
Scoping Review: The Effectiveness Of Sanitation Interventions In Addressing Waterborne Diseases In Vulnerable Communities

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Abstract

Waterborne diseases remain a serious public health concern in vulnerable communities, particularly in areas with inadequate sanitation. WHO reported approximately 505,000 diarrhea-related deaths annually due to unsafe drinking water. Indonesia's 2023 Health Survey showed diarrhea prevalence of 4.3% across all age groups. This scoping review aims to critically map and evaluate the effectiveness of various sanitation interventions in combating waterborne diseases in vulnerable communities based on current scientific evidence. The scoping review followed the Arksey and O'Malley (2005) framework, strengthened with JBI guidance, and reported using PRISMA-ScR guidelines. Searches were conducted through Google Scholar, PubMed, and Scopus (2020-2025). Sixteen articles were analyzed using descriptive thematic analysis. Multi-component sanitation interventions combining behavioral change with infrastructure provision demonstrated higher effectiveness than single interventions. Point-of-use water treatment reduced diarrhea risk by up to 50%, while handwashing with soap reduced risk by 30%. CLTS/STBM programs significantly improved latrine coverage and reduced diarrhea prevalence. Intervention effectiveness was moderated by seasonal variation, geographic context, and community participation levels. Multi-component approaches integrating behavioral change, infrastructure improvement, and institutional strengthening proved most effective. Significant research gaps exist regarding long-term sustainability, cost-effectiveness analysis, and climate change adaptation.

Keywords: **Sanitation Intervention; Waterborne Disease; Vulnerable Community, Scoping Review; WASH; STBM**

INTRODUCTION

Waterborne diseases remain a major public health problem worldwide, especially in low- and middle-income countries. The World Health Organization (WHO) states that drinking water contaminated with microorganisms can transmit several diseases, including diarrhea, cholera, dysentery, typhoid, and polio. Unsafe drinking water is estimated to cause approximately 505,000 diarrheal deaths each year (WHO, 2023). More broadly, diseases related to inadequate water, sanitation, and hygiene (WASH) are among the leading causes of preventable morbidity and mortality. Data from the Global Burden of Disease Study 2023 confirm that unsafe water sources remain one of the major contributors to mortality in developing countries (IHME, 2025).

The groups most affected by waterborne diseases are vulnerable communities, including children under five years of age, people living in remote areas, and low-income populations. Their vulnerability is caused not only by biological factors but also by structural determinants, such as limited access to clean water, inadequate sanitation facilities, and insufficient knowledge and practice of clean and healthy living behavior (PHBS). The latest 2025 report by the WHO/UNICEF Joint Monitoring Programme (JMP) shows that although the proportion of safely managed drinking water services increased globally from 68% to 74% between 2015 and 2024, 2.1 billion people still lacked access to safely managed drinking water services. Even more concerning, around 3.4 billion people still lacked access to safely managed sanitation services in 2024 (WHO and UNICEF, 2025). These data indicate that despite progress, global inequalities in sanitation access remain substantial.

In Indonesia, waterborne diseases remain a serious concern and continue to pose a major challenge to the national health system. Data from the 2023 Indonesian Health Survey (SKI) show that the prevalence of diarrhea, based on diagnosis or symptoms, reached 4.3% across all age groups, with considerable differences across islands. Among children under five years of age, who represent the most vulnerable population, diarrhea prevalence reached 7.4%, with a total of 1,168,393 cases

reported in the same year (Kemenkes RI, 2023). This trend indicates that efforts to control waterborne diseases in Indonesia still need to be strengthened through both technical interventions and changes in community behavior.

Various sanitation interventions have been introduced to address this problem through different approaches. At the global level, a comprehensive meta-analysis by Wolf et al. (2022), published in *The Lancet*, showed that WASH interventions consistently reduce the risk of diarrhea among children in low- and middle-income countries. The main findings of that study indicated that point-of-use water treatment can reduce diarrhea risk by up to 50%, while handwashing with soap campaigns can reduce the risk by 30%. In Indonesia, the Community-Based Total Sanitation program (STBM), an adaptation of Community-Led Total Sanitation (CLTS), has been implemented since 2008 and was formalized through Ministry of Health Regulation No. 3 of 2014 as one of the main strategies for improving community sanitation (Kamiludin and Azizah, 2025). However, a key question remains as to how effective these various interventions are in diverse vulnerable community contexts.

