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The Urban World

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Regional Centre for Urban and Environmental Studies
All India Institute of Local Self-Government, Mumbai

RCUES Mumbai

Regional Centre for Urban & Environmental Studies (RCUES), Mumbai

(Supported by the Ministry of Housing and Urban Affairs, Government of India & Accredited under Capacity Building Commission's National Standards)

All India Institute of Local Self-Government (AIILSG) established in 1926, is a premier & autonomous research and training institution in India. It is a guide to Urban Local Bodies (ULBs) and contributed to the principles and practice of urban governance, education, research and capacity building.

The Regional Centre for Urban & Environmental Studies (RCUES) anchored by All India Institute of Local Self Government (AIILSG), Mumbai, was established in 1968 & supported by the Ministry of Housing and Urban Affairs (MoHUA), Government of India (GoI). The MoHUA, GoI has formed National Review and Monitoring Committee (NRMC) for RCUES, Mumbai in 2018 under the Chairmanship of the Secretary, MoHUA, GoI. The Principal Secretary, Urban Development Department (UDD), Government of Maharashtra (GoM) is the ex-officio Chairperson of the Advisory Committee (AC) of RCUES, Mumbai, which is established by MoHUA, GoI.

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Maharashtra Urban WASH and Environmental Coalition (Maha UWES-C) is a joint initiative of the RCUES of AIILSG, Mumbai, and UNICEF Maharashtra. In 2022, MoU is signed with the Directorate of Swachh Maharashtra Mission, Urban Development Department, Government of Maharashtra for building capacities, facilitating partnerships, and supporting innovations under Swachh Maharashtra Abhiyan - Urban 2.0 under Maha UWES-C.

In 2017, AIILSG was empaneled among one of the 35 agencies in India for conducting Integrated Capacity Building Programmes (ICBP). AIILSG Mumbai is supporting the states of Maharashtra, Rajasthan and Goa for the same.

RCUES, Mumbai is advancing capacity building initiatives by extending its efforts beyond training and workshops, urging strong collaboration with states and ULBs. Driven by a small but passionate team, it remains dedicated to empowering municipal officials, with the goal of strengthening governance, thereby enabling better cities.

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(October - December 2025)

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Contents

RCUES Key Publications

1. Urban Development.
2. Urban Planning.
3. Solid Waste Management - Resource Material.
4. Hospital Medical Waste Management.
5. Planning for Urban Informal Sector in Highly Dense Cities.
6. Study of Municipal Schools with Special Focus on Drop-outs, Standard of Education and Remedies.
7. Rainwater Harvesting.
8. Institutionalisation of Citizen's Participation in Urban Governance.
9. Gender Budgeting.
10. Gender Equality in Local Government - Comparative Study of Four States in Western Region in India.
11. Mapping of Basic Services in Urban Slums.
12. Basic Services to the Urban Poor.
13. Health.
14. Security of Tenure.
15. Resettlement and Rehabilitation.
16. Mumbai Human Development Report, 2009.
    (UNDP / MOH & UPA, GOI / MCGM).
17. Resource Material on Urban Poverty Alleviation.
18. Laws of Meetings.
19. Resource Material on Preparation of City Sanitation Plan (CSP) & Capacity Building for Urban Local Bodies.
20. Implementation of 74th CAA, 1992 in Urban Local Bodies and Impact Assessment of Training of Women Elected Members.

Editorial

Sustainable Sanitation for a Greener Planet

Sanitation lies at the heart of public health, environmental protection, and urban sustainability. Yet, for decades, it has been narrowly understood as a matter of pipes, drains, and sewerage treatment plants. As Indian cities expand rapidly and climate pressures intensify, this limited approach is proving insufficient. Sustainable sanitation today demands a more holistic vision, that connects infrastructure with ecosystems, governance, behavior, and equity. The articles in this volume collectively underline a critical message: sanitation is not merely about managing waste, but about safeguarding water bodies, restoring ecological balance, and securing a greener future for urban India.

The experience of cities like Hubballi–Dharwad, analyzed through the Shit Flow Diagram (SFD) approach, highlights both progress and persistent gaps. While investments in sewage treatment plants have significantly improved wastewater treatment coverage, a substantial proportion of human waste continues to be unsafely managed due to incomplete sewer networks, reliance on on-site sanitation systems, and the absence of fecal sludge treatment facilities. The SFD makes visible what often remains hidden, where waste leaks into the environment, contaminating soil, groundwater, and surface water bodies. Such evidence-based tools are crucial for moving beyond assumptions and guiding targeted, city-specific sanitation planning.

Equally important is the recognition that sanitation outcomes are deeply intertwined with the health of urban ecosystems. The degradation of lakes, rivers, and wetlands across Indian cities is not an isolated environmental issue but a direct consequence of untreated sewage, stormwater mismanagement, and encroachment. Efforts aimed at the rejuvenation of lakes demonstrate that restoring water bodies requires upstream sanitation interventions such as diverting sewage, treating wastewater adequately, and preventing solid and liquid waste from entering natural systems. When sanitation planning aligns with ecological restoration, cities can transform polluted water bodies into resilient blue-green assets that recharge groundwater, moderate urban heat, and enhance biodiversity.

The article Beyond Pipes and Plants reinforces the need to shift from a purely engineering-driven model to an integrated sanitation approach. Infrastructure must be complemented by institutional coordination, financial sustainability, community engagement, and behavioral change. Nature-based solutions, decentralized treatment systems, and safe reuse of treated wastewater and sludge offer promising pathways to reduce environmental footprints while closing resource loops.

Editorial

Ultimately, sustainable sanitation is central to achieving multiple global and national goals from public health and climate resilience to water security and the Sustainable Development Goals. It calls for cities to treat human waste not as an inconvenient by-product to be hidden or flushed away, but as a critical element of urban metabolism that must be managed safely and sustainably. By integrating sanitation planning with water body rejuvenation, land-use planning, and climate strategies, Indian cities have an opportunity to redefine urban development itself.

Sustainable sanitation is no longer an option but a necessity for building resilient, healthy, and environmentally balanced cities. Integrating sanitation planning with ecological restoration, decentralized solutions, and strong governance can significantly reduce pollution and resource loss. When wastewater is treated as a resource rather than waste, it supports circular economies and urban sustainability. A greener planet begins with sanitation systems that work in harmony with nature and communities alike.

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Beyond Pipes and Plants: Nature-Based Solutions Reimagining Urban Sanitation and Wastewater Management

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Abstract

Urban sanitation systems are under growing pressure from rapid urbanisation, climate stress, and limited financial and energy resources. This review assesses Nature-Based Solutions (NBS) as transformative alternatives to conventional wastewater treatment. Drawing on Indian and global case studies, this examination explores how constructed wetlands, living machines, ecological sanitation systems, and hybrid natural processes deliver effective, low-energy wastewater treatment while generating multiple co-benefits. Evidence shows that NBS can match the performance of mechanical treatments while enhancing biodiversity, sequestering carbon, recovering nutrients, and strengthening urban climate resilience. The review argues that mainstreaming nature-based sanitation is essential for achieving SDG 6 and advances related goals on climate action, biodiversity conservation, and sustainable food systems — positioning NBS as a critical pathway for inclusive and climate-resilient urban development.

Keywords: Nature-Based Solutions (NBS), constructed wetlands, ecological sanitation, wastewater treatment, sustainable development, ecosystem services, nutrient recovery, urban resilience.

Introduction

Wastewater management has emerged as a critical environmental challenge of the 21st century. Globally, more than 80% of wastewater is released untreated, degrading ecosystems and threatening public health (United Nations World Water Assessment Programme, 2017). In developing countries, rapid urbanisation and limited investment in conventional sewerage deepen these pressures.

India illustrates this gap starkly: urban areas generate an estimated 72,368 MLD of sewage, yet only about 28% receives effective treatment (CPCB, 2020–21; NITI Aayog, 2022). Cities such as Kolkata produce nearly 750 MLD of wastewater but lack adequate centralised treatment capacity, depending instead on alternative systems (The Better India, 2017). These constraints have accelerated interest in NBS — approaches that use ecological processes to treat wastewater while providing co-benefits such as habitat creation, climate mitigation, and improved resilience (International Water Association, 2021).

NBS represent more than technological alternatives; they signify a shift toward viewing wastewater as a recoverable resource rather than a disposal problem. By harnessing natural purification pathways instead of energy-intensive mechanical systems, NBS offers integrative, resource-efficient options for sustainable sanitation (Andersson et al., 2016). This review synthesises evidence from research, policy, and case studies to examine how constructed wetlands, living machines, ecological sanitation systems, and other hybrid nature-based approaches are transforming urban wastewater management globally and in India.

NBS: Definition, Principles, and Mechanisms

Defining NBS

NBS for wastewater treatment are engineered or semi-natural systems, such as constructed wetlands, ponds, and soil–plant–microbe filtration units that harness ecological processes to remove pollutants (International Water Association, 2021). Designed to enhance the physical, chemical, and biological functions of natural wetlands, these systems rely on sedimentation, filtration, microbial degradation, and plant uptake to treat wastewater.

NBS are grounded in ecological engineering at their core, which aims to design sustainable ecosystems that integrate human and natural processes (Mitsch & Jørgensen, 2004). Instead of substituting natural purification pathways with mechanical or chemical treatment, ecological-engineering approaches work with nature by enabling plants, microbes, soils, and aquatic biota to jointly support water purification (Liu et al., 2021).

Core Mechanisms of Pollutant Removal

Nature-based wastewater systems rely on a suite of complementary physical, chemical, and biological processes.

Physical mechanisms such as reduced flow velocity and filtration through gravel or sand enable the settling and trapping of suspended solids, forming the initial treatment barrier (Gorito et al., 2017).

Chemical transformations occur as wetland matrices create aerobic and anaerobic micro zones: root-associated aerobic areas support nitrification, while anoxic zones facilitate denitrification and other reduction reactions. Wetland plants and biofilms also assimilate nitrogen and phosphorus, transforming them into less harmful forms (Mitsch & Jørgensen, 2004).

The core of treatment is biological activity. Constructed wetlands host diverse microbial communities — nitrifiers, denitrifiers, and heterotrophs, that mineralise organic matter and drive nutrient cycling (Liu et al., 2024). Macrophytes further enhance treatment by providing rhizospheric surfaces and directly absorbing nutrients, contributing an estimated 8.51–33.55% of total nitrogen removal depending on system design (Gaballah et al., 2024).

Categories of Nature-Based Sanitation Solutions

The main categories, design characteristics, and applications of nature-based sanitation systems are summarised in **Table 1**.

Constructed Wetlands

Constructed wetlands are the most widely adopted NBS for wastewater treatment worldwide. These engineered systems replicate natural wetland processes using shallow basins filled with gravel or sand and planted with macrophytes to facilitate filtration, microbial degradation, and nutrient uptake (Vymazal, 2011).

Constructed wetlands typically take three forms. Subsurface flow (SSF) wetlands convey wastewater horizontally or vertically through porous media, reducing odour, pathogen exposure, and mosquito breeding, making them well-suited to urban settings (Kadlec & Wallace, 2008; Vymazal, 2011). Surface flow (SF) wetlands carry water over vegetated surfaces, providing open-water habitat and ecological diversity, though with higher evaporation and pathogen risks (Kadlec & Wallace, 2008; Vymazal, 2011). Hybrid systems combine vertical- and horizontal-flow units to alternate aerobic and anaerobic conditions, thereby improving nitrogen and phosphorus removal (Vymazal, 2011).

