A Spatial Autocorrelation Analysis of Cholera Patterns and Social Risk Factors in Nigeria

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ABSTRACT

Cholera has remained a public health issue since the seventh pandemic, especially in countries like Nigeria, with the disease occurring both in sporadic and epidemic scales. Based on the World Health Organisation's record, Nigeria alone has reported 380,698 (28,898) cases and deaths between 1991 and 2011 – the highest from Africa. This study investigated the geographic pattern of cholera cases and deaths in Nigeria, in order to determine its risk factors and areas that are more at risk. A Global Moran Index spatial autocorrelation was employed to determine the clustering of cholera across the country. Disease rate ratios were computed by categorising the 36 states and Federal Capital Territory of the country in to four strata based on geographical location; population density; absolute poverty; and adult literacy. The result indicates a significant positive spatial autocorrelation of cholera in all the twelve years investigated (Moran I: 0.211, p: < 0.007). Clustering is more pronounced in the northern part of the country, most especially in the northeast, while less clustering is found in the southern part of the country.

Keywords: Cholera, Risk factors, Socioeconomic, Nigeria

INTRODUCTION

Nigeria has a number of infectious diseases; one that still remains a threat to public health is cholera, since the seventh pandemic reached the continent of Africa in the 1970s (Barua and Cvjetanovic, 1970; Cvjetanovic and Barua, 1972; Goodgame and Greenough, 1975). The first reported cases of cholera in Nigeria were in 1971 in a village near the then capital city, Lagos, which resulted in a severe epidemic in which 22,931 cases and 2,945 deaths were recorded (WHO, 2013b). In 1991 nearly 59,478 cases and 7,645 deaths were reported (WHO 2011d). According to United Nations figures in 2010, over 1,555 have died from cholera in Nigeria and nearly 40,000 have been infected, in the country's worst outbreak for nearly two decades. World Health Organisation's (WHO) data showed that Nigeria reported 393,614 cases and 22,664 deaths between 1991 and 2011 - the highest figures in Africa.

As in the case of other countries in West Africa, the human pathogen vibro *cholarae* O1 and O139 (Marin, 2013) are responsible for most of the cholera epidemics and outbreaks in Nigeria. The disease has notable seasonality (e.g., Pascual et al., 2002) and varies both spatially and temporally across the globe, and is well documented to have been influenced by climatic, environmental, and social factors (Harris et al., 2012; Leckebusch and Abdussalam, 2015; Sultan et al., 2005; Rajendran et al., 2011). In Nigeria, the disease tends to occur in sporadic, small outbreaks, and even in large epidemics.

The transmission of cholera in Nigeria might be facilitated by numerous factors such as lack of access to safe drinking water, unhygienic environment, environmental disasters, literacy levels, population congestion, and internal conflicts which usually lead to population being displaced to Internally Displaced Persons (IDPs) camps. Provision of safe drinking water remains a serious issue of concern: this leads people, even in cities, to buy water from street

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vendors, which have high risk of being contaminated. Typical areas at risk might include populations living in urban and peri-urban slums. These areas are mostly densely populated by people on low incomes, and basic infrastructure is not readily available. Despite the availability of the oral cholera vaccines, anecdotal evidence shows that this effective control method is not yet commonly used in Nigeria. The main control method is treatment through rehydration with oral salts after infection.

Investigating long term surveillance epidemiological data is necessary in order to understand pattern and dynamics of infectious diseases; this will help improve the controlling strategies. It will also allow for the determining the areas that are at high risk and the disease driving factors. This would be achieved through exploring existing epidemiological records of the diseases using a GIS based statistical techniques.

MATERIALS AND METHODS

The overall analysis would be based on national epidemiological, socioeconomic, and demographic data. Descriptive statistics (e.g., Chevallier et al., 2004; Sasaki et al., 2008), and spatial statistical techniques (e.g., Borroto and Martinez-Peidra 2000; Osei and Duker, 2008) were used in analysing the geographical pattern of cholera in Nigeria.

