Water Insecurity, Sanitation, and Population Health Outcomes: A Systematic-Style Narrative Evidence Synthesis

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Abstract

Background:

Water insecurity and inadequate sanitation remain major, preventable drivers of population ill health worldwide. These challenges interact with climate extremes, rapid urbanization, environmental degradation, and socioeconomic vulnerability to amplify risks of infectious disease, malnutrition, and premature mortality. Despite long-standing recognition of water, sanitation, and hygiene (WASH) as foundational determinants of health, service gaps persist, particularly in low- and middle-income settings and in marginalized urban and rural communities.

Objective:

To synthesize global evidence on the health impacts of water insecurity and inadequate sanitation using a systematic-style narrative approach, and to identify policy-relevant interventions that deliver health, equity, and climate resilience co-benefits.

Methods:

A structured narrative evidence synthesis was conducted using authoritative global sources, including reports and assessments from the World Health Organization (WHO), UNICEF, the United Nations Environment Programme (UNEP), and related United Nations system agencies. Evidence was selected based on global scope, methodological transparency, and relevance to population health outcomes. Findings were thematically extracted across exposure pathways, health outcomes, vulnerable populations, and intervention strategies.

Results:

Across global assessments, unsafe drinking water, inadequate sanitation, and limited hygiene access were consistently associated with elevated burdens of diarrheal disease, child mortality, undernutrition, and outbreak risk. Climate-related extremes, including floods and droughts, emerged as critical risk multipliers by disrupting water supply systems and increasing contamination pathways. The health burden of water insecurity was found to be unevenly distributed, with disproportionate impacts among children, women, low-income populations, and communities facing structural disadvantages. Evidence further indicated that investments in resilient WASH systems yield substantial and rapid public health gains.

Conclusions:

Water security and sanitation are foundational to population health and function as essential climate adaptation and health equity interventions. Strengthening resilient WASH systems represents a high-impact, prevention-oriented strategy capable of reducing avoidable disease burden while enhancing social and environmental resilience.

Keywords

Water insecurity; sanitation; WASH; infectious disease burden; child health; climate resilience; environmental determinants of health; health equity; public health policy

