Rapid Epidemiological Mapping of Cholera in Some Parts of Abeokuta Metropolis: A GIS-Supported Post-Epidemic Assessment

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Abstract

An outbreak of cholera epidemic was reported in some parts of Abeokuta city in Nigeria. Reports indicated that loss of lives was involved. This study investigates the immediate and remote sources of contamination of water supply system in the city by a GIS supported investigation. The study relied on the integration of Geographic Information System, Global Positioning System and Remote Sensing. The network of water pipelines was digitized from the master plan. The geo-ecological characteristics of the environment were captured from a high resolution (Ikonos) satellite image of the affected communities. Water samples were collected from various points and their coordinates obtained. The water samples collected from Ogun River (abstraction point), water treatment tank and faucets within the affected communities were analyzed for the presence of *Vibrio cholerae*. Results revealed a high load (>180 MPN/1000ml) of cholera bacteria at the abstraction point, which reduced to < 10 MPN/1000ml in the treatment tank. As the assessment progressed from the water works farther into the communities, there was a concomitant progressive increase in cholerae contamination. The Vibrio count has risen above 180 MPN/1000ml by the time the assessment got to the cholerae endemic area. It was found that the sanitary practices of the indigenes of the area were very poor; there were no proper sewage or waste disposal systems, heaps of refuse dumps were found on pipelines. The study established pre and post epidemic water contamination in the area. Although the study could not attribute the incidence to direct negligence of water management board but rather to poor maintenance of the water facilities; which were already old, rusty and leaking. This, in conjunction with the substantiated finding on the poor sanitation of people of the area, can be said to hold a high significance for future cholerae epidemics in this part of the city.

Keywords: GIS, Utility board, Geo-ecological characteristics, Cholera

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 Bubonic plague is given through accurate predictions and decision support with respect to interventions. GIS in its unique capabilities of efficient storage, manipulation, analysis and seamless integration and display of large quantities of environmental data is giving investigators grand support 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 spinoff of Information Communication Technology, GIS through mapping and modeling of spatial information enables better form of communication between people in research and the society at large (Goodchild, 2000; Twigg, 1990).

Available evidence from literature reveals the extreme usefulness of GIS application in specific areas of environmental/public health such as chemical contamination of water and water borne diseases. 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 extent of contamination and location of vulnerable population on the public water supply network. Similarly, the advantage of GIS in drinking water epidemiology through comparison of two supply area with different disinfection practices were presented (Nuckol et al., 1995).

With particular reference to water borne diseases, application of GIS may be relatively new (Dangedorf *et al*., 2002). But several works involving GIS have been done on water quality and quantity assessment. Evidences from available literatures still prove the extreme usefulness of GIS in other areas of health risk assessments. Orebiyi *et al*., (2008) applied Geographical Information System to ground water quality assessment over the city of Abeokuta metropolis while Gbadebo *et al*., (2010) examined the variability distribution of nitrate in ground water of Abeokuta metropolis. Ekpo (2006) applied GIS in the investigation of guinea worm amongst school age children in Ogun state while. Rapid Geographical Assessment of Bancroftian Filariasis (RAGFIL) using GIS was conducted in three countries (Ghana, India and Myamar).

The spatial analyses accompanying this investigation, assisted in discovering the existence of spatial autocorrelation among districts within each country. Gyapong *et al.,* (1996) suggested that the rapid epidemiological studies in Ghana was a good proxy measure of the levels of endemicity of 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.

Background to the 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 in 2005. The case was reported to be pandemic; leading to loss of hundreds of lives. Inhabitants of the affected part of the city blamed the epidemic on human error and carelessness; claiming that they must have been served untreated water by the city water board was at the time of the incidence. The authority of the water board however refuted these allegations 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 of the causes 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. 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, The paper is hence an attempt to contribute to knowledge base with respect to application of space technologies to 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 demonstrates the usefulness of GIS in tracing the source of infections of public water network with vibrio cholera. It lucidly presents spatial information on the source, distribution of V. cholera, and exposure of human populations to cholera infested water.

Materials and Methods

Study Area

The study was conducted in some part of Abeokuta: an ancient city which lies 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). Ogun River is the major water body which has sustained the 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 with a ring on the study area, and an inset map of Nigeria location of Abeokuta city within Nigeria while, plates 1 and 2 are clips of a high resolution satellite image of Abeokuta.

Methods

The pipeline distribution networks, map was 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 persons were imported into the GIS map as events themes.