Disease Data

Epidemiological data were obtained from two sources and at different spatial and temporal resolutions. Firstly, records of annual suspected cholera cases and deaths at state levels between 2000 and 2011 were obtained from the Epidemiology Division at the National Centre for Disease Control (NCDC) of the Federal Ministry of Health (FMoH). These cases are reported by DSNOs in all the 774 Local Government Areas (LGAs) of Nigeria. Although data exists over a longer time period, due to missing values and uncertainties in the record because of the poor surveillance system structure before 2000, annual data has been collected for only 12 years (2000–2011). Secondly, annual national level records of reported cases of both diseases' cases and deaths from 1991 to 2011were extracted from the archives of the WHO. Figure 1 presents the 36 states and Federal Capital Territory (FCT) in Nigeria, showing the spatial distribution of states level average annual incidence rate of cholera and case fertility rate of cholera, per 100,000 of population between 2000 and 2011.

In Nigeria, a suspected cholera case is defined: "as when a patient of 5 years or older shows symptoms or dies of acute dehydration, even in areas where the disease is not common" (WHO, 2011).

Demographic and Socioeconomic Data

State's population census (2006) was obtained from the Nigerian Population Commission (NPC), Nigeria. Annual population estimate for each state was calculated forward and backward using Nigerian population growth rate index provided by World Bank. Population density for each state was computed by dividing each state's population with its aerial cover in square kilometres. The Nigerian National Bureau of Statistics (NBS) provides annual socioeconomic data between 2000 and 2011 for individual states in the country for this study. Data collected includes percentages of population living in absolute poverty and adult literacy.

Analytical Method

Incidence rate (IR) per 100,000 of population and case fatality rate (CFR) for cholera were computed from the WHO national records between 1991 and 2011. IR and CFR were also calculated for each of the 36 states (Figure 1) in Nigeria and the Federal Capital Territory

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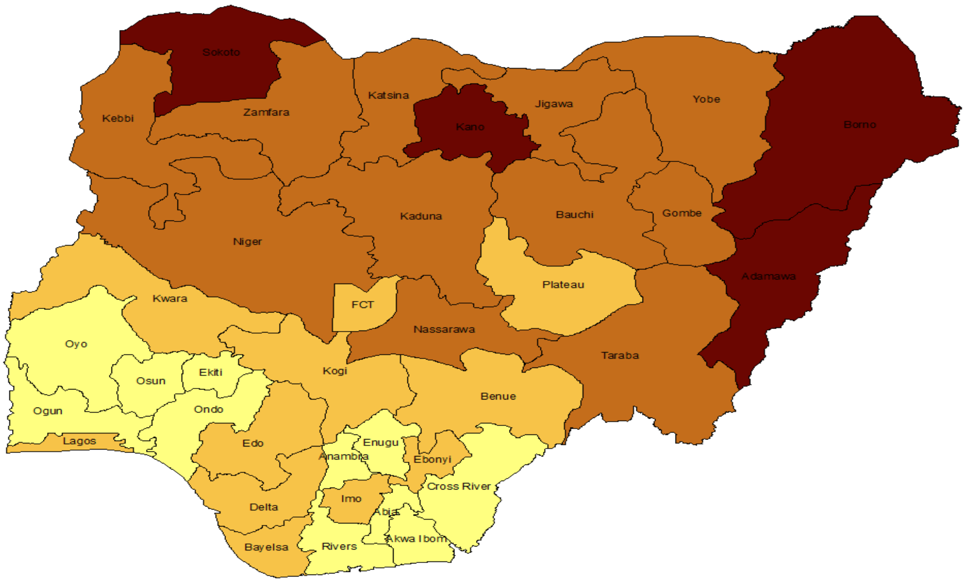
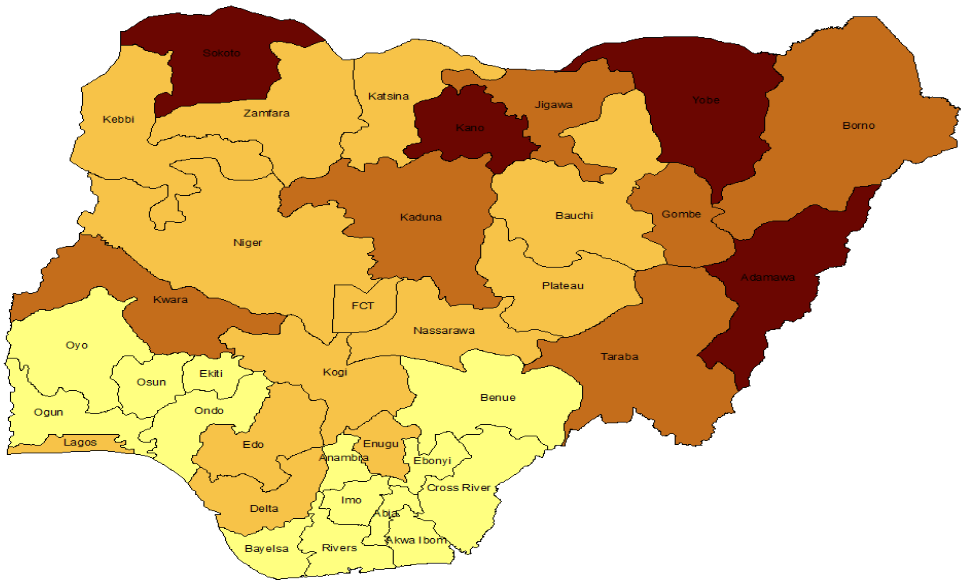
(FCT) Abuja, using the annual state levels cases and deaths reported between 2000 and 2011 obtained from NCDC.

