Asian Journal of Research in Infectious Diseases

Volume 15, Issue 12, Page 89-105, 2024; Article no.AJRID.127298
ISSN: 2582-3221

Cholera in Zambia: Explanatory Factors and Mid-term Impact of the Sustainable Development Goals

Beenzu Siamalube [a*], Emmanuel Ehinmitan [a], Maina Ngotho [b], Justus Onguso [c] and Steven Runo [d]

[a] Department of Molecular Biology and Biotechnology, Pan African University Institute for Basic Sciences, Technology and Innovation, Nairobi, Kenya.
[b] Department of Animal Sciences, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.
[c] Institute for Biotechnology Research, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.
[d] Department of Biochemistry, Microbiology and Biotechnology, Kenyatta University, Nairobi, Kenya.

Authors' contributions

This work was carried out in collaboration between all authors. Author BS designed the study, performed the statistical analysis, conceptualization, and wrote the first draft of the manuscript. Authors SR, JO and MN managed the supervision of the study. Author EE managed literature searches and software. All authors read and approved of the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajrid/2024/v15i12403

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/127298

Review Article

Received: 24/09/2024
Accepted: 28/11/2024
Published: 03/12/2024

ABSTRACT

Cholera, a highly contagious disease caused by *Vibrio cholerae*, poses a severe public health threat, especially in low- and middle-income countries with limited access to clean water and adequate sanitation. Symptoms such as acute watery diarrhoea, vomiting, and muscle cramps can

**Corresponding author: E-mail: siamalube.beenzu@students.jkuat.ac.ke;*

Cite as: *Siamalube, Beenzu, Emmanuel Ehinmitan, Maina Ngotho, Justus Onguso, and Steven Runo. 2024. "Cholera in Zambia: Explanatory Factors and Mid-Term Impact of the Sustainable Development Goals". Asian Journal of Research in Infectious Diseases 15 (12):89-105. https://doi.org/10.9734/ajrid/2024/v15i12403.*

lead to rapid dehydration, and without timely treatment, cholera can be fatal. Globally, cholera incidence has increased significantly, with World Health Organisation data showing a rise from 223,370 cases in 2021 to 472,697 in 2022, with the number of affected countries growing from 35 to 47. In Zambia, cholera outbreaks are recurrent, particularly during the rainy season, with 30 outbreaks recorded between 1977 and 2018. Fishing camps in rural areas and densely populated peri-urban areas, particularly in the Copperbelt and Lusaka provinces, report the highest incidences, attributed to inadequate waste management and poor drainage. This study investigates the factors influencing cholera dynamics in Zambia, focusing on climate variability, population density, and water and sanitation infrastructure. This study employs a mixed-methods approach, analysing historical cholera records, climate data, and socioeconomic factors since 1977. The article seeks to identify correlations between environmental and socioeconomic variables and cholera incidence, to guide effective public health strategies. The findings aim to support Zambia's efforts to eliminate cholera within its borders by 2025, aligned with the Multisectoral Cholera Elimination Plan and Vision 2030.

Keywords: Vibrio cholerae; public health; environmental parameters; epidemiology; Edible cholera vaccines; Zambia.

1. INTRODUCTION

In the public health sector around the world, cholera is still a major concern, heavily bearing down on inhabitants of marginalized areas (Dorsainvil, 2021). The United Nations (UN) Common Analysis Update 2024 classifies Zambia as a low-income country, making most impoverished communities therein vulnerable to the weighty hurdles of infectious diseases (McGowan et al., 2022). According to the Ministry of Health (MoH), Zambia, by the last quarter of 2018 the southern African nation had undergone 30 episodes of cholera outbreaks (Mwaba et al., 2020), which commenced in 1977, six years after the first ever cholera case reported on the African continent (Oprea et al., 2020). The lowest recorded number of cholera cases during the Twenty-year period from 2003 to 2023 was 16 in 2022 (Mbewe et al., 2024), while the highest was 12,149 in 2004 (Olu et al., 2013). This was coupled with a Case Fatality Rate (CFR) of up to 9.3%, which is way above the World Health Organization (WHO) recommended threshold of 1% (Finger et al., 2024). 2006 and 2010 equally experienced severe recurrences enumerating more than 5,000 incidents in each year, with the Copperbelt and Lusaka provinces showing the highest events (Mwape et al., 2020). Mainly because the two provinces are major urban areas covered with impermeable surfaces and poor drainage systems causing blockages during the rainy season and in turn, stagnant water that breeds bacteria (Gething et al., 2023). Additionally, they are overcrowded hubs – leading to the presence of slums, namely: Bulangililo, Kamitondo, Chipulukusu, Kabushi, Matero, Chawama, Mandevu and Kanyama, among others (Mutale et al., 2020). Inadequate access to safe and clean water as well as sustainable sanitation is also a contributing factor to the epidemics in these regions (Ladan et al., 2023). However, it is noted that cholera surges do slowly propagate to other parts of the country; particularly the coastal regions that harbour fishing camps and low-lying areas that are prone to floods (Murebwa-Chirambo et al., 2017). In Zambia, cholera flare-ups habitually emerge during the fortieth week of the year and proceeds to the twenty-third week of the following year (Mwaba et al., 2021). The last crucial occurrence was from October 2023, as of March 6, 2024, the total number of cholera cases reported was 21,007, with 702 deaths (CFR 3.3%) (Muyebe, 2024).

