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Analysis of Spatial-Temporal Environmental Risk Factors of 1990-2019 Cholera Outbreaks in Nairobi County, Kenya

Bocha A. Manaseh[1*], Gachohi John[2], Karanja Simon[2], Mwachari Christine[3]
[1]*School of Public Health, Jomo Kenyatta University of Agriculture and Technology*
[2]*School of Public Health, Jomo Kenyatta University of Agriculture and Technology*
[3]*Graduate School/Kenya Medical Research Institute*

ABSTRACT
BACKGROUND : In developing countries around the world, Cholera is one of the most recurrent water diseases and it still remains a major public health threat. The risk factors differ from one region and country to another, and also vary with various environmental factors including temperature, rainfall and relative humidity. This study therefore sought to determine the spatial-temporal distribution of cholera cases in Nairobi County, Kenya for the period between 1990 and 2019.

MATERIALS AND METHODS : This study applied a retrospective approach to study the historical cases of cholera recorded in Nairobi. Spatial epidemiology was applied to map the spatial-temporal variation of environmental associated with cholera outbreaks. Secondary dataset was utilized and it was analyzed using both descriptive and inferential statistics with the help of Statistical Software for Social Sciences (SPSS) version 22. Descriptive statistics included frequency distributions. Inferential statistics included regression analysis, Pearson correlation analysis and Analysis of Variance.

RESULTS : The results indicated that changes in the amount of monthly rainfall in Nairobi showed a significant relationship with variation in the number of cholera cases (p-value<0.05). However, temperature had no significant relationship with changes in the number of cholera cases (p-value>0.05). The results also indicated that relatively high humidity conditions are likely to significantly cause an increase in the number of cholera cases (r=0.79, R2=0.63, p-value=0.001).

CONCLUSION : The study concludes that rainfall and humidity had a significant influence on the number of cholera cases in Nairobi County. However, temperature had no significant relationship with changes in the number of cholera cases.

KEYWORDS- Kenya, Cholera, Environment, Risk Factors, Spatial, Temporal

I. BACKGROUND

Cholera is one of the major waterborne diseases globally. It is caused by bacteria known as *Vibrio cholerae* sero groups O1 and O139. It is an important public health problem, worldwide. The spread is usually via water that is contaminated. From the initial prevalence which was in Ganges, India in 1817, the cholera epidemic has become worldwide with over seven times presence, causing big catastrophes to populations (1). Most cholera infections are not easily discovered but large cholera epidemics like those seen in Haiti, Viet Nam including Zimbabwe have occurred in recent years. The infection is now commonly found in the tropical and subtropical developing countries. Cholera epidemic is usually found in Africa, Asia, Middle East, and South and Central America. In these regions, epidemics happen during civil strife or war which interfere with sanitation services in public set up. Earthquakes, tsunamis, volcanic eruption, landslides including floods add to the epidemics, changing natures balance.

Cholera has both direct and indirect costs, which are borne by individuals, family members, governments, and employers. Health systems bear the direct costs while indirect cholera costs are borne by the families. These cause a burden to the individual, the family and the employer (2). In the year 2016, the WHO reported 132,121 cholera cases, with 54% occurring in Africa and 32% in Hispaniola. In the same year, 2420 deaths were reported as a result of cholera, representing 86% increase as compared to 2015 (3). One of the aspects of development is to strengthen the health and wellbeing of the people. Eliminating cholera and reducing the risk of spreading the disease among populations is expected to promote Sustainable Development Goals (SDGs). The SDGs goal number three is geared towards ensuring healthy lifestyles and promotion of well-being for all ages. Therefore, reduction in cholera deaths is one of the targets towards achieving Kenya vision 2030. In addition, one of the ways of reducing the transmission of waterborne diseases is to ensure access to safe water and sanitation for all and this minimizes chances of cholera outbreaks (4). While in many countries, mostly developed countries, cholera outbreaks occur during natural disasters, in developing countries outbreaks occur as a result of several factors such as environmental factors. In Haiti, a study on environmental factors influencing the outbreak of cholera established that environmental factors such as rainfall and temperature had an influence on cholera outbreaks (5). In addition, epidemic regions were located close or near to the regional rivers and experienced sporadic outbreaks. In Iran, a study on climate change and cholera disease observed that environmental factors such as high temperatures and low precipitation provided swifter bacterial replication while low rainfall, led to an increase in pathogens' concentration in water media (6). In Inland Africa, s study on Environmental Determinants of Cholera Outbreaks established that these determinants include temperature, floods and relative humidity (7). Similarly, a study on environmental extremes and cholera time varying reproduction number established that environmental factors influencing cholera outbreaks include floods, drought and temperature (8). However, a study on the Interaction between environmental factors and cholera outbreaks established that while drought had a significant influence on cholera episodes, rainfall had no significant influence on cholera episodes (9).

