

Designing Intervention Pathways to Strengthen Health System Resilience to Cholera Outbreaks in Uganda Using Group Model Development and Systems Thinking

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Article: Designing Intervention Pathways to Strengthen Health System Resilience to Cholera Outbreaks in Uganda Using Group Model Development and Systems Thinking

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Abstract

Background

Cholera remains a major public health challenge globally, with sub-Saharan Africa bearing the highest burden. In recent years, several African Union Member States have faced severe and protracted cholera outbreaks, with the African CDC reporting a total of 73,806 cholera cases and 490 deaths (CFR: 0.66%) reported across 22 African Union Member States in 2025. In Uganda, recurrent outbreaks disproportionately affect vulnerable populations such as fishing communities, refugees, and border residents. Despite ongoing interventions, including vaccination campaigns targeting most at-risk populations, national cholera control strategies, and water, sanitation, and hygiene (WASH) improvements, gaps persist in local health system preparedness, surveillance, and response capacity. Using a system thinking workshop, this study engaged diverse stakeholders to analyze the system drivers of cholera vulnerability and identified strategic intervention pathways to strengthen health system resilience.

Methods

We employed a participatory group model development (GMD) approach guided by systems thinking to identify intervention pathways for strengthening health system resilience to cholera outbreaks in Uganda. A two-day workshop was conducted with 20 purposively selected stakeholders from government, academia, the private sector, NGOs, community organizations, and development partners. This process involved (1) reviewing the current situation using prior study findings, (2) identifying the desired outcomes and performance gaps, (3) analyzing key issues and underlying drivers, (4) developing a cause–effect system map (systemigram) using Kumu, (5) identifying and analyzing stakeholders, (6) identifying resilience change levers, and (7) prioritizing intervention pathways through a structured voting process. Data were analyzed using systems mapping and stakeholder analysis techniques. We applied a seven-phase process of systems thinking and cocreation in a two-day workshop involving 20 multisectoral stakeholders.

Results

Three key systemic challenges affecting the health system's capacity to prevent and respond to cholera outbreaks were identified: inadequate water, sanitation, and hygiene (WASH) infrastructure; weak surveillance systems; and poor coordination among stakeholders. The participants also identified and prioritized nine intervention pathways to strengthen health system resilience. The highest-ranked interventions included strengthening multisectoral coordination and leadership, establishing a data-based surveillance system, and enhancing community engagement for sustainable WASH services, in addition to other measures such as innovative sanitation technologies, cross-border vaccination, alternative WASH financing models, local technical capacity building, and strengthened digital surveillance systems.

Conclusion

Group Model Development (GMD) provided a comprehensive framework that integrated a codesign approach and applied systems thinking in the design of intervention pathways to strengthen the resilience of the health system to the cholera outbreak. Future research is needed to evaluate these pathways within the most affected communities.

Introduction

Cholera continues to be a major global health concern, with sub-Saharan Africa accounting for the greatest number of endemic countries [1]. The global burden remains high, with approximately 2.9 million reported cases and more than 90,000 deaths reported every year [2]. In the years preceding 2010, Uganda was reported among countries in Africa experiencing recurrent cholera outbreaks[3, 4]. The literature shows that vulnerability to cholera in Uganda is shaped by environmental exposure, socioeconomic factors, and health system capacity [5]. High-risk populations include fishing communities, displaced persons, refugees, peri-urban slum dwellers, and flood-affected communities in the Albertine region [3, 5]. According to the Ministry of Health in Uganda, cholera accounts for 1,850 cases and 45 deaths annually, with

Nebbi, Hoima, Buliisa, and Mbale contributing 60% of all reported cholera cases between 2011 and 2016 [6, 7]. During the same period, seventeen districts were responsible for 90% of all reported cholera cases in the country, with greater Hoima, Kasese and Nebbi contributing 37%, indicating that these districts are the most affected in Uganda. Since 2015, the number of cases of cholera in Uganda has been declining, with the number of cases decreasing from 1,461 in 2015 to 516 in 2016, representing a reduction of approximately 65%, and since the 88.2% decrease in 2013, the number of cases of cholera has decreased by 31% in 2016 [8, 9].

Several interventions, including vaccination campaigns [10], the National Cholera Control Plan [7], and health system strengthening through improved district-level preparedness, surveillance, emergency coordination, and community readiness for disasters such as floods and outbreaks [11], as well as water, sanitation and hygiene (WASH) improvements [12], have been implemented nationally and regionally. Despite these efforts, gaps in cholera control remain. Subnational health systems still face resource constraints, weak supply chains, and limited surge capacity for responding to disease outbreaks [4, 11, 13, 14]. Evidence is insufficient on the preparedness, adaptability, and recovery capacity of local health systems during cholera outbreaks, as several studies focus mainly on outbreak response and surveillance, with little emphasis on broader health system resilience and long-term adaptive capacity [4, 15]. The perspectives of health workers, communities, and local authorities on system resilience are not well captured in existing epidemiological studies. Failure to strengthen health system resilience in the context of adverse weather events could worsen the reoccurrence of cholera outbreaks and increase morbidity and mortality in high-risk districts. Cholera and other epidemics afflict many communities in Africa, calling for innovative thinking if we are to develop sustainable solutions that will have transformational impact. We therefore need to adopt systems-level thinking in which we make strategic intervention decisions that are informed by a holistic view of the ecosystem and its key stakeholders.

104 Employing systems thinking in cholera outbreak management provides an opportunity to
105 transition from a reactive, isolated response to a holistic, anticipatory strategy. In this study,
106 intervention pathways were defined as strategic sets of interconnected actions, policies,
107 investments, and system changes that target key leverage points within the health system and
108 are expected to produce significant and sustainable improvements in resilience to cholera
109 outbreaks.

110 Using a group model development (GMD) approach grounded in systems thinking, this study
111 convened a team of stakeholders involved in a health care delivery system and facilitated them
112 through a system thinking process [16]. Systems thinking has been widely applied in the design
113 of health interventions and understanding complex interactions within health systems [17, 18].
114 In India, a realist evaluation approach applying systems thinking in healthcare was used to
115 understand organisational change within local health systems in the Tumkur district of southern
116 India [19]. Systems thinking can facilitate understanding of complex implementation contexts
117 and their interactions with interventions, enabling the selection of tailored and effective
118 implementation strategies [20, 21]. These approaches provide a system-wide understanding of
119 complexity, causality and interactions from the perspective of a whole system [22, 23].

120 This study employed a participatory group model development (GMD) approach grounded in
121 systems thinking to identify intervention pathways for strengthening health system resilience
122 to cholera outbreaks in Uganda. Systems thinking provides a conceptual framework for
123 understanding the health system as a complex adaptive system characterized by multiple
124 interacting actors, feedback loops, and dynamic relationships. Group Model Development
125 served as the methodological approach through which stakeholders collaboratively explored
126 these system dynamics, identified key drivers of vulnerability and resilience, and cocreated
127 strategic intervention pathways [16].

Methods

Study design

This study employed a participatory group model development (GMD) approach grounded in systems thinking to identify intervention pathways for strengthening health system resilience to cholera outbreaks in Uganda.

Group Model Development

GMD is a participatory systems research method derived from system dynamics that engages stakeholders in collectively developing representations of complex systems to facilitate shared understanding, learning, and action. This approach enables participants to articulate their mental models, identify causal relationships, examine feedback mechanisms, and determine leverage points for system transformation. In this study, GMD was used to facilitate a structured exploration of the factors influencing cholera preparedness, response, and recovery within the Ugandan health system. The GMD process has been widely used in systems research [24-28].