a



Legend	
Cholera IR	
	0.00 – 4.50
	4.60 – 14.0
	14.1 – 23.0
	23.1 – 38.9

b



LEGEND	
Cholera CFR	
	0.00 – 0.42
	0.43 – 1.40
	1.42 – 2.30
	2.31 – 3.30

Figure 1. Spatial distribution of states level average annual a) incidence rate of cholera and b) case fertility rate of cholera, per 100,000 of population between 2000 and 2011

The IR and CFR of the state's level for the 12 years of data (2000 – 2011) were classified into strata based on their respective values. ArcGIS was used to determine the cut-off point of each interval using the Jenks Natural Break method and subsequently mapped using different colours to represent each of the four intervals. This method basically classifies data by minimising and maximising the variance within and between classes respectively (Jenks, 1967). Global Moran's Index spatial autocorrelation technique is used to investigate the extent to which neighbouring values of IR are correlated and to determine cholera demographic risk factors. The spatial weighing function was determined in respect to the length of the common boundaries by assuming that the states that are sharing longer boundaries are more interconnected than states sharing shorter one or no boundary at all (e.g., Borotto and Matinnez-Piedra, 2000).

The 36 states and FCT were classified into strata based on the following variables: geographic location; population density; poverty status; and adult literacy level according to the computed disease IR. Population-based ratios were then computed for each stratum for the identification of high risk areas, using the stratum with the lowest value of IR in each of the four variables as reference point. To determine the association between these variables and diseases' IR, Mantel-Haenszel *Chi Square* test was used.

Firstly, Nigeria is divided into six geopolitical regions namely: northwest, northeast, northcentral, southwest, southsouth, and southeast based on the country's geopolitical zones consisting of 7, 6, 7, 6, 6, and 5 states respectively. For the purpose of identifying regions with the high burden and risk of the selected diseases, this official regional classification is adopted. Secondly, population density for each of the 36 states and FCT per square kilometre was computed based on projected 2006 population census. Three strata namely: high, medium, and low densely populated were identified, with each consisting of 11, 11, and 15 states. Thirdly, four poverty strata were identified based on the mean of the percentage of population living in absolute poverty per state between 2000 and 2011. In Nigeria, absolute poverty is defined as the percentage of population with income less than a fixed proportion of median income. Classification was made based on states with very-high, high, medium, and low poverty, with each of the stratum consisting of 11, 11, 10, and 5 states respectively. And finally, states were stratified into four, based on mean percentage of population with adult literacy per state between 2000 and 2011. In Nigeria, adult literacy is measured on the ability to read and write with understanding, in English or in any of the Nigerian native languages. Classification was made as states with very-high, high, medium, and low literate adults, with each of the stratum consisting of 10, 7, 8, and 10 states respectively.

The study further investigate the time coherence in terms of interannual variability of both diseases within states in Nigeria, the state level annual cases between 2000 and 2011 were standardised for each state. An average standardised time series from the most affected states were generated for both diseases and correlated with individual states.