Theoretically, the effectiveness of sanitation interventions can be explained through two main conceptual frameworks. First, the Clean and Healthy Living Behavior (PHBS) approach emphasizes the importance of individual and community behavior change in maintaining personal and environmental hygiene. This approach directly supports waterborne disease control by breaking the fecal-oral transmission chain (Sinanto and Djannah, 2020). Second, the CLTS approach emphasizes behavior change through community empowerment and has been shown to increase latrine ownership and reduce open defecation practices in several developing countries, as reported by Geremew et al. (2022) and Tessema et al. (2022). These two approaches complement each other because behavior change cannot be sustained without infrastructure support, while infrastructure will not be used properly without behavior change.

Although many studies have discussed the effectiveness of sanitation interventions separately, there is still no comprehensive critical mapping that integrates scientific evidence from national and international contexts, systematically analyzes the quality of the evidence, and identifies research gaps that need to be addressed. Therefore, this scoping review was conducted with three main objectives. The first objective was to systematically identify and map the literature on the effectiveness of various sanitation interventions in addressing waterborne diseases in vulnerable communities. The second objective was to critically analyze the quality and strength of the available scientific evidence. The third objective was to identify research gaps that can serve as a basis for future studies. A scoping review was selected because it allows for the exploration of heterogeneous evidence from various study designs (Peters et al., 2020).

RESEARCH METHODS

Research Design

This study used a scoping review method following the five-stage framework proposed by Arksey and O'Malley (2005). The method was further strengthened by the latest methodological guidance from JBI, published by Peters and colleagues in 2020 in *JBI Evidence Synthesis*. The results of this scoping review were reported according to the PRISMA-ScR guideline developed by Tricco and colleagues in 2018. The study selection process was presented using the PRISMA 2020 flow diagram template published by Page and colleagues in 2021. The PRISMA-ScR guideline consists of 20 essential reporting items and 2 additional items designed to improve methodological quality and transparency in reporting scoping reviews. The five stages conducted in this scoping review were: identifying the research question, identifying relevant studies, selecting studies, charting the data, and collating, summarizing, and reporting the results.

Stage 1: Identification of Research Questions

The research question was formulated using the PEOS (Population, Exposure, Outcomes, Study design) framework, which aligns with the characteristics of a scoping review. The primary focus of this study is: "How effective are various sanitation interventions in addressing water-related diseases in vulnerable communities based on scientific evidence published between 2020 and 2025?" An explanation of the PEOS framework can be found in Table 1.

Table 1. PEOS Framework (Population, Exposure, Outcomes, Study Design)

Population	Exposure	Outcomes	Study Design
Vulnerable communities living in areas with limited sanitation access, including children under five, rural populations, and low-income communities.	Sanitation interventions, including handwashing with soap (HWWS/CTPS), provision of safe drinking water, construction of toilets, management of domestic waste and wastewater, and STBM and CLTS programs.	Reduction in the incidence of waterborne diseases, including diarrhea, typhoid fever, and cholera, increased sanitation coverage, and changes in clean and healthy living behavior (PHBS).	Observational studies (cross-sectional, case-control), intervention studies, quasi-experimental studies, literature reviews, and community service studies that measured the effectiveness of sanitation interventions.

Stage 2: Identification of Relevant Studies

The literature search was conducted systematically through three electronic databases: Google Scholar, PubMed, and Scopus. These databases were selected to ensure comprehensive coverage of both national and international publications. The search strategy used a combination of keywords and Boolean operators, specifically: (“sanitation interventions” OR “WASH interventions” OR “personal hygiene” OR “STBM” OR “CLTS”) AND (“waterborne diseases” OR “diarrhea”) AND (“vulnerable communities” OR “low-income communities” OR “rural”). The search was limited to articles published between 2020 and 2025 and available in either Indonesian or English.