The two-day Group Model Development workshop involved a multidisciplinary team of stakeholders drawn from the health system and related sectors. The participants represented a broad range of perspectives, including the public health sector, private sector, academia, nongovernmental organizations (NGOs), community-based organizations (CBOs), development partners, innovation specialists, and business experts. A total of twenty participants were purposively selected on the basis of their knowledge, experience, and involvement in the strengthening of cholera prevention, preparedness, response, and health systems.

The workshop focused on the relationships between the components of the resilient system, events, interactions and feedback between these components [29]. The systems thinking workshop applied a cocreation approach that relied on stakeholder input to determine the most

153 strategic and high-priority interventions, which, if addressed, would result in maximum
154 transformational impact using minimal resources.

155 The workshop methodology was adapted from Stanford University's Change Labs framework
156 and other participatory systems methodologies previously applied by the ResilientAfrica
157 Network (RAN) across several African countries to analyze resilience challenges and identify
158 innovation opportunity systems [30-32]. This approach integrates systems thinking tools with
159 group model development techniques to support stakeholder-driven analysis of complex
160 systems and identification of high-leverage interventions.

161 The process focused on understanding the relationships among actors, structures, processes,
162 and outcomes within the cholera preparedness and response system. Participants examined how
163 these elements interact over time and how feedback mechanisms contribute to both system
164 vulnerabilities and resilience. The process generated a shared representation of the system and
165 facilitated the identification of strategic intervention points for strengthening resilience. The
166 primary outputs of the workshop included a system map (Systemigram), stakeholder
167 relationship maps, and a set of prioritized intervention pathways. These outputs provide a basis
168 for understanding system dynamics and identifying opportunities for transformational change
169 within the health system.

170 **Systems thinking workshop process to develop intervention pathways**

171 The workshop methodology was implemented in sequential stages. In the first part of the
172 workshop, participants were given a series of tools to enable them to understand the resilience
173 system and its boundaries regarding cholera outbreaks and the interrelationship with the health
174 system. The seven steps are described below.

175 **Step 1: Understanding the Current System Situation**

The participants received a full briefing on the outcomes of the earlier studies (a high-level summary of the findings from the qualitative and quantitative studies previously conducted plus the literature to obtain grounding in the key resilience issues). This briefing was also shared prior to the workshop as part of the preworkshop materials.

Step 2: Defining the desired outcomes

The goal here was to identify the desired outcomes and performance gaps (issues). Participants collectively identified the desired characteristics of a resilient health system capable of effectively preventing, detecting, and responding to cholera outbreaks. Through facilitated discussions, participants articulated current challenges and corresponding desired outcomes, generating issue–outcome pairs that served as the basis for subsequent analysis.

Step 3: Identifying Key Issues and Underlying System Drivers

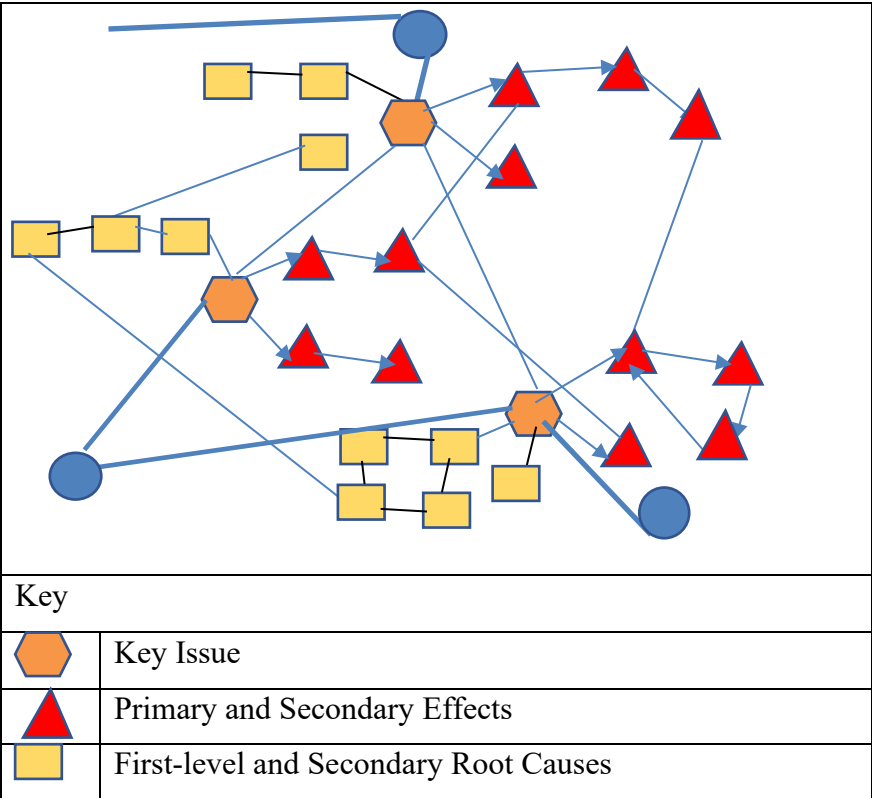
The objective was to identify key driving dynamics for the performance gaps. The participants examined the identified resilience challenges and explored their underlying causes. Through structured group discussions, priority issues affecting cholera preparedness and response were identified and analyzed to elucidate the deeper systemic factors driving the observed performance gaps.

Step 4: Collaborative development of the system map.

A central component of the Group Model Development process involved the collaborative construction of a system map representing the relationships among key issues, causes, effects, and stakeholders. Participants collectively developed a visual representation of the cholera preparedness and response system by identifying causal connections, feedback relationships, and interdependencies. Following the prioritization exercises, three key systemic challenges emerged:

- 1) Limited WASH access, unsafe water, vandalism, hygiene gaps and open defecation increase community cholera vulnerability.
- 2) Weak surveillance systems characterized by limited training, poor coordination, inadequate financing, and climate pressures delay cholera detection, preparedness, and effective community response capacity.
- 3) Poor coordination among stakeholders, including NGOs and the government at the national and district levels, leads to duplication, resource wastage, and fragmented cholera control efforts.

The priority emerging issues, together with their causes and underlying causes, effects and secondary effects, were then used to construct a system map in a practical simulation, showing interrelationships between issues, their causes and their effects. Relationships between issues and sub issues are then connected using relationship lines, as indicated in Figure 1. The raw diagram (Figure 1) was then transferred to a visualization software called KUMU (<https://www.kumu.io>), as highlighted in Figures 2, 3 & 4 in the results.



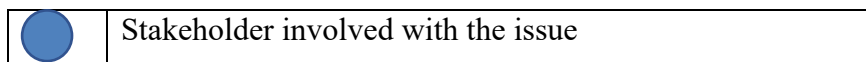


Fig 1: Relationships between issues and sub issues

Step 5: Stakeholder identification and relationship analysis

The objective here was to critically analyze each key stakeholder to understand them and their capacities, barriers and enablers and interests. Participants identified key stakeholders operating within the cholera preparedness and response system and analyzed their roles, interests, capacities, and relationships. Stakeholders were categorized according to their degree of influence and involvement within the system. Participants also explored existing and desired relationships among stakeholders, including flows of information, resources, authority, and collaboration.

