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Analysis of the Re-emergence and Occurrence of Cholera in Lagos State, Nigeria

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Abstract. This paper analysed the factors responsible for the re-emergence of cholera and predicted the future occurrence of Cholera in Lagos State, Nigeria using factor analysis, multiple linear regression analysis and a cellular automata model for the prediction. The study revealed six Local Government Areas (LGAs) under very high threat, nine under low threat, and Surulere and some parts of Amuwo Odofin under medium threat in the near future. These areas have an average population of 200,000 people each with the total tending towards millions of people, all under threat of cholera occurring and re-emerging in their communities. The factors relating to the re-emergence of the disease were discovered to be environmental (rainfall, R^2=0.017, P<0.05 and temperature, R^2=0.525, P>0.05); socio-economic (household size R^2=0.816, P>0.05; income, $R^{2=}$0.880, P>0.05; and education, $R^{2=}$0.827, P>0.05). The Cellular Automata Markov Prediction model showed that by 2016, Lagos State will experience 79 cholera cases which will increase to 143 in 2020. This prediction model revealed that Ikorodu will record 40 cases, Apapa 12, Ojo 5, Mushin 3, while Amuwo-Odofin, Badagry and Ajeromi-Ifelodun LGAs will each record 2 cases between 2011 and 2016. The study concludes that there is a cholera threat in Lagos State and the factors of vulnerability that predispose people to the disease must be tackled over time and space for effective prevention, control and management of the disease.

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1. Introduction

Transmission of infectious diseases has exhibited new spatial and temporal dimensions, hence new diseases have emerged and spread rapidly (Xu et al., 2004). Existing endemic infectious diseases are found to be transmitted in new areas; it is recognized that the transmission of many endemic diseases is being strengthened and accelerated due to the globalization of human activities and environmental change (Xu et al., 2006). According to WHO (2012), poor conditions of health and healthcare are among the factors responsible for the average life expectancy of 47 years in Nigeria. UNICEF (2007) reported that Nigeria is one of the countries in which cholera, polio, measles, tuberculosis, and whooping cough are still present as public health problems.

The current cholera pandemic started in 1961, reaching West Africa and Nigeria in 1970. The first recorded cases of cholera in Nigeria occurred in a village near Lagos State in 1970, leading to an epidemic of 22,931 cases and 2,945 deaths with a case fatality rate of 12.8% in 1971 (WHO, 2012). The high mortality figure due to cholera endemicity revealed that Nigeria is one of the developing countries where cholera continues to constitute a health burden. The high mortality rate could be attributed to lack of sanitation and amenities such as a potable water supply. The United Nations (UN) standards state that a family of four (4) needs 1,560 gallons of water to survive for 30 days. Hence, a person requires 8.6 gallons of water per day; but this amount of potable water is not usually available for use in almost all parts of Lagos State, Nigeria.

In recent times, cases of cholera have been rising and this has constituted a challenge to public health in major urban cities in Nigeria, Lagos included. Reports indicate that some Local Government Areas (LGAs) of Lagos State are experiencing an insurgence of cholera prevalence. For instance, in 2010, cholera outbreaks affected 157 LGAs in Nigeria: a total of 26,240 cases were recorded, 1,182 deaths and a Case Fatality Rate of 4.5 (Adagbada et al., 2012).

This study is based on the concept of human ecology of diseases as presented by May (1958). The world is undergoing rapid change as human-environment relations evolve, global interdependency increases, and previously stable equilibriums are disrupted. Meade and Earickson (2001) opined that one of the consequences of these global changes is that infectious diseases, once thought to be on the wane, are still very much a source of concern both within developed and developing countries. Sack et al. (2004) posited that cholera infection is very much a cause for concern in some places, and for alarm in other places. For a disease to occur there must be interaction between the disease agent, the human and the environment. These factors must act together to bring about the occurrence of a disease. In this case, the Vibrio cholerae (disease agent), the host (human agent) and the environment (physical and social) must have a close relationship. The environment plays a great role as it conciliates the interactions and determines the spatial location of cholera occurrence and resulting populations at risk.

The WHO (1996) asserted that human ecology and human behaviour are the two key factors that determine the transmission of human infectious diseases. In the developing world, scarcity of basic needs such as shelter, food, clothing, electricity, clean water, education, and healthcare is the dominant factor in disease transmission. Cholera thrives more in dirty environments lacking all these basic needs.