Table 1. Reported cholera cases and deaths, incidence rate per 100,000 of population and case fatality rates for Nigeria between 1991 and 2011

Year	*Cases*	*Deaths*	*IR*	*CFR%*
1991	61629	7711	63.4	12.5
1992	8687	663	8.7	7.6
1993	4160	266	4.1	6.4
1994	3171	471	3.0	14.9

Year	*Cases*	*Deaths*	*IR*	*CFR%*
1995	3364	140	3.1	4.2
1996	59134	4508	53.8	7.6
1997	13411	851	11.9	6.3
1998	9254	277	8.0	3.0
1999	22335	1776	18.9	8.1
2000	6354	253	5.3	4.1
2001	7383	374	6.0	5.1
2002	23441	478	18.5	2.0
2003	9335	375	7.2	4.1
2004	13522	149	10.2	1.1
2005	10785	262	7.9	2.4
2006	20526	362	14.7	1.8
2007	12197	185	8.5	1.5
2008	17854	428	12.1	2.4
2009	16913	552	11.2	3.3
2010	46782	1841	30.3	3.9
2011	23377	742	14.8	3.2

RESULTS

According to the WHO records between 1991 and 2011, Nigeria alone has reported over 380,699 cases of cholera and 28898 deaths, with a cumulative IR (248.3) and CFR (5.8%). Table 1 shows that within the 22-year period of data 59.3% and 76.8% of the total cases and deaths occurred in only 7 years (1991, 1996, 1999, 2003, 2006, and 2010). The highest number of cases (61,629 IR = 63.4) and deaths (7,711 CFR = 12.5%) occurred in 1991, while the lowest cases (3,171 IR = 3.0) and death (149, CFR = 1.1%) occurred in 1994 and 2004 respectively. Figure 2 allows for the visualisation of the disease trend between 1991 and 2011 which is characterised with about five peaks occurring in the intervals of about three years each.

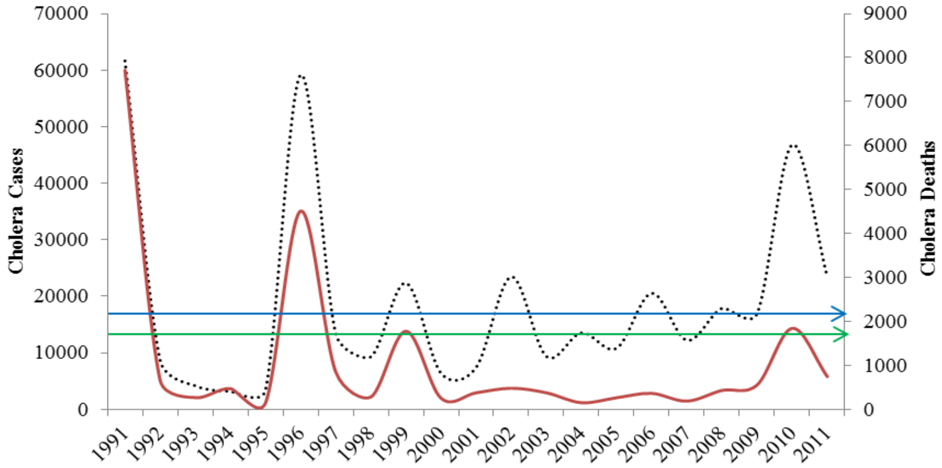


Figure 2. Annual cholera reported cases (dashed-black) and deaths (red) between 1991 and 2011 in Nigeria. The blue and green arrows indicate the average and standard deviation of cases respectively

Within the 12 years of data (2000 – 2011) over 57% and 67% of cases and deaths were reported from the northern states of the country (Adamawa, Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, and Sokoto). The most affected states in terms of cumulative IR are; Sokoto (38.9), Adamawa (34.2), Borno (33.4), and Gombe (28.4), while the least affected states are from the southern part of the country (Akwa Ibom (2.1), Oyo (2.1), Rivers (2.1), and Ogun (2.3).

The Global Moran's Index spatial autocorrelation reveals a statistically significant results (Moran's I = 0.211, z = 2.11, p = 0.004) which suggest a north to south gradient, with higher spatial clustering of IR occurring in the north eastern region of the country (Figure 3). Furthermore, spatial autocorrelation was computed for all years of available state level data and were all found to be statistically significant (p = 0.000 - 0.023) (Table 2).

