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The Role of Water, Sanitation, and Hygiene (WASH) in Preventing Infectious Diseases: A Review of the Evidence

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ABSTRACT

Inadequate water, sanitation and hygiene (WASH) are major contributors to the global burden of infectious diseases in low and middle income countries. Poor or unsafe WASH conditions drive high rates of diarrhoeal diseases, soil-transmitted helminth infections, trachoma, and other communicable illnesses, disproportionately affecting children under five and contributing significantly to disability adjusted life years (DALYs). This narrative review synthesizes evidence on the effectiveness of WASH interventions in reducing infectious disease incidence and morbidity. We examine point-of-use water quality interventions, managed water systems, improved sanitation facilities, hygiene promotion, and integrated WASH packages. Evidence indicates that handwashing with soap consistently reduces diarrhoeal and respiratory infections, while improved sanitation and water supply interventions yield variable results depending on coverage, adherence, and environmental factors. Cluster randomized trials, including WASH Benefits and SHINE, highlight the limited impact of household level interventions without broader community coverage. Disease specific outcomes, such as cholera, typhoid, schistosomiasis, and healthcare associated infections, demonstrate that multi-component WASH strategies can interrupt transmission pathways, including faecal oral and hygiene mediated routes. Implementation challenges, including behaviour change, infrastructure reliability, governance, and equity considerations, are critical determinants of intervention success. Economic analyses underscore the cost-effectiveness of WASH programs, particularly when integrated with broader public health initiatives. This review identifies research gaps in long-term impact evaluation, pathogen specific outcomes, and equity focused assessments. Sustained investment in WASH infrastructure, community level intervention saturation, and evidence informed policy frameworks are essential to maximize the preventive potential of WASH against infectious diseases.

Keywords: *WASH, Infectious diseases, Sanitation, Hygiene, Water quality and Public health.*

Introduction

Infectious diseases remain a significant global health challenge, particularly in regions with inadequate water, sanitation, and hygiene (WASH) services. Unsafe or poor WASH conditions account for approximately 1.4 million deaths and 74 million disability adjusted life years (DALYs) annually, with the burden disproportionately affecting children under five years of age [1, 2]. Diarrhoeal diseases constitute the majority of this burden, causing nearly 829,000 deaths and 49.8 million DALYs globally, highlighting the critical link between WASH and child morbidity and mortality [3, 4]. These statistics are illustrated in Figure 1, which maps the age standardised death rate (ASDR) and DALY rate attributable to WASH-related diseases at the national level in 2019, showing the highest burdens concentrated in Africa and Southeast Asia [5]. Such patterns underscore the urgent need for effective interventions that ensure access to safe water, improved sanitation, and hygiene promotion, particularly in low- and middle-income countries where infrastructure gaps remain widespread.

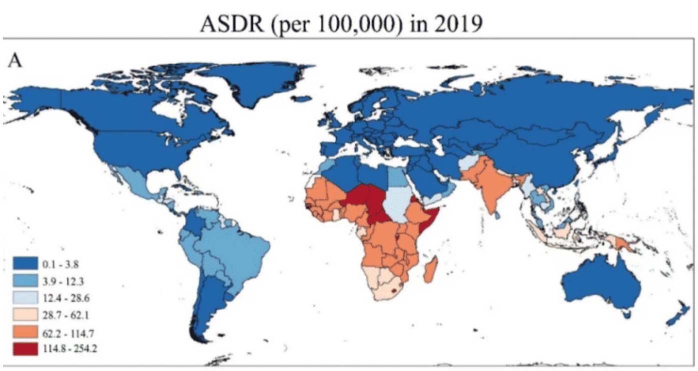
The transmission of infectious pathogens often follows faecal-oral, waterborne, and hygiene-mediated pathways. Contamination of drinking water and food with human faeces, inadequate sanitation facilities, and poor hand hygiene facilitate the spread of pathogens such as Vibrio cholerae, Salmonella Typhi, rotavirus, and soil transmitted helminths [1, 6]. **Figure 2** illustrates how WASH interventions act as barriers that disrupt these transmission pathways and reduce disease risk. Interruption of these pathways through WASH interventions is critical, as access to safe water, improved sanitation, and hygiene practices can significantly reduce exposure to infectious agents [7, 8]. WASH interventions, therefore, play a central role in public health, mitigating both immediate infection risks and long-term consequences such as stunting, undernutrition, and impaired cognitive development in children [9].

Despite recognition of WASH as a cornerstone of public health, evidence on the effectiveness of specific interventions shows considerable variability.

Systematic reviews indicate that handwashing with soap consistently reduces diarrhoeal and respiratory infections, yet the impact of water quality interventions, such as point-of-use chlorination or filtration, is more context-dependent [10]. Similarly, integrated WASH packages that combine water, sanitation, and hygiene interventions demonstrate mixed outcomes in cluster-randomised trials, including the WASH Benefits and SHINE studies [11, 12]. Factors such as adherence, infrastructure reliability, environmental contamination, and coverage levels are critical determinants of the observed effectiveness, emphasising the need to consider local context when implementing interventions.

