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THE INFLUENCE OF ENVIRONMENTAL HYGIENE AND SANITATION ON THE CONTROL AND PREVENTION OF INFECTIOUS DISEASES

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ABSTRACT

Background: Environmental hygiene and sanitation remain foundational pillars in the global effort to control and prevent infectious diseases. Inadequate sanitation and poor hygiene practices continue to drive preventable morbidity and mortality, particularly in low- and middle-income countries (LMICs). **Objective:** This review examines the mechanisms through which environmental hygiene and sanitation influence infectious disease epidemiology, evaluates the evidence base for key interventions, and discusses barriers to implementation and strategies for improvement. **Methods:** A comprehensive review of peer-reviewed literature published between 2020 and 2025 was conducted using PubMed, Embase, Scopus, and WHO/CDC databases. Studies were selected based on relevance to water, sanitation, and hygiene (WASH) interventions, infection prevention and control (IPC), and environmental health. **Results:** Evidence consistently demonstrates that improving water quality, sanitation coverage, and hygiene practices significantly reduces the burden of waterborne, faecal-oral, and healthcare-associated infections. Key WASH interventions, including safely managed sanitation, handwashing with soap, and environmental surface disinfection, reduce diarrhoeal disease risk by up to 47%, respiratory infections by approximately 20%, and healthcare-associated infection (HAI) rates by over 60% when applied systematically. Major barriers include inadequate infrastructure, financial constraints, cultural norms, and weak governance of IPC programmes. **Conclusion:** Integrated, equity-focused WASH and IPC strategies aligned with Sustainable Development Goal 6 (SDG 6) targets are essential for breaking the cycle of infectious disease transmission. Strengthening environmental hygiene systems represents a highly cost-effective investment in global public health.

KEYWORDS: Environmental hygiene; sanitation; infectious disease control; WASH; infection prevention and control; waterborne diseases; hand hygiene; public health.

1. INTRODUCTION

Environmental hygiene and sanitation constitute some of the oldest and most effective tools in the public health armamentarium. From the sanitary reforms of the nineteenth century to the modern era of molecular epidemiology, the built environment has been recognised as a critical determinant of infectious disease transmission. Despite decades of global progress, the

burden of sanitation-related diseases remains unacceptably high. As of 2022, approximately 1.7 billion people worldwide lack access to basic sanitation facilities, and an estimated 419 million individuals still practise open defecation.[1]

Unsafe sanitation accounts for an estimated 564,000 deaths annually, predominantly from diarrhoeal disease, with an additional burden attributable to neglected tropical diseases including schistosomiasis, trachoma, and soil-transmitted helminthiases.[1] The global burden is disproportionately concentrated in LMICs, where convergent socioeconomic, infrastructural, and governance failures undermine the delivery of safe water, sanitation, and hygiene (WASH) services.

In healthcare settings, environmental contamination is a major driver of healthcare-associated infections (HAIs), which impose significant morbidity, mortality, and economic costs on health systems worldwide. The World Health Organization's (WHO) Global Report on Infection Prevention and Control (2022) underscored that only 15.2% of health care facilities globally meet all IPC minimum requirements.[2] These findings signal an urgent need to consolidate and disseminate the evidence base for environmental hygiene interventions across all settings.

This review synthesises current evidence on the relationship between environmental hygiene, sanitation, and infectious disease, examines the efficacy of key interventions, explores barriers to implementation, and identifies priority areas for policy and practice.

2. Methods (Search Strategy and Selection Criteria)

This narrative review was conducted in accordance with general principles for systematic reviews. Literature was searched in PubMed/MEDLINE, Embase, Scopus, the Cochrane Library, and WHO/CDC institutional repositories. Search terms included combinations of: *"environmental hygiene", "sanitation", "WASH", "water sanitation hygiene", "infection prevention and control", "infectious disease prevention", "hand hygiene", "waterborne diseases", "open defecation", "healthcare-associated infections"*. The search was limited to publications from January 2020 to March 2025. Additional references were retrieved from the bibliographies of included articles. Priority was given to systematic reviews, meta-analyses, randomised controlled trials, and WHO/CDC policy documents.

