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SPATIAL CHARACTERISTICS OF UNDERGROUND WATER CHEMISTRY IN SOME SELECTED RURAL AREAS OF OGBOMOSO ZONE OF OYO STATE, NIGERIA

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ABSTRACT

Exploitation of underground water for domestic purposes is prominent in developing countries because of the susceptibility of surface sources to pollutants. Inspite of this, cases of water-associated illnesses and death are still reported. This work examines the quality of underground water in 15 randomly selected rural communities in Oriire, Ogo-Oluwa and Surulere LGAs in Ogbomoso zone of Oyo State, Nigeria. The parameters were analyzed using standard laboratory techniques. The results show that the parameters analyzed are within the permissible limits except pH and potassium which slightly exceeded the maximum standard recommended by WHO and NIS. Explanation of the variations in water quality as extracted by Factor Analysis is dominated by EC, Nitrate, coliform and Phosphate. Thus, water should be treated before consumption to safeguard human health. The suggested remedies to control the concentrations of the parameters include citing wells away from runoff channels and farm plots, concreting the well area and raising its circumference above the earth's surface. Further investigation on seasonal influence on water quality is suggested.

Keywords: Ogbomoso zone; Rural areas; Underground water; Water potability; Water quality.

INTRODUCTION

The survival of man is not only dependent on the availability of water but importantly on the integrity of the available water. The prevalence of different kinds of water-borne and water-related diseases and deaths are evidences of the consumption of distorted water quality by man (Fasunwa et al, 2008). Unfortunately, such contaminated water is often the only source available for man who is hardly intimated on the techniques or methods of improving its quality, especially in the developing nations.

One of the most readily available sources of water to man is underground water which is reached through digging. These hand-dug wells have become common both in rural and urban centres as major sources of water to man. For instance, in its quest to ensure prompt water supply to the rural areas, Oyo State/UNICEF-Assisted Water and Sanitation Project was initiated. Through this initiative, over 800 wells and powered boreholes have been constructed across 28 of the 33 Local Government Areas in the State (Gbadegesin and Olorunfemi, 2007). In fact, in the face of inadequacy, poor network and/or erratic water supply via pipe, well water forms the only better graded water resource in term of its quality for human domestic uses when compared with surface water sources (see also Oteze, 2006; Adekunle et al, 2007; Okeke and Uzo, 2009; Ishaku et al, 2011). The proliferation of hand-dug wells in almost every nook and cranes in both rural and urban areas coupled with reported cases of indiscriminate dumping of refuse and home effluents are some of the characteristics of most human settlements in this part of the world (Taiwo et al., 2011). Government, too, at different levels and other stakeholders often prefer underground sources for rural populace because of its relative cheapness when compared with pipe-borne water. The implication of this is that wells, most often, are indiscriminately located without recourse to the likely effects of the environmental quality on the integrity of underground water. This makes water from such an environment unfit for human consumption. However, Mark et al., (2002) and WHO (2008) had reported that unsafe drinking water contributed to numerous health problems in developing countries such as the one billion or more incidents of diarrhea that occur annually. In buttressing this finding, cases of water-associated diseases have been reported in Nigeria and Oyo State in particular. For instance, incidences of diarrhoea and watery without blood and with blood were respectively 466 and 1,738 in 2005 while that of cholera in the same year was 2,768 (National Bureau of Statistics, 2009). In addition, about 10,432 cases of typhoid fever were reported in 2005 while that of schistosomiasis in the same year was 1,107.

This study is aimed at assessing some of the physico-chemical characteristics of well water from the sampled wells to determine its status and its fitness for man's consumption in relation to the recommended standards. The work is expected to engender some suggestions for policy makers in water supply planning especially in rural areas.

METHODS AND MATERIALS

Study Area

The study area comprises of Ogo-Oluwa, Oriire and Surulere Local Government Areas which form part of the five Local government Areas (LGAs) in Ogbomoso Zone of Oyo State, Nigeria. The remaining two, Ogbomoso North and South LGAs are within Ogbomoso metropolis. The three LGAs, their headquarters, coordinate axis and the villages selected in each for the purpose of this study are shown in Table 1.