A narrative review is well-suited to address these complexities by synthesizing evidence across different settings and study designs. By consolidating findings from randomized trials, observational studies, and meta-analyses, a narrative approach can highlight not only what interventions work but also the mechanisms behind their success or failure [13, 8]. This synthesis is especially important for informing policy and program design, identifying equity gaps, and understanding implementation barriers. Moreover, as WASH interventions are increasingly integrated with other health programs such as nutrition, immunization, and neglected tropical disease control, a comprehensive review can guide strategic allocation of resources to maximize health impacts.

This review aims to examine the role of WASH interventions in preventing infectious diseases across diverse contexts. It evaluates water quality and supply measures, including point-of-use treatments and managed water systems, as well as improved sanitation facilities and hygiene promotion, with particular focus on handwashing with soap. Integrated WASH packages are also assessed, highlighting evidence from household and community-level interventions. Disease-specific outcomes covered include diarrhoeal diseases, cholera, typhoid, soil-transmitted helminths, schistosomiasis, trachoma, and healthcare-associated infections, with attention to mechanisms such as interruption of faecal–oral transmission and reduction of environmental contamination. Implementation considerations behaviour change, coverage, infrastructure reliability, governance, and equity, especially for marginalized populations and women, are discussed. Finally, the review addresses policy relevance, cost-effectiveness, and alignment with Sustainable Development Goal 6, while identifying gaps for future research to inform evidence-based WASH programming and investment strategies.



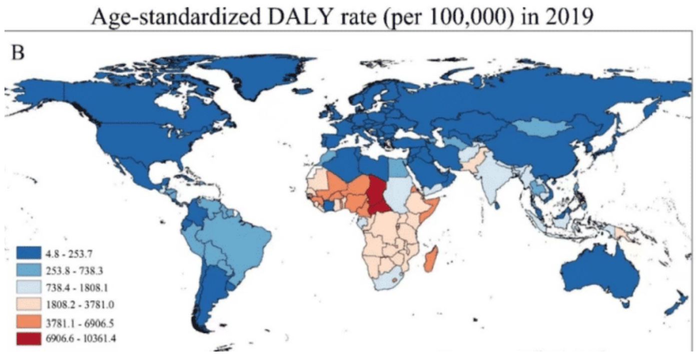


Figure 1. ASDR (Panel A) and age-standardised DALY rate (Panel B) per 100 000 at national level in 2019 (both sexes, all ages). ASDR – disability-adjusted death rate, DALY – disability-adjusted life year. The maps show the global variation in WASH attributable disease burden in 2019. Countries in Africa and Southeast Asia exhibit the highest age-standardised death (ASDR) and DALY rates, while high income regions display much lower burdens. The figure highlights substantial geographic disparities, with some countries showing marked reductions over time.
Source: *Zeng et al. [5]*

WASH and Infectious Disease Prevention and Intervention

Access to safe water, adequate sanitation, and good hygiene practices is fundamental for preventing infectious diseases. WASH interventions disrupt key transmission pathways, including faecal–oral, waterborne, and hygiene-mediated routes, which are responsible for a large proportion of diarrhoeal diseases, soil-transmitted helminths, and other infections [1, 7] (**See Figure 2**). Evidence from systematic reviews and field studies demonstrates that both household-level measures (e.g., point-of-use water treatment) and community-level infrastructure improvements (e.g., piped water, sanitation coverage) can significantly reduce morbidity and mortality [8, 14]. However, the magnitude of health benefits often depends on intervention coverage, adherence, environmental context, and complementary hygiene practices, highlighting the importance of integrated approaches. This section synthesizes the evidence on how water quality, sanitation, hygiene, and combined WASH interventions contribute to infectious disease prevention. **Table 1** summarises key evidence on WASH interventions and their effects on infectious disease prevention, highlighting water, sanitation, hygiene, and integrated approaches along with their observed health outcomes.

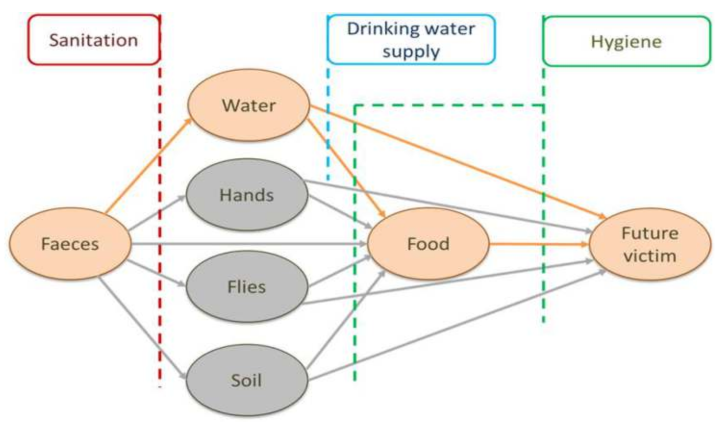


Figure 2. Diseases transmission via fecal-oral routes (arrows) and how WASH act as barriers (dashed lines) for these transmission routes. This figure highlights the transmission pathways of infectious agents and illustrates how WASH interventions such as safe water supply, improved sanitation, and hygiene practices can disrupt these pathways and reduce the risk of disease spread.
Source: *[15, 16]*

Water Quality and Supply

Point-of-use (POU) interventions for water treatment, such as chlorination, filtration, and solar disinfection have been strongly associated with reductions in diarrhoeal disease in low and middle-income countries. A systematic review of POU chlorination showed a pooled relative risk (RR) of 0.71 i.e 29%(95% CI: 0.58–0.87) for childhood diarrhoea, with greater effect sizes in studies that combined treatment with safe storage and educational components [17]. Similarly, a recent meta-analysis found that household water filtration can reduce diarrhoeal disease by approximately 50%, while solar water disinfection (SODIS) can reduce it by around 37% compared with untreated or unimproved water sources [18]. **Figure 3** complements these findings by illustrating the broader impact of water access on parasitic infections. Communities with less than 20% coverage of improved drinking water experienced markedly higher prevalence and severity of soil-transmitted helminth (STH) and schistosomiasis infections, highlighting that limited access to safe water not only increases diarrhoeal disease risk but also exacerbates parasitic burdens.

