Use of Sat Scan for Identification of Cholera Hotspots in a High-Density Suburb of Harare, Zimbabwe.

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Abstract

Background: The cholera pandemic remains a major public health risk in developing nations most of which are in the Sub Saharan regions. However, there is limited data on near real time analysis using the Sat Scan which in this study, of particular concern is the spatial-temporary distribution of cholera cases obtained from the mapping and detection of cholera hotspots or clusters in Budiro on the outbreak, which occurred in September 2018.

Methods: The research study used the spatial geographical distribution approach in order to study the clusters of high diseases incidence in Budiro high-density suburb of Harare, Zimbabwe. The participants in this study included patients from all age groups and gender who were either suspects or confirmed cases of cholera according to the line lists provided by Harare City Health Department. Data was then analysed using the Python, Geographic Information Systems (GIS) and the Sat-Scan. Since this study, is an essential part of the health-needs assessment in the identification of high-risk areas for a disease, understanding the characteristics of high-risk areas was needed to indicate areas, which required improvements in the provision of WASH programmes in order to reduce the risk of cholera outbreaks.

Results: The results from this study showed significant clusters or hotspots of cholera in Budiro for the period of the outbreak (29 September-02 October 2019). People within 0.22km and 0.55km showed a significant risk of being susceptible to cholera ($p=0.001$). Clusters 1-3 were considered to be hotspots ($p<0.05$) for cholera outbreak and correspondingly there were more cases of cholera. These hotspots were linked to contaminated water sources (HA034, HA039 and HA075). Water was contaminated from low flow rate of sewage.

Conclusions: Cholera and other general infectious disease surveillance can benefit from this perspective approach by monitoring outbreaks in real-time as new data becomes available. The results emphasised on the importance of focusing surveillance on emerging and active clusters during epidemics. Further we concluded that safe water provision could reduce the risk of such outbreaks if Sat-scans could be applied in locating possible areas of contamination.

Background

Cholera is a major public health problem in Sub-Saharan Africa where sanitation and safe water provision is reported as a challenge [1]. Zimbabwe particularly has had challenges of being unable to control cholera outbreaks due to lack of adequate provision of Water, Sanitation and Hygiene (WASH) programmes [2]. The country has been reported to be reactive to the outbreaks of cholera and other diarrhoeal diseases [2]. WASH programmes are activated during the outbreaks and thereafter, complacency has been reported [2]. Zimbabwe reported 98592 cases of cholera, including 4288 deaths during the 2008–2009 cholera outbreak [3].

Cholera is viewed as a trans-boundary communicable disease that requires complex interventions in terms of preparedness and response, management, prevention and mitigation [4]. The devastating 2008

to 2009 cholera outbreak in Zimbabwe resulted in the neighbouring countries being affected and reported isolated outbreaks of Cholera[5]. The affected countries from the Zimbabwean outbreak included Angola, Botswana, Malawi, Namibia, South Africa, Swaziland, Zambia and the Democratic Republic of the Congo [6].

Zimbabwe has had a repeat of cholera outbreak in September 2018 [2, 7]. The Ministry of Health and Child Care declared this outbreak in Harare with 11 cases having been confirmed through a rapid diagnostic test (RDT) and the clinical presentation for cholera [8]. This was mainly in a high density suburb of Harare [2, 8]. This resulted in having nearly 2000 suspected cholera cases, including 58 confirmed cases and 24 deaths during the month of September 2018 [7]. However, other locations and high-density suburbs around the index suburb also reported cases of cholera during the same period [7]. This outbreak pointed to inadequate supply of WASH programmes and possible contamination of water sources in the suburbs of Harare and surrounding cities [7]. In Zimbabwe there are no studies that were performed using the near real time data that could characterise and reveal the spatial temporary distribution of cholera outbreaks. Therefore, this study sought to utilise geospatial approach in detecting and mapping the cholera outbreak in Budiriro high-density suburb in Harare, Zimbabwe.

Methods

Study settings

The study was conducted in Budiriro high-density suburb of Harare, Zimbabwe. This was the epicentre of Cholera outbreak with the highest number of reported cases exceeding 600. Following the pattern of cholera outbreak in Budiriro high-density suburb on a daily basis, cholera was at its peak during the mid of September 2018. However there were some fluctuations during the outbreak period (September to October 2018) showing some interventions from the Health officials to control the outbreak. (See Map for Budiriro suburb).

Study Design And Participants

This study followed a geospatial distribution approach. This was designed to identify cases according to their location in the high-density suburb of Budiriro in Harare. We made use of the line listing which was provided by the Harare City Health Department allow for secondary analysis. The line list consisted of 600 cases who were suspects or confirmed cases of cholera. These had been reported from the 1st of September 2018 to the 4th of October 2018. The cases consisted of children who were above 2 years and adults aged 21 years to 63 years. These were either suspects or cases of cholera. A case of cholera is a confirmed case from isolation of vibrio cholera 01 or 0139 from the patient with diarrhoea[6, 9]. The suspected case of cholera is any individual; in areas where a cholera outbreak has not been declare who is 2 years old or older presenting with acute watery diarrhoea and severe dehydration or dying from acute watery diarrhoea or in areas where a cholera outbreak is declared, any person presenting with or dying

from acute watery diarrhoea [10]. These suspect cases or confirmed cases of cholera were people from all age groups and gender who were living in Budiro during the time of the outbreak. The study received approval from Chinhoyi University of Technology and from the Harare City Health Department in order to analyse the secondary data. We obtained the line lists from the Harare City Health Department.

