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Full Length Research Paper

Rapid epidemiological mapping of cholera outbreak in parts of Abeokuta metropolis: A GIS-supported post-epidemic assessment

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The paper presents the outcome of a GIS-supported post-epidemic survey of cholera in pipe-borne water of parts of Abeokuta, southwestern Nigeria. Utility pipelines were digitized and superimposed with analyzed water samples and geo-ecological features of the area. Water samples were then collected from various locations along with the corresponding geographical coordinates. Water samples were collected from Ogun River (abstraction point), from the water board treatment tank and from various faucets within the affected communities. The samples were analyzed for the presence of *Vibrio cholera (V. cholera)*. Results revealed a high load (>180 MPN/1000 ml) of cholera bacteria at the abstraction point, which reduced to <10 MPN/1000 ml in the treatment tank. But as the sampling progressed from the water works into the communities, there was an associated increase in *V. cholerae* contamination level from 60 MPN/1000 ml up to above 180 MPN/1000 ml. The poor sanitary practices of the indigenes of the area namely; improper sewage and waste disposal systems, heaps of refuse dumps with human faeces on old, rusty and leaking water pipes explains the water contamination. This in conjunction with poor sanitation of people holds high significance for future cholera epidemics in this part of the city.

Key words: GIS, utility board, geo-ecological characteristics, cholera, post-epidemic assessment.

INTRODUCTION

As Geographical Information Science (GIS) finds more applications in the fields of environmental health, parasitology and epidemiology, more and more assurance of timely control of bubonic plagues are given through accurate predictions and decision support with respect to interventions. In its unique capabilities of efficient storage, manipulation, analysis and seamless integration and display of large quantities of environmental data, GIS is giving investigators grand support in rapid epidemiological surveys. In recent past, GIS has been developed for a wide range of applications in public health safety studies. Since it is a spin-off of Information Communication Technology, GIS through mapping and modeling of spatial information enables better forms of communication between people in research and the society at large (Good child, 2000).

The usefulness of GIS application in specific areas of environmental/public health such as chemical contamination of water and water borne diseases are documented by many authors. For instance, GIS application in the exposure of man to contaminated drinking water by non volatile organic compounds (VOC) in groundwater reservoir has been demonstrated (Ara and Maslia, 1996). It was possible with this, to determine the extent of contamination and location of vulnerable population on the public water supply network. Similarly, the advantage of GIS in epidemiology of drinking water through comparison of two supply area with different disinfection practices were presented in Nuckol *et al*., (1995).

With particular reference to water borne diseases, Dangedorf *et al*., (2002) noted that application of GIS has been relatively new, but several works involving GIS have been done on water quality and quantity assessment.

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In Nigeria also, it is a fact that information concerning water-borne diseases and outbreaks are rare and not easily available: it is apparent that, works along this line are scanty and so relevant data are very rare. However, evidences from available literature still prove the extreme usefulness of GIS in other areas of health risk assessments. In southwestern Nigeria, Ekpo et al (2006) applied GIS in the investigation of guinea worm amongst school age children in Ogun state, Orebiyi *et al*., (2008) applied Geographical Information System to ground water quality assessment over the city of Abeokuta metropolis; Gbadebo *et al*., (2010) examined the variability distribution of nitrate in ground water of Abeokuta metropolis, Shittu et al (2010a) examined epidemiological features of cholera outbreak, drawing support from GIS in the investigation, while Shittu et al (2010b) applied GIS and Remote sensing in bacteriological examination of water supply in rural community. Rapid Geographical Assessment of Bancroftian Filariasis (RAGFIL) was conducted using GIS in three countries (Ghana, India and Myamar). The spatial analyses accompanying these investigations, assisted in discovering the existence of spatial autocorrelation among districts within each country. Gyapong *et al.,* (1996) suggested that the rapid epidemiological study in Ghana was a good proxy measure of the levels of endemicity or filariasis. Similarly, an informal consultation on Rapid Epidemiological Mapping of Onchocerciasis (REMO) using GIS held in Burkina Faso in1996 had a standard methodology developed (UNDP/World Bank/WHO, 1998b). The implication of these examples of GIS application in environmental health is the possibility of applying it to waterborne epidemics study such as cholera.