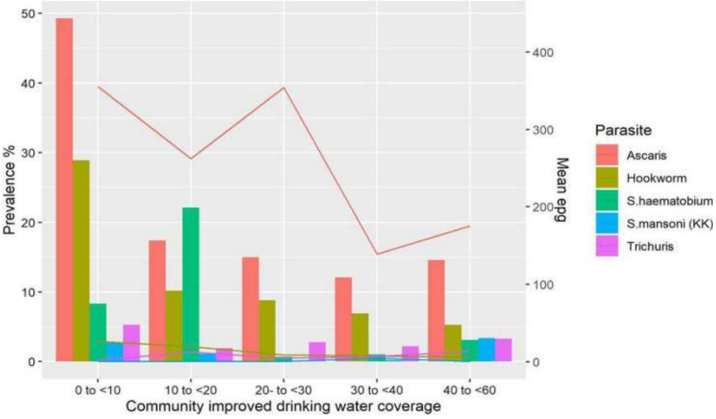


Figure 3. Prevalence of STH (Soil-Transmitted Helminth) and schistosomiasis infection by community access to improved drinking water. The chart depicts that Communities with less than 20% improved drinking water coverage had higher rates of STH and schistosomiasis infection, both in terms of prevalence and severity.
Source: *Phillips et al. [19]*

A more focused systematic review on SODIS found a pooled RR of 0.62 (95% CI: 0.53–0.72), indicating a 38% reduction in childhood diarrhoea risk [20] (See figure 4). However, the long-term effectiveness of SODIS can be limited by recontamination, since there is no residual disinfectant after treatment; safe storage practices are critical to protect treated water [20]. Beyond POU methods, managed water systems especially piped water supply on premises offer sustained potential for health benefits. For example, in a comprehensive meta-analysis, provision of improved water supply directly in homes was associated with a 52% reduction in diarrhoea risk (RR = 0.48) compared to unimproved water sources [18]. Yet, these infrastructure based benefits can be undermined in low-resource settings by supply intermittency, low pressure, frequent leaks, lack of disinfection, and storage behaviours that allow recontamination [18].

Effectiveness of water-quality interventions is further mediated by uptake, fidelity, and environmental factors. Reinforcing consistent use and correct handling is essential: if households do not treat water regularly, or if treated water is wrongly stored, the health benefits diminish [21]. In addition, piped systems may suffer from infrastructure failures, and water may become contaminated through backflow or infiltration, especially when pressure drops or pipes are broken [18].

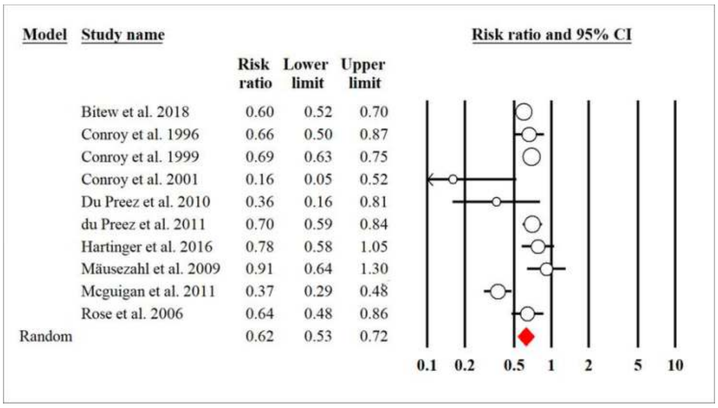


Figure 4. Forest plot showing pooled risk ratio and corresponding 95% CIs of solar disinfection water treatment to reduce childhood diarrhoea. This figure shows that the total pooled RR of childhood diarrhea reported by the ten studies employing the random-effects model was 0.62 (95% CI 0.53 to 0.72). These suggest that the SODIS water treatment procedures considerably reduced the impact of diarrhea by 38%.
Source: *Soboksa et al. [20]*

Sanitation

Improving sanitation facilities such as installing household latrines or connecting to sewer systems has demonstrable effects on reducing diarrhoeal disease, soil-transmitted helminth (STH) infections, and other conditions. In the large meta-analysis by the WHO, basic sanitation reduced diarrhoea risk by 24% (RR = 0.76), and sewer connection was associated with a 47% reduction (RR = 0.53) compared with unimproved sanitation [18]. Regarding STH infections, observational and trial data provide more nuance. A systematic review in Parasites and Vectors observed that improved WASH including sanitation, was associated with 33–70% lower odds of infection with helminths (e.g., Ascaris, Hookworm) in observational studies [22]. However, when examined in randomised trials, the results are more modest or mixed. For instance, the Cochrane review of WASH interventions for STH prevention found only a slight reduction (~14%) in odds of any STH infection in pooled RCTs [23].