3. Environmental Hygiene and Mechanisms of Infectious Disease Transmission

3.1 The F-Diagram: Environmental Pathways

Infectious pathogens, including bacteria, viruses, protozoa, and helminths, are transmitted via environmental routes collectively described by the F-diagram (Fluids, Fingers, Flies, Fields, and Food). These pathways are directly mediated by the adequacy of sanitation infrastructure, hygiene behaviours, and the degree of environmental contamination. Faecal contamination of water sources represents the most consequential pathway, driving epidemics of cholera, typhoid fever, hepatitis A, and rotavirus diarrhoea.[3,4]

Poor solid waste management compounds these risks by attracting disease vectors such as flies and mosquitoes, contaminating surface water through runoff, and generating aerosols from waste burning.[5,6] A 2024 study from Tanzania documented those waterborne diseases (cholera and typhoid) ranked highest in perceived disease burden among communities practising poor waste management, with a Relative Importance Index of 0.84.[7] Figure 1 presents the F-diagram illustrating environmental transmission pathways from faecal matter to human hosts.

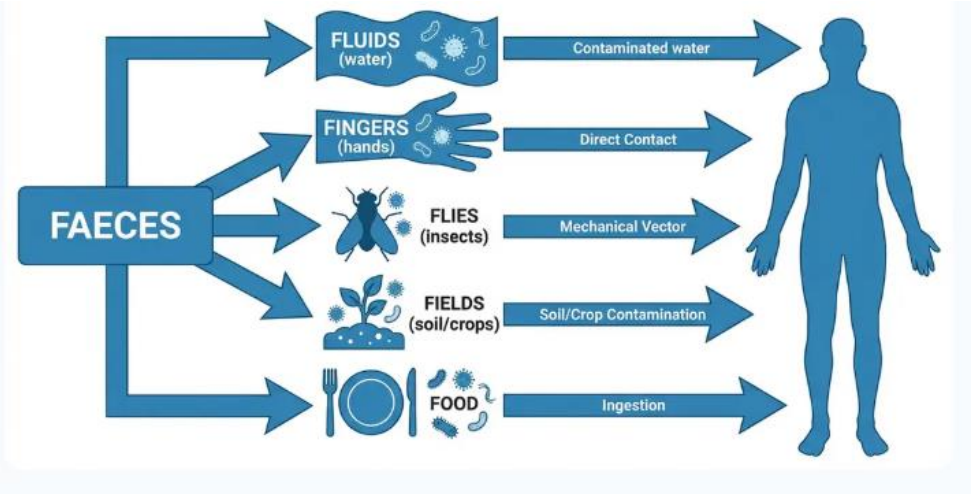

Figure 1: The F-diagram illustrating environmental transmission pathways from faecal matter to human hosts.
Caption: *A detailed scientific infographic depicting the F-diagram of disease transmission. Show a central box labelled 'Faeces' with arrows connecting to five vectors: Fluids (water), Fingers (hands), Flies (insects), Fields (soil/crops), and Food. Each vector connects to a silhouette of a human host.*
Source: Reproduced and adapted from references.[3,8]

3.2 Waterborne and Faecal-Oral Diseases

Waterborne and faecal-oral diseases represent the largest category of sanitation-related infectious disease. A 2022 landmark systematic review and meta-analysis by Wolf et al.[9] published in *The Lancet* demonstrated that safely managed water supply could reduce childhood diarrhoea by up to 47%, while safely managed sanitation could reduce risk by over 45%, compared to unimproved conditions. This analysis, encompassing 124 WASH interventions across LMICs, established the strongest evidence to date for the dose-response relationship between WASH service levels and disease burden.

