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Full Length Research Paper

Water quality of domestic wells in typical African communities: Case studies from Nigeria

B. A. Adelekan

Department of Agricultural and Mechanical Engineering, College of Engineering and Technology, Olabisi Onabanjo University, P. M. B. 5026, Ibogun, Ogun State, Nigeria. E-mail: jideadelekan@yahoo.com. Tel: +234-08062373443, 08023277499.

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Several African communities obtain their domestic water supplies from dug wells and this study takes Ibogun, Pakoto and Ifo communities in Ogun State, Nigeria as being typical. The objective is to assess the quality of the water supply from these dug wells, ascertain the contamination problems that may confront the consumers, and provide appropriate remedies. Twenty dug wells were randomly selected in each community. Water samples from the selected dug wells were collected during July - August 2009. The samples were checked for odour, colour and taste; and through standard methods, they were analyzed for pH, total solids, total hardness, chlorides, sulphate, nitrates, magnesium, calcium, manganese, sodium, copper, zinc, iron and lead; total viable count, total coliform count, faecal coliform count and faecal streptococci count. Most of the pH values of the samples were outside the recommended range of 6.5 – 8.5 for drinking water. Predominantly, the ionic dominance pattern observed were Na > Ca > Mg and HCO_3 > Cl > SO_4, indicating typical cationic characteristics and anionic characteristics of groundwater. For total solids and total hardness, guideline values were largely met. Levels of iron did not exceed the WHO guideline value of 0.2 mg/l for Fe in drinking water. Mean levels of Mn measured were far in excess of the average of 0.01 mg/l for fresh water, while in relation to the WHO guideline value of 0.4 mg/l for Mn in drinking water, the levels measured were low. Generally, the levels of nitrates, sulphate, chlorides, magnesium, manganese and iron were moderately high, but the WHO guidelines were not exceeded. The WHO guidelines for microbiological quality of water were met in several cases. Matching of non-technical and techno-social remedial measures is recommended. These include sensitization of the populace on merits of qualitative domestic hygiene and environmental protection practices such as cleaner compounds and strict enforcement of environmental protection laws.

Key words: Dug wells, water, physico-chemical analyses, microbial analyses.

INTRODUCTION

In many parts of Nigeria and several other African countries, piped water supply is either unavailable or irregular especially in the small-sized communities and towns. Even in most Nigerian cities, the supply of water for domestic purposes has several accompanying inadequacies. According to Sangodoyin (1993), reasons given for these inadequacies include enormous socio economic rate of development, a growing industrial base, poor planning, insufficient funding, haphazard implementation of programs, lack of maintenance culture as well as technically deficient personnel. Adedeji (2001) surveyed the water supply pattern in Lagos, Nigeria and found that for households connected to the public water supply, just 75.2 L per capita per day were assured. Those not connected to the public supply had far less. Furthermore, the national average for access to drinking water was estimated at 32% of households. Even at that, wide variations existed among the states of the federation, with low values of 6 and 8% recorded for Taraba and Benue states respectively and the highest values of 58 and 78% recorded in Ogun and Lagos states respectively. Given such a grim situation, residents are left with no other choice than to seek sources of freshwater from streams, rainfall, and groundwater (by digging wells). A dug well is a large diameter well constructed by excavating with hand tools or power machinery instead of drilling and driving and has the basic purpose of supplying water for domestic needs. It is distinct from a drilled well (commonly called borehole) which is constructed by cable tool or rotary drilling methods. In the absence of perennial streams, groundwater remains the most accessible source.

The assessment of water quality in dug wells is essential because these are often the main sources of water for human consumption in typical African communities. The well-being of people is dependent on the quality of water which they ingest or otherwise make use of. It has become imperative to assess the quality of the water supply from these dug wells and identify the various sources of contaminants in order to ascertain the contamination problems that may confront the consumers. From results obtained, a scientific basis will then be provided for finding appropriate remedies to the situations and the inherent impacts on residents in communities that depend on the wells. It is with this objective in mind that the present study was undertaken in Ibogun, Pakoto and Ifo communities in Ogun State, Nigeria. Populations reported for Ibogun and Pakoto are less than 5,000 persons in each case. Ifo is bigger although its population is still about 20,000 persons (National Population Commission, 2009). The major occupation in Ibogun, Pakoto and Ifo is farming. Ibogun hosts a campus of a university and the student population is included in its total population. In addition to farming, some trading goes on in Ifo, making it less agrarian than the other two communities. All the communities have no industry of note. Essentially the 3 of them are typical African communities and findings regarding them can be of relevance in such small-sized communities scattered all around the continent.

The quality of ground water depends on the various chemical constituents and their concentrations in the water, and they are mostly derived from the geology of the particular location. Although ground water is the purest naturally occurring water, it is still readily contaminated by industrial waste and municipal waste in their various forms. In most parts of the world, the most common form of contamination of raw water sources is from human sewage and in particular human fecal pathogens and parasites. In 2006, waterborne diseases were estimated to cause 1.8 million deaths each year while about 1.1 billion people lacked safe drinking water (Clansen et al., 2007).

To live in good health, people need to have access to good quality water in adequate quantity. Parameters for drinking water quality typically fall under three categories namely physical, chemical and microbiological. Physical quality involves such para-meters as odour, colour and taste. Chemical parameters include pH, total solids, nitrates, sulphates, chlorides, hardness, metals generally as well as some other elements. Microbiological parameters include coliform bacteria, streptococci, *E. coli,* and parasites. This study evaluated the concentrations of these parameters in the samples of water sourced from various wells in these communities, compared those values to International Drinking Water Quality Standards of the World Health Organization, determined the level of pollution of the water and made recommendations as to their safe use.

