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An investigation of selected microbial pollutants in groundwater sources in Yenegoa Town, Bayelsa, Nigeria

Uma investigação de poluentes microbiológicos seletivos em reservas de águas subterrâneas em Yenegoa Town, Bayelsa, Nigeria

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Abstract

Potable water is a scarce resource in Yenegoa (Bayelsa Nigeria) town because of problems of ground water conditions and contamination. Residents in the town depend therefore on imported water and unwholesome ground water sources for sustenance. Over 200 boreholes exist in the city and constitute the major source of domestic water to this growing third world city. Thus, the present study aimed to diagnose the quality of the water consumed by the population. Thirty boreholes were therefore selected and the presence of readily analyzable biological contaminants in ground water sources in the city and their health implications were examined. Selected micro-organisms (coliform, *E. coli, Pseudomonas and Salmonella*) where analyzed and compared with WHO/FEPA water quality standards. Results revealed the presence of hazardous biological communities in the ground water sources especially in the Opolo-Okaka-Old Yenegoa-Swali axis, while groundwater sources from the up-gradient and more clayey Igbogene-Agudama- Okutukutu axis were relatively free of the selected biological contaminants. The study concludes that ground water in the Yenegoa central district and the Swali areas suffer intense biological contamination which therefore exposes inhabitants to water borne diseases such as: cholera, diarrhea, typhoid fever, bacterial and amebic dysentery, polio infections, hepatitis and schistosomiasis. Suspected contamination sources is seepage from oft-ill constructed soak-away pits. Also, groundwater problems arising from the seasonal flooding of porous soil formations leading to the collapse of the water table especially in the long rainy season that characterize the study area is also a major causative factor.

Keywords: Groundwater. Microbial contaminants. Urban ecology. Water quality. Water monitoring.

Resumo

A água potável é um recurso escasso em Yenegoa (Bayelsa, Nigeria), um problema agravado devido a problemas de qualidade e contaminação. Os moradores da cidade dependem de água importada e de fontes de águas subterrâneas para sua sobrevivência. Na cidade existem mais de 200 poços, os quais correspondem à principal fonte de água para uso doméstico desta crescente cidade do terceiro mundo. Desta forma, o presente estudo teve como objetivo diagnosticar a qualidade da água consumida pela população. Para tal, foram selecionados 30 desses poços nos quais foi avaliada a presença de contaminantes biológicos prontamente analisáveis (coliformes, E. coli, Pseudomonas, e Salmonella). As análises foram comparadas com os padrões OMS/FEPA de qualidade de água. Os resultados revelaram a presença de comunidades biológicas perigosas nas fontes de águas subterrâneas, especialmente no eixo Opolo-Okaka-Old Yenegoa-Swali, enquanto as fontes de águas subterrâneas superiores e mais argilosas do eixo Igbogene-Agudama- Okutukutu se apresentaram relativamente livres de contaminantes. O estudo evidencia que a água subterrânea na região central do distrito de Yenegoa e as áreas Swali sofrem contaminação biológica intensa expondo seus habitantes ao risco de contraírem doenças transmitidas pela água, tais como: cólera, diarreia, febre tifoide, disenteria bacteriana e amebiana, infecções da pólio, hepatite e esquistossomose. Possíveis fontes de contaminação incluem vazamentos de poços sépticos mal construídos, bem como problemas decorrentes da inundação sazonal em áreas de solos porosos, especialmente durante o longo período de chuvas que caracterizam a área de estudo.

***Palavras-chave**: Água subterrânea. Contaminantes microbianos. Ecologia urbana. Qualidade da água. Monitoramento da água.*

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Introduction

Ground water has historically been assumed to be safer as a drinking water source than surface water. It is assumed that passage of groundwater through the soil would filter contaminants (Oteze, 1990). However, water borne diseases out breaks are known to have resulted from the use of untreated ground water for domestic purposes. The extent of ground water contamination depend on some factors such as, rainfall pattern, depth of water table, distance from the source of contamination and soil properties such as texture, structure, ions and infiltration rate (Asthana & Asthana, 2006).

