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Socioeconomic Vulnerability and Community Attitudes Toward Wastewater Exposure in Semi-arid Rajasthan: A Synthesis of Evidence

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Abstract

Wastewater exposure in rapidly urbanising and water-scarce regions such as Rajasthan, India, presents significant socioeconomic vulnerabilities and public health challenges. This review synthesises evidence on how demographic, economic, and geographic factors contribute to differential exposure and sensitivity to wastewater hazards, with marginalised populations facing disproportionate risks due to poverty, inadequate infrastructure, and limited access to sanitation. It further explores community attitudes toward wastewater reuse and management, emphasising the influence of cultural beliefs, awareness, and institutional trust on acceptance and resistance to sanitation interventions. The study employs a thematic synthesis of diverse literature, including government policies and empirical research, to elucidate the socio-environmental nexus critical for sustainable wastewater management. The findings underscore the critical need for implementing inclusive policies. Community participation and interdisciplinary research that address social determinants alongside technical solutions. Integrated approaches that combine environmental health and social science perspectives are essential to build resilience, reduce health disparities, and promote equitable sanitation outcomes in semi-arid, resource-constrained contexts such as Rajasthan.

Keywords: *socioeconomic vulnerability, wastewater exposure, community attitudes, sanitation management, Semi-arid*

Introduction

Exposure of communities to wastewater poses significant socioeconomic vulnerabilities and public health challenges, particularly in rapidly urbanising, water-scarce regions such as Rajasthan, India. The Rajasthan State Sewerage and Wastewater Policy (2016) and subsequent environmental monitoring

reports (Rajasthan Urban Development Department, 2025; Urban Department, Government of Rajasthan, 2025) point out the acute scarcity of water and the critical need for sustainable wastewater management to protect public health, improve sanitation services, and conserve precious water resources. Despite infrastructural developments, a substantial proportion of the population, especially in peri-urban and informal settlements, remains vulnerable to untreated or inadequately treated wastewater due to socioeconomic factors such as poverty, limited water access, and inadequate sanitation facilities (Jain, 2019).

Socioeconomic vulnerability underpins differential exposure and sensitivity to wastewater hazards. Prior studies highlight how income disparities, occupation types, housing conditions, and social marginalisation exacerbate risks associated with wastewater exposure (Mshelia *et al*., 2022). For instance, peri-urban agricultural communities may rely on untreated wastewater for irrigation, entailing not only economic benefits but also health risks that interact with community attitudes toward reuse and wastewater treatment initiatives. This socio-environmental nexus necessitates a comprehensive review that integrates environmental health science with social science perspectives to understand vulnerabilities and community responses fully.

The objectives of this review are to synthesise evidence on socioeconomic vulnerabilities related to wastewater exposure and analyse community attitudes shaping the management, reuse, and perception of wastewater risks. By weaving together diverse regional insights and policy frameworks—including Rajasthan's sanitation and water policies (Government of Rajasthan, 2016)—with empirical studies from India and comparable contexts globally, this review aims to provide a nuanced understanding of how social determinants and environmental factors coalesce. It underscores the importance of combining social and environmental perspectives in wastewater research and policy to foster inclusive sanitation solutions and build community resilience (Berkes *et al.*, 2003; Halder & Islam, 2015).

Integrating these perspectives is vital as wastewater management is not solely a technical challenge but also a social process involving behaviour, equity, and governance. Community attitudes toward wastewater exposure influence acceptance, resistance, and adaptation strategies, ultimately determining health outcomes and the sustainability of sanitation interventions (Rani, 2021; Dickin *et al*., 2016). Recognising socioeconomic vulnerability alongside environmental risks enables targeted interventions to ameliorate health disparities, promote safe reuse practices, and enhance the effectiveness of policy implementation. This comprehensive synthesis thus lays the foundation for equitable, evidence-based urban sanitation planning tailored to the socio-environmental realities of Rajasthan and similar semi-arid, resource-constrained regions.