MATERIALS AND METHODS

Sampling

Water samples from the selected dug wells were collected during July - August 2009, with a sample collected from each well. 20 dug wells were randomly selected in each community, giving a total of 60 water samples in all. Two sets of samples, each of 150 ml volume were collected for each well; one set for physico-chemical analysis and the other set for microbial analysis. pH and temperature were measured on site. Each sample was collected in a new factory-fresh plastic bottle with the cap securely tightened. After collection, the samples were immediately placed in ice coolers for transportation to the laboratory where they were then transferred to the refrigerator. Laboratory analyses commenced the same day and within 30 min of arrival at the laboratory in every case. The analyses were conducted in the laboratories of the Institute of Agricultural Research and Training (IAR&T), and Federal College of Agriculture (FCA), both located in Ibadan, Nigeria.

Methods for physico-chemical analyses

The samples were first checked for odour, colour and taste. Afterwards, they were analyzed for major physical and chemical water quality parameters namely pH**,** total solids (TS), total hardness (TH), chlorides, sulphate, nitrates, magnesium, calcium, manganese, sodium, copper, zinc, iron and lead. Samples were subjected to filtration prior to chemical analysis. The determination of TS was done by a gravimetric process, while the total hardness was carried out by EDTA complexometric titration method. Nitrate was determined by colorimetric procedure. The methods of analyses were those detailed in APHA et al. (1998).

Methods for bacteriological analyses

For the preparation of sterile water, 9 ml distilled water was pipetted into a clean dry test tube plugged with clean cotton wool and wrapped with aluminium foil. The test tube was placed inside an autoclave and sterilized by autoclaving at 121°C for 15 min. The media were afterwards prepared as follows:

For preparation of nutrient agar (NA), 28 g of powdered commercially prepared nutrient agar was weighed on a Mettler analytical balance into a clean dry 1 L conical flask and 100 ml of distilled water was added. The flask was then placed inside a water bath set at 90°C to allow the agar dissolve. The solution was then measured into Macconkey bottles and the bottles placed was for 15 min inside autoclave set at 121°C.

For preparation of Macconkey agar (MCCA), 55 g of commercially prepared agar was weighed into a 1 L conical flask and gradually heated to dissolve the agar. It was then distributed

into Macconkey bottles and autoclaved as for nutrient agar.
For preparation of potato dextrose agar (PDA), 39 g of commercially prepared agar was weighed into a 1 L conical flask and gradually heated to dissolve the agar. The solution was then distributed into Macconkey bottles and autoclaved as for nutrient agar.

In all the cases, after autoclaving, the media were placed inside a water bath set at 45°C to maintain the media in a molten state. One millilitre of each water sample was weighed into a test tube containing 9 ml of sterile distilled water in Macconkey bottles was shaken vigorously on a vortex mixer and serially diluted. From it, 1 ml of 10^4 – 10^6 dilutions were plated on to nutrient agar (NA) and potato dextrose agar (PDA). The media were individually poured into separate plates and were duplicated. After solidifying, the plates were incubated at 37°C for nutrient agar and Macconkey agar while potato dextrose agar was incubated at 30°C. All the plates were incubated invertedly. The plates were counted at 48 h for Nutrient Agar and Macconkey Agar while it was read for potato Detrose Agar at 72 h. The pathogens were identified using cultural and morphological features. Isolation and identification of bacteria in the water samples were done using methods detailed in Collins and Lyne (1984), Adegoke et al. (1993) and APHA et al. (1998). The procedures for the biochemical characterization of the isolates which includes (1) cultural profiles on different culture media; (2) growth in air; (3) gram staining; (4) coagulase, catalase and oxidase tests, and (5) carbohydrate fermentation were strictly followed.

RESULTS AND DISCUSSION

Results of the physico-chemical and bacteriological analyses are presented in the Figures 1 – 9.

Since communities within the study areas use the untreated water for domestic purposes, results stated above are compared with both the World Health Organization (WHO) guidelines for drinking water (WHO, 1984, 1993, 1996, 2004) and the international average for fresh water.

Physical characteristics of water samples studied

Water meant for human consumption should be completely free of odour, colour and taste. The presence of any of these in a water sample makes it aesthetically unpleasant and typically reduces its acceptability among consumers. Odour test was performed but odour was absent in all of the 60 water samples analysed. Colour is vital as most water users, be it domestic or industrial, usually prefer colourless water. Determination of colour can help in estimating costs related to elimination of discolouration of the water samples. In Ifo, most of the water samples were colourless.

However in 3 samples, light brown, brown and milky discolourations were observed. In Ibogun, light brown colour was observed in 1 sample while milky colour was observed in another and all the rest were colourless. Light brown colouration was present in 1 sample in Pakoto, while all the rest were colourless. Therefore ordinarily, most of the water samples from the wells in these communities would be aesthetically acceptable to the consumers. This situation in itself may pose some danger and suggests considerable caution among the consumers since aesthetically pleasant water does not necessarily imply that the water is hygienically safe for consumption.