Stage 3: Study Selection

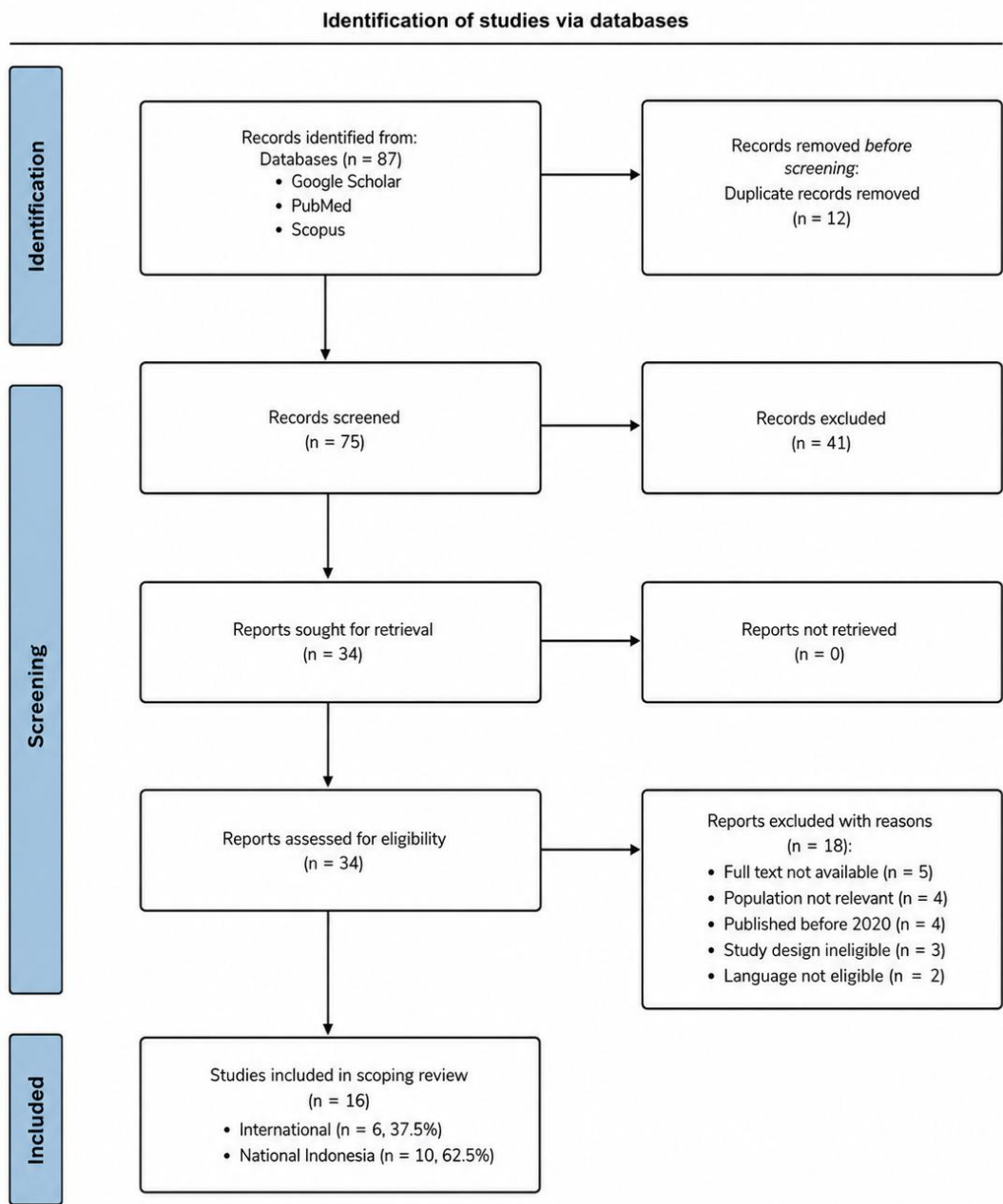
The study selection process was conducted in stages following the procedure proposed by Peters et al. (2020). Initially, all search results were downloaded and imported into Mendeley reference management software to detect and remove duplicate articles. Next, screening was performed based on titles and abstracts to assess their initial relevance to the research question. Articles that passed the initial screening were then reviewed in full through a full-text review based on predetermined inclusion and exclusion criteria. Details of the inclusion and exclusion criteria are presented in Table 2.