Table 1: LGA, their Headquarters, Coordinates and the Selected Villages of Study

Name of LGA	Headquarters	Logitudinal Location	Latitudinal Location	Name of Villages selected
Oriire	Ikoyi	8.16^{o}N	4.10^{o}E	Olorunda, Aitete, Budo-Ode, Alaidan and Saamo
Ogo-Oluwa	Ajaawa	7.56^{o}N	4.07^{o}E	Opete, Iwata, Ladanu, Lagbedu and Pontela
Surulere	Iresaadu	8.05^{o}N	4.24^{o}E	Igbo-Ile, Idi-Ayin, Eleeru, Kueke and Onnipanu

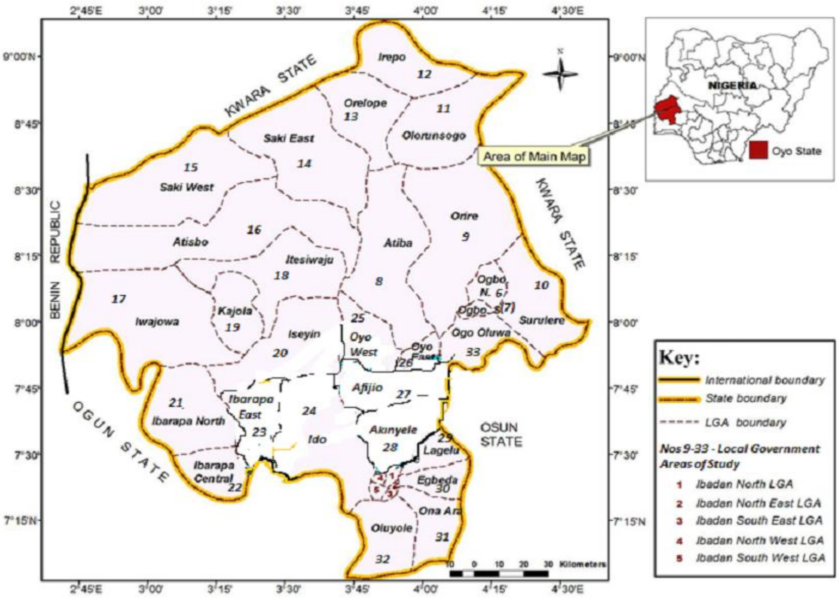

Figure 1: MAP OF OYO STATE SHOWING THE LOCAL GOVERNMENT AREAS (Inset: Map of Nigeria showing Oyo State): Source: Google images

The three LGAs were carved out from the former Ogbomoso LGA together with the other two LGAs located within the city of Ogbomoso (i.e. Ogbomoso North with its headquarters in Kinira-Ogbomoso and Ogbomoso South LGAs with its headquarters at Arowomole-Ogbomoso. Oriire LGA acclaimed to be the biggest in Oyo State with a land area of 2,116 km^2 has a total population of 150,628 according to the census record of 2006. Also, Ogo-Oluwa LGA with an area of coverage of 369 km^2 has a population of 65,184 by the 2006 census. Surulere LGA has a total population of 166,034 of the same year census. One of the major peculiarities of these LGAs is that they consist of rural communities with farming as the dominant occupation. Farm settlements of varying sizes are found within these areas. The predominant geology consists of Precambrian rocks. The prevailing climatic condition is tropical with distinct wet season (March-October) and dry season (November-February). The dominant sources of water are both surface and subsurface. The health hazard associated with consumption of surface source has engendered among others the preference for the subsurface source for domestic utilization. Most of these wells/boreholes were either provided by government at different levels through its agencies, international agencies such as UNDP, community groups and private individual donors. Despite the provision of wells and boreholes, there are still reports of water related illnesses and deaths. Hence this research work aims at examining the quality of this water source for its fitness for human consumption.