Table 2. Global Moran's Index spatial autocorrelation computed for cumulative cholera incidence rate (2000 - 2011), and for each year between this period using state level data

Year	*Moran's Index*	*p-value*
2000	0.154	0.000
2001	0.234	0.002
2002	0.341	0.001
2003	0.034	0.011
2004	0.310	0.000
2005	0.072	0.013
2006	0.183	0.001
2007	0.146	0.023
2008	0.207	0.000
2009	0.173	0.012
2010	0.281	0.003
2011	0.150	0.001
2000-2011	0.211	0.004

The clustering of high rates of cholera was persistent in northeast and northwest regions in all the years shown in Figure 3. Table 3a shows that cholera incidence is 3.9 and 3.4 times higher in northeast and northwest regions respectively, if compared with the southeast region. *Chi Square* test shows cholera IR to have a direct relationship with absolute poverty (p = <0.05), population density (p = <0.01), and a negative but significant relationship with adult literacy (p = <0.05). Table 3a – d shows that the IR of the poorest and densely populated strata are 2.3 and 1.8 times higher than that of their respective lowest stratum, while in the adult literacy stratum, IR is 3.2 times higher in population with less educated literates if compared with that of the highly educated ones.

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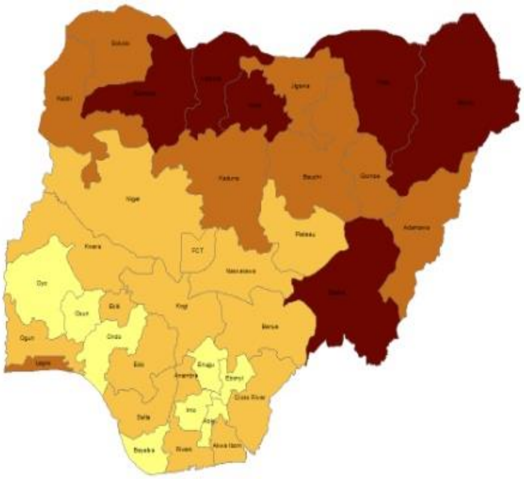
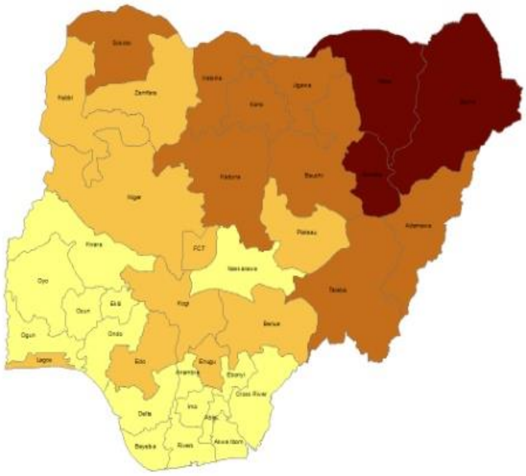
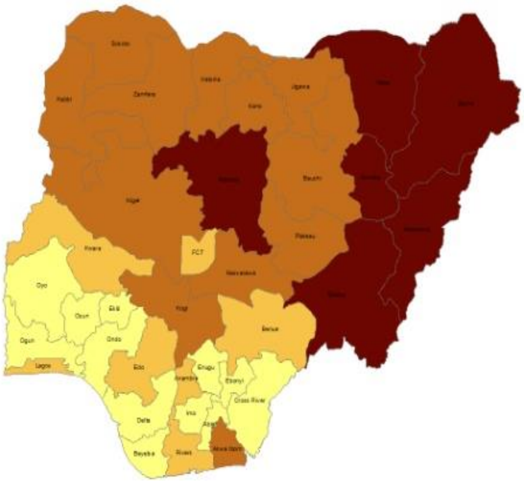
Cholera IR

