Advances in Life Science and Technology
ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol.13, 2013

Bacteriological and Physicochemical Qualities of Well Water in Imota-Lagos Nigeria and Health Effects Associated with its Usage.

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Abstract
Well water is a key source of drinking water in rural areas, such as Imota where this study was carried out. Forty wells made of concrete, comprising of 20 (50%) hand-drawn and 20 (50%) operated through mechanical/electrical pumps in Imota were investigated for their physicochemical and bacteriological qualities. Analytes such as total hardness, magnesium hardness, calcium hardness and nitrate levels were within the recommended WHO standard for water quality. The water from the wells with pH values of 4.5 – 5.9 is acidic and falls below the WHO recommended pH range of 6.5-8.5. Ammonium and iron concentrations in the well water were relatively higher as well as very high bacterial loads and coliform counts were obtained. Calcium and magnesium significantly correlates with each other and both with total hardness ($p<0.001$). Significant positive correlations were obtained between iron concentration and coliform counts (0.039), iron and nitrate ($p=0.033$), as well as coliform and total bacterial load ($p=0.001$). Higher bacterial loads were obtained from wells that are hand-drawn using various containers than wells where water is being pumped using devices. The bacteria isolated include *Staphylococcus aureus, Staphylococcus epidermidis, Staphylococcus equorum, Staphylococcuss carnosus, Kokuria varians, Enterococcus faecalis, Bacillus niacini , Bacillus firmus, Streptococcus pneumoniae, Citrobacter koseri, Enterobacter cloacae, Klebsiella pneumoniae, Enterobacter aerogenes, Acinectobacter baumannii, Pseudomonas* sp., *Salmonella enterica*, *Edwardsiella tarda* and *Buttiauxella agrestis*. The bacterial isolates were highly susceptible to antibiotics except for chloroamphenicol, ampicillin and nitrofurantion which showed 25%, 10% and 28.75% susceptibility respectively.. Symptoms of ill-health commonly reported by participants include fever, chills, headache, weakness/muscle ache, and skin rash, and abdominal pain, diarrhoea, sneezing and coughing. The reported frequencies of ill-health were significantly higher ($t=3.200$, $p=0.013$) among residents that drank water from the well than those that do not. The need to treat the water from these wells before drinking is highly recommended.
Key words: Antibiotic resistance, bacteria, ill-health, quality, well water.

1. Introduction

Water is the most important natural resource in the world, since without it life cannot exist. Human life can exist for many days without food but the absence of water for a few days has fatal consequences. Hence the need for a safe and reliable source of water is an essential prerequisite for a stable community (Tebbutt, 1999). Water is required for various human daily activities such as drinking, cooking, tooth brushing, bathing, washing utensils and also for agricultural and industrial purposes (Centre for Environmental Health, 2005). However, poor water quality continues to be a leading cause of health problems especially in developing countries where it is estimated that 80% of all illnesses are linked to water and sanitation and 15% of all child deaths under the age of 5 years result from diarrhoeal diseases (Thompson and Khan, 2003; WHO and UNICEF, 2004).

Water quality is a growing concern throughout the developing world. Drinking water sources are under increasing threat from contamination, with far-reaching consequences for the health of children and for the economic and social development of communities and nations. Water related diseases caused by insufficient safe water supplies coupled with poor sanitation and hygiene cause 3.4 million deaths a year, mostly among children. Despite continuing efforts by governments, civil society and the international community, over a billion people still do not have access to improved water sources. (UNICEF 2008)

In Nigeria, increasing population and infrastructural breakdown have made municipal pipe-borne water to be inadequate in quantity and quality (Adesunkanmi and Ajao, 1996). Today, less than 30% Nigerians have access to safe drinking water due to these inadequacies and most of the populations have to resort to drinking water from wells and streams especially in the rural and suburban communities. These water sources are largely untreated and might harbour waterborne and vector-borne diseases such as cholera, typhoid fever, diarrhoea, hepatitis and guineaworm (Rahman *et al.,* 2001; Adekunle, 2004; Fenwick, 2006).