Biological contamination of ground water is a phenomenon that is characterized by the deteriorating nature of the quality of ground water as a result of various human activities (Klitoliya, 2004). The World Health Organization (WHO) estimated that 2.1 million people die annually from diarrhea and 10% of the population in less developed countries suffers from parasitic worm infections and 80% of all sickness and diseases in less developed countries can be attributed to water borne infection agents and unsafe water and sanitation conditions. While 90% of the people in developed countries have adequate (safe) sewage disposal and 95% have access to clean drinking water, at least 2.5 billion people in developing countries lack safe drinking water and adequate sanitation. The conditions are especially worst in the remote, developing urban centers where sewage treatment is usually primitive or non-existent and purified water is either not available or too expensive to obtain (WHO, 2004). The most serious ground water contaminations in terms of human health implications worldwide are pathogenic organisms. Among the most significant water borne disease are typhoid, cholera, bacterial and amoebic dysentery, polio infections, hepatitis and schistosomiasis (Cummingham, 2005).

Improper treatment of faecal waste before disposal is a major avenue through which faecal Coliform and other pathogenic micro-organism can be transmitted to ground water system. Other means include leaky soak-away pits and septic tanks and run off from animal feed lot; faeces of warm blooded animal and birds (Schueler, 2002; Bhatia, 2005). Another way in which Coliform bacteria and other micro-organism enter ground water sources is through slime, formed by naturally occurring ground water micro-organisms. The slime or (biofilm) cling to well screens, casings, pipes and pumps. Disturbance during pumping or well maintenance can cause the slime to dislodge, releasing the bacteria. Insects also can carry coliform bacteria into a well due to improper casing or poor well seal or caps. Unplugged or abandon wells can also allow coliforms access into deeper aquifers (WCM, 2007; Michigan Department of Environmental Quality, 2007).

In addition to faecal coliforms, it has been shown that in the United State for instance, viruses and other pathogens contaminate ground water. Hepatitis A virus, salmonella and rota virus from faecal sources was found in 20% of the ground water tested nation wide. According to the Centre for Disease Control, viruses can move through the septic tank systems from toilet to adjacent ground water systems within 18 hours. Microbial pollution of ground water also comes from animals. Cattle can excrete millions of *E. coli* O157:H7, *Cryptosporidium*, *Giardia* and other microbes which find their way through percolating water especially during heavy rainfall to ground water. Chicken wastes carry pathogenic bacteria salmonella and campylobacter (US Centre for Disease Control and Prevention, 2007).

Most coliform bacteria do not cause illness. However, their presence in a water system is a public health concern because they indicate 'recent' faecal contamination of water by faecal matter including the presence of disease causing strains of bacteria and viruses. They are therefore regarded as "indicator species". Typical disease from these organisms include flu- like symptoms such as nausea, vomiting, fever and diarrhea (WCM, 2007; Michigan Department of Environmental Quality. 2007; Geldreich, 1972).

In September 1999 *E. coli*. 0157:H7 from animal yard run off entered a poorly constructed well causing the death of two and over 1000 cases of illness at the Washington County Fair in Albany, New York. In the same September, over 300 people, including 22 were hospitalized, because of infection with *E. COLI* O157 in Petersburg Illinions (Stark & Scott, 1999). Ground water contaminated with pathogenic micro-organisms result not only in human suffering but also in significant economic losses. Epidemiology estimates show that 1.5 million Americans fall ill from infections caused by faecal contamination. In 1993 for instance a pathogen (cryptosporidium) got into Milwaukee community public water making 400,000 people sick and killing at least 100 people. The total cost for this disease amounted to billions of dollars per year. Preventive measures such as protecting water sources and aquifer recharge zones and updating treatment and disinfection system would have cost much less (Cummingham, 2005; US Centre for Disease Control and Prevention, 2007).

