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Review Article

A review of the risk of cholera outbreaks and urbanization in sub-Saharan Africa

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ABSTRACT

The sub-Saharan region of Africa is rapidly urbanizing, that has consequently spurred the development of specific challenges in terms of access to basic services and sanitation. Thus, exposure to waterborne diseases, including cholera, has been a recurrent problem for the people residing in these urban locations. It is important to understand the different risks faced by people in urban areas as it might aid in preventing and controlling the spread of the disease.

A review of literature was conducted, using specific selection criteria to obtain relevant publications that described the risk factors for cholera outbreak in urban areas of sub-Saharan Africa.

A perusal of available literature indicated that despite the heterogeneity in the urban areas of Africa, there are similarities with respect to the risk factors associated with the incidence of cholera epidemics. These risk factors include geographical location, hydroclimatic parameters, urban environment, genomics of the *Vibrio cholerae* virulence, sanitation, and human behavior.

A succinct comprehension of the possible relationship between the different risk factors might prove to be helpful in managing the cholera epidemic.

Contents

1. Introduction

The world has witnessed rapid urbanization, as evidenced by the global growth in the proportion of the population in urban areas. The percentage of people residing in urban areas has increased from 43% to 54% between 1990 and 2015.[1] Several esti-

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mates predict that this growth would encompass 68% of the total world population by 2050.[1,2]

Although Africa is the least urbanized continent, the sub-Saharan region has seen rapid urbanization. It has been estimated that the urban population would increase from 40% to 56–62% between 2010 and 2050.[1,3]

The sub-Saharan Africa (SSA) region includes 46 countries that have several developing cities. These countries have diverse climatic and ecological zones with specific social and economic characteristics. Thus, all these countries have been developing at a different pace in a heterogenous manner.[2]

The cities of this African region are also not homogenous with urbanization associated with inequalities among residents.[4] Therefore, health risk factors such as risk for waterborne diseases might vary across the SSA regions, from country to country, and even within cities.[5,6] However, there are also many similarities in the spread, dynamics, and risk factors associated with waterborne diseases in the urban environment of sub-Saharan Africa.[7]

Waterborne disease outbreaks generally occur in countries with unsafe drinking water and sanitation conditions.[8,9] These conditions are associated with socioeconomic settings and environmental challenges, which have been critical in many SSA countries. The access to improved sanitation facilities is 53% in 2010 – 2015.[10]

Of all waterborne diseases, cholera has had a significant impact in SSA countries since the seventh pandemic of the 1970's.[11,12] As evident, SSA constitutes a region where cholera has persisted because of sporadic epidemics of high mortality, while geographically, it has been recognized as an endemic region. The majority of cholera outbreaks and deaths have been reported in sub-Saharan Africa. Between 2000 and 2015, the World Health Organization (WHO)[13] reported that 83% of the total deaths due to cholera were from the SSA region.[14]

Cholera is generally perceived as a waterborne and environmental disease caused by the ingestion of water or food contaminated with feces. The risk factors associated with the transmission of cholera involved a lack of proper drinking water, poor sanitation, high population density, overcrowding, and low immunity. These environmental factors are often specific to urban areas.[15,16] Also, in sub-Saharan African countries, the incidence of cholera appears to be higher in the urbanized areas.[17]

Therefore, urbanization has an impact on the epidemiology of cholera. A comprehensive understanding of the risk factors specific to the SSA urban setting could be of benefit in the prevention and response to urban outbreaks. In this perspective, a review of the literature was conducted to ascertain the different urban risk factors associated with the incidence of cholera in SSA).

2. Methodology

A review of literature was undertaken to assess the presence of cholera risk factors in the urban environment of SSA. Relevant databases such as MEDLINE, SCOPUS, and Web of Science were utilized to identify publications between January 2000 and October 2019. A PRISMA framework was conducted, and a search combining keywords associated with cholera outbreak risk and sub-Saharan Africa were employed to identify relevant publications. Available reports in English and French language, scientific articles, United Nations reports, government reports, and NGO reports were included in the review. Additional articles were identified manually by searching the reference list from relevant reports. The scientific articles were further screened for relevance by title or by reading the abstract or full text when the title was not sufficiently relevant for the review.

3. Results

The search yielded 144 publications, and 18 were included in the analysis. Table 1 Fig. 1 shows the PRISMA flow chart of the review process.

