Cholera epidemic in Kinshasa 2017-2018: targeted community-grid WaSH strategy rapidly interrupts cholera transmission throughout the city

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Abstract

Background Rapid control of cholera outbreaks is a significant challenge in overpopulated urban settings, and documented results on field interventions are scarce. During the 2017-2018 period, Kinshasa, the capital of Democratic Republic of the Congo, experienced two cholera epidemics of increasing intensity. By January 2018, cholera cases were reported throughout the city. We describe the spatiotemporal evolution of the cholera outbreaks in Kinshasa from 2017 to 2018 and assess the impact of the targeted community-grid WaSH (Water, Sanitation and Hygiene) strategy to quickly interrupt cholera transmission. Methods We carried out a descriptive study of the cholera outbreaks in Kinshasa from 2017 to 2018. Cholera surveillance databases from the Ministry of Health were analyzed to assess the spatiotemporal dynamics of the cholera epidemic using epidemic curves and cartography. Weekly precipitation levels in Kinshasa were also assessed. Additionally, we described the targeted community-grid WaSH strategy and examined the impact of this approach to interrupt cholera transmission in the city. Results From January 2017 to November 2018, a total of 1,712 suspected cholera cases were reported in Kinshasa. During this period, the health zones most affected included Binza Météo, Limeté, Kokolo, Kintambo and Kingabwa. The community-grid WaSH strategy was implemented to rapidly contain the outbreak by targeting interventions in five heavily-affected heath zones. With this strategy, cholera awareness and WaSH activities were carried out in cholera clusters. In Binza Météo, Kintambo and Limeté, the weekly cholera case numbers were reduced by an average of 57% in two weeks and 86% in four weeks. The total weekly case numbers throughout Kinshasa Province dropped by 71% at four weeks after the epidemic peak. Conclusion During the 2017-2018 period, Kinshasa reported two cholera epidemics of increasing intensity. To contain the main epidemic, response interventions targeted case households and nearby neighbors using a community-grid approach, focusing on emergency WaSH activities and awareness campaigns. The community-grid strategy was effective in bringing outbreaks throughout Kinshasa quickly under control. A similar approach may be useful in other urban settings to quickly interrupt cholera transmission.

Background

Cholera is an acute diarrheal disease caused by consumption of water or food contaminated with toxigenic forms of *Vibrio cholerae* (1). Once an individual contracts cholera, subsequent disease transmission is associated with limited access to clean drinking water and poor sanitation conditions (1,2). Therefore, key measures to rapidly control cholera outbreaks include prompt and appropriate case management as well as provision of safe drinking water, adequate sanitation, and health promotion for improved hygiene (3). Due to the short incubation period of the bacterium (2), cholera case numbers can quickly increase, especially in overpopulated areas with poor sanitation (3), thus rendering rapid control of cholera outbreaks a significant challenge in heavily populated urban settings.

The disease continues to represent a global public health concern, especially in Sub-Saharan Africa. Over the past two decades, Democratic Republic of the Congo (DRC) has borne a significant proportion of the cholera burden. Between 2010 and 2017, DRC reported approximately 220,000 suspected cholera cases,

accounting for 25% of all cholera cases notified in Africa (4). Cholera is considered endemic in the African Great Lakes region of eastern DRC, where cholera cases have been consistently reported over the past two decades (5,6). By contrast, cholera outbreaks have only intermittently occurred in the western DRC provinces, including the national capital Kinshasa (6–8).

Kinshasa is located in the far west of the country on the banks of the Congo River. Although Kinshasa has only been sporadically affected by cholera, the city remains vulnerable to large-scale outbreaks. On the heels of a ten-year lull, Kinshasa experienced a large-scale cholera outbreak in 2011. The epidemic had spread outside of the cholera-endemic zone in eastern DRC and along the Congo River towards the west (8,9). The epidemic crossed the entire country, reaching port neighborhoods along the Congo River in Kinshasa in only 130 days (8). The cholera outbreak quickly spread throughout the city (5) and continued in Kinshasa into 2013 (8). Overall, the 2011-2013 cholera outbreak in Kinshasa lasted for 116 weeks (8) and resulted in 2,144 cases and 50 deaths (case fatality rate (CFR) 2.3%). This experience highlighted the need to establish an efficient strategy to rapidly stop cholera transmission once an outbreak began in the city.

In recent years, cholera case numbers have significantly increased in DRC (4,6). The epidemic of 2017 represented the largest cholera epidemic to affect the country since 1994, with approximately 56,000 cholera cases reported nationwide (4). During this time, cholera outbreaks again spread into western provinces, especially in health zones situated along the Congo River, including Kinshasa. Between April 2016 and March 2018, Kinshasa experienced three cholera epidemics of increasing intensity, with weekly case numbers peaking in December of 2017. The heavily-affected neighborhoods were characterized by limited access to potable water, low latrine coverage, poor hygiene and high population density. As the cholera epidemic showed potential to amplify, an innovative water, sanitation and hygiene (WaSH) response strategy was designed and implemented to rapidly contain the epidemic. In this study, we analyzed the spatiotemporal evolution of the cholera epidemic in Kinshasa from January 2017 to November 2018. We also describe the targeted community-grid WaSH strategy, which was designed to stop cholera transmission in heath zones heavily affected by cholera. This integrated strategy involved targeted awareness and health campaigns, reinforced case management using antibiotic therapy, chemoprophylaxis of all immediate contacts of cholera cases and a series of WaSH activities. This strategy focused on two types of sites: 1) cholera case clusters plus surrounding neighbors and 2) cholera treatment centers (CTCs). We assessed the impact of this novel approach to interrupt cholera transmission throughout the city.

Methods

Study design and site

We performed a descriptive study of the cholera epidemic in Kinshasa during the 2017-2018 period covering all administrative health zones of Kinshasa Province. We also describe the targeted community-grid WaSH strategy and assess the impact of this approach to interrupt cholera transmission. Kinshasa

Province is one of 26 provinces in DRC and is coterminous with the national capital. The city-province is divided into 35 administrative health zones. Kinshasa is located in the far west of the country on the banks of the Congo River (*Figure 1*). The province covers approximately 9,965 km^2, with an estimated population of nearly 12 million. Infrastructure measures have not kept pace with urbanization and the increasing population in the city (10). As a result, neighborhoods have been established in flood-prone areas where water drainage is a challenge, thus increasing the risk and severity of flooding, especially during heavy rains in November and April (11).

Figure 1. Map of study area: Kinshasa Province. DRC, Democratic Republic of the Congo.

Surveillance data sources

The National Integrated Disease Surveillance and Response System was established in 2000 by the DRC Ministry of Health in conjunction with the World Health Organization (WHO). The Integrated Disease Surveillance and Response System targets thirteen infectious diseases with epidemic potential, including cholera, for passive surveillance (12). Suspected cases and deaths due to moderate and severe cholera infection are documented via line list in each treatment facility. Trained Ministry of Health officials aggregate and anonymized these data at the health zone level and report the data to the Ministry of Health in Kinshasa every week.