Reagents Used and Their Sources

All the reagents used were of analytical grade and the instruments were pre-calibrated appropriately prior to measurement. Among the reagents are methanol (Park Scientific Ltd. Northampton, U.K); Nitric acid (BDH Laboratory Supplies Poole, England); Sodium hydroxide(Merck, Kennzechung, Germany); HCl(BDH laboratory supplies, Poole, England); H_2SO_4 (BDH laboratory supplies, Poole, England); KI (Park scientific Ltd. Northampton, U.K);, Sodium azide (Kem Light laboratories PVT. Ltd. Mumbai, India.

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Sampling sites

In this study, a total of 15 water samples were collected for the water quality analysis. Samples were collected from hand-dug wells often fetched by the inhabitants in each of the 5 villages selected from each of the 3 Local Government Areas (LGAs). All the wells had headwall inner concrete lining. However, while some cemented surrounding, others were not especially in Surulere LGAs.

Data Collection and Analysis

Samples for water quality and bacteriological studies were collected in 2L plastic bottles that have been previously soaked in 10% nitric acid for 48 h and rinsed with distilled water. The containers were rinsed three times on the site with well water before collecting the water samples. All samples were filtered with cellulose acetate filters before transporting to the laboratory. The samples were stored in the refrigerator prior analysis in order to ensure the physical properties were maintained.

Determination of Physico-chemical parameters

Water temperature and electrical conductivity were determined in-situ using Testr II dual range meter (Eutech instruments, Malaysia) after calibrating with standard buffer solution while pH was measured in-situ using pH Testr metre (Eutech instrument, Malaysia). Sulphate was determined by turbid metric method (Ademoroti, 1996). Phosphate was determined by colorimetric technique (APHA, 1998); Nitrate was determined by ultraviolet screening method (APHA,1998). Sodium and Potassium were determined using flame photometric technique. Oxidation Redox Potentials and TDS were determined with a hand-held digital meter (Model: ATC pH-708). Plate Count Agar was used for the analysis of coliform count in the water samples.

RESULTS AND DISCUSSION

The results of the laboratory analysis of the water samples are presented in Tables 2-4.

Table 2: Underground water quality data, the mean values and standard deviation and the Recommended Standards in Oriire LGA

S/N	Parameter	Vilage Names					M±SD	Recommended Standards	
		Olorunda	Aitete	Budo-Ode	Alaidan	Saamo		WHO (2006)	NSI (2007)
1	pH	9.2	9.0	7.6	9.2	7.8	8.5±0.79	6.5-8.5	6.5-8.5
2.	*EC(µf/cm)*	*340*	*340*	*360*	*680*	*700*	484±188.36	*1000(µf/cm)*	*1000(µf/cm)*
3.	*Temp.(^{o}C)*	*23.4*	*23.3*	*23.3*	*23.2*	*23.2*	23.28±0.08	*25^{o}C*	*25^{o}C*
4.	*TDS(mg/L)*	*241.5*	*242.1*	*243.5*	*546.2*	*549.7*	364.6±167.38	*600mg/L*	*500mg/L*
5.	*ORP(mV)*	*289*	*294*	*294*	*294*	*294*	293.00±2.24	*700mV*	*NA*
6.	*NO^{3}(ms/L)*	*1.04*	*0.58*	*0.49*	*2.96*	*1.16*	1.25±1.00	*50 mg/L*	*50 mg/L*
7.	*PO4(mg/L)*	*0.59*	*0.48*	*0.62*	*0.52*	*1.00*	0.64±0.21	*2.2mg/L*	*NA*
8.	*SO4(mg/L)*	*0.49*	*1.62*	*2.26*	*1.01*	*1.67*	1.41±0.68	*250 mg/L*	*100mg/L*
9.	*Na^{+}(mg/L)*	*17.27*	*12.09*	*21.58*	*30.22*	*19.86*	20.20±6.65	*250mg/L*	*200mg/L*
10.	*K(mg/L)*	*8.5*	*6.5*	*11.01*	*15.75*	*10.25*	10.40±3.46	*10mg/L*	*NA*
11.	*Coliform cfu/mL*	*1.8*	*1.78*	*1.22*	*1.06*	*0.18*	1.21±0.66	*10/100mL*	*10cfu/mL*

***Source:* *Authors' fieldwork; Note: M* is Mean; SD is Standard Deviation; WHO-World Health Organization; NIS- Nigeria Industrial Standard**