4. Discussion

4.1. Geographical location of the urban areas: inland cities-coastal cities

4.1.1. Coastal cities

The cholera transmission foci are located along the urban areas in the African coastal urban regions, particularly in estuarine lagoons and ports such as Luanda (Angola), Cape Coast, and Accra in Ghana, and Pointe Noire in Congo. However, within these coastal areas, cholera transmission occurs mainly in overcrowded areas, such as informal settlements, which are characterized by poor sanitation facilities and limited access to safe water.[18]

The high risk of the incidence of cholera outbreaks in the urbanized coastal areas could be attributed to the surrounding inlets; high and sometimes brackish water tables, as well as floodplains that are prone to surface water contamination. Unmanaged wells

Table 1
Summary of the risk factors associated with cholera outbreaks with citations.

Risk factor	Reference	Number of references mentioning each risk factor and %	Year	Type of document
Geographical location of urban areas	Rebaudet *et al.*	4	2013	Review
	Nkoko *et al.*		2011	WHO report
	Lessler *et al.*	22%	2018	Mapping study
	Rebaudet *et al.*		2013	Review
Hydroclimatology	Rebaudet *et al.*	4	2013	Review
	Lessler *et al.*		2018	Mapping study
	Gwenzi *et al.*	22%	2019	Review
	Rebaudet *et al.*		2013	Review
Urban Environment-sanitation	Penrose *et al.*	10	2010	Cohort study
	Legros *et al.*		2000	Cross-sectional
	Azman *et al.*		2012	Case-control study
	Osei *et al.*		2008	Mapping study
	Sasaki *et al.*		2008	Mapping study
	Sasaki *et al.*	55%	2009	Mapping study
	Okello *et al.*		2019	Case-control study
	Gwenzi *et al.*		2019	Review
	Boyce *et al.*		2019	Review
	Pande *et al.*		2018	Case-control study
Urban behavior	Gwenzi *et al.*	2	2019	Review
	Rebaudet *et al.*	11%	2013	Review

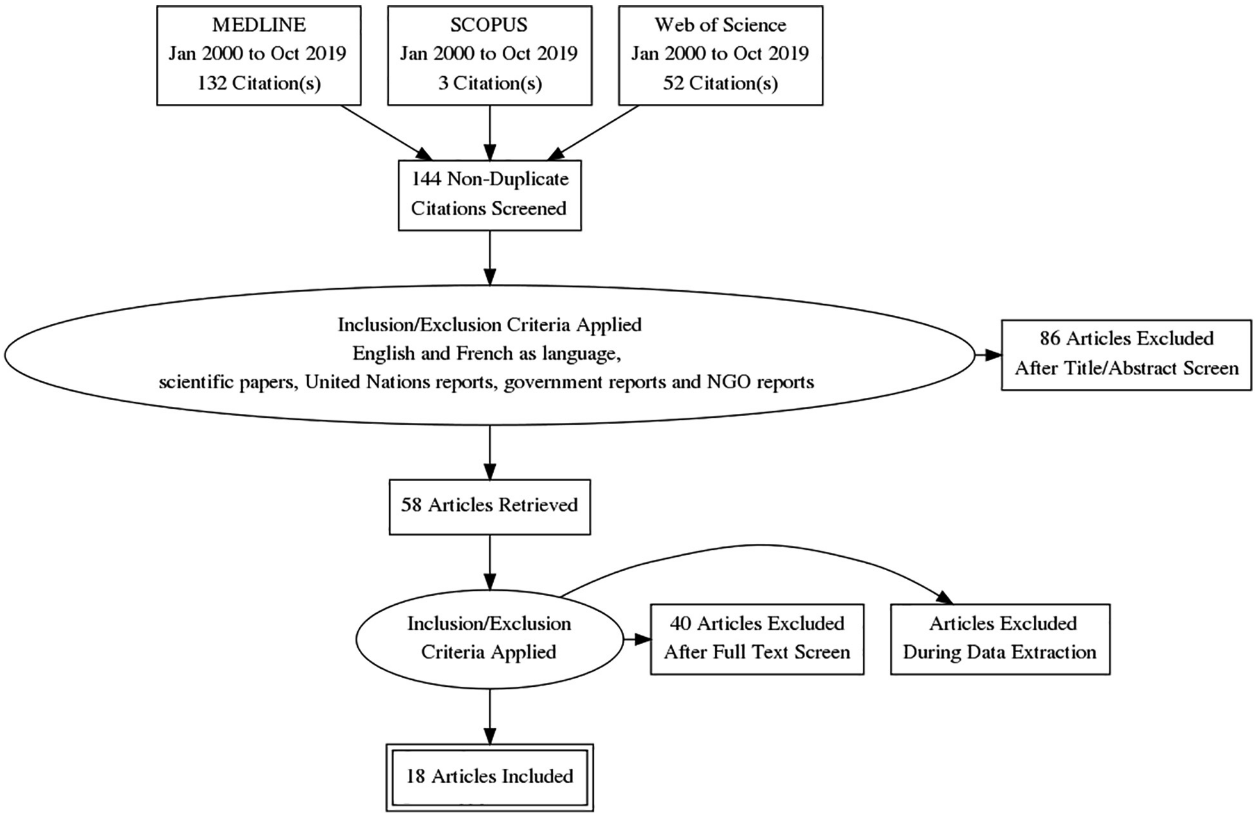

Fig. 1. PRISMA flow chart illustrating the methodology adopted to screen relevant scientific literature.