Step 6: Identification of System Leverage Points

Using the system map and stakeholder analyses, participants identified leverage points where strategic interventions could produce significant system-wide improvements. Through facilitated brainstorming and discussion, participants proposed potential change levers capable of influencing multiple system components and improving resilience outcomes. The participants wrote out the change lever, including a brief description of the lever so that it is understood in context.

Step 7: Prioritization of Intervention Pathways

The objective here was to down select from the pool of change levels. This final stage focused on prioritizing intervention pathways with the greatest potential to strengthen health system resilience to cholera outbreaks. The participants reviewed the identified leverage points and assessed their transformative potential. Through a structured voting process, priority interventions were selected and consolidated into a set of strategic intervention pathways. Nine key intervention pathways were selected and described by the stakeholders

Analysis of the data from the systems thinking workshop

Analysis was conducted at three levels using information derived from the different worksheet tools. In the first-level workshop, participants worked in small groups of approximately 6 individuals to unpack the system by listing what they knew about the cholera outbreak, the desired outcome, and the existing gaps in preparedness and response. This session helped identify the key issues (gaps), underlying causes and effects, and stakeholders involved in the system. It is important to note that the issues do not occur in isolation but rather are part of a complex system of causes (primary and secondary) and effects (primary and intermediate/secondary). The issues, causes, and effects also interconnect with each other in a complex web of hierarchies. The participants consequently went through an exercise in which they constructed a systems diagram (cause-and-effect map) for the fundamental issues described. The causal relationships between the issues and the myriad of interconnected causes and effects were captured in a web-based platform called KUMU.io. To construct a Kumu map for the identified issues, we used the interconnected causes and effects and stakeholder relationships developed during the workshop. We gathered and organized the data into elements (main issue, primary causes, secondary causes, primary effects, secondary effects and stakeholders) and connections (relationships between the different elements) using an Excel spreadsheet. We then created a Kumu project and imported and imported the developed spreadsheet containing the elements and connections after verifying the field mappings. We then categorized and tagged the elements for filtering, chose an appropriate layout and applied styling (colors, sizes, and icons) to reflect attributes and use layers to present different views.

At the second level, a stakeholder analysis was conducted. Participants were asked to identify key stakeholders and their roles within the system. Working in groups, participants analyzed stakeholder–stakeholder interactions with a focus on roles, access to resources, and level of influence between each of the stakeholders within the system. For each of these relationships

mentioned, the current relationship/value, which flows between stakeholders, as well as that which should be flowing but is not flowing, was identified. The workshop participants identified weak, strong and nonexistent relationships on the basis of the roles they played to make the system effective. Stakeholder analysis was also included in the kumu mapping

At the third level, participants were taken through a series of sessions using different tools on how to identify priority change levers that, once well leveraged, could cause a desired change in the entire complex outbreak preparedness and response. Participants examined the system maps and stakeholder relationship worksheets to identify strategic points in the system where an intervention would have significant effects on the system. The participants generated change levers. All similar or interrelated changes were clustered together into intervention pathways. Each participant was provided with 8 sticky votes and asked to vote for at least five intervention pathways. Interventions with less than 5 votes were not considered. Depending on how compelling the pathways are, a participant was welcome to cast one or more of their four votes on a single pathway. The top nine (9) priority pathways were selected.

Results

Analysis of issues and underlying phenomena

Three underlying issues, namely, inadequate WASH facilities and infrastructure, weak surveillance systems, and poor coordination among stakeholders, were identified as key systemic challenges hindering efforts to strengthen the health system to manage cholera outbreaks.

Inadequate access to WASH services

Participants indicated that the current WASH infrastructure is hindered by inadequate safe water sources in the communities and where the water sources were available; participants mentioned that these water sources are sometimes vandalized by unscrupulous individuals in

the community. Participants mentioned that it was very important to understand these deficits at the system level as a way of teasing out interventions that could improve prevention and control mechanisms for cholera outbreaks in the country. Owing to the low coverage of WASH services, such as inadequate access to safe water, communities are forced to use unsafe water alternatives that predispose them to cholera.

Participants identified several primary and secondary causes of inadequate access to WASH services; inadequate water, sanitation, and hygiene (WASH) infrastructure exacerbated by insufficient funding; challenging environmental conditions, such as flooding, destruction or theft of WASH facilities; limited spare parts; and a shortage of local technical expertise, which limits access to safe water and sanitation; prolongs service interruptions; and increases reliance on unsafe alternatives, whereas poverty, high fertility and rapid population growth place additional pressure on strained WASH resources; persistent disputes over water access; low community ownership and care; and cultural practices that discourage latrine use or safe water handling, weak or inactive management systems; additionally, political interference further undermines coordination, accountability, maintenance, and the equitable distribution of services, collectively heightening communities' vulnerability to cholera transmission.

The primary and secondary effects identified include inadequate access to safe WASH services, which forces communities to rely on contaminated water and encourages open defecation, which contaminates the environment and water bodies and accelerates cholera transmission; this poor access undermines handwashing and hygiene, contaminates food during preparation, and contaminates surface and groundwater, sustaining recurrent outbreaks and overwhelming health systems. The resulting frequent illness and absenteeism disrupt learning and reduce academic performance, limit workforce productivity, and drive reliance on untrained providers, delaying effective treatment, while the accumulation of waste and unhygienic living conditions further increase disease burden and vulnerability.

The cause–effect analysis was further elucidated in a systemic diagram using kumu.io, and the interactions between the causes and effects are presented in Figure 1. The stakeholders that influence the relationships are also presented in the figure.