Despite the high rate of occurrences, there has not been adequate effort at identifying the factors of vulnerability to cholera on a local level in Lagos State; particularly the environmental, socio-economic and behavioural factors of vulnerability to the disease which could help to predict the future occurrence and control of the disease in the State. Therefore, the objectives of this study are to analyse the factors of vulnerability to cholera and predict its future occurrence; with a view to providing a framework for effective control of the disease in the State. The imperativeness of studies on the spatial patterns, transmission, and vulnerability factors of diseases cannot be overemphasised; remote sensing and GIS analytical techniques provide a good basis for such.

2. Research Materials and Methods

Primary and secondary data were used for the study. The primary data involved the use of a Global Positioning System (GPS) receiver to obtain the coordinates of relevant phenomena, and a questionnaire to obtain information on cholera occurrence, possible risk factors and probable solutions to the menace of the disease. The secondary data used included topographical maps (scale 1: 50,000) covering the study area, reported cases of cholera, administrative and political maps obtained from the various Local Government Town Planning Offices in the State; the population figures of the LGAs obtained from the National Population Commission; rainfall and temperature data obtained from the Nigerian Meteorological Agency, Lagos, between 2001 and 2011.

The multi-stage sampling procedure was employed to select respondents to the questionnaire. First, Eti-osa, Ikeja and Mushin LGAs were purposively selected for the study based on their socio-economic status in relation to population density. Mushin was chosen to represent the low income/high density LGAs, Ikeja represented the medium income/medium density LGAs and Eti-osa represented the high income/low density LGAs. Second, two wards were randomly selected from each of the three selected LGAs, making a total of six wards. Third, in each selected ward, the households interviewed were randomly selected using the NPC's 2006 household record as frame {(No. of households per LGA/ No. of households in the 3 LGAs)* 543}. In each selected household, the mother of the household was interviewed. A set of 543 questionnaires were administered representing 20% of the total number of households in the study area. The number of questionnaires administered in each LGA was proportionate to the population. Hence, 162, 185 and 196 copies of the questionnaire were administered in Eti-osa, Ikeja and Mushin LGAs respectively.

Descriptive statistics, inferential statistics and Geo-spatial techniques were used to analyse the data collected. Specifically, the descriptive techniques involved the use of frequencies, cross tabulations, charts and diagrams to describe the demographic, socio-economic characteristics and people's perception of cholera. Inferential statistics involved the use of correlation analysis to establish the relationship between vulnerability factors and cholera occurrence. In identifying the relevant factors of vulnerability to cholera in the study site, Principal Component Analysis/Factor Analysis (PCA/FA) was employed. Also, the prediction of the occurrence of cholera was done using Factor Analysis and the Cellular Automata Markov System in the IDRISI environment. Details of specific analyses are given at relevant sections of the paper.

2.1. Study Area

Lagos State, situated in the south-western corner of Nigeria constitutes the study area. The State lies within Latitudes 6°23' N and 6°41' N and Longitudes 2°42' E and 3°42' E. The State is flanked from the north and east by Ogun State, Nigeria; in the west by the Republic of Benin and the south by the Atlantic Ocean/Gulf of Guinea (Fig. 1). The total landmass of the State is about 3,345 square kilometres, which is just about 0.4% of the total land area of Nigeria. Most of the land in Lagos State has an elevation of less than 15m above sea level. Lagos State comprises 20 Local Government Areas (LGAs) and several healthcare facilities located at different strategic areas of the State.

The total population of Lagos State was 9,013,534 in 2006 (NPC, 2006). The UN estimates that at its present growth rate, Lagos will be the third largest mega city in the world by 2015 after Tokyo, Japan and Bombay, India. Out of this population, Metropolitan