Chemical characteristics of water samples

Though pH has no direct effect on human health, nevertheless, high pH causes a bitter taste, makes pipes and appliances to become encrusted and depresses the effectiveness of chlorine disinfection. Water having low pH will corrode and dissolve metals. pH is also an indicator of biological life since most of them thrive in a quite narrow and critical pH range. For human beings, pH value of 7.0 is considered as best or ideal although a range of 6.5 - 8.5 is permissible (WHO, 1993). In the present study the majority of the water samples were typically acidic having pH ranges of 2.6 to 6.0 in Ifo; 4.0 to 5.9 in Ibogun; and 3.8 to 7.1 in Pakoto (Figure 1). These pH ranges elicited further interest to later obtain soil samples around the study areas in an effort to find out what is responsible for general acidity of those samples from the dug wells. In general, the lower the value of pH, the higher the level of corrosion. Gupta et al. (2009) observed that in some cases decrease in pH is accompanied by the increase in bicarbonate, carbonate and hydroxyl ions.

This observation was partly correlated in this study as well. In Ifo for example, the highest value of 1600 mg/l of total solids (Figure 2) and the second highest value of 158 mg/l of total hardness (Figure 3) were measured for a water sample having a pH of 4.0. In Ibogun, the second highest value of 96 mg/l of total hardness (Figure 3) was from a sample which had a pH of 4.0 (Figure 1) while in Pakoto, the highest value of 1900 mg/l of total solids (Figure 2) was measured in a sample having a pH of 4.4 (Figure 1). For these com-munities studied, it is likely that the low pH of the waters is traceable to the presence of carbonates. The geology of the area studied is known to be rich in limestone.

WHO (2004) stated that water meant for human consumption should have a maximum total solids (TS) content of 1500 mg/l. In Figure 2 as shown for Ifo, wells 7 and 20 have values of 1600 and 2200 mg/l respectively, effectively placing these above the WHO guideline. It is also seen from the same figure that well 6 in Ibogun and well 14 in Pakoto have values of 1700 and 1900 mg/l respectively for total solids. All the rest are below the guideline, with the majority being below 500 mg/l. Therefore water from most of the wells where within the guideline of WHO (2004) as far as total solids content is concerned. Total solids (TS), is really a sum of two terms

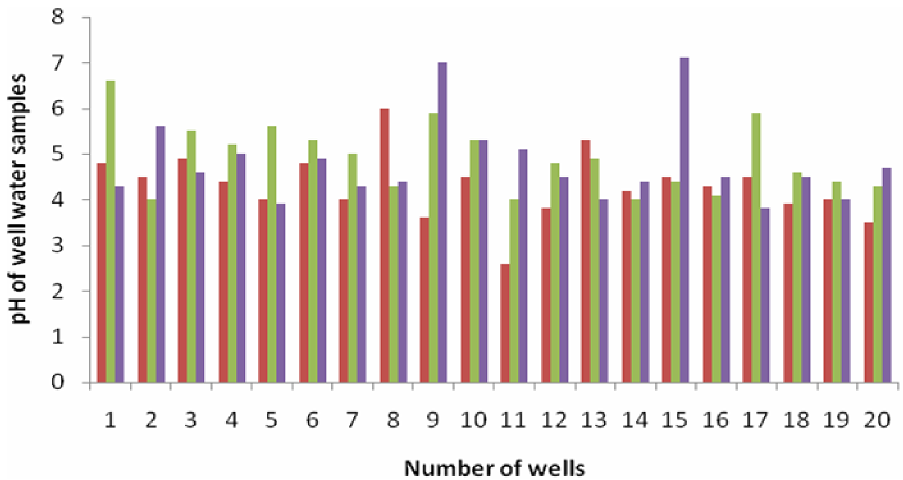

Figure 1. pH of water samples in Ifo, Ibogun and Pakoto.

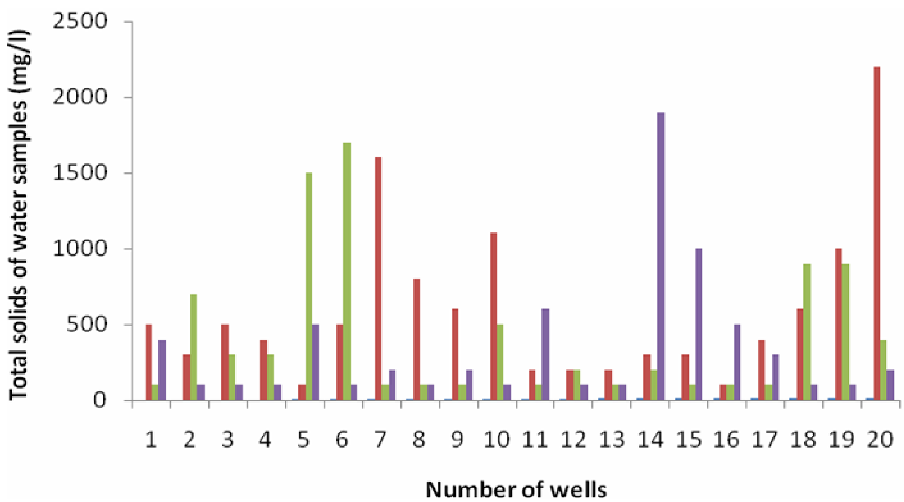

Figure 2. Total solids of water samples in Ifo, Ibogun and Pakoto.