Community level coverage is particularly important for sanitation's protective impact. When sanitation is widely adopted, environmental faecal contamination declines, reducing risk for even those without individual latrines [8]. Empirical data support this; sanitation interventions not only reduce individual exposure but can lower community-level pathogen load, amplifying health benefits. This pattern is illustrated in Figure 5, which shows that communities with poor sanitation coverage (especially below 20%) had higher prevalence and severity of STH infections, while schistosomiasis prevalence was not significantly affected by sanitation coverage. However, sanitation interventions face critical limitations when coverage remains low, or environmental contamination persists. In a cluster-randomised trial nested within the WASH Benefits study in Kenya, providing latrines and child feces management tools did not significantly reduce soil STH egg prevalence in household soil, suggesting that simply building latrines may be insufficient without sufficiently high usage, coverage, or complementary sanitation behaviors [24]. Moreover, shared latrines, poor maintenance, and animal feces can undermine the effectiveness of sanitation interventions, making environmental contamination persistent despite infrastructure [24].

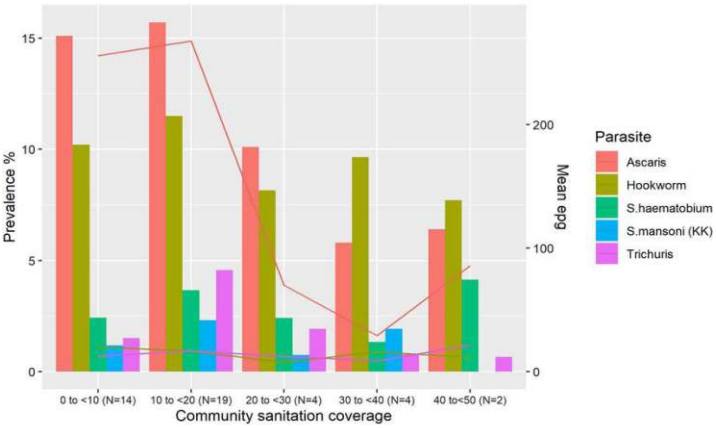


Figure 5. Prevalence of STH (Soil-Transmitted Helminth) and schistosomiasis infection by community sanitation coverage. The figure illustrates the relationship between parasitological outcomes and community-level sanitation. There were no villages with an average increased sanitation coverage of more than 50%. The prevalence and severity of STH infection were generally higher in those who lived in areas with poor sanitation utilization (especially less than 20%). The prevalence and severity of schistosomiasis were not significantly impacted by community sanitation coverage.
***Source:** Phillips et al. [19]*

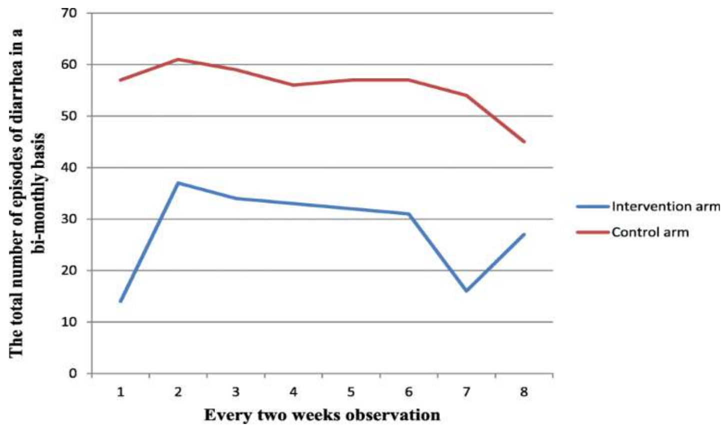


Figure 6. Total number of episodes of diarrhea recorded at 2-week observations of handwashing intervention and control groups in rural Dire Dawa, eastern Ethiopia, 2019. The chart shows that there were 224 diarrheal episodes in the intervention arm (6.9 episodes per 100 person weeks of observation) compared to 446 incidents in the control arm (13.8 episodes per 100 person weeks of observation).
***Source:** Solomon et al. [27]*

Hygiene Practices

Handwashing with soap is one of the most effective hygiene-based interventions for reducing the transmission of infectious diseases. Meta-analyses have consistently shown that improvements in drinking water and sanitation reduce the risk of diarrhoeal disease in children [25]. More recent evidence from a WHO-led systematic review found that handwashing promotion, with or without additional hygiene education, reduces childhood diarrhoea by approximately 30% (RR = 0.70) in low and middle income settings [18]. Observational studies further indicate that poor hand hygiene significantly increases the risk of infection, although effect sizes vary depending on the population and setting. Figure 6 illustrates these effects in a field study in rural Dire Dawa, Ethiopia, showing that the intervention group practicing regular handwashing experienced 224 diarrhoeal episodes (6.9 episodes per 100 person-weeks), compared to 446 episodes (13.8 per 100 person-weeks) in the control group, highlighting the substantial reduction achieved through consistent hand hygiene. Beyond diarrhoeal disease, consistent handwashing interrupts multiple transmission pathways, contributing to the prevention of respiratory infections and certain neglected tropical diseases [8]. However, behavior change is central, providing soap and building handwashing stations are not enough. Sustained adoption depends on regular messaging, reminders, and making hygienic practices socially normative. Accessibility is another critical factor. If water for handwashing is scarce or soap is unavailable, even motivated households struggle to maintain good hand hygiene. Over time, adoption can fade if infrastructure (handwashing stations) breaks down or if upkeep (refilling soap, water) is not prioritized, reducing the long-term health benefit [26].