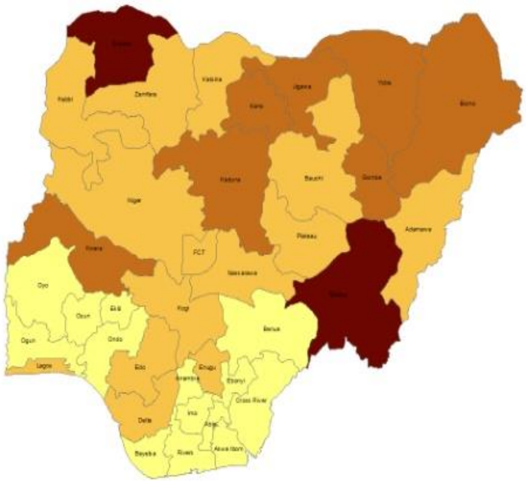
Cholera CFR



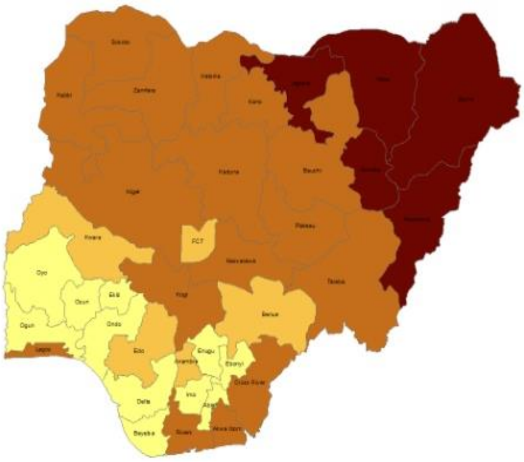


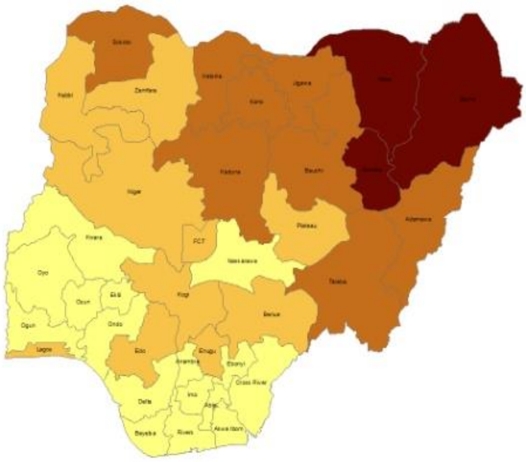
2002





2006





2010

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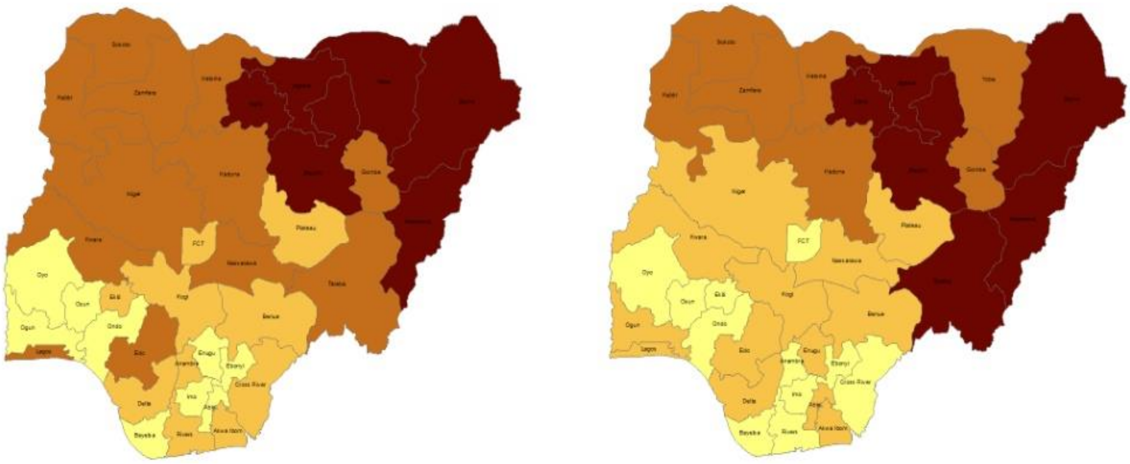

2000 - 2011

Legend	
Cholera IR	
	0.00 – 4.50
	4.60 – 14.0
	14.1 – 23.0
	23.1 – 38.9

Legend	
Cholera CFR (%)	
	0.00 – 4.50
	4.60 – 14.0
	14.1 – 23.0
	23.1 – 38.9

Figure 3. Spatial distribution of states level annual incidence rate per 100,000 for population (left) and case fatality rate (right) of cholera for 2003, 2006, 2009 and the cumulative incidence rate between 2000 and 2011

Figure 4 shows the time coherence of cholera interannual variability within states in Nigeria, obviously states from the north-eastern and north-western part of the country shows higher similarities in terms of the interannual variability of the disease with the reference time series (0.37 – 0.98). In the southern part of the country only Delta, Lagos, Enugu and Cross Rivers correlated well, while states such as Oyo, Ogun, Ebonyi, Anambra, Abia, Imo, and Benue shows very low or no correlation at all (0 – 0.2).

