Rapid cholera outbreak control following catastrophic landslides and floods: A case study of Bududa district, Uganda

Godfrey Bwire[1], Imelda Tumuhairwe[2], Leocadia Kwagonza[1], Milton Makoba Wetaka[1], Anne Nakinsige[1], Emmanuel Samuel Arinitwe[1], Julian Kemirembe[3], Allan Muruta[1], Charles Mugero[4], Christine K Nalwadda[5], Samuel I Okware[6]

1. Ministry of Health, Department of Integrated Epidemiology, Surveillance and Public Health Emergencies, Kampala, Uganda.
2. Department of Health, Bududa District Local Government, Uganda.
3. Ministry of Health, Department of Community Health, Kampala, Uganda.
4. World Health Organization, Pretoria, South Africa.
5. Makerere University, College of Health Sciences School of Public Health, Kampala, Uganda.
6. Uganda National Health Research Organization, Kampala, Uganda.

Abstract

Background: In June 2019, landslides and floods in Bududa district, eastern Uganda, claimed lives and led to a cholera outbreak. The affected communities had inadequate access to clean water and sanitation.

Objective: To share the experience of controlling a cholera outbreak in Bududa district, after landslides and floods.

Methods: A descriptive cross-sectional study was carried out in which outbreak investigation reports, weekly epidemiological data and disaster response reports were reviewed.

Results: On 4 – 5th June 2019, heavy rainfall resulted in four landslides which caused six fatalities, 27 injuries, floods and displaced 480 persons. Two weeks later, a cholera outbreak was confirmed in Bududa district. The Ministry of Health (MoH) rapidly deployed oral cholera vaccine (OCV) from local reserves and mass vaccinated 93% of the target population in 22 affected parishes. The outbreak was controlled in 10 weeks with 67 cholera cases and 1 death reported. However, WaSH conditions remained poor, with only, 24.2 % (879/3,628) of the households with washable latrines, 26.8% (1,023/3,818) had hand-washing facilities with soap and 33.6% (1617/4807) used unsafe water.

Conclusion: The OCV stockpile by the MoH helped Uganda to control cholera promptly in Bududa district. High-risk countries should keep OCV reserves for emergencies.

Keywords: Cholera; outbreak; vaccination; Africa; Uganda; disaster; landslides; epidemic; floods.

DOI: *https://dx.doi.org/10.4314/ahs.v23i4.23*

Cites as: *Bwire G, Tumuhairwe I, Kwagonza L, Wetaka M. M, Nakinsige A, Arinitwe E. S, . . . Okware S. I. (2023). Rapid cholera outbreak control following catastrophic landslides and floods: A case study of Bududa district, Uganda. Afri Health Sci, 23(4). 203-215. https://dx.doi.org/10.4314/ahs.v23i4.23*

Introduction

Landslides are a major natural disaster that can trigger cholera outbreaks due to poor water, sanitation and hygiene (WaSH) conditions that are associated with them [1]. Cholera, an infection due a bacteria *Vibrio cholerae* is an ancient intestinal disease that is a major public health problem in many developing countries [2]. In 2021, 35 countries reported a total of 223,370 cholera cases and 4,159 deaths, to the World Health Organization (WHO) [3]. Cholera is preventable; however, epidemics are most frequent in developing countries in sub-Saharan Africa, Asia and Central America [4]. Big cholera outbreaks have occurred after natural disasters like in Haiti following the earthquake of 2010 [5,6], Mozambique after the floods of 2008 [7] and during some manmade disasters like in Yemen [8,9], and South Sudan [10] during the civil wars. Whatever the circumstance that result in cholera, the method of prevention of cholera is by provision of adequate WaSH [11]. When WaSH is inadequate and possibility of quick

Corresponding author:
Godfrey Bwire,
Ministry of Health, P.O BOX 7272, Kampala, Uganda
Plot 6 Lourdel Road, Nakasero
Tel: +256758805784, 256775730002
Email: gbwire1@yahoo.com

improvement is low, the WHO recommends mass vaccination with oral cholera vaccination (OCV) to prevent cholera outbreak [12–15]. The usual source of the OCV is the WHO stockpile that is controlled by a team of experts based in Geneva, Switzerland [16]. The countries at risk of cholera that need OCV are required to apply for it from the stockpile in Geneva. The application process for the OCV involve sharing of some data on cholera with the Global Task Force for Cholera Control (GTFCC), WHO, Geneva. Sometimes, due to disruption social services and infrastructure resulting from the disaster, the affected communities/countries may not be in position to access emails and timely respond with required information. Hence, the process of application for OCV may take several weeks and even months [16,17]. Often, the vaccines arrive in the cholera affected areas when the outbreak has spread so much or is on declining trend [17,18].

Though cholera is rare in developed countries, it is a major cause of morbidity in East Africa and Uganda in particular [19,20]. In Uganda, cholera outbreaks often occur in the districts located along the major lakes [21,22], communities found in areas around the international borders [23,24], those hosting the refugees [17,25] or where there is inadequate safe water [26]. Several districts in eastern Uganda are prone to recurrent landslides often following heavy rains which result in loss of life and property, ill health and disruption of water supply and sanitation [27]. Bududa district is one such district that is prone to landslides and associated consequences [27,28]. Cholera outbreaks and related diarrheal diseases are a major consequence of landslides in Bududa and surrounding districts such as Mbale and Bulambuli [29–31]. Though landslides occur frequently in Bududa district [27,32,33] and are followed sometimes by cholera outbreaks, few studies have documented the occurrence of these cholera outbreaks and the response instituted in such setting to control them.

In June 2019, Bududa district experienced two days of continuous torrential rainfall which triggered catastrophic landslides in several parishes in the district. Apart from causing many fatalities, the heavy rains and the landslides destroyed water sources, sanitary facilities, houses, roads, domestic and public property, disrupted service delivery and displaced many people. This scenario created suitable condition for outbreaks of infectious diseases. Two weeks after the landslides, cholera was reported. Consequently, the communities in Bududa district experienced multiple natural disasters simultaneously. The objective of this study was to document the lessons learnt during response to a cholera outbreak in Bududa district that was triggered by the catastrophic landslides and floods.

Methods

Study design

A descriptive cross-sectional study was carried out to document lessons learned during response to cholera outbreak in Bududa district for the period June – August 2019. The authors extracted and reviewed Bududa district epidemiological data (a cholera line list and Bududa district cholera daily situational reports) and the landslide disaster response reports for this period.

