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Public Health Interventions for Cholera Control and Prevention: Water, Sanitation, and Hygiene (WASH) Perspective

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ABSTRACT

Cholera remains a significant public health challenge, particularly in endemic regions where inadequate water, sanitation, and hygiene (WASH) conditions prevail. This paper focuses on public health interventions for cholera control and prevention. The study found that integrating WASH programmes into cholera control strategies is critical for reducing the disease burden. Robust evidence demonstrates that enhancing water quality, improving sanitation infrastructure, and promoting effective hygiene practices can significantly lower the risk of cholera outbreaks. Also, community-based approaches focusing on safe water sources and effective purification methods are essential for sustainable cholera prevention. Furthermore, targeted hygiene promotion initiatives emphasizing handwashing and food safety are vital for fostering behavioural change and minimizing transmission. While the challenges of implementing WASH interventions in urban slums and refugee camps persist, successful case studies highlight the importance of coordinated efforts, community engagement, and investment in infrastructure. By prioritizing WASH initiatives within cholera prevention frameworks, stakeholders can significantly enhance their capacity to manage outbreaks and safeguard the health of vulnerable populations. Finally, a broad, multi-faceted approach to WASH is crucial for achieving long-term cholera control and moving toward a future where cholera no longer poses a persistent threat to global health.

1. Introduction

The significance of Water, Sanitation, and Hygiene (WASH) in cholera prevention is enormous, particularly in regions where cholera remains endemic. Cholera, an acute diarrheal disease caused by the bacterium Vibrio cholerae, poses a significant public health challenge, especially in low-income countries with limited access to clean water and adequate sanitation. The relationship between WASH interventions and cholera transmission is well-documented; improvements in water quality, sanitation facilities, and hygiene practices have significantly reduced the incidence of cholera outbreaks. Historical evidence from various regions, including Europe and North America, illustrates that enhanced WASH infrastructure correlates with a marked decline in cholera cases, establishing a foundation for effective disease prevention strategies (Fung et al., 2013; Leung et al., 2022).

In cholera-endemic regions, implementing comprehensive WASH programmes are critical for controlling outbreaks and preventing future occurrences. A systematic review by Wolfe et al. (2018) emphasized that effective WASH interventions must be well-designed to target specific pathways of cholera transmission while considering the preferences of the affected communities. This is particularly relevant in settings where cholera is endemic, as the risk factors associated with cholera transmission often vary. For instance, studies have shown that factors such as unimproved water sources and unsafe water storage significantly increase the likelihood of cholera infection (Kang et al., 2022; Graveleau et al., 2021).

Therefore, tailored WASH programmes that address these specific risks are essential for effective cholera prevention. Moreover, targeted interventions, such as those implemented during the cholera epidemic in Kinshasa, demonstrate the effectiveness of WASH strategies in rapidly interrupting cholera transmission (Bompangue et al., 2019; Bompangue et al., 2020). By focusing on high-risk households and employing a combination of water supply improvements (Jacob et al., 2024a,b,c; Izah et al., 2024a,b) and hygiene promotion, these interventions have shown promising results in reducing cholera cases. The Kinshasa experience underscores the importance of a community-centered approach, where local participation and behavior change are integral to the success of WASH initiatives. Such strategies address immediate health concerns and contribute to long-term improvements in community health resilience.

The Global Roadmap to 2030 further highlights the necessity of WASH in cholera prevention. This roadmap aims to significantly reduce cholera mortality through enhanced WASH infrastructure (Ebob, 2020a). It emphasizes the need for coordinated efforts among various stakeholders, including governments, non-governmental organizations (NGOs), and international organizations, to ensure that WASH interventions are effectively integrated into broader public health strategies. The successful implementation of WASH programmes can lead to sustainable improvements in health outcomes, particularly in vulnerable populations disproportionately affected by cholera.

In addition to infrastructural improvements, education, and community engagement play essential roles in the effectiveness of WASH interventions. Knowledge, attitudes, and practices (KAP) surveys conducted in cholera-affected areas reveal that increased awareness about cholera transmission and prevention methods, such as handwashing and safe water consumption, significantly influences community behavior (Aibana et al., 2013; Childs et al., 2016). This highlights the importance of providing resources and fostering an understanding of their use among community members. Also, effective communication strategies that promote hygiene practices can substantially reduce cholera incidence, as evidenced by various studies that link improved knowledge with better health outcomes (D'Mello-Guyett et al., 2020; Yates et al., 2018).

This paper focuses on the critical role of WASH interventions in preventing cholera outbreaks and reducing transmission. It also explores various aspects, including safe water sourcing and purification, sanitation improvements, and hygiene promotion strategies, while highlighting community involvement and education. Additionally, the paper examines the integration of WASH interventions in cholera outbreak responses, addressing challenges and showcasing success stories from effective programmes implemented in cholera hotspots.