Background

Wastewater is generated primarily from domestic, industrial, and agricultural activities and constitutes a heterogeneous mixture of organic, chemical, and microbial contaminants. In urban and peri-urban regions, especially within semi-arid zones, wastewater is produced in large volumes from household sewage, commercial establishments, and industrial effluents, often without adequate treatment infrastructure (Government of Rajasthan, 2016). Common types include domestic wastewater, stormwater runoff, industrial discharge, and agricultural return flows. Exposure pathways to wastewater contaminants typically occur through direct contact with untreated or partially treated effluents, contaminated water or food ingestion, aerosol inhalation, and dermal absorption. Such exposure is heightened in communities residing near sewerage systems, open drains, untreated wastewater storage ponds, or agricultural fields irrigated with wastewater (Jain, 2019; Dickin *et al*., 2016).

Socioeconomic vulnerability in environmental health refers to the differential susceptibility and adaptive capacity of populations to environmental hazards, shaped by social, economic, demographic, and spatial factors. Vulnerability reflects how poverty, limited education, inadequate housing, and occupation status intersect to amplify risks from environmental exposures, including wastewater contamination (Adelodun *et al*., 2020; Halder & Islam, 2015). For instance, low-income communities often experience higher exposure due to inadequate sanitation infrastructure and limited access to clean water. Their reduced capacity to prevent or cope with health impacts accentuates health inequalities (Rani, 2021; Mshelia *et al*., 2022). Spatially, peri-urban and informal settlements tend to bear disproportionate burdens due to their proximity to contamination sources and lack of representation in planning.

Community attitudes toward wastewater exposure are shaped by socioeconomic status and cultural worldviews, influencing perceptions of risk, hygiene practices, and acceptance of wastewater reuse or sanitation interventions. Cultural norms, traditional knowledge, and local beliefs affect how communities interpret wastewater risks and what behavioural responses they adopt. Economic reliance on wastewater reuse for irrigation may foster pragmatic acceptance despite health concerns, whereas mistrust in governance and previous negative experiences can generate resistance to treatment projects. Understanding these sociocultural dimensions is critical to designing effective, participatory wastewater management strategies that are contextually appropriate and socially inclusive (Berkes *et al.*, 2003; Rani, 2021).

Methodology

The methodology involved identifying, selecting, and synthesising relevant literature on socioeconomic vulnerability and community attitudes related to wastewater exposure.

Studies were selected for relevance to the research objectives, focusing on (1) socioeconomic vulnerability frameworks in environmental health, particularly related to wastewater exposure; (2) community perceptions and attitudes toward wastewater management and reuse; (3) empirical or policy-based research conducted within Rajasthan, India, and comparable global contexts; and (4) publications from authoritative sources such as government reports, peer-reviewed journals, theses, and recognized organizations. A comprehensive search was conducted across multiple academic databases. Additionally, official government documents and policy reports from the Government of Rajasthan and associated departments were reviewed to incorporate key local policy frameworks. Grey literature from institutional websites and repositories supplemented the academic sources to ensure a broad evidence base.

A thematic synthesis approach was employed, grouping evidence under core themes such as vulnerability determinants, exposure pathways, community attitudes, health impacts, and policy frameworks. This qualitative synthesis enabled integration of diverse types of evidence—quantitative data, qualitative insights, and policy analysis—to provide a comprehensive understanding of the interplay between socioeconomic factors and community perspectives concerning wastewater exposure.

Socioeconomic Vulnerability and Wastewater Exposure

Socioeconomic vulnerability to wastewater exposure is shaped by an interplay of demographic, economic, and geographic factors that influence both the level of exposure and the community's capacity to prevent or mitigate adverse health outcomes. Demographic variables such as age, household size, and gender affect vulnerability, with children, the elderly, and women often bearing disproportionate risks due to physiological and social factors (Halder & Islam, 2015; Mshelia *et al*., 2022). Geographically, communities situated in peri-urban areas or informal settlements near wastewater discharge points and treatment plants face heightened exposure due to infrastructure deficits and proximity (Singh, Jain, & Kumar, 2021).