Combined WASH Interventions

Integrated WASH interventions are designed to block multiple transmission routes by improving water quality, sanitation, and hygiene, but major trials show their real-world impact is modest. Findings from the WASH Benefits trials in Bangladesh and Kenya and the SHINE trial in Zimbabwe demonstrated that, despite strong implementation fidelity, combined WASH did not produce additive effects on child linear growth or diarrhoea [12]. Bangladesh saw some diarrhoea reduction, but Kenya did not, and none of the trials improved growth.nA key explanation is insufficient community-level coverage. In Bangladesh, only around 10% of village residents were reached, limiting community-wide reductions in faecal exposure [28].

World Bank analyses similarly stress that high sanitation coverage across communities not isolated households, is necessary in dense environments where pathogens move easily between neighbours [29]. Environmental contamination evidence supports this. A recent meta-analysis found only small reductions in pathogen prevalence (pooled PR ≈ 0.94; 95% CI: 0.90–0.99) and no significant change in human or animal MST markers after WASH interventions [30], indicating persistent environmental transmission. However, context-tailored, multisector approaches can achieve stronger results. In rural Kenya, a programme combining WASH with MCH, nutrition, and ECD interventions produced a 58.2% reduction in all-cause diarrhoea, compared with 22.2% in control areas (95% CI: 39.4–75.3 and 5.9–49.4, respectively) [31]. Overall, the evidence shows that adding WASH components alone is not enough. High community saturation, addressing environmental reservoirs (soil, animal faeces, shared spaces), sustained behaviour change, and embedding WASH within broader health systems are essential for meaningful health impacts.

Table 1. Comprehensive evidence of WASH interventions in preventing infectious Diseases

Intervention type	Region	Key findings	References
Point-of-use chlorination	Developing countries	Chlorination reduced child diarrhoea by 29% (RR = 0.71).	[17]
Combined WASH interventions	LMICs	Overall WASH interventions reduced diarrhoea by 17% (RR = 0.83). Handwashing with soap: 30% reduction. Sanitation: ~ 24% reduction (RR ≈ 0.76). Pooled RR ~ 0.68 (i.e., ~ 32% reduction) for water interventions overall.	[18]
Drinking water, sanitation, handwashing	LMICs	For point-of-use (POU) filtration + safe storage, they report RR = 0.39, i.e. 61% reduction. pooled water intervention: RR ≈ 0.68 (i.e. about 32% reduction). handwashing 30% reduction, sanitation 26% reduction in childhood diarrhoe.	[32]
Solar water disinfection (SODIS)	Multiple developing regions	SODIS reduced childhood diarrhoea by 38% (RR = 0.62).	[20]
Water, sanitation and hygiene interventions	Multi-country	Interventions led to a small reduction in pathogen detection in the environment: Prevalence ratio (PR) ≈ 0.94, i.e., ~6% reduction overall. Bacterial pathogens: PR ≈ 0.92 → ~8% reduction Viruses: PR ≈ 0.90 → not statistically significant, effects varied by study	[30]
Integrated WASH + health + nutrition	Kenya	Diarrhoea prevalence: ~58% reduction in the intervention site. Water microbial quality: Substantial improvement; 81.9% of water samples met microbial-quality standards, with reduced detection of pathogenic E. coli.	[31
Water filtration	Rural settings	Point-of-use water filtration reduced diarrhoea by ~52% (RR ≈ 0.48) in rural settings.	[13]
Handwashing + water treatment	Bangladesh	Soap-based handwashing reduced diarrhoea by ~40%. Water treatment alone had little effect. Combined WASH interventions showed no additional benefit over single interventions.	[26]
Handwashing with soap	LMICs	Handwashing with soap reduced diarrhoea by ~40% unadjusted, and ~23% after bias adjustment across 30+ trials.	[8]
Sanitation interventions	Sub-Saharan Africa	Sanitation interventions improved latrine coverage and environmental hygiene. No significant reduction in diarrhoea was observed in this trial.	[11]
Community sanitation coverage	LMICs	Observational studies suggest reductions of ~35–45% when coverage is ≥60–90%.	[23]
Household water treatment	Global	Point-of-use water treatment reduces diarrhoea: Chlorine: ~25% reduction. Filtration: ~50% reduction	[33]
Combined WASH	Bangladesh	Combined WASH reduced diarrhoea by ~31%. Environmental pathogen reduction occurred in stored drinking water, but not consistently in soil, hands, or food.	[34]
WASH global burden	Global	Inadequate WASH caused ~829,000 diarrhoeal deaths/year	[1]