2. Water Quality Interventions

Cholera remains a significant public health challenge, particularly in regions with inadequate WASH infrastructure. The disease, caused by the bacterium *Vibrio cholerae*, is primarily transmitted through contaminated water sources, making water quality interventions critical for effective cholera control. In Nigeria, where cholera outbreaks are recurrent, the need for safe water sources, purification methods, and robust distribution systems is paramount. The integration of community-based water treatment approaches has emerged as a viable strategy to mitigate the impact of cholera, particularly in rural and underserved areas. The relationship between water quality and cholera outbreaks is well-documented. Studies have shown that access to safe drinking water significantly reduces the incidence of cholera, underscoring the importance of improving water supply systems (Owhonda et al., 2023; Dan-Nwafor et al., 2019). In Nigeria, the challenges posed by flooding and inadequate sanitation have exacerbated the cholera burden, as these factors often lead to the contamination of water sources (Elimian et al., 2019; Denue et al., 2018). Providing alternative potable drinking water during outbreaks is a crucial intervention highlighted in

various studies, emphasizing the need for immediate and effective water quality management (Owhonda et al., 2023; Ngwa et al., 2020). Table 1 shows an overview of water quality interventions for cholera control.

Table 1: Overview of Water Quality Interventions for Cholera Control

Intervention	Description	Advantages	Challenges
Safe Water Sources	Provision of protected wells, boreholes, and piped water systems	Reduces contamination risks, provides reliable water supply	High cost of infrastructure, requires ongoing maintenance
Water Purification Methods	Filtration, chlorination, UV treatment, and boiling of water	Effective in eliminating pathogens, adaptable for household use	Limited access to materials, unsustainable in resource-poor areas
Water Distribution Systems	Implementation of centralized systems for safe water transport and access points	Ensures consistent supply, facilitates large-scale distribution	Infrastructure complexity, contamination risks during distribution
Community-Based Water Treatment Approaches	Use of low-cost, locally managed purification technologies (e.g., sand filters)	Empowers local communities, cost-effective, scalable	Requires education and consistent monitoring for effectiveness

The purification of water is essential to prevent cholera transmission. Traditional methods, such as boiling and filtration, have been supplemented by modern technologies, including solar disinfection and chemical treatments, which have proven effective in rural settings (D'Mello-Guyett et al., 2020; Sow et al., 2022). Community-based water treatment initiatives, which empower local populations to manage their water supply, have shown promise in enhancing water quality and reducing cholera incidence (Kaur et al., 2023; Jahan, 2016). These approaches improve access to safe water and foster community engagement and ownership, which are critical for the sustainability of interventions.

Distribution systems for safe water must be designed to ensure that all community members have equitable access. In many rural areas of Nigeria, infrastructure often needs to be improved or improved, leading to reliance on unsafe water sources (Denue et al., 2018; Salubi & Elliott, 2021). Implementing decentralized water distribution systems, coupled with regular maintenance and community training, can enhance the reliability of the water supply and reduce the risk of cholera outbreaks (Soboksa et al., 2020; Ebob, 2020a). Furthermore, integrating health education into water distribution efforts can raise awareness about the importance of safe water practices, thereby promoting behavioral changes that contribute to cholera prevention (Anetor & Abraham, 2020; Burnett et al., 2016).

Community-based approaches to water treatment have gained traction as effective strategies for cholera control. These initiatives often involve training community members in water purification techniques and hygiene practices, which can significantly reduce the prevalence of waterborne diseases (D'Mello-Guyett et al., 2020; Sow et al., 2022). For instance, the distribution of water treatment supplies, such as chlorine tablets and filtration systems, has been shown to improve water quality at the household level (Soboksa et al., 2020; Kaur et al., 2023; Izah et al., 2023). Additionally, community engagement in monitoring water quality can enhance accountability and ensure that interventions are responsive to local needs (Jahan, 2016; Ogisma et al., 2021).

The role of sanitation in cholera prevention is essential. Effective waste management systems that separate human waste from water supplies are crucial for reducing the risk of contamination (Dan-Nwafor et al., 2019; Elimian et al., 2019; Ogidi & Izah, 2024). In most countries in sub-Sahara Africa, the lack of adequate sanitation facilities often leads to the contamination of drinking water sources, particularly during the rainy season when flooding occurs (Denue et al., 2018; Salubi & Elliott, 2021; Numbere et al., 2024; Moslen et al., 2024; Fayiah et al., 2024; Iyiola et al., 2024). Therefore, integrating sanitation improvements with water quality interventions is essential for a comprehensive approach to cholera control (Ebob, 2020a; Somboonwit et al., 2017). This multi-sectoral strategy addresses the immediate needs of communities and contributes to long-term health outcomes.

