

BUILDING URBAN RESILIENCE: SUSTAINABLE SANITATION SOLUTIONS FOR WATER-SCARCE INDIA

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Abstract:

The lack of access to safe drinking water and adequate sanitation facilities in urban areas of India remains a pressing concern. By 2050, urban areas in India are projected to accommodate half of the country's population. This demographic shift is expected to exacerbate significant challenges, particularly in terms of acute water scarcity. The Composite Water Management Index by NITI Aayog in 2019 revealed that an estimated 163 million individuals in India lack access to safe drinking water, while approximately 210 million people do not have access to improved basic sanitation facilities throughout the nation. Thus, to address this issue, sustainable urban sanitation practices provide a holistic approach that tackles water scarcity and promotes resilience in water-stressed urban areas. By implementing sustainable practices, such as efficient water management, decentralised sanitation systems, and wastewater recycling, these areas can address the pressing issues of water scarcity. Simultaneously, these efforts contribute to advancing progress towards the 17 Sustainable Development Goals (SDGs) by 2030. This alignment is particularly evident in how improving access to clean water and sanitation (SDG 6) positively impacts public health (SDG 3), promotes sustainable cities and communities (SDG 11), and contributes to environmental sustainability (SDG 13). We can work towards a more inclusive, equitable, and sustainable future by adopting an integrated approach. This involves considering the interdependencies among the goals to create comprehensive strategies for positive and lasting change.

In this framework, the study aims to highlight the interlinkages between sustainable urban sanitation, water scarcity, public health, and environmental sustainability. The study also examines how the integration of water-efficient technologies and innovative wastewater treatment systems contributes to water conservation and endurance in urban sanitation. Based on this context, the potential research hypothesis is that the integration of water-efficient technologies and innovative wastewater treatment systems in urban sanitation will lead to significant water conservation and improved resilience, thereby positively impacting public health and environmental sustainability.

Keywords: Sanitation, Sustainable Development, Water-Scarce, Urban.

INTRODUCTION

India, a rapidly developing country with a burgeoning urban population, faces several challenges in ensuring sustainable sanitation practices amidst water scarcity. As urban areas continue to expand, the demand for water resources intensifies, putting a strain on already limited supplies. Water scarcity presents a significant challenge in numerous urban areas across India. The issue is exacerbated by factors like rapid urbanisation and population expansion, creating a critical situation in these regions. This pressing issue is further compounded by the complexities introduced by climate change. Consequently, there is now an imbalance between the supply and demand of water, further worsening the problem of water scarcity.

At present, the nation is contending with a severe water crisis, as indicated by the concerning drop in groundwater levels. This pressing matter is underscored by unsettling figures revealed by the Union Ministry of Agriculture. The Composite Water Management Report 2019 findings suggest that by 2030, the demand for water in India is expected to surpass the available supply by a staggering factor of two. India relies on groundwater for approximately 40% of its water supply. The majority of states have attained less than 50% of the total score in enhancing groundwater resources. This emphasizes the escalating national crisis, with 54% of India's groundwater wells experiencing a decline, and around 21 major cities projected to exhaust their groundwater reserves by as early as 2020. India's water situation is already critical, as per a NITI Aayog report. Nearly 600 million people in the country are facing high to extreme water stress. This situation will impact approximately 100 million individuals. The report highlights the Indian states and urban centers that have grappled with acute water scarcity since 2018. This was based on the estimates of annual groundwater replenishment and its extraction. However, it did not take into account the groundwater availability in the deeper aquifers. The report mentions the following states: Delhi, Gujarat, Haryana, Karnataka, Madhya Pradesh, Punjab, Rajasthan, Tamilnadu, Andhra Pradesh and Uttar Pradesh. Projections based on the present trajectory suggest that within the next two decades, approximately half of India's aquifers could reach critical or over-exploited levels. This alarming trend poses a significant threat to the long-term sustainability of the country's water resources. Hence, water scarcity emerges as a pressing issue, influencing urban sanitation, public health, and environmental sustainability.

