long-term success and sustainability of such systems.

The successful implementation of a resource recovery plan in the Cauvery River Basin will depend on a strong institutional and governance framework. This includes the establishment of monitoring systems to track reuse and recovery performance, the development of financial incentives for municipalities and industries, and the integration of resource recovery objectives into existing national and state-level programs. Capacity building, public awareness, and stakeholder engagement are equally important to promote acceptance and adoption of reuse practices.

6. Investment Plan

The successful implementation of wastewater management and resource recovery strategies in the CRB requires a well-structured and phased investment plan that aligns financial resources with technical priorities and basin-scale objectives. Given the significant treatment gaps, infrastructure deficiencies, and the need for transition toward a circular water economy, investments must move beyond conventional capital expenditure on treatment plants and focus equally on operational efficiency, reuse infrastructure, and long-term sustainability.

At the basin level, investment priorities should be guided by three key considerations: bridging the existing treatment deficit, optimizing underutilized infrastructure, and enabling large-scale reuse and resource recovery. A substantial portion of wastewater in the basin remains untreated or partially treated, primarily due to inadequate infrastructure and incomplete sewerage networks. Therefore, initial investments should focus on expanding and upgrading treatment capacity in major urban centres such as Bengaluru, Mysuru, Erode, and Tiruchirappalli. However, equal emphasis must be placed on improving sewer connectivity, as treatment plants cannot function efficiently without adequate inflow. Investments in trunk sewers, pumping stations, and network rehabilitation are thus critical components of the overall plan.

In parallel, there is a need to prioritize the optimization of existing infrastructure. Many STPs in the basin operate below their design capacity due to operational inefficiencies, poor maintenance, and lack of automation. Targeted investments in retrofitting existing facilities with advanced technologies, improving energy efficiency, and implementing digital monitoring systems can significantly enhance performance at relatively lower costs compared to new construction. This approach ensures better returns on past investments and accelerates improvements in treatment efficiency.

A major component of the investment plan must be dedicated to developing reuse infrastructure. While treatment capacity is essential, the absence of distribution networks, storage systems, and end-use linkages often limits the practical utilization of treated wastewater. Investments in dual pipeline systems, industrial reuse corridors, and decentralized reuse systems are necessary to create a functional market for treated water. This will not only reduce freshwater demand but also generate revenue streams that can support the financial sustainability of wastewater utilities.

Resource recovery systems, including nutrient recovery and energy generation, also require targeted investment. The installation of anaerobic digesters, biogas recovery units, and sludge processing facilities can transform wastewater treatment plants into resource recovery hubs. Although these technologies involve higher initial capital costs, they offer long-term economic benefits by reducing energy consumption, generating revenue from by-products, and lowering operational expenses. In the agricultural context, investments in systems that facilitate the use of treated wastewater and recovered nutrients can further enhance economic returns and promote sustainable farming practices.

In rural and peri-urban areas, the investment strategy must adopt a different approach, focusing on decentralized and low-cost solutions. Systems such as DEWATS, constructed wetlands, and community-level treatment units require relatively lower capital investment and are easier to operate and maintain. Financial support for such systems should be channelled through local governance institutions, with provisions for capacity building and technical assistance to ensure effective implementation. This decentralized investment approach is essential for achieving basin-wide coverage and addressing wastewater management in areas where centralized infrastructure is not feasible.

Financing mechanisms for the investment plan should be diversified to ensure long-term sustainability. Public funding through central and state government programs will remain a primary source, particularly for large infrastructure projects. However, there is significant potential to leverage Public-Private Partnerships (PPP) for the design, construction, and operation of treatment facilities and reuse systems. Performance-based contracts and viability gap funding can be used to attract private sector participation while ensuring accountability and efficiency.

In addition to traditional funding sources, innovative financing mechanisms such as green bonds, climate finance, and user charges should be explored. The integration of wastewater management with climate adaptation and mitigation strategies can unlock access to international climate funds, while appropriate tariff structures for water reuse can generate recurring revenue streams. It is important, however, to ensure that pricing mechanisms remain equitable and do not disproportionately affect vulnerable populations.