Table 3: Underground Water Quality data, the Mean Values, Standard Deviation and the Recommended Standards in Ogo-Oluwa LGA

S/N	Parameter	Village Names					M±SD	Recommended Standards	
		Opete	Iwata	Ladanu	Lagbedu	Pontela		WHO (2006)	NIS (2007)
1	pH	8.0	8.1	7.6	7.6	8.2	7.9±0.28	6.5-8.5	6.5-8.5
2.	*EC(µƒ/cm)*	*440*	*270*	*190*	*160*	*210*	254±111.49	*1000(µƒ/cm)*	*1000(µƒ/cm)*
3.	*Temp. (°C)*	*23.3*	*23.3*	*23.3*	*23.4*	*23.5*	23.36±0.09	*25°C*	*25°C*
4.	*TDS(mg/L)*	*327.6*	*176.6*	*118.9*	*99.97*	*125.30*	169.67±92.73	*600mg/L*	*500mg/L*
5.	*ORP(mV)*	*293*	*293*	*294*	*294*	*294*	293.6±0.55	*700mV*	*NA*
6.	*NO^3(ms/L)*	*0.84*	*1.58*	*0.73*	*0.67*	*1.36*	1.04±0.41	*50 mg/L*	*50 mg/L*
7.	*PO4(mg/L)*	*0.66*	*0.66*	*1.03*	*0.14*	*0.86*	0.67±0.33	*2.2mg/L*	*NA*
8.	*SO4(mg/L)*	*0.92*	*1.14*	*1.11*	*0.37*	*2.01*	1.11±0.59	*250 mg/L*	*100mg/L*
9.	*Na+(mg/L)*	*37.99*	*44.03*	*26.76*	*43.17*	*17.27*	33.84±11.54	*250mg/L*	*200mg/L*
10.	*K(mg/L)*	*8.01*	*15.00*	*7.01*	*11.50*	*10.75*	10.45±3.15	*10mg/L*	*NA*
11.	*Coliform cfu/mL*	*0.65*	*0.24*	*0.63*	*0.75*	*1.05*	0.66±0.29	*10/100mL*	*10cfu/mL*

Source: Authors' fieldwork; M is Mean Value, SD is Standard Deviation

Table 4: Underground Water Quality data, the Mean Values and the Recommended Standards in Surulere LGA

