

Retrospective analysis of a large-scale cholera outbreak in Sudan

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Abstract

Background: Cholera outbreak is a significant public health threat in some parts of Sudan. In 2023, there was a large-scale outbreak in Gadarif State.

Aim: To analyse the 2023 cholera outbreak in Sudan and recommend prevention and control measures for the future.

Methods: In this retrospective study we conducted an epidemiological analysis of data from suspected and confirmed cholera cases, aged ≥ 2 years, from 138 health centres in Gadarif State, Sudan.

Results: A total of 1997 cholera cases were confirmed using rapid diagnostic test between 25 August and 17 December 2023. Most patients (99.2%) had severe watery diarrhoea, and vomiting was reported in over 73% of cases. Dehydration rates were similar for men and women (≈ 55 –60%), average attack rate was 6.7 per 10 000 population. The attack rate varied by locality but not by gender across all age groups. The outbreak lasted 20 weeks and claimed 46 lives, giving a case fatality ratio of 2.6%. Public misconception about water chlorination substantially hindered control efforts.

Conclusion: The prolonged period of the outbreak and the high case fatality ratio highlight the need for better laboratory and epidemiologic surveillance as well as better preparedness and response for future outbreaks, along with educational activities to address myths and misconceptions.

Keywords: cholera, diarrhoea, dehydration, preparedness, attack rate, WASH, Gadarif, Sudan

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Introduction

Cholera, a diarrhoeal illness caused by the bacterium *Vibrio cholerae*, is a well-known global public health threat (1). Despite substantial developments in control and prevention globally, cholera still persists as an indicator of social inequity and lagging development (2,3). Once identified in local water sources, cholera outbreaks have been shown to be relentless; recurring frequently with high morbidity and mortality rates (4). Recent data from the Republic of Sudan suggests that there is a resurgence of large-scale cholera outbreaks in eastern Sudan (5).

Gadarif State in eastern Sudan particularly has a well-documented history of recurring cholera outbreaks (6). Between 1966 and 2018, there were 16 major cholera outbreaks in the state 12 of which (75%) were classified as outbreaks of acute watery diarrhoea (6). However, detailed and accurate data on the true aetiology of these 12 past outbreaks is limited.

Gadarif State borders Ethiopia and has a population of approximately 2.84 million people spread across 12 localities. The state has been experiencing water shortage, making residents to dig unregulated shallow wells throughout Gadarif City and the surrounding rural areas. As of 2023, only a small proportion (140 out of 273) of these water sources were licensed and monitored for quality.

In August 2023, the Gadarif State Ministry of Health (SMOH) disease surveillance system detected 3 suspected cholera cases. However due to financial constraints and a concurrent dengue fever outbreak, the ministry struggled to implement an effective response. The initial 2 stool specimens collected for testing were not transported using appropriate cold chain storage procedures, resulting in false negative results for *V. cholerae*. Only the third sample, which was shipped separately from the first 2 samples and tested using rapid diagnostic kit was confirmed to have the bacteria. Following further laboratory confirmation of the presence of *V. cholerae*, a rapid response team made up of members of the Sudanese Federal Ministry of Health (FMOH) and the World Health Organization, was deployed to Gadarif State in September 2023 to support the control of the outbreak. The team established 2 cholera treatment centres with a combined capacity of over 80 beds in response to the outbreak.

The aim of this report is to describe the 2023 cholera outbreak in Gadarif State. We analysed basic cholera epidemiology such as attack rates and case fatality ratio and assessed water supply and contamination. Based on the results, we suggest an evidence-based strategy for better control and prevention of future cholera outbreaks in Sudan.

Methods

SMOH regularly collects data from 138 health care centres across the state, including 31 in Gadarif City. The rapid response team reviewed all relevant SMOH data available during the outbreak, including demographics, symptoms, dates of illness onset and of reporting and patient outcomes. Subsequently, we defined a suspected cholera case as anyone aged 2 years or older who had been living in Gadarif State for at least one week and had experienced sudden, severe non-bloody watery diarrhoea (with or without vomiting) leading to severe dehydration or death during the outbreak (7). We entered all data into Microsoft Excel spreadsheets and used Epi-Info software for analysis. After this, we performed basic epidemiological analysis, including generation of a time-specific epidemic curve. To validate age-based results, we calculated standard deviation (SD) and interquartile range (IQR).

