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Full Length Research Paper

Epidemiological features of a GIS-supported investigation of cholera outbreak in Abeokuta, Nigeria

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This study seeks to assess the epidemiological features of a GIS supported investigation of a cholera outbreak in Abeokuta. Abeokuta, the capital city of Ogun State, Southwestern Nigeria with an area of 1256 km^2 and a population of 605, 451 people had an outbreak of cholera from 20th November, 2005 to 1st of January, 2006. The outbreak affected the Abeokuta North Local Government area where the municipal waterworks is located. Municipal water consumption was found to be associated with illness [McNemar's Chi square (X^2 = 20.5; p < 0.001) and Odds ratio 10]. The epidemiological surveillance data showed a total of one hundred and fifteen cases and 11 deaths with case fatality rate of 9.6%. Male specific and female specific case fatality rates were 11.9 and 7.1%, respectively. The age group of 15 years and above accounted for 68.3% of the cases and 90.9% of the deaths. Post epidemic environmental investigation showed progressive contamination along distribution points. Cholera is still a major cause of morbidity and mortality among youth and ageing population in Nigeria.

Key words: Cholera, epidemiological studies, outbreak investigation, *Vibrio cholerae*, Abeokuta, Nigeria.

INTRODUCTION

Cholera is a disease characterized by profuse diarrhea accompanied with a severe dehydration and loss of electrolyte (Colwell and Huq, 1994), caused by toxigenic *Vibrio cholerae,* a serologically diverse, environmental, and gram-negative rod bacterium (Li et al., 2002). In the absence of appropriate treatment, there is a high mortality rate. Cholera is a major public health concern because of its high transmissibility, death-to-case ratio and ability to occur in epidemic and pandemic forms (Kaper et al., 1995). Cholera is responsible for an estimated death of 120,000 globally every year (WHO, 2001), and still continues to be a scourge worldwide covering all continents. In developing countries with endemic areas, cholera is still very significant with incidence of more than five million cases per year (Tauxe et al., 1994; Lan and Reeves, 2002).

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The explosive epidemic nature and the severity of the disease and the potential threat to food and water supplies have prompted the listing of *V. cholerae* as an organism of biological defense research (Zhang et al., 2003). In an epidemic, the great majority of cases can be recognized by clinical diagnosis easily and a bacteriological diagnosis is often not required.

Cholera is endemic in Nigeria (Falade and Lawoyin, 1999) and epidemiological features (Utsalo et al., 1991, 1992; Eko et al., 1994; Hutin et al., 2003) have been reported from various parts of the country with investigations on possible sources of outbreaks. Outbreaks of cholera had been reported from various Local Government Areas of Ogun State, Nigeria. Investigations on outbreak of cholera in Nigeria have focused on the epidemiological features, the probable source of contamination and the risk factors without spatial linkage of health data. However, advances in Geographical Information Systems (GIS) technology provides this opportunity and have become an indispensible tool for processing, analyzing and visualizing spatial data within