Health education is vital to any water quality intervention aimed at cholera control. Increasing community awareness about the transmission routes of cholera and the importance of safe water practices can significantly reduce disease incidence (Anetor & Abraham, 2020; Burnett et al., 2016). Educational campaigns focusing on hygiene promotion, such as handwashing with soap and safe food handling, complement water quality interventions and enhance their effectiveness (D'Mello-Guyett et al., 2020; Sow et al., 2022). By fostering a culture of health and hygiene, communities can become more resilient to cholera outbreaks and other waterborne diseases. Implementing oral cholera vaccines (OCVs) alongside water quality interventions has been recognized as an effective strategy for cholera control in endemic regions (Dan-Nwafor et al., 2019; Ngwa et al., 2020). Vaccination campaigns, when combined with improvements in water and sanitation, can significantly reduce cholera morbidity and mortality (Burnett et al., 2016; Ebob, 2020b). In Nigeria, incorporating OCVs into community-based water treatment programmes has shown the potential to

enhance overall public health outcomes (Sow et al., 2022; Dalhat et al., 2014). This holistic approach addresses the immediate threat of cholera andand strengthens the health system's capacity to respond to future outbreaks.

Despite the progress made in cholera control, challenges remain, particularly in fragile regions with limited access to safe water and sanitation (Elimian et al., 2021; Sow et al., 2022). Coordinating multi-sectoral interventions involving government, NGOs, and community stakeholders is critical for achieving sustainable solutions to cholera outbreaks (Sow et al., 2022; Ogisma et al., 2021). By leveraging local knowledge and resources, these partnerships can enhance the effectiveness of water quality interventions and ensure that they are tailored to the specific needs of communities.

3. Sanitation Improvements

Sanitation plays a vital role in public health, particularly about cholera control. The relationship between sanitation and cholera transmission is well-documented, with improved sanitation practices significantly reducing the incidence of cholera outbreaks. The World Health Organization (WHO) emphasizes that access to safe water and adequate sanitation is essential for preventing cholera and other waterborne diseases (Ali et al., 2012). In regions lacking sanitation infrastructure, cholera remains a persistent threat, highlighting the urgent need for comprehensive sanitation improvements.

Controlling cholera has increasingly focused on enhancing sanitation as a primary intervention strategy. Studies indicate that interventions to improve WASH can effectively reduce cholera transmission (Taylor et al., 2015). For instance, implementing community-led sanitation initiatives has shown promise in various settings, demonstrating that local engagement and education can lead to sustainable improvements in hygiene practices (Redae et al., 2023). Furthermore, integrating sanitation improvements with vaccination campaigns has been proposed as a dual strategy to combat cholera effectively (Matias et al., 2017). This multifaceted approach addresses the immediate risks associated with cholera and contributes to long-term public health goals. In regions heavily affected by cholera, such as parts of Africa and Asia, the challenges of implementing effective sanitation measures are compounded by socio-economic factors. Refugee camps often lack basic sanitation facilities, making residents particularly vulnerable to cholera outbreaks (Ali et al., 2017). The crowded living conditions, inadequate waste disposal, and limited access to clean water create an environment conducive to the rapid spread of cholera (Pullan et al., 2014). Addressing these challenges requires targeted interventions that consider the unique circumstances of these populations, such as the establishment of communal sanitation facilities and the promotion of hygiene education.

The role of improved sanitation in preventing cholera transmission cannot be overstated. Evidence suggests that enhancing sanitation infrastructure, such as constructing latrines and providing safe drinking water, is crucial for reducing cholera incidence (Taylor et al., 2015). A systematic review of cholera interventions found that improved sanitation and hygiene practices were associated with significant reductions in cholera cases (Wolfe et al., 2018). Moreover, establishing effective waste management systems is essential for preventing the contamination of water sources, which is a critical pathway for cholera transmission (Graveleau et al., 2021). Therefore, investing in sanitation infrastructure is a public health imperative and a fundamental human right.