Statistical Analysis

We used the Microsoft Excel spreadsheet 2013 and exported it to the Jupiter NoteBook for Python for analysis. We also use the geographical information systems (GIS) for spatial distribution [11]of disease incidence and its relationship to the potential risk factor as it played a vital role in epidemiological studies such as ours. For the near real time analysis, we used the Sat-scan [12] to identify high burdened clusters.

Results

The results from this overall study analysis showed significant clusters or hotspots of cholera in Budiro for the period under study. A total of 600 cases of cholera reported during the 10th of September 2018 to 2nd of October 2018 were included in the analysis. These included children and adults who all were residences of Budiro. These were taken from the line list, which was recorded by the Harare City Health Department. We performed the Sat Scan, which reported high spatial-temporary clusters. Four high clusters purely spatial-temporary were detected and these were statistically significant ($p < 0.05$) (Table 1).

Table 1
Clusters detected from 05 September – 30 October 2018

Cluster	Dimension	Type	Number of cases	Radius	Starting date	Ending date	P-Value
1	Space-time	High	57	0.22 km	29/09/18	02/10/18	0.001
2	Space-time	High	105	0.55 km	10/09/18	13/09/18	0.001
3	Space-time	High	7	0.059 km	21/09/18	23/09/18	0.043
4	Space-time	High	5	0.16 km	24/09/18	24/09/18	0.048

Cluster 1 had a relative risk of 3.10 from the 57 observed cholera cases. This cluster was detected from the period between 29/09/2018 to 02/10/2018 on the point location of 17,895836 S and 30, 935754 E with a radius of 0,22 km. This cluster was highly statistically significant with $p\text{-value} = 0,001$ since Sat Scan requires that $p\text{-values}$ should be < 0.05 for it to be recognised as significant.

Cluster 2 covered a radius of 0,55 km and was the biggest cluster of the four clusters. Cluster 2 recorded 105 cholera cases during the period 10/09/2018 to 13/09/2018. The relative risk was 1.78 from the

observed cholera cases. The p-value was statistically significant per Sat Scan ($p = 0.001$). Cluster 2 was point located on 17,893279s and 30,946710 E.

Cluster 3 was detected from the period 21/09/2018 to 23/ 09/ 2018, and over a duration 3 days with 7 confirmed cases of cholera. This cluster had a relative risk of 8.04 with a p value = 0.043. The location point of the cluster was on 17,877472 S and 30,931704 E covering a radius of 0,059 km.

Cluster 4 was the least significant cluster with a p-value = 0.048 and a relative risk of 13.25. The cluster was detected over one day on 24 September 2018. The cluster was located on 17,877472 S and 30, 931704 E covering a radius of 0,16 km. The Sat Scan was computed which spatially distributed the clusters or hotspots for cholera outbreak in Budiro suburb. (Fig. 1

Table 1: Clusters detected from 05 September – 30 October 2018

Figure 1: Sat Scan map for spatial distribution of Budiro cholera cases in 2018

Cartesian Coordinates Map further helped to show the geo-coordinates for the four hotspots in Budiro suburb (Fig. 2). The google Map showed that there were three decommissioned boreholes that acted as a source of contamination. These are shown on the google map as HA034, HA039 and HA075. HA039 was in Cluster 3, HA034 was in Cluster 1 whilst HA075 was not in any Cluster for cholera. However, this borehole (HA075) acted as a source of transmission for cholera for Cluster 2 as it acted as the main source of water supply for the residences in Cluster 2 (Fig. 3). The boreholes were situated (HA039) at latitude – 17.8901 and longitude 30.9115, HA034 situated at latitude – 17.8972 and longitude 30.9366 while HA075 was at latitude – 17.8924 and longitude 30.9352. All these boreholes (HA034, HA039 and HA075) were identified by the Sat Scan to be less than 50metres from the sewage carriage that was reported to have a low flow rate. Within the residence, there was erratic treated water supply from council water sources. The sewage also experience frequent water shortage and had low flow rate. Borehole (HA075) was situated at the shopping centre. The shopping centre was within the residence and there were several public toilets at the shopping centre and nearer the borehole (HA075). HA039 was very close to a house (~10 m) and falling short of being further away from a source (sewage carriage) of contamination. HA034 was in the residential area and close to sewage carriage.

Figure 2: Cartesian Coordinates Map showing location of hotspots for Cholera in Budiro.

Figure 3. Map of Budiro hotspots for cholera showing decommissioned boreholes marked on the map as HA.

We computed a Sat Scan map for the cholera hotspots which showed that Clusters 1, 2 and 3 were statistically significant ($p < 0.05$) and that there was high transmission of cholera within these clusters. Cluster 4 was not statistically significant ($p = 0.602$) (Fig. 4).