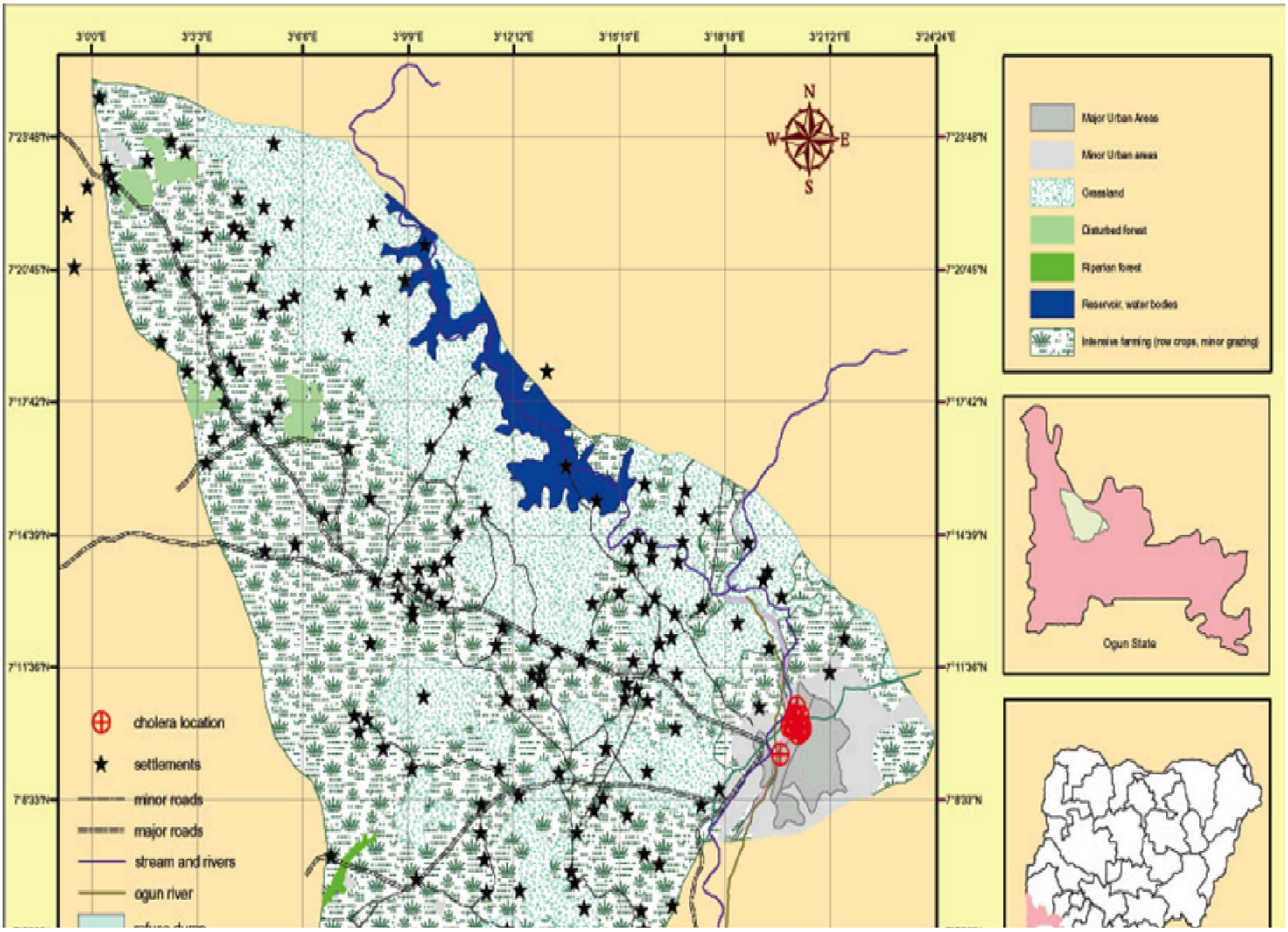

Figure 1. Map of Abeokuta North

the domains of environmental health, disease ecology and public health (Kistemann et al., 2002).

The use of GIS is not new in waterborne disease outbreaks and cholera studies. It has been applied in investigating waterborne disease outbreak (NWW, 1999), microbial risk assessment of drinking water reservoirs (Kistemann et al., 2001a), drinking water supply structure (Kistemann et al., 2001b), and spatial patterns of diarrhoea illness with regards to water supply structures (Dangendorf et al., 2002). In cholera studies, GIS technology has been applied in studying the correlation between socio-economic and demographic indices and cholera incidence (Ackers et al., 1998), environmental risk factors (Ali et al., 2002a), spatial epidemiology (Ali et al., 2002b), health risk prediction (Fleming et al., 2007) and spatial and demographic patterns of cholera (Osei and Duker, 2008). This study seeks to assess the epidemiological features of a GIS supported investigation of a cholera outbreak in the State.

METHODS

Description of the municipality and the epidemic

The study area, Abeokuta the capital city of Ogun State, Southwestern Nigeria with an area of 1256 km^2 and a population of 605, 451 people (projected from 1991 Census at 3.5 growth rate) is located by Latitude 7° 5^1N - 7° 20^1N and Longitude 3° 17^1E -3° 27^1 E of Ogun State, Nigeria (Figure 1). The geographical area of the city covers Abeokuta North, Abeokuta South, part of Obafemi Owode and Odeda Local Government Area. The major occupations of the people are farming, textiles (Tie and dye), pottery and fishing. The municipal tap water for the inhabitants of Abeokuta and its environment is processed from Ogun River, belonging to complex course of rivers and tributaries. The Ogun River passes through the ancient city of Abeokuta while Oyan dam is the main tributaries, joining it from the west. From this point, the catchment area of Oyan dam is 9,000 km^2; occupying parts of Oyo and Ogun States with

annual synthesized flow estimated at 1,770 million cubic metres. A total of 227.5 million litres are expected to be supplied daily from the surface source. The water treatment consisted of aeration, coagulation sedimentation, sand filtration and chlorination. The quality control Laboratory of the water-works routinely examine treated water for residual chlorine concentration and the presence of coliform bacteria in addition to other physicochemical parameters.

Abeokuta North

An epidemic of gastroenteritis with cholera symptoms occurred in the Abeokuta Local Government Area (LGA) between 20th November, 2005 and 20th January, 2006. An extensive environmental and epidemiological investigation was initiated. Because of the spread and extent of the epidemic, a possible waterborne route was suggested. Super chlorination of the municipal water system was performed and cases occurred sporadically thereafter. The Health Department of the affected Local Government Area (LGA) swung into action and interventions were initiated. Emergency preventive and curative measures were implemented which included community health education, transit clinic for free distribution of oral rehydration salt (ORS), antibiotics and supply of water as alternative source.

Public health surveillance

Surveillance data on cholera outbreak was obtained from the Department of Primary Health Care and Disease Control (PHC and DC) and analyzed. The Department of Primary Health Care and Disease Control of the Ministry of Health coordinated disease surveillance in Ogun State. Health data collection involves all the 20 LGA's, and all designated health facilities of the State that has a focal person for data collection. Monitoring and Evaluation officers (M and E) in the LGA's have been trained as Disease Notification Surveillance Officers (DNSO) by the World Health Organization (WHO). The M and E officers reported cases on line listing forms that collect information regarding date of birth, district of residence, gender, and occurrence of death. Other forms were integrated disease notification surveillance (IDNS) form 001 to 003. The data were then processed, summarized and transferred to the State Ministry of Health (SMOH), World Health Organization (WHO) and other relevant agencies. The M and E officers also investigate and provide necessary interventions to epidemic outbreaks.