Using Epi-Info, we calculated attack rates by age, sex, and locality and case fatality ratios (CFR) by gender. Attack rates quantify the incidence (proportion of new cases) of cholera within a population over a specific period. We used the formula: Attack rate = (number of new cases during outbreak period) / (total population at risk) x 100 (X).

We also calculated case fatality ratios, a key epidemiological measure of outbreak mortality. Case fatality ratio is defined as the proportion of individuals diagnosed with a particular disease who ultimately die from it over a specific period. We calculated case fatality ratio by dividing the total number of deaths caused by the disease by the total number of diagnosed cases. We then multiplied this number by 100 to express the result as a percentage. We used the formula; case fatality ratio = (number of deaths from disease in period) / (number of diagnosed cases in period) x (100) (7).

Age-specific case fatality ratios are calculated by dividing the number of deaths from the disease within that specific age group by the total number of diagnosed cases in the same age group. Gender or locality specific CFR, similar to the age-specific estimate, is calculated by dividing the number of deaths due to the disease by gender with the total number of diagnosed cases in each gender (7).

To confirm disease aetiology, we collected stool samples from all suspected cases at the cholera treatment centres established by the rapid response team and sent them to the National Public Health Laboratory of Sudan for confirmation of cholera (*V. cholerae* O1). Suspected cases at cholera treatment centres were also diagnosed using rapid diagnostic tests (RDTs) or PCR tests to ensure timely and appropriate treatment interventions.

The rapid response team and public health officials tried to identify the source of the outbreak by testing water samples from random wells and other unregulated water sources in Gadarif City, including boreholes. They obtained data on chlorine levels in these water sources

and attended regular and special meetings of the Cholera Task Force Committee (TFC).

Results

A total of 1997 suspected cholera cases were identified in Gadarif State. For this report, we excluded 100 cases of children younger than 2 years old from further analysis, providing a total of 1897 analysable cases. Cases were reported from 11 out of 12 localities, with nearly all cases (94.5%) concentrated in 5 localities. Four localities accounted for over 84% of the total cases. The overall attack rate of cholera in Gadarif State was 6.7 per 10 000 people. Attack rates varied across localities, ranging from 0 to 19.5 per 10 000 people (Table 2). The highest rates were in Madinat (Baladeyat) Al Gadarif and Al-Gallabat localities.

Table 1 presents a summary of the socio-demographic characteristics and clinical presentation of cholera cases in Gadarif State in 2023. There was no significant difference between the average age of cases and gender (around 29.9 years old). The male-to-female ratio of cases was nearly equal (1:1). Nearly all cases presented with (99.2%) severe watery diarrhoea, with only a small percentage (0.8%) having mild or less severe diarrhoea. Vomiting was present in over 73% of the cases. Dehydration rates were similar for men and women (around 55-60%).

The rapid response team observed new clusters of cases following social gatherings, especially at funeral homes. Although uncommon, a few cases of suspected

Table 1. Socio-demographic characteristics and clinical presentation of suspected cholera cases, Gadarif State, Sudan, 2023

Variable	Statistic
Mean age in years	
Female	30.9 (20.5; 16–43)
Male	29.5 (21.8; 11–43)
Gender	
Female	983 (50.5%)
Male	985 (48.3%)
Clinical presentation	
Profuse watery diarrhoea	1881 (99.2)
Mild (or less severe) diarrhoea	16 (0.8)
Vomiting	1383 (73.7)
Fever	206 (11.0)
Headache	34 (1.8)
Gender	
Rapid diagnostic tests	448 (97.4)
Stool Culture	12 (2.61)
Severe dehydration by gender	
Female	536 (55.7)
Male	545 (59.6)

Note: The gender of 24 (1.3%) patients was missing

Table 2. Attack rates per 10 000 population by age, gender and locality during an outbreak of cholera in Gadarif State, eastern Sudan, 2023

Age group in years	Population	Female		Male	
		Cases of cholera	Attack rate per 10 000 population	Cases of cholera	Attack rate per 10 000 population
0–9	661 828	230	7.0	190	6.0
10–19	579 099	120	4.0	137	5.0
20–29	520 007	189	7.0	187	5.0
35–39	378 187	129	7.0	159	8.0
40–49	319 096	67	4.0	112	7.0
50–59	236 367	62	5.0	72	6.0
60+	159 548	132	17.0	118	14.0
Total	2 854 132	929	7.0	975	7.0