The burden of disease attributable to inadequate WASH is substantial. Wolf et al. (2023)[10] estimated that unsafe water, sanitation, and hygiene in domestic settings accounts for 1.4 million deaths annually, with diarrhoeal diseases, typhoid, paratyphoid, and intestinal nematode infections contributing the largest shares. Open defecation perpetuates a particularly vicious cycle: faecal matter deposited in the environment contaminates soil, water, and food, sustaining transmission of cholera, typhoid, cryptosporidiosis, and soil-transmitted helminths.[11] Table 1 highlights the Key waterborne and sanitation-related infectious diseases, their transmission routes, and corresponding WASH interventions.

Table 1: Key waterborne and sanitation-related infectious diseases, their transmission routes, and corresponding WASH interventions.

Disease	Pathogen	Transmission Route	Key WASH Intervention
Cholera	Vibrio cholerae	Contaminated water/food	Safe water supply, ODF sanitation
Typhoid Fever	Salmonella typhi	Faecal-oral, contaminated food/water	Improved water treatment, handwashing
Diarrhoeal disease	Multiple (E. coli, Rotavirus, etc.)	Contaminated water and surfaces	Safe water, sanitation, handwashing with soap
Hepatitis A	Hepatitis A virus	Faecal-oral, close contact	Improved sanitation, safe water
Schistosomiasis	Schistosoma spp.	Skin contact with contaminated water	Safe excreta disposal, snail control
Trachoma	Chlamydia trachomatis	Face-to-face, flies, contact	Facial cleanliness, safe water access
Leptospirosis	Leptospira spp.	Contaminated water/soil	Drainage improvement, rodent control

Sources: Compiled from reference[1,9,10]

3.3 Healthcare-Associated Infections (HAIs) and Environmental Contamination

In clinical settings, environmental hygiene is a critical determinant of HAI risk. Contaminated surfaces, equipment, air, and water within healthcare facilities serve as reservoirs for multidrug-resistant organisms (MDROs), including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and carbapenem-resistant *Enterobacterales*.[2,12] The WHO Global IPC Report (2022) estimated that systematic environmental IPC interventions can avert 35–70% of HAIs including ventilator-associated pneumonia (VAP) and surgical site infections (SSIs) across all income settings.[2]

4. Key Environmental Hygiene and Sanitation Interventions

4.1 Water, Sanitation, and Hygiene (WASH) Programmes

WASH programmes constitute the cornerstone of environmental disease prevention in community settings. The Joint Monitoring Programme (JMP) data reported by WHO and UNICEF (2023) showed that by 2022, 57% of the global population used safely managed sanitation, 88% had at least basic sanitation service, yet approximately 1.7 billion people, predominantly in sub-Saharan Africa and South and East Asia, remain without basic facilities.[13] Community-led Total Sanitation (CLTS) has shown success in eliminating open defecation across Asia and sub-Saharan Africa by mobilising community action.[11] Table 2 shows the Global WASH coverage status in 2022 and corresponding disease risk implications.

Table 2: Global WASH coverage status in 2022 and corresponding disease risk implications (Source: WHO/UNICEF JMP 2023).

Service Level Category	Global Population (%)	Population (Billions)	Disease Risk Implication
Safely managed sanitation service	57%	4.6 billion	Low
Basic sanitation service (at least)	88%	7.2 billion	Moderate-Low
Lacking basic sanitation facilities	~21%	1.7 billion	High
Still practicing open defecation	5.2%	0.419 billion	Very High

Deaths attributable to unsafe sanitation annually	—	564,000 deaths	Critical
Under-5 deaths preventable by better WASH	—	395,000 (2019)	Critical

Sources: Adapted and compiled from references[1,13]

4.2 Hand Hygiene

Hand hygiene is universally acknowledged as the single most important infection prevention practice. A 2023 systematic review and meta-analysis by Ross et al.[14] published in *The Lancet* found that handwashing with soap reduced the risk of acute respiratory infections (ARIs) in LMICs by approximately 20%, extending the established evidence base beyond diarrhoeal disease. The 2022 SHEA/IDSA/APIC guidelines[15] updated recommendations for hand hygiene in healthcare settings, emphasising alcohol-based hand rub (ABHR) as the preferred agent in most clinical contexts due to its superior skin-integrity profile and microbiological efficacy.