Bacteria of excretal origin may be grouped based on their characteristic into *Coli aerogenous*, *Clastridium welchii*, Fecal *Streptococci* (Bhatia, 2005). *Clostricluim Welchi* and fecal *Streptococci* bacteria are also found in human intestine, soil, sewage and polluted water. They grow in the presence of bile salt and are capable of growing at temperatures as high as 45% and are pathogenic in nature. Other pathogenic bacteria found in ground water are legionella, and campyho bacteria. They grow in pipe water distribution system. Others include pseudomonas, salmonella, rotavirus, hepatitis virus and Coxsackie's virus (Bhatia, 2005; Usepa, 2007).

Some pathogens that may be naturally present in ground water may be able to cause disease in people with impaired local or general immune defense mechanisms such as elderly or the young, patient with burns or excessive wound, those undergoing immuno-suppressive therapy or those with acquired immune deficiency syndrome (AIDS). If the water used by such people contain sufficient number of those organisms, its can produce various infection of skin and the mucous membranes of the eyes, nose, ears and throat. Examples of such agent are *Pseudomonias acrogiriossi,* and species of *Aciretobacterias* and *Flavo bacterium* (History of water filters, 2010).

Groundwater sources of drinking water are highly polluted especially in big cities and towns. In most urban centers of the world, majority of the houses are served by on site sanitation systems such as septic tanks, pit and bucket latrines. The faecal sludge collected from these systems is discharged indiscriminately or untreated into open urban space drains, streams, and rivers. This poses great threat and risk to water resources and public health (Montangero & Strauss, 2002).

Sewage or human faecal waste dumped in soaked pit can seep and contaminate ground water. Seepage from polluted lake and pond can also contaminate ground water with pathogenic micro-organism. Human faeces which are laden with pathogenic micro-organisms gain access to ground water through the stated means and groundwater is especially vulnerable to such contaminants in areas with shallow groundwater tables, proximity to soak-away pits and disposal sites and otherwise very sandy and porous aquifers like in the Yenagoa area. This study is therefore an attempt to document the level of microbial pollution of groundwater in the Yenegoa city, Nigeria.

Materials and methods

Study area

Yenegoa became the capital city of Bayelsa State of Nigeria in 1996. This created a rush in human populations and an unprecedented pressure on the available urban space thereby causing space, water supply and sanitation difficulties. Surface water bodies became mostly sinks for untreated urban drainage and solid wastes including human excreta. Groundwater sources or imported water therefore present the only option for safe drinking water supply for the ever expanding and sprawling urban center (Figure 1). Yenagoa (located within Latitude 4° 53' N and Longitude 60° 15' E) is generally a lowland region, with highest land elevation being about 15 meters above mean sea level. The area is marked by flat floored creeks. The Epie creek is the most important creek found in the area and serves as a sink for urban waste, a means of transportation and fishing activities. It flows from the North – East to the South – West emptying into the Nun River system. The creek is prone to flooding especially during the wet season mainly because of the heavy rainfall, high ground water table, the flat floored creeks and high clay content of soils in the area (Oyegun, 1999). Yenagoa lies within the tropical region and experience equatorial climate (Koppen's Af–Climate type). It experiences rainfall through all the year while November – March are the driest months. Rainfall sometimes exceeds 2,500 mm annually.

Sample collection and data analysis

Over 200 boreholes exist in Yenegoa city and constitute the population for this study. We selected, 30 boreholes from 20 communities covering the whole of the city (Figure 2). Samples were taken from untreated borehole water sources and taken to the laboratory for analysis.