Cholera case definition

According to WHO policy, a suspected case of cholera is defined as “any person two years of age or older in whom acute watery diarrhea with or without vomiting develops” during a cholera outbreak. The age limit is increased to five years or older in interepidemic periods to reduce the number of false positives. At the beginning of an outbreak, between five and ten stool samples from each health zone are laboratory confirmed through isolation of *Vibrio cholerae* in culture. Subsequent cases of acute watery diarrhea in the same geographic region are presumed to be cholera.

Epidemiological data management and analyses

Secondary data was extracted from surveillance databases. Quality verification of the database was conducted, in which data was verified for consistency and analyzed to determine weekly case numbers per health zone using Microsoft Excel. Epidemic curves per health zone were drawn to assess the temporal evolution of the epidemic in Kinshasa as well as outbreaks in each affected health zone, covering the period week 1 of 2017 to week 45 of 2018 (the epidemic curve shows cases starting from week 15 of 2017, as only limited cases were reported earlier in the year). Total weekly case and death numbers per health zone were also used to perform a descriptive analysis of the epidemic as well as impact following implementation of the community-grid strategy. All suspected cholera cases reported in each health zone from November 1st 2017 to March 31st 2018 was used to represent the geographic distribution of cholera cases during the main epidemic period.

Cartography

The maps of Kinshasa and DRC were generated using QGIS V3.4.3 Madeira with shapefiles provided by the DRC Ministry of Health (DRC health zones, DRC provinces, rivers and lakes). Additionally, shapefiles of Republic of the Congo administrative boundaries and transportation network features (rail and road) were retrieved from DIVA-GIS (http://www.diva-gis.org/gdata). The GPS coordinates of the CTCs were provided by the Kinshasa Ministry of Health for localization in the map.

Precipitation data

Precipitation levels were derived from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset (product: Daily UCSB CHIRPS v2p0 daily-improved global 0p25). The CHIRPS precipitation data is a 30-year quasi-global rainfall dataset supported by University of California Santa Barbara (CA, USA). Daily values were extracted and aggregated by health zone (R environment for statistical computing and graphics). Spatial aggregation from gridded data at the province level for Kinshasa was carried out in R. Daily precipitation levels (mm) were then aggregated by week using Microsoft Excel.

Field visits

Field visits were conducted by joint investigation teams composed of representatives of the National Program for Cholera Elimination and Diarrheal Disease Control (Programme National d'Elimination du Choléra et de lutte contre les Maladies Diarrhéiques [PNECHOL-MD]), Provincial Health Directorates and community agents in each affected health zone. Investigation teams met with local surveillance departments and health facilities. Information was collected concerning potential sources of infection, possible links between cases and risk factors. The investigation teams also evaluated local WaSH conditions that may play a role in cholera dynamics.

Description of community-grid targeted WaSH strategy

As the affected areas included shantytowns vulnerable to flooding, where habitats lack a means of wastewater evacuation, this epidemic showed potential to significantly amplify. Therefore, an innovative outbreak response strategy – the targeted community-grid WaSH strategy - was designed and implemented to rapidly contain the epidemic.

This integrated strategy involved targeted awareness and health campaigns, reinforced case management using antibiotic therapy to reduce the duration of bacteria excretion, chemoprophylaxis of all immediate contacts of cholera cases and a series of WaSH activities, as described in further detail below. In areas characterized by overcrowding and a lack of safe water, 10-m^3 water bladders were installed and refilled every 48 to 72 hours to provide large quantities of safe drinking water to the population. This strategy targeted two types of sites: 1) observed cholera case clusters grouped into blocks of 30 households and 2) CTCs.

A rapid anthropological survey was initially conducted to identify possible factors of community resistance to facilitate implementation of the community-grid strategy, including groups resistant to or

suspicious of modern public health efforts and/or existence of a community action structure or other organization that might consider the strategy activities as competition. The survey focused on members of the population to be targeted with the community-grid approach and aimed to understand their perception of the disease, their perception of the response teams' activities and their opinion on how to control disease transmission.

To define health zones included in the community-grid intervention based on the epidemiological data, the health zones reporting more than 10% of the total suspected cholera cases during the previous three weeks were selected. Subsequently, each new health zone that experienced a lab-confirmed outbreak, for which risk factors that may trigger an increase in cases according to field investigations, was included in the grid approach once the outbreak was laboratory-confirmed. As a result, the five health zones selected for the community-grid WASH approach were Binza Météo, Limeté, Kintambo, Kingabwa and Bumbu.

For each health zone, the operational approach was organized as follows. The household or group of households from which the most recent case or cases originated were identified and localized via GPS, and a circle (500-meter radius) was then delineated around the cluster, which was then subdivided into a grid. Each grid unit representing an average of 30 households, which varied depending on the geographical characteristics of the area (*Figure 2*).

Figure 2. Diagram of targeted community-grid strategy.

Field response teams consisted of a supervisor, two awareness educators (a crier and a door-to-door educator), four chlorinators (two for fixed sites and two for door-to-door household visits), two disinfectors and two attendants at handwashing points. Each team covered at least two 30-household grid units. The number of personnel involved per intervention type in each health zone is detailed in *Table 1*.

The following activities were carried out daily at households within the cluster circle over the course of 14 days:

Mass awareness and targeted door-to-door awareness concerning hygiene education.

Aquatabs^{TM} and drinking water cans were distributed, and all types of household water sources were systematically chlorinated everyday (e.g., water used for drinking, bathing and other household purposes).

Active case search in the community was carried out, prioritizing the immediate entourage of probable and confirmed cases treated at the CTC.

Investigations were carried out by the PNECHOL-MD teams to identify potential sources of contamination and assess the travel history of household members who recently returned (<14 days) from areas experiencing a cholera outbreak (to identify potential asymptomatic carriers).

The following activities were carried out at fixed points in the cluster circle over the course of 14 days:

Swimming in surface waters (e.g., lakes, rivers, streams) was banned during the 14-day period.

At public sites within the grid unit (e.g., water points, markets, schools, hospitals and transport stations), the team installed handwashing points, fixed water chlorination points and water bladders. Handwashing points and fixed chlorination points were installed in the health zones most affected early during the outbreak: Binza Météo and Kintambo. Water bladders were installed in neighborhoods of high population density without a source of safe drinking water nearby, neighborhoods not generally covered by the public water network, and crowded public areas (e.g., markets, etc.).

Furthermore, additional actions were carried out at case households and the 20 contiguous households:

Systematic chemoprophylaxis of all individuals in the same household as a recent cholera case. Adults received a single dose of doxycycline (300 mg), while children and pregnant women received a single dose of ciprofloxacin (20-30 mg/kg).

Sites likely to be contaminated by cholera cases due to poor household hygiene were sprayed within less than 72 hours after patient registration at the CTC.

Hygiene kits (containing soap, 20-liter water storage container and ready-to-use chlorine for disinfection of drinking water) were provided for each household.