Study area

The study was conducted in Bududa district, eastern Uganda. Bududa district is located on the slopes of Mount (Mt.) Elgon. Mt. Elgon is a massive 80-kilometer diameter solitary volcanic mountain on the eastern border of Uganda and western Kenya. Wagagai peak, 01°07'06"N 34°31'35"E, 4,321 metres above sea level and found in Uganda is the highest point of Mt. Elgon [34]. Bududa district has total surface area of 241,551square kilometers [35] with projected population from 2014 census of 259,800 people in 2019 [36,37]. In terms of administrative structure, Bududa district consisted of two counties, 18 sub-counties, 96 Parishes and 955 villages [36]. Bududa Town Council is the biggest town and the district headquarters. Bududa district has mountain vegetation and terrain. The district is hilly with many valleys and rivers. There are several villages or parts of villages in Bududa district that are hard-to- reach. The location of Bududa in Uganda and the parishes therein are shown in Figure 1.

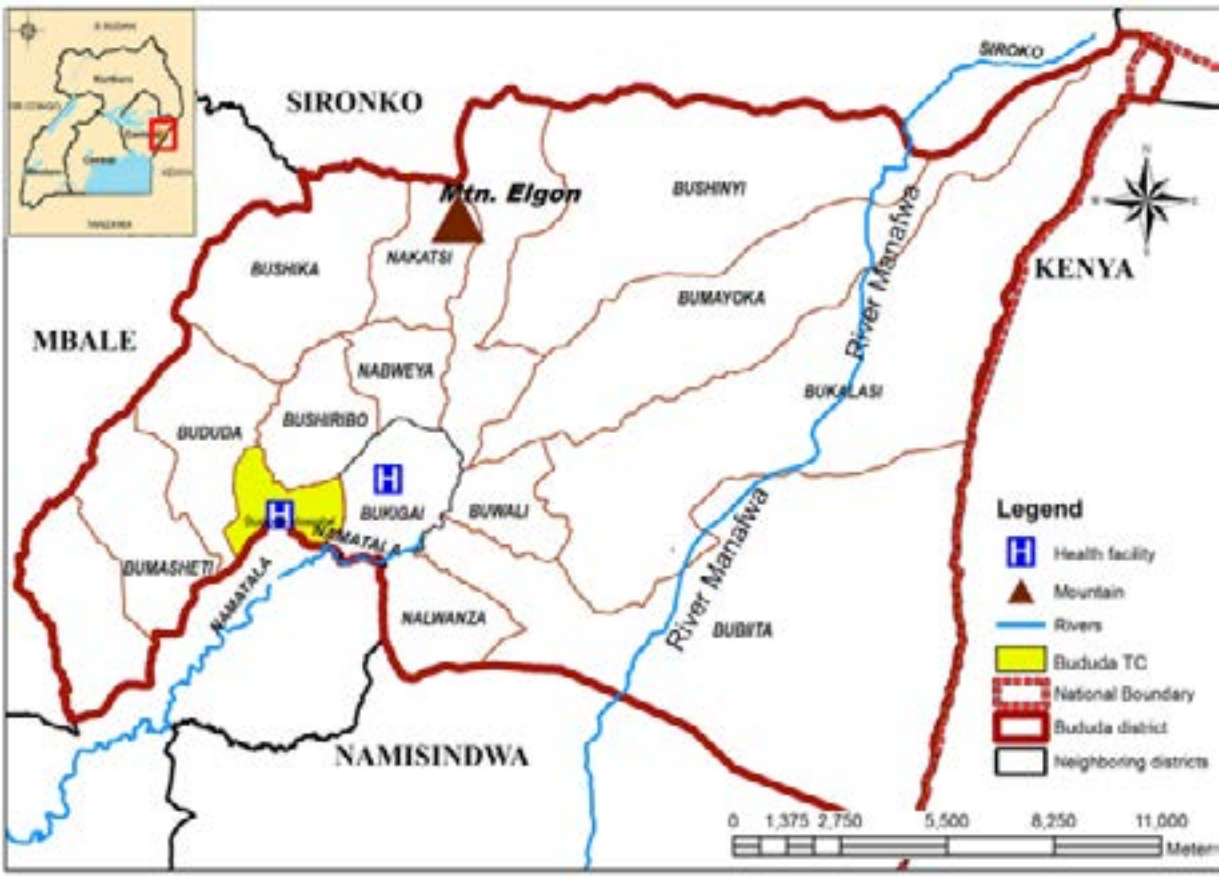

Figure 1: Map of Bududa district showing the sub counties and the major rivers.

Definition of cholera cases and deaths

The definitions employed in this study are based on Integrated Disease Surveillance and Response (IDSR) guidelines [38] and the national standard case definition for cholera below [39]. Four definitions were employed for cholera cases and deaths: 1) Community case definition: Any person with lots of watery diarrhea in an area where a cholera outbreak has been declared, 2) Suspected case definition; Any person aged 5 years or more, presenting with dehydration in an area with no ongoing epidemic, 3) Any death from acute watery diarrhea in an area with cholera epidemic or any person age 2 years or more with acute watery diarrhea, 4) a confirmed cholera case: a suspected case from whose stool sample *V. cholerae* serogroup O1 or O139 has been isolated.

Data variables retrieved and analysed

Variables from the landslide reports

Data on date of landslide occurrence, name of affected villages, number of persons dead, number of persons injured, number of affected households, property damaged, number of persons displaced and alive.

Variable from the line lists and situational reports

The following information were collected and analysed on cholera cases meeting the standard case definition for cholera above and from the reports: daily number of cholera cases, daily number of deaths, total cases by village of origin, number of males, number of females, the age, village of residence, parish, sub county, presenting symptoms, treatment given, status of the case in terms of admitted, discharged or died.

Variable from laboratory reports

Stool samples of suspected cholera cases were tested and report provided to the Ministry of Health and Bududa district health office to guide the management of cases. The following information was extracted: type of stool sample, number of samples collected, samples that tested positive for *V. cholerae*, type of *V. cholerae* serotype identified, antibiotic sensitivity of the *V. cholerae* organisms present in the stool.

Variables on WaSH assessments from reports

All homes in villages listed for having cholera cases were

assessed to determine status of WaSH using a simple checklist by a team of trained community health workers selected from the affected villages. The following variables were assessed; the number of household occupants, presence of latrine, the type of latrine, level of cleanness of the latrine, source of drinking water, mode of water storage, availability of hand washing facility, presence of soap for hand washing, general level of home hygiene.

Variables from outbreak epidemiological and reactive oral cholera vaccination campaign reports

The following information was extracted from the two reports: date the outbreak was notified to the MoH, date the epidemic was confirmed, date the outbreak was declared, date the MoH decided to use OCV, source of OCV used, date the campaign started, date the campaign ended, target population, strategy used to administer OCV, type of OCV, doses of OCV supplied and doses of OCV administered by administrative area.

Data management

Data were collected into spreadsheet, cleaned to remove errors and analysed to generate frequencies, percentages, trends and proportions. The data were presented in tables, graphs and maps. The maps were created from shapefiles obtained from the United Nations High Commission for Refugees (UNHCR) [40] by using ArcGIS Version 10.5 [41].