Despite the clear benefits of improved sanitation, various challenges persist, particularly in urban slums and refugee camps. The lack of financial resources, political will, and infrastructure development often hampers efforts to implement effective sanitation solutions (Graveleau et al., 2021). Additionally, cultural beliefs and practices can influence the acceptance and utilization of sanitation facilities, necessitating culturally sensitive approaches to sanitation interventions (Wolfe et al., 2018). For example, community engagement and education are vital for ensuring that sanitation improvements are embraced by local populations, thereby enhancing their effectiveness (Ali et al., 2012). Furthermore, the impact of climate change on sanitation and water resources poses an additional challenge for cholera control efforts. Extreme weather events, such as floods and droughts, can disrupt sanitation infrastructure and exacerbate water scarcity, increasing vulnerability to cholera outbreaks (Pullan et al., 2014). In this context, it is essential to adopt adaptive strategies that enhance the resilience of sanitation systems to climate-related shocks (Taylor et al., 2015). This may involve integrating climate considerations into sanitation planning and investing in sustainable water management practices

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4. Hygiene Promotion

Hygiene promotion is critical in cholera control, particularly in regions with an endemic or epidemic. Effective hygiene promotion involves several key components, including handwashing, food safety, and personal hygiene education, which collectively contribute to reducing the incidence of cholera outbreaks. Integrating behavioral change interventions and community involvement further enhances the effectiveness of hygiene promotion strategies, creating a multifaceted approach to cholera control.

Handwashing is one of the most effective measures for preventing cholera transmission. Studies have shown that regular handwashing with soap can significantly reduce the risk of cholera infection by interrupting the fecal-oral transmission route (D'Mello-Guyett et al., 2021; Wolfe et al., 2018). The CHoBI7 intervention in Bangladesh demonstrated that promoting handwashing behaviors among households of cholera

patients led to a substantial reduction in symptomatic cholera cases (Zohura et al., 2022; George et al., 2022). This intervention emphasized the importance of hand hygiene and provided the necessary resources, such as soap and water treatment options, to facilitate these practices. Furthermore, distributing hygiene kits during cholera outbreaks has improved handwashing practices and reduced cholera incidence (D'Mello-Guyett et al., 2020; Burrowes et al., 2017).

Food safety is another critical aspect of hygiene promotion in cholera control. Poor food handling and preservation practices can lead to contamination, increasing the risk of cholera outbreaks. Research indicates inadequate food safety measures, such as undercooked meals and improper food storage, are significant risk factors for cholera (Nsagha et al., 2015; Bocha, 2023). Educational campaigns to improve food safety practices can empower communities to adopt safer food handling behaviors, reducing the likelihood of cholera transmission. For instance, initiatives promoting the thorough cooking of food and using clean utensils have proven effective in mitigating cholera risk (Challa et al., 2022; Fung et al., 2013).

Personal hygiene education is vital for fostering a culture of cleanliness and hygiene within communities. Educational programmes that focus on the importance of personal hygiene, including regular bathing and clean clothing, can significantly influence community behaviors (Parker et al., 2017; George et al., 2017). These programmes often incorporate culturally relevant messaging and community engagement strategies to ensure the information resonates with the target audience. For example, in Kinshasa, DRC, targeted hygiene education during cholera outbreaks was instrumental in raising awareness about the disease and promoting preventive behaviors among the population (Bompangue et al., 2019; Endres et al., 2023).

Behavioral change interventions are essential for sustaining hygiene practices over time. More than simply providing information about hygiene is often required; interventions must be designed to address the underlying social and psychological factors that influence behavior (George et al., 2017; Finger et al., 2018). Community-led initiatives, such as participatory workshops and peer education programmes, have been shown to foster a sense of ownership and responsibility among community members, leading to more sustainable behavior changes (Graveleau et al., 2021; Heylen et al., 2021). Integrating local leaders and influencers in these initiatives can further enhance their effectiveness, as they can mobilize community support and encourage adherence to hygiene practices.

Community involvement is a critical component of successful hygiene promotion strategies. Engaging communities in the design and implementation of hygiene interventions ensures that the programs are culturally appropriate and tailored to the specific needs of the population (Bi et al., 2016; Namawejje et al., 2018). For instance, in Niger, community-led total sanitation initiatives significantly improved sanitation and hygiene practices, contributing to a reduction in cholera cases (Graveleau et al., 2021). Additionally, involving community members in monitoring and evaluation processes can help to identify barriers to hygiene practices and inform future interventions.

The role of WASH interventions cannot be overstated in the context of cholera control. Improved access to clean water and sanitation facilities reduces cholera transmission (Fung et al., 2013; Abubakar & Ibrahim, 2022). Studies have demonstrated that WASH interventions, such as providing safe drinking water and constructing latrines, can significantly reduce cholera incidence (Taylor et al., 2015; Hounmanou et al., 2016). However, these interventions must be complemented by hygiene promotion efforts to maximize their impact. For example, the combination of WASH infrastructure improvements and hygiene education is more effective than either intervention alone (Burrowes et al., 2017; Wolfe et al., 2018).