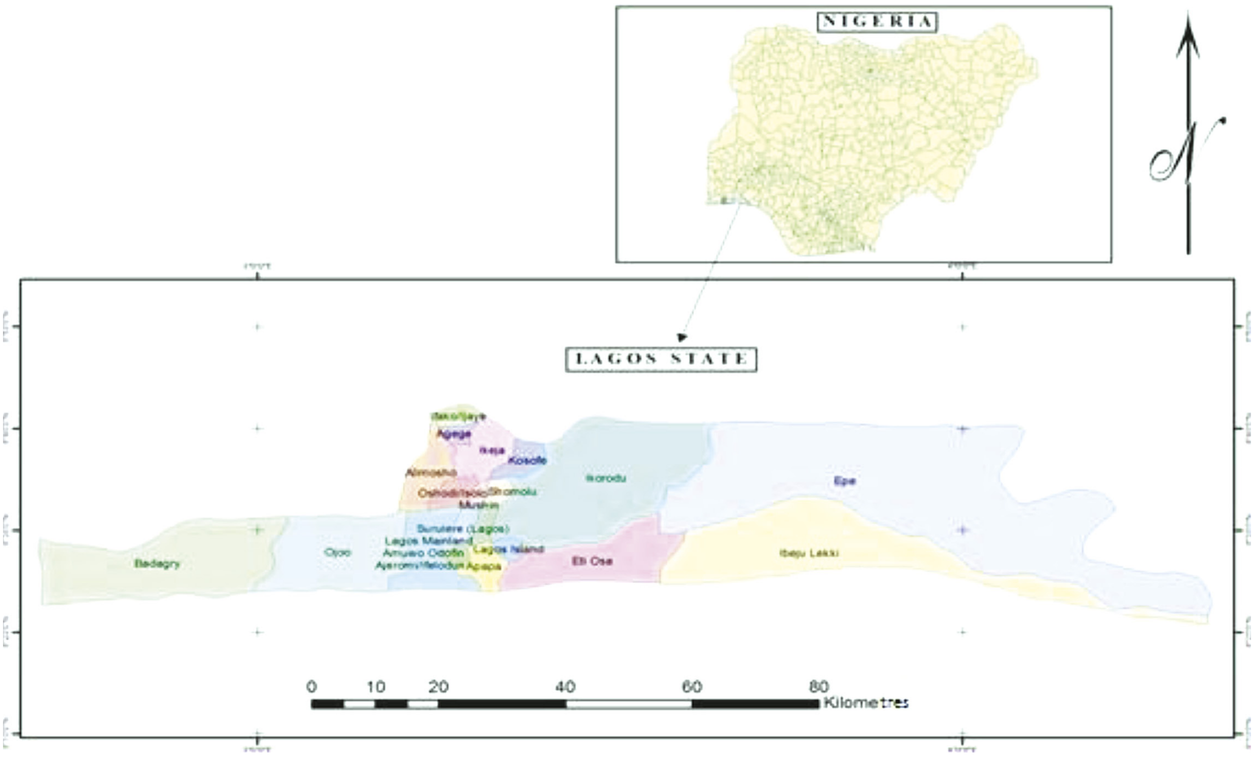

Fig. 1. Map of Lagos State in relation to the map of Nigeria

Source: Developed by authors based on data available at the Office of the Surveyor General, Lagos State

Lagos, an area covering 37% of the land area of Lagos State is home to over 85% of the State's population. The rate of population growth is about 600,000 per annum and the population density is about 4,193 persons per square kilometres. In the built-up areas of metropolitan Lagos, the average density is over 20,000 persons per square km (www.lagosstate.gov.ng).

The climate is the wet equatorial type influenced by nearness to the Equator and the Atlantic. Lagos experiences both the rainy and dry seasons in any given year. On average, the rainy season occurs between April and October; while the dry season occurs between November and March. Normally, flooding occurs at the peak of the rainy season. This is aggravated by the poor surface drainage systems of the coastal lowlands. Lagos State has a constant high temperature, with a mean monthly maximum temperature of about 30°C.

Lagos is undoubtedly the commercial nerve-centre of Nigeria (and possibly Africa), with the largest concentration of industries, even though the administrative and political headquarters of the country have been transferred to Abuja. The State still accounts for more than 70% of the nation's industrial and commercial establishments. The two major seaports in Nigeria, namely Apapa port and Tin-can Island port are in Lagos metropolis. Also, the busiest international airport in the country (Murtala Mohammed International Airport (MMA)) is located in Lagos. Similarly, the domestic wing of the airport, the busiest in the country is located in Lagos. The State has numerous functional primary and secondary healthcare facilities and a teaching hospital.

3. Results and Discussion

3.1. Factors responsible for the re-emergence of cholera

The persistence and re-emergence of cholera in some parts of Lagos State have continued to constitute a public health problem in Lagos State. A trend analysis of cholera occurrence in the State has shown that some LGAs are experiencing an insurgence of cholera. Three factors of vulnerability were identified: environmental, socio-economic, and behavioural. In identifying the three factors of vulnerability in the study site, Principal Component Analysis/Factor Analysis (PCA/FA) was employed to reduce to just seven the twenty one observable variables capable of explaining the re-emergence of cholera in Lagos State. The Varimax rotation method with Kaiser Normalization was used in this study. Rotation converged in 9 iterations. Seven factors were extracted which explained **74.6**% of the total variance. Table 1 presents the twenty one variables that were loaded for factor analysis.