Ethical clearance

This study was conducted as a component of routine integrated surveillance and response to cholera outbreak in Bududa district by the MoH. These types of studies are Institutional Review Board (IRB) clearance exempted. However, clearance to carry out this study was sought from the Uganda Health Research Organization, Ref: UNHRO/res/floods/Bwire/1.08.2022. The data shared were according to that permitted for routine MoH epidemiological surveillance to share with the public. Information shared were anonymous or aggregated and without personal identifiers.

Role of the funding source

The authors assume full responsibility for the analyses made and interpretation of the data and decision to publish the study findings.

Results

Description of the landslides

Data showed that landslides were triggered by the heavy and continuous torrential rainfall that occurred on 4th and 5th June 2019 affecting several villages in Bududa district. There were numerous small landslides that occurred in different parishes of Bududa district but the major ones affected sub-counties of Buwali, Bukalasi, Bumayoka and Bubiita. There were four big landslides that occurred during the two days of heavy rainfall. Two of the landslides were in Buwali sub-county while one was in Bukalasi and another Bumayoka sub-county. These landslides resulted in the deaths of six (6) persons and severe injuries to 27 persons who were retrieved and referred to Bududa general hospital for review, admission and treatment. Overall, 100 households with 669 persons were affected. Due to damage to property, 80 of the affected households (480 community members) were displaced and resettled in the neighbouring villages by friends, relatives and Bududa district Local Government. During the same period (4 – 5th June 2019) as a consequence of the heavy rains, there were floods that burst River *Bugibuni* which is one of the tributaries of River *Manafwa*. These floods destroyed property that included the houses, latrines, crops, water sources and others. Approximately, 111 households with a total of 426 persons were affected. There were no direct flood related deaths (drowning) reported as a result of flood during that week or later.

Cholera outbreak detection, confirmation and outbreak declaration in Bududa district, June 2019

According to the medical records at the district, the first suspected cholera case was seen on 19th June 2019. This was two weeks from the time the floods occurred. This index case was a nine-year-old female who presented at Bushika Health Centre III with severe watery diarrhea and dehydration. The health workers on duty examined the patient and found that she met the standard case definition for the suspected case of cholera. The health workers rehydrated the case and transferred her to Bushigayi HC III for further management. The staff at Bushigayi HC-III agreed with the suspected cholera diagnosis and transferred the patient into an isolation facility /cholera treatment centre and administered appropriate cholera case management. On 20th June 2019, more suspected cholera cases were seen at Bushika Health Centre III originating from the same village. Fresh stool samples were taken from these suspected cases and shipped to Mbale regional referral hospital laboratory where cholera testing and confirmation of the outbreak was done.

In all, a total of four (4) fresh stool samples were collected and tested of which three (3) samples were confirmed positive on 22nd June 2019 for *V. cholerae*, serotype Inaba. Laboratory test showed that the isolated microorganisms from the stool samples were sensitive to several common antibiotics. The district then communicated to the MoH seeking support to control the outbreak. On 22nd June 2019, the MoH received a report of confirmation of cholera outbreak in Bududa district. The Ministry of Health team reviewed the reports and made consultations after which declaration of a cholera outbreak in Bududa district was pronounced. By the end of the outbreak, the total number of cases and deaths were 67 and one (1) death respectively with case fatality rate of 1.5%. Propagation of the cholera outbreak in Bududa district overtime is shown in Figure 2.

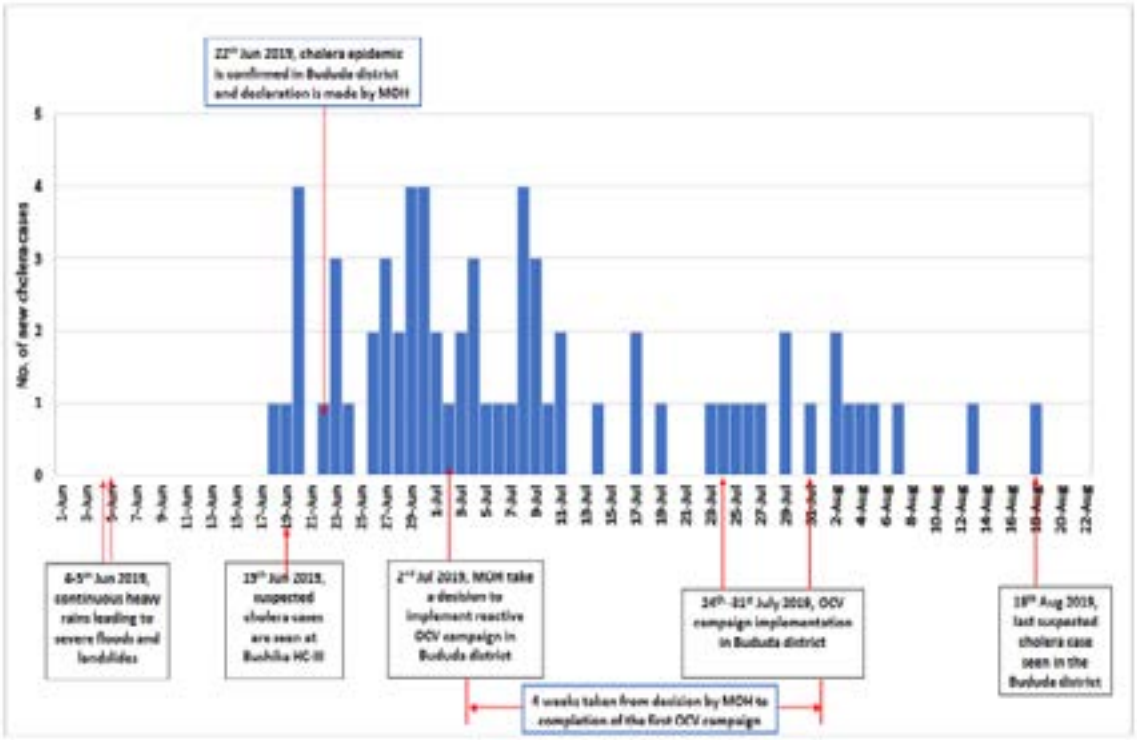

Figure2: The daily number of reported new cholera cases and the actions taken by the MoH and Bududa district Local Government to control the cholera outbreak.

Laboratory tests results

Fresh stool samples were collected from a cluster of the initial suspected cholera cases and tested to confirm the outbreak. Subsequently, stool samples were taken off from few cases regularly to monitor the outbreak and microbial characteristics. Cumulatively, there were 67 cases reported of these 15 cases had fresh stool samples collected and tested. The test positivity rate was high among the tested stool samples with 14 of these (93%) yielding V.cholerae 01, Inaba serotype. The isolated V. cholerae bacteria showed antibiotic sensitivity to chloramphenicol, cotrimoxazole, ciprofloxacin and tetracycline. However, the organisms were resistant to nalidixic acid.