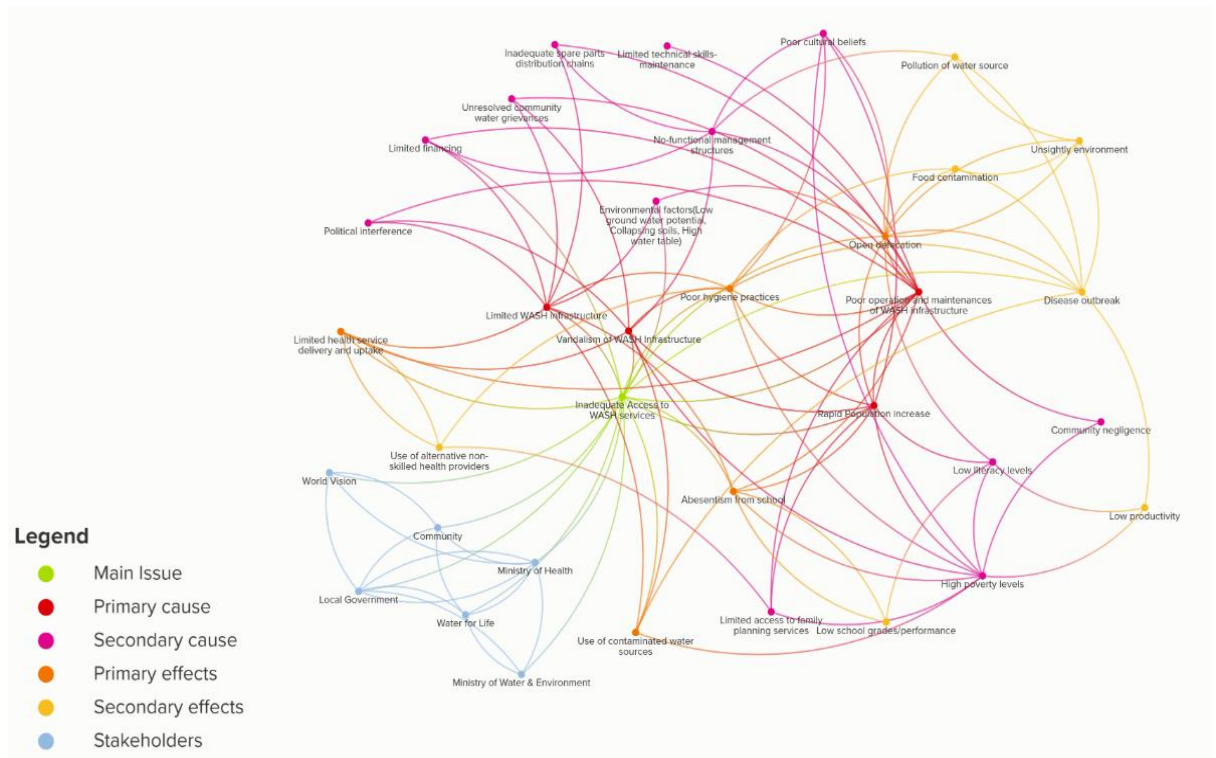


Figure 2: A systemigram showing the interaction between the causes and effects of inadequate WASH facilities.

The network with the greatest impact on the system originates from poor or nonfunctional WASH infrastructure, which is strongly linked to limited financing, poor maintenance, rapid population growth, and weak community engagement (Figure 2). Collectively, these factors generate structural weaknesses within the system that manifest as open defecation, inadequate hygiene practices, and contaminated water sources. These outcomes represent key primary effects that are interconnected through multiple causal pathways and feedback mechanisms. As these effects accumulate, they trigger secondary effects such as increased diarrheal disease burden, recurrent cholera outbreaks, and overstretched healthcare systems, each of which loops back into the causes through mechanisms such as loss of productivity, increased poverty levels,

and reduced community capacity to maintain or operate WASH facilities. Another impact network is driven by limited health promotion and behavior-change communication, which is linked to poor cultural beliefs, low hygiene awareness, and inadequate community mobilization. This cluster highlights risky WASH behaviors, further contaminating the environment and reinforcing disease transmission. The system also highlights how governance and management failures, including weak institutional coordination and unregulated settlements, interact with infrastructural gaps to reduce the sustainability of WASH services, thereby perpetuating the cycle of vulnerability. Overall, the most influential pathways demonstrate a self-reinforcing cycle in which infrastructural deficits, socioeconomic constraints, and behavioral risks combine to deepen the health consequences of inadequate WASH, showing that meaningful improvements require simultaneous action across infrastructure, financing, governance, and community engagement.

Weak disease surveillance systems

Participants identified a weak disease surveillance system characterized by weak real-time monitoring and reporting of suspected cholera cases, irregular updates on case reporting, unsustainable updates, a limited capacity for last-mile diagnosis, and a lack of water quality monitoring at community water points. There was mention of limited capacity at both the national and cross-border levels in terms of coordination, with limited preparedness at border points. The weak surveillance system was also characterized by limited financing amidst varying priorities coupled with refugee influx.

The primary and secondary causes of weak disease surveillance systems identified by stakeholders are as follows: insufficient and poorly supported surveillance capacity characterized by too few personnel for data collection and analysis; the absence of active

surveillance systems; a low index of suspicion among health workers; limited training; funding constraints for field investigations and laboratory testing; gaps in understanding procedures; weak government planning; competing health priorities; and limited institutional attention, undermining cholera detection and response by producing delayed and underreported cases; poor-quality data; fragmented information flows; and weakened coordination, all of which hinder timely outbreak identification, investigation, and control.

Relatedly, several primary and secondary effects emerge from weaknesses in the surveillance system. First, delayed identification and reporting of cholera cases allow transmission to continue undetected, leading to the emergence and expansion of outbreak hotspots. This delay slows the activation of emergency response measures and reduces the effectiveness of outbreak containment efforts. Second, limited and unreliable surveillance data constrain the timely deployment of health workers and resources to high-risk areas. Inadequate information also delays case detection, diagnosis, and treatment, increasing the risk of severe illness and mortality among affected populations.

Third, prolonged outbreaks place additional pressure on the health system, overwhelming health facilities and response capacities. As resources are redirected to manage the outbreak, routine health services may be disrupted, affecting the delivery of essential healthcare. Finally, the increased workload associated with the outbreak response further weakens the surveillance performance. Overburdened health workers may struggle to fulfill surveillance and reporting responsibilities, leading to declining data quality and creating a reinforcing cycle that further compromises outbreak detection and response. The system interactions between the causes, effects and stakeholders are presented in the system diagram in Figure 3.