In this study, the need to trace the source of ravaging cholera outbreak in a particular part of Abeokuta; a large city within south western Nigeria in a post epidemic survey arose as a result of the outbreak of cholera reported in Adedotun/Ilugun area of the city from year to year. The cases were always reported to be pandemic; leading to loss of hundreds of lives. The inhabitants of the affected part of the city have blamed the epidemic of the previous year to the time of this study on human error and carelessness; claiming that they must have been served untreated water at the time of the incidence. The authority of the water board however refuted the allegation and there was the need to investigate into the immediate and remote cause of the disaster. This requires a rapid post-epidemic survey that will locate the source of infection, determine the extent of the contamination, and estimate the population exposed to risk of infection. The task appeared to be onerous, yet the immediate or remote causes of the cholera must be identified and adequately addressed before the situation becomes catastrophic. For effective and timely decision making, a rapid mapping of the cholera must be carried out and the root cause of the problem identified. The only efficient way of doing this in good time is to employ the aid of GIS. Existing spatial and in-situ data must be incorporated into spatial technologies in order to provide an insight to the root of the problem. Geographical Information systems, Remote Sensing and Global Positioning system were therefore integrated with in-situ field data for the investigation. In this paper therefore, the report of the Rapid Epidemiological Mapping of Cholera in Abeokuta city of Nigeria is presented. The paper is an attempt to contribute to knowledge base with respect to application of space technologies in environmental health and epidemiology in Nigeria, while at the same time show casing the efficacy of GIS in rapid investigations on source of water borne infections. The paper also demonstrates the usefulness of GIS in tracing the source of infections of public water network with *Vibrio cholerae* (*V. Cholerae*). It lucidly presents spatial information on the source, distribution of *V. cholerae*, and exposure of human populations to cholera infested water.

MATERIALS AND METHODS

Study Area

The study was conducted in some parts of Abeokuta, metropolis. Abeokuta is an ancient city which lie in the sub-humid tropical region of Southwestern Nigeria (Latitudes $7^{o}\ 5^{o}$ N to $7^{o}\ 20^{o}$ N and Longitudes 3^{o} E to $3^{o}\ 27^{o}$). The city enjoys a tropical climate with distinct wet and dry seasons and a dry spell of about 130 days (10). Like the Nile of Egypt, Ogun River is the major water body which has sustained Abeokuta through several generations. Its importance in agriculture is almost unquantifiable especially with flood plain farming during the dry season. At present, Ogun River is the main source of water for municipal water supply. Figure 1 shows the location of Abeokuta city within Ogun State in Nigeria.

Mapping

The pipeline distribution networks, maps were scanned, imported into a GIS, geo-referenced and digitized at a scale of 1:20000 in layers using Arc views 3.2a software. Other features such as water abstraction point, treatment tank, water faucets and location of affected areas were imported into the GIS map as events themes. The geo-ecological characterization of the study area was captured from (Ikonos) satellite image. Point layers were symbolized differently and overlaid on the base map (Pipeline networks and features extracted from topographic map). The schema above is the cartographic model summarizing the entire methodology for the study.

Water samples analysis and Vibrio cholerae counts

Water samples were collected from the abstraction point and water treatment tank at the Arakanga water works station. Water samples were also collected from the faucets within the affected communities.

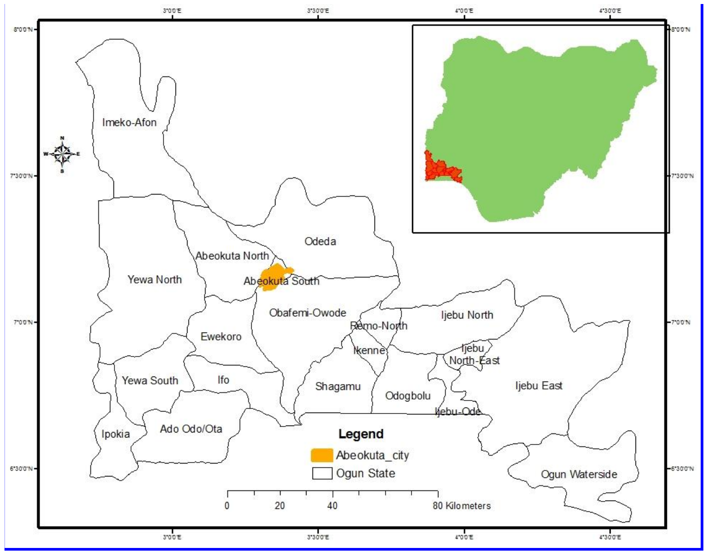

Figure 1. Location of Abeokuta city within Ogun State, (inset map of Nigeria showing location of Ogun State within Nigeria).