A longitudinal study at a Chinese geriatric hospital employing the WHO Plan-Do-Check-Act (PDCA) cycle reported a reduction in hospital infection incidence from 2.63% to 0.90% over six years of a multimodal hand hygiene programme.[16] Despite this evidence, compliance among healthcare workers remains suboptimal globally, and community-level compliance is even lower. A scoping review of 51 international guidelines by Chidziwisano et al. (2023)[17] found that fewer than 10% of recommendations for community hand hygiene were supported by cited evidence, highlighting a persistent evidence-practice gap. Figure 2 presents the The WHO Five Moments for Hand Hygiene framework as applied in healthcare settings.

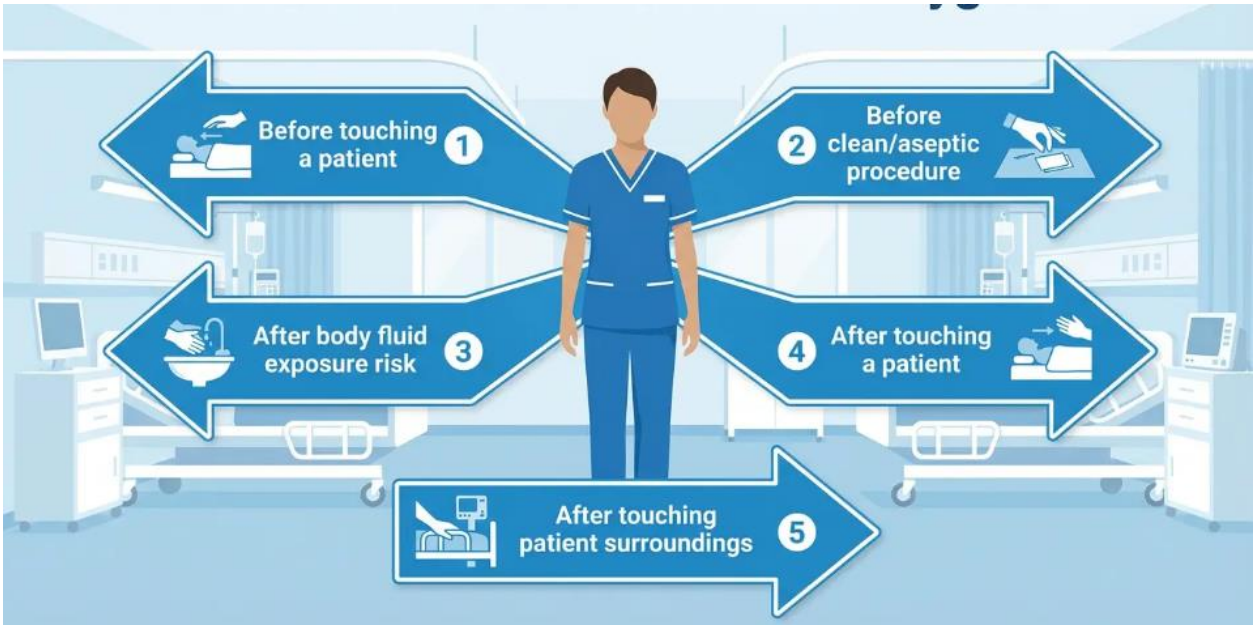

Figure 2: The WHO Five Moments for Hand Hygiene framework as applied in healthcare settings.