During the outbreak, two large CTCs were established to treat cholera patients, in Limeté (Pakadjuma) and Binza Météo (the shantytown of Camp Luka). In addition to standard treatment for cholera patients, antibiotics were systematically administered to patients and their immediate contacts, which includes residents of the same household, colleagues sharing the same work environment, people who accompanied the patient to the CTC, and people in close contact with the patient in cases of recent travel by vehicle, boat, train or plane. Adults received a single dose of doxycycline (300 mg), while children and pregnant women received a single dose of ciprofloxacin (20-30 mg/kg). To improve hygiene and reduce the risk of cholera transmission in and around CTCs, water bladders were installed in Limeté in proximity to the CTC, where they also served to provide safe drinking water to the nearby population. A water bladder was not installed at the Binza Météo CTC, as access to the water network (REGIDESO) was available in the adjacent plot and the organization Médecins Sans Frontières had installed water reservoirs at the CTC.

During the response, daily case admission trends were monitored to assess the epidemiological evolution of the outbreak in real time and adjust response activities accordingly. Epidemiologists regularly assessed risk factors to adjust operational activities in the field. For each new case, risk factor analysis included the details of disease onset, the patient’s travel history over the 10-day period prior to symptom onset, and identification of probable sites of contamination (e.g., home, work, markets, ports, school and water sources).

Ethics

Ethics approval was not required for this study as cholera epidemic disease surveillance and response are covered by national public health laws as an integral part of the public health mandate of the DRC Ministry of Health.

Results

Temporal evolution of cholera outbreaks in Kinshasa during the 2017-2018 period

In the context of a large-scale cholera epidemic in DRC, a total of 1,712 suspected cholera cases and 53 deaths (CFR 3.1%) were reported in Kinshasa from week 1 of 2017 to week 45 of 2018. *Vibrio cholerae* O1 Inaba was identified as the responsible agent. Between January 2017 and June 2018, a total of 590 clinical samples from 29 health zones were tested for laboratory confirmation, and *Vibrio cholerae* O1 Inaba was confirmed for 128 samples. The first outbreak in Kinshasa occurred from mid-May to late-August 2017 and remained primarily confined to a Military Camp in Kokolo (*Figure 3*), a closed environment with very high population density. During this outbreak, which resulted in 220 cases (CFR 6.4%), the index case was a patient from Limeté Health zone, Kinshasa Province.

The second and main outbreak during the two-year period began on November 25, 2017 (13) in densely inhabited Camp Luka in Binza Météo Health zone (*Figure 3*). The index case appeared to be a merchant returning from the town of Kimpese in Kongo Central Province who died a few days after returning to Kinshasa. The burial of the index case reportedly took place under unsafe conditions, which may have played a role in the subsequent cascade of cholera-related deaths in the community soon after the funeral.

Figure 3. Epidemic curve of the cholera outbreaks in Kinshasa and corresponding weekly precipitation levels. The epidemic curve and weekly precipitation levels covers the period week 15 of 2017 to week 45 of 2018. The top panel displays weekly cholera case numbers in the entire city (dashed line) as well as heavily-affected health zones, which are color-coded and ordered based on cumulative number of cholera cases during 2017 and 2018 period (up to week 45, 2018) as displayed in *Additional file 1*. The bottom panel displays the corresponding estimated weekly precipitation levels in Kinshasa (mm).

During the main epidemic at the end of 2017, the initial cholera cases were reported in Binza Météo in late-November 2017, which peaked during the last week of 2017 and continued until early-February 2018 (red line in *Figure 3*). Cholera patients in Camp Luka, Binza Météo Health zone, were transferred to the Pakadjuma CTC in Limeté. An outbreak then started in Limeté during the last week of 2017 (orange line in *Figure 3*). Heavy rains and subsequent flooding during the first week of January 2018 (14), compounded with poor hygiene conditions at the Pakadjuma CTC, further aggravated the cholera outbreak in Pakadjuma followed by other parts of Limeté. During early-January 2018, an outbreak also occurred in Kintambo with 54 suspected cases reported the first week and 51 cases reported the second week (light green line in *Figure 3*).

The epidemic in Kinshasa peaked during the first two weeks of January 2018, when 188 and 189 suspected cases were reported, respectively. By the first week of January, cholera cases had rapidly spread throughout Kinshasa, affecting the health zones of Binza Météo, Kintambo, Bandalungua, Mont Ngafula II, Kokolo and Limeté. An outbreak was also reported in Bumbu during the second week of 2018 (purple line in *Figure 3*). Nine other health zones in the city reported cholera cases by mid-January, and an additional 11 health zones reported cholera cases by late-January. Many early outbreaks within health zones were characterized by a sudden peak in case numbers. Daily field investigations revealed a high degree of household-level transmission, as one in two caretakers of cholera patients also later contracted the disease.

Geographical distribution of cholera cases in Kinshasa from November 2017 to March 2018

From November 2017 to March 2018 (week 45, 2017 - week 13, 2018), a total of 1,097 cholera cases and 11 cholera-related deaths were reported in Kinshasa. The majority of cases were concentrated in health zones in northwest Kinshasa, less than 10 km from the Congo River. During this period, Binza Météo Health zone reported the greatest number of cholera cases, with 37% of all cases (405 cases), followed by Limeté (19%; 208 cases), Kintambo (12%; 134 cases), Kingabwa (6%; 69 cases), Kokolo (3%; 38 cases) and Bumbu (3%; 37 cases). Together, these six health zones reported 81% of all cholera cases in Kinshasa during the five-month period (*Figure 4*).

Figure 4. Total cholera case numbers per health zone in Kinshasa from November 2017 to March 2018. The red circles represent the number of cumulative cholera case numbers (suspected and confirmed) in each health zone during the five-month period. The only areas not represented on the map are the large health zones located in the east of Kinshasa Province, Maluku II and Maluku I, which reported seven and 21 cases, respectively, during the five-month epidemic period. Health zones, main roads, railroads and waterbodies in Kinshasa are indicated. The GPS coordinate-based localization of the CTCs in Binza Météo (Camp Luka) and Limeté (Pakadjuma) is also indicated. Neighboring Republic of the Congo is shown in green. Localization of Kinshasa Province (gray) and the Kinshasa map area (red square) are specified on the map of DRC in the lower right corner.

The health zones of Kingabwa and Limeté are characterized by floodplains and slums (including the Pakadjuma shantytown in Limeté); these health zones were also most affected during previous outbreaks in Kinshasa. Both health zones also host river ports, providing a maritime link between the capital and health zones further northeast, including those regularly affected by cholera outbreaks such as Bolobo, Yumbi, Lukolela, Mbandaka and Kisangani (5). As a result, these health zones represent the entry point for index cases traveling via boat from another region of the country, as observed during previous outbreaks (5).

Implementation of the community-grid strategy and impact on cholera outbreaks

The community-grid strategy was first implemented in Camp Luka (Binza Météo) during the last week of 2017, when 116 weekly cases were reported. Binza Météo was the most affected area and the starting point of the epidemic. In Binza Météo, the weekly number of cases quickly dropped following strategy implementation, with less than five cases per week reported by early February. As the outbreak spread, the community-grid approach was then implemented in Kintambo during the first week of January, followed by Limeté in late-January and both Kingabwa and Bumbu in early-February. In both Kintambo and Limeté, implementation of the community-grid response also led to a rapid decrease in cholera cases. Both outbreaks were brought under control by mid- to late-February (*Figure 5)*.