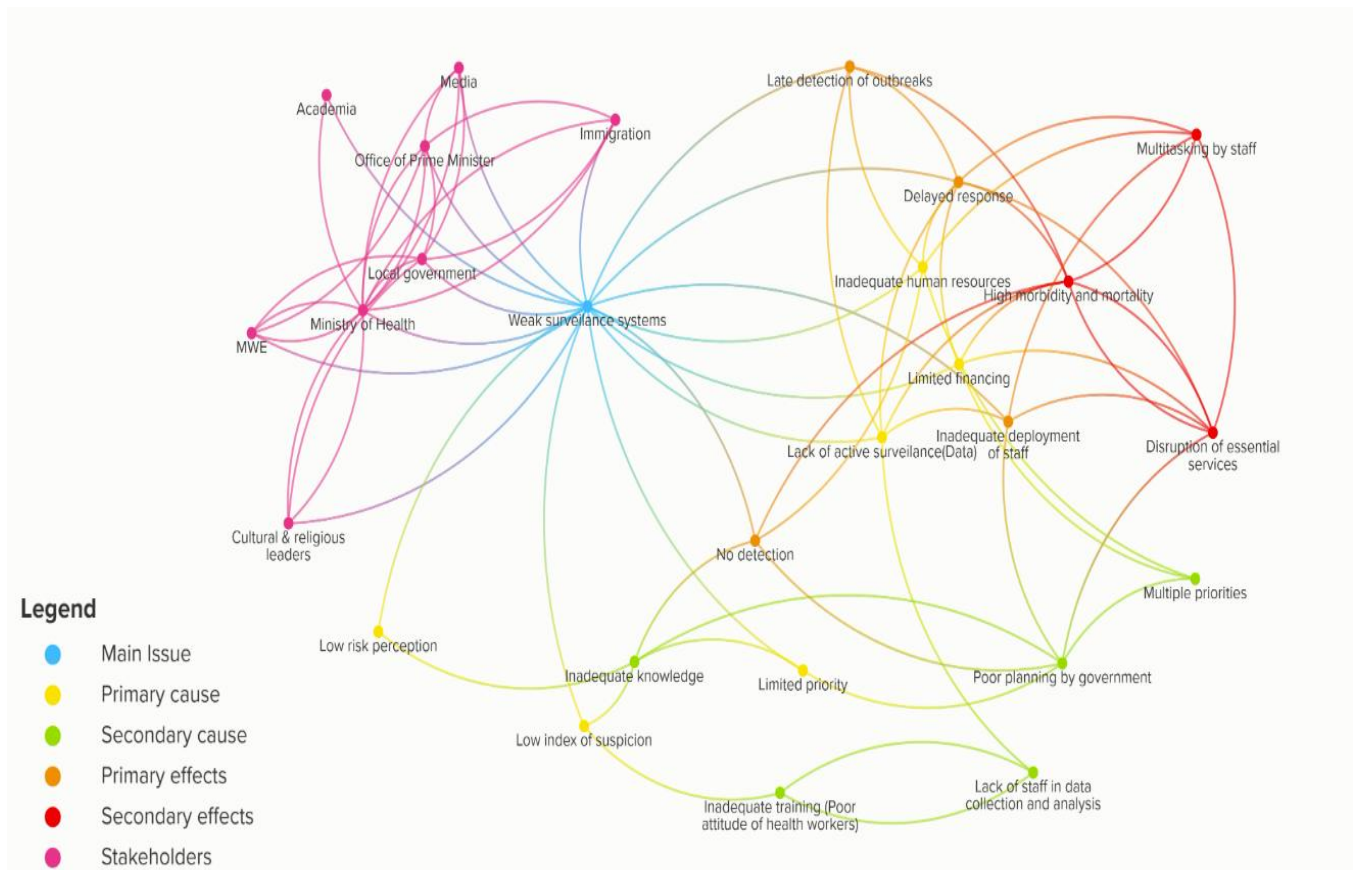


Figure 3: Systemigrams showing the interactions between the causes and effects of a weak surveillance system for preventing and controlling cholera

As presented in Figure 3, one of the key causal pathways originates from inadequate training of health workers, limited skills in data collection and analysis, and low levels of supervision, which collectively undermine data quality and reporting accuracy. These weaknesses flow directly into inadequate knowledge, poor risk perception, and ultimately no detection or late detection of outbreaks, which are among the strongest drivers of downstream effects in the system. The systemigram further illustrates that limited policy support, inadequate government planning, and shortages in human resources constitute an interconnected set of factors that interact with workforce capacity challenges. Together, these factors constrain the effective deployment of surveillance personnel and increase the workload of existing staff through multiple responsibilities and competing demands.

Delayed response is associated with increased morbidity and mortality, disruption of essential health services, and the diversion of attention and resources toward multiple competing priorities. These consequences, in turn, reinforce existing system constraints by placing additional pressure on limited financial resources, thereby constraining investments in workforce training, supportive supervision, and technology adoption. Overall, weak workforce capacity and governance failures lead to poor detection and delayed response, which increases the disease burden of cholera and strains the health system, ultimately feeding back into the same constraints that weaken surveillance.

Weak coordination mechanisms among stakeholders

The workshop participants identified weak coordination among stakeholders as another key issue in cholera prevention and control. The primary and secondary causes of this weak coordination were unclear responsibilities and overlapping mandates; poor communication and isolated data systems; weak leadership; limited or poorly established coordination platforms; political interference; limited cross-border collaboration; misaligned sectoral and donor priorities; inadequate stakeholder engagement; ineffective institutional arrangements; limited transparency and corruption; and shortages of funding, supplies, and transport; service gaps; and delayed actions, all of which reduce the effectiveness and coverage of cholera prevention and response.

Weak coordination among stakeholders results in duplicated interventions in some areas and service gaps in others, leading to inefficient use and misallocation of financial, human, and material resources; fragmented and delayed responses reduce the effectiveness of prevention and control measures; produce inconsistent reporting and limited information sharing; weaken accountability due to unclear roles and poor monitoring; and foster competition and mistrust that undermine collaboration and community participation, all of which delay decision-making,

resource mobilization, and implementation, prolonging and amplifying cholera outbreaks. The above causes and effects are demonstrated in a system diagram in Figure 4.

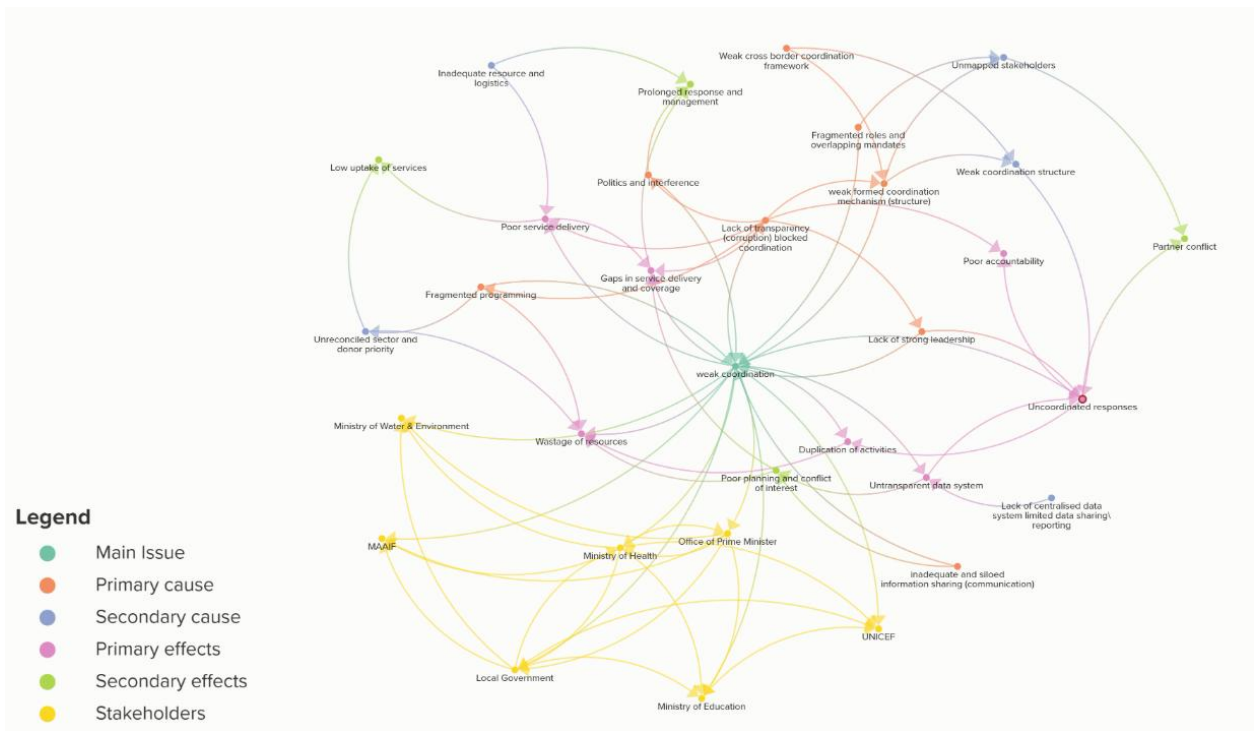


Figure 4: Systemigrams showing the interaction between the causes and effects of weak coordination among stakeholders

As shown in Figure 4, poor planning and unclear role definition, weak leadership, and insufficient coordination structures collectively contribute to fragmented implementation. This results in partners operating independently, with frequent duplication of efforts across programs. These upstream weaknesses flow directly into uncoordinated responses, partner conflicts, and missed opportunities for joint planning, all of which reduce coherence in decision-making and resource allocation. A second high-impact network emerges from inadequate data sharing and weak information flow across agencies, preventing real-time situational awareness and leading to uncoordinated interventions and poor resource mobilization. This in turn contributes to gaps in service coverage, poor service delivery, and delays in emergency response and risk management. These effects loop back into the system by amplifying politics and institutional interests, further weakening transparency and mutual

accountability among stakeholders. Another strongly connected pathway shows how poor accountability mechanisms and low stakeholder commitment reduce compliance with agreed-upon plans and reporting structures, resulting in inconsistencies in service implementation and worsening the coordination gap. Together, these networks create a self-reinforcing cycle: weak leadership and planning lead to fragmented action, which produces inefficient or duplicated efforts, resulting in poor outcomes that further erode trust, leadership credibility, and the willingness of actors to coordinate. Ultimately, the map illustrates that strengthening coordination requires simultaneously building leadership structures, harmonizing information systems, clarifying roles, and institutionalizing joint accountability mechanisms to break the cycle of fragmentation and operational dysfunction.