About 1litre of water samples were collected aseptically, stored in already sterilized plastic bottles. The bottles were then kept in a cooler which has been conditioned to ice temperature (0^oC) in order to arrest chances of getting spurious result on analysis. The water samples were taken to the microbiology laboratory of the university and analyzed for *V. cholerae* tube techniques were then used for enumeration of *V. cholera.*

Data acquisition and Database development

Relevant data that will aid the full realizations of the objectives of the study were acquired. Maps of water distribution facilities and the Ikonos image of the city acquired information on the location and number of people per community were obtained from the Local Government office. Where specific houses and water faucets needed to be mapped, the Local Government health officials guided the tour of the communities. Geographical coordinates of affected houses, water taps were collected and other geo-ecological characteristics of the study area were obtained with the aid of hand-held GPS receiver. The result of the *V. cholerae* count per sample was used to build up the attribute for each of the water sample points in the GIS map. The levels of the contamination could then easily be displayed on the map.

Estimation of population exposure to risk of infection

In order to locate and estimate population exposed to the risk of infection, the water analysis was super imposed on population distribution map which was produced through surface interpolation of unit locations with known population. A unit population location which corresponds to about 500 x 500 m on land was derived from population census enumeration area demarcation of 2006. The level of the populace's exposure to risk of contamination was categorized into 3 namely; high moderate and low risks and was subsequently depicted on the map. The schema in Figure 2 is the summary of the methodology adopted for the study which clearly shows the steps taken to arrive at the epidemiological map.

RESULTS AND DISCUSSION

In Table 1, a summary of the laboratory analysis water sample are presented. The geographic locations of the points at which water samples were collected are recorded as Northings and Eastings as obtained from the Global Positioning Systems hand-held receiver. It can be observed that at the water works abstraction point in Ogun river, the water sample analysis showed a *V. cholerae* count of >180 Most Probable Number per 1000 ml (MPN/1000 ml), but at the water treatment tank, the count was >10 MPN/1000ml; which is an indication of effective treatment of the polluted water from the river. Meanwhile, as the survey progresses into the communities, there was a steady rise in the number of *V. cholerae* count. For example at Ilugun the count was 10 MPN/1000 ml at Ajitadun and Ikereku communities it has risen to 50 and 60 MPN/1000 ml respectively. Within the zone where the impact was mostly felt the count had gone up to 180 MPN/1000 ml as can be seen in the map in Figure 3. The inference that can be drawn from the foregoing is that the water must have been contaminated

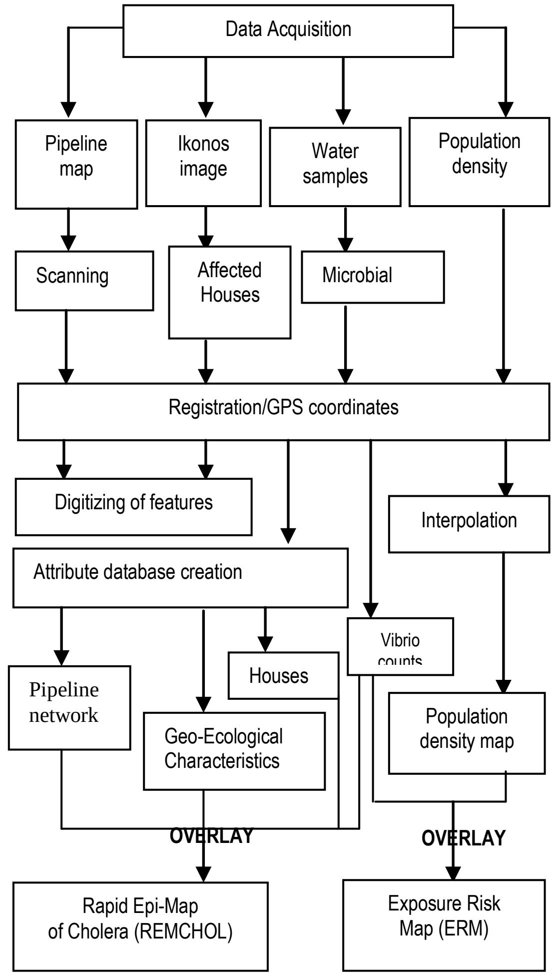

Figure 2. Cartographic model for rapid epidemiological mapping.