All the samples were collected in pre-labeled sterilized 1 L plastic containers and were sent for

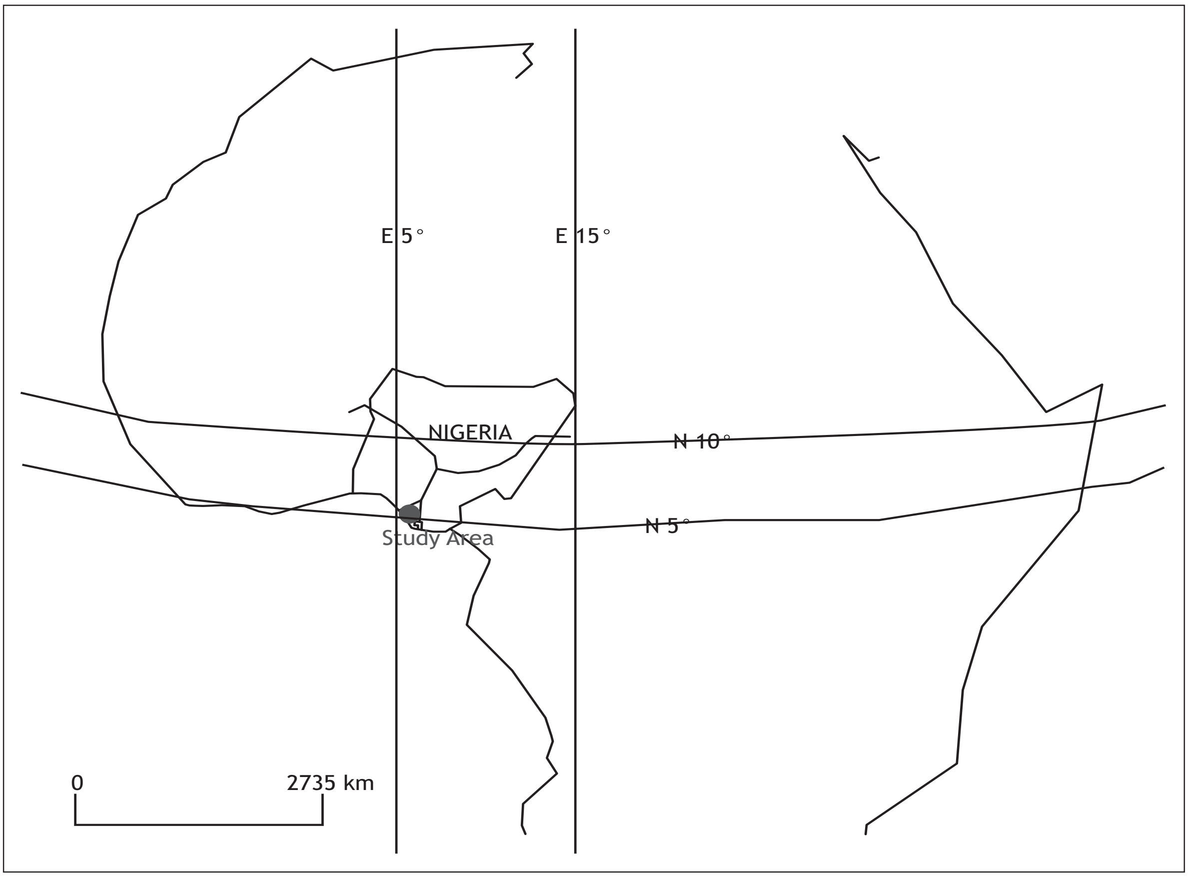

Figure 1 - Location of the study area
Source: Research data.

laboratory within four hours of sample collection. The samples were collected and analyzed within four hours of sample collection. Sample collection and analysis followed the method described by APHA, AWWA, WEF (1998) and Lingireddy (2002). Samples were collected in sterilized plastic bottles of one liter size. As a precaution, all attachments to the well and tap were removed and tap was allowed to flow for about three minutes at medium flow rates, before sample collection. Within this interval we assumed that stable conditions would exist. Sample bottles were also rinsed thrice with the sample (water) before samples were collected; and to avoid external contaminants, the outlets of the taps were also sterilized by means of flame cigarette lighter.