Locality	Population	Female		Male	
		Cases	Attack rate per 10 000 population	Cases	Attack rate per 10 000 population
Madeinat Al Gedaref	609 728	590	19.5	596	19.4
Al-Galabat Al Gharbyah	196 846	83	8.5	114	11.5
Wasat Al Gedaref	261 357	82	6.3	98	5.9
Galabat Ash-Shargiah	259 910	65	5.1	69	5.3
Al Qureisha	164 629	50	6.1	59	7.1
Al Fashaga	132 734	35	5.3	24	3.6
Gala'a Al Nahal	143 267	17	2.4	5	0.7
Other 5 localities	1 085 661	7	0.2	10	0.2
Total	2 854 132	929	6.5	975	6.8

The table does not include localities with less than 5 cases (female + male): Ar Rahad-GD (1 + 4), Al Fao (3 + 3), Basundah (1 + 2), Al Mafaza (2 + 1) and Al Butanah (0 + 0)

cholera presented with a yellowish or bloody diarrhoea instead of the typical "rice-water" type. Other cases, also presenting with severe diarrhoea, reported receiving the oral cholera vaccine (OCV) shortly before testing positive for cholera. Forty-six of the 1897 patients died, resulting in a cases fatality ratio of 2.42%. Our epidemic curve (Figure 1) indicates a median incubation period of 3 days and duration of approximately 20 weeks.

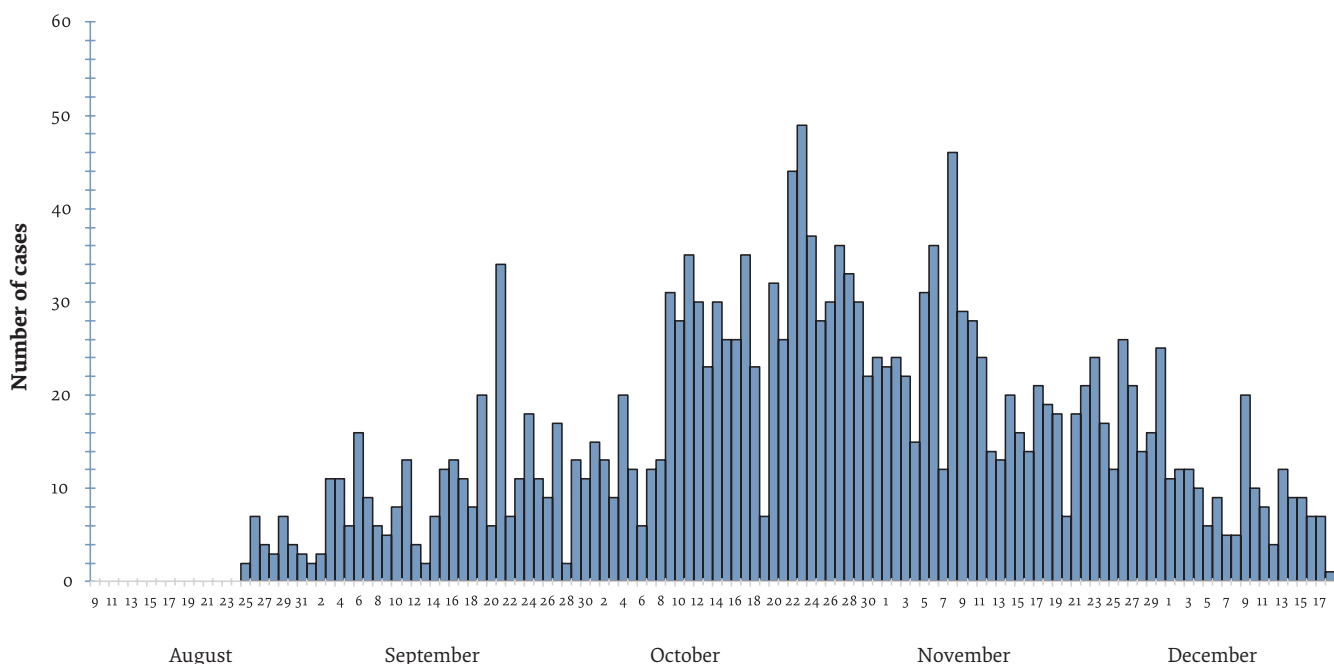
In terms of outreach, SMOH primarily relied on radio and television broadcasts of messages by the FMOH to inform the population in Gadarif about the cholera outbreak. Notably, there were no educational materials displayed at public places like streets, markets or strategic locations within Gadarif City. Some health workers made announcements on the streets with mobile loudspeakers to encourage people to come forward for emergency cholera immunization.