Integrating WASH with cholera outbreak response is a critical public health strategy aimed at mitigating the impact of cholera, particularly in vulnerable populations. Cholera, caused by the bacterium *Vibrio cholerae*, is primarily transmitted through contaminated water and food, making effective WASH interventions essential in controlling outbreaks. The integration of WASH initiatives into cholera response efforts addresses immediate health concerns and contributes to long-term improvements in community resilience against future outbreaks. This multifaceted approach is particularly relevant in regions where cholera is endemic, or outbreaks frequently occur due to poor sanitation and hygiene practices. Table 2 shows the overview of hygiene education and behavioral change interventions in cholera control.

Table 2: Overview of Hygiene Education and Behavioral Change Interventions in Cholera Control

Focus Area	Key Components	Impact	Challenges
Handwashing Education	Training on proper handwashing techniques and timing	Reduces transmission of cholera and other diseases	Lack of water, soap, and consistent behavior change
Food Safety Education	Safe food handling, preparation, and storage practices	Minimizes contamination and cholera outbreaks	Difficult to enforce in informal or crowded settings
Personal Hygiene Education	Promotion of regular bathing and cleanliness	Decreases the spread of pathogens in communities	Limited access to clean water and hygiene supplies

Behavioral Change Interventions	Campaigns to promote hygiene practices	Enhances long-term health outcomes, reduces infections	Resistance to behavior change, cultural barriers
Community Involvement	Active participation in hygiene programmes	Strengthens local ownership and sustainability of efforts	Ensuring widespread engagement and resource allocation

The role of WASH interventions during cholera outbreaks is significant. Studies have demonstrated that targeted WASH strategies can reduce cholera transmission rates. For instance, Bompangue et al. (2019) highlighted the effectiveness of a community-grid WASH strategy implemented during the cholera epidemic in Kinshasa, rapidly interrupting transmission throughout the city. Similarly, systematic reviews have shown that interventions such as handwashing with soap and water treatment can substantially reduce cholera infections, mainly when focused on households of infected individuals (Taylor et al., 2015). These findings underscore the necessity of integrating WASH measures into cholera response frameworks to enhance their effectiveness. Rapid response teams (RRTs) play a crucial role in the emergency response to cholera outbreaks. These teams, often composed of multidisciplinary professionals, are essential for the timely implementation of WASH interventions in affected areas. Their presence can facilitate rapid detection of cholera cases and ensure swift action to mitigate the spread of the disease. For example, in Haiti, the deployment of RRTs was associated with reducing the duration of cholera outbreaks in hotspots (Zohura et al., 2022). However, challenges such as coordination among various stakeholders can hinder the effectiveness of these teams, as observed in Nepal and Yemen, where delays in WASH programme delivery were reported (Zohura et al., 2022).

Emergency interventions during cholera outbreaks must be carefully planned and executed to maximize their impact. Effective monitoring and evaluation of WASH interventions are crucial for understanding their effectiveness and making necessary real-time adjustments. Ricau et al. (2021) emphasized the importance of robust monitoring tools to assess WASH responses during cholera outbreaks, particularly in humanitarian contexts where data collection can be challenging. Integrating real-time data collection and analysis into WASH interventions can enhance the overall response to cholera outbreaks, ensuring that resources are allocated efficiently and effectively. The significance of community engagement in WASH interventions during cholera outbreaks must be considered. Community-led initiatives have shown promise in enhancing the effectiveness of WASH programmes. For instance, the Community-Led Total Sanitation (CLTS) approach has been associated with improved sanitation and hygiene practices, which are critical in controlling cholera transmission (Graveleau et al., 2021). Engaging communities in the planning and implementing WASH interventions fosters ownership and accountability, leading to more sustainable outcomes. Moreover, local knowledge can inform the design of culturally appropriate and context-specific interventions, thereby increasing their acceptance and effectiveness.

In addition to immediate health benefits, integrating WASH with cholera outbreak response can lead to broader public health improvements. Long-term investments in WASH infrastructure can reduce the incidence of cholera and other waterborne diseases, ultimately contributing to enhanced community health and well-being. For example, sustained improvements in water supply and sanitation facilities can decrease the overall burden of diarrheal diseases, which disproportionately affect vulnerable populations (Sauvageot et al., 2016). Therefore, the integration of WASH interventions into cholera response efforts should be viewed as a reactive measure and a proactive strategy for improving public health. The effectiveness of WASH interventions is further enhanced when combined with vaccination campaigns. While vaccination alone may not suffice to control cholera outbreaks, integrating WASH measures can provide a comprehensive approach to outbreak management. Studies have shown that combining large-scale WASH programmes with vaccination efforts can improve health outcomes, although the timing and coordination of these interventions are critical (Roskosky et al., 2020). The synergy between WASH and vaccination strategies can create a more robust defense against cholera, particularly in high-risk areas.