Age and sex distribution of the cholera affected cases

All age groups and sexes were affected. However, in age group 6 – 14 years, the number of males affected were more than their female counterparts. In this age group, the males were more than three times affected by cholera than the females. Age and sex distribution of cases is shown in Figure 3.

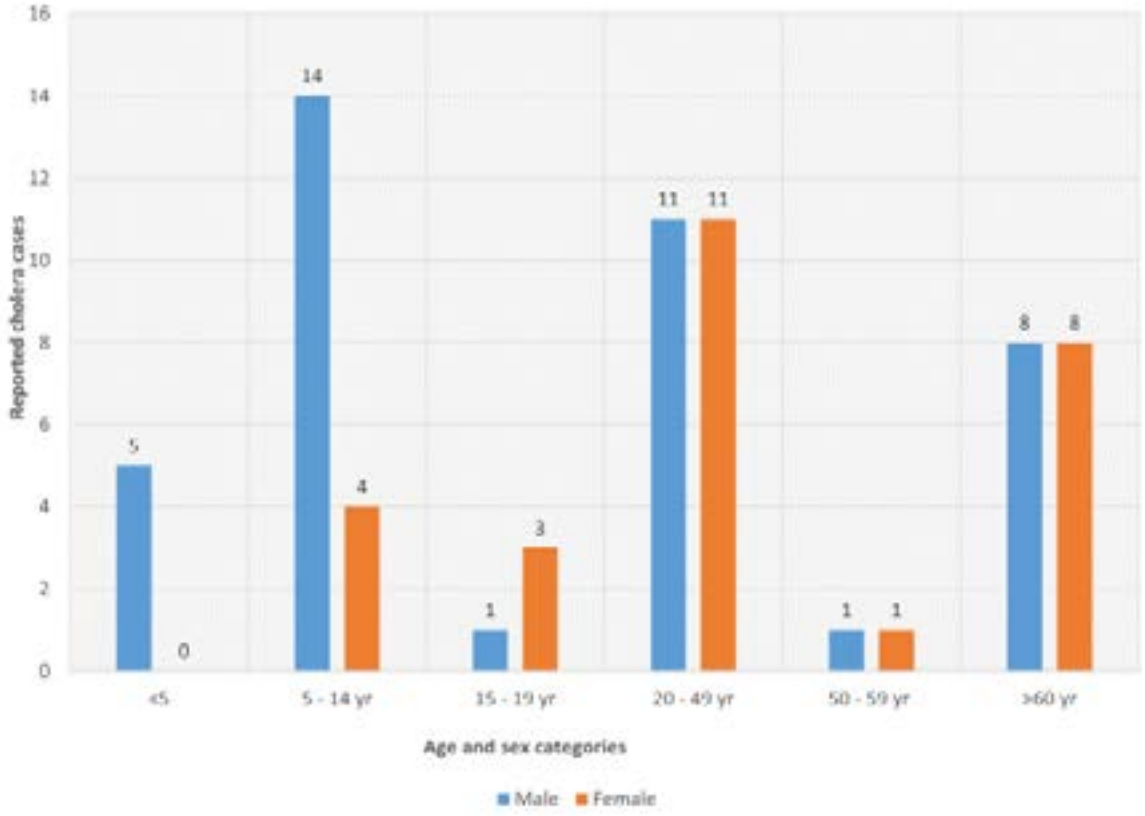

Figure 3: The age and sex distribution of the reported suspected and confirmed cholera cases in Bududa district, 2019.

Spatial distribution of cholera cases in Bududa district, 2019

Most of the cholera cases were from the villages and parishes that were affected by landslides and floods. Some of these parishes were located along the tributaries of River Manafwa as shown in Figure 4.

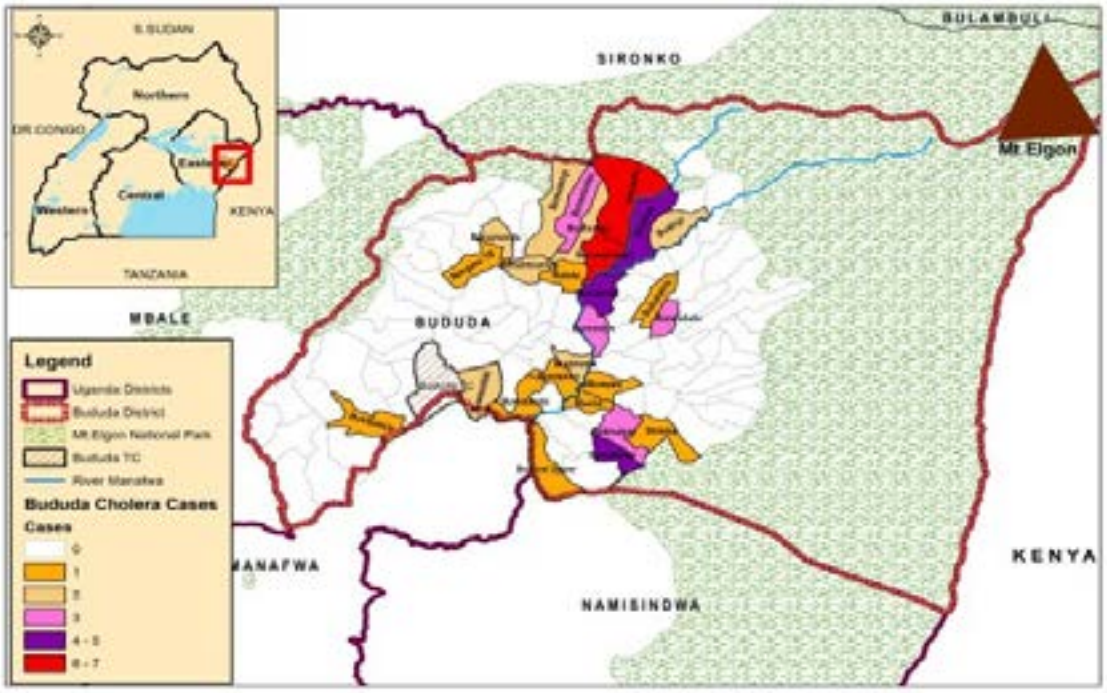

Figure 4: Spatial distribution of the reported cholera cases in Bududa district, 2019.

Water, sanitation and hygiene (WaSH) condition assessment

During the OCV campaigns, a total of 4,727 households were visited and assessed to establish status of WaSH in households. Majority of households 76% (3,600/4,727) used water from protected sources, however 34.2% (1,617/4,727) did not apply any treatment method of household water treatment. In regards to the availability of sanitary facilities, 19.7% (931/4,727) did not have a latrine facility. Only 24.2 % (879/3,628) had an improved latrine that had washable floors, 26.8% (1,023/3,818) had hand washing facilities with soap and WaSH coverage in the affected sub-counties were as shown in Figure 5.