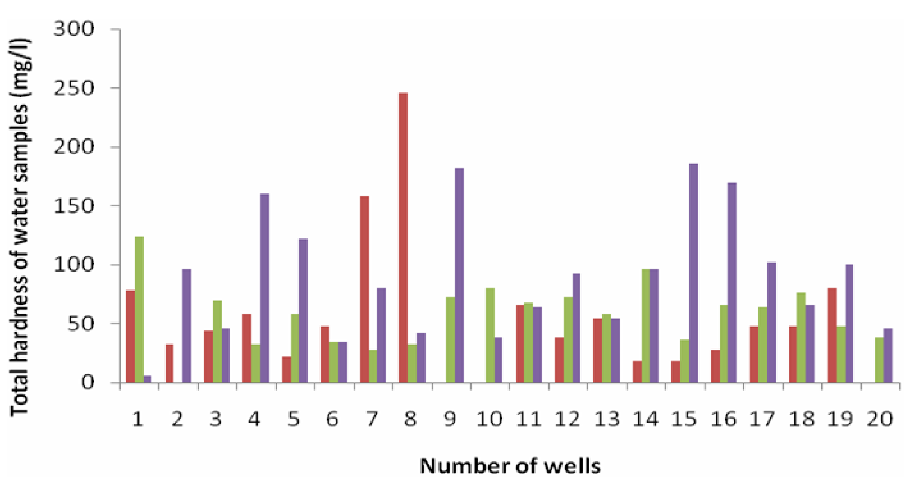

Figure 3. Total hardness of water samples in Ifo, Ibogun and Pakoto.

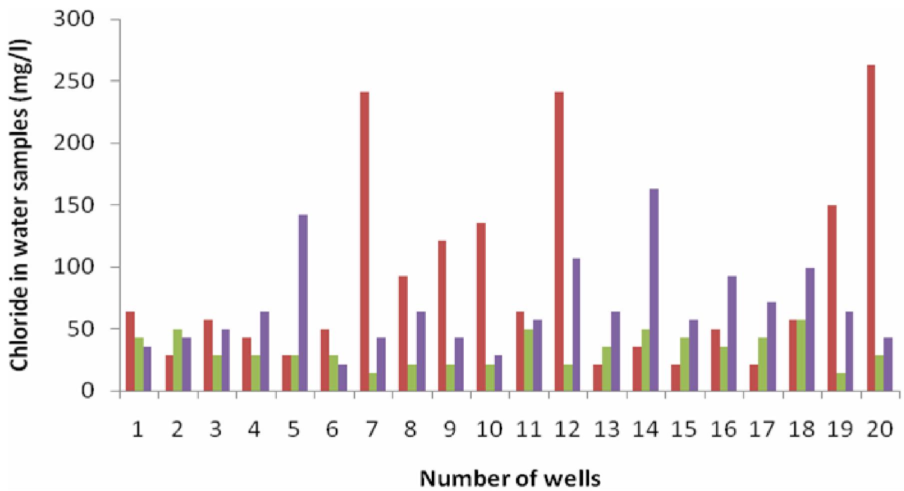

Figure 4. Chloride in water samples of Ifo, Ibogun and Pakoto.

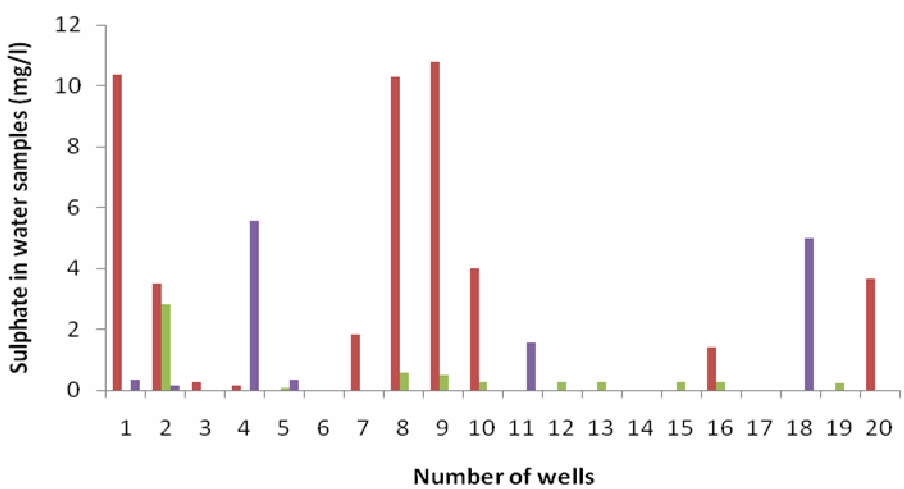

Figure 5. Sulphate in water samples of Ifo, Ibogun and Pakoto.

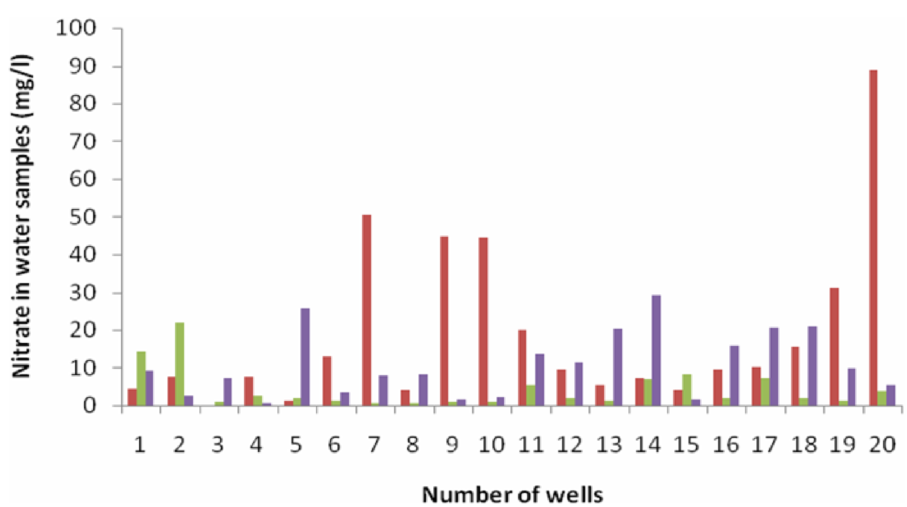

Figure 6. Nitrate in water samples of Ifo, Ibogun and Pakoto.