Table 1. Variables' Names

Symbol	Variable name
Var00001	Age
Var00002	Education
Var00003	Income
Var00004	Household
Var00005	Age of cholera infected person
Var00006	Number of occurrences of Malaria fever per month
Var00007	Number of occurrences of Sores/injuries/accidents per month
Var00008	Number of occurrences of Typhoid per month
Var00009	Number of occurrences of Cholera per month
Var00010	Number of occurrences of Scabies/skin rashes per month
Var00011	Number of occurrences of Diarrhoea per month
Var00012	Number of occurrences of Chicken pox per month
Var00013	Number of occurrences of Measles per month
Var00014	Number of occurrences of Whooping cough per month
Var00015	Number of occurrences of flooding per month
Var00016	Perception of air pollution
Var00017	Perception of waste disposal system efficiency
Var00018	Perception of access to potable water
Var00019	Perception of adequacy of potable water
Var00020	How often do you treat water before drinking?
Var00021	How many persons per room in your household?

Source: Field Survey, 2012

The rule of thumb as opined by Comrey and Lee (1992) suggested that loading values in excess of 0.71 (50% overlapping variance), 0.63 (40% overlapping variance), 0.55 (30% overlapping variance), 0.45 (20% overlapping variance) and 0.32 (10% variance) are considered excellent, very good, good, fair and poor respectively. Tabachnick and Fidell (1996) suggested that variables with loadings 0.32 and above may be interpreted. In similar studies carried out so far, Olayiwola (1990) used 0.32, Adeyinka (2007) used 0.55, Adetoso (2007) used 0.63 and as such this research work used 0.55, which is considered to be good as it has 30% overlapping variance. Thus, all items with primary loadings over 0.55 were observed for factor analysis in this study.

3.1.1. Environmental Factors of Vulnerability to Cholera

The environmental factors considered included rainfall and temperature. The environmental causes of cholera include sanitation, refuse dumps, terrain, flooding, sources of drinking water and sewage disposal systems. The environment is usually degraded, unsanitary and almost blighted in most parts of Mushin LGA. The increasing amount of rainfall yearly is a major factor in the re-emergence of cholera (Fig. 2). The changing magnitude of rainfall by the year brings about a great deal of flooding in most areas of the State especially in the high density areas with overdevelopment of land. Also, due to overcrowding in those areas, there is high demand for land and hence a scramble for space. Open spaces and drainage areas are never left unexploited for their appropriate uses. This often results in flooding and associated consequences. The floods contaminate sources of drinking water and thus the re-emergence of cholera with increasing and prolonged rainfall.

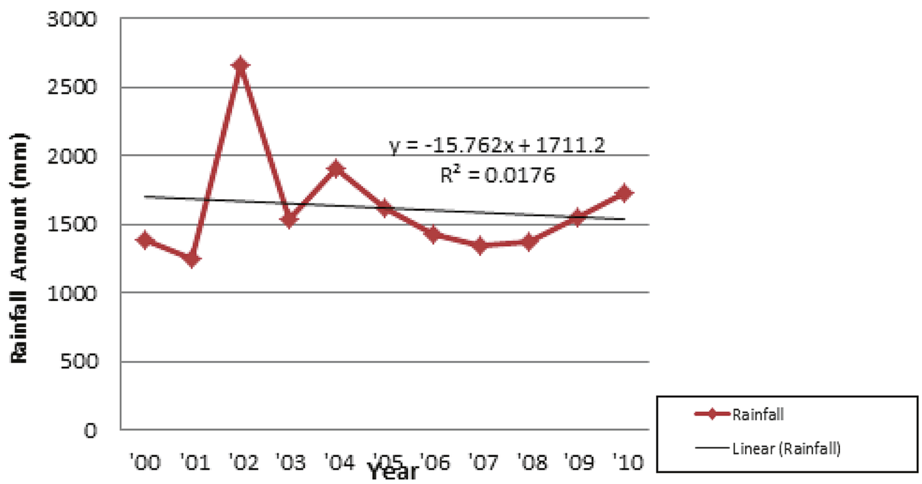

Fig. 2. Annual Amount of Rainfall in Lagos State

Explanation: Annual Amount of Rainfall in mm from 2001 to 2010

Source: Developed by the authors based on data available at Nigerian Meteorological Agency

Another major environmental factor in the re-emergence of cholera is temperature. Lately due to increasing climate change and global warming, the heat of the earth is apparently becoming more intense as the years go by. Cholera prevails more in higher temperatures than lower ones. With a mean minimum and maximum temperature of 24.1°C and 31.6°C, respectively, obtainable in the area, the effect of high temperatures in relation to other factors such as overcrowding and unsanitary environment makes inhabitants vulnerable to cholera outbreaks.