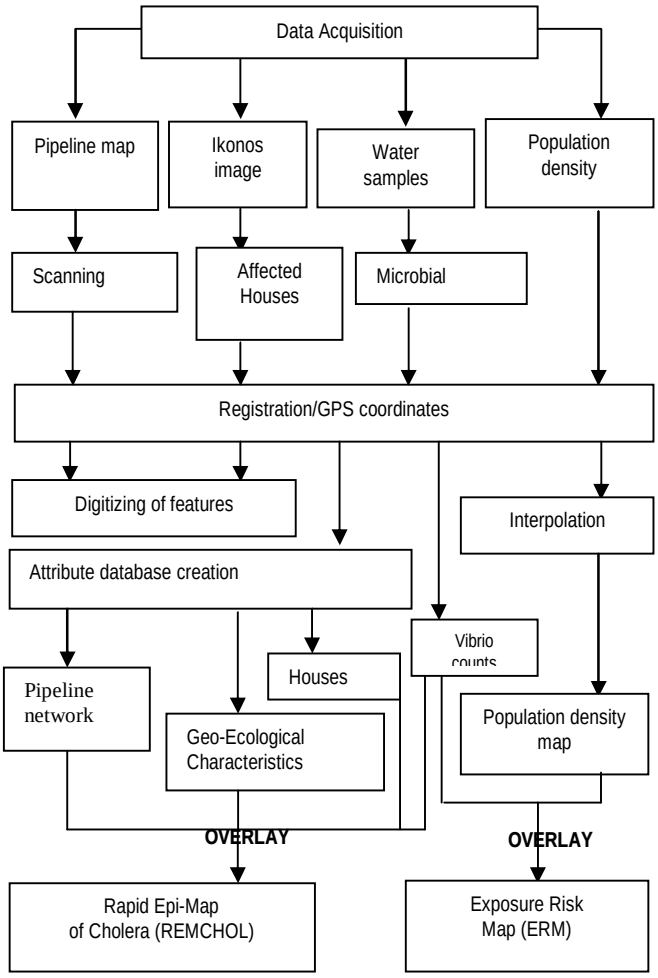

Figure 1**:** Cartographic model for rapid epidemiological mapping

The geo-ecological characterization of the study area was captured from the (Ikonos)s 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. 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 ($0^{o}C$) 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 *Vibrio cholerae* tube techniques were then used for enumeration of *Vibrio cholera*

Data Acquisition

Relevant data that will aid the full realizations of the objectives of the study were acquired. Map 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.

Database Development

The result of the *Vibrio cholerae* count per sample was used to build up the attribute for each of the water sample points in the GSI 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 500x500m 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.

Results and Discussion

In Table 1, a summary of the laboratory analysis water sample are presented. At the water works abstraction point in Ogun river, the water sample analysis showed a *Vibrio cholerae* count of >180 MPN/1000ml, 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 *Vibrio cholerae* count.

For example at Ilugun the count was 10 MPN/1000ml at Ajitadun and Ikereku communities it has risen to 50 and 60 MPN/1000ml respectively. Within the zone where the impact was mostly felt the count had gone up to 180 MPN/1000ml as can be seen in the chart in figure 2.

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

Sample locations	Nothings	Eastings	Vibrio count MPN/1000ml
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