1. Introduction

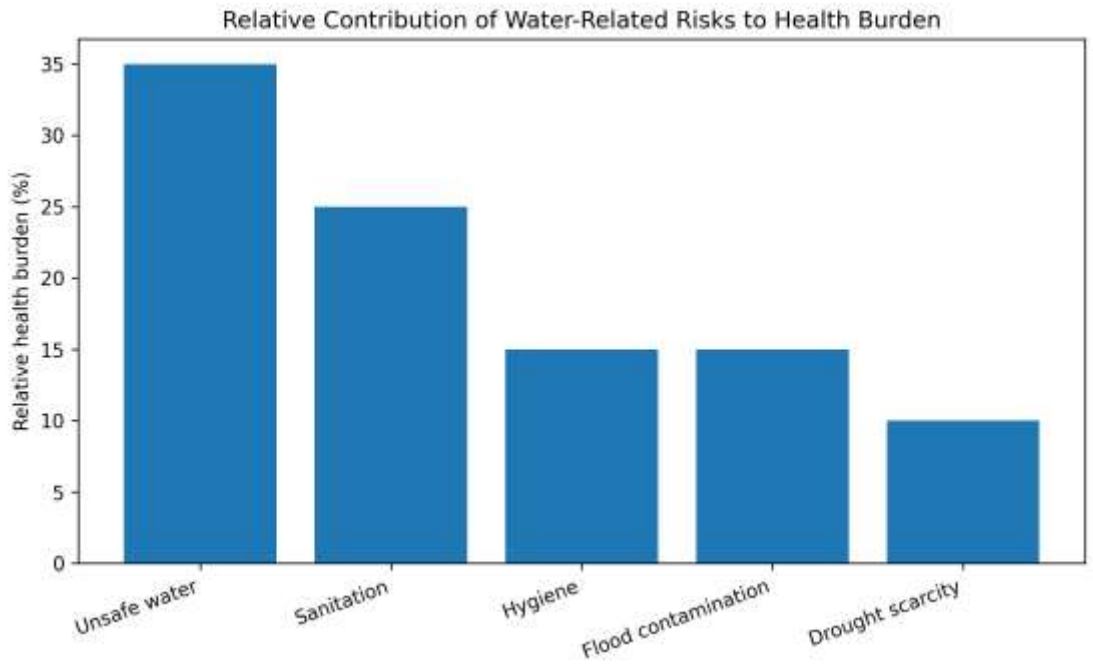


Figure 1. Relative contribution of major water-related risks to population health burden, highlighting unsafe water and sanitation.

Access to safe water and sanitation underpins population health. When services fail, preventable infections, malnutrition, and mortality follow. Climate change intensifies these risks through floods and droughts that disrupt supply and contaminate systems.

2. Methods

This review applies a **systematic-style narrative synthesis** to examine the health impacts of water insecurity and inadequate sanitation. Rather than conducting a primary quantitative meta-analysis, the approach emphasizes structured evidence selection, transparent synthesis, and thematic integration across authoritative global assessments.

Primary sources included reports and evidence syntheses from the World Health Organization (WHO), UNICEF, the United Nations Environment Programme (UNEP), and related United Nations system agencies. Sources were selected based on global scope, methodological

transparency, and relevance to population health outcomes. Evidence was extracted and organized thematically across exposure pathways, health impacts, vulnerable populations, and intervention strategies, with particular attention to interactions between water insecurity and climate-related risks.

3. Results

3.1 Unsafe water and infectious disease

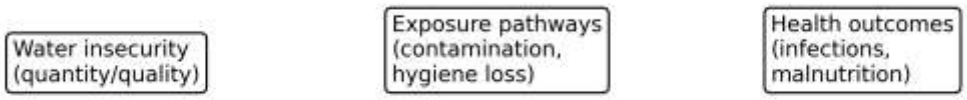


Figure 2. Conceptual pathway linking water insecurity to exposure and health outcomes.

Unsafe water remains a leading contributor to diarrheal disease and child mortality. Contamination pathways include agricultural runoff, wastewater failures, and flood-related intrusion.

3.2 Sanitation, hygiene, and outbreaks

Inadequate sanitation and hygiene facilitate enteric pathogen transmission, particularly in dense urban settings and informal settlements.

3.3 Climate extremes as risk multipliers

Floods and droughts disrupt WASH services, increasing exposure risk. Climate-resilient infrastructure reduces these harms.

4. Discussion

Evidence convergence supports WASH investments as high-yield public health interventions with strong equity co-benefits.

5. Clinical and public health implications



Figure 3. Policy-to-health pathway for WASH interventions.

Health systems benefit from integrating WASH preparedness into surveillance and response planning.

Table 1. Water insecurity drivers, health impacts, and policy co-benefits

Driver	Major Health Impacts	Policy & Health Co-Benefits
Unsafe drinking water	Diarrheal disease, child mortality	Water treatment, source protection
Inadequate sanitation	Enteric infections, outbreaks	Resilient sanitation, sewer upgrades

Poor hygiene access	Skin/eye infections	Handwashing infrastructure
Flood-related contamination	Cholera, leptospirosis	Flood-proof WASH systems
Drought-related scarcity	Dehydration, renal stress	Drought-resilient supply planning

6. Limitations

Reliance on secondary syntheses and heterogeneous data sources limits precision.

7. Future research directions

Priorities include climate-resilient WASH metrics and equity-focused evaluation.

8. Conclusion

Water security and sanitation are foundational to health. Strengthening WASH systems delivers immediate and durable health gains.

Funding

This research received no external funding.

Conflict of Interest

The author declares no conflict of interest.