We assessed the weekly rate in reduction of cholera case numbers following implementation of the community-grid strategy in the health zones experiencing the largest outbreaks: Binza Météo, Kintambo and Limeté. Two weeks after implementing the strategy, the weekly cholera case numbers were reduced by 43%, 63% and 65%, respectively, compared to starting point weekly case numbers. Four weeks after strategy implementation, the weekly case numbers had dropped by 85%, 98% and 75%, respectively. Eight weeks after strategy implementation, the weekly case numbers had dropped by 100%, 100% and 98%, respectively. Considering all cholera cases reported in Kinshasa, the weekly case numbers had dropped by 71% at four weeks after the outbreak peak and by 83% at eight weeks after the peak (*Table 2*).

Figure 5. Cholera epidemic curve of targeted health zones and response activity timeframe. Weekly cholera case numbers are shown on the y-axis and epidemic weeks/years are indicated on the x-axis. The start and end points of community-grid WaSH response activities in each health zone are shown with green and red arrows, respectively. The blue blocks “WB” indicate the health zone and timeframe of water bladder installation. The intervention details for each health zone are indicated on the right.

Overall, the community-grid approach was implemented in five health zones that accounted for 78% of cases reported in Kinshasa between November 2017 and March 2018. Community response activities were initiated in the targeted health zones between one to four weeks after the first local cases were reported, and the outbreaks stabilized between three to seven weeks after intervention activities were initiated.

Discussion

In late November 2017, a large-scale cholera outbreak occurred in Kinshasa, DRC. The outbreak quickly spread throughout the city, affecting 31 of 35 health zones by early-February. The community-grid WaSH strategy was implemented during the peak period to rapidly contain the epidemic by targeting five heavily-affected heath zones in Kinshasa: Binza Météo, Limeté, Kintambo, Kingabwa and Bumbu. This strategy systematically targeted case households and nearby neighbors using a spatial gridded approach, with an emphasis on a series of WaSH activities, chemoprophylaxis of all immediate contacts of cholera cases, and targeted awareness and health campaigns. Water bladders were installed in areas characterized by overcrowding and a lack of safe water, including the CTC in Limeté, to provide ample quantities of safe drinking water to the community. The community-grid strategy was effective in

bringing outbreaks throughout Kinshasa quickly under control. In the three health zones experiencing the largest outbreaks – Binza Météo, Kintambo and Limeté – the weekly cholera case numbers were reduced by an average of 57% by two weeks post-strategy implementation and 86% by four weeks post-strategy implementation. The total weekly case numbers throughout Kinshasa Province had dropped by 71% at four weeks after the outbreak peak and by 83% at eight weeks after the peak.

Previous studies have shown that the risk of cholera infection is significantly higher for household contacts of cholera patients (15), especially during the week after the cholera case seeks treatment (16,17). In our study, we noted a high degree of household-level transmission following CTC admission of a cholera patient, as one in two caretakers of cholera patients also later contracted the disease. Interventions targeting case households using a variety of response measures have been applied during cholera outbreaks, although little evidence has been published concerning the effectiveness, efficiency or optimal implementation strategy. Using a hospital-based intervention, George et al. have found that promoting handwashing with soap and water treatment to cholera patients and case contacts during one-week post-infection resulted in 47% fewer cholera infections (17). Targeting the household is also likely the most effective strategy for sustained hygiene promotion, as revealed by evidence concerning diarrheal diseases that suggested hygiene behavior is best delivered using small groups and frequent personal contact with a hygiene promoter (18).

Furthermore, cholera risk in urban settings has been shown to increase among neighbors living within at least 200 meters of cholera cases during the initial five days following disease onset (19). Increased risk was attributed to exposure to common risk factors as well as increased risk of secondary transmission living in close proximity to a cholera case (19). A recent micro-simulation model has highlighted the potential impact of case-area targeted interventions in response to cholera outbreaks (20). The study also found that early intervention was important to rapidly interrupt disease transmission (20). To ensure a rapid response and quick reduction in cholera case numbers, early case detection, case confirmation and pre-positioning of WaSH and case management supplies are fundamental.

Response strategies targeting case households and nearby neighbors are especially critical in urban contexts due to the limited availability of resources for non-targeted approaches and explosive potential of outbreaks in overcrowded areas. In Africa, cholera amplification has been often observed in urban areas, often characterized by rapid population growth, uncontrolled urbanization, and insufficient sanitation and drinking water infrastructure. Major cities that have been repeatedly affected by large-scale cholera outbreaks include Conakry (21), Douala (22), Lagos (23), Kano (23), Lusaka (24,25), Abidjan (26), Accra (27), Nairobi (28), Mogadishu (29–32) and Luanda (33), among others. Once cholera outbreaks expand in urban settings, cholera has often eventually spread to linked areas within the country or across international borders associated with the travel and migration of at-risk populations (21,27,30). As a result, effective strategies to control cholera outbreaks in urban settings may play a major role in controlling cholera epidemics on a local, national and regional scale.

To provide short-term protection against cholera while long-term water and sanitation interventions are established, oral cholera vaccine (OCV) has also been suggested as a more recent complementary approach in conjunction with other prevention and control strategies (34,35). To respond to cholera outbreaks in Kinshasa in 2016, which primarily affected health zones situated along the Congo River, an OCV campaign was organized targeting approximately 375,000 individuals, from September 30th to October 5th, in five of the most affected health zones: Masina II, N'sele, Kingabwa, Limeté, and Maluku I. The administrative coverage was 94.6% for the first round and 94.0% for the second round (36). Nevertheless, the outbreaks continued for an additional 35 weeks, and a subsequent outbreak occurred in Limeté in late-2017, approximately 15 months after the end of the OCV campaign. A reactive OCV campaign was not included in the community-grid strategy during these recent outbreaks, partly due to the challenges associated with extended time required for campaign implementation, especially in a heavily populated urban setting with a high degree of population movement.

Some study limitations should be noted. First, as we assessed the overall impact of the integrated strategy in this report, we cannot establish the effect of the individual interventions. Confounding effects of individual interventions are also difficult to demonstrate; for example, increasing the supply and quality of available water may also have an effect on improved household hygiene (37). Second, this study lacks a non-intervention control group because the strategy was carried out in all health zones experiencing over 3% of cholera cases from November 2017 to March 2018 (with the exception of the closed environment Kokolo Military Camp), and non-intervention would pose major ethical concerns. Third, as this is the first implementation and assessment of the targeted community-grid WaSH strategy, further studies are needed to fully ascertain the potential of this approach and refine strategy design. Additional studies should include household surveys to assess WaSH indicators and outcome indicators, such as total number households reached for disinfected and awareness sessions as well as overall adhesion to recommendations. A cross-sectional survey should be included to assess the improvements made following the strategy. Systematic molecular biology assessment of water samples should be included to determine the evolution in water quality. Over the course of the strategy, the field team should complete a structured questionnaire to better map the conditions of disease transmission.