Table 2. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Articles discussing sanitation interventions for waterborne diseases	Not relevant to sanitation interventions and waterborne diseases
Populations included vulnerable communities, such as children under five, rural communities, and low-income populations	Published before 2020
Published between 2020 and 2025	Available only as an abstract
Available in Indonesian or English	Non-vulnerable population or studies in developed countries with adequate sanitation infrastructure
Full-text articles were accessible	Editorials, opinion pieces, or letters to the editor
Observational, intervention, quasi-experimental, or literature review study designs	

From the initial search during the identification phase, a total of 87 articles were identified from the three electronic databases: Google Scholar, PubMed, and Scopus. Before proceeding to the screening phase, 12 duplicate articles were removed using Mendeley reference management software, leaving 75 articles for screening. During the screening phase, these 75 articles were evaluated based on their titles and abstracts, and 41 articles were excluded because they did not meet the relevance criteria. Subsequently, the full texts of 34 articles were retrieved for eligibility assessment. During the eligibility assessment stage, 18 articles were excluded for the following reasons: full text not available (n = 5), inappropriate population (n = 4), publication outside the specified time frame (n = 4), study design not meeting the criteria (n = 3), and language mismatch (n = 2). In the final inclusion stage, 16 articles were included in this scoping review analysis, consisting of 6 international articles (37.5%) and 10 national articles (62.5%). The article selection flow is presented in the PRISMA 2020 flow diagram in Figure 1 (Page et al., 2021).

Figure 1. Article Selection Flowchart based on PRISMA 2020 (PRISMA 2020 Flow Diagram)



Source: Adapted from Page et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71.

Stage 4: Data Charting

Data from the 16 selected articles were extracted and mapped using a data charting form. The form covered seven dimensions of information: (a) article identity, including author and year, (b) location and study context, (c) study design, (d) population and sample, (e) type of sanitation intervention studied, (f) key findings, and (g) study limitations.

Stage 5: Compilation, Synthesis, and Reporting of Results

The charted data were analyzed using descriptive thematic analysis as recommended by Peters et al. (2020). Data from the selected articles were grouped into four main themes that emerged inductively from the analysis process: (1) effectiveness of handwashing with soap interventions, (2) effectiveness of community-based sanitation programs, (3) the role of access to clean water and basic sanitation, and (4) supporting and inhibiting factors affecting intervention success. In addition to thematic analysis, research gaps that had not yet been addressed were also identified.

RESULTS AND DISCUSSION

Study Characteristics

Based on the selection process, 16 articles met the inclusion criteria, consisting of 6 international articles (37.5%) and 10 Indonesian national articles (62.5%). The dominance of national publications reflects the search context, which was designed to capture evidence from both national and international sources. In terms of study design, the reviewed literature represented varying levels of evidence strength. At the highest level of evidence, there were 2 systematic reviews and meta-analyses, namely Wolf et al. (2022) and Levy et al. (2025), which provided the strongest evidence regarding the effectiveness of WASH interventions. At the middle level, there was 1 cluster-randomized controlled trial (Geremew et al., 2022) and 1 quasi-experimental study (Tessema et al., 2022), both of which provided causal evidence with a reasonably high level of confidence. The remaining studies consisted of cross-sectional studies (3 articles), scoping reviews (2 articles), literature reviews (2 articles), case studies (2 articles), and other designs that offered important contextual evidence, although with more limited inferential strength.

Based on geographic distribution, the reviewed literature was concentrated in two main areas, namely Indonesia, with 10 studies, and Sub-Saharan Africa, particularly Ethiopia, with 2 studies using randomized controlled trial or quasi-experimental designs. Other international studies were multi-country studies involving low- and middle-income countries through systematic review methods. This geographic concentration should be noted because it may limit the generalizability of the findings to other geographical and sociocultural contexts.

Table 3. Data Charting of Extracted Literature

N o.	Resear chers (Year)	Locatio n	Study Design	Popul ation	Type of Intervention	Finding s
1	Wolf et al. (2022)	Multi-country (low-income and middle-income countries)	Systematic review and meta-analysis	136 WASH studies	WASH (household water treatment, handwashing with soap/HWWS, sanitation)	Point-of-use household drinking water treatment reduced diarrhea risk by up to 50%. HWWS reduced risk by 30%. Combining several interventions