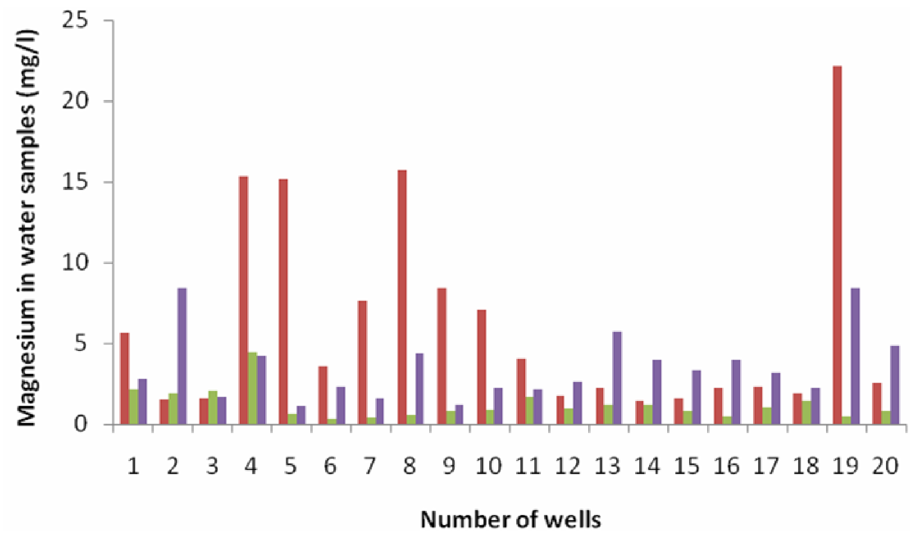

Figure 7. Magnesium in water samples of Ifo, Ibogun and Pakoto.

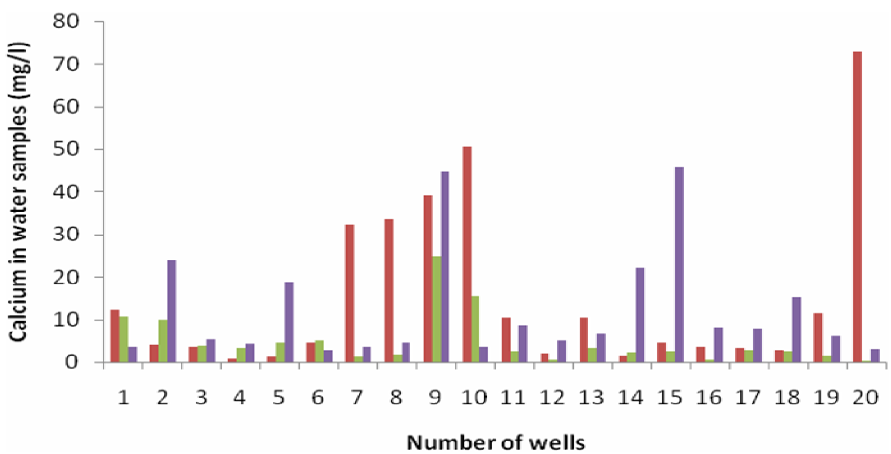

Figure 8. Calcium in water samples of Ifo, Ibogun and Pakoto.

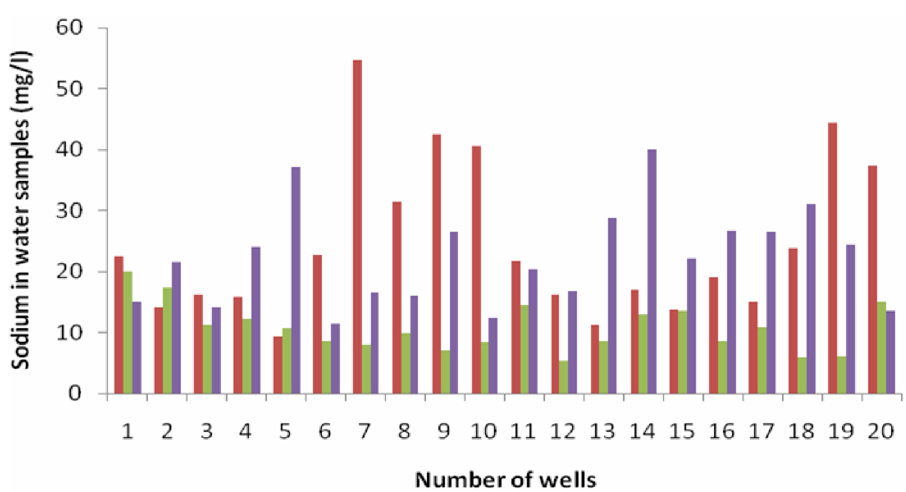

Figure 9. Sodium in water samples of Ifo, Ibogun and Pakoto.