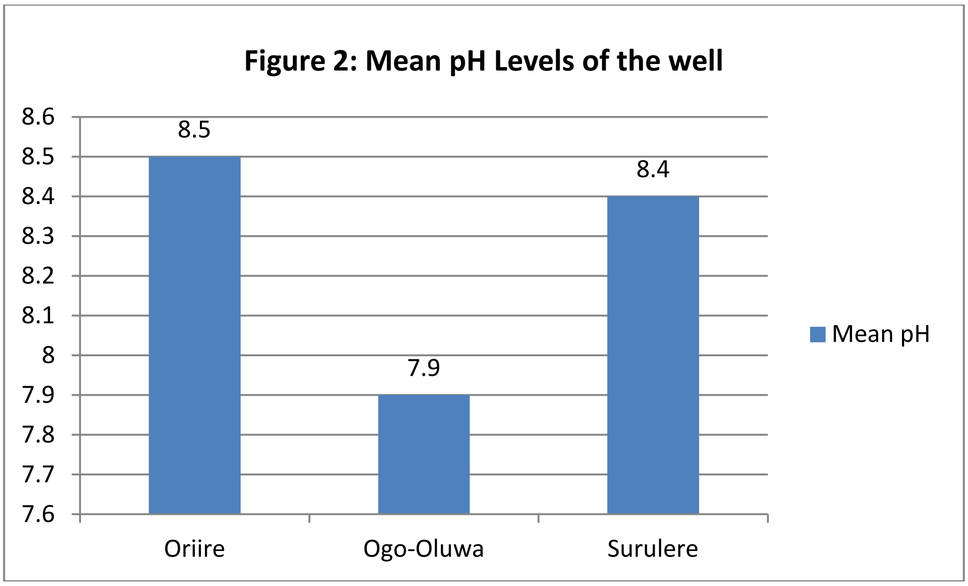
S/N	Parameter	Vilage Names					M±SD	Recommended Standards	
		Igbo-Ile	Idi-Ayin	Eleeru	Kueke	Onipanu		WHO (2006)	NSI (2007)
1	pH	7.9	8.4	9.7	8.2	8.0	8.44±0.73	6.5-8.5	6.5-8.5
2.	*EC(µƒ/cm)*	*200*	*230*	*240*	*260*	*240*	234±21.91	*1000(µƒ/cm)*	*1000(µƒ/cm)*
3.	*Temp. (°C)*	*23.6*	*23.7*	*23.6*	*23.4*	*23.4*	23.5±0.13	*25°C*	*25°C*
4.	*TDS(mg/L)*	*126.7*	*155.4*	*93.74*	*182*	*154.9*	142.6±33.57	*600mg/L*	*500mg/L*
5.	*ORP(mV)*	*293*	*294*	*294*	*294*	*293*	293.60±0.55	*700mV*	*NA*
6.	*NO^3(ms/L)*	*0.58*	*0.27*	*0.73*	*1.22*	*0.96*	0.75±0.36	*50 mg/L*	*50 mg/L*
7.	*PO4(mg/L)*	*0.83*	*0.51*	*0.76*	*0.38*	*0.24*	0.54±0.25	*2.2mg/L*	*NA*
8.	*SO4(mg/L)*	*1.32*	*0.88*	*1.89*	*1.01*	*0.93*	1.21±0.42	*250 mg/L*	*100mg/L*
9.	*Na+(mg/L)*	*17.25*	*18.99*	*23.31*	*22.46*	*25.90*	21.58±3.46	*250mg/L*	*200mg/L*
10.	*K(mg/L)*	*9.01*	*8.5*	*11.75*	*10.25*	*9.5*	9.80±1.27	*10mg/L*	*NA*
11.	*Coliform cfu/mL*	*0.08*	*0.03*	*0.06*	*0.46*	*0.87*	0.30±0.36	*10/100mL*	*10cfu/mL*

Source: Authors' fieldwork; M is Mean Value, SD is Standard Deviation

pH

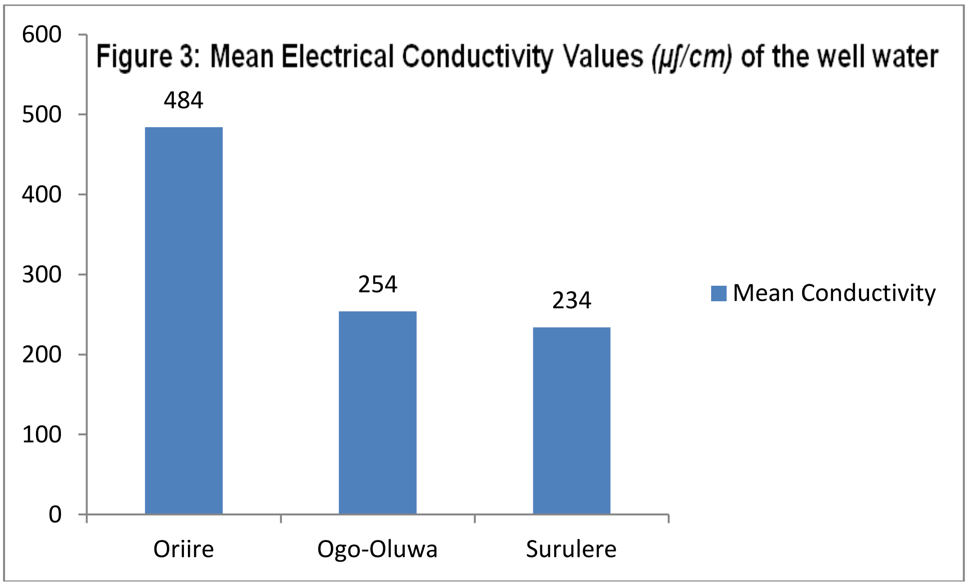
Table 2 shows that in Oriire LGA, pH ranges from 7.8 in Saamo to 9.2 in Olorunda and Alaidan while the mean value is 8.5±0.79; for Ogo-Oluwa LGA, pH ranges from 7.6 in Ladanu and Lagbedu to 8.2 in Pontela with a mean value of 7.9±0.28 (Table 3); and for Surulere LGA, pH ranges from 7.9 in Igbo-Ile to 9.7 in Eleeru and a mean value of 8.44±0.73 (Table 4).