Well water is the traditional source of drinking water in Imota community of Ikorodu Local Government Area, Lagos state. Many residents in the community depend on this source of drinking water till date. This study is an assessment of the quality of well water from this community and possible association of usage of the water with ill-health.

2. Materials and Methods

2.1. *Water sampling*

The study was carried out in Imota, Ikorodu Local Government Area of Lagos State, Nigeria, from January to June 2012. Imota is a sub-urban, non-industrialized area of Lagos State; its geographical coordinates are 6° 40' 0" North, 3° 40' 0" East. Forty wells were randomly selected and a volume of 1000ml of water were drawn from each well into a sterile container. Three water samples were drawn from each well at a week interval.

2.2. *Analysis of physicochemical parameters of water*

The analyses of physicochemical parameters of the well water samples were carried by standard methods. The pH values were determined with the aid of digital pH meter. Concentrations of ammonia, nitrate, iron, and calcium and magnesium hardness were determined by spectrophotometric methods as described by AOCA (1980).

2.3. *Bacteriological investigations*

Total bacteria and coliform counts were determined by pour-on technique using nutrient agar and macConkey agar respectively. Isolates from nutrient agar were further subcultured to obtain pure isolates. Following gram staining, the isolates were subjected to various biochemical tests as described by Barrow and Feltham (1993). The bacterial isolates were characterized on the basis of their cultural, morphological and biochemical properties according to Barrow and Feltham (1993), Garrity *et al.* (2005) as well as the aid of online Gideon Informatics (1993-2013). Antibiotics susceptibility tests were carried out on the bacterial isolates. The antibiotics used are nitrofurantoin (100μg), ceftriazone (30μg), ciprofloxacin (10μg), gentamycin (10μg), ofloxacin (10μg), augmentin (30μg), perfloxacin (30μg), clarithomycin (30μg), chloramphenicol (10μg) and ampicillin (30μg). *Escherichia coli* ATCC 25922 was used as control organism.

2.4. *Questionnaire*

A set of questionnaire was administered to 240 randomly selected individuals in Imota community. The questionnaire was structured so as to obtain information on sociodemographics and symptoms of ill-health such as fever, headache, weakness, skin-rash, abdominal pain, sneezing and coughing. Subjects were asked if they had experienced such symptoms of ill-health that lasted for 2-5 days or more in 6 months preceding the interview.

2.5. *Statistical analysis*

Associations between variables of physicochemical parameters were determined by pearson correlation. Paired t test was used to compare symptoms of ill health among people that drink from well water and those that do not. Analyses were carried out with the aid of SPSS 16.0

3. Results

Forty wells made of concrete, comprising of 20 (50%) hand-drawn and 20 (50%) operated through mechanical/electrical pumps in Imota were investigated for their physicochemical and bacteriological qualities. Analytes such as total hardness, magnesium hardness, calcium hardness and nitrate levels were within the recommended WHO standard for water quality. The water from the wells with pH values of 4.5 – 5.9 is acidic and falls below the WHO recommended pH range of 6.5-8.5. Ammonium and iron concentrations in the well water were relatively higher as well as very high bacterial loads and coliform counts were obtained ((Table 1). Only 15% of the wells do not contain coliforms, and are among wells that are well covered and electrically pumped. Calcium and magnesium significantly correlates with each other and both with total hardness ($p<0.001$). Significant positive correlations were obtained between iron concentration and coliform counts (0.039), iron and nitrate ($p=0.033$), as well as coliform and total bacterial load ($p=0.001$). Higher bacterial loads were obtained from wells that are hand-drawn using various containers than wells where water is being pumped using devices.