(Number of deaths / Number of all cases) x 100% = Case Fatality Rate (CFR)

2. MATERIALS AND METHODS

2.1 Cholera in Zambia in the Past Twenty Years

The MoH, Zambia in conjunction with stakeholders collected cholera data in the country for the past two decades (Fig. 1) (Mbewe et al., 2024; Mwaba et al., 2020; Olu et al., 2013).

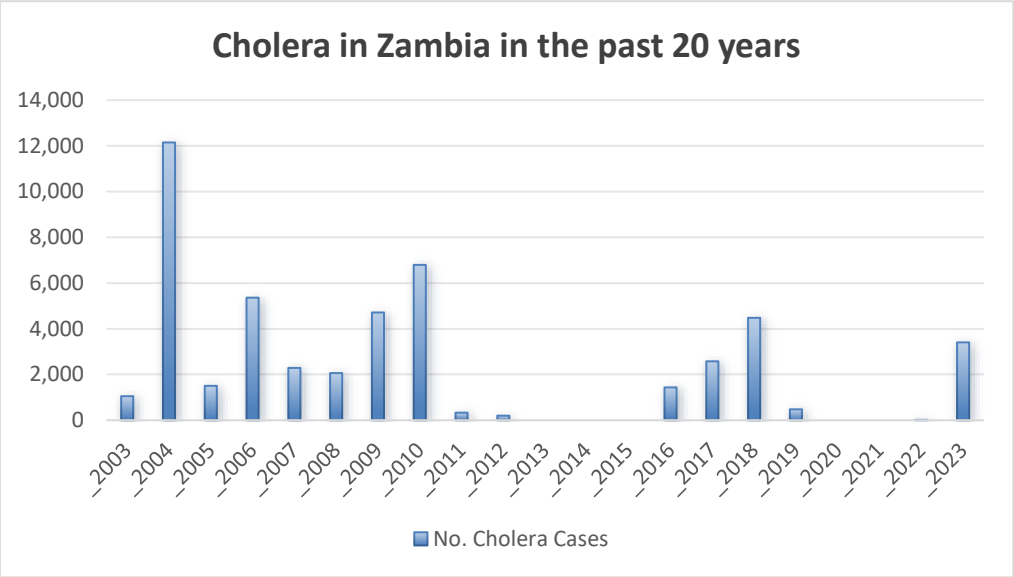

Fig. 1. Yearly cholera cases in Zambia, 2003 – 2023 Ministry of Health, Zambia

Up to one hundred people occupy a square kilometre of peri-urban areas in Zambia's capital city, Lusaka (Kateule et al., 2024). Thus, overpopulation in the country's major economic hub is inevitable, coupled with little to no proper drainages, and unfavourable management of solid waste (Hutchings et al., 2022). During the rainy season, a large portion of the district gets heavily inundated, and streets become impassable (Hassan et al., 2024). Year after year, these environmental influences increase the likelihood of the spread of epidemic susceptible diseases such as cholera (Bastin et al., 2024). The communicable disease outbreaks usually commence in Lusaka and circulate exponentially to other provinces due to the densely dynamic population, and this brings about further public health crises mostly on the vulnerable people of the society (Merrill et al., 2021). Additionally, according to the United Nations High Commissioner for Refugees (UNHCR) Zambia Factsheet, August 2023, approximately 90,000 refugees from other southern African nations are hosted in Zambia, although social support and community-based legal protection are provided by the government with assistance from the UNHCR alongside its partners (Casati et al., 2024). This influx of refugees has created cramped settlements,

Table 1. High-risk cholera areas pinpointed in Zambia

Province	District	Environmental influences	2019 Reference population
Central	Kabwe	Slum areas	258,864
	Kapiri Mposhi	Intersection hub	297,484
	Ngabwe	Lukanga swamps	27,169
	Shibuyunji	Kafue flats	74,860
Copperbelt	Kitwe	Densely populated	293,612
	Ndola	Poor WASH	264,729
Luapula	Chiengi	Refugee camp	143,706
	Nchelenge	Prone to flooding	192,243
Lusaka	Lusaka	Urban areas	1,718,527
Northern	Mpulungu	International port	129,350
	Nsama	Transit point	64,142
Southern	Mazabuka	History of Cholera outbreaks (< 3 years)	241,597
	Monze	Overcrowding	270,939
	Sinazongwe	Fishing camps	143,474
Total			**4,120,696**

where the camps are insufficient to house the huge numbers of people seeking shelter. Moreover, there is inadequacy of delivery of quality healthcare and unsatisfactory Water Sanitation and Hygiene (WASH) facilities (Yasmin et al., 2023).

2.2 Areas of High Cholera Incidence in Zambia

The cholera episodes are often concentrated in specific and small zones in Zambia (Ashraf et al., 2021). These epicentres have a pivotal role in the transmission of the infectious disease to other districts (Thelma et al., 2024). Thus, the initiatives to control cholera in Zambia should prioritize these regions, to minimize the spread of cholera to other areas of the country. About 4 million people are in the vulnerable cholera communities (Ng′ ombe et al., 2022) (Table 1).