In Kenya, there has been an upsurge of multiple cholera cases which seem to erupt almost annually since the first case was reported in 1971. For instance, between the year 2014 and 2017, 30 out of 47 counties in Kenya reported cholera cases. These outbreaks started on the 26th December, 2014, in the county of Nairobi, later affecting more counties. According to WHO May, 2018 weekly bulletin, between October 2016 and 6th April 2018, out of 6,532 cases, 139 deaths were reported. Between January 2018 and April 2018, a cumulative total of 2,333 cases and 50 deaths were reported across the country (10). Therefore, this study sought to determine the spatial-temporal environmental risk factors associated with cholera outbreaks in the period between 1990 and 2019 in Nairobi County

II. MATERIALS AND METHODS

Study Area : This research was based in Nairobi County. Nairobi County lies between 1.2921° South and 36.8219° east. The highest point in Nairobi is approximately 1930 m (6332ft) above mean sea level. The average temperature experience in the city is between 21 and 22°C. The total population of the city is approximately 4 million people with annual growth rate of 5.5 percent and a population density of 4,800 people per square kilometer. Nairobi County comprises of 17 constituencies, 85 wards and covers an area of 696 square kilometers. The county is fairly warm in December to March, while the June to July has cool temperatures. Rainfall is moderate and drizzles occur around summer and autumn.

Study design : This study applied a retrospective approach to study the historical cases of cholera recorded in Nairobi. Spatial epidemiology was applied to map the spatial-temporal variation of environmental associated with cholera outbreaks.

Data collection : Secondary dataset was utilized in this study. Secondary data on Cholera outbreaks was obtained from the Ministry of Health reports and bulletins and County health annual reports.

Secondary data on rainfall, temperature and humidity was obtained from Kenya Meteorological Department (KMD) National office.

Data Analysis: The data was analyzed using both descriptive and inferential statistics with the help of Statistical Software for Social Sciences (SPSS) version 22. Descriptive statistics included frequency distributions. Inferential statistics included regression analysis, Pearson correlation analysis and Analysis of Variance. Correlation analysis was performed to assess the relationships between different factors (population density, population size, rainfall, temperature and humidity) with the outbreak and spread patterns (population) of cholera epidemic. A linear regression analysis was performed to establish association between the independent variables (environmental factors) and the dependent variable, spread of cholera. A 95% confidence level was applied in the study which shows significance level of 0.05. An independent variable has a significant consequence on dependent variable, with p-value being below the significance level-0.05. The R^2 was used to show the variation in the number of cholera cases that can be explained by environmental risk factors.

III. RESULTS

Changes in the amount of monthly rainfall in Nairobi showed a significant relationship with variation in the number of cholera cases (p-value<0.05). Based on 2009 data the results show that R^2=0.11, r=0.33, p-value=0.003. Based on 2015 data the results show R^2=0.34, r=-0.58, p-value=0.01. Based on 2020 data the results show R^2=0.50, r=-0.70, p-value=0.31 (Table 1).

Table 1: Relationship between rainfall and the number of cholera cases

Year	Cholera Cases	Average Monthly Rainfall (mm)	R^2	Pearson correlation (r)	t-Stat	p-value (CI=95%)
2009	71	73.1	0.11	0.33	-6.18	0.003
2015	90	95.6	0.34	-0.58	-4.20	0.01
2019	253	92.9	0.50	-0.70	-1.70	0.31

The analysis on the relationship between temperature and the number of cholera cases using a t-test showed that temperature has no significant relationship with changes in the number of cholera cases since the p-value was greater than 0.05 (Table 2). Although the relationship between temperature level and the number of cholera cases is not significant, an increased number of cholera cases are more likely to occur during high temperature conditions than during low temperatures since the Pearson correlation coefficient (r) is 0.95, R^2=0.90, and p-value of 0.15 (Table 3).