Caption: *A clean medical infographic depicting the WHO 'Five Moments for Hand Hygiene' framework in a hospital ward setting. Show a healthcare worker in scrubs at the centre, with five labelled arrows pointing outward: (1) Before touching a patient, (2) Before a clean/aseptic procedure, (3) After body fluid exposure risk, (4) After touching a patient, (5) After touching patient surroundings.*

Source: Authors illustration adapted from references[15,16]

4.3 Environmental Cleaning and Disinfection in Healthcare

Environmental surface contamination in healthcare facilities plays a major role in the transmission of pathogens including *Clostridioides difficile*, norovirus, and MDROs. Systematic environmental cleaning, proceeding from clean to dirty and from high to low surfaces, is a cornerstone of IPC in clinical settings.[18] WHO recommends that when hospital-approved disinfectants are unavailable, sodium hypochlorite (bleach) or detergent-based cleaning constitutes an acceptable minimum standard.[18] In LMICs, the WHO's *Environmental Cleaning and IPC in Health Care Facilities: Trainer's Guide* (2022)[2] provides practical guidance for low-resource implementation.

4.4 Solid Waste Management

Inadequate solid waste management (SWM) is an underappreciated driver of infectious disease in urban and peri-urban settings. Improper disposal creates breeding grounds for mosquito vectors (malaria, dengue), contaminates water sources (cholera, typhoid), and generates airborne particulates exacerbating respiratory infections.[5,6,7] A geospatial study in Kinshasa, DRC (2024)[19] demonstrated that communes lacking formal waste collection services experienced significantly higher prevalence of malaria and typhoid

fever, confirming the public health premium of functional SWM systems. Table 3 gives the Summary of evidence for the effectiveness of selected WASH and IPC interventions on infectious disease outcomes, while Figure 3 gives the Estimated risk reduction in childhood diarrhoeal disease attributable to WASH interventions at different service levels.

Table 3: Summary of evidence for the effectiveness of selected WASH and IPC interventions on infectious disease outcomes.

Intervention Type	Target Disease(s)	Risk Reduction (RR/RRR)	Reference
Improved water supply (piped/treated)	Diarrhoeal disease (children <5)	Up to 47% reduction	Wolf et al., Lancet 2022
Improved sanitation facilities	Diarrhoeal disease, soil-transmitted helminths	~28% reduction (basic); >45% safely managed	Wolf et al., Lancet 2022
Handwashing with soap	Diarrhoea, respiratory infections (ARI)	23–48% reduction; 20% ARI reduction	Ross et al., Lancet 2023
WASH package (combined interventions)	All-cause child mortality	Improved water supply significant; multi-component synergy limited	Waddington et al., PLoS Med 2023
Healthcare hand hygiene programs	HAIs (hospital-acquired infections)	HAI rate reduced from 2.63% to 0.90% over 6 years	Sun et al., 2025 (PDCA-based IPC program)
Environmental surface cleaning & disinfection	HAIs, C. difficile, norovirus	35–70% reduction in VAP & surgical site infections	WHO Global IPC Report, 2022

Sources: Compiled from references[2,9,13,14]