A mapping operation was carried out to identify endemic cholera areas in Zambia to control and possibly eradicate cholera effectively in the long run (Reaver et al., 2021). As is the country's agenda 2030 to eliminate cholera and have a cholera-free Zambia (Organization, 2020; UNICEF, 2020), which agrees with the African Union established movement – Partnership for African Vaccine Manufacturing (Mathebula et al., 2023; Sinumvayo et al., 2024). From the exercise, up to 14 districts were highlighted as hotspots of cholera while 15 districts were prone to severe risk of cholera outbreaks (Fig. 2). Contextual factors such as environmental influences coupled with geographical locations (Gething et al., 2023), were key elements in the selection of these hotspots (Mwaba et al., 2020). Fishing areas, flood prone settlements, and overpopulated communities were categorized as high rise of refugees (Chibwe et al., 2021). The presence of slums with inadequate WASH services (Ladan et al., 2023), international borders, and districts that have experienced cholera outbreaks within the last five years, are equally such notable features of the selection process of the cholera hotspots in Zambia (Libanda et al., 2024). To further guide decision making such as administration of Oral Cholera Vaccines (Mukonka et al., 2023), the government through the Ministry of Health (MoH) pledges to undertake yearly surveillance (Xu et al., 2024) to analyse data collected across the country and the mitigation measures to be implemented in the cardinal situations (Matenga & Zulu, 2023).

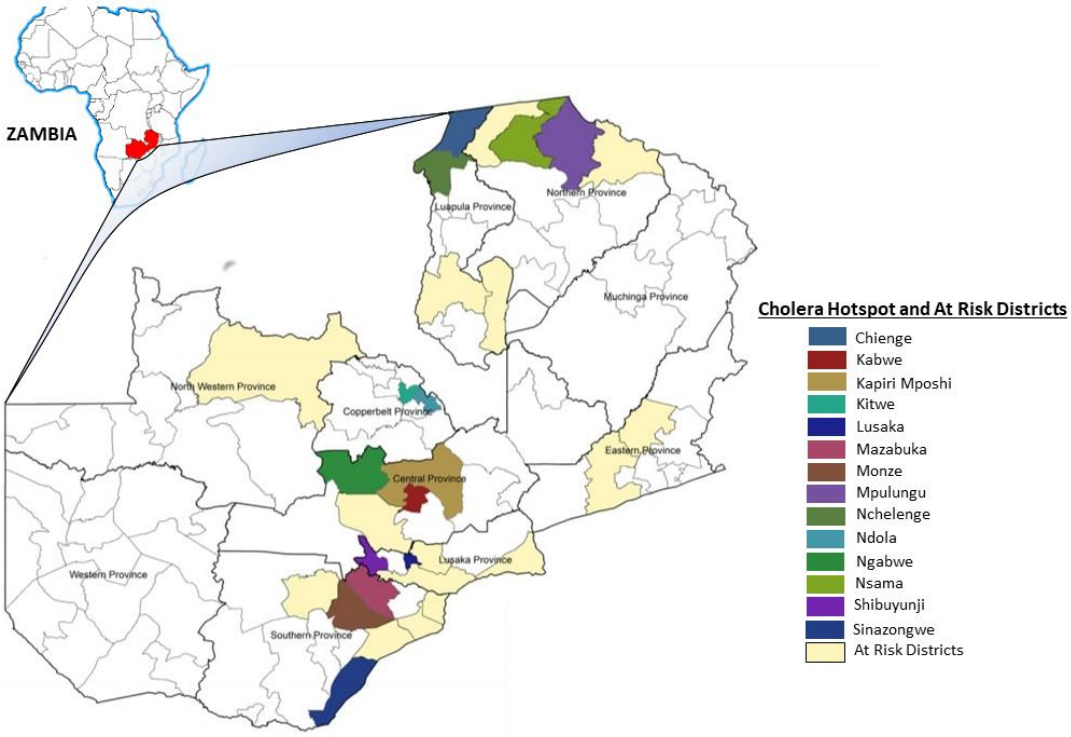

Fig. 2. Zambia's cholera hotspots and at-risk districts

3. RESULTS AND DISCUSSION

3.1 The Natural World of *Vibrio cholera*

Vibrio cholera is a Gram-negative bacterium that naturally inhabits in waterlogged spaces; it is the agent that causes cholera (Montero et al., 2023), bringing about acute diarrhoea and vomiting to the infected persons. This cholera-causing pathogen has distinct characteristics: it is primarily of serotype O1 (Mwaba et al., 2021), though occasionally of serotype O139. It carries a range of pathogenicity islands and virulence genes (Raskin et al., 2020), notably including the CTXϕ prophage, which encodes the cholera toxin (CT) responsible for most of the symptoms associated with cholera diarrheal syndrome (Mavhungu et al., 2023).

