Sustainable Urban Development in Bhubaneswar's Slums: Innovative Strategies for Water and Sanitation Access

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Abstract. Over the past twenty years, India's cities have undergone significant transformation due to rapid urbanization. Bhubaneswar, the capital of Odisha, is a prime example of this shift, where a steady flow of migrants has led to the fast expansion of informal settlements along the city's edges. These slum areas face critical shortages in clean water, sanitation, and basic infrastructure, trapping residents in cycles of poverty and health challenges. While government programs and NGO efforts have tried to improve conditions, they often fall short in consistently providing safe and equitable access to water and sanitation.

This research examines how rapid urban growth and the emergence of slum communities in Bhubaneswar have exacerbated inequalities in access to water and sanitation. Using a combination of scientific testing, infrastructure assessments, and spatial mapping, the study uncovers key barriers to sustainable urban development. It found that contaminants such as arsenic, fluoride, and iron frequently exceed safe limits, and issues like inconsistent water supply and poor drainage systems further increase health risks. The study emphasizes the need for an integrated policy approach that strengthens infrastructure, encourages community involvement, and holds stakeholders accountable to build inclusive urban resilience and help meet global sustainability goals, particularly SDG 6 (clean water and sanitation) and SDG 11 (sustainable cities and communities).

Keywords: Sustainable Urban Development, Water and Sanitation Inequality, Slum Infrastructure, Inclusive Urban Governance, Bhubaneswar Smart City.

1 Introduction

India's cities are growing at an incredible pace. Between 2001 and 2011, the urban population jumped from 27.8% to over 31%. While cities offer better job prospects and services, they also expose stark inequalities, especially in informal settlements where living conditions are far from ideal. According to the 2011 Census, nearly one in five urban households live in slum-like conditions, highlighting the scale of urban poverty.

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Bhubaneswar, once admired for its model of planned urban design, is now grappling with a sharp rise in slum settlements, particularly on its outskirts. These communities are primarily composed of migrant workers from rural areas of Odisha and neighboring states. They often live in cramped and poorly serviced areas, with limited or no reliable access to clean water and basic sanitation. Despite the legal recognition of the right to water in India, the reality on the ground reveals fragmented and uneven implementation.

The Bhubaneswar Municipal Corporation (BMC) has introduced initiatives, including water treatment plants and filtered water reservoirs. However, service delivery still faces serious hurdles. Poor drainage maintenance, contamination issues, and infrastructure gaps continue to undermine long-term development goals.

This study aims to investigate the extent to which slum communities in Bhubaneswar can access clean water and sanitation, as well as the impact of overcrowding in unauthorized areas on their living conditions. By combining data sources and real-life experiences, the research aims to provide a deeper understanding of these urban challenges and suggest strategies for a fairer distribution of essential resources.

2 Literature Review

Existing research highlights significant disparities in access to basic urban services among India's poor. Anand (2007) and Mara (2003) examined the challenges of water and sanitation, emphasizing the health implications of poor-quality water. Bapat and Agarwal (2003) and Singh et al. (2013) explored the socio-economic and gendered dimensions of slum life, underscoring water and sanitation as determinants of dignity and well-being.

Lenka (2018, 2022) and Rout (2008) specifically studied Bhubaneswar's slums, documenting inequality in service provision and the proliferation of unauthorized colonies. Price et al. (2019) and Alice et al. (2023) presented empirical evidence of fluctuating water quality and inadequate sanitation infrastructure in urban slums in India.

Studies by Sridhar and Kumar (2013) and Satapathy (2014) further link urban environmental degradation to inadequate drainage and solid waste management. Collectively, the literature points to persistent gaps in implementation and accountability. However, limited research integrates spatial, environmental, and social dimensions of these issues within the Bhubaneswar context. This paper addresses that gap by combining water quality testing, sanitation assessment, and spatial overcrowding analysis. Table 1. Highlights the major studies focusing on issues in Urban Slums related to Water, Sanitation, and Overcrowding.

Table 1. Major Studies Highlighting Water, Sanitation, and Overcrowding Issues in Urban Slums

SL No.	Reference Paper	Focus/ Contribution
R1	Anand, P. B. (2007)	Discusses challenges and progress in India's drinking water supply, providing context on water quality issues.