Fig. 3. Average Annual Temperature

Explanation: Annual Temperature in °C from 2001 to 2010

Source: Developed by the authors based on data available at Nigerian Meteorological Agency, 2012

A rise in temperature was recorded between 2001 and 2005 (Fig. 3) with the highest average in 2003 (28.1°C). These were periods of high cholera occurrence in most parts of the State (Table 2).

Table 2. Total Occurrence of Cholera in Lagos State between 2001 and 2011

LGA	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Lagos Mainland	0	0	0	0	0	0	0	0	0	0	14	14
Lagos Island	0	0	0	14	0	0	2	0	1	0	20	37
Amuwo Odofin	0	0	0	6	2	0	0	0	0	0	0	8
Oshodi	0	0	0	0	0	0	0	0	1	0	2	3
Agege	0	0	1	0	0	0	0	0	0	0	0	1
Shomolu	0	0	0	7	3	0	0	0	1	0	3	14
Apapa	0	0	27	24	0	0	0	0	0	0	0	51
Surulere	0	0	0	0	0	0	0	0	0	0	2	2
Ikorodu	0	0	0	112	0	0	0	0	0	0	0	112
Alimosho	0	0	0	0	1	0	0	0	1	0	0	2
Ajeromi	0	0	0	0	11	0	0	0	0	0	0	11
Badagry	0	0	0	10	1	0	0	0	0	0	0	11
Ojo	0	0	25	0	15	0	0	16	0	0	0	56
Ikeja	0	5	0	0	1	0	0	0	2	0	0	8
Mushin	0	0	0	0	20	0	0	0	0	0	0	20
Eti-Osa	0	0	0	0	0	0	20	0	1	4	0	25
TOTAL	0	5	53	173	54	0	22	16	7	4	41	375

Source: Lagos State Ministry of Health

The summary of rainfall and temperature in relation to cholera occurrence in the study site showed that cholera occurrences were high in the periods with high records of average temperature and increased rainfall amount as shown in Figures 2 and 3. The reports of cholera occurrence in Eti-osa, Ikeja and Mushin were analysed in relation to rainfall and temperature to examine the hypothesis stated below:

H_0 = There is no significant relationship between the occurrence of cholera in the study site and factors of rainfall and temperature.

H_a = there is a significant relationship between the occurrence of cholera in the study site and factors of rainfall and temperature.

In order to ascertain the relationship between the occurrence of cholera in the study area and environmental factors (rainfall and temperature); records of cholera occurrence in Eti-osa, Ikeja and Mushin in relation to rainfall and temperature were analysed (Tables 3 and 4).

Table 3 revealed the descriptive statistics and analysis results of cholera occurrence in Eti-osa, Ikeja and Mushin in relation to rainfall and temperature. In Table 3 the multiple regression model with all five predictors (i.e. *temperature, Eti-osa cholera, Mushin cholera, Ikeja cholera, rainfall)* produced R^2 = .372, F =.593, p > .001. The regression (***R = 0.610***) indicated that there exists a moderately strong correlation between years as dependent variables and the predictors ($x_{1...}$ x_5). The coefficient of multiple determinations is 0.372. This implies therefore that about 37.2% of the variation in *years (y)* is explained by its predictors.

Table 3. Model Summary of the Relationship between the Occurrence of Cholera and Factors of Rainfall and Temperature

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.610[a]	.372	-.255	3.716

Explanation: a – Predictors: (Constant), temperature, Eti-Osa cholera, Mushin cholera, Ikeja cholera, rainfall

Source: Authors' Calculations

Table 4. ANOVA[a] of the Relationship between the Occurrence of Cholera in the study site and Factors of Rainfall and Temperature

	Model	Sum of Squares	Df	Mean Square	F	Sig.
	Regression	40.964	5	8.193	.593	.710
1	Residual	69.036	5	13.807		
	Total	110.000	10			

Explanation: a – Dependent Variable: Years

Source: Authors' Calculations

The Null Hypotheses H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ and the alternative one *Ha:* at least one $\beta_1 \neq 0$ are succinctly stated thus: At Significance Level $\alpha = 0.05$, reject the null hypothesis if p-value ≤ 0.05. From the ANOVA Table **(Test Statistic and p-value)** (Table 4) F = 0.593, p-value > 0.001. It could therefore be concluded that since p-value < 0.001 ≤ 0.05, the null hypothesis was accepted. At $\alpha = 0.05$ level of significance, therefore, the model is useful for the prediction of cholera outbreaks in the study area.