							provided substantially greater protective effects.
2	Chirambo et al. (2022)	Southern Africa	Scoping review	18 scientific articles	WASH infrastructure and community involvement	Geographic disparities and climate change were major barriers to program implementation. Active community involvement and infrastructure improvement were key factors for program success.	
3	Geremew et al. (2022)	Rural Ethiopia (48 villages)	Cluster-RCT	906 children under five	CLTS (Community-Led Total Sanitation)	Latrine ownership increased from 0% to 35% within 10 months. Diarrhea prevalence decreased significantly in the intervention group compared with the control group.	
4	Tessema et al. (2022)	Southwestern Ethiopia	Quasi-experimental	Children under five	CLTSH (total sanitation plus hygiene component)	Diarrhea incidence decreased by 8.2 percentage points. Improved latrine ownership increased by 5.6 percentage points, and latrine utilization increased by 10.7	

							percentage points.
5	Levy et al. (2025)	Multi-country (low-income and middle-income countries)	Systematic review and meta-analysis	WASH intervention studies	WASH (water, sanitation, hygiene)	WASH program effectiveness was strongly influenced by season. Intervention benefits were greater during the dry season than the rainy season. Program adaptation to climate change is needed.	
6	D'Mello-Guyett et al. (2020)	International guidelines	Scoping review	Cholera prevention guidelines	WASH for cholera prevention	Substantial variation was found in WASH recommendations across global institutions. Standardized international guidance based on strong scientific evidence is needed.	
7	Kamiludin & Azizah (2025)	Indonesia	Literature review	8 articles on STBM	STBM (5 pillars)	STBM pillars, especially handwashing and household water and food management, were effective in reducing diarrheal disease among children under five.	
8	Rivai & Rivai (2025)	Donggala, Central Sulawesi	Case study	100 respondents	STBM program	The STBM program made a real contribution to improving environmental sanitation.	

							Community hygiene awareness increased significantly after the intervention.
9	Elvieta & Ernita (2024)	North Aceh	Cross-sectional	95 mothers with children under five	Basic sanitation facilities and clean and healthy living behavior (PHBS)	There was a statistically significant association between physical sanitation facilities, maternal PHBS, and the frequency of diarrhea among children under five (p = 0.003).	
10	Sinanto & Djannah (2020)	Indonesia (various locations)	Literature review	8 articles on HWWS	Handwashing with soap (HWWS/CTPS)	HWWS was highly effective in reducing diarrheal disease and other infectious diseases in several community settings, including households, schools, and health centers.	
11	Hariani et al. (2025)	Tulungagung, East Java	Cross-sectional	30 respondents	Hand hygiene	There was a significant association between hand hygiene compliance and typhoid fever incidence (p = 0.004). Personal and environmental hygiene were	

							key factors in prevention.
2	1	Wulandari et al. (2023)	Kebayoran Baru, Jakarta	Intervention study	Street food vendors	Food hygiene and sanitation intervention	Environmental sanitation at vending sites and personal hygiene among vendors were directly related to food safety. The intervention successfully increased vendors' hygiene awareness.
3	1	Fathurrohman (2025)	Malang, East Java	Non-experimental	Children under five in a public health center catchment area	Maternal PHBS and environmental sanitation	A significant association was found between maternal clean living behavior and diarrhea incidence among children under five (p = 0.00). Environmental sanitation was a major contributing factor.
4	1	Wardani & Angraini (2025)	Lampung	Case study	1 pediatric patient (5 years old)	Family medicine approach and PHBS	A holistic family medicine approach improved personal hygiene among the child and family. Typhoid fever was successfully managed through behavioral change.
5	1	Andolita & Adu (2021)	Kupang, East Nusa Tenggara	Community service	Elementary school students	Handwashing education	Education through singing was

						through singing	effective in improving knowledge and handwashing practice skills among elementary school children.
6	1	Sabira et al. (2024)	North Sumatra	Cross-sectional (secondary data analysis)	57,311 respondents (2023 SKI data)	Environ mental factors (water, sanitation, waste and wastewater)	Househ old environmental health factors were significantly associated with diarrhea incidence. Diarrhea prevalence in North Sumatra (4.7%) was higher than the national average (4.3%).

Synthesis of Findings

Through thematic analysis of the 16 selected articles, the findings were grouped into four main themes. Unlike a conventional descriptive narrative approach, this synthesis used a configurative method. This approach did not merely describe the findings of each study but also analyzed patterns of similarity and difference across studies, assessed the weight of evidence within each theme, and identified practical and theoretical implications.