R2	Lenka, A. K. (2018)	Examines access to water supply and sanitation among the urban poor in Bhubaneswar, highlighting water access challenges.
R3	Lenka, A. K. (2022)	Focuses on inequalities in Bhubaneswar's water supply and sanitation facilities, emphasizing the need for improvements.
R4	Mara, D. D. (2003)	Reviews water, sanitation, and hygiene issues, stressing the health impacts of water contamination.
R5	Press Information Bureau (2013)	Provides governmental perspectives on potable water access and quality management, underscoring policy gaps.
R6	Price, H., Adams, E., & Quilliam, R. S. (2019)	Investigates the temporal dynamics of drinking water access and quality in urban slums.
R7	Alice, A. et al. (2023)	Offers a cross-sectional study on sanitation and drinking water facilities among slum households, detailing infrastructure gaps.
R8	Bapat, M., & Agarwal, I. (2003)	Provides insights into the sanitation needs and priorities of slum communities, supporting efforts to improve infrastructure.
R9	ENS Economic Bureau (2019)	Presents statistical evidence on the gaps in water and sanitation facilities in urban areas.
R10	Satapathy, B. K. (2014)	Emphasizes the importance of safe drinking water in slums, with a focus on sanitation and the maintenance of drainage systems.
R11	Singh, A. L. et al. (2013)	Explores the right to water for the urban poor, discussing both sanitation challenges and the impact of overcrowding on service delivery.
R12	Priya, R. (2006)	Examines urban poor settlement patterns and the challenges of overcrowding in slum areas.
R13	Rout, N. R. (2008)	Investigate the growth of slums in Bhubaneswar, with a focus on unauthorized residential areas and overcrowding.
R14	Sridhar, K. S., & Kumar, S. (2013)	Provides context on environmental challenges in densely populated urban settings, relevant to overcrowding and its impacts.

Based on the reviewed literature, the study focuses on three specific objectives:

1. (O1) Assess the extent of access to improved water sources.
2. (O2) Evaluate sanitation infrastructure and maintenance practices.
3. (O3) Analyze the impact of overcrowding in unauthorized settlements.

3 Research Methodology

3.1 Design and Approach

A mixed-methods framework combining field data collection, laboratory testing, and spatial mapping was adopted. The approach integrates quantitative water quality analysis with qualitative stakeholder interviews to capture both infrastructural and social aspects of access and usage.

3.2 Water Quality Assessment

Water samples were collected from multiple slum clusters in Bhubaneswar to measure contamination levels of arsenic, fluoride, and iron. Standard laboratory methods were employed to assess compliance with WHO and BIS standards. Structured questionnaires captured household perceptions of water reliability, frequency of supply, and treatment practices.

3.3 Sanitation Infrastructure Evaluation

Field inspections were conducted to examine both open and closed drainage systems, as well as waste disposal mechanisms. Interviews with BMC officials and sanitation workers provided insights into maintenance cycles, service gaps, and logistical constraints.

3.4 Overcrowding and Spatial Mapping

GIS tools were used to map unauthorized residential areas and correlate population density with access to water and sanitation services. Spatial data were triangulated with demographic information to identify areas with service deficiencies.

3.5 Data Analysis

Descriptive statistics quantified contamination levels and access disparities, while qualitative responses elucidated lived experiences of scarcity, distance, and irregularity. The integration of both data streams strengthened the validity of the findings.

4 Findings and Results

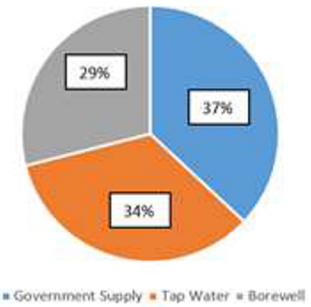
4.1 Water Sources and Quality

Bhubaneswar's water supply primarily depends on the Mahanadi River and local aquifers. Laboratory results revealed arsenic at 0.05 ppm (five times the safe limit), fluoride

at 1.5 ppm (exceeding the permissible limit of 1.0 ppm), and iron at a level near the upper threshold of 0.3 ppm.

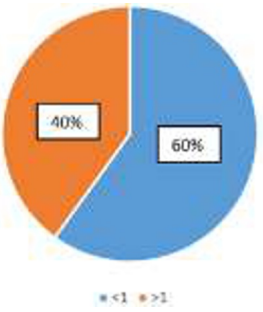
Distribution of Water Sources among Households is shown in Figure 1. Approximately 37% of households depend on government sources, 34% on tap water, and 29% on bore wells.