In addition to the foregoing, residents of the study area reported that they are consistently faced with problems such as flooding, pollution and other environmental problems (Table 5). Respondents in Ikeja (55.5%), Mushin (53.7%) and Eti-Osa (60%) LGAs reported that flooding was a major environmental concern. Water pollution accounted for 28.5%, 25.2% and 28% of the environmental problems; while air pollution accounted for 5.8%, 5.7% and 8% of environmental problems in Ikeja, Mushin and Eti-Osa LGAs respectively; other environmental problems such as bushy paths along the road and oozing odours from the gutter accounted for 10.2%, 15.4% and 4% in Ikeja, Mushin and Eti-Osa respectively. In the factor analysis, *Factors five and six* (sewerage system and drinking water) had three variables each loaded on them. The eigenvalues of these variables are 1.911 and 1.830, which accounted for 9.099% and 8.716% respectively of the entire seven factors. In cumulative terms, the entire factors – up to factor six – are accounted for by 67.434% of the entire factors. These variables as revealed in Table 4 suggested the re-emergence of cholera in Lagos State as influenced by physical-environmental factors.

Table 5. Environmental Problems Reported by People in Lagos State (%), 2012

Problems	Ikeja	Mushin	Eti-osa	Total Average
Flooding	55.5	53.7	60	56.4
Water Pollution	28.5	25.2	28	27.2
Air pollution	5.8	5.7	8	6.5
Other environmental problems	10.2	15.4	4	9.9
Total	100	100	100	100

Source: Authors' Calculations

3.1.2. Socio-economic Factors of Vulnerability to Cholera

The examination of residents' social, economic and demographic attributes in a perception study cannot be underestimated. Thus, attributes such as gender, age, education, marital status, income status and household size, as well as obtainable factors of susceptibility and length of stay of residents in the study area were examined.

The factor analysis from a rotated component matrix (Table 6) revealed that three variables collapsed on factor two (population, education). The eigenvalue as obtained for *factor two* and *factor three* are 2.316 and 2.200 respectively and these accounted for 11.029% and 10.478% of the entire seven factors. These were *household size **(0.816)**, number of persons per room **(0.641)** and number of occurrences of scabies/rashes **(-0.570)***. Factor three had only two variables loaded on it. These are average monthly income ***(0.880)*** and education ***(0.827)***. This loadings pattern as established in the rotated component matrix informed that *factor two and factor three* (education and level of income) connote ***socio-economic factors***. It may be posited therefore that apart from health factors, socio-economic factors are also responsible for the re-occurrence of cholera in Lagos State.

Correlation values revealed that there exists a fairly strong positive correlation among cholera re-emergence and that of malaria fever, typhoid fever, measles and whooping cough. The coefficients of multiple determinations of these relationships are 0.121, 0.062, 0.065 and 0.0576, meaning that about 12%, 6%, 6% and 5% of the variation in the re-emergence of cholera are explained by refuse dump distance to kitchen/dining/living rooms, access to health care facilities, quality of water sources for domestic uses and how often residents wash kitchen utensils/used cutleries.

3.1.3. Behavioural Factors of Vulnerability to Cholera

Behavioural factors of vulnerability considered in the study include hygiene of the people, people's perception about cholera, adequacy of healthcare facilities and distance of health centres from residents. Five variables were collapsed on a *factor* and the loadings pattern on factor analysis suggested that the factor connotes **health behaviour factors**.

As indicated in Table 6, the eigenvalue for *factor one* and *factor four* are 3.872 and 2.032 respectively, which accounted for 18.438% and 9.675% respectively of all seven factors. These variables as collapsed on factor one had various disease variables. These were number of occurrences of typhoid **(0.906)**, number of occurrences of measles **(0.810)**, number of occurrences of whooping cough **(0.717)**, number of occurrences of Sores/injuries/accidents **(0.699)** and number of occurrences of malaria fever **(0.672).** Similarly, factor four had three variables loaded on it. These are number of occurrences of diarrhoea **(0.819)**, number of occurrences of chicken pox **(0.591)** and age of the cholera infected person **(0.558)**. These loadings patterns suggested that factor one and four connote **health behaviour factors**. This implies that one of the factors responsible for the re-emergence of cholera in Lagos State is the behavioural/ /health factor.