Performance studies report robust pollutant removal, with vertical-flow systems achieving nitrogen removal via denitrification (4.12–47.12%) and microbial assimilation (8.51–38.96%) (Liu et al., 2024). Phosphorus removal typically ranges from 39–76%, depending on design and influent characteristics (Gaballah et al., 2024). Constructed wetlands also offer substantial economic advantages, with operation and maintenance costs often 2–10 times lower than conventional treatment systems (Vymazal, 2011).

Living Machines

Living Machines are intensified ecological engineering systems developed by John Todd to concentrate natural treatment processes within a compact, engineered ecosystem (Todd & Josephson, 1996). They consist of a series of treatment cells populated with diverse organisms, including bacteria, algae, plants, invertebrates, and fish that sequentially degrade organic matter, cycle nutrients, and polish effluent. Early cells support microbial and algal breakdown of organics, while later cells, dominated by aquatic plants, enable nutrient uptake and extensive biofilm development. Some systems incorporate tidal-flow wetlands, where fill–drain cycles increase oxygen transfer and enhance treatment efficiency (Wu et al., 2011).

Their design is informed by Todd's ecological design principles, which emphasise diversity, gradients, modularity, high exchange rates, and the integration of multiple sub-ecosystems to build resilience and redundancy within the treatment chain (Todd & Josephson, 1996). By mimicking the functional complexity of natural ecosystems, Living Machines maintain performance even when individual pathways fluctuate.

Applications range from small community-scale systems — such as those in the Findhorn Ecovillage — to large institutional facilities, including municipal and military installations (Ecovillage Findhorn, n.d.). A related example of large-scale ecological treatment is the Arcata Marsh and Wildlife Sanctuary in California, a 307-acre hybrid natural treatment system that serves approximately 16,000 residents while providing habitat for more than 300 bird species (City of Arcata, n.d.).

Decentralized Ecological Wastewater Treatment Systems (DEWATS)

DEWATS are modular, decentralized wastewater treatment systems designed for off-grid and resource-constrained communities, enabling treatment close to the point of generation and reducing the need for extensive conveyance infrastructure (BORDA, 2009). Typical configurations combine pretreatment (screening, grit removal), primary anaerobic treatment through septic tanks or anaerobic baffled reactors (ABRs), secondary filtration, and final polishing in constructed wetlands or planted gravel filters. Their modularity allows phased implementation as resources permit.

Performance assessments in Asia show that DEWATS achieve up to 90% removal of suspended solids and organic loads in primary units, with complete systems generally reaching 60–80% BOD reduction. Polishing stages such as wetlands can provide over 99% pathogen removal, while ABRs alone may remove up to 90% of influent BOD, easing the burden on downstream units (BORDA, 2009).

International applications include a DEWATS-based constructed wetland for rural wastewater treatment in Kramovik, Kosovo, implemented under the DRIN Basin Programme as a low-energy, low-maintenance solution (Drin Core Group, 2018).

Ecological Sanitation (Ecosan) Systems

Ecological sanitation (Ecosan) promotes source separation, nutrient recovery, and closed-loop nutrient cycling, contrasting with conventional systems that mix and dilute human excreta (Esrey et al., 1998; Winblad & Simpson-Hébert, 2004). By separating urine and faeces, Ecosan enables targeted treatment and resource recovery.

Common models include urine-diverting dry toilets (UDDTs), which collect nutrient-rich urine for reuse and dehydrate faeces through ventilation, and thermophilic composting systems, which sanitise excreta via high-temperature aerobic processes (Ryals et al., 2021). Both produce safe, nutrient-rich amendments suitable for agricultural use.

Evidence from Haiti shows that nutrients recovered through Ecosan — particularly nitrogen, phosphorus, and potassium — can substantially offset national fertilizer demand, reframing sanitation as a contributor to agricultural productivity and circular economy transitions (Ryals et al., 2021).

Table 1: Categories of Nature-Based Sanitation Solutions

Category	Core Description	Key Features	Typical Applications
Constructed Wetlands	Engineered wetland systems using vegetation, gravel/sand media, and microbial processes to treat wastewater.	• Horizontal-flow, vertical-flow, and hybrid configurations • Low energy & low O&M • High removal of BOD, nutrients, pathogens; habitat creation	Urban & peri-urban wastewater; rural sanitation; polishing of mechanical plant effluent
Living Machines	Intensified ecological reactors comprising sequential planted cells containing diverse organisms that mimic natural purification.	• Multi-cell ecological design • Tidal flow enhances aeration • High treatment efficiency in compact footprints	Institutions, campuses, eco-communities, office buildings
DEWATS (Decentralized Ecological Wastewater Treatment Systems)	Modular, decentralised systems combining primary anaerobic treatment (e.g., ABRs) with filtration and wetland polishing units.	• Screens, sedimentation, ABRs, gravel filters, wetlands • Very low energy • High solids & BOD removal; strong pathogen reduction in final units	Rural settlements, small towns, off-grid communities, low-income urban areas
Ecological Sanitation (Ecosan)	Source-separating sanitation focused on nutrient recovery through urine diversion and composting.	• Urine-diverting toilets (UDDTs) • Thermophilic composting • N, P, K recovery for agriculture	Rural households, agriculture-linked communities, climate-stressed regions

Case Studies: India

East Kolkata Wetlands (EKW)

The East Kolkata Wetlands (12,500 ha) form one of the world's largest operational examples of nature-based urban wastewater management, treating ~980 MLD of Kolkata's sewage through a network of shallow ponds and fisheries (Bera et al., 2021). Wastewater enters through controlled inlets managed by fishery cooperatives, where settling and natural purification occur through sunlight, algal photosynthesis, and microbial action (The Better India, 2017).

Studies show that EKW outperforms conventional plants in reducing BOD, nutrient loads, and coliform levels, with biodegradation rates reaching $k = 0.7\ day^{-1}$ — far above controlled laboratory rates (Sarkar et al., 2009; Taylor & Francis, 2024). Beyond treatment, the wetlands support the world's largest wastewater-fed aquaculture system, sustain local livelihoods, and provide habitat for diverse avifauna (Sarkar et al., 2009).

However, increasing urban encroachment, industrial pollution, and climate pressures threaten long-term sustainability, underscoring the need for integrated management and continuous monitoring (Taylor & Francis, 2024).

Baindi Village, Haryana: Waste Stabilization Pond System

Baindi village in Yamuna Nagar adopted a five-pond waste stabilization system (2016–2018) to address severe wastewater stagnation and drainage failures (UN SDGS Partnerships, 2016). The system comprising anaerobic, facultative, and maturation ponds that stabilises organics, reduces pathogens, and produces effluent suitable for reuse.

The intervention transformed Baindi's sanitation landscape: open drains disappeared, treated sludge and biomass were reused as manure, groundwater recharge improved, and the surrounding area evolved into a green belt. These changes also reduced time spent on water collection, enabling greater women's participation in education and income-generating activities (UN SDGS Partnerships, 2016).

The Baindi model demonstrates the cost-effectiveness and replicability of nature-based wastewater solutions in rural India.

Ujjain, Madhya Pradesh: Reed Bed Systems

In the mid-2000s, residents of Ravindra Colony and the Mahakaleshwar Temple Board established horizontal subsurface-flow reed bed systems to treat ~13 KL/day of mixed domestic sewage (Down to Earth, 2016). Wastewater is pre-filtered through a boulder-filled chamber and distributed through perforated pipes into a 42 m^2 gravel bed planted with Phragmites.

Reed roots facilitate nutrient uptake and oxygen transfer, enabling effective removal of nitrates, phosphates, and organics. The system produces no sludge, requires no energy inputs, and maintains steady operation even during power outages, which is an advantage in many Indian cities. Treated water can be reused for irrigation or groundwater recharge (Down to Earth, 2016).

Institutional and Policy Context Supporting NBS in India

<u>Swachh Bharat Mission (Urban) [SBM-U]</u>

SBM-U Phase 2.0 (2021) emphasises integrated solid and liquid waste management in smaller Urban Local Bodies (ULBs), promoting nature-based systems as appropriate decentralised solutions where conventional sewer networks remain unviable (MoHUA, 2021).

NITI Aayog Initiatives

NITI Aayog's 2023 strategy on wastewater reuse highlights the role of natural treatment systems in supporting circular economy objectives and reducing water stress (NITI Aayog, 2023a). Its compendium of best practices documents state-level examples involving riparian restoration, natural filtration, and decentralised ecological treatment (NITI Aayog, 2023b).

River Rejuvenation Programs

Under the National Mission for Clean Ganga (NMCG) and related river-conservation initiatives, policy frameworks increasingly support hybrid approaches combining conventional treatment with decentralised and nature-based interventions, including NMCG's (2023) guidelines on constructed wetlands.

Global Case Studies

Arcata Wastewater Treatment Plant and Wildlife Sanctuary, California

The Arcata Marsh in California is a flagship hybrid natural–engineered wastewater system combining conventional headworks with oxidation ponds, treatment wetlands, and enhancement marshes (City of Arcata, n.d.). Clarified effluent undergoes algal–bacterial degradation in 55-acre oxidation ponds before passing through wetlands and three polishing marshes (Allen, Gearheart, Hauser), which support over 300 bird species. The 307-acre site functions as both a treatment facility and a wildlife sanctuary, receiving national recognition for innovation. Arcata demonstrates how integrated ecological design can deliver effective treatment while enhancing biodiversity, recreation, and community value (City of Arcata, n.d.).

Living Machines at the Port of Portland, USA

The Port of Portland installed a Living Machine in its administrative building lobby, treating greywater and stormwater through a series of planted ecological cells housed within a greenhouse (Kirksey, 2010). The system reduces potable water use for landscaping while serving as an educational and aesthetic feature.

Constructed Wetlands in Ethiopia

Cities such as Adama and Shashemene have adopted constructed wetland systems for condominium wastewater treatment under programs led by WASTE (Netherlands), Ecofyt, World Waternet, and local utilities (WASTE, n.d.). These decentralised wetlands offer scalable, low-energy treatment options in rapidly urbanising contexts lacking centralised sewerage.

Living Machine Development at Findhorn, Scotland

The Findhorn Foundation pioneered small-scale Living Machine systems, demonstrating that compact ecological treatment units can meet effluent standards while delivering habitat and aesthetic benefits. These early installations helped advance the global development of ecological engineering.

Nature-Based Solutions for Climate Adaptation

Nature-based solutions are increasingly embedded in national climate strategies. A 2024 synthesis of 57 National Adaptation Plan (NAP) documents found that 44 explicitly reference NBS or ecosystem-based adaptation (Terton et al., 2024). Wetland-based systems offer key climate benefits, including flood buffering, groundwater recharge, and biodiversity support, strengthening ecosystem and community resilience (Ramsar Secretariat, 2018; Conlisk et al., 2022).

Environmental and Ecological Benefits

The major environmental and ecological benefits of nature-based sanitation systems are summarised in Table 2.

Table 2: Environmental & Ecological Benefits of NBS

Benefit Category	Key Functions	Supporting References
Biodiversity & Habitat	Provides habitat for birds, fish, amphibians, and invertebrates; enhances urban ecological connectivity	CBD Secretariat (2010); Zhang*et al.*(2020);ILG (n.d.)
Carbon Sequestration	Biomass accumulation + slow soil decomposition store carbon long-term; lower GHG emissions vs. mechanical systems	Mitsch & Gosselink (2015); Bailey *et al.* (2021)
Nutrient Cycling	Recovers N, P, K via plant uptake and sludge reuse; reduces synthetic fertilizer demand	Pausta *et al.* (2024)
Pollutant Removal	Removes heavy metals, POPs, and pharmaceuticals via microbial degradation, plant uptake, and filtration	Riggio *et al.* (2018); Vymazal (2011)

Biodiversity and Habitat Provision

Constructed wetlands operate as both treatment systems and biodiversity refuges. Natural wetlands are among the world's most species-rich ecosystems, supporting diverse plant, fish, bird, amphibian, and invertebrate communities (CBD Secretariat, 2010). Research shows that engineered wetlands can replicate many of these ecological functions, providing habitat in urban and peri-urban areas where natural wetlands have declined (Zhang et al., 2020). The Arcata Marsh in California exemplifies this dual role, supporting over 300 bird species while serving as a municipal treatment facility (Institute for Local Government, n.d.).