Microbiological assays followed standard methods (APHA, AWWA, WEF, 1998) for detecting presumptive faecal coliforms, *Escherichia coli, Pseudomonas* and *Salmonella* which include filtration, followed by culture of filters on a medium that selectively permits growth of gram-negative bacteria and differentially detects lactose utilizing bacteria was adopted. Faecal coliform, *E. coli, Salmonella* and supplementary microorganism *Pseudonomas aeruginosa* were enumerated by the membrane filtration technique, and the results expressed as colony forming units (cfu) per 100 mL. The selective and recovery media used and incubation conditions were the following: Nutrient agar for total coliform, violet red bile lactose (VRBL) agar for presumptive *E. Coli* counts, Samonella agar for *Salmonella* and centrimide agar for Pseudonomas aeruginosa counts. Nutrient agar plates were incubated at 28+- 1 °C and counted after 24 hours and 48 hours. All other plates were incubated at 37 °C and counted after 48 hours.

All the media used were weighed out and prepared according to the manufacture's specification, with respect to the given instructions and directions. A serial dilution method was used for total viable count

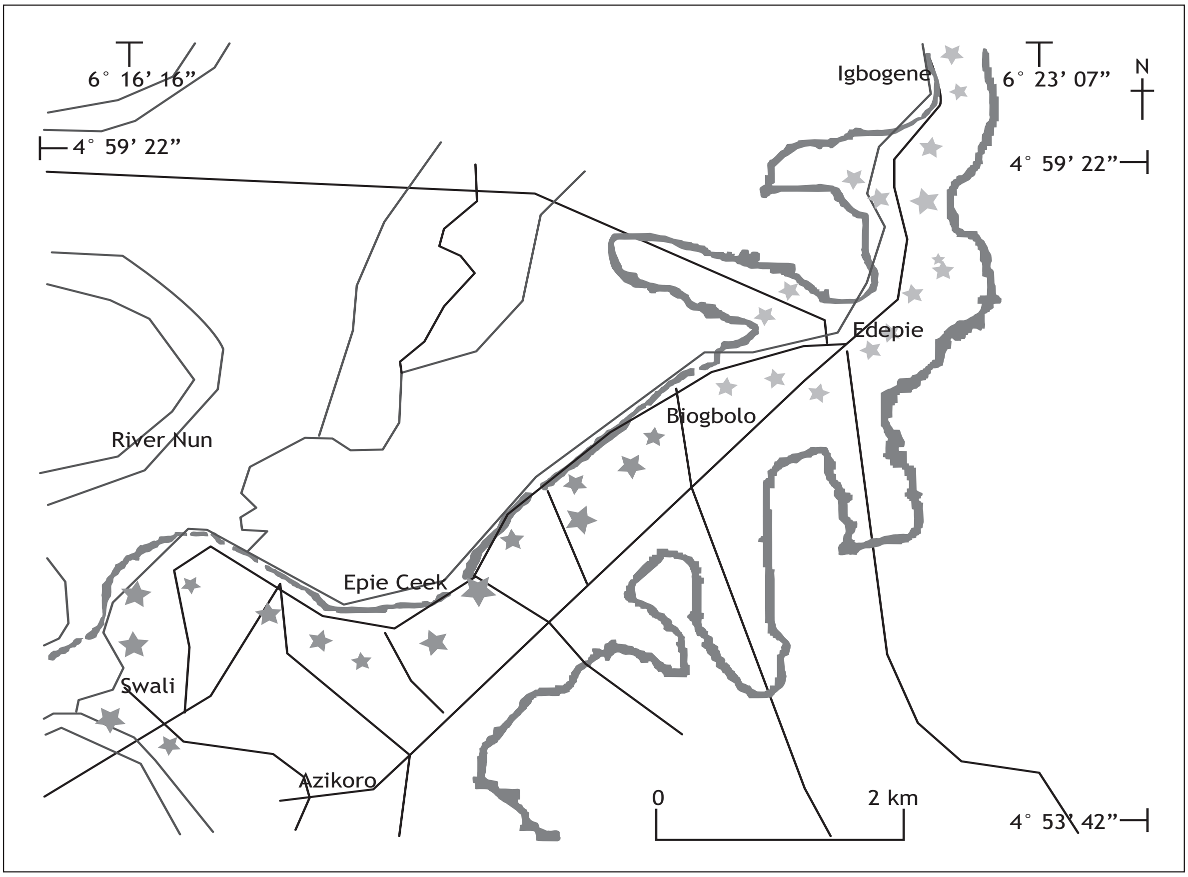

Figure 2 - Points of water sampling
Source: Research data.

and the presumptive test for coliforms. The sterility of each batch of test medium was confirmed by incubating one or two uninoculated tubes or plates along with the inoculated tests. The uninoculated tubes or plates were always examined to show no evidence of bacterial growth. Any uninoculated tube or plate that showed evidence of bacterial growth was discarded. The pure cultures of the bacterial isolates were subjected to various morphological and biochemical characterization tests to determine the identity of the bacteria isolates with reference to Bergey's Manual of Determinative Bacteriology (Buchanan & Gibbons, 1974).

Results and discussion