Theme 1: Effectiveness of Handwashing with Soap as a Primary Intervention

The available evidence consistently shows that handwashing with soap is one of the most cost-efficient sanitation interventions and can be widely implemented. From the perspective of the strongest available evidence, the meta-analysis by Wolf et al. (2022), which combined 136 studies from low- and middle-income countries, indicated that the promotion of handwashing with soap can reduce the risk of diarrhea among children by 30%. This result is supported by contextual evidence from studies conducted in Indonesia. Sinanto and Djannah (2020), through a literature review, showed that the effectiveness of handwashing with soap remained consistent across various community settings, including homes, schools, and health facilities. Hariani et al. (2025) demonstrated a significant association between hand hygiene and typhoid fever incidence ($p = 0.004$) in Tulungagung Regency, although the small sample size ($n = 30$) limits the broader applicability of this finding.

From an implementation perspective, an interesting finding reported by Andolita and Adu (2021) was the success of an innovative educational method. Learning about handwashing through singing was shown to improve handwashing knowledge and behavior among primary school children in Kupang Regency. This finding is important because it indicates that the success of handwashing interventions depends not only on message content but also on delivery methods that are appropriate to the characteristics of the target population.

Levy et al. (2025) added an important temporal perspective by finding that the performance of handwashing and WASH interventions as a whole is influenced by seasonal variation. These interventions tend to be more effective during the dry season than during the rainy season. This finding

has important implications for designing interventions in Indonesia, which has a tropical climate with a long rainy season. Therefore, intervention strategies need to be adjusted by strengthening protection against water contamination during the rainy season.

Theme 2: Community-Based Sanitation Programs as a Transformative Approach

Community-based sanitation programs such as CLTS at the international level and STBM in Indonesia show the potential to create broader change beyond infrastructure provision alone. The strongest evidence comes from the cluster-randomized controlled trial conducted by Geremew and colleagues (2022) in 48 rural villages in Ethiopia. The study showed that the CLTS intervention increased the proportion of households owning latrines from 0% at baseline to 35% within 10 months, accompanied by a reduction in diarrhea cases in the intervention group compared with the control group. However, it should be critically noted that although the increase to 35% represented a significant improvement from zero, 65% of households still did not have sanitation facilities. This indicates that although CLTS can act as a driver of change, additional interventions and a longer implementation period are needed to achieve universal access.

A quasi-experimental study by Tessema and colleagues (2022) in southwestern Ethiopia strengthened these findings by showing that CLTSH, which combines CLTS with a hygiene component, reduced diarrhea prevalence by 8.2 percentage points, increased ownership of improved latrines by 5.6 percentage points, and increased latrine use by 10.7 percentage points. When compared, the two studies by Geremew and Tessema suggest that adding hygiene components may influence behavioral change related to latrine use. These differences may be influenced by different baseline conditions and contexts, but they suggest that community-based programs combining multiple components tend to produce more comprehensive behavioral change.

In Indonesia, evidence on STBM effectiveness is supported by Kamiludin and Azizah (2025), who found that the STBM pillars, particularly handwashing with soap and household food and drinking water management, were able to reduce diarrhea cases among children under five. Rivai and Rivai (2025) also provided contextual evidence from Lero Village in Donggala Regency, showing that STBM contributed to improved sanitation conditions and increased community awareness. However, both studies have significant methodological limitations. Kamiludin and Azizah used a literature review without a structured search protocol, while Rivai and Rivai applied a case study design without a comparison group. Therefore, evidence of STBM effectiveness in Indonesia remains indicative and requires confirmation through more rigorous study designs.

The perspective on facilitators and barriers from Chirambo et al. (2022) provides a useful interpretive framework. Their scoping review of 18 studies in Southern Africa showed that the success of WASH programs depends on collaboration among infrastructure improvement, local community involvement, latrine ownership, and social capital development. The main barriers included geographic inequality, the impacts of climate change, limited investment, and insufficient community knowledge. This pattern is highly relevant to Indonesia, where significant gaps in sanitation access remain between Java and regions outside Java, as well as between urban and rural areas.