The rapid response team found that public misconceptions about chlorine use were widely circulating among the population in Gadarif State during the outbreak. People were misinformed that chlorine causes infertility, harms religious practices and has a bad taste. Water sellers resisted chlorination for the control of the outbreak due to concerns that they would not make sales. The TFC discussed control measures, including procurement of chlorine.

Discussion

In this report we have described and analysed a large-scale cholera outbreak that occurred in 2023 in Gadarif State, Sudan. Our aim was to describe the outbreak by age, gender and locality and identify potential factors that increased its spread. We were surprised to find similar attack rates across all age groups, suggesting the entire population was equally susceptible to infection. This indicates a common factor applicable to the entire population, most likely environmental. Compared to other countries, Gadarif's overall attack rate was higher, further supporting the common factor idea (9-11). Water scarcity and poor sanitation are prime suspects for the outbreak's spread. Some cases presented with atypical symptoms like bloody or yellowish diarrhoea. This suggests potential co-infection with other bacteria diseases, possibly dysentery, and highlights the possibility of heavy water contamination. The proximity of some wells to pit latrines further increased concerns about cross-contamination (12,13). Although we do not have any confirmatory evidence, we suspect Gadarif's unregulated and complex water system likely played a key role in the outbreak. However, public misconceptions led residents and water sellers to refuse chlorine treatment. We observed that the number of active cholera cases decreased when chlorination efforts eventually improved. This highlights the need for educational campaigns to address misconceptions and emphasize

Figure 1. Epidemic curve for daily number of cases by date of onset during an outbreak of cholera in Gadarif State, eastern Sudan, 2023



X-axis shows days of the month, and the Y-axis shows the number of cases of cholera

the safety and effectiveness of water chlorination against highly contagious waterborne diseases like cholera. Strengthening collaboration between local authorities (municipality, health department, and police) is crucial to enforce existing regulations on water quality and sanitation practices.

We were concerned about the extended duration of the outbreak in 2023, which lasted 20 weeks. Other reports of cholera outbreaks in sub-Saharan Africa found 13-week cycles to be more common (14). Several factors likely contributed to this prolonged outbreak. Limitations in laboratory and epidemiologic surveillance and response activities, along with inconsistent implementation of control measures, may have hampered early detection and containment efforts. Delays in confirming cholera diagnoses, in sharing critical data with decision-makers, and implementing a swift response likely slowed down the outbreak's control. The limited number of sentinel sites and high healthcare worker turnover may have further hindered early detection efforts (15). The epidemic curve itself shows periods of declining cases, possibly coinciding with intensified control measures by the rapid response team. However, these efforts were followed by surges in cases, suggesting a premature relaxation of control measures (16).

Underlying vulnerabilities within the population also likely played a role in prolonging the outbreak (17). Poverty, lack of access to clean water, improper water storage and sanitation practices, and contact with infected individuals likely contributed to the persistence of the disease. Financial constraints further hampered the

ability of SMOH to develop and distribute educational materials to the public. This limited public engagement also meant less involvement of trusted community figures, religious leaders, and youth or women groups that could have promoted disease control activities. Similarly, there was minimal use of local communication channels, including social media, to disseminate health information and address rumours or misconceptions.

Several factors limit the generalizability of this study's findings. The number of cholera cases and deaths reported may be lower than the actual figures due to weaknesses in Gadarif's disease surveillance systems. Other pathogens besides *V. cholerae* can cause cholera-like symptoms in children, potentially leading to an under-estimation of the true number of cholera cases. Economic constraints may have prevented some individuals from seeking medical care, leading to further under-reporting. A lack of reliable data on internally displaced persons in the region makes it difficult to fully assess their contribution to the outbreak's spread.