Epidemiological investigation

A retrospective (Dangerdorf et al., 2002) study was initiated to determine the incidence of cholera and a possible common source of infection. A case of cholera was defined as acute watery diarrhea of rapid onset provoking severe dehydration in a patient (Hutin et al., 2003) since 20th November, 2005. For each cholera case confirmed at Sacred Heart Hospital, Lantoro, Abeokuta, a subject was sought of the same sex, the same age decade, and the same neighborhood. Control subjects were sought from the same epidemic community. Sample size was set to a total of 30 cases and 30 controls. Consent was sought from the Local Government before commencement of research project. With the support of Health officers of Water, Sanitation and Health Department of the affected LGA, visits were made to the communities affected. Households were questioned about the symptoms observed, the onset and the time of illness, also illness among contact persons, eating history and consumption of municipal tap water in five days preceding illness. No question concerning specific food items was asked. Observational studies on the sanitation of the environment and water quality testing with samplings at abstraction points at the waterworks and the distribution points of community supplies were conducted.

A hand held global positioning system (GPS) receiver (Gamin GP 12 Personal Navigator) was used to obtain co-ordinates of households with fatalities, as well as the Health Clinics/Hospital within the study area. The topographic and administrative maps of the study area were obtained from the Geological survey Department of the State Ministry of Works, Lands and Housing while the water distribution network was obtained from the water works. The maps were scanned, imported into ArcView GIS and geo- referenced using point with known geographical co-ordinates. The scanned map was then captured by on screen digitizing at a scale of 1:20,000. The geo-ecological characterization of the study area was captured from the 'Ikonos' satellite image. The co-ordinates obtained were entered into Microsoft Excel Worksheet and saved as Data base documents. ArcView 3.2a Program (Environmental System Research Institute [ESRI], Inc., Redland) was used as a basic GIS Software. Other health facilities where cholera patients were admitted were visited and relevant information was obtained from their case note and log books.

Data management and analysis

Epidemiological data were analyzed by use of EpiInfo 6.0 (CDC, Atlanta, GA). The McNemar's chi square test for paired samples was used for the statistically significant test and the relative risk (RR) calculated as estimated odd ratio of incidence in exposed and unexposed for consumption of drinking water from the municipal water works. An exposure was considered to be statistically significant if the summary of positive and negative response was larger than 10 at the degree of freedom 1 and $P < 0.01$ while for RR, the summary risk ratio did not include 1.0.

Clinical and environmental laboratory method

Isolates from stool samples cultured at the Microbiology Laboratory of the Sacred Hearth Hospital, Lantoro, Abeokuta were obtained. Water samples (1 L) were collected aseptically, and enriched in alkaline peptone water (APW peptone 1% (wt/vol) , NaCl 1% (wt/vol), pH 8.5. Enrichments were incubated at 25 - 30°C for 18 h. An aliquot of surface pellicle was streaked on thiosulphate citrate bile salt sucrose agar (TCBS). Suspected *Vibrio* colonies were confirmed to be *V. cholerae* by biochemical testing and API 20E diagnostic kit and laboratory reagents. The Most Probable Number technique of 1 x 500 and 5 x 100 mL tube series was used to obtain presumptive *Vibrio* enumeration, using equal volume in double strength alkaline peptone water.

RESULTS

Descriptive epidemiological investigation

A total of one hundred and fifteen cases and 11 deaths were recorded with case fatality rate of 9.6%. The outcome of the disease showed that 90% survived and 10% died. Male specific and female specific case fatality rates were 11.9 and 7.1%, respectively (Figure 2a). The age group of 15 years and above accounted for 68.3% of the cases (Figure 2b) and 90.9% of the deaths (Figure 2c). The only child that died was a two-year-old girl