Table 3. Cholera incidence rate and population-based rate ratio by strata of states classified based on (a) geopolitical locations, (b) population density, (c) percentage of population living in absolute poverty, and (d) percentage of literate adults between 2000 and 2011

		a		
Geopolitical Region	*Cholera Cases*	*Population*	*IR (per 100,000)*	*Rate Ratio*
Northwest	80357	40497542	198.4	3.4
Northeast	48494	21469225	225.9	3.9
Northcentral	29208	22933883	127.4	2.2
Southsouth	18960	23780792	79.7	1.4
Southwest	20584	31212581	65.9	1.1
Southeast	10866	18538039	58.6	Reference
		b		
Population Density	*Cholera Cases*	*Population*	*IR (per 100,000)*	*Rate Ratio*
High	98163	57031901	172.1	1.8
Medium	57425	45166916	127.1	1.4
Low	52881	56233246	94.0	Reference

c				
Absolute Poverty %	*Cholera Cases*	*Population*	*IR (per 100,000)*	*Rate Ratio*
Low	23740	29360751	80.9	Reference
Medium	40859	39881488	102.5	1.3
High	69152	49548594	139.6	1.7
Very high	74718	39641231	188.5	2.3

d				
Adult Literacy %	*Cholera Cases*	*Population*	*IR (per 100,000)*	*Rate Ratio*
Low	101749	48912976	208.0	3.2
Medium	49855	29962622	166.4	2.6
High	21590	25446225	84.8	1.3
Very high	35275	54110240	65.2	Reference

DISCUSSIONS

For decades, cholera has remained important public health and social problem in Nigeria. The disease has become endemic in the poorest and less educated states of northern Nigeria; notably Borno, Zamfara, Bauchi, Kano, Katsina, Sokoto, Yobe and Adamawa. However, cholera also remains endemic in some of the southern states such as Lagos, Imo, Anambra and Delta. Lower IR and CFR were seen in the southern part of country. Analysing the spatial autocorrelation for individual years state level data (Table 2) showed that irrespective of epidemic or non-epidemic year, there is persistent significant positive clustering ($p<0.05$) of cases in the northern part of the country. Also time coherence in terms of the interannual variability of disease occurrence is seen most especially in the northern eastern part of the country (Figure 3).

Despite the fact that the high incidence of cholera is persistently occurring in the northern part of the country, however it does not reflect the uneven distribution as in the case of other infectious diseases in the country. Table 3a shows the IR and rate ratio of cholera with respect to the six geopolitical regions in the country, although the northeast region has the highest IR, but is only 3.9 times higher if compared with region with the lowest incidence (southeast). The clustering of cholera as illustrated in Figure 3 showed a consistent occurrence in the north eastern states of Adamawa, Borno, Yobe, and Gombe. The reason for this could be seen in the vicinity of Lake Chad basin which the states are neighbouring, the basin has been reported to be the most affected area in the West African region in terms of cholera incidence. Over 60% and 50% of cholera cases and deaths reported from West Africa in 2010 occurred in the countries (Nigeria, Chad, Niger, and Cameroon) surrounding the basin (IRIN, 2014). Risk of cholera from this basin might be connected to contamination from the lake, either from the water environment itself or from food contamination (Fewtrell et al., 2007). The epidemiology of cholera and risk related factors in this basin have been discussed in a collaborative study between Water, sanitation and hygiene (WASH) and UNICEF (Oger and Sudre, 2013).