or shallow boreholes could also be significant risk factors in specific locations.[19,20]

Indeed, the reports of cholera outbreaks in many densely populated urban areas have been associated with lowland areas with hydroecological features. This has been implicated in numerous outbreaks in African cities such as Lomé, Douala, Djibouti, Beira, and Tamatave, where flood-prone urban areas carried the risk of surface water contamination through unprotected wells, or shallow boreholes.[18]

In addition, areas neighboring the inlet, backwater, or lagoon were affected by cholera in many coastal cities such as Abidjan, Conakry, and Cotonou.[21]

4.1.2. Inland cities

The African Great Lakes Region and the Lake Chad Basin are two inland regions where most of the cases of cholera were reported.[22,23]

The Lake Chad region comprises the Sahelian region of Niger, Nigeria, Cameroon, and Chad, while the African Great Lakes region was constituted by the Albertine rift of Kenya, Uganda, Rwanda, Burundi, DRC, and Tanzania. These regions are dotted with several lakes and rivers, and the proximity of lakes or the fact that a river runs through a city have been reported as a risk factor for cholera.[23,24]

4.2. Urban environmental reservoir

Phytoplankton and zooplankton can be an important reservoir of cholera infection in water sources within the environment, independent of humans influence.[25] Indeed, *Vibrio cholerae*, the bacterium responsible for cholera, has been associated with cyanobacteria, free-living amoebae, crustaceans such as copepods, bivalves, and intestines of certain fishes and aquatic sediments.[27,28] This presents a risk of infection, especially since some of these organisms are often components of the marine food chain.

During interepidemic periods, *V. cholerae* can survive in adverse environmental conditions due to its capacity to enter a viable coccoid state.[28]

V cholerae spreads rapidly in overcrowded locations where there are unchecked water sources and where solid and/or liquid wastes and human excreta cannot be safely disposed of.[12]

Surface water pollution poses a high risk of cholera spread, especially when a river crosses an overcrowded urban area. The contamination usually arises from human excrement and wastewater.[17]

The scarcity of pit latrines, proximity to refusal dumps, poor domestic storage conditions, insufficient drainage network, and lack of efficient treatment of water could be major urban factors that favor the spread of *V. cholerae*.[29–33]

The growth and proliferation of the pathogen responsible for cholera can also benefit from nutrient-rich brackish and saline water from septic tanks and pit latrines.[34] Additionally, these on-site sanitation systems in poor urban areas are often located near drinking water sources such as boreholes and shallow wells.[35] Moreover, there might be connectivity between on-site sanitation and the groundwater source when the soil is sandy, thereby resulting in contamination of drinking water sources with resident feces.[35,36]

Informal settlements that are closely associated with rapid urbanization in sub-Saharan Africa, are often overcrowded with inadequate sanitation and basic services. As per the WHO estimates, these factors contribute to a higher risk of communicable diseases, including diarrheal diseases such as cholera.[36,37]

4.3. Environmental factor influencing the virulence of V. cholerae

As facultative pathogens, many bacteria from the Vibrionaceae family do not depend on human hosts for their survival. However, other microbes from the same family such as *V. cholerae* can provoke illness.[38]

V. cholerae are generally found in estuarine and brackish natural environments, wherein they are often associated with aquatic organisms, including copepods, crustaceans, waterfowl, cyanobacteria, chironomid eggs, arthropods, shellfishes, and fishes.[39–44] Most *V. cholerae* strains in the aquatic environments are nonpathogenic.[44,45,46]

It is in its natural environment that the emergence of the virulence trait of *V. cholerae* occurs under biotic and abiotic pressures. Indeed, changes in pH, temperature and salinity, nutrient limitation, protozoan grazing, and phage predation are abiotic and biotic stressors to which *V. cholerae* is usually confronted, which threatens its survival.[26,47,48]

The acquisition of virulence capacity through environmental pressures gives *V. cholerae* survival advantage in its aquatic environment. Therefore, this adaptive bacterial capacity increases the ability to infect and colonize the human organism via the mechanism of colonization factor of N-acetyl glucosamine binding protein A or by the expression of the *cholerae* toxin gene (ToxR).[38]

