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Geospatial analysis of cholera outbreak mapping of prone areas in communities in Ondo State, Southwestern, Nigeria

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Abstract

Cholera stands as an abrupt intestinal infection brought about by the consumption of food or water contaminated with comma-shaped bacteria, specifically Vibrio cholerae. The prime objective of this study is to employ Geospatial methodologies in the mapping of cholera occurrences within Ondo State. Geographical Information System (GIS) is utilized to chart the instances of cholera outbreaks. The pivotal aims of this endeavor encompass:

- delineating the prevalence of cholera incidents across all Local Government Areas (LGA) within Ondo State;
- assessing the trajectory of cholera occurrences within the research locale;
- identifying the principal causes of cholera within Ondo State;
- Outlining and suggesting potential strategies to counteract the incidence of cholera in the state; and
- Forecasting the occurrence of cholera cases over the subsequent 5 to 10 years.

Recorded instances of cholera were sourced from the ministry of health, supplemented by the use of questionnaires to amass primary data. The research leveraged both ArcGIS and SPSS as analytical tools. ArcGIS facilitated the mapping of cholera causes and plausible remedies. It is evident that Local Government Areas (LGAs) boasting larger populations recorded more cholera cases compared to their smaller counterparts. Furthermore, it is observed that the highest count of reported cholera cases across all LGAs was reached in 2014. The study establishes the potential for early diagnosis and preventive measures to obliterate the disease and integrate the resulting database into the primary health sector. It was discovered that there's know significant differences in reported cases of cholera in all the Local Government Areas (LGA) despite the fact that the values looks similar or varies. The study recommends advancing the field of cholera mapping to unveil risk factors and preclude potential cholera outbreaks within the state. Anticipated production of risk maps will identify regions prone to future cholera attacks within the state.

Keywords: Vibrio cholerae; ANOVA**;** Mapping; Geographic Information systems(GIS); ArcGIS

1. Introduction

The World Health Organization (WHO) in 2010 stated that Cholera, a waterborne ailment, is closely tied to unfavorable environmental conditions. The absence or scarcity of safe water, proper sanitation, and inadequate waste management are the primary factors contributing to the disease's transmission (WHO, 2018). Typically caused by Vibrio cholerae, cholera presents as an acute watery diarrhea illness and has become a significant global health concern. According to WHO (1993), cholera stands as one of Africa's deadliest diseases, with an afflicted individual potentially experiencing severe dehydration within 2-3 hours of the onset of uncertain symptoms and facing mortality within 24 hours if left untreated (Sack et al., 2004; WHO, 2010). In Nigeria, cholera is endemic and outbreaks are not uncommon, as evidenced

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by more than 260 reported fatalities in the final quarter of 2009. Reports from that period indicate that over 260 individuals lost their lives to cholera in four northern states, including 96 in the Bauchi state council areas of Maidugari, Biu, Gwoza, Dikwa, and Jere (Igomu, 2011). The 2010 outbreak of cholera and gastroenteritis, along with the resulting fatalities in certain regions of Nigeria, underscored the susceptibility of vulnerable groups, particularly children, to the infection (Ajoke et al., 2012). The impact of this scourge was felt across several regions in Nigeria, encompassing Jigawa, Bauchi, Gombe, Yobe, Borno, Adamawa, Taraba, FCT, Cross River, Kaduna, Osun, and Rivers. Although the outbreaks were concentrated in these regions, epidemiological evidence indicated that the entire nation faced a risk, and Ondo State was no exception. The outbreak was attributed to hyper-virulent strains of the organism (Gyoh, 2011).

Some of the identified challenges of Cholera in Ondo State include:

- Inadequate socioeconomic conditions and insufficient sanitary and water supply systems, which subsequently impact personal hygiene levels;
- An uptick in reported cases in densely populated areas such as Akure, Ikare, and Ondo town, raising concerns of a potential major outbreak.

This research aims to utilize geospatial techniques to create a cholera map in Ondo State, highlighting areas affected by the disease. The following research inquiries drive the achievement of the research objectives:

- What are the primary factors contributing to Cholera in the study area?
- How can the occurrences of Cholera cases across all Local Government Areas in the study area be visually represented?
- How can the trends in Cholera occurrences in the study area be assessed?
- What potential solutions can be proposed to address the Cholera outbreaks in the state?
- What is the projected status of Cholera cases in the study area over the next 5 to 10 years?