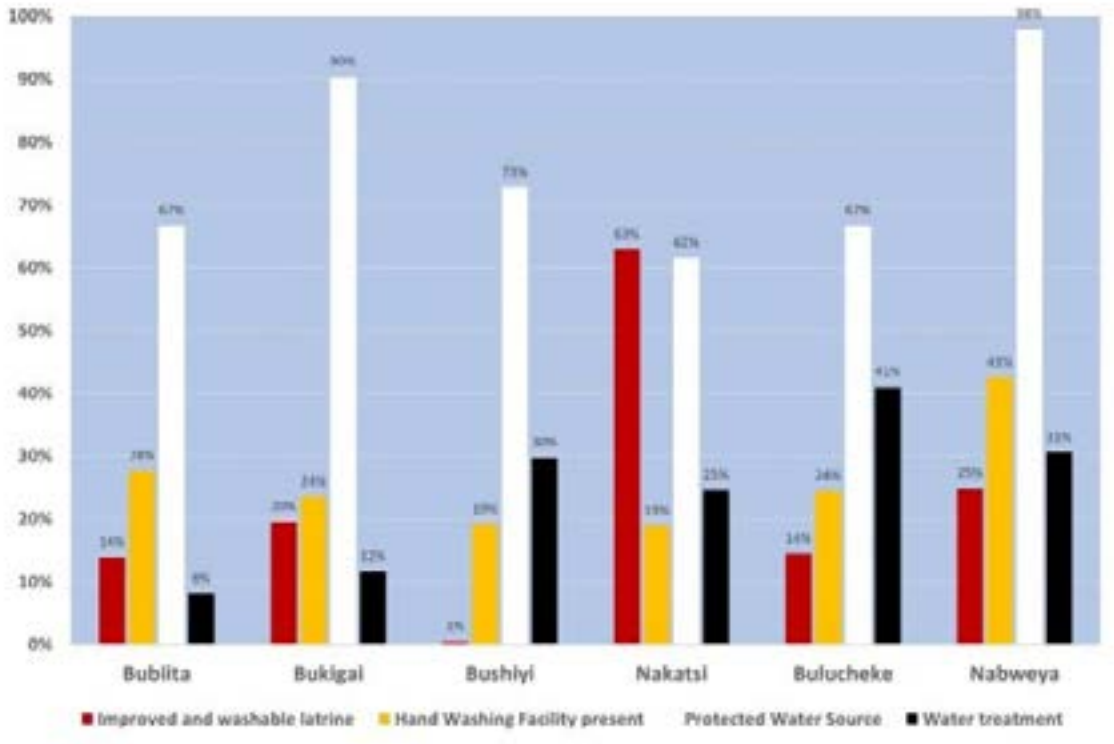

Figure 5: Water, sanitation, hygiene and hand washing coverage of the cholera affected sub-counties in Bududa district, 2019.

Oral cholera vaccination campaign coverage

Oral cholera vaccine mass campaign targeted 52,023 persons in the parishes that reported cholera cases. The administrative OCV coverage for both the first and second OCV doses were high and, in some parishes, above 100% since people in the neighbourhood were also interested. OCV coverage by parish are shown in Table 1.

Table 1: Oral cholera vaccine coverage by the affected parishes in Bududa district, 2019

Parishes Vaccinated	Target	Persons Vaccinated OCV Round 1	Round 1 coverage (%)	Persons Vaccinated OCV Round 2	Round 2 Coverage (%)	Persons Received 1st dose during R2	Total vaccinated in Round 2
Maaba	1,342	2,067	154	1,338	99	215	1,553
Shihulusi	1,480	1,633	110	1,470	99	175	1,645
Buwashi	1,202	1,520	127	1,198	99	165	1,363
Bumakhwa	715	1,724	241	708	99	123	831
Bumusi	996	1,472	148	986	98	148	1,134
Bumatanda	2,046	2,296	112	1,698	83	420	2,118
Bunaporo	2,157	2,546	118	1,812	84	424	2,236
Bukibokolo	4,771	5,363	112	3,951	83	345	4,296
Busiliwa	2,578	3,009	117	2,580	100	345	2,925
Bushiyi	3,002	2,633	88	2,957	98.5	123	3,080
Bubukasha	1,627	2,760	170	1,641	100	154	1,795
Bunambatsu	3,107	2,788	90	2,665	86	65	2,730
Bushiwunya	3,059	2,916	95	2,695	88	33	2,728
Bumusenyi	3,856	3,455	90	3,363	87	43	3,406
Bunamanda	2,124	2,885	136	1,812	85	22	1,834
Bumwalukani	3,514	3,120	89	3,117	88	458	3,575
Saskusaku	4,772	3,663	77	3,657	76	593	4,250
Bumwalye	2,124	2,861	135	2,758	129	160	2,918
Bumasata	1,472	1,902	129	1,788	121	118	1,906
Bunandutu	2,050	5,241	256	2,037	99.3	214	2,251
Bunatsmya	1,509	2,438	162	1,492	98.8	149	1,641
Bulobi	2,521	2,784	110	2,500	99.1	284	2,784
22	**52,023**	**6,1076**	**117**	**48,223**	**92.3**	**4,776**	**52,999**

Discussion

This study showed that in early June 2019, Bududa district experienced catastrophic landslides and flash floods that were later followed by a cholera epidemic. There were multiple major public health emergencies affecting the same population and communities in the district over a short time frame. Fortunately, the cholera epidemic was detected early and rapidly controlled by implementation of a package of targeted measures that included among others reactive oral cholera mass vaccination campaign. The response to control the cholera epidemic was unique in several ways. First, in contrast to the previous reactive OCV mass vaccination campaigns in Uganda and elsewhere where the source of OCV was GTFCC, Geneva, Switzerland [17,42], in this case the OCV stockpile/ reserve was within Uganda and not requiring shipment. Second, there was little or no need for the paper work and complex application processes and approvals for the vaccines to be deployed to the affected community since authorization to use the vaccines was in the country by the MoH top leadership with support from the WHO- country office. Third, the time taken from decision to use of OCV by MoH for the reactive campaign on 22nd June 2019, to completion of the first campaign on 8th July 2019, was four (4) weeks. This was shorter time compared to similar reactive mass OCV campaign to control cholera epidemic during major public health emergencies such as was the case of the 2018 cholera epidemic in Hoima district, in mid-western Uganda where the campaign was conducted after the outbreak had subsided [17]. In this study, the time for OCV intervention was also shorter than that used during reactive OCV campaigns in other countries in Af-

rica such as South Sudan and Nigeria [16,18]. Fourth, the beneficiary of OCV campaign were extremely targeted to those specific parishes with the highest risk of infection or where cholera cases had been reported as opposed to the entire sub-county (5 or more parishes). Consequently, the cholera epidemic was rapidly controlled. The rapid epidemic control had potential to prevent cholera spread to other districts in Eastern region that were experiencing heavy rainfall and floods during the same time.