The bacteria isolated include *Staphylococcus aureus, Staphylococcus epidermidis, Staphylococcus equorum, Staphylococcuss carnosus, Kokuria varians, Enterococcus faecalis, Bacillus niacini , Bacillus firmus, Streptococcus pneumoniae, Citrobacter koseri, Enterobacter cloacae, Klebsiella pneumoniae, Enterobacter aerogenes, Acinectobacter baumannii, Pseudomonas* sp., *Salmonella enterica*, *Edwardsiella tarda* and *Buttiauxella agrestis* (Figure 1). The bacterial isolates were highly susceptible to antibiotics except for chloroamphenicol, ampicillin and nitrofurantion which showed 25%, 10% and 28.75% susceptibility respectively (Table 3).

The socio-demograhics of the studied population of residents of Imota are as presented in Table 4. All the participants bath with well water as well as make use the water in kitchen, 10% drink from well water. Symptoms of ill-health commonly reported by participants include fever, chills, headache, weakness/muscle ache, and skin rash, and abdominal pain, diarrhoea, sneezing and coughing. The reported frequencies of ill-health were significantly higher (t=3.200, p=0.013) among residents that drank water from the well than those that do not (Figure 2).

4. Discussion

Water plays a significant role in supporting human life, but if contaminated, it has a great potential of transmitting a wide variety of diseases and illness. In developed countries there is efficient supply of portable water, but in developing nations millions of people are not assessable to safe water supply Tebbutt (1998). As a result there is prevalence of water related diseases and millions of people die without safe water supply. Safe sources are important, but it is only with improved hygiene, better water storage and handling, improved sanitation and in some cases, household water treatment, that the quality of water consumed by people can be assured (UNICEF, 2008). Most rural areas do not have access to clean drinking water. They depend on unreliable water sources such as wells, rivers and streams for water supply. Few have access to bore-hole water or water from a treated source.

In Imota, a suburban settlement in Lagos Nigeria, without effective public water supply most residents depend on well water for most of their daily needs. The physicochemical qualities of water from these wells are more or less within the acceptable values, but the bacteriological status is of serious concern. The high level of coliforms in some wells and the prevalence of drug resistant bacteria may expose the inhabitants of Imota to high risk of diseases. It is evident from the study that participants that drink water from the wells reported significantly higher incidence of symptoms of diseases than those that drink packaged water. Coliforms are routinely found in diversified natural environments, as some of them are of telluric origin, but drinking water is not a natural environment for them. As a result, their presence in drinking water must be considered as harm to human health. Positive presence of coliforms in treated water which is usually coliform-free may indicate treatment ineffectiveness (Chan *et al*., 2007). The significant positive correlation between coliforms and iron concentration obtained in this study may be an indication of presence of iron bacteria in the water. Elevated levels of iron and manganese in water wells have been reported to often give rise to the growth of iron bacteria. Such bacteria can produce filamentous and slimy deposits that can clog filters and plumbing (Environmental Services, 2010).