UNRAVELING THE CONNECTIONS

The interlinkages between sustainable water scarcity, urban sanitation, public health, and environmental sustainability are of paramount importance in the context of urban India. As a rapidly developing nation with a growing urban population, India encounters distinctive challenges. Ensuring access to clean water, promoting proper sanitation practices, safeguarding public health, and maintaining environmental sustainability are integral aspects of these challenges. Understanding and addressing these interlinkages is vital for creating healthy, resilient, and sustainable urban environments.

Sanitation in Urban Areas

Water scarcity has a direct and significant impact on urban sanitation services. It poses numerous challenges in providing safe and adequate sanitation facilities to the growing urban population. Water scarcity limits the availability of **clean water** for basic sanitation needs such as handwashing, bathing, and cleaning of sanitation facilities. Without sufficient water, maintaining proper hygiene becomes challenging, potentially leading to compromised sanitation practices for individuals. People may have to ration water or prioritise other essential needs. As a case in point, to address the acute water shortage, the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) implemented water rationing measures in 2019. The primary objective was to ensure equitable distribution of available water resources among residents.

Moreover, in water-scarce regions, individuals may be compelled to **recycle the same water** for multiple purposes, including sanitation, which amplifies the hazard of contamination and the dissemination of diseases. In urban India, one notable case study is the slum settlement of Dharavi in Mumbai. Dharavi is one of the largest slums in Asia and is characterised by overcrowded living conditions, inadequate sanitation facilities, and limited access to clean water. Due to the scarcity of water in the area, many residents are compelled to recycle the same water for various purposes. For instance, water collected from public taps or communal sources is often used for washing, cooking, bathing, and even for flushing toilets. This practice significantly increases the risk of contamination and the spread of waterborne diseases.

Water scarcity can hinder the proper functioning of **sewage systems**. In urban areas, sewage systems are designed to safely transport and dispose of wastewater. However, inadequate water availability can impede the flow of sewage, leading to clogging and pipe blockages. As a result, wastewater may back up, causing

sewage overflows and contaminating the environment. Such as according to a report by the Bengaluru Water Supply and Sewerage Board, the city faces an annual water shortage of around 1000 million liters per day (MLD). Water scarcity affects the flow of wastewater in the sewage system, leading to pipe blockages and inadequate disposal. Reports suggest that a significant portion of Bengaluru's sewage ends up in lakes and water bodies due to malfunctioning sewage infrastructure. One example of the detrimental effects of sewage overflows contaminating water bodies can be seen in the case of the Bellandur Lake in Bengaluru, Karnataka, India.

Wastewater treatment plants play a crucial role in treating and purifying wastewater before it is released back into the environment. However, water scarcity can hamper the efficient operation of these plants. Insufficient water supply to treatment facilities can limit their capacity to treat wastewater effectively, compromising the treatment process and resulting in the release of partially treated or untreated wastewater. This can have detrimental effects on the environment and public health. A remarkable example is the severe water scarcity experienced in Chennai, India, in recent years, which led to reduced functioning of wastewater treatment plants and increased pollution in water bodies.

Water scarcity affects the ability to maintain adequate **hygiene standards**, particularly in public spaces such as schools, hospitals, and community centers. Insufficient water availability can result in inadequate cleaning and disinfection practices, increasing the risk of disease transmission. As per the Hyderabad Metropolitan Water Supply and Sewerage Board, the city faces a water deficit of around 30 million gallons per day (MGD) during the dry seasons. The water scarcity in Hyderabad affects the maintenance of proper hygiene standards in public spaces, which can have implications for schools, hospitals, and community centers.

Public Health in Urban Areas

Moreover, the severity of water scarcity and urban sanitation carries profound implications for various aspects, including public health. Limited water availability can lead to the **use of unsafe water sources or inadequate water treatment**. It has the capacity to foster the spread of diseases carried by contaminated water. In water-scarce situations, individuals may be forced to resort to using contaminated water sources for various sanitation needs, such as bathing, cleaning, or flushing toilets. The use of untreated or polluted water has played a significant role in the escalation of waterborne diseases and the transmission of pathogens. For instance, in Chennai, alternative water sources and compromised sanitation practices have resulted in reported cases of cholera and typhoid.