Carbon Sequestration and Climate Mitigation

Wetlands — including constructed systems — act as carbon sinks: aquatic vegetation sequesters carbon, and waterlogged soils suppress decomposition, enabling long-term carbon storage (Mitsch & Gosselink, 2015). Because natural systems avoid the high aeration and pumping demands of mechanical treatment, they generate lower operational greenhouse gas emissions. Given that wastewater treatment contributes 3–7% of global energy-related CO_2 emissions, NBS offer meaningful mitigation potential (Bailey et al., 2021).

Nutrient Cycling and Soil Enhancement

Nature-based systems recover nitrogen, phosphorus, and potassium by incorporating them into plant biomass and sediments. Harvested vegetation and nutrient-rich sludge can be processed into compost or soil amendments, reducing reliance on synthetic fertilizers. Life-cycle assessments show that nutrient recovery from wastewater can reduce freshwater eutrophication impacts by ~83.6% and eliminate mineral resource scarcity impacts relative to conventional fertilizer production (Pausta et al., 2024).

Water Quality Enhancement and Pollutant Removal

Constructed wetlands remove heavy metals, organic micropollutants, and pharmaceutical residues through integrated processes, including plant uptake, microbial degradation, sedimentation, and filtration (Riggio et al., 2018; Vymazal, 2011). Their root-zone complexity creates a diverse set of redox and microbial environments capable of transforming contaminants that often persist after conventional mechanical treatment.

Challenges and Limitations

Space Requirements

Nature-based sanitation systems require larger land areas. Horizontal subsurface-flow wetlands typically need 1–2 m^2 per person equivalent, while vertical-flow wetlands require 0.8–1.5 m^2, substantially more than compact mechanical systems (UN-Habitat, 2008). This limits applicability in dense urban areas, though intensified designs such as vertical configurations and Living Machines can reduce footprint requirements.

Climate and Environmental Variability

Performance is sensitive to temperature, sunlight, rainfall, and seasonal variation. Cold climates reduce microbial and plant activity, impairing nutrient and organic-matter removal, while arid regions may face high evaporation and hydraulic imbalance. Effective implementation, therefore, requires climate-responsive system design (Kadlec & Wallace, 2009).

Plant Selection and Management

Constructed wetland performance depends on selecting species well-adapted to local climates and loading conditions. In India and other tropical contexts, indigenous macrophytes such as Phragmites karka are increasingly favoured for their resilience and nutrient-removal performance (Qadiri et al., 2021). Routine harvesting and control of invasive species are essential for sustained function.

Regulatory and Institutional Barriers

Regulatory standards and institutional practices often prioritise conventional mechanical treatment, leaving limited familiarity or acceptance of nature-based systems. Water quality norms reflect expectations from engineered plants, and capacity for ecological system monitoring and adaptive management remains limited in many regions (India Water Portal, 2023). Institutional inertia and perceived risks further hinder adoption.

Integration with Centralized Infrastructure

The role of NBS within cities with existing sewerage remains evolving. Rather than competing with centralised plants, nature-based systems can complement them through secondary polishing, decentralised treatment in unsewered areas, and provision of flood-buffering and water-quality enhancement services (Castellar et al., 2022).

Mechanisms for Scaling and Mainstreaming NBS

Policy and Governance Frameworks

Scaling NBS requires policies that formally recognise ecological engineering as a viable alternative to conventional treatment. India's policy landscape, through SBM-U Phase 2.0, NITI Aayog initiatives, and river-rejuvenation programs — has begun endorsing NBS, but further progress is needed in setting design and monitoring standards, creating dedicated financing pathways, and building institutional capacity in ecological engineering.

Financing and Economic Models

Because NBS generate multiple ecosystem services alongside wastewater treatment, financing must account for co-benefits such as biodiversity, groundwater recharge, and carbon sequestration. Emerging mechanisms include payment-for-ecosystem-services schemes, green bonds, and blended finance combining public investment with instruments like carbon credits (NITI Aayog, 2023a).

Capacity Building and Knowledge Sharing

NBS implementation demands technical skills distinct from conventional wastewater engineering. Universities, development agencies, and practitioner networks must strengthen training in ecological design, monitoring, and adaptive management. Global platforms such as SuSanA and wetland knowledge networks play a key role in sharing lessons and accelerating adoption (SuSanA, n.d.).

Integration with Urban Planning and Green Infrastructure

Nature-based sanitation performs best when embedded within broader green-infrastructure and urban-planning frameworks. Multi-functional landscapes that combine treatment with stormwater management, cooling, biodiversity habitat, and recreation enhance urban resilience. Examples such as Arcata and recent blue-green initiatives in cities like Mumbai and Bengaluru illustrate this emerging integration (India Forum for Nature-Based Solutions, 2023).

Contribution to Sustainable Development Goals

SDG 6: Clean Water and Sanitation

NBS expand access to safe sanitation by enabling decentralised, low-cost wastewater treatment in areas where conventional infrastructure is impractical. Case studies such as the East Kolkata Wetlands and Baindi demonstrate that effective sanitation is achievable without mechanical plants.

SDG 13: Climate Action

NBS reduces operational energy use compared to mechanical treatment and sequesters carbon in biomass and sediments. Their ecological design also enhances climate resilience by buffering floods, improving water security, and stabilising ecosystems under variable climate conditions.

SDG 14 and SDG 15: Life Below Water & Life on Land

Constructed wetlands protect both terrestrial and aquatic biodiversity by preventing untreated wastewater discharge and creating habitat-rich green spaces. Urban wetlands contribute to SDG 15, while reduced aquatic pollution supports SDG 14.

SDG 2: Zero Hunger & Circular Economy

Ecological sanitation and nutrient-recovery systems return nitrogen, phosphorus, and potassium to agriculture, improving soil health and reducing fertiliser dependence. These closed-loop cycles support food security and advance circular-economy goals (Ryals et al., 2021).

Future Research and Development Priorities

Long-Term Performance Monitoring

Despite strong short-term results, long-term (>10 years) data on nature-based wastewater systems remain limited. Future research must assess treatment performance, ecological function, and operational sustainability under varying environmental and management conditions. Particular focus is needed on system responses to changing influent quality — including emerging contaminants and pharmaceuticals — and to climate variability (Hassan et al., 2021).

Optimization of Design Parameters

Key design variables such as hydraulic loading, retention time, plant species, substrate composition, and system geometry require systematic evaluation across tropical, temperate, arid, and cold regions. Advanced modelling and machine-learning tools can help integrate existing studies and guide design optimization (Riggio et al., 2018).

Integration with Advanced Treatment Technologies

Hybrid systems that pair NBS with technologies like slow sand filtration, advanced oxidation processes, or biochar filtration could enhance treatment efficiency while preserving cost and sustainability benefits. Research on such integrated configurations is critical for applications facing land or climate constraints (Wang et al., 2022).

Evaluation of Ecosystem Services and Economic Valuation

More comprehensive assessment of ecosystem services, such as biodiversity support, carbon sequestration, groundwater recharge and recreation is needed. Coupling hydrological, ecological, carbon-accounting, and economic-valuation approaches will help inform policy, financing, and comparative cost-benefit analyses of nature-based wastewater solutions.

Conclusion

NBS are not merely alternatives to conventional wastewater infrastructure as they reflect a deeper shift toward working with ecological processes rather than against them. Evidence from the East Kolkata Wetlands, Arcata Marsh, and emerging systems in Ethiopia shows that ecological treatment can match mechanical performance while simultaneously restoring habitat, storing carbon, recycling nutrients, and enhancing community well-being.

In India, where rapid urbanization and limited resources challenge centralized wastewater systems, nature-based approaches offer practical, low-cost, and culturally grounded pathways to expand sanitation access. Examples such as Baindi's stabilization ponds and Ujjain's reed beds demonstrate how communities can build and manage effective ecological systems when supported by enabling policies.

Scaling these approaches now depends less on technical feasibility — well-established by decades of research — and more on overcoming institutional, regulatory, and financing barriers. As national initiatives like SBM-U 2.0, NITI Aayog's wastewater strategies, and river-rejuvenation programs gather momentum, the opportunity exists to mainstream ecological engineering within India's urban and rural sanitation frameworks.

The imperative is clear: nature already provides the processes needed for sustainable wastewater management. The task ahead is mobilizing policy, investment, and professional capacity to bring these proven solutions to scale.

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Rejuvenation of Lakes – Identifying and Addressing the Challenges

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Abstract

Urban lakes play a critical role in hydrological regulation, biodiversity conservation, micro-climate moderation, and social well-being. However, rapid urbanization, unplanned land-use changes, untreated sewage inflows, and weak institutional coordination have led to severe degradation of these water bodies across Indian cities. The study synthesizes technical, ecological, institutional, and socio-economic challenges commonly encountered in lake restoration projects, including catchment degradation, water quality deterioration, sediment contamination, encroachments, fragmented governance, and post-restoration sustainability. A detailed case study of the Bandra Lake (Swami Vivekanand Sarovar, Bandra) Rejuvenation Project in Mumbai is presented to illustrate practical constraints, decision-making processes, and adaptive solutions implemented during planning and execution. Drawing on direct expert involvement in the project, this study highlights strategies such as sewage interception and diversion, in-situ treatment interventions, ecological restoration, stakeholder engagement, and long-term operation and maintenance.

The findings underscore that lake rejuvenation is not merely an engineering exercise but a multidisciplinary process requiring convergence of environmental science, urban planning, governance reforms, and community participation. The study concludes with key lessons and replicable insights that can inform policymakers, urban local bodies, and practitioners engaged in sustainable lake management and urban water body rejuvenation initiatives.

Keywords : Urban lake rejuvenation; Sewage interception and treatment; Ecological restoration; Sustainable urban development; Bandra Lake of Mumbai.

Introduction

Importance of Urban Lakes in Ecological and Urban Systems

Urban lakes are vital components of city ecosystems, providing multiple ecological, hydrological, and socio-economic services. They function as natural stormwater retention systems, groundwater recharge zones, and urban heat island moderators, while supporting aquatic and avian biodiversity. Beyond their environmental role, urban lakes contribute to recreational spaces, cultural identity, and public well-being. In the context of climate change, lakes enhance urban resilience by mitigating flood risks and improving microclimatic conditions.

Status and Degradation of Lakes in Indian Cities

Across Indian cities, a significant proportion of urban lakes have experienced severe deterioration due to rapid urbanization, population growth, and unplanned infrastructure development. Many lakes have been converted into receptacles for untreated or partially treated sewage, solid waste, and stormwater runoff carrying pollutants. Studies indicate declining water quality, eutrophication, loss of native species, and frequent algal blooms in urban lakes, reflecting systemic failures in urban water management and regulatory enforcement.

Need for Systematic Lake Rejuvenation

Given the ecological and urban importance of lakes, ad-hoc beautification or isolated engineering interventions are insufficient to restore their functionality. Systematic lake rejuvenation requires an integrated approach that addresses pollution sources, catchment processes, ecological restoration, and long-term management.