Intervention pathways

To address the causes and effects of these system challenges, workshop participants identified nine intervention pathways for strengthening the resilience of the health system. Table 1 presents the priority intervention pathways identified during the systems thinking workshop as well as the number of votes per intervention. Multisectoral coordination and leadership, data-based surveillance and community engagement for WASH sustainability scored the highest number of votes.

448 **Table 1: Selected intervention pathways with respective numbers of votes**

No	Intervention	No of votes
1	Strengthening Multisectoral Coordination and Leadership	29
2	Data-Based Surveillance System	14
3	Enhanced Community Engagement for WASH Sustainability	12
4	Innovative Low-Cost Latrine Facilities Acceptable to Communities	09
5	Joint Cross-Border Vaccination of Incoming Travelers from Cholera-Affected countries	08
6	Mindset Change on Water and Sanitation	06
7	Alternative Financing Model for WASH Interventions	05
8	Training Local Mechanics and Masons on Maintenance of WASH Facilities and Infrastructure	05
9	Strengthening Digital Data Systems for Surveillance and epidemic Response	05

449 *Note: Each participant had eight votes and was required to vote for at least five interventions.*

450 *Interventions with fewer than five votes were excluded from Table 1.*

451 **Strengthening Multisectoral Coordination and Leadership**

452 The participants identified improved coordination and leadership as a critical intervention
453 pathway. This intervention received almost twice the number of votes as the issue that came
454 second during the prioritization. Optimized resource utilization is expected to result from
455 effective leadership and collaborative planning. Intermediate outcomes include joint planning
456 processes, updated health workforce matrices, improved data-sharing mechanisms, and
457 strengthened resource mobilization. Progress is monitored using indicators such as the
458 frequency of coordination meetings, the existence of data-sharing agreements, and the use of
459 workforce planning tools. Changes in system behavior include joint planning processes,
460 multisectoral mapping, and coordinated resource allocation. Human behavioral change
461 involves government agencies and partners transitioning from siloed implementation toward

collaborative engagement and shared accountability. The theory of change assumes that coordinated leadership improves efficiency, strengthens preparedness, enhances early detection and response, and ultimately reduces disease outbreaks and mortality.

Data-based Surveillance System

The participants emphasized the importance of strengthening surveillance systems through continuous real-time data collection and analysis. The proposed data-based surveillance pathway aims to enhance early outbreak detection, improve data quality, and strengthen coordination among stakeholders. The data-based surveillance system pathway seeks to establish a continuously functioning mechanism for collecting, analyzing, and using real-time health data to detect and respond rapidly to disease threats. The goal of the data-based surveillance system is to establish an integrated, real-time, and action-oriented public health intelligence system that enables continuous detection, analysis, and rapid response to cholera and other epidemic-prone diseases at the community, district, and national levels. Stakeholders propose a shift from passive reporting toward proactive surveillance by strengthening routine data collection at health facilities and community levels, automating data transmission through interoperable digital platforms involving Village Health Teams, and generating timely alerts that trigger predefined response actions at the district and national levels. At scale, the surveillance system ensures that suspected cases are detected early, verified rapidly, and communicated seamlessly across sectors to support coordinated decision-making and resource deployment. The intervention seeks to institutionalize data use within health system workflows by equipping health workers and decision makers with analytical tools, dashboards, and feedback mechanisms that translate data into operational responses such as targeted vaccination, WASH interventions, and risk communication. Ultimately, the vision is to create a resilient surveillance ecosystem capable of expanding geographically and functionally

without system failure, thereby enabling early containment of outbreaks, efficient resource utilization, and sustained reduction in cholera incidence and mortality. System behavior transformations include automated alerts, rapid reporting feedback loops, transparency, and accountability in data use. Human behavioral change involves health workers, district leaders, and policy makers adopting data-driven decision-making and improved intersectoral communication.

Enhanced Community Engagement for WASH Sustainability

This intervention seeks to foster ownership and co-financing of WASH services. Participants envisioned empowered communities capable of managing and sustaining WASH infrastructure to improve functionality and sustainability. The scaled vision is empowered communities capable of managing and investing in their WASH systems with expected outcomes such as increased functionality of water user committees and improved awareness of sanitation options. Such interventions would shift system behavior toward community-led management and maintenance of WASH facilities, involving a community's increased willingness to pay for maintenance, safeguarding of infrastructure, and active participation by community members. The theory of change under such an intervention is that when communities perceive WASH facilities as shared assets and participate in decision-making and financing, sustainability improves, infrastructure reliability increases, and sanitation outcomes are strengthened, ultimately reducing cholera risk.

Innovative Low-Cost Latrine Facilities Acceptable to Communities

To address affordability barriers, participants proposed community-centered design and the adoption of innovative low-cost latrines tailored to local environmental and socioeconomic conditions. This intervention pathway promotes the design and adoption of affordable, locally

appropriate sanitation technologies developed through participatory community engagement. The scaled vision is improved sanitation coverage through widespread construction and the sustained use of innovative low-cost latrines. Intermediate outcomes include reduced open defecation and increased household latrine construction, monitored through indicators such as the number of latrines built and the proportion of open-defecation-free communities. System behavior emphasizes community-centered design and locally adaptable sanitation solutions. Human behavior change focuses on acceptance, correct usage, and community participation in sanitation innovation. The theory of change assumes that affordable and culturally acceptable sanitation options increase adoption rates, resulting in improved hygiene, reduced disease transmission, decreased mortality and malnutrition among children, and improved overall community health outcomes.

Joint Cross-Border Vaccination of Incoming Travelers from Cholera-Affected Countries

Participants identified cross-border transmission as a critical driver of recurrent outbreaks, leading to the development of a joint cross-border vaccination pathway targeting travelers arriving from cholera-affected areas. The joint cross-border vaccination intervention pathway focuses on screening travelers at points of entry and vaccinating individuals arriving from high-risk cholera-affected areas to prevent cross-border transmission. The scaled vision for this pathway is to ensure that all travelers from high-risk regions are screened and vaccinated upon arrival, contributing to the elimination of cholera through the prevention of importation and onward transmission. Expected intermediate outcomes include early detection of cases, controlled disease spread, and the achievement of vaccination coverage exceeding 80% among high-risk travelers, measured through indicators such as vaccination uptake rates and the detection of suspected cases at border points. At the system level, human behavioral shifts to be tracked involve increased acceptance of screening and vaccination among travelers and

communities, alongside complementary uptake of WASH practices. The theory of change assumes that strengthening border screening and vaccination systems, combined with community compliance and coordinated public health action, interrupts transmission chains early, thereby preventing possible cross-border outbreaks and reducing the national cholera burden.