Furthermore, healthcare workers' role in promoting WASH practices during cholera outbreaks is vital. Training healthcare workers on WASH-related interventions can empower them to effectively communicate the importance of hygiene and sanitation to affected communities. Elimian et al. (2023) noted that community health extension workers were crucial in promoting risk communication and distributing essential supplies during cholera outbreaks in Kenya. By leveraging healthcare workers' trust and rapport within their communities, WASH interventions can be more effectively disseminated and adopted.

Environmental factors, including overcrowding and inadequate sanitation facilities often exacerbate the challenges associated with cholera outbreaks. In internally displaced persons (IDP) camps, for instance, the risk of cholera transmission is heightened due to poor living conditions and limited access to clean water (Ngwa et al., 2020). Addressing these environmental determinants through targeted WASH interventions is essential for controlling cholera outbreaks in such settings. Providing safe water supplies, proper sanitation facilities, and hygiene education can significantly reduce

the risk of cholera transmission in vulnerable populations.

5. Challenges and Success Stories

Cholera remains a significant public health challenge in various regions worldwide, particularly in areas characterized by inadequate sanitation, limited access to clean water, and insufficient health infrastructure. The endemic nature of cholera in areas such as Sub-Saharan Africa, South Asia, Southeast Asia, the Caribbean, the Middle East, and Latin America highlights the urgent need for effective control measures. The challenges associated with cholera control are multifaceted, involving barriers to implementing adequate WASH programmes and identifying successful interventions that have demonstrated efficacy in cholera hotspots (Table 3).

Table 3: Challenges and success stories of cholera

Category	Barriers	Case Studies (Successes)
Water Access and Quality	In many cholera hotspots, particularly in Sub-Saharan Africa and South Asia, inadequate access to clean drinking water is a significant barrier. For instance, the Democratic Republic of the Congo (DRC) and Somalia face challenges related to the contamination of water sources due to poor infrastructure and conflict, which exacerbates the cholera burden (Ali et al., 2015; Spiegel et al., 2019). Furthermore, in Yemen, ongoing conflict has severely disrupted water supply systems, leading to increased cholera cases (Spiegel et al., 2019). The lack of investment in water infrastructure and maintenance also contributes to the persistence of cholera in these regions (Ricau et al., 2023).	Successful interventions in water quality management have been observed in Bangladesh, where extensive WASH programmes have been implemented, significantly reducing cholera incidence (Khan et al., 2023). In Myanmar, the establishment of community-managed water supply systems has improved access to clean water, contributing to a decline in cholera cases (Islam et al., 2021). Additionally, in the DRC, the implementation of the Multisectoral Cholera Elimination Plan (MCEP) has led to improvements in water quality monitoring and access, demonstrating a positive impact on cholera control (Taty et al., 2023).
Sanitation Improvements	Poor sanitation facilities are a major barrier to cholera prevention in many affected countries. In Nigeria and Tanzania, inadequate sewage systems and open defecation practices contribute to the spread of cholera (Ali et al., 2015; Mahapatra et al., 2014). The lack of proper sanitation infrastructure is compounded by socio-economic factors, such as poverty and food insecurity, which hinder investment in sanitation improvements (Richterman et al., 2019). In Yemen, the destruction of sanitation facilities due to conflict has led to a resurgence of cholera outbreaks (Spiegel et al., 2019).	In Haiti, targeted sanitation interventions, including the rehabilitation of latrines and the promotion of safe waste disposal practices, have been effective in reducing cholera transmission (Guillaume et al., 2019). Similarly, in Zimbabwe, community-led sanitation initiatives have improved hygiene practices and reduced cholera outbreaks (Semá Baltazar et al., 2017). The African Cholera Surveillance Network has also facilitated the sharing of best practices in sanitation improvements among member countries, leading to successful interventions in Mozambique and Tanzania (Munier et al., 2017).
Hygiene Promotion	Hygiene practices are often neglected in cholera-endemic regions due to cultural beliefs, lack of education, and insufficient resources for hygiene promotion (Baličević et al., 2023). In countries like Somalia and Yemen, the challenges of promoting handwashing and other hygiene practices are exacerbated by ongoing conflict and instability (Spiegel et al., 2019). Additionally, misinformation about cholera and its transmission can hinder effective hygiene promotion efforts (Baličević et al., 2023; Démolis et al., 2018).	Successful hygiene promotion campaigns have been implemented in Cox's Bazar, Bangladesh, where extensive community engagement and education efforts have led to increased awareness and adoption of hygiene practices among Rohingya refugees (Khan et al., 2023). In Vietnam, government-led initiatives to promote handwashing with soap have resulted in significant improvements in hygiene behaviors, contributing to a decline in cholera cases (Tran et al., 2012). Furthermore, in Haiti, community health workers have played a crucial role in promoting hygiene practices during cholera outbreaks, leading to improved community resilience (Guillaume et al., 2019).