In Oriire LGA, as shown in Figure 2, pH is generally high as the mean value of 8.56 slightly exceeds 8.5 permissible limit as recommended by WHO and NIS. The value in Ogo-Oluwa LGA ranges between 7.6 in Ladanu and 8.2 in Pontela with a mean value of 7.9 which falls below the acceptable limit. Similarly, the contents of pH range between 7.9 in Igbo Ile and 9.7 in Eleeru. The mean value of 8.4 in Surulere LGA is high due to closeness to the standard limit recommended by WHO. The variation in the pH is generally attributed to the exposure of such sampled wells to surface runoff (Ishaku et al, 2011)



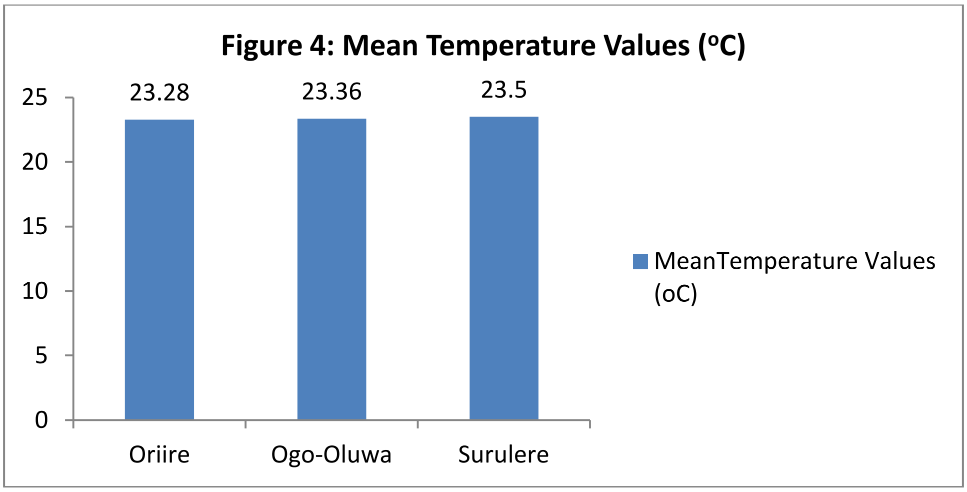
Electrical Conductivity

Electrical conductivity, according to Olajire and Imeokparia (2001) is viewed as a valuable indicator of the amount of dissolved materials in water The values of electrical conductivity across the three local government areas as shown in Tables 2-4 and depicted in Table 3, revealed that the values fall within the maximum permissible of 1000us/cm by WHO and NIS. For instance, the values range between 340 in Olorunda and Aitete, and 700 in Saamo of Oriire LGA. The range is 160 in Lagbedu to 440 in Opete, all in Ogo-Oluwa LGA while the values in Surulere range from 200 in Igbo-Ile to 260 in Kueke. This makes the water fit for human consumption.