Majority of the bacterial isolates from this study are of public health importance. *Staphylococcus aureus*, a coagulase positive *Staphylococcus*, is a major pathogen for humans. Almost everyone will have one form of *S. aureus* infection in lifetime, ranging from food poisoning or minor skin infection to severe life trathening infections (Brooks *et al.,* 2010). *Staphylococcus epidermidis, Staphylococcus equorum* and *Staphylococcuss carnosus* are coagulase negative staphylococci and constitute part of the normal flora of human and animals but sometimes cause infections. *S. aureus* as well as coagulase negative staphylococci can produce mucoid exopolysaccharide (referred to as slime) that allows them to form biofilm on surfaces of medical devices. These staphylococci are frequently involed in troublesome infections because of the difficulty in treating biofilm with antibiotics (Barua and Basu, 2009). *Streptococcus pneumoniae* are commonly associated with cases of pneumonia, meningitis, endocarditis, otitis media and sinusitis. *Enterococcus faecalis* belongs to the group D streptococci. *E. faecalis* causes 85 – 90 % of enterococcal infections, while *E. faecium* causes 5-10%. Enterococci are among the most frequently causes of nosocommial infections. *E. faecalis* has been associated with cases of abdominal abscess, urinary tract infection and endocarditis (Brooks *et al.* 2010). *Bacillus niacini* and *Bacillus firmus* are naturally occurring soil bacteria. *Bacillus firmus* isolate 1582 possesses nematicidal activity. It protects roots from nematode infestation, when applied directly to the soil, foliar treatment to turf, and as seed treatments. Although it causes mild eye irritation and immune responses, *B. firmus* I – 1582 was approved as biopesticide based on the low toxicity/lack of infectivity and pathogenicity of the active ingredient. (Bacchus, 2008). *Citrobacter* species are often isolated from clinical specimens as opportunistic pathogens. *Klebsiella pneumoniae* is frequently isolated from patients with urinary tract infections, pneumonia and bacteraemia. *Enterobacter aerogenes* and *Enterobacter cloacae* could cause a broad range of hospital acquired infections such as pneumonia, urinary tract infections as well as wound and device infections (Brooks *et al.,* 2010). *Acinectobacter baumannii* has been isolated from many clinical specimens. Most *Acinectobacter* species isolated from nosocomial infections belongs to this species. *Pseudomonas* species can cause a variety of diseases in human and animals. *P. aeruginosa* is an opportunistic human pathogen, most commonly affecting immunocopromised patients such as those with cystic fibrosis or AIDS. *P. aeruginosa* affects many parts of the body especially respiratory tract causing pneumonia and it is commonly associated with wound infections. *P. plecoglossicida* and *P. anguilliseptica* are common pathogens of fish. Infections due to pseudomonas are difficult to treat due to multiple drug resistance. Most sub-species of *Salmonella enterica* cause gastroenteritis in human, while *Salmonella enterica* Typhi causes enteric fever. *Edwardsiella tarda* is found in association with a variety of animals but rarely in faeces of healthy people. It is an opportunistic pathogen and may cause wound infections. *Buttiauxella agrestis* has been found to be associated with human infections such as appendicitis, wound infections and some cases of diarrheal diseases (Garrity *et al.,* 2005).

It is evident that well water in Imota is not portable. It is proffered that in rural communities like Imota, simple hygiene and basic water treatments should be adopted. Well contamination by microorganisms can be prevented by proper disposal of refuse, covering wells when not in use and drawing water with clean containers where pumps are unaffordable. Simple water disinfection methods like boiling, filtering and chlorination should be encouraged.

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Table 1: Physiochemical qualities and bacterial load of Imota well water samples

Parameters	Concentration in Imota Well Water Range (Mean±SD)	WHO Stanard for Drinking Water
pH	4.5 - 5.9 (5.07±0.64)	6.5 – 8.5
Total Hardness (ppm)	10.00 – 130.00 (36.0±35.65)	
Calcium Hardness (ppm)	5.00 – 65.00 (21.00±18.07)	40 -80\
Magnesium Hardness (ppm)	5.0 – 65.0 (17.00±18.14)	20 – 30
Nitrate (ppm)	0.06 – 0.77 (0.27±0.32)	50
Iron (ppm)	0.22 – 0.67 (0.35±0.16)	0.3
Ammonium	0.60 – 42.00 (5.81±12.92)	1.5
Microbial Load (cfu/ml)	2.0 – 1600.0 (243.44±358.38)	
Coliforms (cfu/ml)	0 – 257.0 (83.28±91.10)	0

ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol.13, 2013

Table 2: Correlations between analytes determined in Imota well water.

