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THE HIDDEN BURDEN: ASSESSING THE EMPIRICAL GAPS IN RESEARCH LINKING WATER, SANITATION, AND HYGIENE (WASH) TO CHILDHOOD ACUTE INFECTIONS IN LOW- AND MIDDLE-INCOME COUNTRIES

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ABSTRACT

Sustainable Development Goal 3 (SDG 3) emphasizes ensuring healthy lives and promoting well-being for all. However, child mortality in low- and middle-income countries (LMICs) remains unacceptably high, largely due to inadequate access to clean water, sanitation, and hygiene (WASH) services. This persistent health challenge threatens LMICs' progress toward SDG 3 by 2030. This systematic review assessed the current scope of empirical research examining child health outcomes associated with WASH access across LMICs, identifying global gaps in evidence related to diarrhea, child development and stunting, and acute infections (excluding diarrhea). Following PRISMA guidelines, a comprehensive search was conducted in June 2025 across Taylor & Francis, EBSCOhost, and PubMed, yielding 230 records. After removing duplicates, 111 studies were screened, and 48 met inclusion criteria for thematic and content analysis. Only empirical studies reporting measurable child health outcomes were included. Findings revealed a disproportionate research emphasis: diarrhea accounted for 62.5% of all outcomes, reflecting its major global health burden. Child development and stunting represented 29.17%, while acute infections, such as respiratory infections, helminths, and trachoma, were severely underrepresented (8.33%). Geographically, evidence was highly concentrated in Ethiopia (29.0%) and India (25.8%), limiting generalizability. The most common independent variables were specific WASH components (e.g., sanitation, handwashing). Critical theoretical and methodological gaps were identified: 92.6% of studies lacked explicit theoretical frameworks, and most relied on cross-sectional designs, limiting causal inference. Moreover, 96.6% failed to test mediating variables, leaving mechanisms linking WASH and acute infections poorly understood.

Keywords: *WASH, Child Health, Diarrhea, Stunting, Systematic Review, Acute Infections, Public Health.*

INTRODUCTION

The provision of and access to safe water, adequate sanitation, and essential hygiene practices (WASH) is universally acknowledged as a cornerstone of sustainable human development and a fundamental prerequisite for global public health. In low- and middle-income countries (LMICs), the deficits in these basic services continue to perpetuate cycles of poverty and poor health, placing an enormous and disproportionate burden on the youngest populations. While the mortality associated with diarrheal disease is well-documented and forms a central focus of global health initiatives, the wider spectrum of acute infections linked to poor WASH conditions often receives insufficient attention, creating a significant and perilous gap in the global evidence base. The failure to comprehensively research the impact of WASH on non-diarrheal acute infections risks underestimating the true public health dividend of WASH interventions and diverting critical resources away from highly effective, yet under-recognized, control strategies.

Globally, the scale of the challenge posed by inadequate WASH remains monumental. As reported by the WHO/UNICEF Joint Monitoring Programme (JMP) in 2023, billions of people worldwide still lack access to safely managed services: 2.2 billion lack safely managed drinking water, and 3.5 billion lack safely managed sanitation. Furthermore, an estimated 2.3 billion people do not have basic handwashing facilities with soap and water at home. These deficiencies create an environment rife with pathogens, facilitating the fecal-oral transmission of disease, as well as the spread of aerosolized, vector-borne, and contact-based infections. The direct consequences of this pervasive infrastructural and behavioral deficiency extend far beyond the well-known threat of diarrhea to include a wide array of non-diarrheal acute infections that contribute significantly to childhood morbidity and mortality. Among the most critical of these are Acute Respiratory Infections (ARIs), such as pneumonia and bronchitis.

While often considered separate from the WASH domain, ARIs, particularly pneumonia (the single leading infectious cause of death for children under five globally), are strongly linked to poor household hygiene. Poor handwashing practices can transmit respiratory pathogens (via hands contaminated with fecal matter or respiratory secretions), and inadequate sanitation can contribute to overall household microbial load, weakening a child's immune response. In addition, the lack of improved sanitation often leads to open defecation, which increases exposure to Soil-Transmitted Helminths (STHs), including roundworm, whipworm, and hookworm. These

parasites cause acute infections that lead to anemia, malnutrition, and impaired cognitive development. Though often chronic in their impact, the initial infection, the worm burden, and secondary bacterial infections that arise from the parasitic damage to the gut are acute events. Other acute infections include Trachoma, the leading infectious cause of blindness worldwide, whose transmission is directly and intimately linked to facial cleanliness and adequate access to water for hygiene purposes, as well as skin infections (e.g., scabies and impetigo) that are prevalent in environments lacking basic hygiene. The morbidity and associated co-morbidities from these acute infections place immense stress on LMIC healthcare systems and severely undermine a child's health trajectory.