2. Literature Review

The practice of mapping disease occurrences and prevalence has long been integral to public health, epidemiology, and disease-related research in human populations (Koch, 2005). The term "disease mapping" originated from Clayton and Kaldor (1987) (Lance et al., 2010). Mapping stands as a pivotal objective within spatial epidemiology, as disease intensity and distributed maps offer an immediate visual representation of the scale and extent of a public health issue (Huq, 2005). Several scientists have delved into researching Cholera outbreaks. For instance, Mayala et al. (2003) undertook a study to map cholera outbreaks in vulnerable areas within Tanzania's Ilala districts (22 districts), utilizing GIS to identify predisposing factors for cholera. Sasaki et al. (2008) conducted a spatial analysis of risk factors for a Cholera outbreak during 2003-2004 in a peri-urban region of Lusaka, Zambia. Their research included analyzing the distribution of cholera cases, modes of transmission, and risk factors using a Geographic Information System (GIS) and a matched case-control approach. Oyedepo et al. (2013) employed rapid epidemiological mapping to study a cholera outbreak in certain parts of the Abeokuta metropolis while Gbolahan et al. (2013) performed a spatial analysis of a cholera outbreak in Egbeda Local Government Area of Oyo State. Notably too, Musa et al. (2013) explored the application of GIS mapping as a tool for public health, ranging from Cholera to Cancer.

The literature review thus validates that remote sensing techniques and Geographic Information Systems (GIS) can indeed be harnessed for mapping cholera. However, despite these comprehensive efforts, several affected regions in Nigeria remain relatively unexplored. Specifically, there is a lack of significant geospatial research on cholera within the study area. This research aims to bridge this gap and contribute to the understanding of cholera dynamics in the region.

3. Materials and Methods

3.1. Study Area

The study area is Ondo State (Figure 1), which comprises of eighteen (18) Local Government Areas with a total area of 15,500km^2 (6000sq mi). The capital of Ondo State is Akure and also the largest population, other major cities include; Ondo town, Owo, Ore , Okitipupa and Ikare Akoko. Ondo State have a population of 3,460,877. Geographically Ondo State lies within longitudes 4° 30’ and 6° 00’ East of Greenwich Meridian, 5° 45’ and 8° 15’ North of the Equator. The main occupation includes farming, trading, logging, fishing, crafting and public service. The climate of the state is tropical rain forest (raining and dry season), the precipitation of the state includes the annual rainfall, which varies from

2000mm in the southern part and 1150mm in the northern parts while the monthly mean temperature is 27˚C in the south and 30˚C in the north respectively.