By selecting and amplifying the virulence clone and its traits, the human host enables the emergence and evolution of pathogenic *V. cholerae*.[38]

V. cholera can live in different environments and infect the human gut. Within the gut, some of the genes of the pathogen accelerate their activities and make the bacterium 700 times more infectious.[49]

There are also reports that indicated the lateral transfer of genetic material in the bacterium. Indeed, genes that confer virulence are disseminated in the environment by different *V. cholerae* serogroups, thereby creating an environmental reservoir of virulent gene.[50]

The combined condition of temperature and salinity (optimum 2–14 g/L) might raise the probability of the presence of *V. cholerae* with an accuracy of 75.5% to 88.5% in some environments. Moreover, these physicochemical parameters have been shown to display seasonal patterns.[51]

In addition, there is a significant correlation between the elevated sea surface temperature, the *El Niño* event, and the cholera incidence.[51]

4.4. Urban behavioral factors

The spread of cholera might benefit from certain anthropogenic factors, including human migration, trade, poor sanitation, and crude hygiene practices.[35]

The lack of the practice of handwashing before eating and after using the toilet as well as the consumption of leftovers without heating are unhealthy practices associated with many cholera outbreaks. Moreover, some African foods such as millet gruel and peanut sauce might be adequate for the growth of *V. cholerae*.[15] Also, the consumption of contaminated aquatic foods such as fish might pose a risk of infection.[34]

The spread of cholera has also been associated with drinking and swimming in contaminated rivers and lakes.[15] In addition, commercial areas such as the African market might contribute to the spread of cholera in urban areas. Furthermore, cholera can also spread by land and sea from the coastal cities to create a transboundary epidemic.[15]

4.5. Hydroclimatic factors

The temporal patterns of cholera outbreaks were influenced by rainfall patterns in many parts of Africa because the seasonal variation in human exposure to *V. cholerae*-contaminated water might be related to a seasonal pattern.[15]

The incidence of cholera might increase during the rainy season due to contamination of water supply sources. However, incidences of cholera might also spike up during the drought period because populations would be forced to use unhealthy water supplies in the absence of better alternatives.[53] Moreover, during the dry season, groundwater levels might be low due to excessive water extraction in shallow wells and boreholes. This could expose the groundwater to *V. cholerae* contamination through the establishment of connectivity with the sanitation system.[35]

The rainfall patterns are influenced by global climate trends such as ENSO events (*El Niño*-Southern Oscillation), particularly in East and West Africa. Furthermore, these global climate trends generate hydro-meteorological disasters such as droughts or floods with simultaneous outbreaks of cholera.[18] These natural disasters do not trigger cholera outbreaks, but promote the spread of epidemics, especially in densely populated areas.[18]

4.6. The burden of cholera in sub-Saharan Africa

Through their characterization of the geographical distribution of the risk of cholera in sub-Saharan Africa, Lessler *et al*. revealed that more than 200 million peoples live in areas with at least some instances of cholera incidence. Moreover, 87.2 million live in a district with high incidence and 21.7 million in areas with high cholera incidence.[52]

As per the reports from the African nations to the WHO, there were 4 million cholera cases in the five past decades.[54]

In 2017, DRC, Ethiopia, Nigeria, Somalia. South Sudan, Sudan, and Zambia have witnessed cholera outbreaks.[55] In the same year in Africa, there were 179,835 cases and 3220 deaths, with case fatality rates ranging from 0 to 6.8%. Notably, in Zambia, the case fatality rate was 3.8%, while in Angola and Chad, it was 5.2% and 6.8% respectively.[7]

However, the number of cholera cases is often underreported and could be much higher than the official records of WHO. Indeed, in 1970, 16 African countries reported data for cholera cases, 45 in 2006, and 17 in 2017.[54] Furthermore, there is no permanent data for cholera. This might be due to inadequate surveillance systems.

A large part of the cholera burden occurs in urban areas, particularly in dense urban settings. This is evident from the attack rates and the cases per 1000 people in different demographic settings. Notably, it was reported that cases per 1000 people ranged from 1.2 in low-density residential suburbs to 90.3 in overcrowded suburbs.[15,54,55]

5. Conclusion

Cholera remains a major scourge for the Sub-Saharan African population as it is contracted by the consumption of contaminated water and food. Moreover, urban areas with inadequate sanitation and limited access to safe water are likely to acquire this waterborne disease as well as spread it.

V. cholerae exists in natural aquatic environments, and a multidisciplinary approach to investigate the different relationships between the genomic and ecological characteristics of the bacterium and African urban anthropic behavior could be useful in containing the spread of the disease.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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