Disease-Specific Evidence

Understanding the disease-specific impacts of water, sanitation, and hygiene (WASH) interventions is essential for evaluating their role in reducing infectious disease burdens across diverse epidemiological contexts. Although WASH broadly reduces exposure to enteric and environmentally mediated pathogens, different diseases respond to interventions through distinct transmission pathways and environmental dynamics. Figure 7 illustrates this relationship, showing that under-5 children in households with improved sanitation, water, and child excreta disposal facilities experienced lower prevalence of diarrhoea, fever, and chronic cough compared to those without improved facilities [35]. Evidence accumulated from randomized controlled trials, observational studies, and meta-analyses demonstrates variable but often substantial protective effects across diarrhoeal diseases, cholera, typhoid, neglected tropical diseases such as soil-transmitted helminths and trachoma, and healthcare-associated infections. Examining these conditions individually helps clarify the mechanisms such as reduced pathogen ingestion, decreased environmental contamination, and interruption of person-to-person spread through which WASH improvements contribute to disease prevention and control.

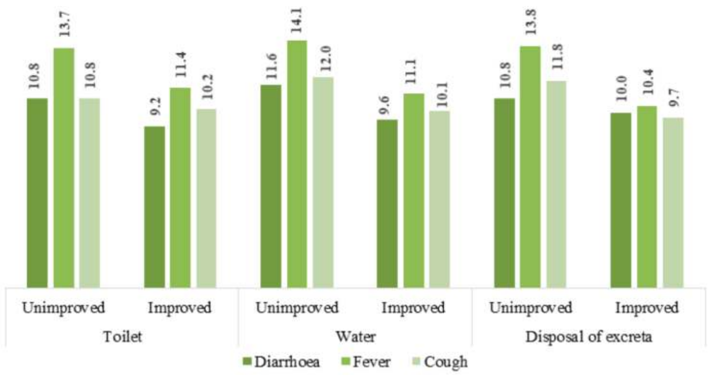


*Figure 7. Prevalence of diarrhoea, fever and cough among under-5 children stratified by type of toilet, water, and child's excreta disposal facilities. This figure illustrates the prevalence rates of diarrhoea, fever and chronic cough among households with and without access to improved sanitation, water and child excreta disposal facilities. It revealed that household that had improved facilities also had lower rates of prevalence of all three types of diseases. **Source:** He et al. [35]*

I. Diarrhoeal Diseases

Diarrhoeal disease has the strongest and most consistent evidence linking WASH improvements to reduced morbidity in children. Point-of-use water treatment (chlorination, filtration, SODIS) and promotion of handwashing with soap show consistently protective effects in meta-analyses and randomized trials: pooled analyses report relative risk reductions in childhood diarrhoea on the order of ~25–40% for household water treatment and ~25–35% for handwashing interventions [14, 17, 18]. Community-scale piped or reliably managed water supplies yield larger and more sustained reductions where they provide continuous safe water on premises [1, 18]. However, large cluster trials (e.g., WASH Benefits, SHINE) show that household-level WASH packages do not always produce expected reductions in child growth or diarrhoea when community contamination persists or when coverage/adherence is low, highlighting the importance of implementation fidelity and community saturation [12]. Mechanistically, water treatment reduces pathogen ingestion by lowering organism concentrations in drinking water; handwashing interrupts person-to-person and foodborne transmission by removing pathogens from hands; and reliable piped supplies reduce exposure pathways that arise from unsafe sources and unsafe storage [17, 18, 30].

Figure 8. WASH methods of Diarrhoea prevention. This figure illustrates key WASH methods for diarrhoea prevention, highlighting how access to safe water, improved sanitation, and proper hygiene practices disrupt transmission pathways and reduce disease risk.
Source: *http://blog.ebolaalert.org/dear-lagosians-staysafe-from-diarrhoeal-diseases/*

i. Cholera (prevention and outbreak control)

Cholera is highly waterborne and responds rapidly to targeted WASH actions. During outbreaks, household water treatment, safe storage, point-of-use chlorination, rapid repair of broken supply links, household disinfection of drinking water, and intensive hygiene promotion for case households are core measures recommended by WHO and evidence syntheses [36, 37]. Systematic reviews of cholera case-control studies and program reports show that improved water quality and immediate safe-water measures are associated with substantially lower cholera risk; interventions in outbreak settings are judged effective when combined with surveillance, case-finding, and vaccination where appropriate [18, 36]. The principal mechanisms are removal or inactivation of Vibrio cholerae in drinking water, interruption of faecal-oral transmission during care and food preparation, and reduced environmental contamination in households and communal points [18, 36].

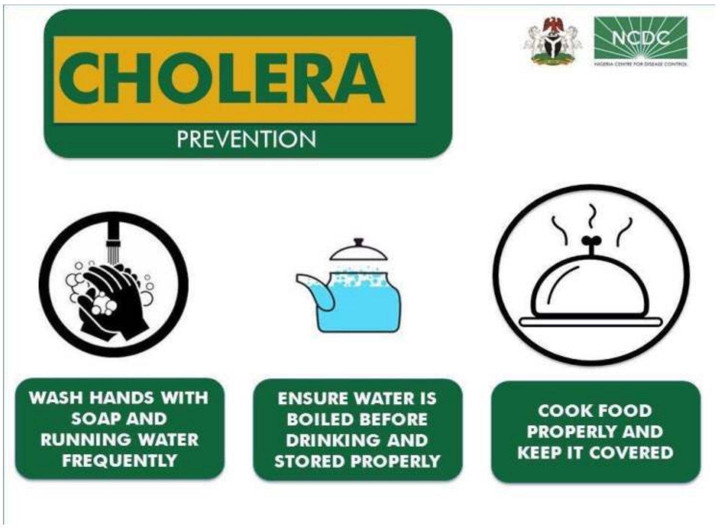


Figure 9. Common Cholera prevention practices. The figure highlights common cholera prevention practices, including safe water use, proper sanitation, hand hygiene, and food safety measures.
Source: *https://nigeriahealthwatch.medium.com/federal-ministry-of-health-supports-borno-state-response-to-outbreak-of-cholera-4a3d614840f6*

