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Climate and socioeconomic influences on interannual variability of cholera in Nigeria

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ABSTRACT

Cholera is one of the most important climate sensitive diseases in Nigeria that pose a threat to public health because of its fatality and endemic nature. This study aims to investigate the influences of meteorological and socioeconomic factors on the spatiotemporal variability of cholera morbidity and mortality in Nigeria. Stepwise multiple regression and generalised additive models were fitted for individual states as well as for three groups of the states based on annual precipitation. Different meteorological variables were analysed, taking into account socioeconomic factors that are potentially enhancing vulnerability (e.g. absolute poverty, adult literacy, access to pipe borne water). Results quantify the influence of both climate and socioeconomic variables in explaining the spatial and temporal variability of the disease incidence and mortality. Regional importance of different factors is revealed, which will allow further insight into the disease dynamics. Additionally, cross validated models suggest a strong possibility of disease prediction, which will help authorities to put effective control measures in place which depend on prevention, and or efficient response.

1. Introduction

The link between climate and specific infectious diseases has been observed for over a century. One of these meteorologically-sensitive infectious diseases that remain a major health burden in Nigeria for several decades is cholera. The influence of climate on cholera dynamic has been well documented in literature, for example, in Asia (e.g., Bouma and Pascual, 2001; Pascual et al., 2000), South America (e.g., Colwell, 1996; Speelmon et al., 2000), and in Africa (e.g., De Magny et al., 2012; Fernandez et al., 2009; Traerup, 2010). On seasonal time scales cholera, as other diseases in Nigeria (e.g., Olouko et al., 2014), shows a seasonality with increased burdens from May to August. Additionally, social risk factors are playing an important role in transmission and outbreak of cholera, for example, the disease has been termed the 'disease of poverty' (Charles and Ryan, 2011; Snowden, 2008) and was associated with inadequate environmental sanitation conditions and untreated drinking water (e.g., Ali et al., 2002a, 2002b; Hashizume et al., 2007; Penrose et al., 2010; Rajendran et al., 2011; Reiner et al., 2012; Talavera and Perez, 2009). Previous studies have demonstrated the possibility of predicting cholera epidemics (e.g., Reyburn et al., 2011), however, the importance of combining the effects of social risk factors in addition to meteorological conditions in studying the dynamics of the disease has been pointed out (e.g., Pascual et al., 2000; Chou et al., 2010).

In Nigeria, cholera is one of the primary causes of morbidity and mortality, with incidence occurring in both small outbreaks and 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 level, population congestion, and internal conflicts which may results to population displacement to Internally Displaced Persons (IDP) camps. Provision of safe drinking water remains a serious issue of concern and this necessitate people even in cities to buy street vended water which has the high risk of being contaminated. Typical areas at risk might include population living in urban and peri-urban slums, these areas are mostly densely populated by low income earners and basic infrastructures are not readily available. Despite the availability of the oral cholera vaccines, anecdotal evidence reveals that this effective control method is not yet commonly used in Nigeria. The main control method is mainly treatment through rehydration with oral salts after infection (WHO, 2011).

The current study aims to statistically model the influences of meteorological and socioeconomic factors on the interannual and spatiotemporal variability of cholera disease in Nigeria. Despite the fact Nigeria is reporting the largest number of cholera of cases and deaths to WHO (WHO, 2012), this study is the first to investigate this type of relationship. The model development and results are based on 22-years (1990–2011) of clinically diagnosed hospital-

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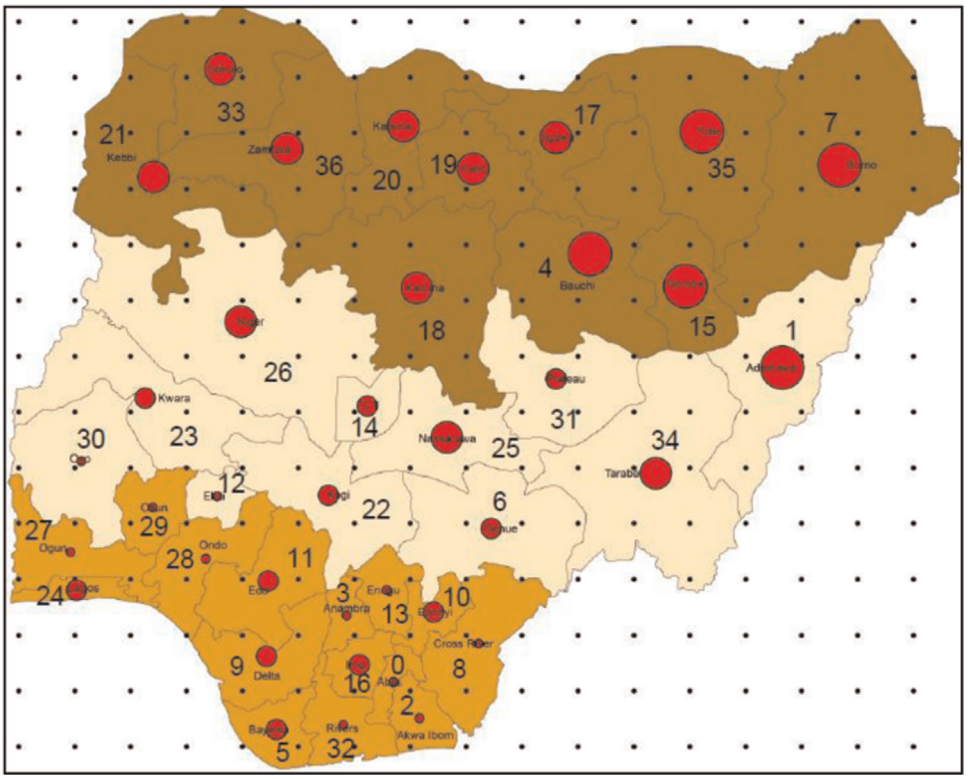