Theme 3: Access to Clean Water and Basic Sanitation as Fundamental Determinants

The availability of clean water and adequate sanitation facilities is a key element in preventing waterborne diseases. A meta-analysis conducted by Wolf et al. (2022) found that point-of-use water treatment can reduce diarrhea risk by up to 50%, making it one of the most effective interventions in the WASH sector. This finding indicates that improving the quality of water directly consumed by households has a greater impact than interventions at other points in the water supply chain.

At the national level, evidence on the importance of access to sanitation facilities comes from three mutually reinforcing studies. Elvieta and Ernita (2024) quantitatively showed that the availability of adequate sanitation facilities was significantly associated with reduced diarrhea cases among children under five ($p = 0.003$) at Tanah Pasir Public Health Center in North Aceh. Fathurrohman (2025) confirmed a significant association between maternal clean living behavior, including clean water management, and diarrhea incidence among children under five ($p = 0.00$) at Pandanwangi

Public Health Center in Malang City. From the perspective of sample representation, Sabira et al. (2024), through an analysis of the 2023 SKI data involving 57,311 respondents in North Sumatra, found that environmental factors such as drinking water sources, sanitation access, and waste management were significantly associated with diarrhea incidence. Diarrhea prevalence in North Sumatra was recorded at 4.7%, which was higher than the national average of 4.3%, indicating that the province requires strengthened sanitation interventions.

The consistency of findings from these three national studies strengthens the argument that although behavioral interventions such as handwashing with soap are important, the availability of basic infrastructure, such as clean water sources and sanitation facilities, is an indispensable prerequisite. This finding is consistent with SDG 6, which emphasizes the importance of the availability and sustainable management of clean water and sanitation for all (WHO and UNICEF, 2025).

Theme 4: Moderator Factors Affecting Intervention Effectiveness

Cross-study analysis shows that the success of sanitation interventions is not absolute but is influenced by diverse contextual factors. Therefore, sanitation programs should be adapted to the conditions of each area and the characteristics of the local population.

The first factor is seasonal and weather variation. Levy et al. (2025) clearly stated that WASH interventions were more effective during the dry season than during the rainy season. This finding is consistent with epidemiological understanding that during the rainy season, the risk of water contamination increases because floods and runoff can carry pathogens from fecal matter into water sources. In the Indonesian context, where rainfall is high, this indicates the need to strengthen source water protection during the rainy season, which cannot be achieved adequately by relying only on behavioral change.

The second factor is geographic condition and regional inequality. Chirambo et al. (2022) identified geographic inequality as a major challenge, while Sabira et al. (2024) showed variations in diarrhea incidence across provinces in Indonesia. These differences indicate that intervention strategies must vary according to regional characteristics and cannot rely on a one-size-fits-all method.

The third factor is the implementation approach. D'Mello-Guyett et al. (2020) observed significant differences in WASH recommendations from various international institutions for cholera prevention, indicating the absence of consensus on best practices. On the other hand, Wardani and Angraini (2025) showed that a comprehensive family medicine approach can be an effective strategy at the individual level. Wulandari et al. (2023) added an important perspective on sanitation interventions in the informal sector, such as among street food vendors, showing that interventions need to cover settings beyond households and health facilities.

Based on all findings, sanitation interventions appear to be more successful when behavior change is implemented together with infrastructure development and community participation. This pattern is consistent with the meta-analytic evidence from Wolf et al. (2022), which showed that combined WASH interventions have greater effects than stand-alone interventions.

Identification of Research Gaps

An in-depth analysis of the 16 reviewed articles revealed several significant research gaps that need to be addressed by future studies. The identification of these gaps was conducted systematically by comparing available evidence with information needs for policy decision-making and effective sanitation program design. A summary of the research gaps is presented in Table 4.