Objectives and Scope of the Study

This study aims to identify the key challenges associated with urban lake rejuvenation and examine practical approaches to addressing them through a multidisciplinary lens, such as technical, ecological, institutional, and social dimensions.

Rationale for selecting Bandra Lake for a Case Study

Bandra Lake, located in the highly urbanized western suburbs of Mumbai, represents a typical yet complex case of urban lake degradation and restoration. The lake has been subjected to prolonged sewage inflows, catchment disturbances, and ecological decline, while being embedded within a dense residential and commercial landscape.

Literature Review

Global Perspectives on Lake Rejuvenation and Restoration

Literature on lake restoration emphasizes a transition from purely engineering-driven solutions toward integrated ecosystem-based approaches. Early restoration efforts focused largely on physical interventions such as dredging, shoreline hardening, and pollutant dilution. However, studies from Europe, North America, and Australia highlight that long-term success depends on controlling external nutrient loads, restoring natural hydrological regimes, and enhancing ecological resilience.

Urban Lake Degradation: Causes and Impacts

Extensive research identifies untreated sewage inflows, urban runoff, industrial effluents, and solid waste dumping as primary drivers of urban lake degradation. Catchment alteration due to impervious surfaces reduces infiltration and increases pollutant loading during rainfall events. Eutrophication, characterized by excessive nutrient enrichment and algal blooms, is frequently reported in urban lakes, leading to hypoxia, fish kills, and loss of biodiversity.

Indian Experience in Lake Rejuvenation

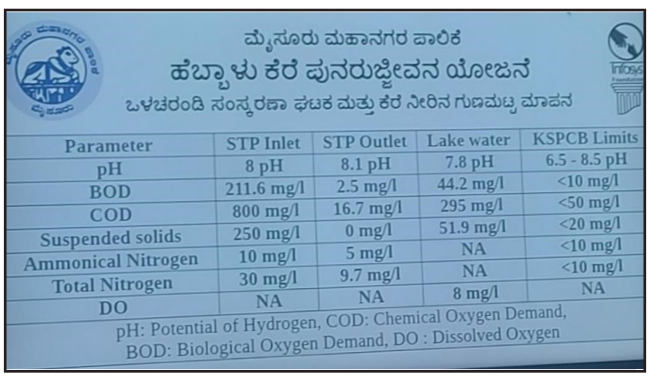
In the Indian context, urban lake restoration has gained policy attention over the past two decades, particularly in metropolitan regions such as Bengaluru, Hyderabad, Chennai, and Mumbai.

Studies highlight common challenges, including fragmented institutional responsibilities, absence of reliable baseline data, and prioritization of aesthetic improvements over ecological health.

As the urbanization process increased in India, the water bodies, such as lakes got contaminated with mostly sewage and sometimes by industrial effluents. Due to this many adverse impacts occurred on the quality of lakes such as fish death, development of weeds, visible pollution like foam development, greenish algae development due to eutrophication process etc.

Hebbal Lake, Mysuru

Hebbal Lake in Mysuru was rejuvenated with the support of Infosys Foundation in the year 2018. The lake is spread across an area of 48 acres. The project undertaken followed the steps: (1) Dewatering; (2) Desludging; (3) Creation of artificial islands to enhance biodiversity; (4) Sewage Treatment Plant (STP). The sewage is diverted and treated in the STP of 8 MLD capacity. The technology adopted for STP is MBR (Membrane Bio-Reactor).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Parameter	STP Inlet	STP Outlet	Lake water	KSPCB Limits
pH	8 pH	8.1 pH	7.8 pH	6.5 - 8.5 pH
BOD	211.6 mg/l	2.5 mg/l	44.2 mg/l	<10 mg/l
COD	800 mg/l	16.7 mg/l	295 mg/l	<50 mg/l
Suspended solids	250 mg/l	0 mg/l	51.9 mg/l	<20 mg/l
Ammonical Nitrogen	10 mg/l	5 mg/l	NA	<10 mg/l
Total Nitrogen	30 mg/l	9.7 mg/l	NA	<10 mg/l
DO	NA	NA	8 mg/l	NA

pH: Potential of Hydrogen, COD: Chemical Oxygen Demand, BOD: Biological Oxygen Demand, DO : Dissolved Oxygen

Water quality parameters at different locations vis-à-vis limit at Hebbal Lake

Ulsoor Lake, Bengaluru

Ulsoor Lake is a large lake of around 123.6 acres located near the central business district of Bengaluru. It is a manmade lake built by Kempe Gowda in the 17th century. It has several islands. The lake has been polluted and silted over 25 years. One of the main reasons of the pollution is the disposal of sewage which had affected its ground water table and storage capacity.

Ms. Madhushree, Executive Engineer, Bruhat Bengaluru Mahanagara Palike (BBMP), explained the Ulsoor Lake revival project to Mr. Shashank Mehendale and Mr. Chandrashekhar Marathe from Shashank Mehendale and Associates, and Dr. Milind Kulkarni and Dr. Prashant Bhave, Members of the Expert Committee.

Dahisar River, Mumbai

In Mumbai, Dahisar river rejuvenation project is undertaken by the Brihanmumbai Municipal Corporation (BMC). Here, the sewage from the nallahs is diverted and treated in a STP, which is constructed right above the river without affecting the natural flow of the river.

Dingeshwar Lake, Mumbai

This lake is rejuvenated using steps: (1) Dewatering; (2) Desilting; (3) Mobile Sewage Treatment Plant based on MBR technology; (4) Aeration. In addition, the sides of the lake are covered with geotextiles to stop sewage intrusion.

Technical and Ecological Approaches Documented in Literature

A wide range of technical interventions for lake rejuvenation are discussed in existing studies.

These include sewage interception and diversion, in-situ treatment technologies such as aeration and bioremediation, desilting and sediment management, and shoreline stabilization. Ecological restoration approaches such as creation of littoral zones, planting of native macrophytes, and habitat enhancement for avifauna are recognized for improving ecological integrity. However, several studies caution against over-reliance on mechanical or chemical treatments without addressing root causes of pollution, noting that such approaches may offer temporary relief but fail to ensure long-term sustainability.

Governance, Institutional, and Policy Dimensions

Many studies show that governance plays an important role in the success of lake rejuvenation. Urban lakes often fall under multiple agencies responsible for water supply, sewerage, stormwater, land management, and environment, leading to coordination challenges and accountability gaps.

Social Dimensions and Community Participation

Social science literature highlights the role of local communities in influencing both degradation and restoration of urban lakes. Public awareness, behavioral practices, and stakeholder engagement significantly affect pollution control and post-restoration maintenance.

Research Gaps and Positioning of the Present Study

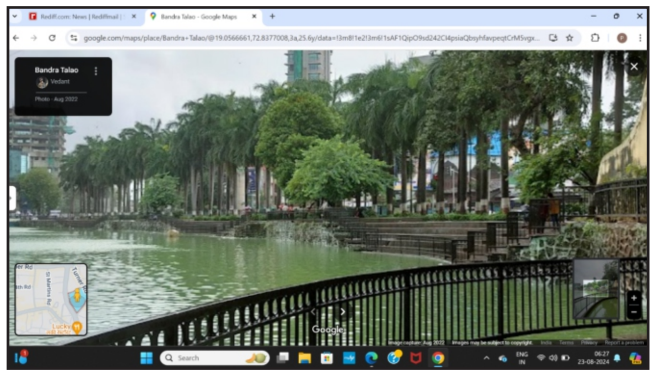
Despite extensive literature on lake rejuvenation, gaps remain in documenting the practical challenges encountered during implementation in dense urban contexts, particularly in Indian cities. Many studies focus either on technical solutions or policy frameworks, with limited integration of expert-led decision-making and adaptive management experiences.

Case Study – Bandra Lake Rejuvenation, Mumbai

Background and Significance of Bandra Lake

<u>Location, Catchment Characteristics, and Historical Context</u>

Bandra Lake or Swami Vivekanand Sarovar is a prominent landmark of Mumbai. It is in Bandra (West), which is popularly known as the "Queen of the Suburbs" in Mumbai and is the primary area within the H/West Ward of the BMC.



Bandra Lake, Mumbai.

<u>Pre Rejuvenation Condition</u>

In Mumbai the water bodies are undergoing tremendous degradation due to anthropogenic activities. The pollution of the water bodies has often led to events of dying fishes due to lack of oxygen, harmful algal bloom, eutrophication, etc. The pollution levels are increasing at an alarming rate. Thus, there is a necessity to rejuvenate the urban water bodies.

The environmental status of a water body helps us understand the level of pollution of a water body. In the city like Mumbai, due to rapid urbanisation, there is an increase in population density leading to encroachment near public places like water bodies, railway track, etc, which is a common scenario. In the olden days the lake water used to be pristine and of acceptable quality. However, the late urbanization of Mumbai has resulted in an adverse impact on the quality of lake water. Presently, the lake water appears greenish in colour with many other floating debris. M/s Shashank Mehendale & Associates (SMA) are appointed as Project Management Consultants (PMC) for the project by BMC. Dr. Milind Kulkarni and Dr. Prashant Bhave are working as Experts in this project.

Identified Issues and Baseline Assessment

Water Quality Status

During the site visit to Bandra Lake, the following were the observations:

- The lake appeared visibly polluted with the profuse algal growth.
- Floating debris were cited in the water body.
- It was decided to have the sampling of the water body covering the complete lake, with the positions of the sampling locations decided tentatively.

The water samples from 5 locations were collected on 12 March 2024. The pollution parameters analyzed were BOD, COD, TSS, pH, Nitrates, phosphates, DO, Temperature, Turbidity.

Water samples were collected from the following locations in the lake:

1. S. V. Road North Point
2. S. V. Road South Point
3. Central Point
4. Station Road South Point
5. Station Road North Point

Results of the laboratory analysis are presented in the table below:

Bandra Lake – Water Samples Lab Analysis Report									
Sample Collected: 12/04/2024			Lab Analysis Report: 22/04/2024					mg/L	
SN	Location	BOD	COD	DO	FC#	Turbidity #	pH#	Nitrates	Phosphates
1	SV Rd N point	124	426	<1	240	261	7.39	<0.1	11.86
2	SV Rd S	108	372	<1	>1600	244	7.11	<0.1	7.21
3	Lake mid	100	344	<1	>1600	248	7.31	<0.1	7.87
4	Stn Rd S	124	438	<1	>1600	295	7.29	<0.1	6.47
5	Stn Rd N	108	381	<1	240	299	7.19	<0.1	5.34

	Range	100-124	344-438	<1	240-1600	244-299	7.11-7.39	<0.1	5.34 -11.86
	Average	112.8	392.2	<1	240-1600	269.4	7.11-7.39	<0.1	7.75

Summary of testing results and comparison with NGT standards are presented in the table below:

SN	Parameter	Range for Lake Samples	NGT Standard for Treated Sewage
1	pH	7.11 to 7.39	6.5 to 8.5
2	BOD	100-124 mg/L (Avrg. 112.8)	< 10
3	COD	344-438 mg/L (Avrg. 392.2)	< 20
4	Fecal Coliforms	240-1600 per 100 ml	100
5	Dissolved Oxygen	< 1 mg / L (Avrg. < 1 mg/lit)	(> 4 mg/lit)
6	Turbidity	244 - 299 NTU	(< 10 NTU)
7	Nitrates	< 0.1 mg / L (Avrv <0.1)	< 10 mg/lit
8	Phosphates	5.34 -11.86 mg/L (Avrg 7.75)	< 1 mg/lit

Inference on the Laboratory Analysis of the Samples:

The summary of the result shows high level of water pollution caused by urbanization and seepage / disposal of sewage water into the lake.