Table 1. Presumptive Vibrio count in water samples at various locations.

Sample locations	Northings	Eastings	Vibrio count (MPN/1000 ml)
Abstraction point	7.19357	3.33660	>180
Water works	7.19334	3.33981	~0
Ilugun	7.17685	3.34666	<10
Ajitaadun	7.17748	3.34166	50
Ikereku	7.17920	3.34260	60
Ita – Aka	7.17636	3.34051	>180
Mokola	7.17290	3.34260	150
Ago- Ika	7.16057	3.33660	>180

between the water works station and the affected communities. But where exactly the source of contamination is located still remains a puzzle yet unraveled. Geo-ecological characterization of the area revealed the general sanitation while is very poor as refuse dump and unhygienic waste disposal are found

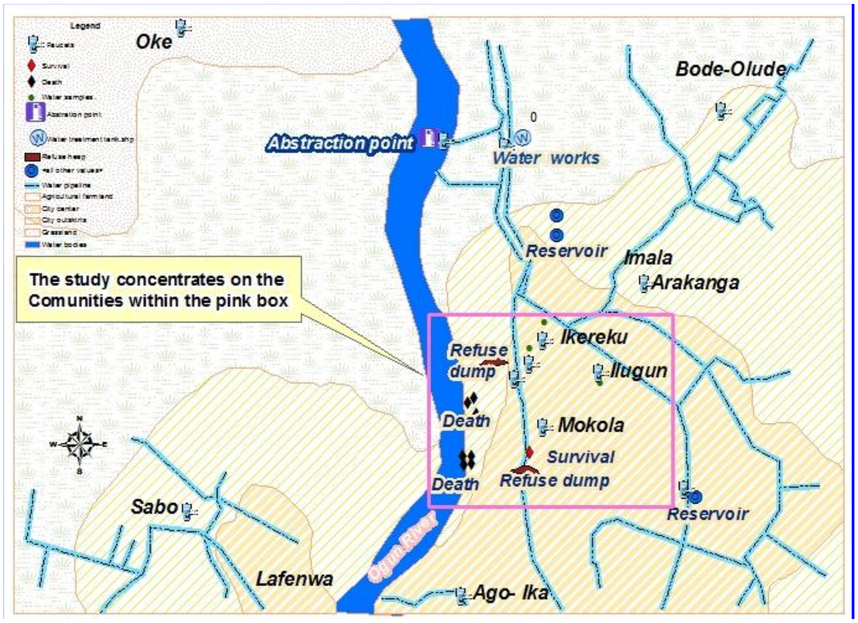

Figure 3. Contamination with distance from water works.

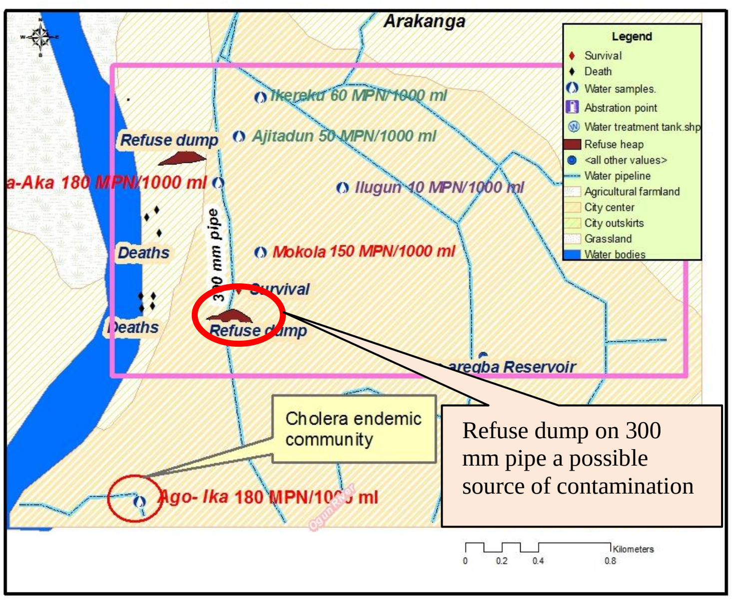

Figure 4. Map showing possible sources of contamination of drinking water in pipes.