Water scarcity often hampers the availability and functionality of proper **sanitation facilities**, including toilets and sewage systems. As per the Swachh Bharat Mission (SBM) report, released by the Ministry of Housing and Urban Affairs in 2019, around 53% of urban households in India have access to individual household toilets, while the remaining rely on shared or public sanitation facilities. Likewise, according to the Joint Monitoring Programme (JMP) report by United Nations Children's Fund and World Health Organisation, as of 2019, an estimated 46 million people in urban areas of India were practising open defecation. Thus, the lack of hygienic toilets creates a conducive environment for open defecation to thrive, perpetuating unhygienic practices and posing serious health risks.

In water-scarce urban areas like Bengaluru, the scarcity of water poses significant challenges in maintaining **proper hygiene and cleanliness** in public spaces, particularly in key facilities like hospitals and community centers. The limited availability of water can result in inadequate disinfection practices. This, in turn, can hinder regular hand washing. Consequently, it leads to an increased risk of disease transmission and healthcare-associated infections.

Vulnerable populations, including children, the elderly, and individuals with weakened immune systems, are particularly affected by water scarcity. These groups face disproportionate risks of increased health hazards due to limited access to clean water and sanitation facilities. Specifically in the urban areas of

Delhi, children and the elderly, who are more susceptible to waterborne maladies, experience the adverse consequences of inadequate access to clean water and sanitation facilities.

Environmental Impact on Urban Areas

The compromised state of urban sanitation due to water scarcity can indeed have a range of environmental impacts, many of which are interconnected. One notable effect is the **contamination of water sources**, which carries substantial threats to both human and ecological well-being. It can lead to the dissemination of diseases that are transmitted through water. Additionally, it contributes to the degradation of ecosystems and the loss of biodiversity. Drinking water sources may become polluted, putting communities at risk of consuming contaminated water and suffering from waterborne illnesses.

In water-scarce urban areas, the lack of sufficient water for proper waste management results in improper disposal of wastewater. Wastewater containing harmful substances, such as pathogens, chemicals, and pollutants, may be discharged directly into water bodies or seep into the soil, contaminating water sources. This leads to **water pollution**, negatively impacting water quality, aquatic life, and the overall ecological balance. As an example, the Yamuna River in Delhi suffers from severe water pollution due to improper waste management practices. The rapid urbanisation and population growth in Delhi have overwhelmed the city's waste management infrastructure. As a result, untreated domestic and industrial wastewater, along with solid waste, is discharged into the Yamuna River. The polluted water poses a risk to public health, leading to the spread of waterborne diseases. Additionally, the high levels of pollutants have caused a decline in biodiversity and have negatively impacted agricultural productivity. Efforts are underway to address this issue through improved wastewater treatment infrastructure, public awareness campaigns, and stricter regulations. However, significant challenges remain in effectively managing the pollution and restoring the health of the Yamuna River. This case serves as a prominent example highlighting the consequences of improper waste management in water-scarce urban areas. Additionally, the lack of proper waste management procedures results in the inappropriate disposal of solid waste, including dumping it in open spaces or inadequate landfill sites. Improperly managed waste can release toxins, leach harmful chemicals, and degrade the soil quality. **Soil pollution** not only affects the health and fertility of the soil but can also impact plant growth, agricultural productivity, and overall ecosystem functioning. For instance, the Perungudi Dumping Ground in Chennai, Tamil Nadu, is one of the major solid waste disposal sites in the city. Inadequate water availability for proper waste management has led to the dumping of large quantities of solid waste in the open landfill site. The decomposition of organic waste and the leaching of harmful chemicals from the waste has contributed to soil pollution. The contaminated soil negatively impacts nearby agricultural lands, affecting crop growth and soil fertility. It also poses environmental and health risks to the surrounding communities. In urban settings where water resources are constrained, the unavailability of water for dust suppression becomes a significant factor driving up air pollution. Dust particles from uncovered waste, open defecation areas, or dry soil can become airborne, leading to respiratory problems and compromising air quality. Additionally, the burning of waste in the absence of proper waste management facilities can release harmful pollutants and contribute to **air pollution**. For instance, the Deonar Dumping Ground in Mumbai, Maharashtra, is one of the largest and oldest landfill sites in the city. The lack of water for dust suppression and improper waste management practices have contributed to significant air pollution in the surrounding areas. The uncovered waste and dry soil release dust particles into the air, leading to high levels of particulate matter and compromising air quality. The burning of waste at the landfill site, especially during the monsoon season, releases toxic pollutants, further exacerbating the air pollution problem.