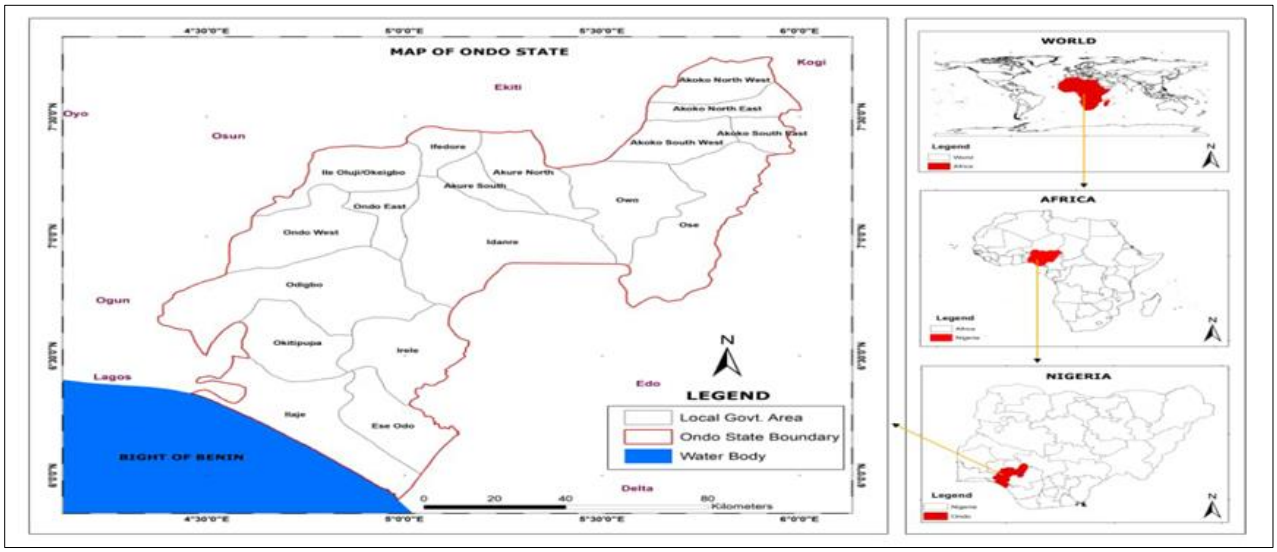

Figure 1 Map of Ondo State

3.2. Data Collection and Processing

Data acquisition was carried out through the procurement of the administrative chart of Ondo State; the tally of recorded cholera instances in all medical facilities within the state was amassed from the Health Ministry. The secondary data was the complete sum of documented cholera cases across all hospitals within each Local Government Area in Ondo State from 2011 to 2018 was derived from the Health Ministry, Akure. To handle pre-processing, the map was subjected to scanning, imported into ERDAS IMAGINE, and aligned using designated geographical coordinates. Subsequently, the scanned map was converted into digital form. The yearly rate of cholera cases was integrated into a spatial database. As a rudimentary GIS software, ArcGIS version 10.2 was employed for the creation of thematic maps. The dataset harnessed for this study is comprehensively outlined in Table 1

Table 1 Data characteristics and Sources

S/n	Name	Format / resolution	Date	Source
1.	Ondo State Administrative Map.	Digital	2014	OSGOF
2.	Secondary data (Reported cholera cases from 2011-2018)	Analogue	2019	Ministry of Health, Akure
3.	Primary Data (Questionnaire)	Analogue	2018	State owned Hospitals in Ondo State

(Source: Author)

Throughout the pre-processing phase, Microsoft Office software was employed for documentation and the generation of tables while Statistical analysis, encompassing Analysis of Variance (ANOVA) was conducted using the SPSS (Statistical Package for Social Sciences) software. Within the SPSS environment, the cholera data was entered to construct a cluster chart, which in turn was employed to distinguish the case counts across five Local Government Areas (LGAs) that have reported cases of cholera above 100 for analysis.

4. Presentation and Analysis of Results

This section was divided into four subsections namely: incidence of Cholera in Ondo State, the trend of cholera occurrence and projection of cholera cases in the study area.

4.1. Incidence of Cholera in Ondo State

From table 2, the total number of choleras reported casas was 1,599 for a period of 8 years which translated to about 200 cases every year throughout the length and breadth of the State. Essentially, Akure South Local Government Area have the most significant cholera cases in the study area with 285 victims from 2011 to 2018 followed by Ondo East LGA with 225 reported cases while Idanre and Owo Local Government Areas had 201 documented cases each throughout the study period. Similarly, Akoko North West LGA and Odigbo Local Government Areas had over 100 case histories while the remaining Local Government Areas have reported cases which were below 100. Specifically, the higher number of reported cases of Cholera in Akure South may be as a result of the role the local government played in the study area, since the creation of Ondo State on 3rd^{h} February, 1976. Akure South is the capital city of Ondo State as well as the commercial hub of the State. The population is increasing on daily basis due to influx of visitors from neighboring states and the residential houses are clustered from aerial view but significantly the sanitary, waste disposal management system and pipe borne water are lacking such that the various effort of Government over the years does not yield the required results.