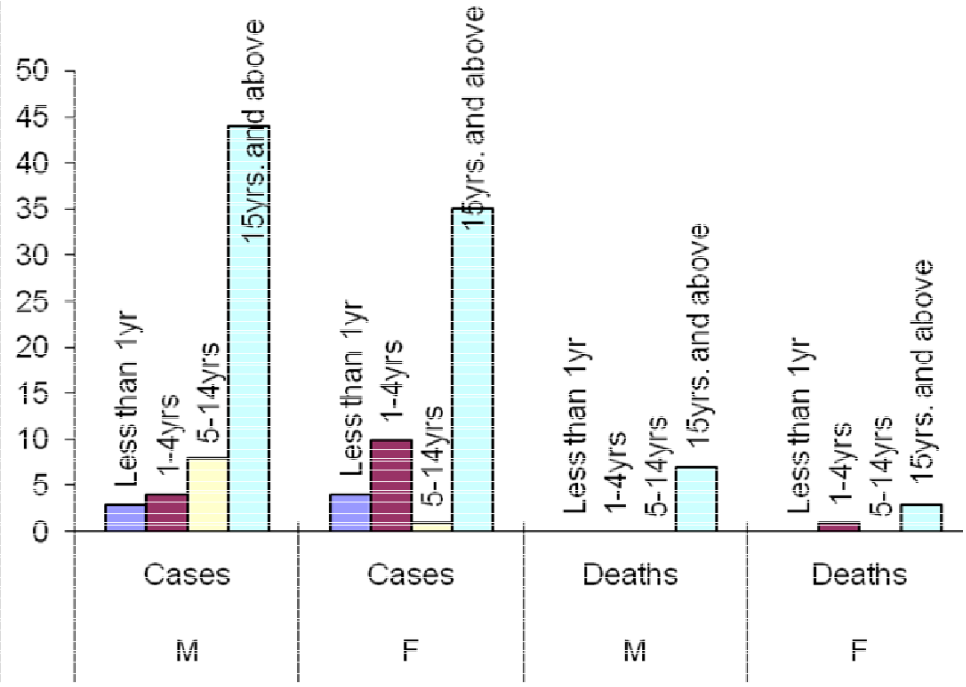

Figure 2a. Sex specific cases and deaths of cholera outbreak in Abeokuta North, Nigeria, Africa.

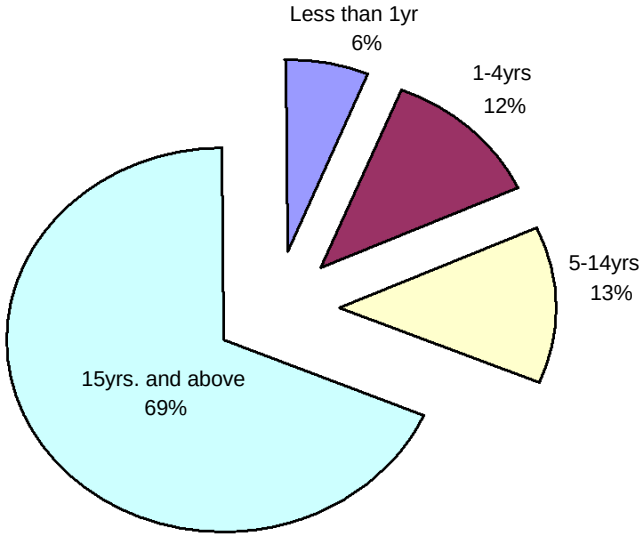

Figure 2b. Percentage by age distribution of cases of cholera outbreak in Abeokuta North, Nigeria, Africa.

Figure 2c. Percentage by age distribution of death cases of cholera outbreak in Abeokuta North, Nigeria, Africa.

visiting Abeokuta with her parents. Peak period of outbreak was 29th November, 2005 to 1st January, 2006 with an attack rate of 88.5 per 100,000. The weekly number of reported cases (Figure 2d) peaked in the first week and subsequently declined. Average length of hospital stay calculated from the logbook of all the health facilities was 2 to 5 days. Out of the eleven deaths, only two (18%) occurred within 24 h of hospital admission, while 82% of the deaths occurred within the households.

Most cholera cases clustered within Ikereku, Ago-Odo, Ikija and Ilugun (Figure 3), characterized by dense population, poor sanitation and sewage disposal systems. The entire community depends on pipe borne

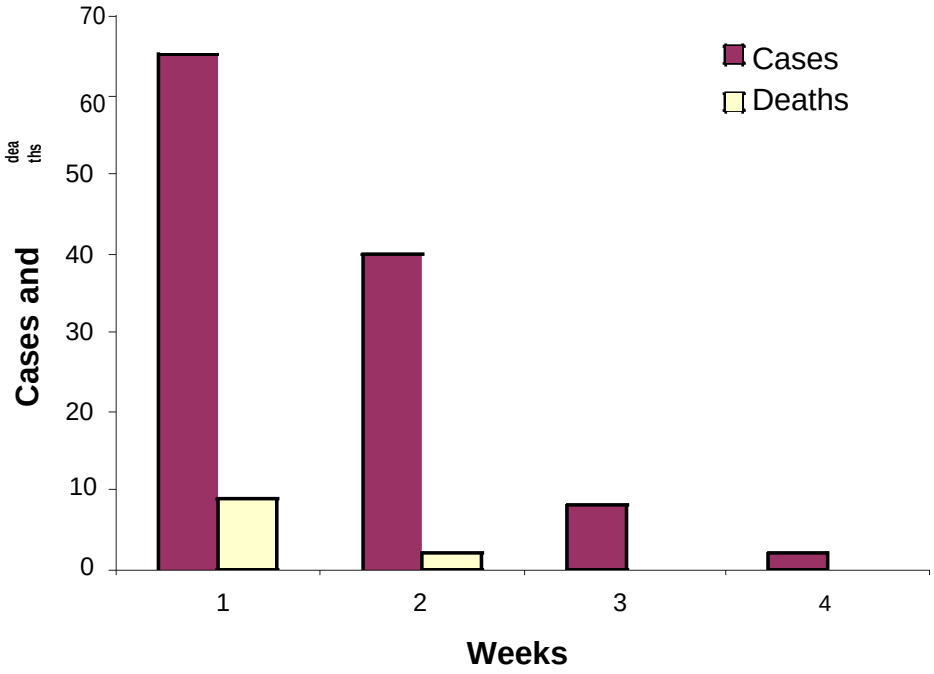

Figure 2d. Time record of reported cases and deaths per week cholera outbreak in Abeokuta North, Nigeria, Africa.