Changes in Water and Sanitation Mindset

The mindset change intervention pathway focuses on reducing open defecation through behavioral change communication that emphasizes dignity, cultural values, and social norms surrounding sanitation. It involves the transformation of social norms, beliefs, and behavioral practices that sustain open defecation and poor hygiene behaviors within communities, thereby addressing a key underlying driver of cholera transmission. Rather than relying solely on infrastructure provision, this pathway recognizes sanitation as a social and cultural practice shaped by perceptions of dignity, acceptability, and collective responsibility. Activities include participatory community dialogs, the engagement of cultural and religious leaders, sanitation campaigns led by village health teams and extension workers, and locally tailored messaging addressing prevailing norms that normalize open defecation because of a lack of alternatives or long-standing cultural practices. Particular attention is given to gender and household dynamics, given that sanitation decisions often involve shared responsibilities among men, women, and children. The scaled vision is the achievement of open-defecation-free communities where safe sanitation practices are socially expected, culturally reinforced, and sustainably maintained without continuous external enforcement. Intermediate outcomes include improved household sanitation and increased latrine use, measured through indicators such as the proportion of households with functional latrines and a reduced prevalence of open defecation. At the system level, behavior shifts toward routine community monitoring, local

leadership accountability, and the integration of sanitation promotion into primary health and community outreach structures. Human behavioral transformation targets men, women, and children through shifts in perceptions linking sanitation with dignity and social acceptance, reinforced by cultural and political leadership. The theory of change suggests that when sanitation behaviors become socially valued and culturally embedded, communities self-regulate hygiene practices, leading to sustained reductions in environmental contamination. Improved sanitation behaviors interrupt fecal oral transmission pathways, thereby reducing the incidence of cholera and other diarrheal diseases.

Alternative financing model for WASH interventions

The participants highlighted inadequate financing as a systemic constraint and proposed alternative financing models involving government, private sector actors, development partners, and community contributions. The alternative financing model for the WASH intervention pathway addresses persistent funding gaps that limit the development, maintenance, and sustainability of water, sanitation, and hygiene infrastructure in cholera-prone communities. The scaled vision of this intervention is the establishment of sustainable, diversified, and locally owned financing mechanisms capable of supporting long-term WASH investments while reducing dependence on short-term donor funding. The model promotes shared financial responsibility among government institutions, development partners, private sector actors, financial institutions, and communities. Intermediate outcomes include increased budget allocation, expanded WASH infrastructure development, and improved local revenue mobilization, measured through financial allocation and expenditure indicators. System behavior shifts toward structured financing mechanisms, transparent resource management, and accountability systems. Human behavioral changes include increased stakeholder commitment to financing WASH services and strengthened financial stewardship. The theory

of change posits that predictable and diversified financing enables continuous investment in WASH infrastructure, improving sanitation coverage and reducing cholera vulnerability in high-risk communities.

Training Local Mechanics and Masons on the Maintenance of WASH Facilities and Infrastructure

focused on improving the sustainability of water and sanitation systems through training local mechanics and masons in the preventive maintenance and repair of WASH infrastructure. This intervention pathway aims to increase local technical capacity, thereby improving the sustainability and reliability of water and sanitation systems. The scaled vision progresses from pilot training of small groups to district-wide expansion and eventual institutional integration of trained personnel into district WASH systems. Intermediate outcomes of this capacity building would include reduced breakdown of facilities, improved access to safe water and sanitation, cost savings through preventive maintenance, and local job creation, monitored through indicators such as routine inspections, timely reporting of faults, and correct use of maintenance tools. Changes in human behavior in this intervention emphasize the adoption of preventive maintenance practices by technicians and increased community participation through reporting breakdowns and supporting maintenance activities. The theory of change for this intervention proposes that locally available technical skills reduce the downtime of WASH facilities, ensuring continuous service delivery, strengthening community resilience, and ultimately reducing water- and sanitation-related diseases, including cholera.

Strengthening Digital Data Systems for Surveillance and Response

In complementing surveillance strengthening, participants proposed the harmonization and digitization of fragmented reporting platforms. This intervention pathway addresses the

limitations of paper-based and fragmented reporting systems by developing harmonized digital platforms for real-time surveillance and response. The scaled vision is a unified digital system providing continuously updated, accessible data products for planning and decision-making. Intermediate outcomes include the development of digital tools, training of focal persons, creation of visualization dashboards and GIS mapping systems, and improved human resource capacity for data management, monitored through indicators such as operational dashboards and trained personnel. System behavior shifts from manual reporting toward real-time digital data entry, integrated information sharing, and regular reporting cycles. Human behavior change involves ownership and buy-in from the Ministry of Health staff, politicians, and data entrants, alongside the adoption of prompt digital reporting practices. The theory of change posits that digitizing data systems and strengthening analytical capacity improves situational awareness and planning, enabling faster outbreak response and reducing the incidence and impact of cholera outbreaks.

Discussion

This study applied a participatory group model development (GMD) approach guided by systems thinking to identify intervention pathways for strengthening health system resilience to cholera outbreaks in Uganda. The results of the systems thinking workshop comprised two main components. First, participants identified key systemic challenges affecting the health system's capacity to prevent and respond to cholera outbreaks. Through small group discussions, three major underlying issues emerged: inadequate water, sanitation, and hygiene (WASH) infrastructure; weak surveillance systems; and poor coordination among stakeholders. Second, participants identified and prioritized nine intervention pathways aimed at strengthening health system resilience to cholera. When participatory voting was used, the most highly prioritized interventions included strengthening multisectoral coordination and leadership, establishing a data-based surveillance system, and enhancing community

engagement for sustainable WASH services, alongside other interventions such as innovative low-cost sanitation technologies, cross-border vaccination, behavioral change initiatives, alternative WASH financing models, local technical capacity building for infrastructure maintenance, and strengthened digital surveillance systems.

Analysis of issues and underlying phenomena

System-wide analysis revealed three underlying issues that hinder the system from effectively managing cholera outbreaks. The system analysis process used to identify these issues was designed to foster a contextualized understanding of the specific system and the barriers to behavior change. Systems thinking methods require a holistic diagnosis of the full range of varying components that impact a given system, which allows us to break away from linear solution models by diagnosing and then addressing the gaps and barriers identified within each underlying issue. These interactions are presented in a dynamic way within the system. The system is defined by these dynamic, multifaceted, and potentially asymmetric linkages and relationships [33]. This was done to achieve a sustainable model of evidence-based decision-making, and strong and effective linkages between causes and effects are critical. In this analysis, we observe inadequate water, sanitation, and hygiene (WASH) infrastructure, weak surveillance systems, and poor coordination among stakeholders. In Uganda, inadequate WASH infrastructure is widely recognized as a systemic issue rooted in chronic underinvestment, governance gaps, and uneven service delivery across regions. Evidence from the Economic Policy Research Centre shows that underfunding remains severe: in FY2022/23, WASH services received UGX 2.7 trillion, far below the UGX 5 trillion required annually, and this gap is projected to widen to UGX 10 trillion by 2030, constraining life-saving interventions and slowing progress toward national and SDG 6 targets [34, 35]. Beyond financing, systemic weaknesses have been identified, including inconsistent budget execution, limited integration of WASH services into local government systems, and infrastructure that is often climate

vulnerable, particularly in districts such as Kasese and Kamwenge, among others where climate change is degrading water sources and damaging sanitation systems [36, 37]. These interconnected challenges reveal that inadequate WASH access in Uganda is not a result of isolated project failures but rather a structural problem involving financing, governance, climate resilience, and service management requiring comprehensive, coordinated, and long-term system strengthening approaches.