Table 2 Incidence of Cholera in Ondo State between 2011 and 2018

LOCAL GOVERNMENT AREAS	2011	2012	2013	2014	2015	2016	2017	2018	Total
AKOKO NORTH EAST LGA	3	4	7	22	0	0	0	0	36
AKOKO NORTH WEST LGA	0	1	9	130	6	0	0	0	146
AKOKO SOUTH EAST LGA	3	0	0	30	2	0	0	0	35
AKOKO SOUTH WEST LGA	1	1	3	9	0	3	0	0	17
AKURE NORTH LGA	0	4	3	43	1	1	0	0	52
AKURE SOUTH LGA	33	28	26	171	16	3	4	4	285
ESE ODO LGA	1	1	2	24	0	0	0	0	28
IDANRE LGA	1	0	0	179	18	3	0	0	201
IFEDORE LGA	1	0	0	31	8	0	1	0	41
ILAJE LGA	0	1	0	13	3	0	0	0	17
ILE OLUJI/OKEIGO LGA	0	3	2	24	1	0	0	0	30
IRELE LGA	0	1	0	18	0	0	0	0	19
ODIGBO LGA	0	1	1	98	8	3	0	0	111
OKITIPUPA LGA	0	0	2	52	0	0	2	0	56
ONDO EAST LGA	6	6	14	187	4	0	8	0	225
ONDO WEST LGA	0	0	0	12	7	0	0	0	19
OSE LGA	1	1	0	46	31	1	0	0	80
OWO LGA	3	4	3	179	3	9	0	0	201
TOTAL	53	56	72	1268	108	23	15	4	1599

4.2 The trend of cholera occurrence in the study area

The rate of cholera outbreak in each Local Government Areas during the period 2011-2018 was analyzed from the data collected. It is noted that there was a gradual increase in cholera cases from 2011 to 2014. Reported cases of cholera reach its peak in 2014 in all Local Government Areas (LGAs) in Ondo State (figure 2).

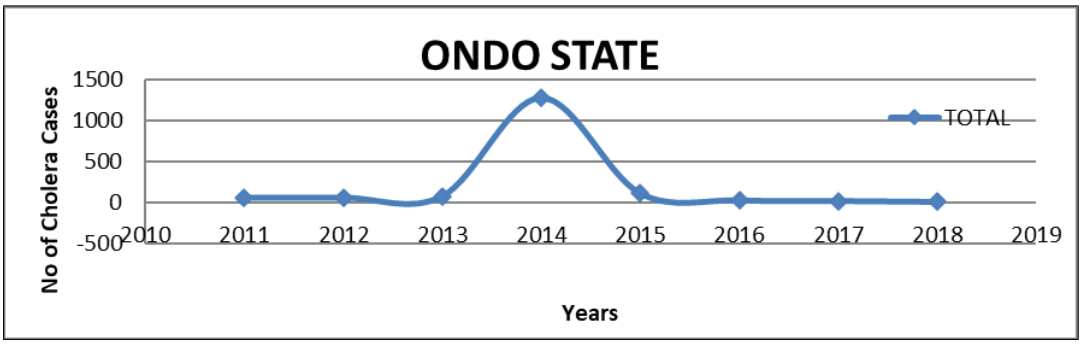

Figure 2 Trend of Cholera Cases in Ondo State from 2011 to 2018

With LGAs like Ondo East LGA (187), Owo LGA (179), Idanre LGA (179) Akure South LGA (171) and Akoko North West LGA (130), all having the highest number of cholera cases in 2014 and are also the only LGAs with cases above 100.The likely reasons for this epidemic may be increased urbanization rates and elevated population density, which strain current resources to provide better sanitation and portable water systems. Inadequate sanitation facilities combined with intermittent supply of piped water in urban regions pose a danger of cholera to the population (Osei et al, 2008). Cholera took an epidemic form in 2014 with the number of Cholera cases in the state reach 1268 in all LGAs in Ondo State. There is a sudden decrease of cholera in 2015 with a total number of 108 cholera cases in the state against the previous year 2014. It is observed that little or no cases of cholera are reported in 2016-2018 in all the LGAs in the state. It is a proven fact that improved health facilities and preventive measures have largely contributed in reducing the incidence rate. The cholera attack rate declined progressively since 2016.