Fig. 1. Map of Nigeria showing: (a) ERA interim grid points covering the country (black dots), (b) grouping of states based on annual rainfall totals into region R1, R2, and R3 (from South to North, coloured; details confer text), and (c) annual mean of cholera incidence rate (IR) for individual states between 2000 and 2011 (red circles). Additional information on states name is added in the appendix (Appendix Table A1). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

reported cases of cholera, and also 12-years (2000–2011) states level reported cholera cases and deaths (cf. Fig. 1). The study will provide more understanding of the meteorological and socio-economic drivers of cholera outbreak in Nigeria, which could help to a larger degree in the epidemic prediction, thereby allowing authorities to effectively prepare and respond in good time to prevent outbreaks through measures such as vaccinating the vulnerable population. Our paper is the first to report a relationship between meteorological and socioeconomic conditions and cholera in Nigeria.

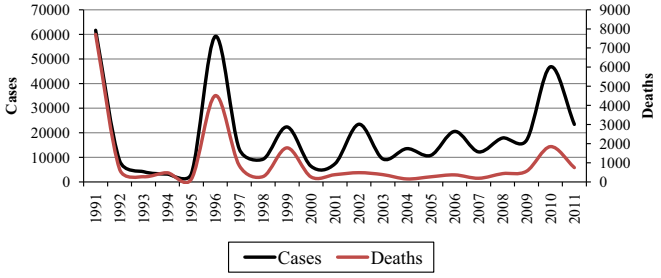

Fig. 2. Reported number of annual cholera cases and deaths to the World Health Organisation (WHO) from Nigeria between 1991 and 2011. Data sourced from WHO: Global health observatory data repository (http://apps.who.int/gho/data/node.main.175).

2. Investigation methods and data collection

Two statistical modelling approaches were adopted for this study in order to take advantage of the two different set of disease data obtained. The choices of explanatory variables were based on previous studies that have already documented the importance of these variables. These include meteorological variables such as maximum and minimum temperatures, rainfall, and relative humidity (e.g., Hashizume et al., 2007; Rajendran et al., 2011; Reyburn et al., 2011), absolute poverty (e.g., Traerup, 2010) adult literacy (e.g., Hashizume et at., 2007) access to safe drinking water (e.g., Penrose et al., 2010) and population density (Ali et al., 2002a, 2002b).

2.1. Epidemiological data

An overview of the annual variability of reported cholera cases in Nigeria (from WHO sources, cf. Fig. 2) for the last 30 years reveals a high level of interannual variability. To investigate spatio-temporal variability, two different sets of epidemiological records of suspected cholera cases were obtained. Firstly, monthly counts of clinically diagnosed cholera cases reported between 1990 and 2011 were collected from selected hospitals in Northwest Nigeria: Kano, Sokoto and Gusau. The selection of hospitals was based on proximity to meteorological stations with long-term records of measurements, and consistency in reporting cases of infectious disease. Data from these hospitals were successfully used to study meningitis in this region (Abdussalam et al., 2014a, 2014b), which corroborates the quality of data from these sources. Secondly, annual counts of cholera cases and deaths for the entire country at individual state level were obtained from the Nigerian National Centre for Disease Control (NCDC)-a unit of the Federal Ministry of Health: disease surveillance data across the country covering the time period 2000 and 2011 (cf. Fig. 1).

2.2. Meteorological data

Based on the epidemiological data obtained, two sets of meteorological data were used. Firstly, digital records of four variables