Analytes		Hardness	Calcium	Magnesium	Nitrate	Iron	Ammonia Nitrogen	pH	Microbial Load	Coliforms
Hardness	Pearson Correlation	1	**0.962****	**0.991****	**-0.325**	**-0.117**	**0.049**	**-0.363**	**-0.437**	**-0.332**
	Sig. (2-tailed)		**0.000**	**0.000**	**0.360**	**0.748**	**0.893**	**0.303**	**0.206**	**0.348**
Calcium	Pearson Correlation	**0.962****	1	**0.942****	**-0.368**	**-0.130**	**0.079**	**-0.345**	**-0.452**	**-0.356**
	Sig. (2-tailed)	**0.000**		**0.000**	**0.295**	**0.721**	**0.828**	**0.329**	**0.189**	**0.312**
Magnesium	Pearson Correlation	**0.991****	**0.942****	1	**-0.332**	**-0.158**	**-0.019**	**-0.437**	**-0.420**	**-0.344**
	Sig. (2-tailed)	**0.000**	**0.000**		**0.348**	**0.663**	**0.958**	**0.206**	**0.227**	**0.330**
Nitrate	Pearson Correlation	**-0.325**	**-0.368**	**-0.332**	1	**0.673***	**0.434**	**0.357**	**0.312**	**0.528**
	Sig. (2-tailed)	**0.360**	**0.295**	**0.348**		**0.033**	**0.210**	**0.311**	**0.380**	**0.117**
Iron	Pearson Correlation	**-0.117**	**-0.130**	**-0.158**	**0.673***	1	**0.682***	**0.021**	**0.508**	**0.657***
	Sig. (2-tailed)	**0.748**	**0.721**	**0.663**	**0.033**		**0.030**	**.954**	**0.134**	**0.039**
Total Ammonia Nitrogen	Pearson Correlation	**0.049**	**0.079**	**-0.019**	**0.434**	**0.682***	1	**0.268**	**-0.075**	**0.154**
	Sig. (2-tailed)	**0.893**	**0.828**	**0.958**	**0.210**	**0.030**		**0.455**	**0.836**	**0.671**
pH	Pearson Correlation	**-0.363**	**-0.345**	**-0.437**	**0.357**	**0.021**	**0.268**	1	**-0.337**	**-0.115**
	Sig. (2-tailed)	**0.303**	**0.329**	**0.206**	**0.311**	**0.954**	**0.455**		**0.341**	**0.752**
Microbial Load	Pearson Correlation	**-0.437**	**-0.452**	**-0.420**	**0.312**	**0.508**	**-0.075**	**-0.337**	1	**0.875****
	Sig. (2-tailed)	**0.206**	**0.312**	**0.227**	**0.380**	**0.134**	**0.836**	**0.341**		**0.001**
Coliform	Pearson Correlation	**-0.332**	**-0.356**	**-0.344**	**0.528**	**0.657**	**0.154**	**-0.115**	**0.875****	1
	Sig. (2-tailed)	**0.348**	**0.189**	**0.330**	**0.117**	**.039***	**0.671**	**0.752**	**0.001**	