water for drinking purposes while well water is only used for washing and bathing in the absence of water from the Water board. Water is consumed without any point-of-use treatment. Household with fatalities investigated revealed that most of the cases started at about 12 midnight and by 4.00 am, the patient would have died. Household treatment was based on herbal concoction. The community believed the outbreak was superstitious and appeasement and sacrifices were made to the gods for the outbreak to stop. The trends of cholera showed a decline in cases and death by the fourth week of the outbreak which the communities believed it was an answered prayer due to their various sacrifices. GIS mapping have several registered and unregistered health facilities within the 500 m in the study area (Figure 4) and this showed that the high case fatality rate was uncalled if patients had been presented to hospitals in time.

Analytical epidemiology

A total of 30 pairs were included in the case control studies. The whole communities depend on pipeborne water for drinking. Prior to the outbreak, there was acute water shortage in the district for about one week after which the water supplied by the waterworks was colored, and it flowed for 3 days. The McNemar's Chi square for significant testing (X^2 = 20.5; $p < 0.001$) showed that the association was not due to chance and the estimated relative risk showed that those who consumed municipal tap water had 10 times higher risk than those who consumed Sachet water (produced in the same locality) in the period preceding the outbreak [Odds Ratio (OR) 10.0].

Clinical investigation

The laboratory investigation of rice water stool cultures of patients presenting with gastroenteritis in a single health facility yielded (30%) positive cultures to *V. cholerae*.

Environmental investigation

The water quality testing (Figure 5) revealed that the residual chlorine level of 0.2 mg/ml optimum goal was insufficient to maintain drinking water standards at community supplies (distribution) points. Mean Vibrio Count (MVC) at abstraction and distribution points were > 180 and 90 MPN/mL while within the water works, MVC was less than 10 MPN/mL. The Mean coliform count for all the water sampled were > 1800 MPN/ml. Figure 6 shows points of recontamination along map distribution.

DISCUSSION

An outbreak of cholera associated with municipal tap water has been described of cholera outbreak in