From time immemorial, during a cholera outbreak, the *V. cholerae* strains have been detected through clinical laboratory tests using epiflurorescent microscopy to ascertain its presence in a suspected environment (Islam et al., 2020). Nonetheless, prior to the arrival of molecular markers culture assays were used to scientifically determine that a given area is colonized with *V. cholerae* (Kang et al., 2006). These techniques had a major shortfall to appropriately detect the bacterium as it can metamorphose into a viable but non-culturable (VBNC) phase making the investigations inconclusive. Between outbreaks, the environment becomes unfavourable for bacterial growth and reproduction, hence the bacterial cells in the VBNC stage activate metabolic dormancy in their cycle making them undetectable (Wu et al., 2020). On the other hand, when the environment becomes favourable for the bacterium again, the cells retain their virulency and become culturable (Girotto et al., 2024). Additionally, *V. cholerae* has the potential to go from biofilm to motile way of life and vice versa, by attaching itself to zooplankton as well as phytoplankton and in turn increasing its rate of survival in its natural setting – coastal waters (Martinelli Filho et al., 2020) *V. cholerae* is mainly hosted in copepods, hence drinking plankton contaminated water without treating it, by boiling or chlorination greatly enhances the likelihood of cholera infection (Feng et al., 2023). Seasonal outbreaks take place every year in areas where cholera is endemic albeit, alterations in the aquatic ecosystem has the potential to affect the gravity of a cholera outbreak. Warmer months of the year tend to record higher cholera cases, especially in Sub-Saharan Africa (Perez-Saez et al., 2022) and Latin America, whereas the Bengal Delta region reports bi-modal peaks (Koppio et al., 2020). Notwithstanding, climatic changes such as temperature increase in water bodies prolongs the active period of *V. cholerae* causing serious public health concerns. Given that the bacterium plays a pivotal role in the cycling of nutrients, and it is indigenous to the aquatic milieu, complete eradication of the disease is not totally guaranteed (Armando et al., 2024). Hence, it is imperative to fully grasp the ecology of *V. cholerae*, having knowledge of the environmental influences that vehicle cholera, more so as a recurring virulent disease (Usmani et al., 2021). Mathematical models to predict the emergence and construct possible control measures can be designed to further strengthen the surveillance services and contain the spread of cholera. Not only that, but cholera hotspots also need advanced real-time risk monitoring platforms to proactively detect cholera threats and safeguard public health (Baltazar et al., 2022; Miggo et al., 2023).

3.2 Impact of Climatic Changes on Cholera

Climate changes impacts cholera transmission and prevalence significantly (El-Sayed & Kamel, 2020), increase in temperature for instance causes waters to be warmer creating a conducive natural habitat for *V. cholera* to breed easily and expand its niche. Secondly, during heavy downpours of the rainy seasons, or natural disasters such as cyclones the sea-levels rise drastically and cause soil erosion in the coastal regions (Christaki et al., 2020). The flood prone areas tend to harbour bacterial contaminants and the movement of water from one region to the other contributes majorly to the spread of cholera as it disrupts water sources and interferes with the sanitation infrastructure. Stagnant water equally harbours *V. cholera* and people who use it are at risk of contracting the infection (Bastin et al., 2024). Lack of water therein can also be because of climatic change that leads to the spread of cholera, areas susceptible to drought or little to no rainfall usually have inadequate resources for good hygiene and/or proper sanitation facilities, and this increases the chances of cholera episodes (Asadgol et al., 2020). Drought often results in famine as most farmers cannot produce sufficient food crops or dairy and meat products, which brings about a malnourished community and makes affected individuals vulnerable to illnesses (Obasohan et

al., 2020), cholera is one such infectious disease that can arise from malnutrition and food insecurity. Due to all these aforementioned factors, people get displaced and opt to migrate to new areas (Gabutti et al., 2020). However, if they already contracted the bacterium, they risk transmitting it to different people groups along their sojourn and of course where they finally decide to settle in.

Cholera is fondly referred to as a disease of poverty, due to limited access to clean water and sanitation, coupled with underdeveloped medical facilities in endemic areas (Hsiao et al., 2022). The sequence of cholera crises in Zambia suggests that it is a cholera prone country (Thelma et al., 2024), with low socio-economic pointers namely: overcrowding especially in peri-urban slums (Mutale et al., 2020), lack of waste management facilities, inadequate education on the awareness of cholera, fishing camps that do not have ample WASH infrastructure (Murebwa-Chirambo et al., 2017), and weak governance policies to effectively respond to cholera prevention measures (Olu et al., 2013).

3.3 The WASH Condition in Zambia

Over three quarters of the Zambian population does not have adequate access to passable solid waste management. According to the Zambia Demographic Health Survey (ZDHS) of 2013 – 2014, about 69% of people living in Zambia have unsatisfactory access to clean water (Fig. 3a) (Reaver et al., 2021) and 39% have little to no provision for standard sanitation services (Fig. 3b.) (Ashraf et al., 2021). The national population reported zero percent in the comfortably managed category for both water supply and sanitation services (Libanda et al., 2024). These incidences are majorly reported from cholera hotspots. Although close to 90% of the populace settled in urban and peri-urban localities receive payable though inconsistent water supply, the service is costly for the less privileged in slum zones (Yasmin et al., 2023). While only 6% short of half the people in rural settings can acquire basic water and sewerage amenities, the majority can at best source water from rivers, lakes, and boreholes. During Zambia's 2017/2018 cholera outbreak, the ZDHS tested the drinking water sources in Lusaka and documented 31% faecal contamination, depicting that the larger populace does not treat their drinking water (Mwape et al., 2020). Studies have shown that washing hands with antibacterial soap can lower the prevalence of diarrhoeal diseases. Hence implementing such good personal hygiene habits in tandem with practices of proper treatment of water at source level and at consumer level may lessen the cholera transmission (Sikder et al., 2023).