Economic factors profoundly shape individual and household susceptibility. Low income limits access to improved sanitation services and safe water sources, increasing the likelihood of interaction with untreated wastewater (Adelodun *et al*., 2020; Larsen *et al*., 2022). Occupational exposure is significant for workers in agriculture using wastewater for irrigation, sanitation maintenance, and informal recycling, where inadequate protective measures elevate health risks (Mshelia *et al*., 2022). Housing conditions also influence exposure; inadequate or crowded housing without proper sewage systems exacerbates contact with contaminated water (Jain, 2019).

Educational status is linked to awareness and the adoption of protective behaviours. Lower education levels correlate with limited knowledge of wastewater risks and reduced engagement in safe practices,

which magnifies health vulnerabilities (Rani, 2021). This nexus of occupational, economic, and educational disadvantages converges to create systemic exposure disparities evident both globally and within Rajasthan's semi-arid context. For example, Rajasthan's wastewater management reports highlight that marginalised populations in secondary towns suffer more from poor sanitation and associated disease burdens compared to affluent urban neighbourhoods (Government of Rajasthan, 2016; Urban Department, Government of Rajasthan, 2025).

Internationally, studies in Nigeria (Mshelia *et al.*, 2022) and India (Adelodun *et al.*, 2020) underscore similar patterns of socioeconomically driven exposure inequities. These reveal that vulnerable groups often occupy environmentally compromised spaces, bear greater disease burdens, and have less access to healthcare, pointing to urgent needs for equity-focused interventions.

Community Attitudes Toward Wastewater Exposure

Community perceptions of wastewater risks, reuse, and management practices are critical determinants shaping the acceptance and success of wastewater treatment and reuse initiatives. While many communities recognise the environmental and economic benefits of wastewater treatment, apprehension often persists around health risks, especially when direct human contact is possible. Studies show that although a majority approve of treated wastewater use in agriculture and other non-potable applications, there is considerable reluctance toward potable or direct-contact uses (Scott *et al.*, 2009). For instance, an international survey found over 80% support for irrigation uses but very low acceptance for drinking or cooking with recycled water (Pathiranage *et al.*, 2024).

Cultural beliefs, levels of awareness, and trust in governance significantly influence these attitudes. Cultural norms may associate wastewater with impurity or disease, leading to resistance against reuse despite scientific assurances of safety (Faria, 2022). Awareness of wastewater treatment technologies and associated health risks is often low in many settings, undermining informed acceptance. Trust deficits toward water authorities or service providers also erode community confidence in wastewater reuse programs, reinforcing scepticism, primarily where past mismanagement or lack of transparency exists. Religious perspectives can further mediate acceptance; while non-contact use of recycled water often crosses cultural boundaries, direct-contact applications are more contentious across diverse faiths.

Case studies illustrate varied community responses based on context and engagement strategies. A notable example is Baindi village in Haryana, India, where a government-supported five-pond wastewater treatment system transformed an unhygienic environment into a clean, green space. Despite initial resistance, sustained community involvement—including leadership by local governance, transparent communication, and demonstration of tangible benefits—fostered acceptance and ownership, improving

sanitation and quality of life (UN SDGs, 2016). Conversely, in some peri-urban Indian contexts, wastewater reuse for irrigation persists out of economic necessity, even amid community concerns about health risks, highlighting pragmatic but reluctant acceptance.

These findings underscore the importance of combining educational outreach, culturally sensitive communication, and trust-building with participatory management to enhance community acceptance. Effective wastewater management policies should address underlying socioeconomic factors, incorporate local knowledge, and foster collaborative governance to align technological solutions with community needs and values.

Health Impacts Linked to Wastewater Exposure

Exposure to untreated or inadequately treated wastewater is directly associated with a range of waterborne and vector-borne diseases that disproportionately affect vulnerable populations.

Waterborne diseases such as diarrhoea, dysentery, typhoid, and cholera often arise from faecal contamination and microbial pathogens present in wastewater (Halder & Islam, 2015; Dickin *et al*., 2016). Additionally, stagnant wastewater bodies create breeding grounds for disease vectors such as mosquitoes, thereby facilitating the spread of vector-borne diseases, including malaria, dengue, chikungunya, and filariasis (WHO, 2024).