Figure 1. Distribution of Water Sources among Households



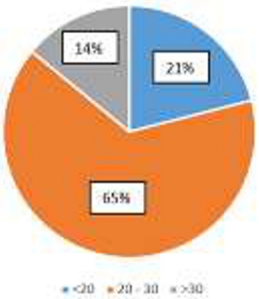
Water supply irregularity is widespread. Average travel distance to fetch water is shown in Figure 2. 60% of households travel more than one kilometer daily to fetch water, and only 17% treat it before consumption.

Figure. 2. Travel Distance to Fetch Water



Variation in daily water usage is shown in Figure 3.

Figure 3. Variation in Daily Water Usage



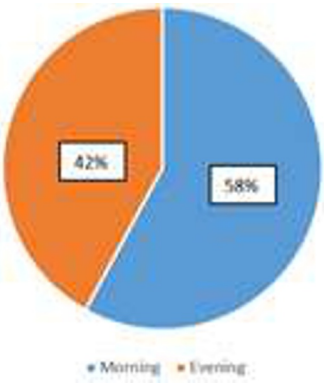
These findings highlight the persistent reliance on physically demanding and unsafe water collection methods, underscoring the need for decentralized, community-based water distribution systems.

4.2 Water Access and Contamination Risks

The city's dependence on aquifers and the Mahanadi River makes it vulnerable to contamination from open drains and industrial effluents. Seasonal fluctuations worsen the problem; monsoons bring flooding, leading to stagnation and infiltration of contaminated runoff.

Water quality variation across seasons is shown in Figure 4.

Figure 4. Water Quality Variation across Seasons



Continuous water supply systems exhibit lower contamination rates; however, intermittent distribution systems increase bacterial growth in pipelines. Therefore, regular monitoring and investment in resilient pipeline infrastructure are essential for ensuring water safety.

4.3 Sanitation and Waste Management

Bhubaneswar's sanitation network remains underdeveloped in slum areas. Around 57% of households rely on open drains, 43% on closed systems (as shown in Figure 5), while some regions lack drainage altogether. Maintenance remains irregular; 13% of drains are cleaned monthly, 65% are cleaned twice a month, and 22% are not maintained (as shown in Figure 6) , even during overflows.

Figure 5. Types of Drainage Systems in Bhubaneswar Slums

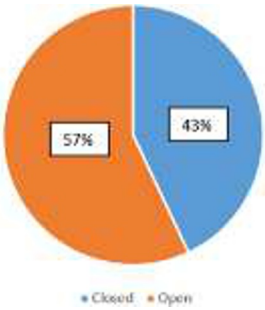
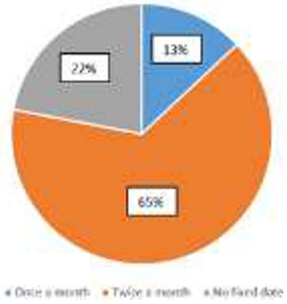


Figure 6. Frequency of Drainage Cleaning



Drainage and Maintenance Characteristics of drains is shown in Table 2.

Table 2. Drainage and Maintenance Characteristics

Component	Coverage	Condition	Maintenance Frequency
Open Drainage	57%	Poor	Monthly
Closed Drainage	43%	Fair	Bi-monthly
Sewage Drainage	35%	Critical	Weekly
Waste Collection	62%	Moderate	Daily

The absence of structured maintenance cycles contributes to frequent overflow, clogging, and groundwater contamination. Community awareness regarding waste segregation remains low, further aggravating the issue.

4.4 Overcrowding and Service Delivery

GIS mapping identified high-density unauthorized settlements in Khordha district, where the infrastructure fails to keep pace with population growth. Overcrowding intensifies demand for shared sanitation facilities and water sources, creating hygiene challenges.

Overcrowded slums exhibit weak drainage, poor ventilation, and heightened exposure to vector-borne diseases. Women and children bear the brunt of this infrastructural inadequacy, spending a significant amount of time collecting water and managing household sanitation.