Table 4. Identification of Research Gaps and Recommendations

Gap Area	Current Scientific Evidence	Recommendations for Future Research
Sustainability	Most studies used cross-sectional designs. Only one study (Geremew et al., 2022) monitored outcomes for 10 months. It remains unclear whether sanitation behavior change in communities can truly be sustained for years.	Long-term cohort studies with at least 2 years of follow-up are needed to assess the consistency of community behavior and maintenance of sanitation facilities.
Economic Value Analysis	None of the 16 reviewed articles calculated the costs or financial benefits of the sanitation interventions conducted.	Economic evaluation should be integrated with effectiveness studies to support resource allocation in limited-budget settings.
Climate Change Adaptation	Only Levy et al. (2025) examined seasonal variation in WASH effectiveness. Chirambo et al. (2022) identified climate change as a barrier, but did not provide clear quantitative estimates.	Climate-resilient sanitation intervention models need to be developed and tested, particularly for flood-prone and drought-prone areas in Indonesia.
Vulnerable Urban Groups	Twelve of the 16 studies still focused on rural communities. Research in urban slum areas remains very limited.	More research should target dense urban settlements and informal urban areas, which have sanitation challenges that differ from rural areas.
Integration with the Health System	Only one study (Wardani & Angraini, 2025) linked the intervention to a family medicine approach. Comprehensive integration with public health centers has not been widely explored.	Models integrating WASH programs directly into primary health care services (Puskesmas) and community health worker networks need to be evaluated.
Gender and Equity	No study specifically analyzed the impact of sanitation interventions on women, even though women bear the largest domestic burden related to water and sanitation.	Gender-sensitive indicators and social equity analysis should be included in future evaluations of sanitation programs.

The most urgent gap to address is the lack of evidence on the long-term sustainability of sanitation intervention impacts. Of the 16 studies analyzed, only Geremew et al. (2022) provided follow-up data over a 10-month period, while the other studies were mostly cross-sectional and captured conditions at a single point in time. In practice, sanitation behavior change appears vulnerable to regression, especially when intervention programs end and external support is withdrawn. Without long-term evidence, it is difficult to determine whether the reported reduction in waterborne diseases is permanent or temporary.

In addition, no study specifically examined the cost-effectiveness of sanitation interventions. In resource-limited settings, policymakers need information on which interventions provide the best health outcomes for each unit of cost incurred. The absence of such data makes budget allocation for sanitation programs less optimal, particularly in areas with limited fiscal capacity.

The third gap concerns the adaptation of intervention programs to changing climate conditions. The findings of Levy et al. (2025) regarding the effect of seasonality on WASH intervention effectiveness provide an important reference. However, no study has specifically designed and evaluated sanitation interventions that are resilient to climate change. Given that Indonesia is highly vulnerable to climate change impacts, such as increasing floods and droughts, this gap is important to investigate.

CONCLUSIONS

Through a scoping review of 16 articles published between 2020 and 2025, three important conclusions were identified. First, the control of diseases caused by unsafe water among vulnerable groups can be optimized through integrated interventions that combine behavior change education with the provision of adequate infrastructure. This combined approach is more effective than single interventions. Meta-analytic data from Wolf et al. (2022) strengthen this conclusion, showing that point-of-use household drinking water treatment can reduce diarrhea risk by up to 50%, while handwashing with soap can reduce the risk by 30%. This pattern is consistent with CLTS/STBM programs, which have been shown to reduce diarrhea cases in the field by emphasizing community self-reliance.

Second, the effectiveness of sanitation interventions strongly depends on local environmental factors, including seasonal variation (Levy et al., 2025), geographic inequality, as reported by Chirambo et al. (2022) and Sabira et al. (2024), and the implementation approach used. These findings indicate that sanitation policies or programs should not be generalized. Instead, program planning must be sensitive to regional contexts so that outcomes can be optimized.

Third, this review identified significant research gaps. Several areas remain underexplored, including the long-term sustainability of intervention impacts, cost-effectiveness analysis, resilience to climate change, gender-sensitive impacts, and integration with primary health care systems. Given that studies in Indonesia remain dominated by cross-sectional designs and narrative literature reviews, future research should be directed toward large-scale experimental or quasi-experimental studies to generate stronger and more accurate scientific evidence.

The limitations of this scoping review include the use of only three databases, namely Google Scholar, PubMed, and Scopus, which may not have captured all relevant literature. In addition, this study did not conduct a quantitative meta-analysis because the scoping review method focuses on thematic mapping. There is also a potential language bias due to the restriction of articles to Indonesian and English.

As follow-up steps, future research is recommended to conduct systematic reviews with quantitative meta-analysis. Longitudinal studies are also needed to monitor the sustainability of intervention impacts, evaluate economic value and cost-effectiveness, and develop sanitation intervention models in Indonesia that are more adaptive to climate change and sensitive to gender issues.

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