Water scarcity in urban areas can have detrimental **effects on biodiversity**, particularly in relation to urban sanitation. The presence of contaminated water sources and polluted habitats can cause harm to various aquatic organisms. Additionally, the degradation of ecosystems resulting from pollution and inadequate waste management can lead to habitat loss. This, in turn, leads to disturbances in the natural equilibrium of species and their interactions. For instance, Hussainsagar Lake in Hyderabad, Telangana, has suffered

from significant pollution and deterioration due to insufficient water availability for effective waste management. The lake has become a recipient of untreated sewage and industrial waste. This has led to water contamination and the degradation of its habitat. Consequently, the polluted water has negatively impacted the populations of aquatic organisms, including fish, disrupting the lake's ecosystem and its natural balance. The decline in biodiversity has had far-reaching consequences on the overall ecological functioning of the lake.

Indeed, the water scarcity issue in urban regions of India poses considerable hurdles for both sanitation services and public health. With inadequate availability of water resources, ensuring proper access to safe sanitation facilities becomes a pressing concern. Moreover, the heightened risk of waterborne diseases underscores the urgency for implementing sustainable and creative solutions to address these interlinked challenges. India can improve urban sanitation practices in water-scarce areas by promoting water conservation, decentralised sanitation systems, public awareness, and government interventions. This will ensure the well-being of its citizens and the sustainable development of its cities.

GOVERNMENT INITIATIVES FOR WATER AND SANITATION

Water and sanitation are a state subject, yet the central government has undertaken numerous crucial measures specifically targeting. These initiatives aim to address water scarcity, improve water resource management, and promote sustainable sanitation practices across the country. There are notable government initiatives in India, such as Namami Gange and Swachh Bharat Mission, that aim to achieve sustainable water and sanitation goals in water-scarce regions. These initiatives have had a significant impact on improving water quality, wastewater management, and access to sanitation facilities across the country.

It is crucial to highlight that the Government of India has also proactively implemented strategies for conserving and managing groundwater, with a particular emphasis on the successful execution of rainwater harvesting initiatives on a national scale. For example, several states have made commendable strides in water conservation and harvesting, exemplified by initiatives like 'Mukhyamantri Jal Swavlamban Abhiyan' in Rajasthan, 'Jalyukt Shibir' in Maharashtra, 'Sujalam Sufalam Abhiyan' in Gujarat, 'Mission Kakatiya' in Telangana, 'Neeru Chettu' in Andhra Pradesh, 'Jal Jeevan Hariyali' in Bihar, 'Jal Hi Jeevan' in Haryana, and the 'Kudimaramath' scheme in Tamil Nadu, among others.

However, several challenges hinder the government's ability to achieve their goals. These challenges include infrastructure deficits, limited financial resources, population growth and urbanisation, water resource management issues, the need for behavioral change, implementation capacity, and the impacts of climate change and environmental factors.

In light of this scenario, it becomes imperative to explore and implement sustainable sanitation solutions. Overcoming these obstacles requires sustained efforts, increased investment, effective governance, and multi-stakeholder collaborations. It also necessitates innovative approaches, technology adoption, and community participation to ensure the successful implementation and achievement of water and sanitation goals in India.