- The values of Average BOD of lake water along with COD is that of moderate to strong sewage. The standards for BOD, COD, Phosphates and Coliforms are exceeded by huge margin.
- The Dissolved Oxygen (DO) level is less than 1 mg/L. This indicates that the fish and other aquatic life will not survive in Bandra lake except the fish which survives in the polluted water with less DO.
- BOD to COD ratio of sewage and bio-degradable waste is normally 0.5 or more. Here it is around 0.28. This indicates presence of significant quantity of non-biodegradable substances such as housekeeping chemicals, detergents etc. The presence of high concentration of phosphates confirms the pollution caused by detergents.
- Phosphates and nitrates damage the quality of lake water by eutrophication process. Therefore, any proposed treatment for the revival of lake should comprise removal of nitrogen and phosphorus, also.

Sources of Pollution

The results of the laboratory analysis of lake samples indicate that the lake is highly polluted. The pollution is taking place for a long time, and it is a legacy issue. As the BOD is high, sewage intrusion due to dense urbanisation is the main source. The quality of lake water is very close to that of sewage. It is estimated that the quality of lake water near the bottom will be worse due deposition of organic and inorganic sludge.

Ecological and Social Challenges

As the levels of dissolved oxygen are very low, the survival of aquatic life is difficult. This is a major challenge for the thriving of healthy ecosystem including migratory birds. The side walls of the lake are concretised at majority of the perimeter. This also poses challenges for the development of ecosystem. Dumping of debris is rampant due to high level of footfall.

Rejuvenation Strategy and Interventions

The primary objective of the Bandra lake rejuvenation is aimed at upgrading the quality of lake water. The proposed upgradation of water quality needs to be substantial and to bring it to an acceptable level on water quality parameters attaining the surface water body standards for lake water (as stated for the outside bathing water standards of Central Pollution Control Board (CPCB) / Ministry of Environment, Forests & Climate Change (MoEF & CC).

At present, there is no specific water quality criteria developed in respect of lakes. Hence Designated Best Use surface waters for bathing quality as given by CPCB shall be the target for lake water quality. (Source: Guidelines for National Lake Conservation

Plan) As per the objectives of BMC discussed above Designated Best Use of "Propagation of Wildlife and Fisheries", Class of Criteria D is specified for Bandra Lake and the same needs to be maintained by the successful bidder. The CPCB criteria for this Class D are as follows:

1. pH between 6.5 to 8.5
2. Dissolved Oxygen 4 mg/lit or more
3. Free Ammonia (as N) 1.2 mg/lit or less

There are several unique challenges associated with the rejuvenation Bandra lake as follows: -

1. **Legacy Contamination:** The water quality of Bandra lake has deteriorated over the number of years, due to the disposal of waste from urban settlements, particularly sewage. The laboratory analysis confirms these facts. As the lake water contains high concentrations of BOD, COD, and Phosphates which are accumulated over the number of years, it is necessary to dewater and de-sludge the lake water completely so that all the pollutants are removed.
2. **Identification of Sources of Contamination:** BMC has provided sewerage system as well as storm water drainage system for Bandra area, hence the chances of direct disposal of sewage in the lake are less. Hence, identification of sources of contamination, such as sewage disposal will be a challenge.
3. **Availability of Area:** Land is very scarce in Mumbai and so is the case for Bandra lake. Hence before selecting the technology for sewage treatment this fact needs to be kept in mind and STP technologies requiring less areas should be preferred
4. **Biodiversity Enhancement:** Creation of artificial islands is one of the mechanisms for lake rejuvenation. This enhances ecology and attracts migratory birds.
5. **Behavioral Change:** Bandra lake is surrounded by urban settlements. Because of lack of civic sense, disposal of solid waste and other garbage takes place in the lake. To avoid this, it is required to sensitize the public around the lake and this needs to be a continuous activity.
6. **Co-ordination between different Government Authorities:** Co-ordination between different BMC authorities, such as SWD, SWM, SO, as well as state government authorities such as MPCB, MMRDA is needed so as avoid contamination of lake due to sewage.

<u>Dewatering, Desilting, and Sludge Management</u>

Dewatering: Dewatering is essential to dispose of the legacy contaminants accumulated in the lake over the years and responsible for continuous depletion of dissolved oxygen, algal growth and eutrophication.

Desilting: Silt comprises solid layer of silt/sand sized particles accumulated at the bottom of the lake. This is essential to increase the storage capacity of the lake and to dispose of the legacy waste accumulated.

Desludging: As the sludge consists of around 99% water, desludging is considered in the scope of dewatering. The sludge samples were taken at five points. The sludge has occupied large portion of the lake. The surface area of the lake is around 6.18 acres (25000 m2). The average water depth is assumed to be 1.6 m.

<u>Sewage Interception and Diversion</u>

As discussed, there is no direct sewage disposal into Bandra lake. There are chances that during dewatering process, some sewerage lines may get exposed. It is planned that such sewer lines will be connected by an intercepting sewer and the sewage will be taken to the proposed 1 MLD STP.

In-situ Treatment Measures

The in-situ treatment measures selected are as follows:

STP: Determining the capacity of STP is a challenge as the exact source is not known. It is assumed that the lake water is polluted due to seepage of sewage from surrounding high population density areas. Different technology alternatives such as natural treatment systems such constructed wetland, Sequential Bio Reactor (SBR), Moving Bed Bioreactor (MBBR) and Membrane Bio Reactor (MBR) were assessed and MBR technology was selected. MBR technology is the most advanced technology and amongst the three technologies discussed it gives excellent quality of treated effluent which can meet the stringent NGT standards.

Lake Aerators : Even after taking care of the treatment of sewage, considering the large areas, there are chances of intrusion of sewage and other contaminants. Therefore, it is necessary to make provision of aeration in the entire lake body.

Measures to Enhance Biodiversity: All the case studies visited involve the construction of multiple islands within the lake body. Proper plantations like Miyawaki forest need to be created on these islands. These islands attract a lot of flora and fauna and increase the biodiversity of the lake. They may also attract migratory birds.

Landscaping and Public Interface Planning: As this project is done from "Water bodies rejuvenation funds" of the central government, the expenditure on landscaping and aesthetical aspects is not permitted. However, these aspects can be taken care of through other funds of BMC at a later stage.

Policy and Planning Implications

Recommendations for Urban Local Bodies (ULBs)

ULBs should regularly monitor the quality of water bodies for parameters such as dissolved oxygen, BOD, COD, etc. Quality parameters should be displayed at the water body site with an electronic dashboard.

Integration with City Master Plans

Water bodies such as rivers and lakes should be identified in the city master plans, and the protection of these water bodies should be an integral part of the planning of any project works.

Long-term Operation and Maintenance (O&M) Frameworks

Long-term O&M should be an integral part of the project. The responsibility of maintaining the quality of water bodies should be entrusted to the contractor for O&M period of at least 5 or more years.

Alignment with National Missions [Swachh Bharat Mission (SBM-U), Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Climate Resilience, etc.)

Projects for the rejuvenation of urban water bodies should be supported on priority basis from funds available under SBM-U 2.0, AMRUT, Climate Resilience. Proper weightage should be given to the quality of urban water bodies in Swachh Survekshan competition of ULBs.

Benefits of Lake Rejuvenation Project

- Bringing & maintaining lake water quality on grade 'D' will itself be a proud achievement for BMC and its success story will pave the way for similar lake rejuvenation projects.
- Eutrophication and algal growth in the lake will be reversed which will enhance dissolved oxygen in the lake and promote aquatic life such as fish and other flora and fauna.
- The ground water quality will be improved and the level of ground water in the surrounding area will also increase.
- Rejuvenation of lakes will give rise to aquatic life, attract birds and enhance biodiversity of not only Bandra lake but surrounding area.
- At present, the lake is releasing foul gases which is reducing the recreational potential of the lake. After lake revival, this will stop and the recreational potential of the lake will be improved. Release of methane gas will stop which will help combat climate change, global warming and enhancing sustainable development.
- The fountain will enhance the aesthetic beauty of the lake and the city.
- The project has the potential to become an important knowledge center for revival of lakes in Maharashtra.

Conclusion

Bandra Lake is in the prime western suburb of Bandra (W) in Mumbai. The lake is spread over an area of around 7.5 acres (30000 m2). The DPR mainly involves (i) Assessment of the present status of Bandra Lake; (ii) Literature review; (iii) Visit and study of success stories of lake revival at Mysuru and Bengaluru; (iv) Project proposals; and (v) Cost estimates with timeline. The main project components proposed are (i) Dewatering including desludging; (ii) Desilting; (iii) Sewage treatment; (iv) Enhancement of bio-diversity; (v) Knowledge Center; and (vi) Monitoring and Public Awareness. Water quality criteria given in the guidelines of CPCB for category D water bodies will be maintained for Bandra Lake. National Green Tribunal (NGT) standards are stipulated for the STP.

It is expected that after the execution of the project, the Bandra Lake will be rejuvenated and aquatic life will flourish in the lake resulting in significant environmental, social and sustainable benefits.

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Shit-Flow Diagram for Hubballi-Dharwad City, Karnataka

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Abstract

This study assesses the sanitation landscape of Hubballi-Dharwad, Karnataka, with a focus on wastewater and fecal sludge management in the twin cities. Despite a combined population of over 1 million and growing urbanization, the 2011 City Sanitation Plan (CSP) revealed the complete absence of sewage and fecal sludge treatment facilities, resulting in widespread unsafe disposal. Using a combination of household surveys (covering 4,000 households across all 67 wards), key informant interviews, and secondary data (Census 2011 and official records), we updated and verified the status of sanitation infrastructure and service delivery. Our analysis shows that while two Sewage Treatment Plants (STPs) — a 40 MLD unit in Hubballi and a 20 MLD unit in Dharwad — have since been commissioned, raising treatment coverage to approximately 53% by 2018, key challenges remain. Around 12% of households rely on on-site sanitation, with only 71% of the resulting fecal sludge being collected and none safely treated. Open defecation persists among 3% of households, and a significant number use unsafe pits. The Shit Flow Diagram (SFD) generated as part of this study indicates incremental progress in sanitation safety since 2015 but highlights that further gains will require expanded sewer networks, a Fecal Sludge Treatment Plant (FSTP), and targeted interventions for vulnerable households. The findings underscore the need for integrated policy measures and infrastructure investments to achieve universal and safe sanitation in Hubballi-Dharwad.

Keywords : Urban Sanitation, Sewage Treatment Plants (STPs), Fecal Sludge Management, Shit Flow Diagram (SFD), Hubballi-Dharwad.

Introduction

Hubballi-Dharwad, the second-largest urban agglomeration in Karnataka, comprises two historically distinct cities that were merged under a single municipal corporation in 1965. Located in north-west Karnataka, the twin cities have a combined population of over one million (Census 2011) and continue to experience steady urban growth. Despite this demographic and economic expansion, sanitation infrastructure has long lagged. As of 2011, the cities lacked any operational STP or fecal sludge treatment facility, resulting in the direct discharge of untreated wastewater into natural drains (nalas) and unsafe disposal of fecal sludge.

Sanitation service delivery in Hubballi-Dharwad has historically been fragmented, with data inconsistencies between institutions such as the

Hubballi-Dharwad Municipal Corporation (HDMC) and the Karnataka Urban Water Supply and Drainage Board (KUWSDB). In 2016, plans were announced for the installation of five STPs with a combined capacity of 145 MLD to address the city's growing wastewater treatment needs. By 2018, only two of these — one 40 MLD plant in Hubballi and one 20 MLD plant in Dharwad — had been completed. This study aims to assess the status of sanitation infrastructure and service delivery in Hubballi-Dharwad, based on a comprehensive household survey, key informant interviews, and secondary data analysis. By constructing a SFD, we map the fate of human waste across containment, emptying, transport, treatment, and disposal stages. The findings help evaluate recent progress and identify the infrastructural, institutional, and behavioral gaps that must be addressed to achieve safely managed sanitation for all residents.