5 Discussion

5.1 Interconnections between Urbanization, Water, and Sanitation

The findings reveal a strong correlation between unregulated urban expansion and declining service efficiency. Bhubaneswar's slums illustrate how rapid migration and informal settlement formation outstrip infrastructural capacity. The persistence of high contaminant levels and irregular water supply indicates weak enforcement of water safety standards.

The lack of maintenance cycles and community participation in sanitation management underscores institutional limitations. Moreover, the city's reliance on outdated drainage systems undermines resilience to climate-induced rainfall variability. Without integrated planning, the benefits of urban growth risk being offset by deteriorating public health conditions.

5.2 Policy and Institutional Dimensions

Bhubaneswar's experience mirrors a national pattern where urban planning prioritizes economic development over environmental and social sustainability. Initiatives like AMRUT and the Swachh Bharat Mission have improved visibility of urban sanitation, yet their reach in informal settlements remains limited.

Policy frameworks need to shift from project-based interventions to systemic integration, combining land regularization, community-managed water kiosks, and decentralized waste management. Accountability mechanisms, such as ward-level monitoring committees and digital grievance tracking systems, can help bridge service delivery gaps.

5.3 Towards Inclusive and Sustainable Urban Governance

An inclusive approach to urban development requires collaboration among municipal bodies, NGOs, and local communities. Training residents as sanitation ambassadors, promoting micro-entrepreneurship in waste recycling, and incentivizing water conservation practices can foster long-term sustainability. A framework for inclusive urban governance is proposed in Table 3.

Table 3. Framework for Inclusive Urban Governance

Stakeholder	Key Functions	Collaborative Linkages	Expected Outcomes
Municipal Bodies	• Urban planning and infrastructure development • Policy formulation and monitoring • Budget allocation and interdepartmental coordination	• Work with NGOs for outreach and implementation • Integrate citizen feedback via digital platforms	• Improved service delivery • Accountability in infrastructure maintenance
NGOs and Civil Society	• Community mobilization and capacity building • Advocacy for marginalized groups • Technical assistance in sanitation and waste management	• Liaise with local communities • Partner with municipal bodies for inclusive programs	• Increased citizen participation • Social inclusion and awareness
Local Communities	• Identify local needs and priorities • Participate in maintenance and monitoring • Promote behavioral change in hygiene practices	• Collaborate with NGOs for training • Report service gaps via digital platforms	• Ownership of infrastructure • Sustainable utilization of resources
Digital Monitoring Systems	• Data collection and analytics • GIS mapping of service access • Real-time reporting and transparency	• Interface for all stakeholders • Dashboard for grievance redressal	• Evidence-based decision-making • Transparency and responsiveness

The integration of GIS-based monitoring within urban planning can further enable targeted interventions and transparency. Ensuring that Bhubaneswar's growth remains

both economically vibrant and socially equitable depends on mainstreaming slum improvement within broader city Planning frameworks.

6 Conclusion

Bhubaneswar's journey toward sustainable urban development reflects a dynamic blend of achievements and enduring challenges. The city's proactive initiatives under the Bhubaneswar Municipal Corporation (BMC), including the establishment of water treatment plants, filtration reservoirs, and a systematic waste collection system, mark substantial progress in enhancing urban infrastructure. Yet, persistent issues such as water contamination, inefficient drainage systems, and growing overcrowding continue to impede the realization of true urban sustainability. This study highlights the need for integrated policy interventions that prioritize infrastructure upgradation through continuous investment in piped water networks, closed drainage systems, and decentralized sewage treatment facilities. Ensuring maintenance accountability by institutionalizing regular cleaning schedules, strengthening local monitoring mechanisms, and enhancing transparency in reporting processes is equally vital. Furthermore, sustained community engagement, through the inclusion of slum residents in planning, awareness programs, and co-management of sanitation resources, can foster ownership and ensure long-term effectiveness. Environmental safeguards must also remain central, with stricter pollution control measures and sustainable solid waste management to protect local water bodies and aquifers. Achieving these goals would align Bhubaneswar's developmental trajectory with India's broader commitment to Sustainable Development Goals 6 (Clean Water and Sanitation) and 11 (Sustainable Cities and Communities). As a Smart City, Bhubaneswar holds the potential to evolve into a national model of inclusive urban transformation, where economic growth harmonizes with social equity and environmental stewardship.

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