Considering these findings, strengthening sentinel surveillance and response systems is crucial. Improving data sharing and communication channels will be essential for faster and more effective responses. Securing adequate funding for essential supplies and response teams is vital for outbreak control. Developing public education programmes and using local communication channels are critical for promoting disease awareness and dispelling misinformation. By implementing these control measures, Gadarif State and similar settings can be better equipped to prevent and control future cholera outbreaks.

Analyse rétrospective d'une flambée épidémique de choléra de grande ampleur au Soudan

Résumé

Contexte : Les flambées épidémiques de choléra représentent une menace importante pour la santé publique dans certaines parties du Soudan. En 2023, un tel phénomène de grande ampleur s'est produit dans l'État de Gadarif.

Objectifs : Analyser la flambée épidémique de choléra survenue au Soudan en 2023 et recommander des mesures de prévention et de lutte pour le futur.

Méthodes : La présente étude rétrospective a permis de réaliser une analyse épidémiologique des données relatives à des cas suspects et confirmés de choléra, âgés de deux ans et plus, provenant de 138 centres de soins de santé de l'État de Gadarif, au Soudan.

Résultats : Un total de 1997 cas de choléra ont été confirmés par test diagnostique rapide entre le 25 août et le 17 décembre 2023. La plupart des patients (99,2 %) souffraient de diarrhée aqueuse sévère, et des vomissements ont été signalés dans plus de 73 % des cas. Les taux de déshydratation étaient similaires chez les hommes et chez les femmes ($\approx 55-60\%$), le taux d'attaque moyen était de 6,7 pour 10 000 personnes. Ce dernier variait en fonction du lieu mais pas du sexe, et ce, dans toutes les tranches d'âge. La flambée épidémique a duré 20 semaines et causé la mort de 46 personnes, correspondant à un taux de létalité de 2,6 %. Les conceptions erronées des populations concernant la chloration de l'eau ont considérablement entravé les efforts de lutte contre la maladie.

Conclusion : La persistance de la flambée épidémique et son taux de létalité élevé soulignent la nécessité de renforcer la surveillance épidémiologique et biologique, ainsi que la préparation et la riposte pour les flambées futures. Il est également primordial de mettre en place des activités éducatives en vue de combattre les mythes et les conceptions erronées.

تحليل استرجاعي لفاشية كوليرا واسعة النطاق في السودان

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الخلاصة

الخلفية: تمثل فاشية الكوليرا تهديداً صحياً كبيراً للصحة العامة في بعض أنحاء السودان. وفي عام 2023، حدثت فاشية واسعة النطاق في ولاية القضارف.

الهدف: هدفت هذه الدراسة الى تحليل فاشية الكوليرا التي أصابت السودان في عام 2023، وتدابير الوقاية والمكافحة الموصى بها في المستقبل. طرق البحث: أجرت هذه الدراسة الاسترجاعية تحليلاً وبيئياً لبيانات تخص حالات الكوليرا المشتبه فيها والمؤكدة، لأشخاص تبلغ أعمارهم عامين أو أكثر، من 138 مركزاً صحياً في ولاية القضارف، بالسودان.

النتائج: أكد تشخيص 1997 حالة كوليرا باستخدام الاختبار التشخيصي السريع في الفترة من 25 أغسطس / آب إلى 17 ديسمبر / كانون الأول 2023. وعانى معظم المرضى (99.2%) إسهالاً مائياً حاداً، كما أبلغ عن قيء في أكثر من 73% من الحالات. وكانت نسب الإصابة بالجفاف متماثلة على مستوى الرجال والنساء (55-60%)، وكان متوسط معدل الإصابة 6.7 لكل 10000 نسمة. وتباين معدل الإصابة من منطقة محلية إلى أخرى، ولكن لم يختلف حسب نوع الجنس في جميع الفئات العمرية. واستمرت الفاشية 20 أسبوعاً وأودت بحياة 46 شخصاً، وبلغت نسبة إماتة الحالات 2.6%. وأدت الأفكار العامة المغلوطة بشأن معالجة المياه بالكلور إلى إعاقة جهود مكافحة بشكل كبير.

الاستنتاجات: إن المدة الطويلة للفاشية وارتفاع معدل إماتة الحالات تبرزان الحاجة إلى ترصد مختبري ووبائي أفضل، فضلاً عن تحسين التأهب والاستجابة للفاشيات في المستقبل، بالإضافة إلى الحاجة إلى أنشطة تثقيفية لمعالجة الخرافات والمفاهيم الخاطئة.

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