Community Engagement	Community engagement is often limited by socio-economic barriers, lack of trust in health authorities, and inadequate representation of local voices in decision-making processes (Baličević et al., 2023). In many cholera hotspots, such as Nigeria and Somalia, the absence of community involvement in health interventions has led to ineffective responses to cholera outbreaks (Richterman et al., 2019). Additionally, cultural factors can influence community participation, making it challenging to implement health programmes (Baličević et al., 2023).	In Yemen, community engagement strategies during the cholera outbreak response have proven effective, with local leaders mobilizing resources and facilitating health education (Spiegel et al., 2019). In Bangladesh, the involvement of community health workers in cholera vaccination campaigns has enhanced community trust and participation, leading to higher vaccination coverage (Khan et al., 2023). Moreover, in the DRC, the MCEP has emphasized community involvement in cholera prevention efforts, resulting in increased local ownership of health initiatives (Taty et al., 2023).
Funding and Resources	Insufficient funding for cholera prevention and control programmes is a significant barrier in many affected countries. In Sub-Saharan Africa, countries like Zimbabwe and Nigeria often struggle to allocate adequate resources for health infrastructure, leading to persistent cholera outbreaks (Ali et al., 2015; Richterman et al., 2019). In Yemen, the ongoing humanitarian crisis has diverted resources away from cholera response efforts, exacerbating the situation (Spiegel et al., 2019). Additionally, reliance on external funding can lead to inconsistencies in programme implementation and sustainability (Antwi et al., 2021).	Successful funding initiatives have been observed in Bangladesh, where international organizations and NGOs have collaborated to provide resources for cholera prevention and control, resulting in significant reductions in cholera incidence (Khan et al., 2023). In the DRC, the implementation of the MCEP has been supported by various international donors, leading to improved funding for cholera response efforts (Taty et al., 2023). Furthermore, the African Cholera Surveillance Network has facilitated resource mobilization among member countries, enhancing their capacity to respond to cholera outbreaks (Munier et al., 2017).

In Sub-Saharan Africa, countries like the Democratic Republic of the Congo (DRC), Somalia, Nigeria, Tanzania, and Zimbabwe frequently report cholera outbreaks, particularly in urban slums and rural areas. The cholera outbreak in Kinshasa, DRC, from 2017 to 2018, is a pertinent example of the challenges faced in controlling cholera in such settings. The targeted water supply and hygiene response strategy implemented during this outbreak revealed that while immediate interventions can mitigate transmission, long-term solutions are essential for sustainable cholera control (Bompangue et al., 2020). The study emphasized the importance of establishing a safe and sustainable drinking water supply and improved sanitation to prevent future outbreaks.

In South Asia, nations such as India, Bangladesh, and Pakistan experience cholera outbreaks, particularly during monsoon seasons and in densely populated areas. The spatial clustering of cholera cases in the Kathmandu Valley, Nepal, underscores the role of poor hygiene and sanitation conditions in exacerbating outbreaks. Contaminated water sources, particularly during monsoon rains, contribute significantly to cholera transmission, indicating that hygiene practices must be prioritized alongside water quality improvements (Roskosky et al., 2020). A comprehensive approach addressing water quality and hygiene practices is crucial for effective cholera control in these regions.

Southeast Asia, particularly Myanmar and Vietnam, has also experienced cholera cases, often following natural disasters or in areas with poor sanitation. The cholera epidemic in Haiti, which began after the 2010 earthquake, illustrates the dire consequences of inadequate sanitation and water infrastructure. The ongoing cholera epidemic in Haiti has been perpetuated by a lack of effective WASH interventions, highlighting the critical need for coordinated efforts to improve sanitation and water quality (O'Connor et al., 2011). The experience in Haiti demonstrates that cholera control is not solely a matter of immediate response but requires sustained investment in infrastructure and community education. The Middle East, notably Yemen, has faced significant cholera outbreaks exacerbated by conflict and displacement.

The multi-sectorial emergency response to a cholera outbreak in Internally Displaced Persons (IDP) camps in Borno State, Nigeria 2017, illustrates a successful intervention that leveraged existing health infrastructure to implement cholera control measures. The rapid response campaign targeted over 891,000

individuals and adapted polio vaccination strategies to suit the cholera context, demonstrating the importance of utilizing established health networks for effective cholera control (Ngwa et al., 2020). This case exemplifies how leveraging existing infrastructure can enhance the effectiveness of cholera interventions in crises. Despite these success stories, significant barriers to implementing effective WASH programmes persist. In Haiti, for instance, the cholera alert-response activities launched in 2013 faced numerous challenges, including limited resources and inadequate infrastructure (Bulit et al., 2018). The need for coordination among various stakeholders further complicated efforts to control cholera transmission. The experience in Haiti underscores the necessity for a well-coordinated approach that integrates WASH interventions with broader public health strategies to combat cholera effectively.