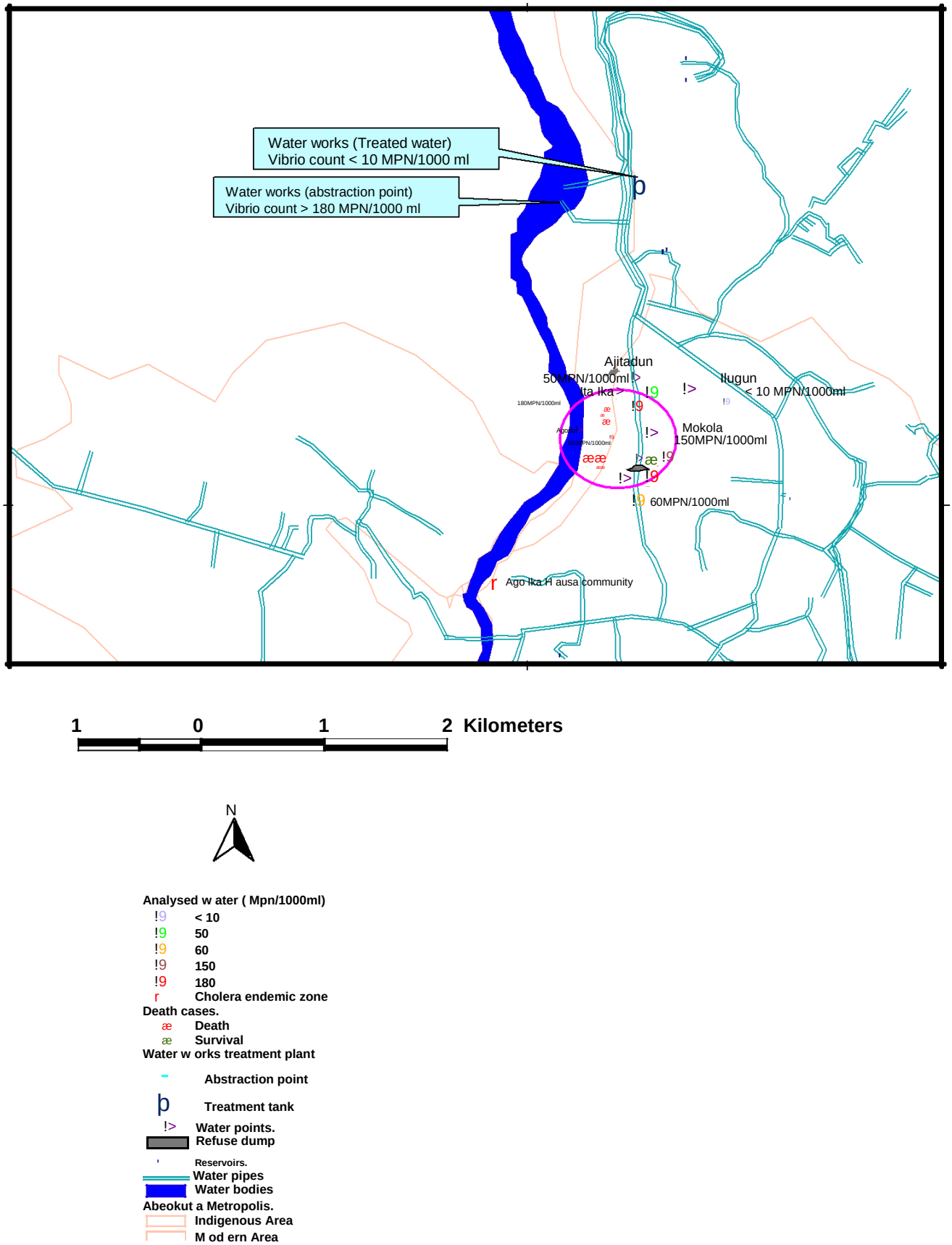

Figure 3. Community with clustered cases areas of cholera of cholera outbreak in Abeokuta, Nigeria, Africa.

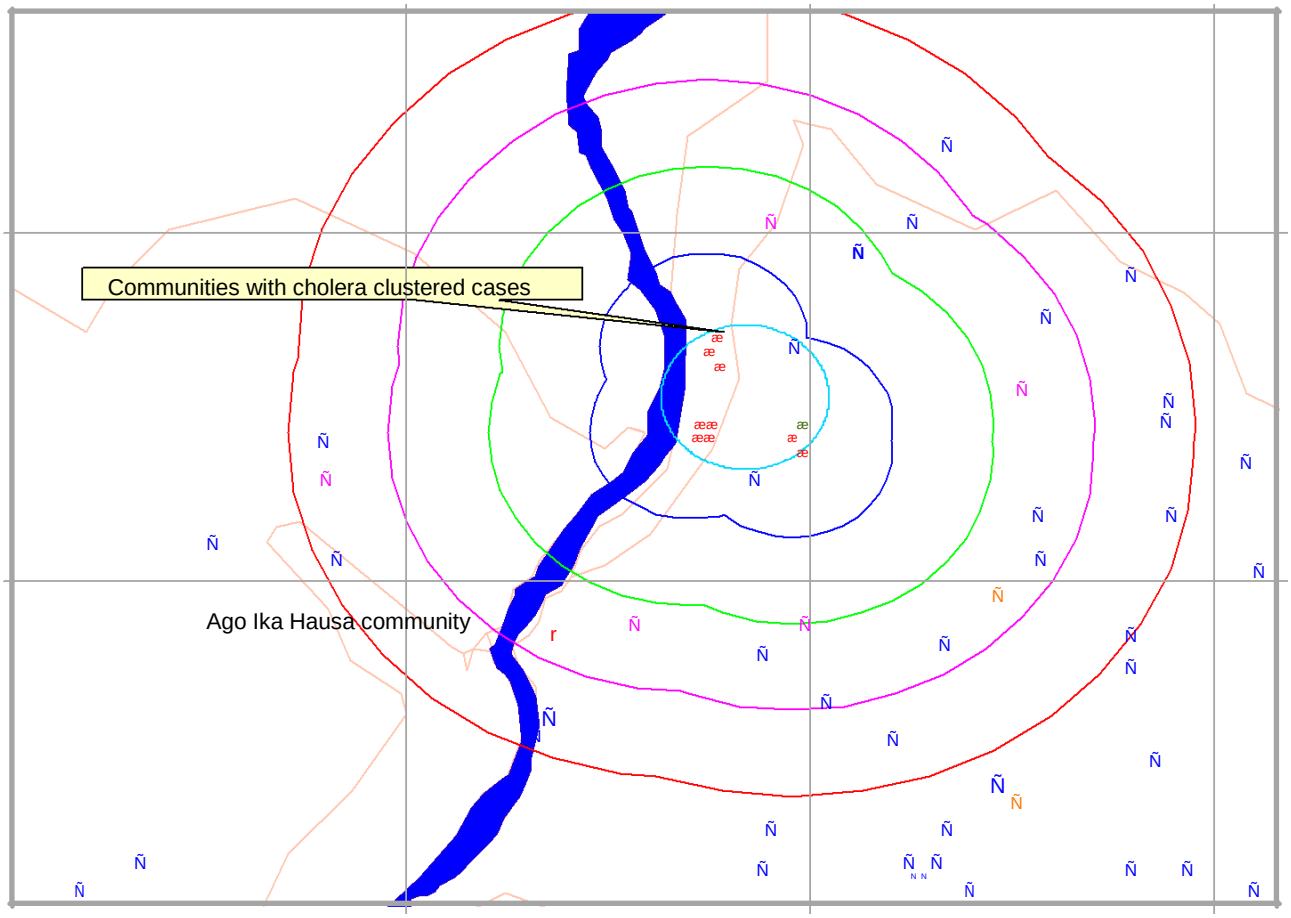

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Figure 4. Health facilities within the cholera affected area of cholera of cholera outbreak in Abeokuta, Nigeria, Africa.