Table 6. Rotated Component Matrix of Cholera prevalence variables, 2012

	Components						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Number of times per week drainage/surroundings are disinfected	.906	.016	.100	-.301	.002	-.008	-.002
Number of times per week toilets are disinfected	.810	.052	.054	.046	-.105	.015	.074
Number of times per week kitchens are cleaned	.717	-.081	-.092	.519	.010	.073	-.074
Distance between refuse dump point and kitchen	.699	.073	-.174	.146	-.042	-.140	-.113
Distance between refuse dump point and source of water for domestic use	.672	-.433	.003	.127	.311	.102	.163
Population density of the area	.254	.816	.063	.060	.100	-.012	.095
Occupancy ratio	-.375	.641	-.276	-.035	.059	.175	-.107
How soon used kitchen utensils are washed	.533	-.570	-.352	.103	-.180	.089	-.048
Average Monthly Income	-.061	-.026	.880	-.064	-.046	-.079	-.115
Education Level	.025	-.002	.827	.216	.092	.056	.344
Health care service adequacy	.090	.333	.140	.819	.009	-.136	-.100
Health care facilities accessibility	.320	-.397	-.373	.591	.017	.077	-.162
Age of Cholera infected person	-.078	-.377	.129	.558	.024	-.087	.199
Level of awareness of cholera	-.126	.088	-.074	.098	.848	-.212	.036
Level of vulnerability to contaminant	.005	-.238	-.084	.033	-.711	-.126	.452
Number of times of occurrence of Cholera	.482	-.188	.290	-.352	.526	.140	-.009
Quality of source of water for domestic use	-.134	.106	.177	.048	-.155	-.770	-.046
Quality of sewerage system	-.154	.047	.034	-.098	-.209	.685	.325
How often do you treat water before drinking?	.001	.240	.296	-.050	-.321	.619	-.268
Perception of adequacy of potable water	-.192	.360	-.285	.287	.243	.408	.349
Age distribution	.040	.038	.121	-.053	-.114	.146	.848
Eigenvalue	3.872	2.316	2.200	2.032	1.911	1.830	1.508
% of Variance	18.438	11.029	10.478	9.675	9.099	8.716	7.176
Cumulative %	18.438	29.466	39.944	49.619	58.719	67.434	74.613

Explanation: Extraction Method (used for the Factor Analysis):
Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization.
Source: Authors' Calculations

3.2. Prediction of the future occurrence of cholera in Lagos State

One of the statistical tools that can be used to predict occurrence is multiple linear regression (MLR) analysis. In line with the suggestions of Yvan et al., (2003) variables such as occupancy ratio (number of persons per room in the household), number of occurrences, pollution, age of cholera infected persons, perception of adequacy and access to potable water, treatment of water before drinking, average monthly income, perception of efficiency of waste disposal, household size, and literacy level were used as independent variables; and occurrence of cholera as a dependent variable to generate a model that could be used to predict future occurrence.

A geospatial approach was employed for spatial prediction. The possible pattern of cholera in the worst case scenario in Lagos State between 2011 and 2016 was analysed. With all situations remaining the same and all factors of vulnerability consistent in the study area between 2001 and 2016, the potential cholera situation in the state will leave many areas at high risk of cholera prevalence as shown in Figure 4.