The challenges faced in cholera control are not unique to Haiti. In many cholera-endemic regions, the absence of reliable data on cholera incidence and risk factors complicates the development of targeted interventions. The updated global burden of cholera in endemic countries highlights the need for accurate data collection and analysis to inform decision-making and resource allocation (Ali et al., 2015). Additionally, the disproportionate impact of cholera on vulnerable populations, particularly children under five, necessitates targeted interventions that address the specific needs of these high-risk groups.

Successful WASH interventions in cholera hotspots have demonstrated the potential for reducing cholera transmission. For instance, implementing the CHoBI7 cholera rapid response programme in Bangladesh emphasized the importance of early detection and rapid response in controlling cholera outbreaks (Zohura et al., 2022). The programme's success was attributed to its focus on community engagement and education, which fostered improved hygiene practices and increased awareness of cholera prevention measures. Community-driven approaches are essential for sustaining WASH interventions and ensuring their long-term effectiveness.

In Haiti, the case-area targeted rapid response strategy implemented from 2013 to 2017 showcased the feasibility of coordinated cholera control efforts despite facing obstacles related to resource allocation and infrastructure (Rebaudet et al., 2019). The strategy involved rapid response teams that addressed cholera cases in affected areas, demonstrating the importance of timely interventions in mitigating the spread of cholera. The lessons learned from this implementation can inform future cholera control strategies in similar contexts.

The role of education and community engagement in cholera prevention cannot be overstated. A study conducted in rural Haiti following an oral cholera vaccination campaign revealed significant improvements in knowledge and practices related to cholera prevention (Childs et al., 2016). Integrating educational messaging with vaccination efforts enhanced awareness of waterborne diseases and improved hygiene practices among community members. This highlights the necessity of combining health interventions with educational initiatives to foster sustainable behavior change. In addition to education, providing safe drinking water and adequate sanitation is crucial for cholera control. The experience from Latin America in the 1990s, where WASH improvements contributed to eliminating cholera, highlights the importance of investing in water and sanitation infrastructure (Gelting et al., 2013). The significant increase in access to potable water in Mexico during this period resulted in a marked decrease in mortality from diarrheal diseases, demonstrating the long-term benefits of WASH investments in cholera-endemic regions.

Despite the successes observed in various cholera control efforts, the sustainability of WASH interventions remains a critical concern. A systematic review of household water treatment (HWT) programmes in Haiti revealed that the sustainability of these interventions needs to be more adequately evaluated (Lantagne & Yates, 2018). The need for ongoing monitoring and evaluation of WASH programmes is essential to ensure their effectiveness and adaptability in changing contexts. With sustained commitment and investment, the gains made in cholera control may be protected. As outlined in international guidelines, the global momentum to tackle cholera emphasizes the need for comprehensive strategies that integrate WASH interventions with broader public health initiatives (D'Mello-Guyett et al., 2020). Establishing an internationally agreed roadmap to eliminate cholera by 2030 underscores the urgency of addressing the underlying determinants of cholera transmission, including inadequate sanitation and poor water quality. Collaborative efforts among governments, NGOs, and international organizations are essential for achieving these goals.

6. Conclusion

Integrating WASH programmes into cholera prevention strategies is crucial for mitigating the disease's burden in endemic regions. The evidence supporting the effectiveness of sustainable WASH interventions demonstrates that enhancements in water quality, sanitation, and hygiene practices can significantly reduce the risk of cholera outbreaks. In regions such as Nigeria, where cholera remains a persistent threat, implementing safe water sources, effective purification methods, and community-based sanitation initiatives is vital. Fostering long-term behavioral changes through health education will

promote public health and improve cholera control. By prioritizing WASH initiatives, stakeholders can work towards a future where cholera no longer poses a significant public health risk.

Looking ahead, innovations in WASH programme design and delivery are essential for achieving sustainable health outcomes. A comprehensive and multi-faceted approach that includes community engagement, investment in infrastructure, and consideration of climate impacts will be necessary to address the challenges faced in urban slums and refugee camps. Effective WASH interventions should also be integrated with cholera outbreak response efforts to ensure a coordinated approach that addresses immediate health concerns while building resilience against future threats. By learning from success stories and applying evidence-based strategies, the global community can enhance its capacity to manage cholera outbreaks and ultimately aim to eliminate cholera as a public health threat.

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