Project Area Description

The city centers of Hubballi and Dharwad are in north-west Karnataka, 476 km south of Mumbai, and 411 km north of Bangalore. The two cities were founded separately, but due to their proximity (being separated by only 20 kilometers), their municipal governments were combined into one common administration in 1925, and in 1965, this entity gained its status as the HDMC. The combined population in the 2011 census was roughly 1 million people, second only to Bangalore among cities in Karnataka. The twin cities source almost all their municipal piped water from the Malaprabha River and Neer Sagar Lake. Hubballi-Dharwad has 67 wards, comprising 46 in Hubballi and 21 in Dharwad, covering an area of 202 square kilometers, with an average population density of 2,362 per square kilometer. The average family size is 5.0 and the average literacy rate is 87%. A total of 138 slums have been identified, representing 19% of the total population.

Sanitation in Hubballi-Dharwad

According to the city sanitation report, as of 2011, there was no sewage treatment plant, nor any fecal sludge treatment facility, indicating that all wastewater produced went directly into the local nalas, and all the fecal sludge collected was dumped in an unsafe and unregulated manner. There is some discrepancy in the data on sewage; in the city sanitation report, data were taken from both KUWSDB and HDMC (**Table 1**).

Combined collection of wastewaters from individual toilets and storm water eventually collects in two existing outfalls: the Gabbur nallah in Hubballi and the Madihal nallah in Dharwad. From there, it flows out of each city respectively, but much of this nutrient-rich wastewater is diverted and used in local agricultural fields south of Hubballi and Dharwad. (WRG 2016) The KUWSDB estimates that in 2011, Hubballi-Dharwad produced a total of 78 MLD of wastewater, all of which went untreated.

Table 1: Types of Sanitation Access / Lack of Access

<table>
<tr><th>Description</th><th>HDMC</th><th>KUWSDB</th></tr>
<tr><td>Individual Toilets, discharge to underground drains</td><td>70%</td><td>50%</td></tr>
<tr><td>Individual Toilets, discharge to open drains</td><td>10%</td><td>5%</td></tr>
<tr><td>Septic Tanks</td><td>14%</td><td rowspan="3">45%</td></tr>
<tr><td>Pit</td><td>3%</td></tr>
<tr><td>Open Defecation</td><td>3%</td></tr>
</table>

In a report prepared by WRG in 2016, based on conversations had with authorities at the HDMC, there were plans for the installation of five STPs, two of them were planned for Hubballi, each of 40 MLD treatment capacity in Hubballi; and three were planned for Dharwad, two of 20 MLD, and one of 25 MLD treatment capacity. If all these plans were implemented, the total tertiary treatment capacity of the twin cities would be 145 MLD by 2029 (WRG 2016). All these planned STP investments were coupled with investment in trunk mains as well.

The STP capacity in Hubballi-Dharwad, and the network coverage, have now changed from the scenario described in the CSP (2011). A central part of this study is to verify the current sewer network coverage and STP capacity. Verification of these proposed plans through newspaper articles and publicly available documents put out by the Asian Development Bank (ADB) shows that loan amounts were approved for two modular units of 25 MLD each to be installed at Gabbur (in Hubballi) and one unit of 24 MLD can be installed at Hossayellapur (in Dharwad). These plants were scheduled for completion in 2016, according to a 2009 document. (ADB 2009) Likewise, an ADB document from 2011 describes two 20 MLD plants to be installed at a site in Madihal, Dharwad (ADB 2011). An ADB document from 2016 shows pictures of the Madihal plant, as well as detailed plans for trunk main investment and increased coverage of individual latrine connections to the sewer network. We interviewed officials from the HDMC and Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC) and obtained cost and capacity estimates for the two STPs completed to date (**Table 2**). This gives Hubballi-Dharwad a total capacity of 60 MLD, assuming a daily wastewater production of approximately half of the total capacity needed for full coverage by centralized treatment plants.

Table 2: Details of Completed STPs in Hubballi-Dharwad

Description	Hubballi (near Gabbur)	Dharwad (near Madihal)
Period of Construction	2011 - 2015	2013 - 2017
O&M 3-year Contract	Ended in 2018	Ends in 2020 or the beginning of 2021
O&M Contract	₹1 Cr for three years	(Not available)
Capacity Designed for	40 MLD	20 MLD
Capacity Currently Used	37 MLD	20 MLD
Capex for UGD Installation	₹75 Cr	₹25 Cr
Capex for STP Construction	₹20.35 Cr	₹29 Cr
O & M	₹60 lakhs/year - Electricity: ₹1.5 lakhs/month - Labour, chemicals, misc. consumables: ₹3 lakhs/month	(Not available)

Study Design

Data was gathered through key informant interviews, a household survey and secondary data sources. Data from the Housing Census of India (2011) at the ward level was obtained from the Census website. This data was used to verify our own data on access to public services as a proportion of the population at the ward level. Public services include details on the proportions that are connected to open or closed sewers, septic tanks or pits. In collaboration with the Centre for Multidisciplinary Development Research (CMDR) we conducted a household survey of 4,000 households over the course of 2 months. Data was collected in all 67 municipal wards, and the sample size for each ward was proportional to the population of that municipal ward (**Appendix 1, Table 1**). Interviews were held with officials at the urban local body (ULB) level. ULB representatives were identified both at the local KUWSDB office as well as the HDMC. The goal of these interviews was to ground-truth the data collected in the household survey and the housing census; to collect data on the locations and capacity of the STPs, and any information they might have on informal dumping practices. We also interviewed local operators of fecal sludge collection services to get information on the volumes and frequency of collections.

Data Analysis

The SFD generating tool created by GIZ was used to create the SFD **(Figure 1**). For this tool, we input the proportions of the population that avail themselves of each option for each of the stages of the sanitation service chain. The sanitation service chain includes five stages: (1) the access point/containment; (2) emptying; (3) transport; (4) treatment; and (5) disposal/reuse. For the containment stage, we determined that the permeability of the soil and the height of the groundwater table make a pit an unsafe option. At the transport stage, whether a closed or open sewer was used determined if transport was safe for sewage and the discharged supernatant. For the treatment stage, if the sewage, supernatant or fecal sludge was properly treated, it was considered safe at disposal; otherwise, it was considered unsafe.

In our household survey, we asked a few key questions to classify the type of sanitation access at a particular house. For each household, we asked whether they have a toilet at home. If they did not have a toilet at home, we asked if they practiced open defecation or used a public toilet, and if so, how often. If they had a toilet at home, we then asked where that toilet discharged to, with answer options being either a septic tank, a pit, an open drain or an underground drain (UGD). For all households that reported using either a septic tank or a pit, we then asked additional questions about their on-site sanitation system to verify the accuracy of their answers. The key follow-up questions were: (1) where did the supernatant discharge to (if there was any discharge at all); (2) what was the shape of the pit/tank (these were either circular or rectangular); and (3) what was the floor of the pit/tank made of (concrete, plastic or open). We assumed that any on-site system that was rectangular, had a closed bottom and an outlet for supernatants, was a septic tank, while anything that was either circular or had an open bottom was a pit. We classified pits that produced an outfall as 'lined pits' and those that did not as 'unlined pits.

We estimated the percentage of fecal sludge which is collected by first estimating the volume of fecal solids produced, then estimating the volume collected, and taking the ratio of the latter over the former. According to the Indian Census, the population of Hubballi-Dharwad in 2011 was 9,43,000, and the average annual population growth between 2001 and 2011 was 1.84%. Using this growth rate, the projected population in 2018 is 10,71,000. Based on our household survey, we estimated that 12% of households had some sort of on-site sanitation system, using our population projection, this gives an estimated 1,29,000 people using on-site sanitation in 2018. If each person produces, on average, 0.7 kilograms of feces per day, this gives approximately 33 million kilograms of fecal solids going into septic tanks and pits per year.

Eight vacuum trucks are operating in Hubballi-Dharwad, each with a hauling capacity of 4000 liters. We interviewed several to collect data on their monthly revenue streams and all on-going business costs. Based on this data, we estimated that these trucks perform an average of 2 trips per day. We verified this through data collected from households on the frequency that pits are emptied. Only 42% of households with on-site sanitation systems reported having emptied before, and 94% of these households could remember the frequency of pit emptying. Of these, 12 households reported emptying more than once a year, indicating either abnormally small pits or recording error. Of the households which reported an emptying frequency of once a year or less, we calculated a probability that any given household would request emptying services in a year at around 32%. Using our estimate from above for the number of people using a septic tank or pit, and the average household size, this yields a total number of approximately 8000 empties requested per year. For eight trucks, that averages to 2.8 empties per day, indicating that our estimate of 2 empties per day may be slightly conservative.

We assumed each trip that a vacuum truck made contained a full 4000 liters of sludge, a likely overestimate in collection volume to estimate a maximum rate of collection possible; this assumption allowed us to estimate that a maximum of 71% of fecal solids are collected from septic tanks and pits in Hubballi-Dharwad. None of the collected sludge is safely treated before disposal or reuse.

Results and Discussion

We present our SFD in Figure 1; in 2018, we estimate that just under half of all human waste is properly treated before disposal. This is in stark contrast to the estimates made by the SFD created by Grattan Maslin and Heather Purshouse in 2015 (**Figure 2**); they estimated that 99% of all human waste was not properly treated before disposal or reuse. The change can be attributed entirely to the construction of the two STPs; on-site sanitation seems to cover roughly the same proportion of the population now as it did then. Building more treatment capacity might increase the proportion of human waste that is safely managed, up from 53% to a maximum of 85%. Beyond that will require increased coverage of underground sewers, or the construction of a FSTP, and conversion of the open-bottomed pits to water-tight septic tanks (we estimate that at least 3% of households are using open-bottomed pits). Additionally, we found roughly 3% of households were not using any latrine at all; we do not know whether this gap is due to poverty (and the relatively high cost of latrine construction), a lack of public toilets or a lack of land tenure; most likely it is due to some combination of all three. A policy solution for these households would need to be formulated to make human waste 100% safely treated in Hubballi-Dharwad.