As very few reports have described and evaluated the implementation of outbreak response activities, we also encourage other governments and response agencies to document lessons learned and analyze cholera response strategies to assess effectiveness and better inform WaSH policy. Furthermore, considering the potential risk of bacterial drug resistance, the use chemoprophylaxis should be closely evaluated, as is the case in DRC (38).

Our results suggest that rapid WaSH interventions targeting the residential area of cholera cases and nearby neighbors early on via the community-grid strategy was key to prevent cholera cases and reduce the duration of the epidemic in Kinshasa. Rapid response is also a key component of the new multi-sectoral approach promoted by the Global Task Force on Cholera Control to reduce cholera deaths by 90% and eliminate the disease by 2030 (39). Our findings provide valuable lessons from the field for actors and international donors involved in cholera control. To eventually eliminate cholera, it is important

to establish long-term solutions to ensure a safe and sustainable drinking water supply and improved sanitation for the population (40–42). However, until potable water and proper sanitation can be ensured in a sustainable manner in at-risk areas, the community-grid WaSH strategy may also be adapted and applied for other settings to quickly stop cholera transmission.

Conclusions

In 2017-2018, the city of Kinshasa reported two cholera epidemics of increasing intensity. By January 2018, cholera cases were reported throughout the city. The community-grid WaSH strategy was developed and implemented to rapidly contain the epidemic by targeting five heavily-affected heath zones. This strategy systematically targeted case households and nearby neighbors using a grid approach, with an emphasis on a series of WaSH activities, chemoprophylaxis of all immediate contacts of cholera cases, and targeted awareness and health campaigns. The community-grid WaSH strategy was effective in bringing outbreaks throughout Kinshasa quickly under control. In health zones experiencing the largest outbreaks - Binza Météo, Kintambo and Limeté - the weekly cholera case numbers were reduced on average by 57% two weeks post-strategy implementation and by 86% four weeks post-strategy implementation. With appropriate adaptations, a similar approach may be useful in other urban settings to quickly stop cholera transmission.

List Of Abbreviations

CFR Case fatality rate

CHIRPS Climate Hazards Group InfraRed Precipitation with Station

CTC Cholera treatment center

DRC Democratic Republic of the Congo

OCV Oral cholera vaccine

WASH Water, sanitation and hygiene

WHO World Health Organization

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

The datasets analyzed during the current study are not publicly available, beyond the data supplied in the *Additional file 1*, due to data transfer agreements. However, the surveillance data may be available upon reasonable request with permission from the DRC Ministry of Health (contact email: pnecholmd01@gmail.com).

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

DB and TV designed the study. NT curated the surveillance data. DB, SM, NT, BS, BI, RM, FM, TV and TB analyzed and interpreted the data. SM produced and analyzed the epidemic curves and maps. BS performed the precipitation extraction and analysis. DB and NT performed field investigations. DB, NT and SM wrote the manuscript. DB, SM, BS and TV reviewed and edited the manuscript. All authors read and approved the final version of the manuscript.

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References

1. Kaper JB, Morris JG, Levine MM. Cholera. Clin Microbiol Rev. 1995;8(1):48–86.

2. Sack DA, Sack RB, Nair GB, Siddique AK. Cholera. 2004;363:223–33.

3. World Health Organisation. Prevention and control of cholera outbreaks: WHO policy and recommendations [Internet]. 2018. Available from: http://www.who.int/cholera/prevention_control/en/

4. World Health Organization. Cholera, number of reported cases (data by country) [Internet].

5. Ministry of Health Democratic Republic of the Congo. Cholera Surveillance Data, 1994-2018.

6. Ingelbeen B, Hendrickx D, Miwanda B, Van Der Sande MAB, Mossoko M, Vochten H, et al. Recurrent Cholera Outbreaks, Democratic Republic of the Congo, 2008 – 2017. Emerg Infect Dis. 2019;25(5):856–64.

7. Nkoko DB, Giraudoux P, Plisnier P, Tinda AM, Piarroux M. Dynamics of Cholera Outbreaks in Great Lakes Region of Africa , 1978 – 2008. 2011;17(October 2010):2026–34.

8. Bompangue D, Vesenbeckh SM, Giraudoux P, Castro M, Muyembe J, Ilunga BK, et al. Cholera ante portas – The re-emergence of cholera in Kinshasa after a ten-year hiatus. PLOS Curr Disasters. 2012;1:1–12.

9. Moore S, Miwanda B, Sadji AY, Thefenne H, Jeddi F, Rebaudet S, et al. Relationship between Distinct African Cholera Epidemics Revealed via MLVA Haplotyping of 337 Vibrio cholerae Isolates. PLoS Negl Trop Dis. 2015 Jun;9(6):e0003817.

10. Kayembe Wa Kayembe M, De Maeyer M, Wolff E. Cartographie de la croissance urbaine de Kinshasa (R.D. Congo) entre 1995 et 2005 par télédétection satellitaire à haute résolution. Belgeo Rev belge géographie. 2009 Dec;(3–4):439–56.

11. Mutombo HK. Urbanisation et fabrique urbaine à Kinshasa: défis et opportunités d'aménagement. 2014;533.

12. Ministrère de la Santé Publique - République Démocratique du Congo. République Démocratique du Congo. Ministrère de la Santé Publique (2009). Directives pour la surveillance intégrée des maladies et la riposte. 2009.

13. WHO. Cholera – Kinshasa, Democratic Republic of the Congo [Internet]. Emergencies preparedness, response. 2018. p. 1–5. Available from: http://www.who.int/csr/don/02-march-2018-cholera-drc/en/

14. International Federation of Red Cross. Emergency Plan of Action Operation Update 1 - Democratic Republic of the Congo : Floods and Cholera in Kinshasa [Internet]. 2018. Available from: https://reliefweb.int/sites/reliefweb.int/files/resources/MDRCD024ou1.pdf

15. Kone-Coulibaly A, Tshimanga M, Shambira G, Gombe N, Chadambuka A, Chonzi P, et al. Risk factors associated with cholera in Harare City, Zimbabwe, 2008. East Afr J Public Heal. 2010;7(4):311–7.

16. Weil AA, Khan AI, Chowdhury F, LaRocque RC, Faruque A, Ryan ET, et al. Clinical Outcomes in Household Contacts of Patients with Cholera in Bangladesh. Clin Infect Dis. 2009;15(49):1473–9.

17. George CM, Monira S, Sack DA, Rashid MU, Saif-Ur-Rahman KM, Mahmud T, et al. Randomized controlled trial of hospital-based hygiene and water treatment intervention (CHoBI7) to reduce cholera. Emerg Infect Dis. 2016;22(2):233–41.

18. Cairncross S, Shordt K. It does last! Some findings from a multi-country study of hygiene sustainability. Waterlines. 2004;22(3):4–7.

19. Azman A, Alcalde FJL, Salje H, Naibei N, Adalbert N, Ali M, et al. Micro-hotspots of Risk in Urban Cholera Epidemics. bioRxiv. 2018 Jan;248476.