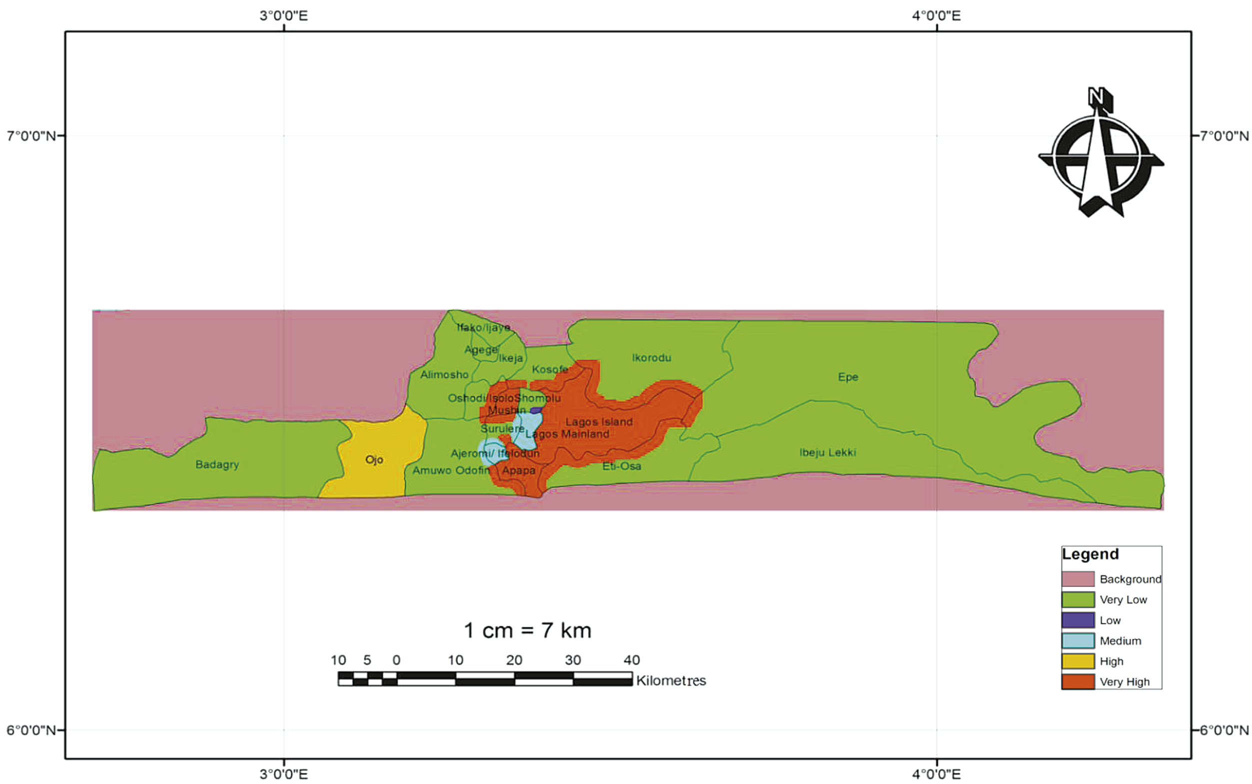

Fig. 4. Predicted Cholera Occurrence in Lagos State, 2016

Source: Authors' Computation

Using IDRISI, the technique was largely based on discriminant analytical and maximum likelihood methods which use known presence and absence distribution data to 'train' the prediction process – in essence by establishing statistical relationships between the predictor (satellite image) variables and the observed fly presence/absence data. Output was given as the probability of presence for each sample point.

The Markov chain was used to generate a probability table of values from 0 to 1. Two cholera spatial data of an earlier and later year (2005 and 2011) were converted to raster format using the IDRISI software. The attribute data of the images also contained the observed and operating factors of vulnerability and re-emergence of cholera in the State. The values on a row of the image (range = 0 - 1) represents the class values of the image and the probability that one class will change or remain the same. Any value above 0.5 on the probability table denotes a strong probability. A projected value of 5 years from 2011 was computed for projection. Cellular Automata Markov was adopted to generate the spatial distribution and output presented in Figure 4. Results showed that six Local Government Areas – Mushin, Shomolu, Lagos Island, Oshodi/Isolo, Kosofe and Apapa LGAs – are under a very high threat of cholera prevalence as the year runs by if adequate control measures are not adopted. Clearly, these areas are close to each other and the disease is seen to have diffused through these areas with high vulnerability components. Places like Ojo and Amuwo-Odofin LGAs are also under high threat. The low threat areas include Ikeja, Eti-Osa, Epe, Ifako/Ijaye, Ibeju-Lekki, Badagry, Agege, Ikorodu and Alimosho LGAs while Surulere LGA is under medium threat.

4. Conclusions

Total hygiene is the recommended strategy for control. This is because the cholera vaccine so far available only gives protection for 3-6 months. Long term vaccine protection is yet to be discovered. Therefore, vaccination is not a popular recommendation for the control of cholera because it may give a false sense of security to those vaccinated, the general public and health authorities, who may become complacent.

Efforts of the State Government in reinstating public toilets, especially in the low income areas, are highly commendable. This has had a positive effect on the sanitary situation in the State. However, relevant authorities should also intensify efforts in providing potable water to communities for drinking and sundry uses.

The findings of this study have shown that cholera transmits through several pathways. The key to preventing its spread is limiting the growth and survival of the organism that causes it. Outbreaks can be minimized by educating the public about food and water safety, the importance of hand washing, the need to use water closet toilets and well developed soak away systems of waste disposal. And vaccination should not replace standard prevention and control measures. Drinks (including water) sold in cups, nylon, and even bottles may not be safe for consumption. Therefore regulatory agencies should see to it that unhygienic food items are not sold to people for consumption.

The study results suggest that there are 'cholera hot-spots' in the State. Relevant authorities and stakeholders should take this into consideration, particularly the results of this study, when planning cholera control measures. Cholera Risk maps should be produced and updated on a regular basis as new data emerges. Maps have always been a precursor to monitoring, evaluation and interventions in epidemiological control. Identifying geographic risk factors and populations at risk are all critical steps towards disease eradication. The risk map created in the effort to predict the occurrences of cholera in the study area showed areas at risk of cholera. Areas marked high and very high on the prediction map are the hottest spots that require immediate attention. Care should also be taken to manage areas with medium and low cases because these areas could embrace more cholera vulnerability factors that could intensify cholera conditions in such areas.

The study concludes that there is a cholera threat in Lagos State and the factors of vulnerability that predispose people to the disease must be tackled over time and space for effective control and management.

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