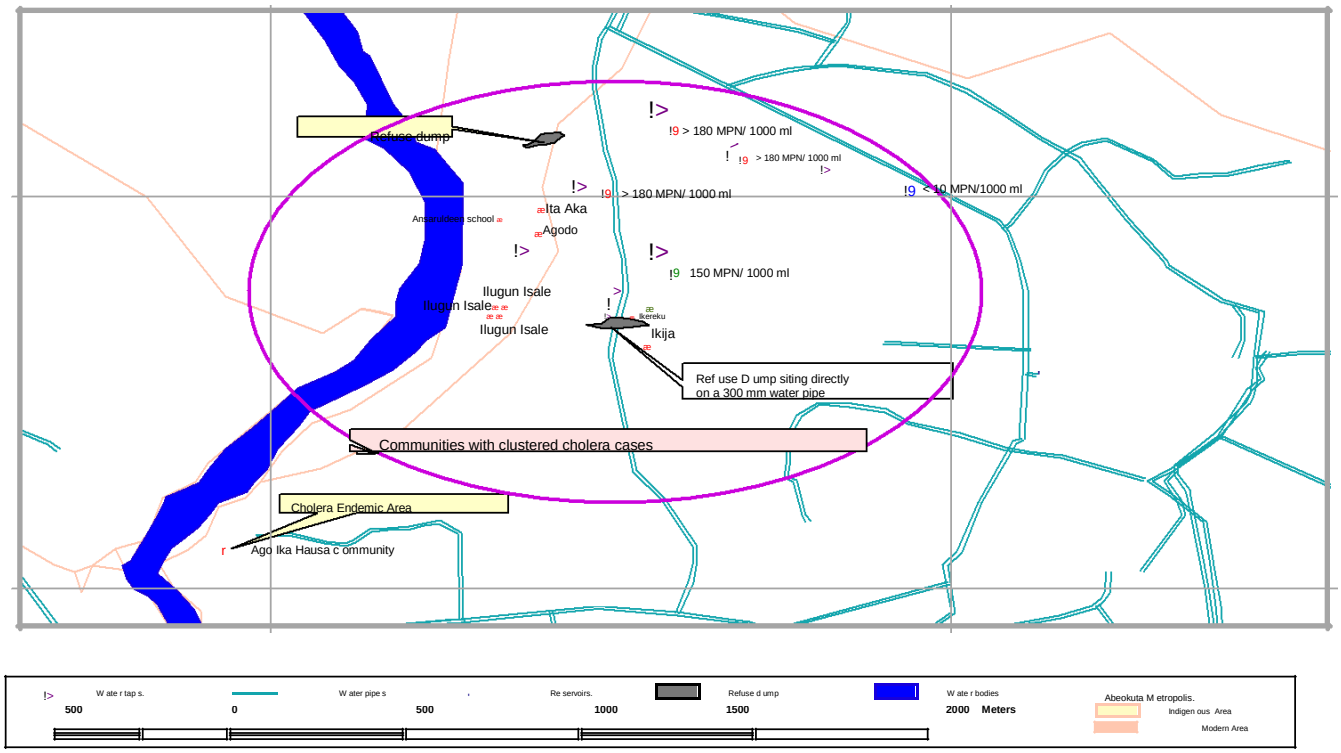

Figure 5. Water quality testing for Vibrio within affected area during cholera outbreak in Abeokuta, Nigeria, Africa.

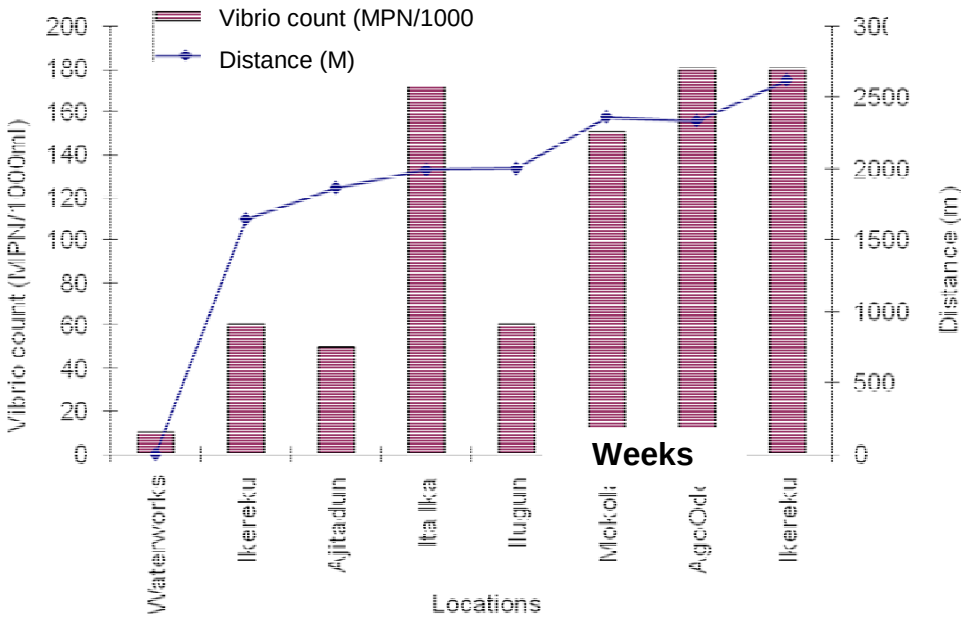

Figure 6. Vibrio counts (MPN/1000mL) among distribution map point and relative distance areas of cholera outbreak in Abeokuta, Nigeria, Africa.