Table 2: Relationship between temperature and the number of cholera cases

Year	Cholera Cases	Average Monthly Temperature (°C))	R^2	Pearson correlation (r)	t-Stat	p-value (CI=95%)
2009	71	25.3	0.90	0.95	-1.76	0.15
2015	90	23.3	0.24	0.49	-0.56	0.61
2019	253	22.9	0.25	0.50	1.05	0.39

The results show that relatively low humidity levels have a negative relationship with increasing number of cholera cases, but with no significant influence since p-value >0.05. Relatively high humidity conditions are likely to significantly cause an increase in the number of cholera cases (r=0.79, R2=0.63, p-value=0.001) (Table 3).

Table 3: Relationship between relative humidity and the number of cholera cases

Year	Cholera Cases	Relative Humidity (%)	R^2	Pearson correlation (r)	t-Stat	p-value (CI=95%)
2009	71	78.5	0.63	0.79	-8.80	0.001
2015	90	70.4	0.01	-0.09	-4.68	0.009
2019	253	74.9	0.22	-0.47	-0.79	0.48

Based on a multivariate regression, the study found that the population size in a given residential area significantly influences the number of cholera cases such that areas with high population tend to have high number of cholera cases (p-value= 0.002). The weather parameters show little influence in the variation of the number of cholera cases since the p-values> 0.05. The analysis of variance showed that population and environmental variables including rainfall, temperature and humidity account for 72% overall proportion of variance with a Pearson correlation coefficient of 0.85 (Table 4).

Table 4: Analysis of variance

ANOVA	*df*	*SS*	*MS*	*F*	*Sig. F*	*R Square*	*R*
Regression	4	15871.73	3967.933	6.353571	0.008237	0.717	0.847
Residual	10	6245.202	624.5202				
Total	14	22116.93					

IV. DISCUSSIONS

The analysis on the relationship between rainfall and the number of cholera cases showed that an increase or decrease in the rainfall is likely to contribute in the increase or decrease in the number of cholera cases. The findings also concur with a study conducted in Haiti that showed that there was a positive relationship between rainfall and cholera incidences (12). Other factors associated with rainfall for example WASH may have contributed to changes in the number of cholera cases. Areas served with limited water and sanitation are likely to be contaminated during rainy seasons (11,12, 13). This also supports our findings particularly in densely populated residences. This study revealed that during high temperatures (>25°C), more cholera cases were reported. A study conducted in Haiti asserted that cholera bacteria can easily spread in moist environment where temperature is above 17°C therefore high number of cholera cases are likely to be reported during high humidity and temperature conditions (14). This explains our findings. During high humidity conditions (>78%), the number of cholera cases are also likely to be significantly high. The study revealed that relatively low humidity conditions are not significantly associated with the increasing number of cholera cases. Studies elsewhere have associated the aforementioned characteristics of the environment with increase in number of cholera cases (15).

Study Limitations : Several challenges were experienced during the collection of data. First, some of the secondary data was not available online and in the websites of various institutions. As such, the researcher had to visit specific institutions to obtain the data. For instance, data on Nairobi shape files was obtained from Survey of Kenya and data on Rainfall and Temperature data for the period between 1990 and 2019 was obtained from Kenya Meteorological Department (KMD) National office.

V. CONCLUSIONS

This study concluded that environmental factors partly influence the risk of cholera outbreaks in Nairobi. The study also concludes that rainfall and humidity had a significant influence on the number of cholera cases in Nairobi County. Changes in the amount of monthly rainfall in Nairobi showed a significant relationship with variation in the number of cholera cases. The study also established that relatively high humidity conditions are likely to significantly cause an increase in the number of cholera cases. However, low humidity levels have no significant relationship with increasing number of cholera cases. The study also found that temperature had no significant relationship with changes in the number of cholera cases. Nonetheless, an increased number of cholera cases are more likely to occur during high temperature conditions than during low temperatures. There is need to study the role of population density, rainfall, temperature differences. The weather indices from the study can be used to predict cases as an early warning system

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