20. Finger F, Bertuzzo E, Luquero FJ, Naibei N, Touré B, Allan M, et al. The potential impact of case-area targeted interventions in response to cholera outbreaks: A modeling study. von Seidlein L, editor. PLOS Med. 2018 Feb;15(2):e1002509.

21. Rebaudet S, Mengel MA, Koivogui L, Moore S, Mutreja A, Kande Y, et al. Deciphering the Origin of the 2012 Cholera Epidemic in Guinea by Integrating Epidemiological and Molecular Analyses. PLoS Negl Trop Dis. 2014;8(6):e2898.

22. UNICEF WCARO. Cholera Epidemiology and Response Factsheet - Cameroon [Internet]. 2014. Available from: https://reliefweb.int/sites/reliefweb.int/files/resources/UNICEF_Cameroun_ Cholera Factsheet_Draft.pdf

23. UNICEF WCARO. Cholera Epidemiology and Response Factsheet - Nigeria [Internet]. 2014. Available from: http://platefor.mywhc.ca/attachments/article/236/UNICEF-Factsheet-Nigeria-EN-FINAL.pdf

24. Olu O, Babaniyi O, Songolo P, Matapo B, Chizema E, Kapin'a-Kanyanga M, et al. Cholera epidemiology in Zambia from 2000 to 2010: implications for improving cholera prevention and control strategies in the country. East Afr Med J. 2013 Oct;90(10):324–31.

25. Sinyange N, Brunkard JM, Kapata N, Mazaba ML, Musonda KG, Hamoonga R, et al. Cholera Epidemic — Lusaka, Zambia, October 2017–May 2018. MMWR Morb Mortal Wkly Rep. 2018 May;67(19):556–9.

26. World Health Organization: Global Task Force on Cholera Control. Cholera country profile: Cote d'Ivoire Cholera Outbreak in 2011. 2011.

27. Moore S, Dongdem AZ, Opare D, Cottavoz P, Fookes M, Sadji AY, et al. Dynamics of cholera epidemics from Benin to Mauritania. PLoS Negl Trop Dis. 2018;12(4):1–16.

28. Global Task Force on Cholera Control, WHO. CHOLERA COUNTRY PROFILE : KENYA. 2010.

29. WHO Somalia. FACT SHEET – HEALTH SOMALIA. 2011.

30. WHO. Somalia Emergency Weekly Health Update (May 5-11, 2012). 2012.

31. OCHA. OCHA SOMALIA Flash Update 4. 2015.

32. UNICEF ESARO. February 2016: El Niño sweeps across parts of Africa, destroying children's futures. 2016.

33. Gerstl S, Alberti K. Overall response to cholera epidemics in Angola in 2006: Evaluation of the MSF intervention. 2007.

34. Bi Q, Ferreras E, Pezzoli L, Legros D, Ivers LC, Date K, et al. Protection against cholera from killed whole-cell oral cholera vaccines: a systematic review and meta-analysis. Lancet Infect Dis. 2017;17(October):1080–8.

35. WHO. Meeting of the Strategic Advisory Group of Experts on immunization, October 2009 – conclusions and recommendations. Wkly Epidemiol Rec. 2009;50(84):517–32.

36. WHO. Cholera – Kinshasa, Democratic Republic of Congo [Internet]. Disease outbreak news. 2018 [cited 2019 Apr 21]. p. 1–3. Available from: https://www.who.int/csr/don/02-march-2018-cholera-drc/en/

37. Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. Bull World Health Organ [Internet]. 1991;69(5):609–21. Available from: https://www.ncbi.nlm.nih.gov/pubmed/1835675

38. Miwanda B, Moore S, Muyembe J, Nguefack-tsague G, Kabangwa IK, Ndjakani DY, et al. Antimicrobial Drug Resistance of Vibrio cholerae, Democratic Republic of the Congo. Emerg Infect Dis. 2015;21(5):847–51.

39. Global Task Force on Cholera Control. Ending Cholera. A Global Roadmap to 2030. World Health Organization (WHO); 2017 Oct.

40. Fee E, Brown TM. The Public Health Act of 1848. Bull World Health Organ. 2005;83(11):866–7.

41. Beau De Rochars VEM, Tipret J, Patrick M, Jacobson L, Barbour KE, Berendes D, et al. Knowledge, Attitudes, and Practices Related to Treatment and Prevention of Cholera, Haiti, 2010. Emerg Infect Dis. 2011;17(11):2158–61.

42. Rao M. Of Cholera and Post-Modern World. Econ Polit Wkly. 1992;27(34):1792–6.

Tables

Table 1. Number of personnel involved by intervention type for each health zone.

Health zone	Number of personnel by intervention type				
	Community awareness educators	*Community chlorinators*	*Disinfectors*	*Community activity supervisors*	*Total Personnel*
Binza Météo	135	60	42	20	257
Limeté	8	10	10	4	32
Kintambo	40	8	10	5	63
Kingabwa	18	17	10	5	50
Bumbu	40	40	30	8	118
Total	241	135	102	42	520

Table 2. Reduction in number of cholera cases following community-grid strategy implementation.

	Strategy starting point	**Reduction in number of cholera cases (%) compared to implementation week**			
Health zone	**No. of weekly cases during week of strategy implementation**	**after one week**	**after two weeks**	**after four weeks**	**after eight weeks**
Binza Météo	116	20.7%	43.1%	84.5%	100%
Kintambo	54	5.6%	63%	98.1%	100%
Limeté	40	22.5%	65%	75%	97.5%
	No. weekly cases once strategy was implemented in two health zones				
Kinshasa Province Total	188	-0.5%	11.7%	70.7%	83%

Kingabwa and Bumbu were not included in the health zone-specific analysis, as weekly cholera case numbers remained below 14 and four, respectively, once the strategy was implemented.

Figures

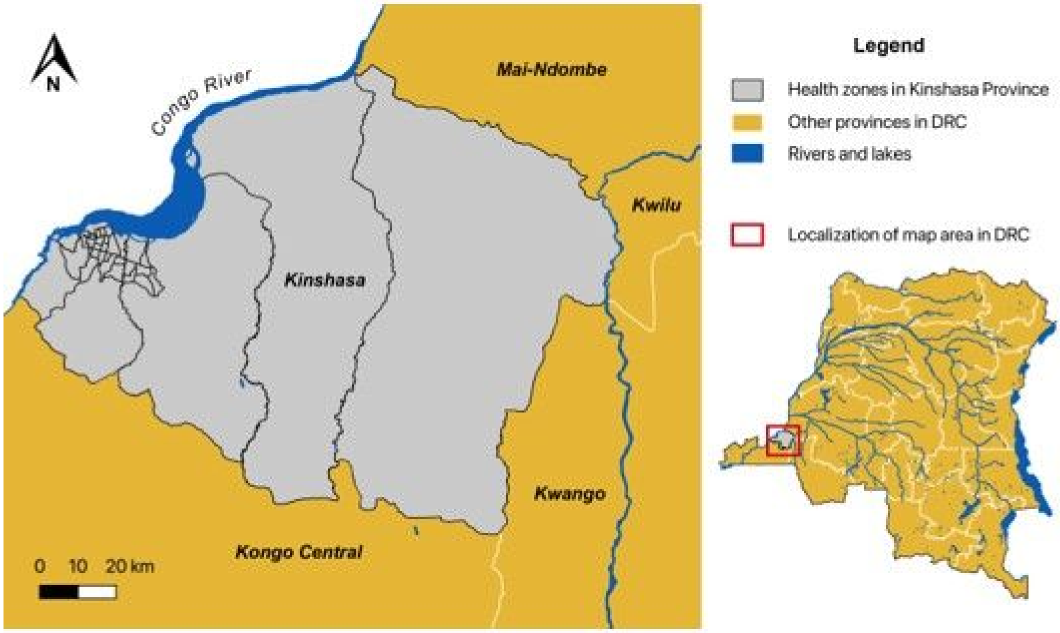

Figure 1

Map of study area: Kinshasa Province. DRC, Democratic Republic of the Congo.