Abeokuta, Nigeria, Africa.

Even though, consumption of municipal tap water was shown to be significantly associated with illness by epidemiological investigation, a more confident astringent cause could not be described, because epidemiological investigation and environmental testing were conducted shortly after the outbreak and moreover the water sample for five days preceding the illness was not available and super chlorination had been initiated. This is complicated by the fact of the quality control laboratory of the waterworks conducted quality testing once a month and therefore data for that period were not available. There was no explanation from the waterworks as to whether the water supplied immediately after the one week water shortage was whether chlorinated. There were 'insinuations' that the outbreak period coincided with the time that Waterboard had shortage of alum and chlorine for water treatment. However, evidence from the community showed that the water was colored and it flowed during three days which implied that the water was not likely chlorinated; considering the economic and maintenance problem associated with our system.

The *Vibrio* counts among distribution map point and relative distance areas of cholera outbreak indicated that pipeline leakages and seepage of fecal contamination occurred along the distribution network. Looking at the utility map, the location of refuse dump along a major distribution pipeline line (300 mm), we considered this as a risk factor to this outbreak of cholera and illness incidence of gastrointestinal disease could there be pipeline leakage along the distribution network. Observational studies also revealed clandestine connections of household pipelines inside drainage system. These showed that sanitation contribute greatly to produce cholera outbreak in this area. Having water shortage for about one week, fecal contaminants must have piled up in the leaking pipelines only to be distributed along with "potable water". The microbiological analysis conducted retrospectively still showed a highly significant difference between treated water at the waterworks and the community supplies.

This indicates that there were continuous and steady contaminations of otherwise potable water along the distribution lines. If this situation is not corrected, another outbreak of cholera is imminent except the community has already developed herd immunity to the epidemic strain.

This strongly argues against the people's demand of the water- board pumping dirty water before the outbreak. However, this could be mostly related with the lack of chlorination/treatment failure during the outbreak, all these conditions must have contributed to provoke the outbreak in the study area in a short period of time. The epidemiological features of the outbreak reflected the health usage pattern of the study area and their knowledge, attitude and practices to attend gastrointestinal diseases. The entire community depends solely on pipe-borne water for drinking which is consumed without boiling or further treatment because the people feel it is safe for human consumption. Considering the poor sanitation of the community and the occurrence of several undetected pipeline leakage, household water treatment is imperative both in the cholera affected and in the non affected area. The peoples believed that the

outbreak had nothing related with the water system; but it was as a result of smallpox afflicted by the supernatural powers. This superstitious belief was evidenced in the location of the central shrine and Statues all over the places. Even though, majorities are farmers and traders, their level of education strongly reflect their level of knowledge. They strongly believed that the outbreak came to an end as a result of sacrifices offered to the gods despite the fact that this investigation was conducted after the community had received Health education on gastrointestinal diseases/cholera. The period of appeasement however coincided with the introduction of super chlorination of water supplies.

An outbreak of cholera associated with pipeline leakages was described very recently (Kumar, 2005) and this showed that municipal associated waterborne cholera outbreak is still occurring. Water treatment and distribution system are among the listed specific critical control points in the development of HACCP for microbial risk assessment in drinking water production (Kistemann et al., 2001b) and thus should be critically monitored by the water works.

Out of the eleven deaths, only two (18%) occurred within 24 h of hospital admission, which may have indicated delayed presentation to health facilities and inadequate early rehydration, while 82% of the deaths occurred within the households. This shows that knowledge on household handling is lacking. In conclusion, suspected unchlorinated municipal water supply and pipeline leakages are the major causes of cholera outbreak in the study area. The pipeline leakages along the distribution line are responsible for the widespread transmission of the disease. These call for community education on point-of- use water treatment method; household management of gastroenteritis/-cholera; early presentation of cases to health facilities; proper construction of water pipelines and changing community beliefs on waterborne diseases. Also, sanitation practices and improved sewage disposal need to be addressed within the community. Cholera is still a major cause of morbidity and mortality in youth and ageing population in Nigeria.

This study has demonstrated the usefulness of GIS in waterborne disease outbreak investigation, tracking possible sources of contamination of municipal water and monitoring the effectiveness of residual chlorine at distribution points.

1. This study has also shown that cholera is still a major cause of morbidity and mortality in the youth and ageing population in Nigeria.
2. This work has also revealed that in the midway to the millennium development goals (MDGs), municipal piped water is still unsafe without point of use household treatment and this call for community education.
3. This study had shown that inadequately maintained pipes and clandestine connections are major problems that need to be addressed in the area with pipe borne water in order to prevent future outbreaks of waterborne diseases.

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