The disproportionate burden of these WASH-attributable acute infections is acutely felt in Sub-Saharan Africa (SSA). In this region, only 31% of the population had access to safely managed drinking water and 24% to safely managed sanitation as of 2022. The resulting environmental contamination drives endemic infectious diseases. In Kenya, for example, while diarrheal disease accounts for a significant portion of child morbidity, the entire spectrum of WASH-related acute infections further stresses the vulnerable population. The national health statistics consistently show ARIs as a major cause of hospital visits and mortality among children under five. In Kenya, nearly 10 million people still rely on contaminated surface water, a practice that facilitates the spread of bacterial and parasitic agents responsible for not only diarrhea but also various other acute infections. The endemic nature of these acute diseases, compounded by high rates of open defecation (practiced by millions), makes the population highly susceptible to the non-diarrheal acute infections that are often overlooked in WASH literature.

Despite the clinical evidence that strongly links inadequate water access, poor sanitation, and deficient hygiene to this broad array of non-diarrheal acute infections, a profound empirical gap exists. This systematic review aims to bring this issue to the forefront by quantitatively demonstrating the current neglect of acute infections (which accounted for only 8.33% of the outcomes in the reviewed literature) compared to diarrhea (62.5%). The objective is to synthesize the current evidence landscape and rigorously identify the systematic gaps theoretical, methodological, and empirical that have prevented a comprehensive understanding of the impact of WASH interventions on this hidden, yet vital, category of childhood illness. By focusing on this

critical oversight, this manuscript seeks to guide future research toward a more holistic, robust, and ultimately more impactful public health agenda.

MAIN BODY: SYSTEMATIC REVIEW FINDINGS ON ACUTE INFECTIONS AND WASH

The systematic review was conducted in June 2025 with the explicit aim of gathering and synthesizing empirical research linking WASH to comprehensive child health outcomes, including the neglected domain of acute infections. The methodology strictly followed the PRISMA guidelines to ensure an unbiased, transparent, and reproducible process for literature retrieval and assessment. The comprehensive search strategy utilized keywords such as "Water, Sanitation and Hygiene (WASH)," "Children health outcomes," "Diarrhoea," "Acute infections," and "Child development," ensuring the inclusion of studies that examined the non-diarrheal health outcomes of interest. The search was executed across major academic repositories, including Taylor and Francis, Ebscohost, and PubMed, among others.

The PRISMA selection process began with an initial identification of 230 records. After a thorough de-duplication process removed 119 records, 111 unique studies remained for screening. The established Inclusion Criteria stipulated that studies must be empirical journals reporting primary research with child health outcomes as the dependent variable. Crucially, the Exclusion Criteria eliminated non-empirical papers and secondary reviews. This rigorous assessment led to the exclusion of 63 records based on titles and abstracts, culminating in a final, core sample size of 48 empirical journals selected for the final synthesis and thematic analysis. This final cohort of studies formed the evidence base from which the extent of research into acute infections was quantified.

ACUTE INFECTIONS: THE EMPIRICAL CRISIS OF NEGLECT

The content analysis categorized the dependent variables from the 48 included studies into three primary themes: Diarrhea, Child Development & Stunting, and Acute Infections. The resulting distribution clearly exposes a profound bias in the research focus, revealing an empirical crisis of neglect surrounding non-diarrheal acute infections.

Frequency of Dependent Variables

The category of Acute Infections (excluding diarrhea, but including ARIs, STHs, Trachoma, and other non-enteric acute illnesses) was found to be the most significantly under-researched

outcome. This category accounted for a meager 4 mentions out of the total, representing only 8.33% of all dependent variables investigated across the entire systematic review.

This percentage stands in stark contrast to the overwhelming majority of research dedicated to the other two categories:

i. Diarrhea: Dominant, accounting for 30 instances (62.50%).
ii. Child Development & Stunting: Secondary, but well-researched, with 14 mentions (29.17%).