littering open places. In Figure 4, the map reveals possible sources of contamination of drinking water in pipes. For instance, a huge refuse dump is located directly on a 300 mm pipe. This is a probable source of contamination especially where the pipes are leaking; infiltration under low pressure is easy. Water samples collected from the faucets around this area show a very high *V. cholerae* count of above 180 MPN/1000 ml., the map showing the distribution of water taps and the value of *V. cholerae* counts in the samples analyzed in Figure 4 is represented in an enlarged and zoomed in format in Figure 5. The enlarged map revealed that the clustered cholera cases were found where the contamination values were highest (above 180 MPN/1000 ml). The circle in the map represents the areas where the cases were severe. Where death occurred; it is symbolized by black flags while a cross symbolizes survival. In Table 2, the estimation of human population exposed to risk of

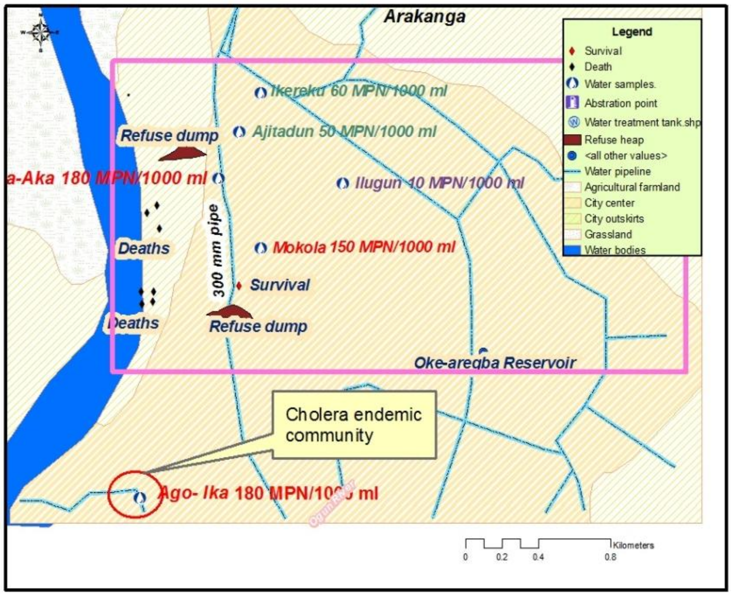

Figure 5. Enlarged map showing distribution of taps with the value of *Vibrio cholerae* counts and area of severity.

Table 2. Estimated population exposed to risk of infection.

Community	Population	Level of exposure
Ilugun - Isale	580	Low
Ajitaadun	276	Moderate
Ikereku	274	Moderate
Ita – Aka	377	Very High
Mokola	720	Very High
Ago – Ika	492	Very High
Ilugun – Oke	583	Moderate
Total	3306	

infection in the area is presented. The level of risk varies spatially. This could be explained by the level of sanitation from place to place. Generally, the study area is the very indigenous area of Abeokuta city; as such the level of sanitation in the area is very low relative to the well planned modern area of the city. Poor refuse and sewage disposal characterizes the area. The houses are also not well spaced and ventilated. This possibly could aid the spread of the disease. The population exposed to risk of infection in is quite significant (3,306) compared to the area of study (1.2 km^2). Since the pipeline is a network the entire city might not be exempted from the epidemic. Abeokuta city is densely populated with population density of 3,964 persons per square kilometers it is highly essential to give attention to monitoring systems.

CONCLUSION

The rapid investigation of cholera outbreak in this part of Abeokuta city was supported and accelerated substantially by the use of GIS. It was possible to trace likely source of contamination to the sanitary practices of the area and not necessarily due to the negligence of the water board. Possible source of contamination was identified with the aid of GIS.

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