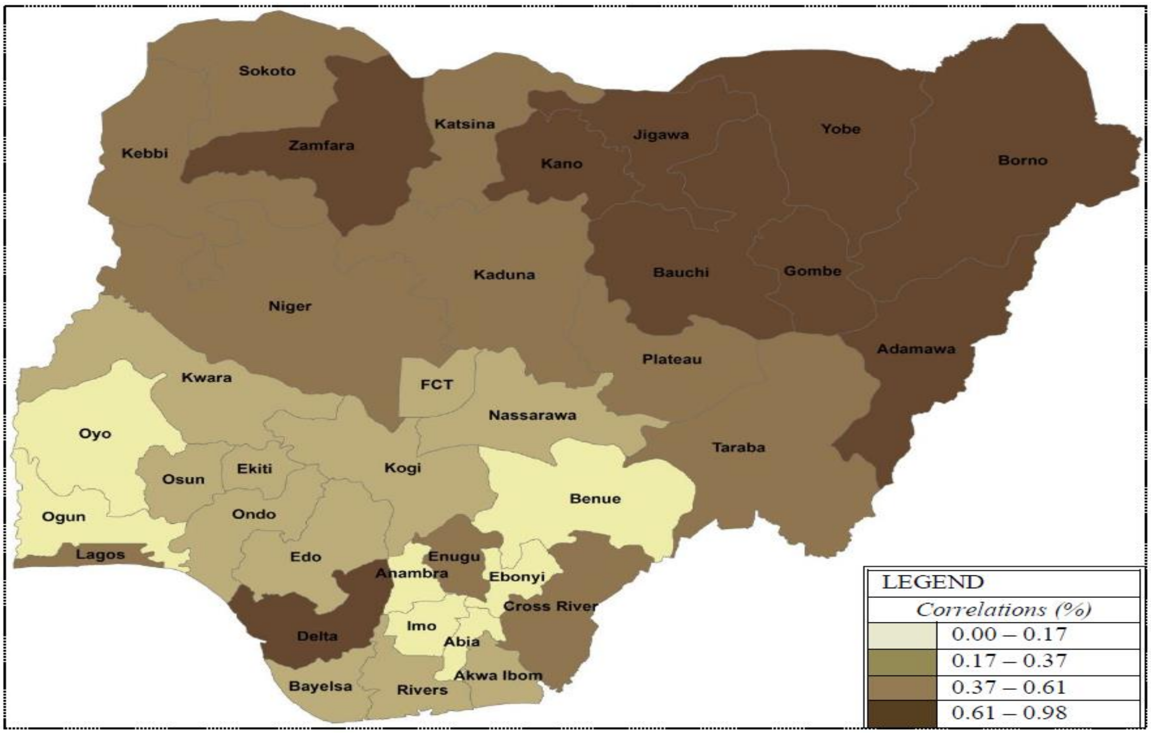

Figure 4. Time coherence of the interannual variability of standardised cholera cases within states of Nigeria between 2000 and 2011

Results from this study confirm that absolute poverty, adult literacy and population density are very important social factors in determining the spatial distribution of cholera in addition to climate. For example, previous studies have linked the incidence of cholera in population with less education (e.g, Hashizume et al., 2008), population density (e.g., Penrose et al., 2010), and poverty (e.g., Traeup, 2010). Cholera is known to proliferate in population with insufficient education and careless attitudes towards hygienic conditions, lack or limited access to safe drinking water, inadequate facilities for sewage disposal and treatment (Glass et al., 1992). Higher cholera IR and CFR may not be unconnected with these social factors, because most of the states with low adult literacy and high poverty are located in this region.

The result of the spatial autocorrelation should be treated with caution; this is because in Nigeria, national surveillance data may have been marred with uncertainties because of underreporting of cases, particularly in remote villages where access to health care facilities is difficult or totally absent. Population living in these areas tend not to report cases by resorting to traditional medication, and when death occurred they hurriedly buried the body without reporting. Another issue is the differences in sizes and shapes among the states which may affect the scales of spatial patterns that could be detected. Also the relatively small number of states (only 36 and FCT) may reduce the robustness of the spatial correlation.

CONCLUSION

This study analyses the pattern of cholera in Nigeria, and identified the hotspots of the disease in the country. Also, the study has confirmed the important role of social risk factors on the spatial distribution of this infectious disease. Geographical location, poverty, overcrowding and literacy status all appears to be linked to the spatiotemporal distribution of diseases in addition to climate. These results will help in identifying specific regions where research should be focused; it will also help in knowing where attention should be given in terms of human and resource allocation by relevant authorities.

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