The investment plan should be implemented in a phased manner to ensure effective resource allocation and measurable outcomes. In the short term, efforts should focus on improving operational efficiency of existing infrastructure and initiating pilot reuse projects. The medium-term phase should prioritize expansion of treatment capacity, development of reuse networks, and scaling up of resource recovery systems. In the long term, the objective should be to establish a fully integrated, basin-wide circular water economy, where wastewater is systematically treated, reused, and reintegrated into the hydrological cycle.

Institutional strengthening is a critical enabler of the investment plan. Adequate financial resources must be complemented by improved governance, coordination among agencies, and capacity building at all levels. Monitoring frameworks should be established to track investment outcomes, assess performance, and ensure compliance with environmental standards. Transparent reporting and stakeholder engagement will further enhance accountability and build public trust in wastewater management initiatives.

7. Recommendations

a. Budgetary Roadmap for Domestic Wastewater Management in the CRB

A structured and realistic budgetary roadmap is essential to translate wastewater management strategies into actionable outcomes across the CRB. Given the scale of domestic wastewater generation, existing infrastructure gaps, and the need to transition toward reuse and resource recovery, financial planning must adopt a phased, prioritized, and outcome-oriented approach. The roadmap should not only focus on capital investment for infrastructure creation but also ensure sustained funding for operation, maintenance, and system optimization.

At the outset, the allocation of financial resources should be guided by basin-level priorities, with a clear distinction between urban and rural requirements. Urban centres, which generate the majority of domestic wastewater, require substantial investments in expanding treatment capacity, upgrading existing STPs, and strengthening sewerage networks. A significant portion of the budget should therefore be directed toward bridging the treatment gap, particularly in high-load cities such as Bengaluru, Mysuru, and Tiruchirappalli. However, it is equally important to recognize that investments in treatment infrastructure alone are insufficient without corresponding improvements in conveyance systems. Therefore, funding must also prioritize the development and rehabilitation of sewer networks, pumping stations, and household connections to ensure that wastewater reaches treatment facilities efficiently.

In addition to infrastructure expansion, the roadmap should allocate dedicated funding for performance enhancement of existing systems. Many treatment plants in the basin operate below their design efficiency due to operational constraints, inadequate maintenance, and lack of automation. Targeted investments in retrofitting, energy optimization, and digital monitoring systems can significantly improve treatment efficiency at comparatively lower costs. This approach not only maximizes the return on previous investments but also accelerates improvements in wastewater treatment outcomes.

A key component of the budgetary roadmap should be the development of reuse infrastructure and distribution systems. While treated wastewater is increasingly recognized as a valuable resource, its utilization remains limited due to the absence of storage facilities, conveyance pipelines, and end-use linkages. Allocating funds for dual pipeline systems, industrial reuse corridors, and decentralized reuse applications will enable the creation of a functional market for treated water. This, in turn, can generate revenue streams that contribute to the financial sustainability of wastewater utilities and reduce dependence on freshwater resources.

Resource recovery should also be integrated into the budgetary framework. Investments in technologies such as anaerobic digestion, biogas recovery, and sludge processing can transform wastewater treatment plants into resource recovery centres. Although these interventions involve higher initial capital costs, they offer long-term economic benefits by reducing energy consumption, generating revenue from by-products, and lowering operational expenses. The inclusion of such systems in the budgetary roadmap reflects a shift from a linear treatment approach to a circular economy model.

In rural and peri-urban areas, the financial strategy must be adapted to local conditions, emphasizing low-cost and decentralized solutions. Investments in systems such as DEWATS, constructed wetlands, and community-level treatment units require relatively modest capital outlays and can be implemented through local governance institutions. The roadmap should include provisions for technical support, capacity building, and community engagement to ensure the effective operation and maintenance of these systems. This decentralized approach is critical for achieving comprehensive wastewater management coverage across the basin.