4.3 Projection of cholera cases in the next 5 and 10 years (2029- and 2034)

The cholera data from 2011 to 2018 acquired from the ministry of Health was used to predict the cases of cholera in the next 5 and 10 years. The projection formula generated by Ayamga et al (2015) and Aladekoyi et al (2016) as shown in equation (i) and (ii) below:

$$r = 100\left(\frac{P1}{Po}\right)^{1/d} \text{..... i}$$

$$Po = Po\left(\frac{r}{100}\right)\ d \text{.....ii}$$

Po = current cholera case
P1 = cholera case in the previous year
Pn = future cholera case
r = growth rate of cholera
d = projected number of years

Table 3 Projection of cholera for the next 5 and 10 years

LOCAL GOVERNMENT AREAS	2011	2012	2013	2014	2015	2016	2017	2018	Rate	2029	2034
AKOKO NORTH EAST LGA	3	4	7	22	0	0	0	0	0	0	0
AKOKO NORTH WEST LGA	0	1	9	130	6	0	0	0	0	0	0
AKOKO SOUTH EAST LGA	3	0	0	30	2	0	0	0	0	0	0
AKOKO SOUTH WEST LGA	1	1	3	9	0	3	0	0	0	0	0
AKURE NORTH LGA	0	4	3	43	1	1	0	0	0	0	0
AKURE SOUTH LGA	33	28	26	171	16	3	4	4	3	5	6
ESE ODO LGA	1	1	2	24	0	0	0	0	0	0	0
IDANRE LGA	1	0	0	179	18	3	0	0	0	0	0

IFEDORE LGA	1	0	0	31	8	0	1	0	0	0	0
ILAJE LGA	0	1	0	13	3	0	0	0	0	0	0
ILE OLUJI/OKEIGO LGA	0	3	2	24	1	0	0	0	0	0	0
IRELE LGA	0	1	0	18	0	0	0	0	0	0	0
ODIGBO LGA	0	1	1	98	8	3	0	0	0	0	0
OKITIPUPA LGA	0	0	2	52	0	0	2	0	0	0	0
ONDO EAST LGA	6	6	14	187	4	0	8	0	0	0	0
ONDO WEST LGA	0	0	0	12	7	0	0	0	0	0	0
OSE LGA	1	1	0	46	31	1	0	0	0	0	0
OWO LGA	3	4	3	179	3	9	0	0	0	0	0
TOTAL	53	56	72	1268	108	23	15	4	3	5	6

Source : Author

4.2. Statistical analysis

From table 4. there is no statistically significant difference between the reported cases of cholera in five Local Government areas as determined by one-way ANOVA. Therefore, the null hypothesis (H_0) was not rejected and it was concluded that the level of occurrence of cholera in Akure South LGA is not significantly different from the level of occurrence in Akoko North West LGA, Idanre , Ondo East and Odigbo LGAs. Similarly, the level of occurrence of the disease in Akoko North West LGA is not statistically significant from the occurrence level in Idanre LGA, Akure South LGA, Odigbo, and Ondo East LGAs Specifically, it is concluded that none of the occurrence are really more severe than any other in the five LGAs in a way that would be statistically significant despite the fact the total cases of cholera recorded for selected LGAs varies.

Table 4 ANOVA Single Factor

Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
0	8	292	36.5	3953.714		
33	8	537	67.125	10882.41		
1	8	401	50.125	7524.982		
6	8	444	55.5	8752		
0	8	222	27.75	2262.786		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7736.35	4	1934.087	0.289743	0.882649	2.641465
Within Groups	233631.3	35	6675.179			
Total	241367.6	39				

5. Conclusion

This research effectively demonstrated the capability of GIS software in mapping disease occurrences and gauging their severity across diverse Local Government Areas (LGAs) in Ondo State. The analysis of results revealed a positive correlation between the size of the population in an LGA and the prevalence of cholera cases – LGAs with larger populations exhibited higher incidences of cholera compared to their smaller counterparts. The data on reported cholera cases pinpointed the year 2014 as having the highest number of cholera cases across all LGAs. Consequently, this insight aids in identifying the most vulnerable regions for disease prevention and integrated management, enabling close monitoring of these areas. An additional significant revelation stemming from this study is the potential for early

diagnosis and precautionary measures to combat the disease, incorporating the derived database into the primary health sector outcomes. This sector can leverage the GIS system to enhance its preparedness, accurately forecast potential outbreaks, and proactively undertake measures to avert the spread of the disease.

Recommendation

This study therefore recommends that government should encourage the use GIS in diseases mapping especially cholera in the state, to know the areas prone to cholera attack. This study should be adopted by the Ondo state Government in order to understand the present condition of cholera in the state. Advanced work in cholera mapping can be used to depict the risk factors of cholera and avoid any cholera outbreak in the state. Future production of risk map will depict areas that will be prone to future attack of cholera in the state.

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