Results of analysis displayed in Table 1 shows a comparison of sample results with WHO (Lenntech, 2004) drinking water standards and Nigeria's Federal Environmental Protection Agency/ National Food and Drug Law Administration Council (FEPA/ NAFDAC, 1991) standards of which offshoots of the former. Results are compared with WHO (Lenntech, 2004) drinking water standards and Nigeria's Federal Environmental Protection Agency/National Food and Drug Law Administration Council (FEPA/ NAFDAC, 1991) standards of which offshoots of the former. There were inter-site as well as inter regional spatial variations in the occurrence of biological communities in groundwater. The presence of biological contaminants ranged between 0 and 5 in the Opolo-Swali axis of the town, while the Igbogene--Okutukutu axis seems to be free from biological communities. All the water samples in the Opolo-Swali areas which are in the heart of Yenegoa town exceeded at least the limits in one of the tested biological communities indicating a high level of pollution and palpable health problems.

Table 1 - Results of biological analysis of ground water contaminants

Parameter	Media	Locations																WHO/FEPA
Coliform	Nutrient broth (NB)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16-30	
Coliform	Nutrient broth	0	0	2	3	1	2	2		1	0	0	1	2	3	1	0	0 in 100 mL
E-Coli	Violet Red Bile (VRB)	1	0	2	2	4	2	3	0	0	0	0	1	2	2	0	0	0 in 100 mL
Pseudomonas	Centrimide Agar (CA)	2	1	1	1	2	5	1	2	1	0	0	0	1	1	0	0	0 in 250 mL
Salmonella	Salmonella Agar (SA)	1	2	3	1	2	3	0	1	4	3	1	2	4	1	2	0	No guide line

Source: Research data.

Further investigations revealed that the Igbogene--Okutukutu area of the town is less densely populated as such the problems of faecal pollution of groundwater could be less endemic. Also this part of the town is situated up-gradient of groundwater movement and has more clayey soils than the down-gradient and heavily populated Opolo-Swali areas. Moreover the Opolo-Swali areas is located in the Y-shaped River Nun bifurcation area and contains more sandy material probably from cut and fill material that created the confluence of the Nun in this area.

Health implication of biological contaminants in ground water

The result of the laboratory analysis of ground water in the area of study indicates that biological contaminants are present far above internationally recommended standards for drinking water.