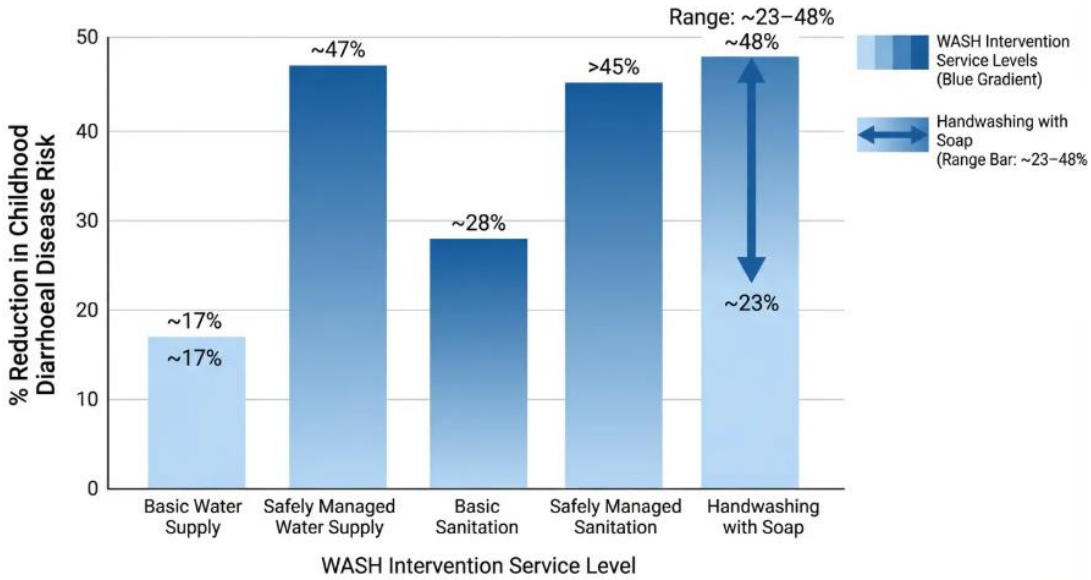

Figure 3: Estimated risk reduction in childhood diarrhoeal disease attributable to WASH interventions at different service levels.

Caption: A professional bar chart or data visualisation infographic showing percentage reduction in childhood diarrhoeal disease risk associated with different WASH intervention service levels: basic water supply (~17% reduction), safely managed water supply (~47% reduction), basic sanitation (~28% reduction), safely managed sanitation (>45% reduction), handwashing with soap (~23-48% reduction).

Source: Data derived from reference.[3]

5. Barriers To Environmental Hygiene and Sanitation Improvement

Despite a robust evidence base, significant barriers impede the translation of WASH and IPC knowledge into sustained practice. These operate at individual, community, institutional, and systemic levels.

Infrastructural and financial barriers: A large share of households in LMICs lack access to safely managed sanitation due to inadequate infrastructure investment. Only 22% of rural households in developing countries had access to basic sanitation services as of 2023.[20] High upfront costs of latrine construction and

maintenance, combined with unreliable cost-recovery mechanisms, perpetuate service gaps.

Behavioural and cultural barriers: Social norms, particularly around open defecation, are deeply entrenched in many communities. Even when latrines are constructed, uptake and sustained use may be low due to perceived convenience, cultural preferences, or lack of education on disease transmission.[11,21] Studies indicate that as many as 13% of beneficiaries revert to open defecation within two years of latrine provision without robust behaviour change programmes.[21]

Governance and programmatic barriers: The WHO Global IPC Report (2022) found that the percentage of countries with a national IPC programme did not improve between the 2017–2018 and 2021–2022 surveys, and only 15.2% of health care facilities met all IPC minimum requirements.[2] Absence of dedicated IPC budgets, trained workforce, and functional monitoring systems undermines programme sustainability.

Climate and environmental barriers: Climate change threatens WASH gains through increased frequency of extreme weather events, which can contaminate water sources, damage infrastructure, and trigger outbreak conditions. WASH interventions in dry seasons reduce diarrhoeal disease risk by 33%, yet effectiveness drops to 18% during rainy seasons, underscoring the need for climate-resilient designs.[22] Table 4 gives the Key barriers to environmental hygiene and sanitation improvement and recommended mitigation strategies.

Table 4: Key barriers to environmental hygiene and sanitation improvement and recommended mitigation strategies.