Coordination between community structures and health facilities is often inconsistent with the absence of standardized community surveillance indicators and the limited integration of WASH data into surveillance systems, hence hindering comprehensive risk assessment and timely preparedness for cholera outbreaks. Relatedly, facility-based surveillance in these districts is similarly constrained by systemic challenges. Health facilities frequently face shortages of diagnostic supplies, inadequate laboratory capacity for cholera confirmation, and gaps in documentation within the Health Management Information System (HMIS). These systemic challenges have been documented in some studies [38-41]

Systematic reviews highlight that surveillance systems in African countries, including Uganda, often fail to integrate critical multisectoral and laboratory linkages, resulting in weaknesses in early detection, data sharing, and coordinated response [42, 43]. Moreover, outbreaks such as the May 2024 cholera incident at the Kasensero Landing site reveal gaps at frontline facilities: shortages of rapid diagnostic test kits, insufficiently trained staff, and poor record-keeping undermine rapid case confirmation and timely response [44]. These weaknesses, combined with broader regional challenges such as inadequate financing, competing health priorities, and limited genomic surveillance capacity, impede Uganda's ability to manage recurrent cholera threats. While initiatives such as Africa CDC's surveillance strengthening programs and global roll-out of RDT-based cholera diagnostics offer opportunities for improvement, the systemic

shortcomings in local surveillance infrastructure, laboratory capacity, and cross-border coordination continue to pose substantial risks to timely cholera detection and control in Uganda [43].

Strengthening multisectoral coordination, data-driven surveillance, and community engagement was identified as essential for building sustainable WASH services in Uganda and strengthening the health system to address cholera outbreaks. When viewed through a systems-thinking lens, this recognizes the interdependence of institutions, information flows, and community behaviors. Recent efforts by the national WASH Steering Committee at the Ministry of Health, bringing together the Ministry of Health, Ministry of Water and Environment, Ministry of Education and Sports, and development partners demonstrate how high-level coordination enhances policy direction, investment prioritization, and accountability for WASH service delivery. These coordinated actions have supported improvements such as the rollout of the WASH Management Information System (WASH-MIS) and the electronic Community Health Information System (e-CHIS), which strengthen data-based decision-making and monitoring across sectors [37, 45]. Moreover, system assessments reveal persistent fragmentation of WASH data across ministries, difficulty in standardizing performance indicators, and weak linkages between local and national monitoring platforms, underscoring the need for a fully integrated surveillance system capable of routinely tracking service functionality, financing, and equity gaps. Strengthening community engagement remains equally critical: approaches such as Community-Led Total Sanitation (CLTS) and area-wide sanitation programming promote collective responsibility, reinforce local governance structures, and ensure that behavioral and cultural dimensions are embedded in system-wide WASH improvements. When these elements of multisectoral leadership, integrated surveillance systems, and empowered communities work in tandem, Uganda will be

better positioned to establish resilient, inclusive, and sustainable WASH systems capable of withstanding demographic pressures, climate risks, and public health threats.

A key limitation of the participatory group model development (GMD) approach guided by systems thinking is its reliance on a relatively small number of purposively selected stakeholders, which may limit the breadth of the perspectives captured. Although efforts were made to ensure multisectoral representation, certain voices, particularly community members affected by cholera outbreaks and lower-level health facility staff, were underrepresented, potentially affecting the completeness of the system representation. In addition, the workshop-based nature of GMD means that findings are shaped by participants' perceptions, experiences, and group dynamics at a single point in time, which may not fully reflect the evolving nature of cholera outbreaks and health system responses. The complexity of systems mapping also requires simplification of real-world relationships, which may lead to omission of important variables or feedback loops. Finally, while the approach is strong in generating contextualized and actionable insights, the identified intervention pathways require further empirical validation and quantitative testing before large-scale implementation.

Despite these limitations, the GMD approach remains highly valuable for addressing complex public health challenges such as cholera. Its participatory nature promotes shared understanding among diverse stakeholders, enhances the ownership of findings, and facilitates collective learning about system dynamics. By integrating multiple perspectives within a structured systems thinking framework, the approach enables the identification of leverage points and intervention pathways that are both contextually relevant and practically actionable for strengthening health system resilience.

Conclusion and recommendations

This study demonstrates that cholera vulnerability in Uganda is driven by interconnected systemic weaknesses, particularly inadequate WASH infrastructure, weak surveillance systems, and limited coordination among stakeholders. The systems thinking approach revealed how these factors interact to create self-reinforcing cycles that sustain outbreaks, delay detection, and weaken response capacity. The participants identified nine intervention pathways, with strengthening multisectoral coordination and leadership, establishing data-based surveillance systems, and enhancing community engagement for sustainable WASH services emerging as the most critical leverage points. These findings highlight that cholera control cannot rely solely on isolated interventions but requires integrated, system-wide strategies addressing infrastructure, governance, behavior, and data systems simultaneously.

From a policy and programmatic perspective, governments and partners should prioritize strengthening multisectoral coordination mechanisms that align actors across health, water, sanitation, and environmental sectors to ensure coherent planning and efficient resource utilization. Investments in integrated and digital surveillance systems are essential for real-time data sharing, early outbreak detection, and evidence-based decision-making across districts and border regions. Expanding sustainable WASH infrastructure and promoting community ownership through behavior change initiatives and locally appropriate sanitation solutions will also be critical for reducing exposure to cholera transmission pathways. Additionally, targeted strategies such as cross-border vaccination and improved coordination at points of entry can help prevent the importation and spread of cholera in high-risk border districts. Finally, strengthening local technical capacity, diversifying financing mechanisms for WASH services, and institutionalizing community participation enhance long-term system resilience.

Declarations

Abbreviation

CDC: Centers for Disease Control; CFR: Case Fatality Rate; CBOs: Community-Based Organizations; DRC: Democratic Republic of Congo; GMD: Group Model Development; NGO: Non-Governmental Organization; MakSPH: Makerere University School of Public Health; RAN: Resilient Africa Network; WASH: Water, Sanitation, and Hygiene WHO: World Health Organization.

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Authors' contributions

NT performed the research and wrote the manuscript. RWM, AML, SK, FS & JS reviewed and edited the manuscript. RWM & JS also supported the design of the workshop tools and materials. FS supported the integration of the GMD approach into systems thinking.

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Availability of data and materials

The datasets generated during and/or analysed during the current study are available from the corresponding author and has been uploaded in the supplementary information files

Ethics approval

Ethical approval for this study was obtained from the Makerere University School of Public Health Research and Ethics Committee (SPH-2024-675). The study was conducted in accordance with internationally recognized ethical standards for research involving human participants, including the principles of the Declaration of Helsinki, the Belmont Report, and the guidelines of the Council for International Organizations of Medical Sciences (CIOMS).

Prior to participation, all workshop participants were provided with information about the study objectives, workshop procedures, potential benefits and risks, confidentiality measures, and the intended use of the findings. Participants were given the opportunity to ask questions and seek clarification before deciding whether to participate. Participation in the workshops was entirely voluntary, and participants were informed of their right to decline or withdraw from participation at any stage without any consequences. Informed consent to participate was obtained from all participants before the commencement of workshop activities. Attendance registers were used to document participation during the two-day workshops.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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