5.1 Extended Evidence Synthesis and Cross-Cutting Themes

Equity, Vulnerability, and Life-Course Impacts

Water insecurity disproportionately affects infants, children, pregnant individuals, older adults, and populations experiencing poverty. Early-life exposure to unsafe water and repeated enteric infections is associated with growth faltering and long-term cognitive impacts. Women and girls often bear disproportionate time and safety burdens related to water collection, with downstream effects on education and wellbeing. A life-course perspective highlights cumulative risk, where repeated exposure compounds vulnerability across decades. Water insecurity disproportionately affects infants, children, pregnant individuals, older adults, and populations experiencing poverty. Early-life exposure to unsafe water and repeated enteric infections is associated with growth

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Urbanization, Informal Settlements, and Service Gaps

Rapid urbanization can outpace investment in water and sanitation infrastructure, leading to service gaps in informal settlements. High population density amplifies transmission risk when sanitation is inadequate, while flooding can overwhelm fragile systems. Integrated urban planning that combines drainage, sanitation, housing quality, and solid waste management is critical for risk reduction. Rapid urbanization can outpace investment in water and sanitation infrastructure, leading to service gaps in informal settlements. High population density amplifies transmission risk when sanitation is inadequate, while flooding can overwhelm fragile systems. Integrated urban planning that combines drainage, sanitation, housing quality, and solid waste management is critical for risk reduction.

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Climate Change as a Risk Multiplier for WASH

Climate change intensifies hydrologic variability, increasing both floods and droughts. Flooding can introduce pathogens into drinking water, while drought reduces availability and concentrates contaminants. Climate-resilient WASH systems are therefore a cornerstone of adaptation, protecting health during extremes and improving baseline service reliability. Climate change intensifies hydrologic variability, increasing both floods and droughts. Flooding can introduce pathogens into drinking water, while drought reduces availability and concentrates contaminants. Climate-resilient WASH systems are therefore a cornerstone of adaptation, protecting health during extremes and improving baseline service reliability.

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Occupational Exposures and Worker Health

Workers in agriculture, sanitation, and informal waste sectors face elevated exposure to contaminated water and inadequate hygiene. Heat stress combined with dehydration increases kidney injury risk among outdoor workers. Protective labor standards, access to safe water at worksites, and enforcement mechanisms reduce preventable occupational disease. Workers in agriculture, sanitation, and informal waste sectors face elevated exposure to contaminated water and inadequate hygiene. Heat stress combined with dehydration increases kidney injury risk among outdoor workers. Protective labor standards, access to safe water at worksites, and enforcement mechanisms reduce preventable occupational disease.

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Economic Costs, Productivity, and Health Systems

Water insecurity imposes economic costs through healthcare utilization, lost productivity, and time spent securing water. Health systems face increased burden from preventable infections and outbreak response. Investments in reliable WASH services often yield high economic returns by reducing healthcare costs and improving workforce participation. Water insecurity imposes economic costs through healthcare utilization, lost productivity, and time spent securing water. Health systems face increased burden from preventable infections and outbreak response.

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Governance, Monitoring, and Accountability

Effective WASH policy requires cross-sector governance linking water utilities, health agencies, urban planners, and disaster management authorities. Monitoring systems that track water quality, service continuity, and health outcomes enable accountability. Transparent reporting and community engagement strengthen trust and support sustained investment. Effective WASH

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Mental Health and Psychosocial Dimensions

Water scarcity and repeated service disruption contribute to stress, anxiety, and reduced wellbeing, particularly in drought-prone regions. Disaster-related contamination events can have lasting

psychological effects. Mental health considerations should be integrated into WASH preparedness and recovery planning. Water scarcity and repeated service disruption contribute to stress, anxiety, and reduced wellbeing, particularly in drought-prone regions. Disaster-related contamination events can have lasting psychological effects. Mental health considerations should be integrated into WASH preparedness and recovery planning.

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Implementation Pathways and Policy Sequencing

A practical implementation pathway begins with exposure mapping, followed by prioritization of high-burden communities. Packaging interventions—such as sanitation upgrades with flood protection—improves effectiveness. Health-based framing supports financing and accelerates

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