Major Initiatives

- 2019: Jal Shakti Abhiyan: Catch the Rain
- 2019: Atal Bhujal Yojana
- 2019: Jal Jeevan Mission
- 2015: Pradhan Mantri Krishi Sinchayee Yojana
- 2015: Atal Mission for Rejuvenation and Urban Transformation
- 2015: Smart Cities Mission
- 2014: Clean India Mission
- 2014: National Mission for Clean Ganga
- 2012: National Water Policy
- 2011: National Water Mission
- 2009: Integrated Watershed Management Program
- 2008: National Urban Sanitation Policy

INTEGRATING WATER-EFFICIENT SYSTEMS IN URBAN SANITATION

The integration of water-efficient technologies can play a crucial role in water conservation and thriving in urban sanitation. Here are some ways in which this integration contributes to these goals:

Water-efficient technologies for urban sanitation are specifically designed to minimise water consumption while still maintaining effective sanitation practices. Examples of such technologies include low-flow fixtures and toilets, waterless urinals, sensor-activated faucets, dual-flush systems, and smart irrigation systems. This innovative solutions aim is to reduce the amount of water used for various sanitation purposes, promoting water conservation and sustainable water management in urban areas. By **reducing the overall demand for water**, these technologies help alleviate the strain on water resources and ensure a sustainable supply for both domestic and industrial use. Alongside the mentioned water-efficient technologies, smart monitoring and control systems play a central role in efficient water management in urban areas. These systems utilise advanced sensors, data collection, and analysis to optimise water usage and minimise losses.

Innovative wastewater treatment systems, such as greywater and blackwater **recycling**, enable the recovery and treatment of water from various sources. Greywater, which includes water from sinks, showers, and laundry, can be treated and reused for non-potable purposes like toilet flushing, irrigation, or industrial processes. This reduces freshwater demand and ensures efficient use of water resources. Blackwater, which includes water from toilets, can be treated using advanced treatment methods, such as membrane bioreactors or anaerobic digestion, and reused for irrigation or even potable purposes after extensive treatment.

Integrating water-efficient technologies with **stormwater management systems** helps mitigate the impact of urban runoff on water resources. Green infrastructure, such as rain gardens, permeable pavements, and rooftop gardens, can capture and treat stormwater, reducing the burden on wastewater treatment plants and preventing pollution of natural water bodies.

Sustainable **urban sanitation technologies** play a pivotal role in establishing effective waste management within urban regions. Instances of such technologies encompass secure disposal techniques for human waste, decentralized systems, waterless or dry toilets, urine-diverting toilets, and Ecosan toilets. These innovations are custom-designed to effectively tackle the intricate challenges of sanitation, ultimately leading to improved community well-being.

The integration of sustainable urban sanitation technologies with **renewable energy sources** such as solar and wind can significantly enhance the environmental impact and long-term sustainability of sanitation systems. For instance, renewable energy can be used to power water treatment plants, sewage treatment facilities, or biogas digesters. Solar panels can generate electricity to power pumps, motors, and other equipment, while wind turbines can generate energy to run sanitation infrastructure.

The implementation of water-efficient technologies and innovative wastewater treatment systems plays a vital role in enhancing the liveability of urban areas. This is particularly important in the face of water scarcity, climate change, and extreme weather events. These systems contribute to diversifying water sources by incorporating practices such as rainwater harvesting, treated wastewater reuse, and efficient groundwater management. This leads to the development of a water infrastructure that is more self-sufficient and resilient. This heightened resilience is vital for ensuring uninterrupted water and sanitation services, particularly during crises.

Overall, the integration of water-efficient technologies and innovative wastewater treatment systems in urban sanitation is essential for conserving water and improving water management. Additionally, it plays a crucial role in fostering adaptability in the face of water-related challenges. These measures promote sustainable development, protect the environment, and ensure the availability of safe and adequate water resources for urban populations.

POLICY APPLICATIONS AND SUGGESTED MEASURES

A comprehensive strategy is essential to tackle the challenge of water scarcity and its repercussions on sewage systems. This approach entails the implementation of policy interventions to effectively manage and mitigate the impacts on water resources and sewage infrastructure. Governments can play an important role in managing the impacts of water scarcity on sewage systems. They can take various measures to promote sustainable water use, protect the environment, and ensure the well-being of urban communities. Implementing the following policy implications can be beneficial in this regard. For instance, develop an **integrated policy framework** that addresses water management, sanitation, and hygiene in a holistic manner. This framework should consider the interconnections between water resources, wastewater management, and public health while aligning with broader sustainability goals.