The quantitative evidence is undeniable: The health outcomes resulting from acute infections are marginalized in the current WASH research agenda. This empirical void has significant policy implications, as the minimal data available prevents a proper estimation of the full impact and cost-effectiveness of WASH interventions in preventing these widespread, but often overlooked, illnesses. The research agenda appears to be driven almost exclusively by the highest mortality figure (diarrhea), neglecting the substantial cumulative morbidity and long-term consequences of conditions like recurrent ARIs or helminth infections.

Operationalization and Target Population

While the few studies focusing on acute infections were too sparse to establish a dominant operational definition, the general context of the systematic review suggests that the target population followed the trend of the field: Children under five (0–59 months) constituted the focus of the vast majority of studies, suggesting that the few acute infection studies that exist also primarily target this vulnerable age group. Similarly, the Independent Variable (IV) investigated in the acute infections research likely revolved around "Specific WASH Components," such as the presence of a handwashing facility (hygiene link to ARIs and Trachoma) or access to improved sanitation (sanitation link to STHs). For instance, studies on Soil-Transmitted Helminths (STHs) likely relied on stool sample analysis to quantify worm burden, while research on Trachoma would have used clinical examination (e.g., the WHO simplified grading system for clinical signs) and studies on Acute Respiratory Infections (ARIs) would have relied on mother-reported fever, cough, or difficulty breathing, or clinical diagnosis. The fact that the research on these varied conditions is grouped under a single, neglected category (8.33%) highlights a failure to specialize and rigorously investigate the distinct causal pathways for each type of acute infection.

GEOGRAPHICAL AND METHODOLOGICAL CONSTRAINTS

The minimal evidence base for acute infections is further weakened by severe geographical and methodological constraints, compromising the internal and external validity of the few findings that do exist.

Geographical Concentration

The systematic review revealed a pronounced geographical concentration of research efforts across all outcomes, which inherently limits the available evidence for acute infections to just a few contexts. The studies were heavily skewed toward:

i. Ethiopia: The most frequent location, with 9 mentions (29.0%).
ii. India: The second most frequent location, with 8 mentions (25.8%).

These two countries accounted for over half of the research locations. This concentration means that the sparse evidence (8.33%) gathered on non-diarrheal acute infections primarily reflects the specific socio-cultural, climatic, and public health environments of Ethiopia and India. The findings are therefore difficult to generalize to other critical regions, such as West Africa, Southeast Asia, or Latin America, which may have different endemic acute infections (e.g., varying strains of ARIs, different STH prevalence, or unique seasonal patterns affecting disease transmission). This geographical homogeneity exacerbates the empirical void for acute infections globally.

Methodological Limitation: The Inability to Establish Causality

A critical methodological shortcoming identified across the entire body of literature, and by extension, in the small fraction dedicated to acute infections, was the over-reliance on Cross-sectional Study designs. While efficient for quantifying disease prevalence (e.g., the prevalence of an ARI in a population at one time), this design can only establish a statistical association between variables. It is fundamentally incapable of demonstrating that a WASH intervention caused a reduction in the incidence of an acute infection.

For acute infections, this limitation is particularly problematic:

ARIs: They are often seasonal and episodic. A cross-sectional study cannot distinguish between a recent, brief exposure that caused the ARI and the long-term, underlying WASH conditions.

Longitudinal tracking is necessary to monitor the *incidence* (new cases over time) following an intervention.

STHs: The life cycle of helminths requires months to establish a measurable infection. A single-point-in-time survey cannot connect the provision of a latrine today with the reduction in worm burden six months from now.

The predominance of this weak methodological approach means that the scarce 8.33% evidence base for acute infections is primarily descriptive and correlational, lacking the necessary rigor to inform policy decisions requiring definitive causal proof of intervention efficacy.

THE TRIPLE VOID: GAPS IN THEORETICAL, EMPIRICAL, AND CAUSAL PATHWAYS

The most debilitating factor affecting the research on acute infections is the systematic failure to engage with theoretical models, causal pathways, and moderating factors.

Theoretical Gaps and the Fragmentation of Acute Infection Knowledge

The systematic review revealed a pervasive theoretical void, with the finding of "No Specific Theory Mentioned / Not Explicitly Stated" accounting for an overwhelming 92.6% of all mentions related to theoretical frameworks. This gap is not merely an academic oversight; it has profound implications for understanding and preventing non-diarrheal acute infections.