Beyond physical health, wastewater exposure generates significant psychological distress for affected communities due to continuous exposure to foul odours, unsightly conditions, and fears of disease transmission (Phan *et al*., 2021; Vantarakis *et al*., 2016). This psychological burdenis compounded by stigma and social exclusion often experienced by those living near wastewater sites. Economically, households incur substantial out-of-pocket healthcare expenses and lost productivity attributable to illness from contaminated

water and related diseases, exacerbating financial vulnerabilities in low-income settings (Ali *et al*., 2021). The high cost of illness reduces household capacity to invest in sanitation improvements, perpetuating cycles of exposure and poverty.

Epidemiological studies and health risk assessments further quantify these impacts. Risk modelling indicates elevated hazard quotients and cancer risks associated with heavy metals and chemical pollutants in wastewater. In contrast, microbial risk assessments reveal unacceptable probabilities of infection through multiple exposure pathways (Chaudhary *et al*., 2017). Coalson *et al*. (2021) highlight the complex interactions between wastewater exposure and flooding events that exacerbate human morbidity, particularly in vulnerable urban populations. Such evidence underscores

the urgent need for integrated wastewater management and public health interventions targeting exposure reduction and improved access to sanitary infrastructure.

Policy and Institutional Context

Effective wastewater management relies on comprehensive policies and institutional frameworks that operate at both national and state levels, aiming to mitigate health risks, ensure environmental sustainability, and promote public welfare. In India, the National Policy on Urban Sanitation and the Swachh Bharat Mission lay foundational mandates for improving sanitation infrastructure. At the same time, state-specific policies, such as the Rajasthan State Sewerage and Wastewater Policy (2016), articulate localised strategies that reflect regional water scarcity and urbanisation dynamics (Government of Rajasthan, 2016; NITI Aayog, 2022). These policies emphasise decentralised wastewater treatment, the integration of sanitation with water resource management, and the prioritisation of vulnerable communities. The Rajasthan Secondary Towns Development Sector Project and reports by the Urban Department further reinforce a staged approach to capacity building, infrastructure upgrading, and monitoring to address diverse urban wastewater challenges (Rajasthan Urban Development Department, 2025; Urban Department, Government of Rajasthan, 2025).

Community participation emerges as a pivotal component for effective policy implementation and resilience building within wastewater governance. Social-ecological system (SES) frameworks highlight the interconnectedness of environmental, institutional, and societal elements in sustaining wastewater systems under complex and changing conditions (Berkes *et al*., 2003). Engaging local communities through participatory planning, education, and co-management not only enhances trust but also ensures that policies align with local needs, knowledge, and capacities (Manisha *et al*., 2023). Case studies reveal that inclusive governance increases compliance, encourages sustainable wastewater reuse practices, and strengthens adaptive responses to environmental stressors (Scott *et al*., 2009; UN SDGs, 2016).

Despite these advances, significant challenges persist in policy implementation and governance. Fragmented institutional responsibilities, insufficient funding, and technical deficits hinder the scaling up of wastewater infrastructure, especially in smaller urban centres and peri-urban areas (NITI Aayog, 2022). Governance weaknesses include a lack of coordination across agencies, limited data-driven decision-making, and inadequate enforcement of environmental regulations (Rajasthan Flood Action Plan, 2024). Moreover, policies occasionally fail to account fully for social inequities, leading to uneven service delivery and sustained vulnerability among marginalised groups (Adelodun *et al*., 2020). Addressing

these institutional barriers through integrated policy frameworks, enhanced capacity building, and robust stakeholder engagement is essential for advancing equitable and resilient wastewater management systems in Rajasthan and similar contexts.