Barrier Category	Description	Recommended Strategies
Infrastructural	Lack of piped water networks, sewerage, and maintained latrines	Invest in WASH infrastructure; SDG 6 financing
Financial	High cost of sanitation installation and maintenance for low-income households	Subsidies, community-led total sanitation (CLTS)
Behavioural/Cultural	Norms supporting open defecation; low perceived need for handwashing	Behaviour change communication; community mobilisation
Knowledge & Education	Limited public awareness of disease transmission pathways	Health education campaigns; school WASH programmes
Governance	Weak national IPC programmes; absence of dedicated WASH budgets	WHO IPC core components implementation; national IPC plans
Climate & Environment	Climate change exacerbates waterborne disease risks; seasonal variability	Climate-resilient WASH systems; integrated surveillance

Sources: Adapted from references[2,13,17,23]

6. Global Frameworks and Policy Responses

Several global frameworks align environmental hygiene with broader health system goals. The WHO Global Strategy on Infection Prevention and Control (2023).[24] adopted by the World Health Assembly in May 2023, articulates three strategic objectives: preventing infections in health care, ensuring IPC programmes are in place and implemented, and coordinating IPC with WASH, antimicrobial resistance (AMR), and other complementary domains.

Sustainable Development Goal 6 (SDG 6), ensuring availability and sustainable management of water and sanitation for all by 2030, provides the political architecture for WASH investment.[25] However, current rates of progress are insufficient: universal safely managed sanitation coverage would require a fivefold increase in the current pace of improvement.[1] The service ladder approach embedded within SDG 6 monitoring, managed by the WHO/UNICEF Joint Monitoring Programme (JMP), provides a useful framework for stratifying intervention priorities according to existing coverage levels.

WASH in healthcare facilities (WASH-HCF) remains a critical yet poorly served priority. The WHO/UNICEF Global Action Plan for WASH in HCF highlights that IPC minimum requirements, including functional handwashing stations, safe water, and adequate sanitation, are not met in large proportions of facilities across all WHO regions.[2,18] Figure 4 shows the Global distribution of WASH service coverage and sanitation-attributable disease burden by WHO region (2022).

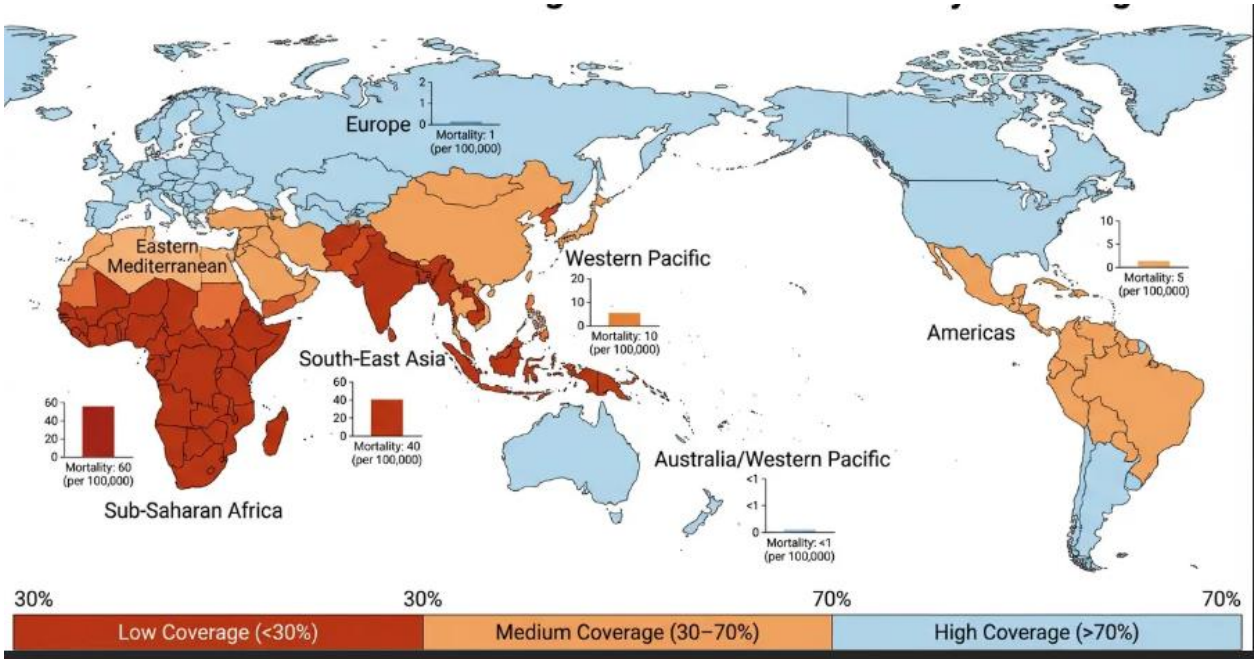

Figure 4: Global distribution of WASH service coverage and sanitation-attributable disease burden by WHO region (2022).