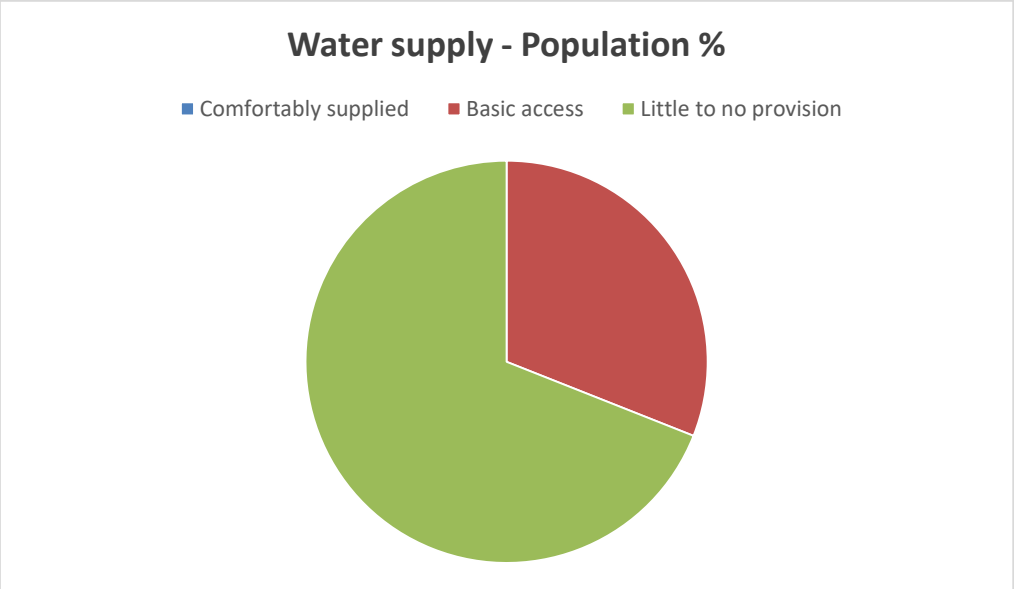

Fig. 3a. Percentage of population with access to drinking water

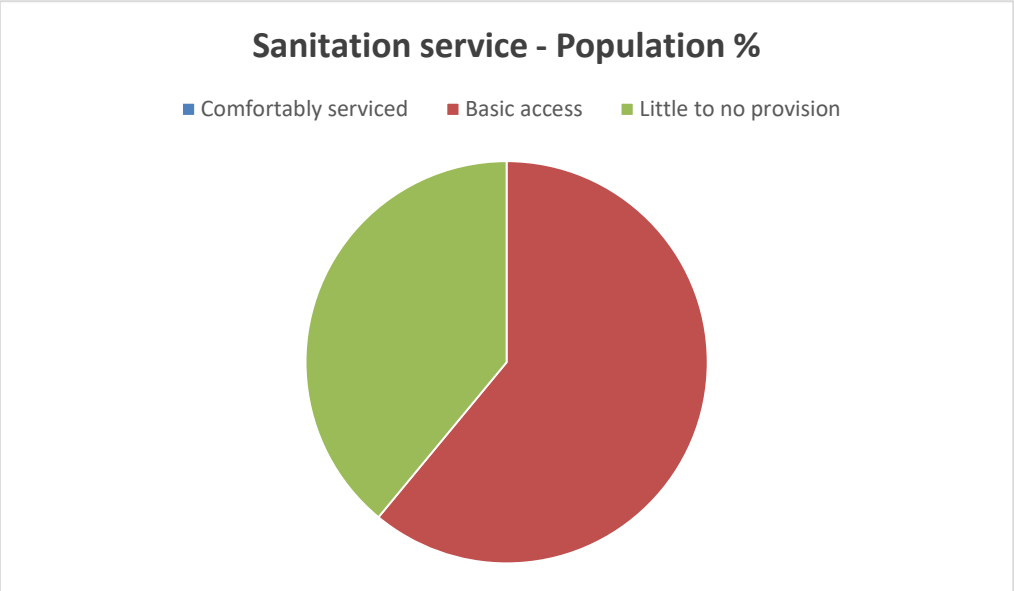

Fig. 3b. Percentage of population with access to sanitation services

3.4 Socioeconomic Factors

In 2017, United Nations International Children's Emergency Fund (UNICEF) and WHO held a Joint Monitoring Program (JMP) for Sanitation and Water Supply, this survey illustrated that approximately 11.3 million people in Zambian households had no access to fundamental sanitation systems, while 6.4 million people lack essential requirements to acquire standard drinking water necessities, representing 69% and 39% respectively, of the then Zambian population (Gething et al., 2023). In schools, 34% of pupils have no means to obtain sanitation amenities, whereas 21% of them have undersupply of primary water services. According to the JMP, it was reported that despite notable progress being seen regarding the betterment of core WASH infrastructure in Zambia, the slight upticks fall short of the existing void and rising requirement of these pertinent services. To attain Sustainable Development Goal (SDG) six (6) of universal WASH access by the year 2030, the southern African country has a duty to annually provide vital hygiene services to 1.46 million people, standard sanitation to 1.16 million people and ample water supply to 660,000 people (Ladan et al., 2023).