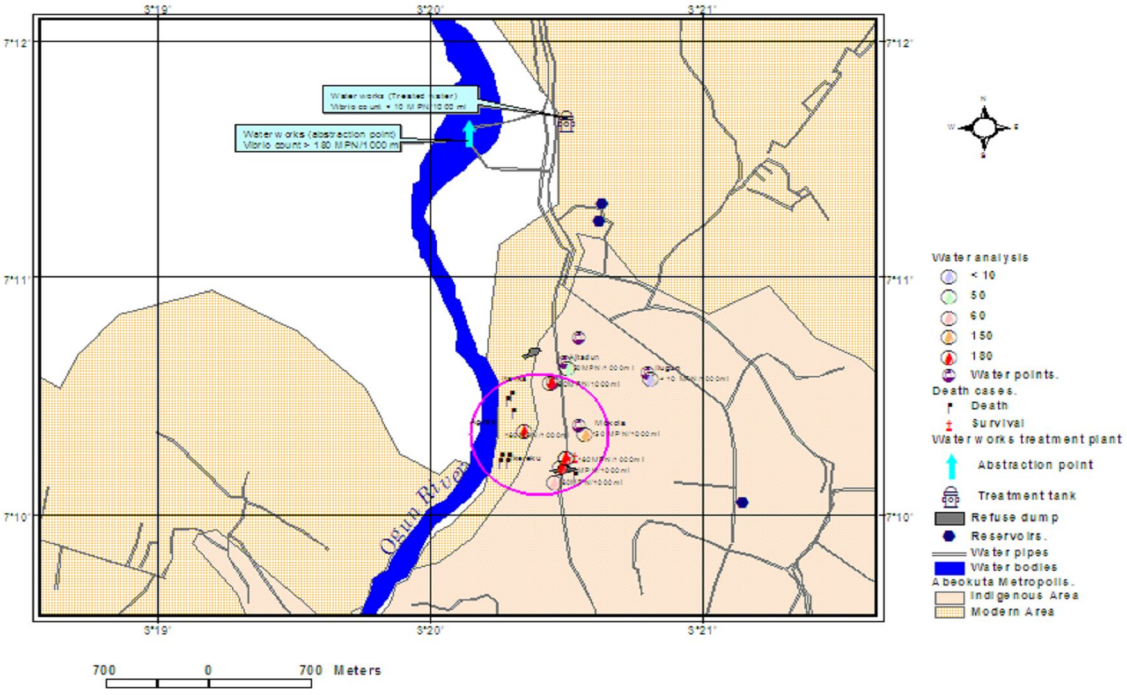

Figure 2: Contamination with distance from water works.

The inference that can be drawn from the foregoing is that the water must have been contaminated 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 littering open places. As can be seen in Figure 3, the map reveals possible sources of contamination of drinking water in pipes. For instance, a huge refuse dump is located directly on a 300mm pipe. This is a probable source of contamination especially where the pipes are leaking; infiltration under low pressure is easy.

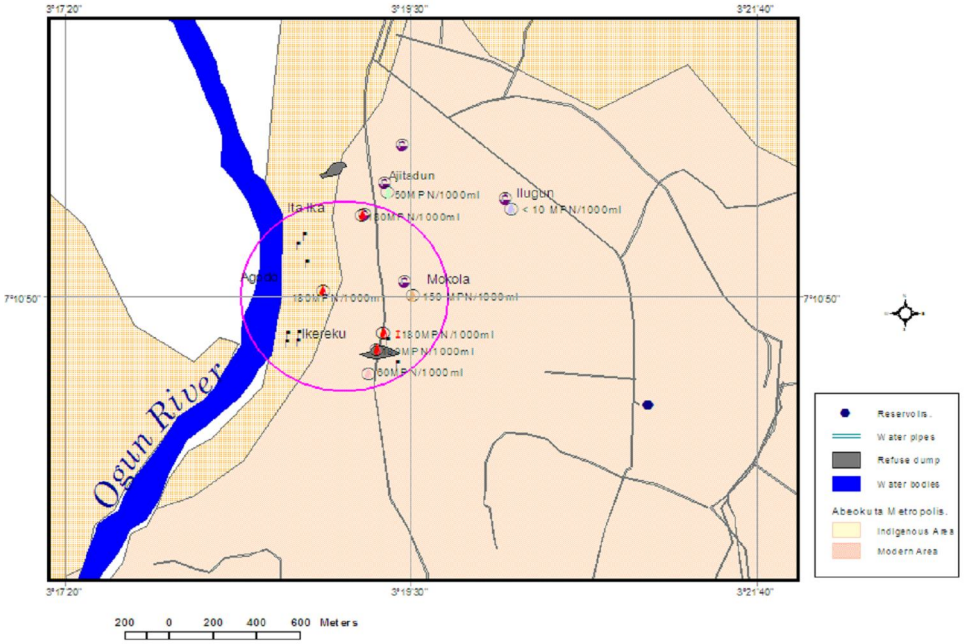

Figure 3: Map showing possible sources of contamination of drinking water in pipes.

Water samples collected from the faucets around this area show a very high *Vibrio cholerae* count of above 180 MPN/1000ml.

In Figure 4, the map showing the distribution of water taps and the value of *Vibrio cholerae* counts in the samples analyzed is presented. The map revealed that the clustered cholera cases were found where the contamination values were highest (above 180 MPN/1000ml). The circle on the map shows the area where death occurred. Black flag symbols imply death while the road cross symbols implies survival.