Caption: *A world map infographic showing global WASH service coverage by WHO region. A colour-coded choropleth map where darker shades of red/orange indicate lower safely managed sanitation coverage and higher disease burden (Sub-Saharan Africa, South/East Asia), and lighter blue shades indicate higher coverage (North America, Europe, Australia). A legend showing percentage safely managed sanitation, and small inset bar charts for each region showing mortality attributable to unsafe WASH.*

Sources: Adapted from references[1,13]

7. DISCUSSION

This review confirms that environmental hygiene and sanitation interventions constitute one of the highest-value investments in global public health. The evidence from recent systematic reviews and meta-analyses consistently demonstrates large, clinically meaningful reductions in disease incidence attributable to WASH improvements. Critically, higher service levels, particularly safely managed water and sanitation, yield substantially greater gains than basic service provision, supporting the ambition of SDG 6 targets.[9,14,23]

Several important nuances emerge from the literature. First, the efficacy of WASH packages (combined multi-component interventions) appears to be limited by synergy constraints: improvements in water supply appear to be a prerequisite for hygiene and sanitation benefits, as adequate water quantity is needed to enable handwashing and defaecation practices.[23] This finding has important implications for programme design in resource-limited settings, suggesting that sequenced delivery, beginning with reliable water supply, may be more effective than simultaneous multi-component deployment.

Second, the role of antimicrobial resistance (AMR) as a downstream consequence of poor environmental sanitation is increasingly recognised. Open defecation and inadequate wastewater management facilitate the dissemination of AMR genes in the environment, compounding the global AMR crisis.[2,11] This linkage reinforces the argument for positioning WASH investment within AMR national action plans.

Third, climate change introduces an additional layer of complexity, with seasonal variation in WASH intervention effectiveness documented across multiple studies.[22] Climate-resilient WASH design, incorporating flood-resistant latrine construction, water source protection, and drought-adaptive water management, will be increasingly necessary to sustain health gains.

Limitations of this review include potential publication bias toward positive-outcome studies in the WASH literature, heterogeneity across study populations and intervention types, and the predominance of evidence from LMICs. There remains a need for context-specific evidence from fragile and conflict-affected settings.

8. CONCLUSION

Environmental hygiene and sanitation are indispensable determinants of infectious disease control and prevention. The cumulative evidence from 2020 to 2025 underscores that safely managed water, sanitation, and hygiene interventions can achieve dramatic reductions in the burden of diarrhoeal diseases, respiratory infections, HAIs, and vector-borne diseases. Achieving these gains at scale requires sustained political will, equitable resource allocation, robust governance frameworks, and

behaviour change communication strategies that are culturally sensitive and evidence-based.

The WHO Global Strategy on IPC (2023), SDG 6 commitments, and the growing evidence base for multimodal WASH and IPC strategies provide a coherent architecture for action. Pharmaceutical and public health scientists must advocate for the integration of environmental hygiene into antimicrobial stewardship programmes, health systems strengthening initiatives, and pandemic preparedness plans. Addressing the global sanitation deficit is not merely a humanitarian imperative, it is an indispensable component of achieving universal health coverage and sustainable health security.

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Conflicts of Interest
The authors declare no conflicts of interest.

Data Availability Statement
Not applicable. This is a review article.

Author Contributions

DECLARATIONS
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Author Contributions: Conceptualisation, literature search, writing, and critical review: all authors contributed equally.
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