namely total suspended solids (TSS) and total dissolved solids (TDS). Total suspended solids in freshwater is an indication of the amount of erosion that took place nearby or upstream. This parameter would be a most significant measurement as it would depict the effectiveness of and indicate the level of compliance with control measures, for example prevention of direct contact between well water and surface erosion. An internationally accepted maximum value of TDS in fresh water is 100 mg/l (Meybeck and Helmer, 1989). As far as the studied communities are concerned, the values of TDS were less than 100 mg/l in 50% of water samples from Ibogun and Pakoto. This correlates to an accepted common practice of building a 1 m high protective concrete ring on top of each well and fixing a tight cover over it, thus preventing contamination with dust and other solids from outside the system. In Ifo, the measured TDS was lower than 100 mg/l in just 40% of the wells. Perhaps the reason for this is that the number of people depending on each well was higher in Ifo than in the other 2 communities. Therefore more people had direct access to the well, increasing the risk of contamination of the water with foreign particles borne on containers being used to draw water from the well.

Water hardness is the traditional measure of the capacity of water to react with soap; hard water requiring considerably more soap to produce lather. Hardness is one of the very important properties of ground water from utility point of view particularly for domestic purposes. As reported in the literature, the concentration of total hardness in drinking water sources ranged between 75 and 1110 mg/l (Nawlakhe, 1995). Shastri et al. (1996) also reported a study where water samples from ponds and wells were very hard ranging from 222.8 - 1094.4 mg/l. However, WHO (2004) specified a maximum guideline value of 400 mg/l of total hardness for water meant for human consumption. In the present study, no sample exceeded that maximum limit. The highest values of total hardness measured in Ifo were in wells 8 and 7 which showed 246 and 158 mg/l respectively, while the rest were 80 mg/l (well 19) or less (Figure 3). Similarly in Ibogun, the highest value was 124 mg/l found in well number 1, while the rest were 96 mg/l (well 14) or less as seen in the same figure. In Pakoto, as shown in Figure 3, the highest and least values were 186 and 6 mg/l measured in wells 15 and 1 respectively. Whenever freshwater has a high concentration of total hardness, this may be due to dissolution of polyvalent metallic ions from sedimentary rocks, seepage and run off from soil. However high concentration was not measured in any water sample analysed. It is well known that hardness is not caused by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cation, although other cations like barium, iron, manganese, strontium and zinc also contribute. In the present study, some trace metals namely copper, iron and zinc were analysed but found to be 0 mg/l in all the samples studied. WHO (2004) guidelines for these are 2, 0.2 and 3 mg/l respectively. All the samples therefore did not exceed these limits. As regards magnesium and calcium, the measured values were remarkably low. As seen in Figure 7, values of magnesium in water samples ranged from 1.5 - 22.2 mg/l; 0.35 - 4.48 mg/l; and 1.1 - 8.5 mg/l in Ifo, Ibogun and Pakoto, respectively. For calcium the ranges were 1.2 - 72.9; 0.5 - 24.9 and 2.9 - 44.6 mg/l respectively as shown in Figure 8. These values were below the maximum guidelines given by WHO (2004). These comparatively low values for these cations definitely contributed to the low values measured for total hardness in the water samples.

The WHO guideline value of 0.2 mg/l for iron (Fe) in drinking water (WHO, 2004) was not exceeded by water from dug wells in the 3 communities since iron was analysed but was found to be 0 mg/l in all of the samples. By implication, the levels also did not exceed the iron average of 0.01 mg/l for fresh water (Meybeck and Helmer, 1989). It may thus be inferred that iron is minimally present in the soil in those communities. Manganese (Mn) is a common problem element in natural waters. In drinking waters, this element may cause unsightly stains and produce a brown/black precipitate. Although it is an essential element, the chronic ingestion of Mn in drinking water is associated with neurological damage (Kondakis et al., 1989). In the present study, Mn was analysed but was found to be 0 mg/l in about 50% of water samples from Ifo and Pakoto and in almost 100% of the samples from Ibogun. Among the measured values, ranges of 0.02 -0.62 and 0.02 - 0.08 mg/l were recorded in Ifo and Pakoto respectively. All these values were higher than the average of 0.01 mg/l of Mn for fresh water (Meybeck and Helmer, 1989). However, when compared to the guideline value of 0.4 mg/l for Mn in drinking water (WHO, 2004), almost 100% of the levels measured in this study were lower.