* Significant **Highly significant $p<0.001$

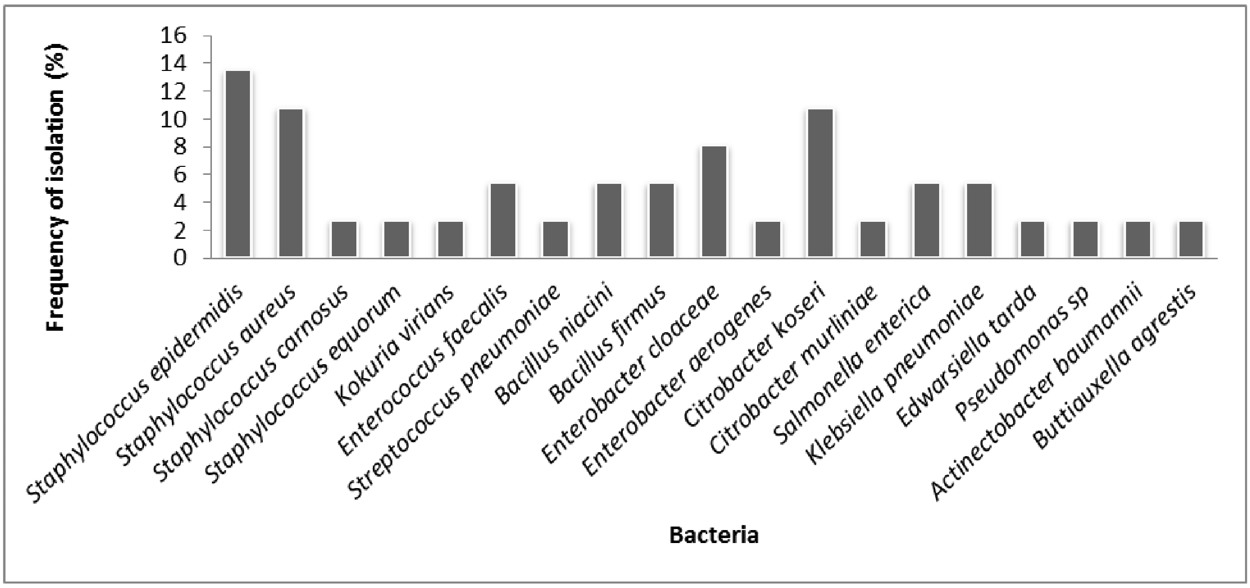

Figure 1: Frequency of isolation of bacteria from well water

Table 3: Antibiotics susceptibility of bacterial isolates

Drug (μg)	Susceptibility (%)
Nitrofurantoin (100)	28.6
Cefriazone (30)	60.7
Ciprofloxacin (10)	89.3
Gentamycin (10)	89.3
Ofloxacin (10)	100
Augmentin (30)	100
Perfloxacin (30)	100
Clarithromycin (30)	78.6
Chloramphenicol (10)	25.0
Ampicillin (30)	10.7

Table 4: Socio-demographics of studied population

Characteristics	N0 (%)
Sex Male	108 (45)
Female	132 (55)
Age (years):	
11 – 20	62 (25.8)
21 – 30	82 (34.2)
31 – 40	53 (22.1)
41 – 50	31 (12.9)
51 – 60	12 (5.0)
Well water used for bathing	240 (100)
Well water used food preparation	240 (100)
Source of drinking water:	
Commercial sachet/bottle water	216 (90)
Well water	24 (10)

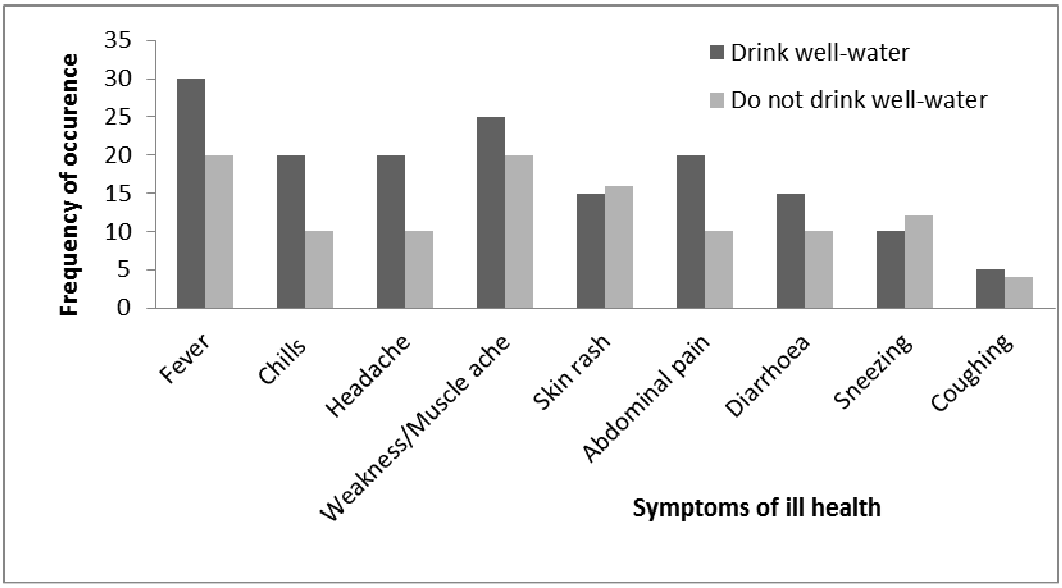

Figure 2: Frequency of occurrence of symptoms of ill health among Imota residents that drink from well ware and those that do not (t=3.200, p=0.013)