Most importantly, though Bududa district is a hard-to-reach area due to the challenging terrains, floods and landslides effects, the time interval from decision to use OCV for epidemic control to implementation of OCV campaign was very short. Also, the OCV coverage for both first and the second doses were high which increased the impact of the OCV campaign on the cholera epidemic. In some parishes the OCV coverage were above 100% possibly due to the high acceptability of the OCV by the affected communities and the influx of people from the surrounding parishes and sub-counties which had not been targeted. Furthermore, the affected communities appreciated the impact of cholera on their health and cooperated with the health workers. Other possible reason for the high coverage could be due to strategy used where the health workers moved from home to home which allowed for all homes to be reached.

Despite the destruction of infrastructure and disruption of social services caused by landslides and floods, only one death was reported from the 2019 cholera outbreak in Bududa District. This could be due to resettlement of affected people in camps away from hard-to-reach areas, the presence of emergency responders and rapid mass OCV campaigns. On the other hand, the WaSH conditions coverage was found to be low and without vaccination, this scenario could provide suitable conditions for transmission of cholera as was observed previously in Tanzania [43] and in South Africa [44].

Cholera kills and spreads rapidly [45] and the incubation period ranges from a few hours to five days [46] yet the current requisition procedure for OCV, approval of the request, shipment of vaccines, to actual implementation of the campaign takes 2 – 3 months or more [16–18]. However, when the vaccines are prepositioned in endemic setting as was the case with the vaccine stockpile used in Bududa reactive mass vaccination campaign, it is possible for the duration to be less than one month or days to one (1) week for an emergency medicine delivery order from the Uganda National Medical Stores. Furthermore, by decentralizing / prepositioning OCV in endemic countries it is possible that the cost of implementation of the OCV campaign could be reduced by integration of OCV into routine vaccination schedules in cholera affected districts. The findings of this study address the knowledge and practice gap regarding feasibility of stockpiling/prepositioning of OCV in cholera endemic countries verses the status quo where OCV is located somewhere in Europe or Asia awaiting finalization of lengthy approval procedures and shipment. Currently, there is no local production of OCV on the African continent although under the auspices of the new public health order of the Africa Centres for Disease Control and Prevention (Africa CDC), there are efforts to explore local vaccine manufacturing on the African continent. We think that these promising steps of having local OCV stockpile in affected Partner States and OCV production on African continent should be first tracked to enable the countries in sub-Saharan Africa eliminate cholera by 2030 as per WHO cholera roadmap [14].

As part of the process to strengthen capacity for epidemic preparedness and response (EPR), prior knowledge of risk and vulnerability profile of an area are very important. Taking for example risk factors, such as water sources contaminated with faecal material as was the case in Bududa district following heavy rains and landslides, the potential for cholera to spread and affect many people in short time, it is very important to quickly institute a package of known prevention and control interventions [47]. This is critical and calls for review of guidelines regarding rapid access and timely implementation of reactive OCV campaigns to enhance effectiveness of the interventions for prevention and control of cholera. Therefore, quick decision making that goes with rapid implementation of mass OCV campaign has potential to curtail the spread of cholera and attain quick control of the outbreak.

Cholera is one of the major health issues affecting several countries each year [48]. Oral cholera vaccine stockpile for reactive campaigns is accessed through application to International Coordinating Group (ICG). However, some countries experiencing cholera outbreaks have not

accessed these vaccines [49]. There could be several reasons for this relatively low access to OCV despite the morbidity and mortality from cholera in the endemic countries being an important health issue [50]. One, the requisition process involves to and from communication and often is time consuming. Time to focus on outbreak control is lost in technicalities where by countries have to conduct risk assessment, write report and send it to WHO secretariat in Geneva, Switzerland. Often, there is time constraint on responders who also have to oversee known effective cholera control interventions (case management, surveillance, promotion of access to safe water and sanitation among others) to save lives. Most importantly, the availability of OCV stockpile within Uganda facilitated policy-makers to discuss and decide to implement OCV campaign in shortest time possible since powers of advisory and decision on vaccination were vested in them.

In this study, the area targeted were the parishes (5,000 persons) as opposed to sub counties (20,000 - 50,000 persons) in Hoima district OCV campaign [17]. Since access to OCV is still limited and not affordable by most cholera endemic countries, studies are needed to guide stakeholders on ideal administrative unit to target for mass OCV vaccination. Furthermore, given the resurgence of cholera in African continent [50], continental and regional actors/bodies (Africa Centres for Disease Control (Africa CDC), East African Community (EAC), Economic Community of West Africa (ECOWAS), Southern African Developmental Community (SADC) and Intergovernmental Authority on Development (IGAD)) which are closer to the affected countries/communities should consider stockpiling OCV and empower national authorities to supplement the GTFCC efforts.

Strength and weakness of this study

This study combined cholera control with assessment of WaSH conditions through community survey which generated data to guide disaster recovery process. This information is important for planning and prevention of future cholera outbreaks. Use of the community health workers to conduct assessment increased community knowledge and participation in finding local solution for community problem. It may not be possible to generalize our finding to other States since there may be differences in reporting, detection and declaration of cholera outbreaks.

Conclusion

This study shows that Bududa district experienced heavy rains with floods and catastrophic landslides that were followed by cholera outbreak. However, early detection and institution of control measures that included targeted mass OCV campaign using OCV stockpile that was in Uganda at the time of the disaster, facilitated quick field deployment of OCV and ultimately rapid control of the cholera outbreak. Furthermore, it is possible that this rapid intervention prevented cholera spread to surrounding districts with similar risk factors within the region. Therefore, countries at high risk of cholera outbreaks should stockpile OCV for future emergency rapid deployment. As we strive to attain the Africa Union agenda 2063 "the Africa we want" with capacities and capabilities to detect and respond to public health threats. We recommend Africa CDC to fast track the local manufacturing of essential commodities such as OCV to meet the growing demand on the continent.

Acknowledgement

The authors thank the teams from the Uganda MoH, Bududa district Local Government, residents in affected communities and World Health Organization for excellent cooperation and support during documentation of this work. The authors in very special way would like to thank the MoH for funding the study and Mr. Ambrose Buyinza Wabwire and Ms. Joan Badebye for generating the study area maps.