3.5 Governance Structure and Administrative Framework

In the last quarter of 2016, the Government of the Republic of Zambia (GRZ) established the Ministry of Water Development, Sanitation, and Environmental Protection (MWDSEP). This move recognized the crucial role of coordination and leadership in driving the WASH framework and promoting economic growth, social development, and public health (Mogasale et al., 2021). In addition, a dedicated Department of Water Supply and Sanitation was created within the ministry, whose objective was to deliver robust leadership to the WASH sector. The full-fledged body aims to enhance coordination for WASH programs by establishing a robust planning framework and strengthening financial capabilities (Ramamurthy & Ghosh, 2021). This aligns with Zambia's aspirations for Vision 2030 – seeking to transform the country into a prosperous middle-income nation by 2030, besides the United Nations Sustainable Development Goals (UNSDGs) for 2030. During the 7th National Development Plan (NDP) in the period between 2017 and 2021, the government emphatically reaffirmed its plan to elevate the WASH system by primarily aiming at increasing access to Water and Sanitation for all Zambians (Muyebe, 2024).

The National Urban and Sanitation Strategy, the Water Supply and Sanitation Capacity Building Strategy, and the Open Defecation-free Zambia Strategy 2030 all support two vital national programs. These programs guide the provision of WASH services under the MWDSEP: the National Rural Water Supply and Sanitation Program (NRWSSP) (2016-2030) and the National Urban Water Supply and Sanitation

Program (NUWSSP) (2011-2030) (Ko et al., 2022). Additionally, a legal foundation called Solid Waste Regulation and Management Act No. 20 of 2018 was developed by the Ministry of Local Government to regulate and manage solid waste services in the country. This ministry together with the MWDSEP looks forward to creating a Water Supply, Sanitation and Solid Waste Management Policy to further refine the policy framework and enhance coordination within the sector.

3.6 Public Education and Behaviour Change Communication

Expanding public education and community awareness on cholera in Zambia requires a multi-faceted approach that engages diverse audiences with clear, actionable information. Zambia can enhance its efforts by integrating the following approaches in its MCEP.

A. Strengthening Community Engagement

- **Community Health Volunteers (CHVs):**
  - Train and deploy CHVs to educate communities about cholera prevention, symptoms, and treatment.
  - Use CHVs to conduct door-to-door awareness campaigns, especially in high-risk and rural areas.
- **Religious and Community Leaders:**
  - Partner with trusted leaders to share cholera prevention messages during gatherings like church services, traditional meetings, and markets.
  - Encourage leaders to model and advocate for safe hygiene practices.
- **School-Based Programs:**
  - Integrate cholera education into school curriculums, teaching children about handwashing, water safety, and food hygiene.
  - Provide schools with resources like handwashing stations and water purification tablets.

B. Leveraging Media Platforms

- **Radio and Television Campaigns:**
  - Broadcast short, engaging messages in multiple local languages on cholera prevention and symptoms.
  - Feature testimonials from cholera survivors to highlight the importance of early treatment and prevention.
- **Social Media and Digital Campaigns:**
  - Use platforms like Facebook, WhatsApp, and Twitter to disseminate educational infographics and videos targeting urban and tech-savvy audiences.
  - Partner with influencers to amplify health messages.
- **Community Theatre and Drama:**
  - Organize participatory theatre performances in rural and peri-urban areas to demonstrate the impact of cholera and preventive actions.

C. Promoting Hygiene Practices

- **Handwashing Campaigns:**
  - Establish annual handwashing days in schools, clinics, and markets.
  - Distribute free soap and water purification tablets during campaigns.
- **Behavioural Nudges:**
  - Install handwashing stations at public places like markets, bus stops, and schools, accompanied by signs reminding people to wash hands with soap.
  - Use stickers and posters in local languages in households and community spaces to promote hygiene practices.

D. Collaboration with Stakeholders

- **Private Sector Engagement:**
  - Partner with businesses to sponsor cholera awareness initiatives, such as branded soap or water buckets with cholera prevention tips.
- **Non-Governmental Organizations (NGOs):**
  - Collaborate with NGOs experienced in public health outreach to design and implement campaigns in vulnerable areas.

- **Health Workers and Clinics:**
    - Train healthcare workers to provide cholera education during routine consultations, vaccination drives, and outreach programs.

E. Incorporating Traditional Knowledge and Practices

- Work with traditional healers to ensure accurate information about cholera is shared within their communities.
- Respect and integrate local beliefs into messaging while promoting evidence-based practices.

F. Monitoring and Evaluation

- Conduct surveys to understand community knowledge, attitudes, and practices (KAP) around cholera.
- Use feedback from communities to refine and improve education strategies.
- Monitor the impact of campaigns through changes in behaviours like handwashing and water treatment.

Expanding public education and community awareness in Zambia requires consistent efforts, localized messaging, and partnerships with key stakeholders. Empowering communities with knowledge and tools can significantly reduce the incidence and spread of cholera.