Figure 1: An SFD, created using Data Collected during our Household Survey (2018)

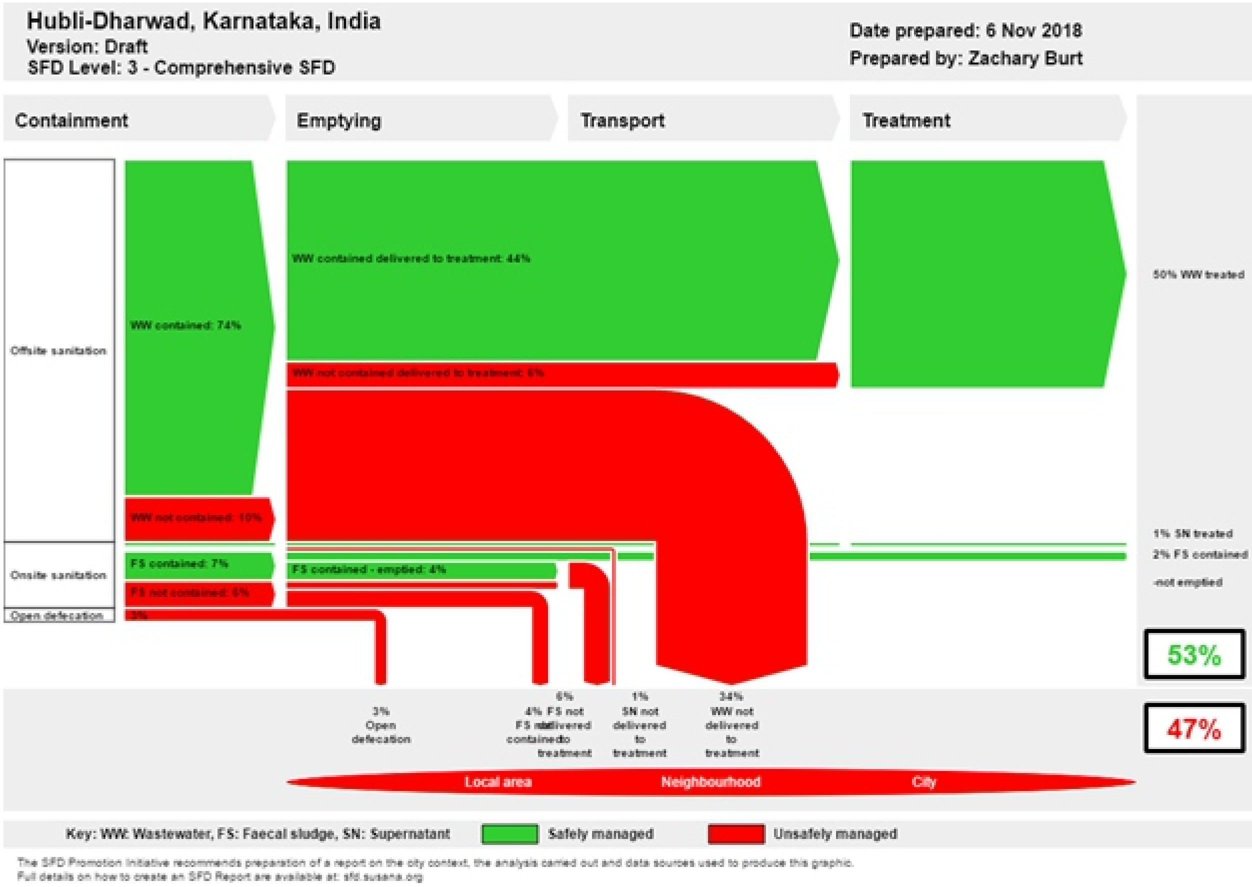
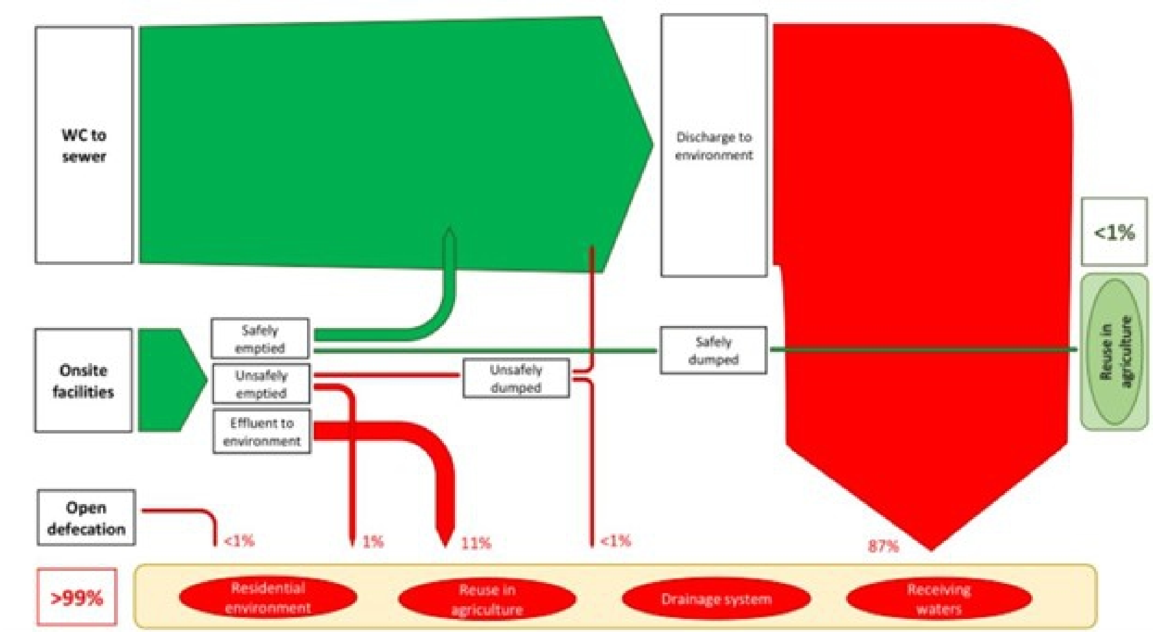


Figure 2: An SFD created in 2015, before the Construction of the STPs



Appendix 1: Ward Population and Sample Size

The ward household population and slum household population numbers were taken from the CSP, since the original data sources were not publicly available. Those sources were the HDMC and the Asha Kiran Mahiti (AKM). AKM is a web-based application of the Karnataka Municipal Reforms Cell. This is an effort by the Karnataka state government to map and collect vital household data from over 3400 slums all over the state. Sample sizes for each ward were calculated based on a total sample size of 4000 and keeping the number from each ward proportional to the household population of each ward.

Table 1: Household Population, Slum Household Population, and Sample Size at the Ward Level

Ward No.	Households	Slum Households	% Slum	Sample Size Target	Total Completed
1	3782	1758	46%	80	80
2	2688	0	0%	60	60
3	2994	425	14%	60	63
4	2820	0	0%	60	63
5	2623	0	0%	60	60
6	2657	1266	48%	60	68
7	2848	470	17%	60	75
8	2496	499	20%	50	53
9	1913	332	17%	40	44
10	2527	339	13%	50	70
11	2504	738	29%	50	48
12	2188	0	0%	50	48
13	2526	1142	45%	50	68
14	3061	353	12%	60	60
15	3061	0	0%	60	59
16	3487	2811	81%	70	75
17	3314	563	17%	70	72
18	3060	1556	51%	60	75
19	3416	212	6%	70	101
20	3366	1649	49%	70	72

Ward No.	Households	Slum Households	% Slum	Sample Size Target	Total Completed
21	3830	94	2%	80	80
22	2938	1233	42%	60	64
23	3700	0	0%	80	82
24	3260	260	8%	70	84
25	2713	79	3%	60	60
26	2796	0	0%	60	60
27	3007	562	19%	60	74
28	2471	681	28%	50	47
29	3751	637	17%	80	88
30	3535	130	4%	70	68
31	2435	116	5%	50	58
32	2428	536	22%	50	69
33	2174	211	10%	50	40
34	3856	504	13%	80	84
35	3324	482	15%	70	67
36	3332	1696	51%	70	72
37	4172	587	14%	90	91
38	3769	1108	29%	80	80
39	2947	0	0%	60	60
40	2761	1439	52%	60	69
41	2519	145	6%	50	47
42	2792	581	21%	60	57
43	2621	1116	43%	60	62
44	2707	837	31%	60	69
45	1688	995	59%	40	49
46	2252	0	0%	50	59
47	3179	512	16%	70	73
48	1885	530	28%	40	42
49	3011	245	8%	60	83
50	2192	1687	77%	50	64
51	2251	1187	53%	50	32
52	1980	0	0%	40	68

Ward No.	Households	Slum Households	% Slum	Sample Size Target	Total Completed
53	2246	441	20%	50	52
54	2066	119	6%	40	44
55	2356	210	9%	50	50
56	1840	0	0%	40	52
57	2086	0	0%	40	42
58	2302	771	33%	50	53
59	1727	221	13%	40	62
60	3278	0	0%	70	69
61	2158	760	35%	50	61
62	2628	0	0%	60	61
63	3439	0	0%	70	83
64	2768	1200	43%	60	65
65	4189	0	0%	90	90
66	2906	1650	57%	60	78
67	3653	296	8%	80	80
Total	**189249**	**37971**	**-**	**4000**	**4358**

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ROUND & ABOUT

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Why the election of Mr. Mamdani as New York City Mayor made big news - The power of the post rather than the ethnicity factor

Strong mayor system and weak mayor system

The election of Mr. Zohran Mamdani as Mayor of New York City in November 2025 made big news. The reasons are partly attributed to the ethnic factor, but the real reasons are more of the powers of a Mayor in New York. If Mr. Mamdani had been elected Mayor of Mumbai, this would not have made big news. This needs some explanation.

IN NYC MAYOR IS BOSS, IN MUMBAI FIGUREHEAD

MUMBAI MAYOR

How elected
Elected from the 227 corporators of BMC. The post is reserved for different categories (general, women, etc) via a lottery every 2.5 years

2.5 years Term

Powers | Mayor is the ceremonial 'first citizen' of Mumbai, presiding over meetings but holding no real executive or financial powers. Municipal commissioner (state govt-appointed bureaucrat) holds true authority. Mumbai mayor's duties are symbolic, representing the city at events, but without control over the city's budget or administration

Power erosion | Over time, Mumbai mayor's role has weakened due to reservations, which critics say limit the pool of eligible candidates, and the absence of executive powers. Senior corporators often prefer roles with actual decision-making power (like standing committee chair) over mayor's post

To make matters worse, BMC's elected term ended on March 7, 2022, and it has since been run by an administrator (municipal commissioner). With no elected corporators, all powers of general body and standing committee now rest with the administrator, a situation continuing until at least March 2026

NEW YORK MAYOR

How elected | Elected directly by New York City voters in a general election held every four years. Candidates run citywide as individuals, not by district

4 years Term
(maximum of two consecutive terms)

Powers | Serves as the city's chief executive, overseeing all municipal agencies, services and the city budget. Appoints commissioners, proposes laws, and implements policies. Holds substantial administrative and financial authority

Impact on city | NYC's mayor shapes nearly all aspects of city life — from policing, housing and transport to education and sanitation. Policies directly impact millions, setting the tone for city governance and often influencing state and national urban policy debates

There are two mayoral systems in the world - the strong mayor system and the weak mayor system. Under the former system, the mayor of the city has wide executive and financial powers relating to policy making, administration, finance, appointments, etc. In other words, he acts as the real chief executive of the city administration. Under the latter, i.e. weak mayor system, the mayor is a ceremonial head. He has high protocol and presides over the meetings of the body. But he does not have executive powers. In India, both systems are in vogue. Proponents of the weak mayor system say that if a mayor has wide executive and financial powers, and through the democratic process an incompetent person is elected on the post (this is possible in a democracy based on various factors), then the whole administration of the city would suffer. In this system, the executive and financial powers are distributed between an executive committee with a defined mandate and the commissioner. The theory is that a group with definite powers of policy making, budget, administration, acting through a deliberation process, plus having a commissioner made responsible for implementation, will result in judicious use of the whole set of powers for better administration of the city. In Maharashtra, a weak mayor system is followed, having a strong Standing Committee supported by other subject committees and the Commissioner having select executive powers. In other states, either a strong system or a weak mayor system is in operation. The election of Mr. Mamdani mattered as the Mayor of New York City has wide executive and financial powers on the basis of which he can make a difference to the administration, development and lives of the citizens of New York, which has international fame.

[Reference: The Times of India, Mumbai, 6 November 2025]

Carbon Credit Trading Scheme

Greenhouse Gas Emissions Intensity Targets

The Ministry of Environment, Forests and Climate Change, Government of India has issued the Greenhouse Gases Emission Intensity Target Rules, 2025 by a notification dated 8th October 2025, for certain sectors for implementation of the Carbon Credit Trading Scheme, 2023. Under the rules, the following production units are allotted maximum permissible emissions.