Establish and enforce **regulations and standards** for sustainable urban sanitation practices. This includes setting water quality standards, promoting water-efficient technologies, regulating wastewater disposal, and ensuring compliance with sanitation guidelines. Regular monitoring and enforcement mechanisms are essential to maintain accountability and adherence to these regulations.

Implement a system of **financial incentives**, subsidies, or tax benefits aimed at motivating individuals, businesses, and institutions to engage in the adoption of sustainable sanitation technologies and practices. These mechanisms can help offset initial costs and promote widespread adoption.

Foster **coordination and collaboration** among different government departments, agencies, and stakeholders involved in water management and sanitation. The process involves creating mechanisms for collaborative planning, data exchange, and resource coordination. These mechanisms aim to guarantee the efficient execution of sustainable sanitation policies.

Invest in **capacity-building and training programs** for government officials, sanitation practitioners, and community members. These programs should focus on technical skills, sanitation infrastructure operation and maintenance, behaviour change communication, and monitoring and evaluation techniques. Enhancing capacity at all levels ensures sanitation projects' successful implementation and long-term sustainability.

Promote **knowledge sharing and research** on sustainable sanitation practices, including innovative technologies, best practices, and lessons learned. Encourage partnerships between research institutions, government agencies, and private sector entities to generate and disseminate knowledge on effective approaches for water-scarce areas.

Foster **public-private partnerships** to leverage private sector expertise, resources, and innovation in sustainable sanitation projects. Create an enabling environment for private sector participation through transparent procurement processes, risk-sharing mechanisms, and clear roles and responsibilities. These partnerships can help to bridge funding gaps, promote innovation, and ensure the scalability of sustainable sanitation initiatives.

Integrate **community engagement and empowerment** as a core element of policy interventions. Involve communities in decision-making processes, promote participatory approaches, and ensure that the needs and perspectives of local communities are considered in policy development and project implementation. Facilitate **knowledge transfer and technical assistance** from experienced organisations and institutions to support the implementation of sustainable sanitation projects. This can involve partnerships with international organisations, development agencies, and experienced practitioners who can provide technical expertise, guidance, and resources to water-scarce areas.

Develop strong systems for **monitoring, evaluation, and learning** to effectively trace the progress, efficiency, and influence of sustainable sanitation policies and project implementations. Regularly assess the outcomes, identify challenges and successes, and use the findings to inform policy revisions and improvements.

Therefore, the proposed measures and policy applications need to be customized to line up with the distinctive contexts and obstacles of regions grappling with water scarcity.

CONCLUSION

In conclusion, the need for strengthening urban resilience through sustainable sanitation solutions in water-scarce India is paramount. Urban India is currently contending with multiple challenges, including water scarcity, rapid urbanisation, and inadequate sanitation infrastructure. In order to effectively address these issues, it is crucial to emphasise the importance of adopting innovative and sustainable approaches. Integrating water-efficient technologies can help India address the challenges posed by water scarcity. Innovative wastewater treatment systems offer a pathway to enhance public health while managing water resources effectively in India. Additionally, promoting behavior change will contribute to environmental sustainability. It is utmost to recognise the collaborative efforts of various stakeholders, including governments, non-profit organisations, communities, and individuals. The development and implementation of comprehensive strategies, backed by supportive policies and adequate funding, are vital for the successful adoption of sustainable sanitation solutions across India.

Furthermore, the quest for sustainable urban sanitation aligns with worldwide sustainability objectives, including the United Nations' Sustainable Development Goal 6, which advocates for universal access to clean water and sanitation. By adopting sustainable approaches, India can make a significant contribution to the attainment of these global targets, all while tackling its distinct water scarcity issues. India has the potential to establish resilient and sustainable cities that flourish despite water scarcity. Therefore, through this endeavour, India can lead the path towards a future that is both resilient and sustainable.

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