3.7 Zambia's Cholera Elimination Plan

In line with the Global Task Force on Cholera Control's (GTFCC) mission to eradicate cholera in endemic regions by 2030, Zambia took a proactive stance by sponsoring a resolution at the 71st World Health Assembly (WHA) in 2018. This resolution aimed to eliminate cholera worldwide by 2030, as outlined in the Global Roadmap 2030. Furthermore, Zambia took an ambitious and bold move to end cholera within its borders by 2025 (Siamalube & Ehinmitan, 2024), earlier than the global target date. To achieve this objective, Zambia has developed its premier Multisectoral Cholera Elimination Plan (MCEP), scheduled to run from 2019 to 2025. The main objective of this strategic plan is to decrease deaths and ailments associated with cholera, ultimately having a cholera-free Zambia, come 2025 (Maity et al., 2023). Government ministries, donors and health partners put together collaborative efforts to form the MCEP, incorporating useful lessons learned from preceding cholera outbreaks, drawing on experiences and best practices while handling past shortfalls in the response to the public health threat. The plan was cemented on the cholera elimination and control campaigns currently running, constituting of the comprehensive situational analysis of cholera in Zambia, and an evaluation of the epidemiological status, ongoing capacities to control the infectious disease and well as technical and financial assistance from partners and donors (Chowdhury et al., 2022).

In concordance with the Global roadmap, the MCEP outlines two pivotal goals: short-term involving the control of cholera with focus on campaigns of OCV, and the long-term goal is the elimination of cholera with emphasis on enhanced provision of WASH facilities in high-risk areas. Improved surveillance on case management and local community involvement following a well-established channel of communication, are some additional strategies the plan has implemented (Mbewe et al., 2024). To achieve these goals, the MCEP employs comprehensive three-pronged approaches (Fig. 4) to attain the 90% reduction in cholera-related mortalities.

3.8 Cholera Elimination Strategies in Selected African Countries

While Zambia has made strides in urban areas like Lusaka, rural WASH infrastructure remains underdeveloped. Other countries, like Kenya, have achieved broader improvements in universal WASH access and sustained community hygiene.

1. Kenya

- Focuses on preventive measures through assessment of sanitation infrastructure to determine its resilience to extreme flooding and rainfall (Lebu et al., 2024).
- Conduct mapping activities in cholera hotspots to promote hygiene education (Kiama et al., 2023).
- Strong emphasis on environmental health and waste management to eliminate open defecation.

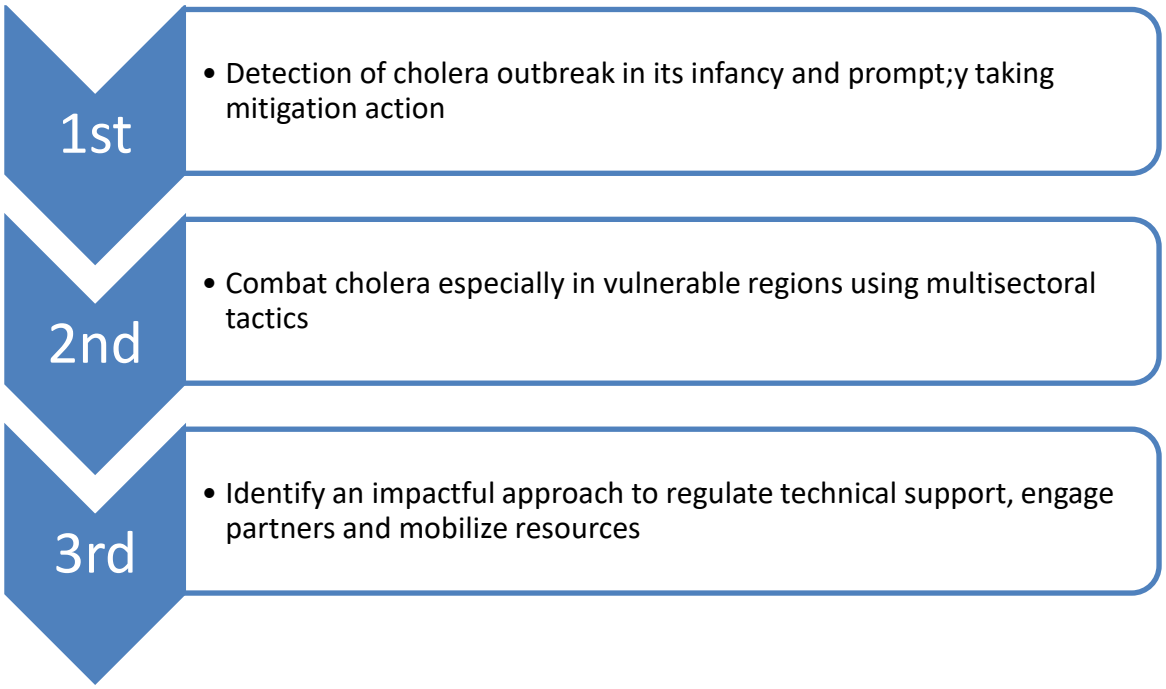

Fig. 4. Strategic approaches for cholera elimination

2. Nigeria

- Established cholera emergency operations centres to coordinate outbreak responses (Charnley et al., 2023).
- Partners with international agencies for OCV distribution and WASH interventions in northern Nigeria (Ngwa et al., 2021).
- Leverages community-based health workers to spread hygiene awareness (Elimian et al., 2024).