References

1. UNOCHA. Cholera cripples Bududa one week after landslide - Uganda | Relief Web [Internet]. report. 2012 [cited 2023 Jul 15]. Available from: https://reliefweb.int/report/uganda/cholera-cripples-bududa-one-week-after-landslide

2. Deen J, Mengel MA, Clemens JD. Epidemiology of cholera. Vol. 38, Vaccine. Elsevier Ltd; 2020. p. A31–40.

3. World Health Organization. Weekly Epidemiological Record (WER), 16 September 2022, Vol. 97, No 37, 2022, pp. 453–464 [EN/FR] - World | Relief Web [Internet]. Weekly epidemiological record (WER). 2022 [cited 2023 Jul 15]. Available from: https://reliefweb.int/report/world/weekly-epidemiological-record-wer-16-september-2022-vol-97-no-37-2022-pp-453-464-enfr

4. European Centre for Disease Prevention and Control. Cholera worldwide overview [Internet]. European Centre for Disease Prevention and Control. 2020 [cited 2020

Mar 31]. Available from: https://www.ecdc.europa.eu/en/all-topics-z/cholera/surveillance-and-disease-data/cholera-monthly
5. Lantagne D, Balakrish Nair G, Lanata CF, Cravioto A. The cholera outbreak in Haiti: Where and how did it begin? In: Current Topics in Microbiology and Immunology. 2014.
6. Zarocostas J. Cholera outbreak in Haiti-from 2010 to today. *Lancet (London, England)*. 2017;389(10086):2274–5.
7. Sidley P. Floods in southern Africa result in cholera outbreak and displacement. [Internet]. Vol. 336, BMJ (Clinical research ed.). *BMJ Publishing Group*; 2008 [cited 2022 Jun 22]. p. 471. Available from: /pmc/articles/PMC2258379/
8. Qadri F, Islam T, Clemens JD. Cholera in Yemen - An Old Foe Rearing Its Ugly Head. *N Engl J Med*. 2017;
9. Camacho A, Bouhenia M, Alyusfi R, Alkohlani A, Naji MAM, de Radiguès X, et al. Cholera epidemic in Yemen, 2016–18: an analysis of surveillance data. *Lancet Glob Heal*. 2018;6(6): e680–90.
10. Jones FK, Wamala JF, Rumunu J, Mawien PN, Kol MT, Wohl S, et al. Successive epidemic waves of cholera in South Sudan between 2014 and 2017: a descriptive epidemiological study. *Lancet Planet Heal* [Internet]. 2020 Dec 1 [cited 2022 Jun 22];4(12): e577–87. Available from: http://www.thelancet.com/article/S2542519620302552/fulltext
11. Lamond E, Kinyanjui J. Cholera Outbreak Guidelines: Preparedness, Prevention and Control. *Oxfam GB*. 2012.
12. World Health Organization. Addendum to "Oral cholera vaccines in mass immunization campaigns. Guidance for planning and use" [Internet]. 2013 [cited 2022 May 12]. Available from: http://www.who.int/cholera/vaccines/AddendumGuideVaccinationForShanchol050913.pdf
13. World Health Organization. Guidance on how to access the Oral Cholera Vaccine (OCV) from the ICG emergency stockpile [Internet]. 2013 [cited 2019 Jan 2]. Available from: https://www.who.int/cholera/vaccines/Guidance_accessing_OCV_stockpile.pdf
14. World Health Organization. Ending cholera: A global roadmap to 2030. Glob Task Force Cholera Control [Internet]. 2017;32. Available from: https://www.who.int/cholera/publications/global-roadmap.pdf
15. Pezzoli L. Global oral cholera vaccine use, 2013–2018. Vol. 38, Vaccine. *Elsevier*; 2020. p. A132–40.
16. Abubakar A, Azman AS, Rumunu J, Ciglenecki I, Helderman T, West H, et al. The First Use of the Global Oral Cholera Vaccine Emergency Stockpile: Lessons from South Sudan. *PLoS Med* [Internet]. 2015 Nov 1 [cited 2022 Jun 4];12(11). Available from: /pmc/articles/PMC4648513/
17. Bwire G, Roskosky M, Ballard A, Brooks WA, Okello A, Rafael F, et al. Use of surveys to evaluate an integrated oral cholera vaccine campaign in response to a cholera outbreak in Hoima district, Uganda [Internet]. Vol. 10, *BMJ Open. BMJ Publishing Group*; 2020 [cited 2021 Feb 22]. p. e038464. Available from: http://bmjopen.bmj.com/
18. Ngwa MC, Alemu W, Okudo I, Owili C, Ugochukwu U, Clement P, et al. The reactive vaccination campaign against cholera emergency in camps for internally displaced persons, Borno, Nigeria, 2017: a two-stage cluster survey. *BMJ Glob Heal [Internet]*. 2020 Jun 29 [cited 2022 Jun 4];5(6): e002431. Available from: https://gh.bmj.com/content/5/6/e002431
19. Loharikar A, Briere E, Ope M, Langat D, Njeru I, Gathigi L, et al. A national cholera epidemic with high case fatality rates-Kenya 2009. *J Infect Dis*. 2013;208(SUPPL. 1).
20. Bwire G, Malimbo M, Maskery B, Kim YE, Mogasale V, Levin A. The Burden of Cholera in Uganda. Ryan ET, editor. *PLoS Negl Trop Dis [Internet]*. 2013 Dec 5 [cited 2013 Dec 11];7(12): e2545. Available from: http://dx.plos.org/10.1371/journal.pntd.0002545
21. Bwire G, Munier A, Ouedraogo I, Heyerdahl L, Komakech H, Kagirita A, et al. Epidemiology of cholera outbreaks and socio-economic characteristics of the communities in the fishing villages of Uganda: 2011-2015. *PLoS Negl Trop Dis*. 2017;11(3).
22. Oguttu DW, Okullo A, Bwire G, Nsubuga P, Ario AR. Cholera outbreak caused by drinking lake water contaminated with human faeces in Kaiso Village, Hoima District, Western Uganda, October 2015. *Infect Dis Poverty [Internet]*. 2017 Dec 10 [cited 2020 Jul 9];6(1):146. Available from: http://idpjournal.biomedcentral.com/articles/10.1186/s40249-017-0359-2
23. Bwire G, Mwesawina M, Baluku Y, Kanyanda SSE, Orach CG. Cross-border cholera outbreaks in Sub-Saharan Africa, the mystery behind the silent illness: What needs to be done? *PLoS One*. 2016;11(6).
24. Abubakar A, Bwire G, Azman AS, Bouhenia M, Deng LL, Wamala JF, et al. Cholera epidemic in South Sudan and Uganda and need for international collaboration in cholera control. *Emerg Infect Dis*. 2018;24(5).
25. Bwire G, Ali M, Sack DA, Nakinsige A, Naigaga M, Debes AK, et al. Identifying cholera "hotspots" in