Figure 4. Sat Scan map for variances within clusters of cholera cases in Budiro suburb.

Discussion

To the authors' knowledge, studies performed using Sat Scans to identify the possible hotspots for cholera are limited to the developed nations like the UKs and the USA. The use of Sat Scans is relatively new to the study population. Our study, which sought to identify the clusters highly affected by cholera outbreak in Budiro suburb of Harare, Zimbabwe, using the Sat Scan revealed the existence of four clusters associated with cholera outbreak. All clusters included people of all age groups and gender who had a confirmed cholera disease. The decommissioned boreholes, were identified as the main sources of water supply in the suburb, and were the epicentres for the cholera outbreak. These boreholes were identified to be closer to the sewerage carrying pipes within Budiro suburb. It is imperative to conduct these Sat Scans in order to identify potential sources of cholera outbreak, that can play a phenomenal role in outbreak control and prevention.

Cholera outbreak is particularly very high in densely populated areas like Budiro in Zimbabwe were our study observed that WASH programmes were inadequate leading to the high transmission of the communicable diseases. This clearly pointed to the need for ensuring that clean water supply and sanitation and hygiene programmes performed continuously could address the risk of contracting cholera. Our study corroborated with Faso [13], Campbell et al [14] and Geltings et al [15] who reported that WASH programme works on long-term prevention and control measures for improving health, reducing poverty, and improving socio-economic development as well as responding to world-wide public health emergencies and outbreaks of life-threatening diseases like cholera.

Our study revealed that there was a high risk of contracting cholera if the source of water supply for domestic use was proximal to a low flow rate sewage carriage and this was the case with cluster two, which revealed high infection rate with cholera. Low flow rate of sewage has a high risk of causing contamination of water sources for domestic use. This particularly may act as a catapult to a surge in infection rates of cholera. This finding of ours concurred with a study that was carried in Egypt [16] on time-space analysis of the single largest cholera outbreak. The study by Smallman-Raynor et al [16] in Egypt revealed that there were clusters which had a high risk of developing cholera and these were synonymous with contaminated water bodies. Another study by Rinaldo et al [17] further elaborated that most of the burden of waterborne infections is attributable to an unsafe water supply, a lack of sanitation, and poor hygienic conditions, which may affect exposure and transmission rates either directly or indirectly which was the case with the Budiro cholera outbreak in Zimbabwe.

Although, Budiro high-density suburb in our study reported the outbreak of cholera, there were only four clusters of epidemiological importance and these we revealed to have common risk factors, which included erratic water supply and low flow rate of sewage. Cluster analysis provides opportunities for the epidemiologists to understand possible associations between demographic and environmental exposures and the spatial distribution of diseases [18, 19]. Further, the Sat Scan helped to reveal the spatial distributions of cholera cases in Budiro high-density suburb. The identification of clusters of cholera hotspots in our study has helped to stratify the ecological factors inherent in the location that

favoured the risk of cholera outbreak. Our findings were also echoed by Elliot et al [20], Lawson [21], Biggerri et al [22] and Lawson et al [23] who reported that a significant interest in spatial epidemiology lies in identifying associated risk factors which enhance the risk of infection, the so-called ecological analysis or geographic correlations studies.

Conclusion

Cholera and other general infectious disease surveillance can benefit from the Sat Scan mapping which improves near real time analysis. The Sat Scan improves case identification and at risk groups and environmental factors associated with the risk. Although our study was performed using the near real time analysis, it could have been beneficial to also conduct a case control analysis to identify possible risk factors for cholera. The researcher emphasises the importance of focusing surveillance on emerging and active clusters during epidemics, since these would assist in instituting preventive measures to the outbreak of cholera.

Abbreviations

WASH: Water, Sanitation and Hygiene; SAT SCAN: Satellite Scanning; RDT: Rapid Diagnostic Test; GIS: Geographic Information Systems.

Declarations

Disclaimer

Opinions expressed in this paper are those of the authors and do not necessarily reflect the views of their respective institutions.

Ethical approval and consent to participate

We obtained approval to conduct the study from Harare City Health Department and Chinhoyi University of Technology. We did not seek ethical clearance from the Medical Research Council of Zimbabwe because we were performing a secondary analysis of data.

Competing interests

None

Funding

This study did not receive funding. This was purely done for academic purposes.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

LC and PC conceived the idea. LC with the assistance of PC designed the protocol and revisions were done by PC and PN. LC designed the protocol. LC wrote the first draft of the manuscript and all authors (LC, PC and PN) reviewed changes. All authors read and approved the manuscript for submission to the journal.

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Figures

Figure 1

Sat Scan map for spatial distribution of Budiriro cholera cases in 2018 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Cartesian Coordinates Map showing location of hotspots for Cholera in Budiriro.

Figure 3

Map of Budiriro hotspots for cholera showing decommissioned boreholes marked on the map as HA. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 4

Sat Scan map for variances within clusters of cholera cases in Budiriro suburb. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.