There are many diseases that can affect human beings as a result of drinking of contaminated groundwater. As earlier stated faecal bacteria contaminated water has been linked outbreak of disease like cholera, typhoid, diarrhea and dysentery (Lingireddy, 2002). Also it can lead to diseases of the gastro intestinal tract and cause life threatening disease like hepatitis (A, B, and C) and legionnaire's disease (History of water filters, 2010). Infection with legionnaire's disease can be fatal with painful symptoms as high fever, incessant cough, lung congestion and subsequent pneumonia. The disease can permanently damage such vital internal organs as the heart and lungs and may result in higher rate of spontaneous abortion in pregnant women. *Pseudomonas* on the other hand is of the genus of gammaproteobacteria, belonging to the family *Pseudomonadaceae*. Common *Pseudomonas* spp., include *Aeruginosa* sp*., Fluorescens* sp*., Putida* sp*. or Stutzeri* sp. *Pseudomonas aeruginosa* is a gram-negative bacterium commonly found in soil and ground water. It rarely affects healthy people and most community acquired infections are associated with prolonged contact with contaminated water (HPA, 2011).

According to the United Kingdom Health Protection Agency, *P. aeruginosa* is increasingly important clinically as it is a major cause of both healthcare-associated infections and chronic lung infections in people with cystic fibrosis. Although *P. aeruginosa* is an opportunistic pathogen, it can cause a wide range of infections, particularly among immune-compromised people (HIV or cancer patients) and persons with severe burns, diabetes *mellitus* or cystic fibrosis. *P. aeruginosa* is one of the more common causes of healthcare-associated infections and is increasingly resistant to many antibiotics (HPA, 2011).

Currently an *E. coli* scare is hunting the whole of Europe. Outbreaks *E. coli* have been in Germany, France and the United Kingdom. In Germany alone according to the European Centre for Disease Prevention and Control, more than 4,000 people were infected lead ing to the death of about 50 persons. Also millions of Euros were lost in revenue from closure of businesses connected to suspected infection sources and in health care costs (Daily Sun Newspapers, 2011). Deaths from *E. coli* infection in many other developed countries has also been reported in many international media organizations. Also an 8% rise in bacteremia is from *Pseudonomas* spp., was also reported in England, Wales and Northern Ireland between 2006 and 2008; while in 2010 alone 90% of *Pseudomonas* spp. isolates from bacteremia were identified to species level (3,432 reports), with 93% of these identified as *P. aeruginosa* in England, Wales and Northern Ireland (HPA, 2011).

There is clear evidence from this preliminary study that groundwater in Yenegoa town is not safe for human consumption without treatment. Since bacteria contamination cannot be detected by taste, smell, or sight, all drinking water well should be tested at least annually at least for indicator species. Also the Michigan state' (USA) well construction code (Michigan Department of Environmental Quality, 2007) which requires all new, repaired or reconstruction wells to be disinfected with chlorine to kill bacteria that may have been introduced during well construction or repair need to be applied in Yenegoa. Wells with total or fecal coliform count above drinking water guidelines of 10 cfu per 100 mL should not be used for drinking or for food preparation purposes without disinfection.

Alternatively microbial contaminated water should be boiled at least for ten minutes before usage. Disinfection with ultraviolet light (UV) or reverse osmosis can be used to destroy or remove bacteria viruses or other organisms in water and due to the potential for bacterial re-growth in distribution lines, liquid bleach should be used to disinfect faecal contaminated water sources and tanks thoroughly washed and free of residue and retested before being applied to domestic usage again. Test for indicator species should also be carried out immediately if; a sudden change occur in water tastes, appearance and, or odour, or when the water turns cloudy; and septic tanks, soak away pits and barn yards should be located at least 15 meters away from well head positions. There is also a serious need for public health education on basic water treatment and sanitation.

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References

American Public Health Association [APHA], American Water Works Association [AWWA], & Water Environment Federation [WEF], (1998). *Standard Methods for the Examination of Water and Wastewaters*. (20th ed.). Washington, DC: American Public Health Association.

Asthana, D. K., & Asthana, M. (2006). *A Textbook of Environmental Studies*. India: S. Chand.