3. Mozambique

- Vulnerable to cholera due to cyclones and floods.
- Integrates cholera prevention into disaster preparedness programs (Armando et al., 2024).
- Conducts mass OCV campaigns and rebuilds WASH infrastructure after natural disasters (Baltazar et al., 2022).

4. Uganda

- Strengthened surveillance systems, especially in refugee settlements.
- Provides free WASH supplies like water treatment tablets and soap in affected areas.
- Implements OCV campaigns alongside regular vaccination programs (Bwire et al., 2023).

5. Democratic Republic of the Congo (DRC)

- Faces frequent outbreaks due to poor infrastructure and conflict (Taty et al., 2024).
- Relies on mobile health teams for outbreak containment (Taty et al., 2023).
- Partners with organizations like Médecins Sans Frontières (MSF) to provide cholera treatment (D'Mello-Guyett et al., 2022).

6. Burundi

- Prioritized cholera control through extensive public awareness campaigns.
- Invested heavily in urban sanitation and clean drinking water supply.
- Established a robust surveillance system with rapid response teams (Debes et al., 2021).

7. Ethiopia

- Prioritized cholera control through extensive public awareness campaigns.
- Invested heavily in urban sanitation and clean drinking water supply.

- Established a robust surveillance system with rapid response teams (Hussen et al., 2024).

3.9 Key Lessons from Other Countries

- **Integrated Development**: Countries like Burundi and Ethiopia show the importance of integrating cholera prevention into long-term national development plans.
- **Proactive Disaster Preparedness**: Mozambique and Nigeria's approaches to link cholera control with disaster response (Eneh et al., 2024) could benefit Zambia, especially in flood-prone areas.
- **Community Engagement**: Uganda's use of local health workers ensures that communities take ownership of hygiene practices.

Zambia could enhance its cholera prevention by scaling up rural WASH programs, strengthening disaster response frameworks, and drawing lessons from successful African models (Lawal et al., 2024).

3.10 Traditional Oral Cholera Vaccine Versus Plant-based Edible Cholera Vaccines

During the 2018 cholera outbreak in Zambia, the Euvichol oral cholera vaccine was used (Mukonka et al., 2023). In contrast, the 2021 campaigns employed the Shanchol vaccine, targeting Sinazongwe and Nsama districts (Qadri et al., 2020). The survey yielded great results as there were no cholera cases reported in 2020 and 2021 (Ng′ ombe et al., 2022). While Oral Cholera Vaccines (Song et al., 2021) are available in the international market (López-Gigosos et al., 2011), they are very costly (Saluja et al., 2020) and usually do not meet the demands especially in Sub-Saharan Africa (Trolle et al., 2023).

It is imperative to develop alternative and sustainable means of immunization. Yuki *et al.,* (Yuki et al., 2021) reported that edible vaccines derived from rice carrying cholera toxin B subunit presented a groundbreaking point of view to immunization. The oral MucoRice-CTB vaccine was proven safe after a randomized clinical trial in healthy American adults (Yuki et al., 2022). Plant-based edible vaccines promise to offer potential benefits such as cost-effectiveness (Vijayakumar et al., 2024), ease mode of administration (Bahramnejad et al., 2023), low spoilage rate (Loc & Thinh, 2020), near-user site, eradicate the need for cold chain storage and stimulation of both mucosal and systematic immunities (Beenzu et al., 2024). They utilize the natural production capabilities of plants to develop innovative, minimally invasive, and highly accessible vaccine delivery systems, making them ideal candidates for "green factory" vaccines (Kim et al., 2024). Although, ongoing studies are important to determine the efficacy and safety of these vaccines (Zandinava et al., 2024), crucial points are to be considered in the scaling up manufacture, regulatory approvals on development of genetically modified crops (Kokei & Bahramnejad, 2020) as well as how they can be integrated into the existing healthcare systems, i.e. the dosage issues and distribution strategies to ensure equal access of these vaccines, globally (Morris et al., 2021).

4. CONCLUSION AND FUTURE PERSPECTIVE

Addressing cholera's public health impact requires a comprehensive and multi-layered approach. Investments in innovative technology and organized data analysis are essential to improve outbreak surveillance before, during, and after it occurs. Predictive mathematical models could serve as early warning systems, enabling timely management of health risks tied to seasonal changes. For a coordinated response, the Zambian government could collaborate closely with health organizations and local communities to advance cholera elimination efforts. Regular evaluation of the Multisectoral Cholera Elimination Plan, along with transparent program adaptations, will ensure evolving needs are met and support the goal of a cholera-free Zambia by 2025.

To promote health and prevent cholera outbreaks, Zambia must prioritize consistent adherence to water, sanitation, and hygiene (WASH) practices while advancing strategies that meet global standards. Building a climate-resilient healthcare system is key to mitigating climate-related health challenges. Integrating advanced drainage solutions into urban planning could reduce flooding risks, while targeted interventions addressing food insecurity and policies tackling social inequality would further protect vulnerable populations. Expanded public health education and personal hygiene awareness will empower individuals to adopt healthy practices and support sustainable, long-term improvements in public health.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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