i. Typhoid and Enteric Fever

Evidence for WASH protection against typhoid/enteric fever is biologically plausible and supported by observational and intervention studies: improved drinking water supplies, piped connections, and sanitation are associated with lower typhoid incidence in ecological and case-control studies [1, 18]. Randomized trials specifically targeting typhoid are rare, but evaluations of safe water and sanitation scale-ups indicate declines in enteric fever incidence where safe, piped water and sewage removal are implemented. Mechanistically, typhoid reduction follows reduced ingestion of Salmonella Typhi from contaminated water/food and from blocked environmental reservoirs. Integrating WASH with surveillance and vaccination yields the strongest outbreak and long-term control [1].

ii. Soil-Transmitted Helminths (STH) and Schistosomiasis

WASH interventions are widely promoted as complementary to preventive chemotherapy for STH and schistosomiasis. Systematic reviews and program evaluations show that sanitation and safe faeces management reduce odds of STH infection (species-specific effects vary), and water quality or reduced contact with contaminated water can lower schistosome exposure where snail hosts are present [34]. The pooled RCT evidence is mixed: some trials and meta-analyses report modest reductions in STH prevalence attributable to sanitation and water improvements, while others show limited incremental benefit when mass drug administration is ongoing, largely because environmental reservoirs and reinfection dynamics require high sanitation coverage and sustained behaviour change to interrupt transmission [23, 34]. Mechanisms include preventing faecal deposition into the environment (sanitation), reducing hand-to-mouth ingestion of eggs (hygiene), and reducing contact with infested water bodies (safe water and environmental management).

iii. Trachoma

Evidence linking WASH to trachoma control focuses on facial cleanliness (F) and environmental improvement (E) components of the SAFE strategy. Observational studies and meta-analyses indicate that regular face washing and access to water and sanitation are associated with lower prevalence of active trachoma; however, randomized trials that isolate WASH effects are fewer and results variable [38]. WASH likely reduces trachoma by decreasing ocular/nasal discharge that attracts flies and by lowering transmission via hands, flies and fomites. Given this mechanistic plausibility, integrating hygiene/face-washing promotion with antibiotic distribution and environmental sanitation remains the recommended approach [38].

iv. Healthcare-Associated Infections (HCAIs)

Within healthcare settings, basic WASH safe water, functional sanitation, hand hygiene infrastructure (running water or alcohol-based rubs), and safe waste management is central to preventing HCAIs. Systematic evidence in low-resource facility settings shows that improved water and hand hygiene reduce rates of neonatal sepsis, surgical site infections and other facility-acquired infections when combined with infection prevention and control practices [1]. Mechanistically, WASH interrupts patient-to-patient and patient-to-staff transmission, reduces environmental contamination of surfaces and instruments, and enables safe delivery and post-natal care.

Table 2. Comprehensive evidence summary of WASH interventions and disease specific impacts

Diseases	Key WASH interventions	Exact Reports	Sources
Diarrhoeal diseases	Handwashing with soap, Point-of-use chlorination, Household filtration, SODIS (solar disinfection) and Safely managed piped water (on-premises, continuous).	Reports shows a measurable %reduction in diarrhoea.	[14, 17, 18, 20]
Cholera	Rapid POU chlorination, safe storage, household disinfection, hygiene promotion, repair of supply breaks	Program and outbreak evaluations report substantial reductions, POU chlorination and safe storage repeatedly identified as core effective measures in outbreak response guidance.	[18]
Typhoid / enteric fever	Improved piped water; sanitation; food hygiene	Observational / program data show reduced incidence where piped water and sanitation are improved. Exact effect sizes vary by study and context.	[1, 18]
Soil-transmitted helminths (STH)	Sanitation, safe faeces disposal, combined WASH + MDA	Systematic reviews report modest reductions. RCT evidence mixed — sanitation associated with lower odds in observational syntheses but effect sizes smaller or non-significant in many RCTs unless coverage is high.	[30, 34]
Schistosomiasis	Reduced human water contact (piped water), sanitation, snail control	Program evaluations show substantial prevalence declines when water contact is reduced and environmental control is done; quantified effects vary by setting and combined interventions	[34, 36]
Trachoma	Facial cleanliness (face washing), sanitation	Observational/meta-analytic associations: face washing and improved water access associated with lower active trachoma prevalence	[38]
Healthcare-associated infections (HCAIs)	Facility water, sanitation, hand hygiene + IPC	Facility WASH + IPC shown to reduce neonatal sepsis and surgical site infections in program studies	[1, 36].