Bhatia, S. C. (2005). *Environmental Pollution and Control in Chemical Process Industries*. (pp. 2–13). Delhi: Romesh Chander Khanna for Khanna Publishers.

Buchanan, R. E., & Gibbons, N. E. (1974). *Bergey's Manual of Determinative Bacteriology* (8th ed.). Baltimore: The Williams and Wilkins company.

Centre for Disease Control and Prevention. (2007). *National Centre for Prevention Services, Division of Oral Health. Water supply statistics.* Atlanta, Georgia: Centres for Disease Control and Prevention.

Cummingham, W. P. (2005). *Environmental Science: A Global Concern*, (8th ed.). New York: McGraw Hill.

Daily Sun Newspapers. (2011). *E. coli outbreaks linked to Egypt*. Nigeria, Friday, July 1, 2011.

Fepa. (1991). *National Environmental Protection. (Effluent Limitation) Regulations (S.1.8).* Lagos, Nigeria: Fepa, FGPL.

Geldreich, E. E. (1972). Water-borne pathogens. In R. Mitchell (Ed.). *Water pollution Microbiology*. (pp. 207–241). NewYork: Wiley-Interscience.

Health Protection Agency – United Kingdom. [HPA- UK]. (2011). *Pseudomonas spp. and Stenotrophomonas maltophilia* bacteraemia *in England, Wales, and Northern Ireland, 2006 to 2010.* Recovered on January 25, 2013, from http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1309968922480

History of water filters. (2010). *Contaminates Resulting from Biological matter in water*. Human and Animal, faeces. Recovered on July 3, 2013, from http://www.history of water filters.com/human.animal-faeces.html

Klitoliya, R. K. (2004) Environmental Science, (2nd ed.). India: New Central Agency Ltd. Recovered on april 23, 2007, from http://www.lenntech.com/heavy-metals.htm

Lenntech. (2004). *Comparative Table of WHO (1993) and EU (1998) Standards*. Recovered on April 23, 2007, from http://www.lenntech.com/heavy-metals.htm

Lingireddy, S. (Ed.). (2002). *Control of Microorganisms in drinking water*. Reston: American society of Civil Engineers.

Michigan Department of Environmental Quality. (2007). *Coliform Bacteria and Water well Sampling. DEQ Factsheet.* Recovered on January 25, 2013, from: http://www.michigan.gov/documents/deq/deq-wd-water-fos-tsu-SampleSitePlan_247612_7.pdf

Montangero, A., & Strauss, M. (2002). *Lecture notes IHB Delft*. (8th ed.). Recovered on January 25, 2013 from http://www.sandec.ch/sos/refences

Oteze, G. E. (1990). Trace elements in the groundwater in the Sokoto Basin, Nigeria. *Water Resources*, *l2*(1), 7–13.

Oyegun, C. U. (1999). Climate, Relief and Drainage. In E. J. Alagoa (Ed.). *The land and People of Bayelsa*. Port Harcourt: Onyoma Research Publication.

Schueler, T. R. (2002). *Microbes and Urban Watersheds: Concentrations, Sources, & Pathways. The Practice of Watershed Protection*. Ellicott City, MD: Center for Watershed Protection.

Stark, C., & Scott, D. (1999). *E. coli in Drinking Water fact sheet: Cornell Extension*; NY State Health Department press releases. Recovered on January 25, 2013 from http://www.epa.gov/safewater/ecoli.html

Usepa. (2007). Environmental indicators of water quality in the United States. EPA 841R96002. Recovered on January 25, 2013, from http://www.yosemite.epa.gov/water/owrccatalog.nsf

Washtenaw County Michigan [WCM], (2007). *Environmental health fact sheet coliform bacteria and drinking water.* Recovered on January 25, 2013 from http://www.ewashtenaw.org/government/departments/environmental_health/wells_septic/well_septic_pdf/eh_coliformfactsheet.pdf

World Health Organization [WHO], (2004). *Water for health: Guidelines for drinking-water quality*. Geneva: WHO.