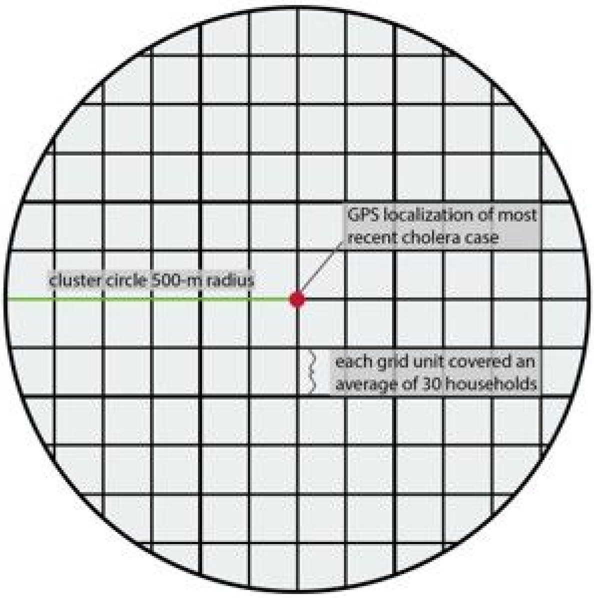

Figure 2

Diagram of targeted community-grid strategy.

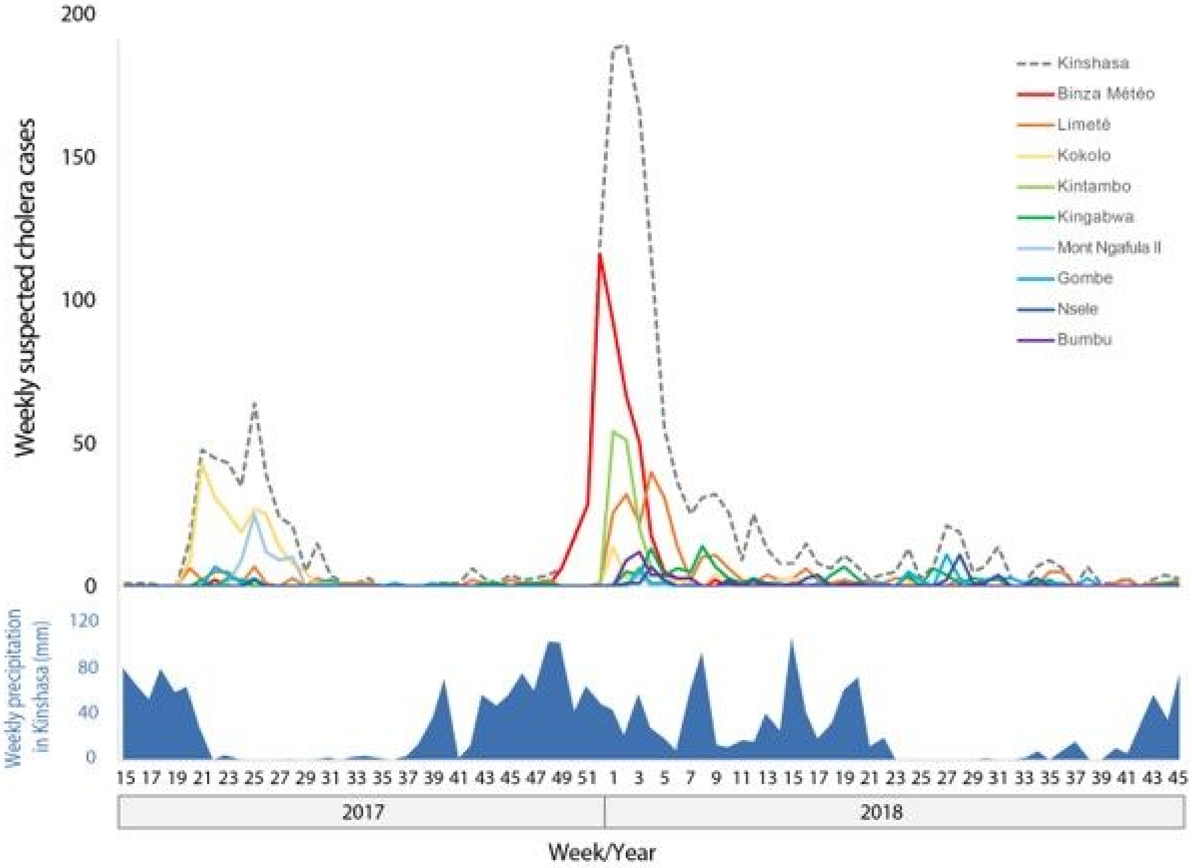

Figure 3

Epidemic curve of the cholera outbreaks in Kinshasa and corresponding weekly precipitation levels. The epidemic curve and weekly precipitation levels covers the period week 15 of 2017 to week 45 of 2018. The top panel displays weekly cholera case numbers in the entire city (dashed line) as well as heavily-affected health zones, which are color-coded and ordered based on cumulative number of cholera cases during 2017 and 2018 period (up to week 45, 2018) as displayed in Additional file 1. The bottom panel displays the corresponding estimated weekly precipitation levels in Kinshasa (mm).