Discussion

This review synthesises critical insights on the interplay between socioeconomic vulnerability and community attitudes toward wastewater exposure, revealing a complex nexus that shapes both health outcomes and the effectiveness of wastewater management strategies. Socioeconomic factors such as income, occupation, housing, and education significantly influence exposure risk and adaptive capacities, often marginalising vulnerable populations through disproportionate disease burden and limited access to sanitation services (Adelodun *et al*., 2020). Concurrently, community attitudes—shaped by cultural beliefs, awareness levels, and trust in governance—mediate the acceptance and sustainability of wastewater reuse and treatment interventions (Faria, 2022). The social-ecological systems (SES) approach underscores the need for integrating these social dimensions with environmental management to build resilient, equitable sanitation infrastructure (Berkes *et al*., 2003).

Despite growing recognition of social factors, significant research and practice gaps remain. Many studies focus on either environmental health metrics or technical wastewater treatment aspects, with relatively few adopting interdisciplinary frameworks that capture the full socioeconomic context (Manisha *et al*., 2023). Limited longitudinal data are available to track how community perceptions evolve in response to policy changes or climate impacts, hindering dynamic adaptation planning. Moreover, the voices of marginalised and informal communities are often underrepresented in policymaking and research, constraining the design of culturally appropriate and socially inclusive programs (Rani, 2021). Monitoring and evaluation systems often lack the disaggregated data needed to address inequities explicitly.

For policy and planning, these insights demand a shift from top-down, technocratic approaches toward participatory, multi-stakeholder governance that centres community knowledge and equity. Policies must explicitly target vulnerable groups, enhance social awareness of wastewater risks and benefits, and build institutional trust through transparency and accountability (NITI Aayog, 2022). Community engagement should be embedded early and continuously in planning, leveraging local networks to foster behavioural change and safeguard health. Integrating wastewater management with broader urban development and climate resilience initiatives can amplify benefits and resource efficiencies (Rajasthan Flood Action Plan, 2024).

Overall, advancing equitable wastewater governance requires interdisciplinary research that bridges environmental science, social psychology, and public policy, alongside capacity-building for inclusive decision-making. Investments in both infrastructure and social capital are crucial to reduce vulnerabilities and enhance community resilience toward the ongoing challenges posed by wastewater exposure in Rajasthan and comparable contexts globally.

Recommendations

Reducing socioeconomic vulnerability to wastewater exposure requires multifaceted strategies that integrate inclusive policies and resilient infrastructure development. Policymakers should prioritise equitable access to safe sanitation and wastewater management systems, targeting marginalised and peri-urban communities through subsidies, capacity-building, and the decentralisation of treatment facilities (Government of Rajasthan, 2016; NITI Aayog, 2022). Infrastructure investments must incorporate climate resilience, adaptive technologies, and community-maintained systems to ensure long-term sustainability, particularly in semi-arid regions like Rajasthan (Manisha *et al*., 2023).

Improving community awareness and participation is critical to fostering local ownership and safe practices. Tailored educational campaigns addressing cultural beliefs and misconceptions can enhance understanding of wastewater risks and benefits, while participatory governance mechanisms—such as community water committees and co-management frameworks—build trust and responsiveness (UN SDGs, 2016). Leveraging existing social networks and local leaders promotes sustained engagement and behavioural change, which are essential complements to technical interventions.

Research priorities should focus on integrated social-environmental studies that cross disciplinary boundaries. Longitudinal and mixed-methods research capturing changes in vulnerability, attitudes, and health outcomes will inform adaptive management. Emphasis on disaggregated data and community-driven participatory research can illuminate inequities and contextual factors often overlooked (Manisha *et al*., 2023). Collaborative research with policymakers and practitioners is recommended to translate findings into actionable policy and practice.

Conclusion

This review highlights the intricate linkages between socioeconomic vulnerability and community attitudes in shaping wastewater exposure risks and management outcomes. Key insights affirm that wastewater challenges are not only technical but deeply embedded in social structures, requiring inclusive, culturally sensitive, and participatory approaches to sanitation governance. Addressing social dimensions—through equity-focused policies, community engagement, and interdisciplinary research—

enables more effective interventions that protect health, enhance resilience, and promote sustainable development.

Recognising and integrating these social factors alongside environmental science is essential to overcoming persistent disparities and achieving resilient wastewater management in Rajasthan and beyond.

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