Implementation Considerations

The effectiveness of WASH interventions in real-world settings depends not only on the technologies provided but also on the social, environmental, and governance contexts in which they are implemented. Key determinants include service coverage, user uptake, infrastructure functionality, behavioural adherence, and broader structural factors such as equity, gender, and governance. Reliable coverage and sustained uptake are central to achieving meaningful health gains. Studies consistently show that high community level coverage amplifies impact, while partial adoption reduces the likelihood of disrupting transmission pathways [8, 39]. Behaviour change remains one of the most challenging components; interventions such as handwashing and sanitation require continuous reinforcement, supportive social norms, and easy access to materials like soap and clean water [40]. Without long-term engagement strategies, behaviour often declines after initial project periods. Infrastructure reliability is another limiting factor, particularly in low-resource settings where water systems suffer from intermittent supply, poor maintenance, and financial constraints. Non-functional sanitation facilities and irregular water availability undermine user trust and reduce consistent use [41]. Effective governance including clear institutional responsibilities, adequate financing, and transparent monitoring greatly influences whether systems remain functional over time.

In humanitarian and emergency contexts, WASH interventions are critical for preventing outbreaks of cholera, diarrhoea, and other infections. However, challenges such as displacement, insecurity, and rapid population movement make coverage and quality difficult to maintain [42]. Emergency WASH responses must therefore be rapid, context-specific, and integrated with health and nutrition services. Equity and gender considerations shape both access to WASH and the distribution of burdens. Marginalized groups, including rural communities, people with disabilities, urban slum residents, and the poorest households, disproportionately face unsafe water and inadequate sanitation [43]. Women and girls experience unique vulnerabilities: they are primarily responsible for water collection, face higher risks of harassment when using distant or unsafe sanitation facilities, and require inclusive WASH services for menstrual hygiene and maternal health. Incorporating gender-transformative approaches, accessible infrastructure, and community participation is therefore essential to ensure that WASH interventions produce equitable and sustainable health benefits.

Economic and Policy Implications

Economic analyses consistently show that WASH interventions provide strong value for money. Global cost–benefit studies by WHO estimate that both water supply and sanitation generate returns greater than their investment when accounting for reduced illness, medical savings, productivity gains, and time saved from water collection [44, 45]. Hygiene promotion is among the most cost-effective public health actions: WHO [46], reports that investing about US$1 per person annually in hand hygiene in low-income settings could prevent hundreds of thousands of infections each year. Recent economic evaluations further confirm that point-of-use water treatment and sanitation improvements are cost-effective for reducing diarrhoeal disease when coverage and adherence are sufficient [47].

From a policy perspective, long-term health and economic benefits depend on reliable infrastructure, sustained behaviour change, and effective maintenance. Integrating WASH with nutrition, immunization, and neglected tropical disease programmes enhances impact and is strongly recommended by global guidelines [48]. Achieving SDG 6 also requires policies that address equity: subsidised services for poor households, gender-responsive planning, and prioritization of rural and informal settlements remain essential to ensuring universal access and maximizing health gains [1].

Research Gaps and Future Directions

Despite substantial progress, important evidence gaps remain in understanding the full impact of WASH interventions on infectious diseases. First, many pathogen-specific outcomes such as effects on enteric viruses, protozoa, and emerging antimicrobial-resistant organisms are still poorly quantified because most trials rely on caregiver-reported diarrhoea rather than molecular detection [30]. Long-term follow-up studies are also limited; most randomized trials evaluate outcomes over one to two years, leaving uncertainties about durability, behavioural decay, and sustained health effects.

Economic and cost-effectiveness analyses remain uneven, especially in low-income and humanitarian settings where infrastructure reliability and supply chains frequently affect implementation [45]. In addition, equity-focused evaluations examining how WASH outcomes differ for women, people with disabilities, informal settlement residents, displaced populations, and other marginalized groups are still insufficient, even though inequity remains a major barrier to achieving SDG 6 [49].

Future research must prioritize community-saturated and context-specific interventions rather than isolated household approaches, acknowledging evidence from large trials showing that limited coverage undermines population-level impact [12]. Improved environmental monitoring using microbial source tracking, pathogen quantification, and exposure mapping will help clarify transmission pathways and intervention mechanisms [30]. Integrated WASH strategies that combine behaviour change, infrastructure reliability, nutrition, and infection-prevention programs are also needed to address the multifactorial nature of enteric and environmentally mediated diseases. Strengthening mixed-methods research, implementation science, and locally led innovation will be essential for developing scalable, resilient, and context-appropriate WASH solutions in the years ahead.

Conclusion

Water, sanitation, and hygiene interventions remain central to reducing the global burden of infectious diseases, with strong evidence showing that improvements in water quality, sanitation access, and hygiene practices can substantially lower exposure to harmful pathogens. However, experience from diverse settings demonstrates that household-level interventions on their own are often not enough to achieve large, sustained health gains. True impact depends on broad community coverage, consistent behaviour change, reliable infrastructure, and the reduction of environmental contamination at scale. Integrated approaches that combine safe water provision, improved sanitation, hygiene promotion, and complementary health strategies offer the most promising pathway to durable disease prevention. Moving forward, evidence-informed policy, stable funding, and long-term investment in WASH systems will be essential to protect population health, strengthen resilience, and advance progress toward universal access to safe and sustainable WASH services.

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Conflict of Interest

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