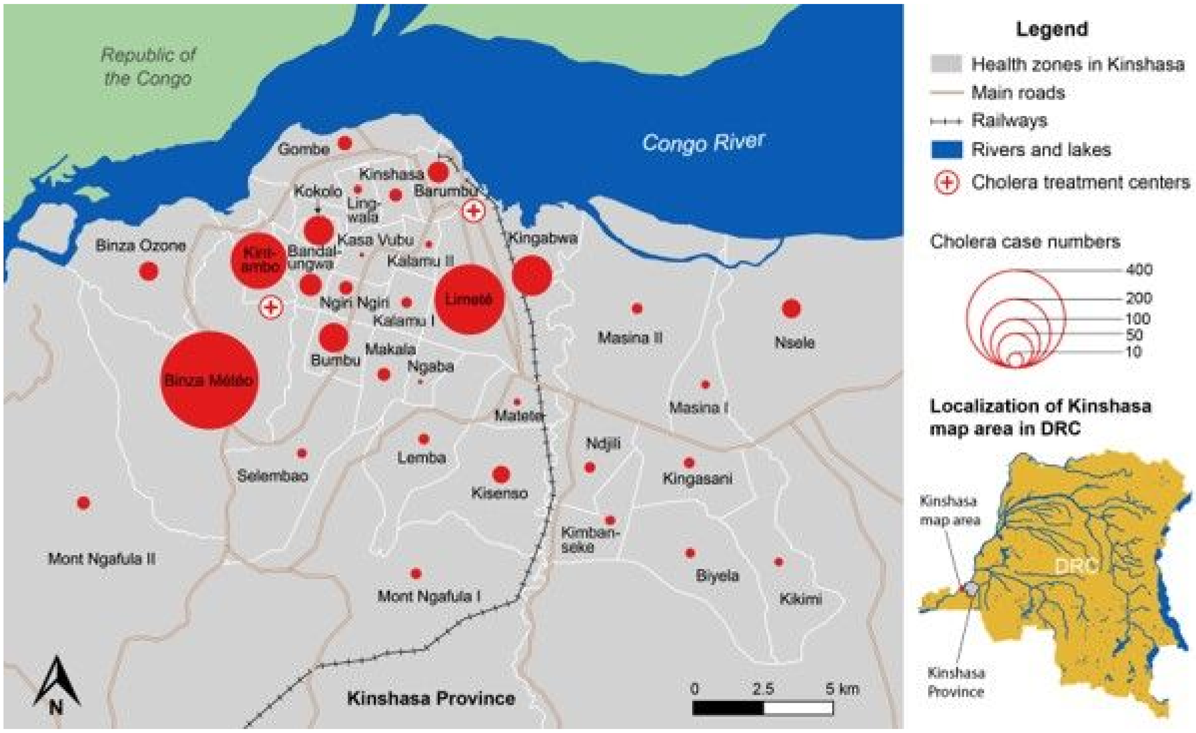

Figure 4

Total cholera case numbers per health zone in Kinshasa from November 2017 to March 2018. The red circles represent the number of cumulative cholera case numbers (suspected and confirmed) in each health zone during the five-month period. The only areas not represented on the map are the large health zones located in the east of Kinshasa Province, Maluku II and Maluku I, which reported seven and 21 cases, respectively, during the five-month epidemic period. Health zones, main roads, railroads and waterbodies in Kinshasa are indicated. The GPS coordinate-based localization of the CTCs in Binza Météo (Camp Luka) and Limeté (Pakadjuma) is also indicated. Neighboring Republic of the Congo is shown in green. Localization of Kinshasa Province (gray) and the Kinshasa map area (red square) are specified on the map of DRC in the lower right corner.

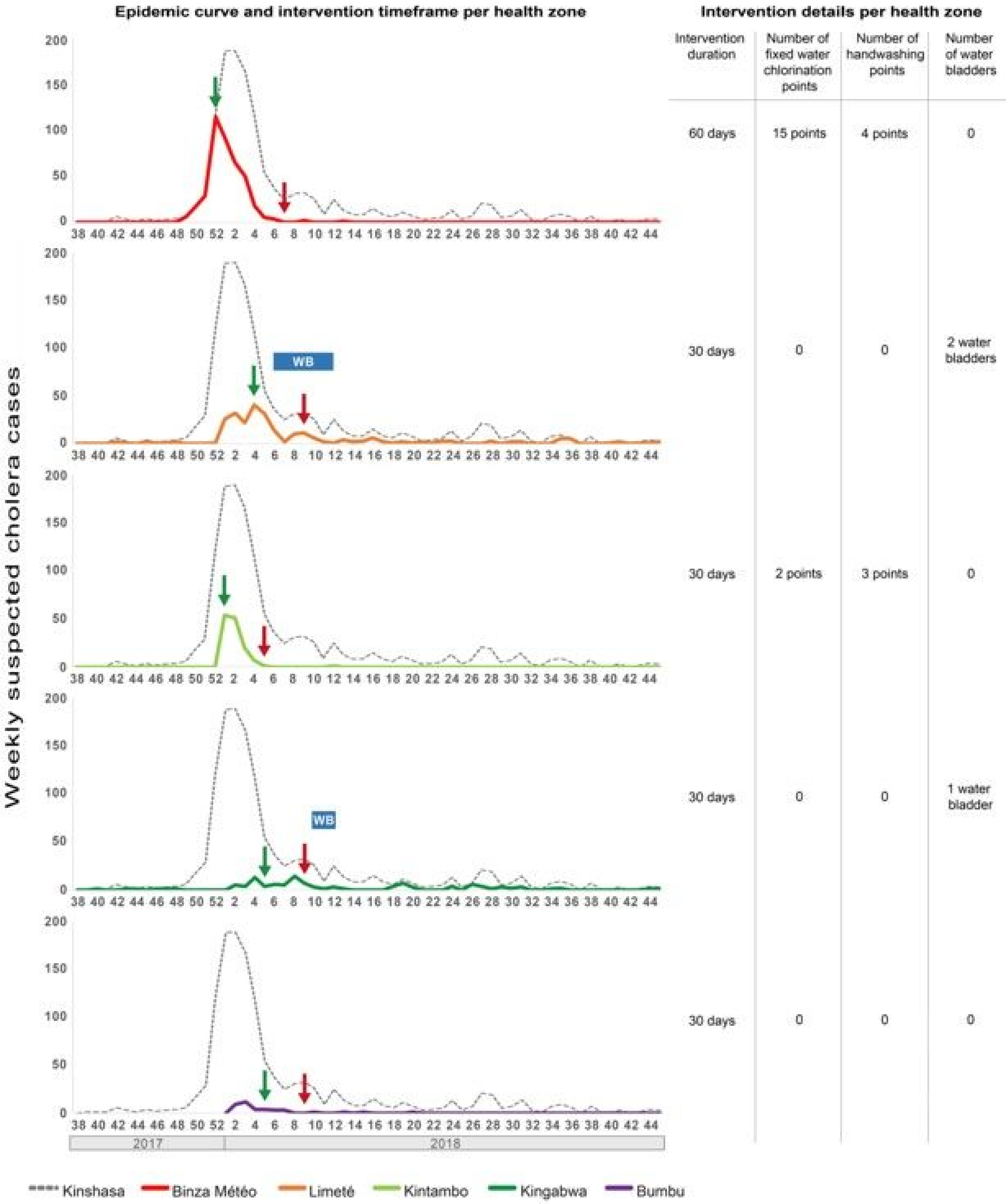

Figure 5

Cholera epidemic curve of targeted health zones and response activity timeframe. Weekly cholera case numbers are shown on the y-axis and epidemic weeks/years are indicated on the x-axis. The start and end points of community-grid WaSH response activities in each health zone are shown with green and red arrows, respectively. The blue blocks "WB" indicate the health zone and timeframe of water bladder installation. The intervention details for each health zone are indicated on the right.

Supplementary Files

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- supplement1.docx