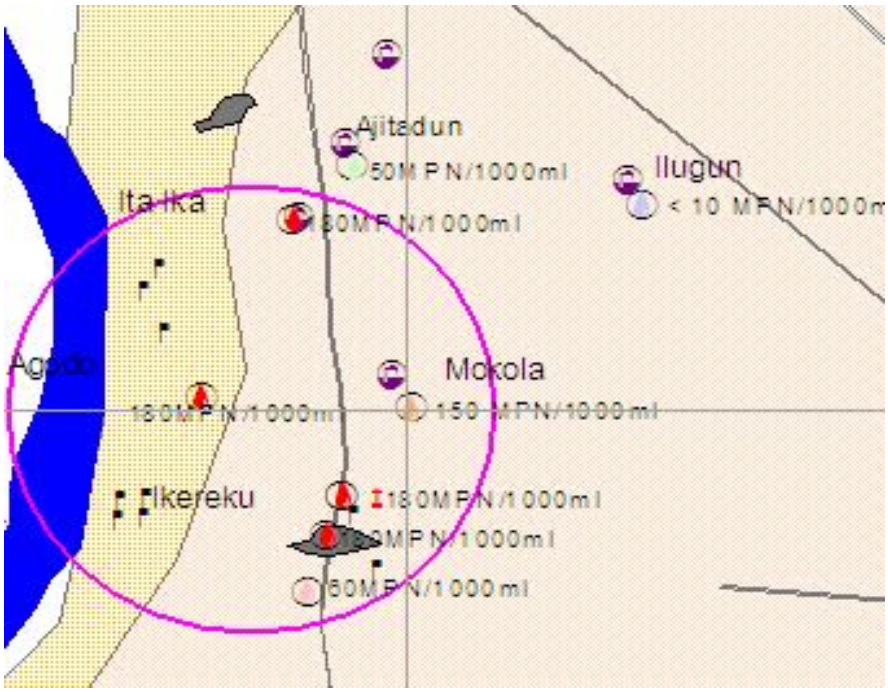

Figure 4: Map showing distribution of water taps and the value of *Vibrio cholerae* counts in the water from the faucets

Table 2 is the population exposed to risk of infection in the area. The level of risk varies spatially. This could 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 (3306) compared to the area of study (1.2km^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 3964 persons per square kilometers it is highly essential to give attention to monitoring systems.

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	

Conclusion

One major area in which GIS and health research have come together is the study of environmental and geographical epidemiology (Kistemann et al 2000). 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.

Firstly, a possible and ready source of contamination is exposed by GIS, and secondly the affected communities are contagious with the cholera epidemic zone in the city.
Links between disease outbreak, environment, and disease clustering etc with the aid of GIS have been established in past studies (Clarke et al 1996; Dunn,1992).

References

Goodchild, M. F. 2000. "Communicating geographic information in a digital age". *Ann. Am. Geographers* 90(2):344-355

Twigg. L. 1990. "Health based geographical information systems: Their potential examined in the light of existing data sources". Social Science and medicine 30(1):143–155

Aral, M. M. and M.L Maslia. 1996. "Evaluation of human exposure to contaminated water supplies using GIS and modeling". Kover K.: Nachtnebel, H.P. (Eds.): Application of geographic information system in hydrology and water resources management. IAHS-publication Pp 233–252

Nuckols, J.R., L. Stallones J. Reif, and R. Calderon, 1995. "Evaluation of the use of a geographic information system in drinking water epidemiology". Reichard, E.: Zapponi, G. (Eds.): Assessing and managing health risks from drinking water contamination – approaches and applications. IAHS-publication 233:111–122.

Gbadebo, A.M., J.A. Oyedepo, and A.M. Taiwo. 2010. "Variability of Nitrate in Groundwater in Some Parts of Southwestern Nigeria". Pacific Journal of Science and Technology. 11(2):572-584

Dangendorf, F., S. Herbst, R. Reintjes, and T. Kistemann. 2002. "Spatial pattern of diarrhoeal illness with regard to water supply structure – a GIS analysis". International Journal of Hygiene and Environmental Health. 205(3):183–191

Kistemann T., F. Dangendorf, and M. Exner. M. 2001. "A Geographical Information System (CIS) as a tool for microbial risk, assessment in catchman areas of drinking water reservoirs". International Journal of Hygiene and Environment Health, 203(3):225–233.

Orebiyi, E.O., J.A Awomeso and J.A. Oyedepo 2008. Assessment of bacteria pollution of shallow well water in Abeokuta, Southwestern Nigeria. Life Science Journal, 5(1):59–65.

Ekpo, U.F., C.F Mafiana, C.O. Adeofun, A.R.T. Solarin and A. Idowu 2008. “Geographical information system and predictive risk maps of urinary schistosomiasis in Ogun State, Nigeria”. BMC Infectious Diseases. 8:74

Koppen, W. 1918. "Classification des klimas nach Temperator" Niederschlag and jahreslaus, Petermans Geographische Mitteilung; 64:193–203

Faruque, S.M., N Chowdhury, N. Kammzzaman, M. Dziejman, M.H. Rahman, D.A. Sack, G.B. Nair and J.J Mekalanos. 2004. "Genetic diversity and virulence potential of environmental *Vibrio cholerae* population in a cholera endemic area". PNAS, 101:2123–2128

Kistemann, T. 1997. "Trinkwasserinfektionen – Risiken in Hochentwickelten Versorgungsstrukturen". Geogr. Rundschau, 29(4): 201–215

Clarke, K.C., S.L and McLafferty, B.J. Tempalsky 1996. “On epidemiology and geographic information systems: a review and discussion of future directions”. Emerg. Infect. Disease. 2(2):85–92.

Dunn, C. 1996. “GIS and Epidemiology”. AGI publication, number 5,92 Association for Geographic Information, London.