A strong theoretical framework is required to model the complex and often multi-modal transmission routes of acute infections:

ARIs and Hygiene: While the F-diagram (Feces, Fluids, Fingers, Flies, Fields) is a useful, albeit simple, model for fecal-oral diseases (like diarrhea), it is insufficient for ARIs. The transmission of respiratory pathogens often involves surfaces (Fingers), air droplets, and environmental factors like dust or biomass smoke (poor ventilation often associated with poor household infrastructure). A theory that integrates the socio-ecological model (individual hygiene, household environment, and community sanitation) is necessary, but overwhelmingly absent.

STHs and Environment: The epidemiology of helminths requires a theoretical model that integrates soil contamination and human behavior (e.g., barefoot walking, children playing in

contaminated areas). Simple health belief models often fail to account for the deep, structural poverty that necessitates these behaviors.

The lack of theory means the few studies on acute infections are isolated, pragmatic snapshots rather than building blocks in a cohesive scientific edifice. This theoretical fragmentation makes it impossible to design interventions that address the root causes of all WASH-related illnesses holistically.

The Empirical Failure to Map Causal Pathways (Mediators)

The empirical depth of WASH research, especially concerning acute infections, is critically undermined by the systematic failure to investigate mediating variables. Mediating variables explain how a WASH intervention leads to a health outcome. The review found that the category "Not Applicable / Not Explicitly Tested / Not Stated" accounted for a staggering 96.6% of all mentions related to mediating variables.

For the minimal evidence on acute infections (8.33%), this gap is devastating:

WASH and ARIs: A study might show that a handwashing intervention is associated with fewer ARIs. But the mediator the *mechanism* is unknown. Is it a reduction in fecal-oral contamination that strengthens gut immunity, or is it a reduction in hand-to-face touching that prevents direct viral/bacterial transfer? Without testing mediators, the intervention cannot be refined or optimized.

Sanitation and STHs: An improved latrine reduce open defecation. The mediator is a reduction in environmental fecal contamination (EFC). Failure to measure EFC means we can only conclude the latrine works, not *why* or *how much* environmental cleanup is necessary to stop the STH cycle.

The lack of mediator testing forces researchers and policymakers to rely on "black box" evidence, where they know an intervention works, but not *why* it works for a given acute infection, making its transferability to new contexts purely speculative.

Neglect of Conditional Factors (Moderators)

Research on acute infections also suffers from a generalized failure to assess moderating variables the factors that determine for whom or under what conditions an intervention is most effective. The systematic review highlighted this general weakness in the field, with the category "Not

Applicable/Not Explicitly Tested / Not Mentioned" accounting for 56.3% of all moderation-related findings.

For acute infections, moderators are vital:

i. Seasonality: The effect of a water quality intervention on Trachoma (eye infections) might be significantly moderated by the dry season (when water scarcity is worse).
ii. Socioeconomic Status (SES): The efficacy of a sanitation intervention in reducing STHs might be moderated by the household's SES—children in ultra-poor households might still play in or near contaminated public areas, negating the effect of the private latrine.
iii. Co-morbidity: The impact of WASH on ARIs might be moderated by a child's nutritional status (e.g., stunting). A well-nourished child may bounce back from an acute infection quickly, while a stunted child's immune system is overwhelmed, leading to a more severe outcome.

Without systematic investigation into these conditional factors, the few available findings on acute infections are presented as universal truths, when in reality, their impact is likely highly context-dependent and variable across communities and households.

CONCLUSION

This systematic review concludes that global WASH research is heavily skewed toward diarrhea and child development outcomes, leaving non-diarrheal acute infections such as acute respiratory infections, soil-transmitted helminths, and trachoma severely under-researched despite their substantial contribution to child morbidity and long-term developmental harm. The evidence base is quantitatively weak and geographically concentrated, with acute infections representing only a small fraction of existing studies, most of which rely on cross-sectional designs, lack guiding theoretical frameworks, and fail to examine causal pathways or mediating mechanisms that explain how and why WASH interventions work. This combination of methodological, theoretical, and empirical gaps limits causal inference, policy relevance, and external validity. The review therefore calls for an urgent reorientation of WASH research toward non-diarrheal acute infections through longitudinal and experimental designs, explicit use of multi-level socio-ecological theories, and systematic testing of mediating and moderating variables, in order to generate robust,

generalizable evidence capable of informing effective interventions and advancing child health outcomes in line with SDG 3.

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