As shown in Figure 4, chloride was measured in all the samples with values ranging from 21.3 - 262.7; 14.2 - 56.8, and 21.3 - 99.4 mg/l in Ifo, Ibogun and Pakoto respectively. The WHO (2004) guideline for chlorides in drinking water is 250 mg/l. Only well number 20 in Ifo which measured 262.7 mg/l exceeded this limit, while no sample in Ibogun and Pakoto exceeded it. Remarkable differences were noticed in the average readings of chloride in the water samples of the wells in the 3 communities and these were 89.1, 39.4 and 67.4 mg/l for Ifo, Ibogun and Pakoto respectively. These differences may perhaps be due to urbanization. Ifo is by far the most populated and most urbanized of the three and generates wastes of different kinds at a higher quantity which are amassed in open dumps. Incident rainfall leaches salts from these dumps and from running effluent from homes which later infiltrate into the ground to dissolve in the water. Ibogun is the most agrarian among the three and the use of fertilizers is not commonly practiced on their farms. As a result, there appears to be fewer natural sources of chlorides to pollute the water there. Sulphate was analysed and found to be 0 mg/l in 50% of water samples in Ifo and Ibogun as well as in 70% of samples in Pakoto (Figure 5). Among the measured samples, sulphate ranged from 0.2 - 10.8 mg/l in Ifo; 0.1 - 2.8 mg/l in Ibogun and 0.2 - 5.6 mg/l in Pakoto. Although the concentrations of sulphate in some samples from wells 1, 8 and 9 in Ifo and wells 4 and 18 in Pakoto exceeded the average of 4.8 mg/l reported for fresh water (Meybeck and Helmer, 1989), yet the WHO (2004) guideline for sulphate is 500 mg/l. Therefore it may be inferred that sulphate does not have a strong presence in the groundwater of any of the communities studied. Sodium (Na) was detected in all the water samples. As shown in Figure 9, values ranged from 9.3 - 54.7; 5.3 - 17.3, and 11.5 - 40.0 mg/l in Ifo, Ibogun and Pakoto respectively. However, these values were well within the limits of the guideline value of 200 mg/l set by WHO (2004). The ionic dominance for water bodies according to Stumm and Morgan (1981) are: Ca > Mg > Na > K and HCO_3> SO_4 > Cl for fresh waters. Generally, the ionic dominance pattern observed in this study for groundwater was Na > Ca > Mg and HCO3 > Cl > SO_4. Some of these cations were in relatively high concentrations.

Health considerations regarding infants point in the direction of having domestic water entirely free of nitrates. Nitrates are strongly linked to the occurrence of blue baby syndrome otherwise known as infant methaemoglobinaemia (Powlson et al., 2008). However, water which has zero nitrates hardly occurs in nature. WHO (2004) set an upper limit of 50 mg/l of nitrates for water meant for domestic consumption. In this study, concentrations of nitrates ranged from 1.4 - 88.1; 0.8 - 22.0, and 0.8 - 29.2 mg/l for Ifo, Ibogun and Pakoto respectively as shown in Figure 6. It was observed that the WHO (2004) guideline was exceeded only by 10% of the samples in Ifo and no samples in Ibogun and Pakoto. However, considering the global average of 0.1 mg/l for nitrates in fresh water (Meybeck and Helmer, 1989), it is seen that the levels of nitrates measured in the samples are much higher than this value. This could be as a result of infiltration from domestic wastes and fertilized farm lands. Nitrate is made in the human body (Green et al., 1981), the rate of production being influenced by factors such as exercise (Allen et al., 2005).

Therefore presence of nitrates in groundwater in domestic settings is one of the indicators of contact with human wastes. Also the use of highly soluble fertilizers which contain nitrates causes water pollution problems as rainwater leaches out these nitrates and carries them into nearby streams while some portion infiltrates into the ground (Stoddard et al., 2005). Various health concerns have been expressed regarding the issue of drinking water containing high levels of nitrates (WHO, 1996; L'hirondel, 2002; Ward et al., 2006). Agricultural activities are reported to contribute about 50% of the total pollution source of fresh water by means of the higher nutrient enrichment, mainly ammonium ion (NH_4) and nitrate (NO_3), derived from fertilizers (Islam and Tanaka, 2004; Benson et al., 2006). Water used for drinking and other domestic purpose should also be free from toxic elements. In the present study, the heavy metal lead (Pb) was analysed and found to be absent in all the samples. By implication, no sample exceeded the guideline value of 0.01 mg/l for drinking water (WHO, 2004). This is understandable since the 3 communities are largely agrarian and they contain no heavy industries which may be the source of heavy metals in the environment.

Microbiological analyses

Total viable count is the sum of the total coliform count, faecal coliform count, faecal streptococci count and other pollutants in the water. Although high viable counts are usually indicative of the contamination of the water and the presence of bacteria other than aquatic bacteria, they do not necessarily indicate pollution by faeces and or sewage. Furthermore, the bacteria may be mostly soil saprophytes. Thus a high viable count alone is not evidence that a source of water is potentially dangerous due to the possible presence of intestinal pathogens. Nevertheless, water supplies with high viable counts are undesirable since they still carry the associated risk of possible pollution. As seen in Table 1, none of the water samples analysed met the guideline for total viable count which is 0/250 ml for all waters intended for drinking. Total coliform count is the microbiological test used to detect the level of pollutions caused by living things especially human beings who reside in a location. According to WHO (1993), coliform bacteria must not be detectable in any 100 ml sample of all water intended for drinking. The guideline value for total coliform is therefore 0/100 ml (WHO, 1993) for water intended for such a purpose. This guideline value was met in 55, 30 and 100% of samples in Ifo, Ibogun and Pakoto, respectively (Table 2). Also, for the test conducted at 37°C, the maximum colony count allowed is 20 cfu/ml (WHO, 1993). By implication, more than half of total samples analysed did not meet the WHO guidelines for total coliform count for water intended for drinking. This indicates that the ground water has been polluted by microbes sourced from living organisms. The ready explanation for this is that there may be some form of interaction between these wells and nearby septic tanks or waste dumps. However this could not be confirmed. WHO (1993) points out that on its own, total coliform count is not a definite indicator of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary

Table 1. Total viable count (x 10^5cfu/ml)

Well No.	Ifo	Ibogun	Pakoto
1	1.8	1	0.6
2	1.8	1.4	1.1
3	2	1.2	1
4	1.4	1	0.9
5	1.6	1.8	1.2
6	1.2	1	1.1
7	2.2	0.6	0.8
8	0.8	0.6	0.6
9	1.2	1.4	0.4
10	0.8	1.6	0.8
11	0.6	1.2	1.4
12	1.2	0.8	1.6
13	0.8	0.6	1.1
14	2	1.6	1
15	1.9	1.4	1.1
16	1.6	1.6	0.6
17	1.4	0.8	0.6
18	1.2	0.6	0.4
19	1	0.6	0.8
20	1.4	0.4	1

Table 2. Total coliform count (×10^5cfu/ml).