The implementation of the budgetary roadmap should follow a phased timeline to ensure effective resource allocation and measurable progress. In the short term, investments should focus on improving the performance of existing infrastructure and initiating pilot reuse projects. The medium-term phase should prioritize the expansion of treatment capacity, development of reuse networks, and scaling up of decentralized systems. In the long term, the objective should be to establish a fully integrated and financially sustainable wastewater management system that supports a circular water economy at the basin scale.

Institutional strengthening and governance reforms are essential to support the effective utilization of financial resources. Clear accountability mechanisms, performance monitoring systems, and inter-agency coordination frameworks must be established to ensure that investments translate into tangible outcomes. Regular evaluation and adaptive management will further enhance the efficiency and impact of the budgetary roadmap.

Future Plan for Wastewater Management

The future of wastewater management in the CRB requires a paradigm shift from fragmented, infrastructure-heavy approaches toward a basin-integrated, technology-enabled, and resource-recovery-driven framework. Considering the rapid urbanisation, rising water demand, climate variability, and ecological vulnerability of the basin, a long-term forward-looking plan must address infrastructure expansion, operational efficiency, governance reforms, circular economy principles, and strong community engagement. The forthcoming decades will require a strategic blend of centralized, decentralized, and nature-based solutions supported by digital monitoring, policy incentives, and inter-state coordination. This section outlines a comprehensive three-page future roadmap articulated through integrated planning, technological interventions, reuse pathways, and institutional restructuring.

A key priority for the basin is the development of adequate and resilient wastewater infrastructure. While centralized systems remain essential for major urban agglomerations such as Bengaluru, Mysuru, Erode, and Tiruchirappalli, the basin also includes numerous peri-urban and rural settlements where DEWATS and constructed wetlands can offer cost-effective and environmentally sustainable alternatives. Over the next decade, urban local bodies should focus on bridging the sewerage gap by expanding pipeline networks and eliminating bottlenecks at pumping stations. Simultaneously, newly emerging townships and industrial corridors must adopt modular treatment systems, ensuring that infrastructure keeps pace with urban growth. Climate resilience should be incorporated into all future wastewater assets by designing flood-proof pumping stations, stormwater–sewage segregation, and standby energy systems for uninterrupted STP operations during extreme weather events.

Another transformative pillar of future wastewater management in the CRB is the creation of a digital ecosystem for real-time monitoring and compliance. SCADA-enabled STPs, IoT-based flow meters, integrated telemetry systems, and online dashboards should be deployed across all treatment facilities to ensure performance transparency and regulatory enforcement. Remote monitoring will allow state pollution control boards and ULBs to track inflows, energy consumption, effluent quality, and reuse distribution continuously. Basin-wide data integration preferably under a unified cCauvery Digital Water Platform will significantly enhance planning, auditing, and decision making. In the long term, predictive analytics and AI-driven process optimisation can improve efficiency, reduce O&M costs, and ensure that treated effluent consistently meets standards for safe reuse.

A robust reuse-oriented wastewater strategy is central to achieving long-term sustainability. The basin's water scarcity and climate stress make reclaimed water an indispensable resource for industry, agriculture, landscaping, and groundwater recharge. Future plans must include a well-defined reuse corridor network linking major STPs with industrial estates, urban green belts, and agricultural command areas. Karnataka and Tamil Nadu have already initiated reuse pipelines and tertiary treatment facilities; scaling these initiatives across the basin will substantially reduce dependence on freshwater withdrawals. Agriculture, which consumes the largest share of water, presents a major opportunity. Safe reuse protocols guided by WHO and national standards can support non-potable irrigation, reduce fertilizer input through nutrient-rich treated effluent, and stabilise yields in drought-prone districts. Similarly, industrial estates in Mysuru, Mandya, Erode, Karur, and Puducherry must transition to reclaimed water for cooling and processing operations through policy mandates and tariff incentives.

The shift to a circular wastewater economy requires embracing resource recovery as a core element of wastewater planning. Modern treatment plants can generate energy through biogas, recover nutrients such as nitrogen and phosphorus,

Fig. 9. Integrated circular model illustrating the future plan for sustainable wastewater management in the CRB.

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