Uganda: An analysis of cholera surveillance data from 2011 to 2016. Ivers LC, editor. *PLoS Negl Trop Dis [Internet]*. 2017 Dec 28 [cited 2021 Apr 6];11(12):e0006118. Available from: https://dx.plos.org/10.1371/journal.pntd.0006118
26. Bwire G, Sack DA, Kagirita A, Obala T, Debes AK, Ram M, et al. The quality of drinking and domestic water from the surface water sources (lakes, rivers, irrigation canals and ponds) and springs in cholera prone communities of Uganda: an analysis of vital physicochemical parameters. *BMC Public Health [Internet]*. 2020 Dec 17 [cited 2020 Jul 19];20(1):1128. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-020-09186-3
27. UNESCO. Landslides in Uganda [Internet]. 2019 [cited 2020 Dec 16]. Available from: http://unesco-uganda.ug/wp-content/uploads/2019/02/LandSlides-In-Uganda.pdf
28. Claessens L, Kitutu MG, Poesen J, Deckers JA. Landslide hazard assessment on the Ugandan foot slopes of mount elgon: The worst is yet to come. In: Landslide Science and Practice: Landslide Inventory and Susceptibility and Hazard Zoning. 2013. p. 527–31.
29. Sauvageot D, Njanpop-Lafourcade B-M, Akilimali L, Anne J-C, Bidjada P, Bompangue D, et al. Cholera Incidence and Mortality in Sub-Saharan African Sites during Multi-country Surveillance. *PLoS Negl Trop Dis*. 2016;10(5).
30. Okello PE, Bulage L, Riolexus AA, Kadobera D, Kwesiga B, Kajumbula H, et al. A cholera outbreak caused by drinking contaminated river water, Bulambuli District, Eastern Uganda, March 2016. *BMC Infect Dis [Internet]*. 2019 [cited 2019 Dec 18];19(1). Available from: https://doi.org/10.1186/s12879-019-4036-x
31. Sauvageot D, Njanpop-Lafourcade B-MM, Akilimali L, Anne J-CC, Bidjada P, Bompangue D, et al. Cholera Incidence and Mortality in Sub-Saharan African Sites during Multi-country Surveillance. *PLoS Negl Trop Dis [Internet]*. 2016 May 17 [cited 2016 May 23];10(5): e0004679. Available from: http://pubmedcentralcanada.ca/pmcc/articles/PMC4871502/pdf/pntd.0004679.pdf
32. Atuyambe LM, Ediau M, Orach CG, Musenero M, Bazeyo W. Land slide disaster in eastern Uganda: rapid assessment of water, sanitation and hygiene situation in Bulucheke camp, Bududa district. *Environ Health*. 2011; 10:38.
33. Agrawal S, Gopalakrishnan T, Gorokhovich Y, Doocy S. Risk factors for injuries in landslide- and flood-affected populations in Uganda. *Prehosp Disaster Med [Internet]*. 2013;28(4):314–21. Available from: http://www.scopus.com/inward/record.url?eid=2-s2.0-84886781798&partnerID=tZOtx3y1
34. Uganda Wildlife Authority. Wagagai Peak, Hike to Wagagai Peak on Mount Elgon [Internet]. [cited 2023 Jul 17]. Available from: https://www.insidemountelgonnationalpark.com/mount-elgon-wagagai-peak.html
35. Uganda Bureau of Statistics. National Population and Housing Census 2014: Area Specific Profiles. *Natl Popul Hous Census*. 2017;(April).
36. Uganda Bureau of Statistics. Statistical Abstract, 2019. Uganda Bur Stat Stat [Internet]. 2019; Available from: http://www.ubos.org/onlinefiles/uploads/ubos/pdf documents/abstracts/Statistical Abstract 2013.pdf
37. Uganda Bureau of Statistics. National Population and Housing Census 2014. Uganda Bur Stat 2016, Natl Popul Hous Census 2014 – Main Rep, Kampala, Uganda [Internet]. 2014;1–209. Available from: http://www.ubos.org/onlinefiles/uploads/ubos/NPHC/2014 National Census Main Report.pdf
38. WHO and CDC. Technical Guidelines for Integrated Disease Surveillance and Response in the African Region. 2010;1–416. Available from: http://www.cdc.gov/globalhealth/healthprotection/idsr/pdf/technicalguidelines/idsr-technical-guidelines-2nd-edition_2010_english.pdf
39. Ministry of Health Uganda. Prevention and Control of Cholera Operational Guidelines for the National and District Health Workers and Planners [Internet]. 2017 [cited 2019 Feb 13]. Available from: http://www.health.go.ug/sites/default/files/Final CHOLERA GUIDELINES 2017_0.pdf
40. UNHCR. Uganda Districts Shapefiles 2020 [Internet]. 2020 [cited 2022 Jun 17]. Available from: https://data.unhcr.org/en/documents/details/83043
41. ESRI, Redlands, California US. Arcmap Software | ArcGIS Pro [Internet]. Version 10.5. [cited 2023 May 15]. Available from: https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview
42. Msyamboza KP, M'bang'ombe M, Hausi H, Chijuwa A, Nkukumila V, Kubwalo HW, et al. Feasibility and acceptability of oral cholera vaccine mass vaccination campaign in response to an outbreak and floods in Malawi. *Pan Afr Med J*. 2016; 23:203.
43. Picarelli N, Jaupart P, Chen Y. Weather shocks and health in Dar es Salaam. Int Growth Cent [Internet]. 2017

[cited 2022 Aug 23] ;(July):1–16. Available from: https://www.theigc.org/wp-content/uploads/2017/08/Picarelli-et-al-2017-working-paper.pdf
44. Sidley P. Floods in southern Africa result in cholera outbreak and displacement. [Internet]. Vol. 336, BMJ (Clinical research ed.). *BMJ Publishing Group*; 2008 [cited 2022 Aug 23]. p. 471. Available from: /pmc/articles/PMC2258379/
45. Sidder A. How Cholera Spread So Quickly Through Haiti [Internet]. National Geographic. 2016 [cited 2022 Aug 23]. Available from: https://www.nationalgeographic.com/science/article/haiti-cholera-crisis-united-nations-admission
46. Azman AS, Rudolph KE, Cummings DAT, Lessler J. The incubation period of cholera: A systematic review. *J Infect*. 2013 May 1;66(5):432–8.
47. R P. Epidemiology of cholera: What happened in Haiti since October 2010? Vol. 16, *Tropical Medicine and International Health*. 2011. p. 28–9.
48. World Health Organization. Cholera, 2020 [Internet]. Weekly epidemiological record (WER). 2021 [cited 2022 May 15]. Available from: https://reliefweb.int/report/world/weekly-epidemiological-record-wer-17-september-2021-vol-96-no-37-pp-445-460-enfr
49. World Health Organization. International coordination group on vaccine provision for epidemic meningitis: report of the annual meeting: Geneva, 10 September 2019 [Internet]. 2020 [cited 2022 Aug 25]. Available from: https://apps.who.int/iris/handle/10665/333250
50. Mavhunga C. Cholera: World Health Organization warns of rising cases in Africa. *BMJ [Internet]*. 2023 Mar 1 [cited 2023 Jul 24];380: p488. Available from: https://www.bmj.com/content/380/bmj.p488