Well No.	Ifo	Ibogun	Pakoto
1	0	0.2	0
2	0	0.2	0
3	0	0.3	0
4	0	0.1	0
5	0.1	0	0.1
6	0.1	0	0
7	0.2	0.1	0
8	0	0.1	0
9	0	0	0
10	0	0	0.2
11	0.2	0.2	0
12	0.1	0.6	0
13	0.1	0.3	0
14	0	0.1	0.1
15	0	0.2	0.1
16	0.2	0.4	0
17	0.2	0	0
18	0.1	0.1	0
19	0	0.2	0

significance occur in almost all untreated supplies. Therefore the certainty of pollution of all these waters in which coliform bacteria was detected may not be concluded. Faecal coliform count is a test based on coliform bacteria as the indicator organism. The presence of these indicative organisms is evidence that the water has been polluted with faeces of humans or other warm-blooded animals. The WHO (1993) guideline for faecal coliform count in water intended for drinking is 0/100 ml. This guideline was met in 80, 70 and 100% of samples in Ifo, Ibogun and Pakoto respectively (Table 3). Therefore 20, 30 and 0% of water samples in these communities had contamination which originated from human beings or other warm blooded animals.

The occurrence of faecal streptococci as a supplement to faecal coliforms reinforces the incidence of faecal pollution by warm blooded animals. Since faecal streptococci have a limited survival time outside the animal intestine and are not capable of multiplying in the environment, their presence indicates a very recent pollution. With respect to faecal streptococci count, 80, 85 and 75% of wells in Ifo, Ibogun and Pakoto (Table 4) respectively did not meet up with the guideline of 0/100 ml set by WHO (1993). Therefore the quality of the majority of those samples can definitely be improved with adequate treatment.

Conclusions

Most of the pH values of the samples were outside the recommended range of 6.5 – 8.5 for drinking and other form of ingestion. Predominantly, the ionic dominance pattern observed were Na > Ca > Mg and HCO3 > Cl > SO4, indicating typical cationic characteristics and anionic characteristics of groundwater. Levels of iron did not exceed the WHO guideline value of 0.30 mg/l for Fe in drinking water in the 3 communities studied. Mean levels of Mn measured were far in excess of the average of 0.01 mg/l for fresh water, while in relation to the WHO guideline value of 0.40 mg/l for Mn in drinking water, the levels measured in this study were low. Generally, the levels of nitrate, sulphate, chloride, trace elements (e.g. manganese and iron) were moderately high, indicating organic contamination of the groundwater but the WHO guidelines were not exceeded. Guidelines for microbiological quality were met in several cases and the physical guidelines for colour, odour and taste were met in most cases.

Therefore aesthetically pleasant water that is sourced from groundwater through these dug wells appeared safe for consumption. Most of the wells did not have any readily noticeable source of contamination in their environments. The use of such dug wells in domestic settings in typical African communities is recommended. However there is a need for the enforcement of existing laws against improper disposal of domestic wastes as well as those guiding the location of septic tanks in relation to the location of dug wells in domestic settings.

Matching of non-technical and techno-social remedial

Table 3. Faecal coliform count (× 10^5cfu/ml).

Well No.	Ifo	Ibogun	Pakoto
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0.1	0
8	0	0	0.1
9	0	0	0
10	0	0	0.1
11	0.1	0.2	0
12	0.1	0.1	0
13	0.1	0	0
14	0	0	0
15	0	0.2	0.1
16	0.2	0.1	0.1
17	0	0	0
18	0	0	0
19	0	0.1	0
20	0	0	0

Table 4. Faecal streptococci count (x10^5cfu/ml).

Well No.	Ifo	Ibogun	Pakoto
1	0.2	0.2	0.1
2	0.4	0.1	0
3	0.4	0.3	0.1
4	0.3	0.1	0.1
5	0.2	0	0.2
6	0	0.4	0.1
7	0.6	0.1	0.3
8	0.2	0.1	0.1
9	0.4	0.3	0.1
10	0.1	0.2	0.2
11	0	0.4	0
12	0	0.2	0.1
13	0.2	0.1	0.1
14	0.6	0	0.1
15	0.8	0	0.2
16	0.6	0.3	0
17	0.7	0.2	0
18	0.2	0.2	0
19	0.2	0.1	0.2
20	0.1	0	0.1

measures is recommended. These include sensitization of the populace on merits of qualitative domestic hygiene and environmental protection practices such as cleaner compounds and strict enforcement of environmental protection laws. Another important issue for pollution mitigation measures pertains to the need to educate all stakeholders such as the local population, the wards, local governments, policy and legal authorities, and other interested parties, and include them in planning and decision making regarding sourcing water for use in domestic settings and the protection of the environments.

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