Aluminum sector	13
Cement sector	186
Chloro-alkali sector	30
Pulp and paper sector	53

Working of the Scheme

Targets & Credits	Energy-intensive industries (like cement, steel) are allotted annual maximum emission intensity targets (CO_2 per ton of product)
Compliance	If a company emits less, it earns Carbon Credit Certificates (CCCs), each worth one ton of CO_2 equivalent (tCO_2e), which it can sell to others who have exceeded the targets.
Trading	Companies that emit more must buy these CCCs from overachievers (those who saved). Thus, a market system of buying and selling of carbon credits is set up.
Incentive	This makes reducing emissions profitable, turning sustainability into a business advantage.

[References: (1) The Ministry of Environment, Forests and Climate Change, Government of India, Notification dated 8th October 2025; (2) Graphic: The Times of India, Mumbai, 21 August 2025]

WHAT IS A CARBON CREDIT?

Carbon credits act as a kind of "pollution currency", allowing different countries and organisations to balance their greenhouse gas emissions. In simple terms, one credit equals permission to emit one tonne of carbon dioxide. Companies that cut emissions below their limit can sell their unused credits, while those exceeding can buy them. The system creates a financial incentive to invest in cleaner projects and technologies, rewarding industries that reduce their carbon footprint.

1 carbon credit = permission to release 1 tonne of carbon dioxide

If a country/firm pollutes less than its allowance, it earns extra credits.
If a country/firm pollutes more, it must buy credits from others who have extra.

Here's an example: The Mumbai Metropolitan Region Development Authority earned 85,849 Carbon Offset Units from modal shifts — more commuters choosing metro over personal vehicles — which reduced greenhouse gas emissions from Jan 2023 to Dec 2024. The avoided emissions were translated into tradeable carbon credits recognised by the Universal Carbon Registry.

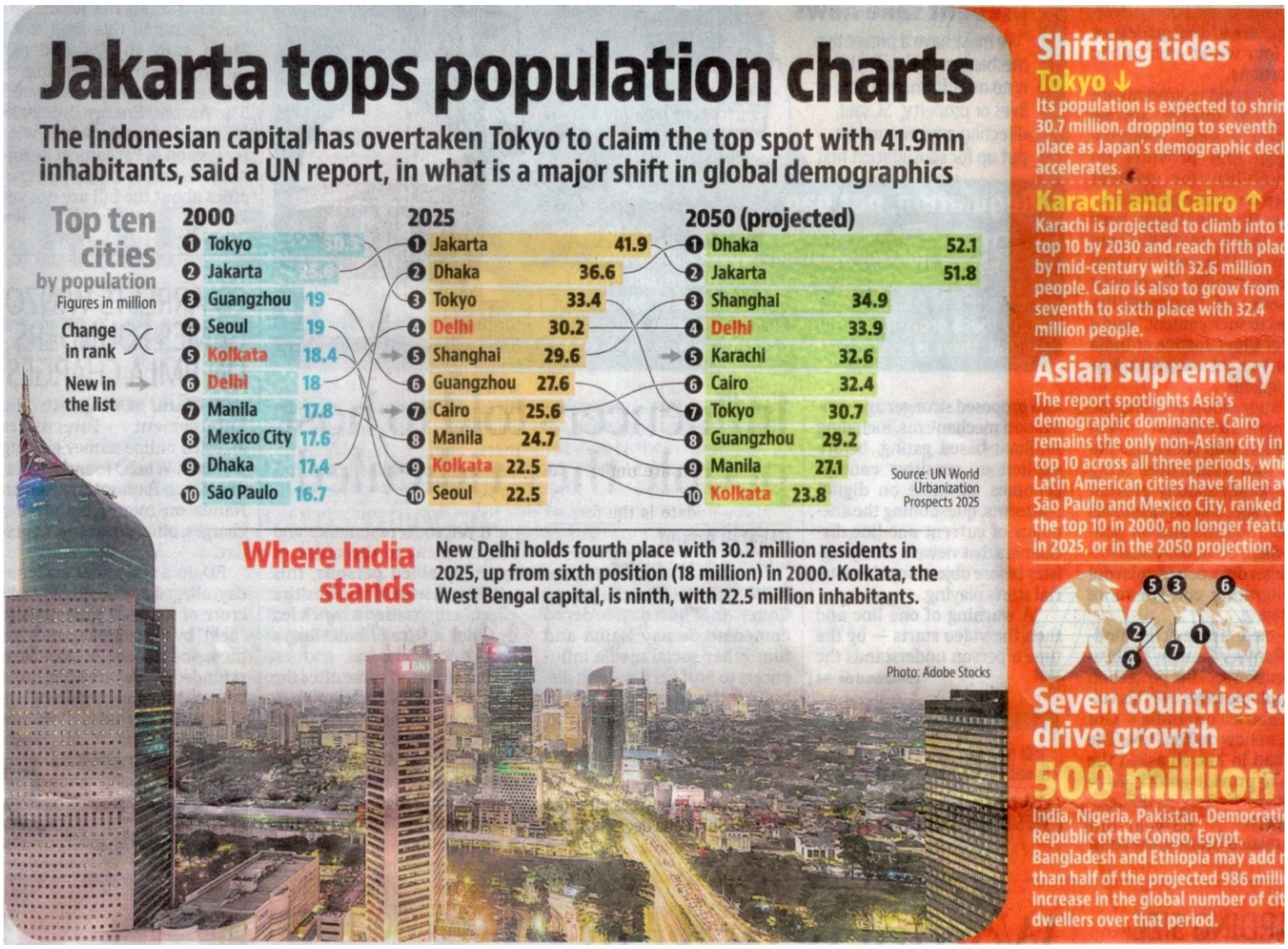
India's position in the global carbon market

India aims to align with its Paris Agreement goals, targeting a 45% reduction in greenhouse gas emissions by 2030 (from 2005 levels) and achieving net-zero emissions by 2070.

Source: Media reports, Investopedia

Changing Size of the Mega Cities

In urbanization studies and research worldwide, there is an increased focus on cities – their population, employment levels, GDP, environment, and so on. The UN World Urbanization Prospects 2025 report has revealed interesting facts about the changing sizes of the world's megacities. A graphic that appeared in *Hindustan Times, Mumbai, 27 November 2025* depicts these exciting facts.



Jakarta tops population charts

The Indonesian capital has overtaken Tokyo to claim the top spot with 41.9mn inhabitants, said a UN report, in what is a major shift in global demographics

Top ten cities by population
Figures in million

	2000		2025		2050 (projected)	
1	Tokyo	[illegible]	Jakarta	41.9	Dhaka	52.1
2	Jakarta	[illegible]	Dhaka	36.6	Jakarta	51.8
3	Guangzhou	19	Tokyo	33.4	Shanghai	34.9
4	Seoul	19	Delhi	30.2	Delhi	33.9
5	Kolkata	18.4	Shanghai	29.6	Karachi	32.6
6	Delhi	18	Guangzhou	27.6	Cairo	32.4
7	Manila	17.8	Cairo	25.6	Tokyo	30.7
8	Mexico City	17.6	Manila	24.7	Guangzhou	29.2
9	Dhaka	17.4	Kolkata	22.5	Manila	27.1
10	São Paulo	16.7	Seoul	22.5	Kolkata	23.8

Change in rank
New in the list

Source: UN World Urbanization Prospects 2025

Where India stands New Delhi holds fourth place with 30.2 million residents in 2025, up from sixth position (18 million) in 2000. Kolkata, the West Bengal capital, is ninth, with 22.5 million inhabitants.

Photo: Adobe Stocks

Shifting tides

Tokyo ↓
Its population is expected to shrin 30.7 million, dropping to seventh place as Japan's demographic decl accelerates.

Karachi and Cairo ↑
Karachi is projected to climb into t top 10 by 2030 and reach fifth plac by mid-century with 32.6 million people. Cairo is also to grow from seventh to sixth place with 32.4 million people.

Asian supremacy

The report spotlights Asia's demographic dominance. Cairo remains the only non-Asian city in top 10 across all three periods, whi Latin American cities have fallen a São Paulo and Mexico City, ranked the top 10 in 2000, no longer featu in 2025, or in the 2050 projection.

Seven countries t drive growth

500 million

India, Nigeria, Pakistan, Democrati Republic of the Congo, Egypt, Bangladesh and Ethiopia may add r than half of the projected 986 milli increase in the global number of cit dwellers over that period.

Policy to Process, Reuse Wastewater in Urban Areas

The Maharashtra Cabinet on 7 October 2025, approved the policy to promote a circular economy by processing and reusing sewage and wastewater for all 424 urban local bodies in the state.

POLICY TO PROCESS, REUSE WASTEWATER IN URBAN AREAS

Maharashtra cabinet on Tuesday approved the policy to promote a circular economy by processing and reusing sewage and wastewater for all 424 urban local bodies, reports **Chaitanya Marpakwar**

₹500cr provision approved for urban development department, which will act as coordinator for implementation of the policy

- A significant portion of the sewage generated in Maharashtra still being discharged untreated into rivers and the Arabian Sea, causing water pollution and health risks like waterborne diseases
- This policy aims to use treated wastewater for purposes other than drinking and to promote a circular economy of water

48% of the state's population lives in urban areas

- The priority order of use of treated water will be thermal power plant, industry, urban use, and agricultural irrigation. For this, there will be a district joint monitoring committee, led by the district collector or municipal commissioner. At the state level, there will be a state-level high-level steering committee led by the chief secretary

"Sustainable management of wastewater and reuse of treated water are effective solutions to the growing demand for water in urban areas. Emphasis will be placed on promoting the reuse of treated wastewater

— A SENIOR STATE GOVT OFFICIAL

Wastewater reuse and circular economy principles have been taught in schools and colleges and frequently highlighted in public discussions. However, developing a policy involves issuing implementation instructions, identifying responsible authorities, and providing the necessary financial support. Over the years, numerous reports have highlighted the discharge of sewage into rivers and the sea. With the state policy now in place, it is hoped that it will be implemented in earnest to achieve meaningful outcomes.

[Reference: The Times of India, Mumbai, 8 October 2025]

The 30th Conference of the Parties (COP30) under the auspices of UNFCCC

The COP30 was held in Belem, Brazil, from 10-21 November 2025. Every year, during the last two months, a COP is held in a select country in which member countries submit their plans for climate action known as nationally determined contributions (NDCs) and review is taken of the plans and the efforts of the member countries for climate actions required under the mandated agreement, which is Paris Agreement 2015 at present.

It would be of interest to know about the COPs, their history and functions.

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to assess the state of existing knowledge about climate change, its science, the environmental, economic and social impacts and possible response strategies.

At the same time, there was a need for a forum or body of nations to act together and deliberate upon the findings of the IPCC, and take decisions collectively.

Under the auspices of the UN, countries of the world joined in an international treaty "to co-operatively consider what they could do to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts were, by then, inevitable." It came into force from 21 March 1994. The treaty resulted in the formation of the United Nations Framework Convention on Climate Change (UNFCCC). It is also the name of the body.

Commitments under the UNFCCC

The UNFCCC sets an overall framework for international efforts to tackle the challenge of climate change. Parties to the Convention agreed to several commitments to address climate change:

- To develop and periodically submit national reports containing information on the greenhouse gas emissions of that Party and describing the steps it has taken and plans to take to implement the Convention.
- To put in place national programs and measures to control emissions and to adapt to the impacts of climate change.
- To promote the development and use of climate-friendly technologies and the sustainable management of forests and other ecosystems.

[Reference: Website: https://cop30.br/en. Widely reported in the Press]

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