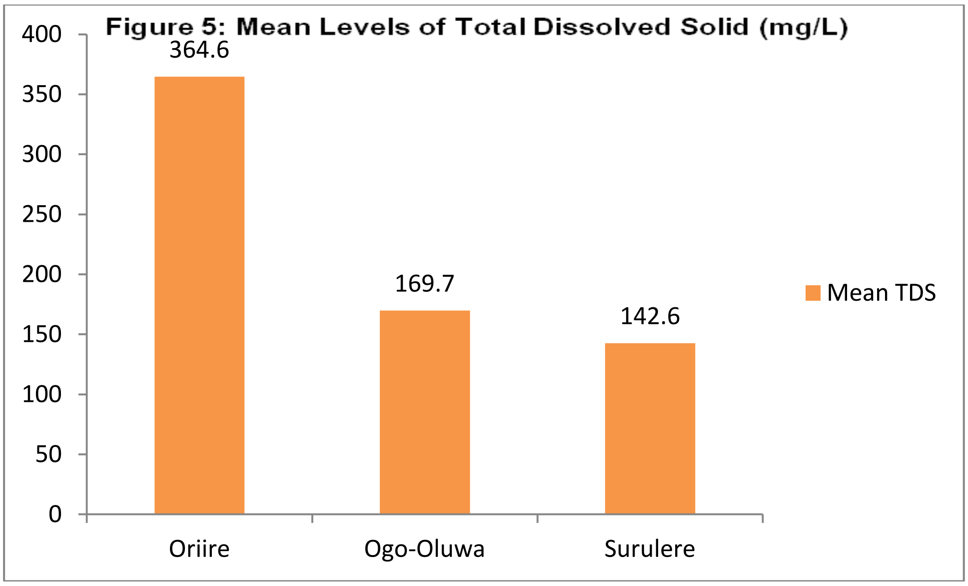
Temperature

According to Tables 2-4 and shown in Figure 4, none of the samples in the villages investigated had temperature values exceeding the WHO and NIS 25°C recommended standard. The value ranges from 23.2 in Alaidan and Saamo to 23.4°C in Olorunda in Oriire LGA. Also, the range in Ogo-Oluwa LGA is from 23.3 in Opete, Iwata and Ladanu to 23.5°C in Pontela while the range is 23.4°C in Kueke and Onipanu and 23.7°C in Idi-Ayin in Surulere LGA. Determination of water temperature in the well and or boreholes according to Mink (1964) and Hutton (1983) is a good measure of contamination as it marked effect on bacteria and chemical reaction rates in water.



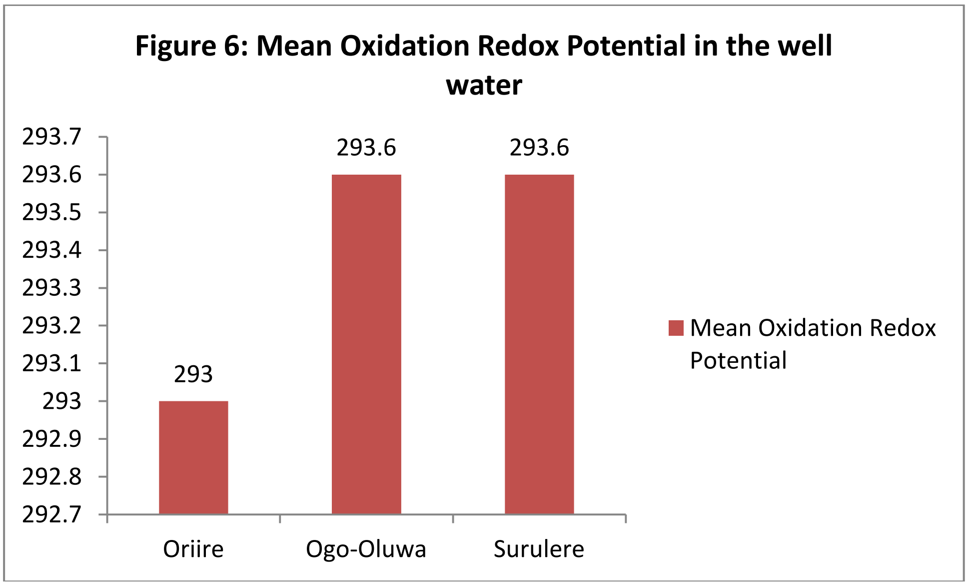
Total Dissolved Solid (TDS)

The values of TDS across the three LGAs, as presented in Tables 2-4 and shown in Figure 5, reveal that the values fall below the WHO recommended standard of 600 except in Oriire LGA. It was observed that the values in Saamo and Alaidan are respectively 549.7mg/L and 546.2mg/L. The finding may be attributed to the release of pollutants via surface runoff into the well water. According to Abdulahi et al., (2011) the TDS is an indication of the degree of dissolved substances such as metal ions in the water.



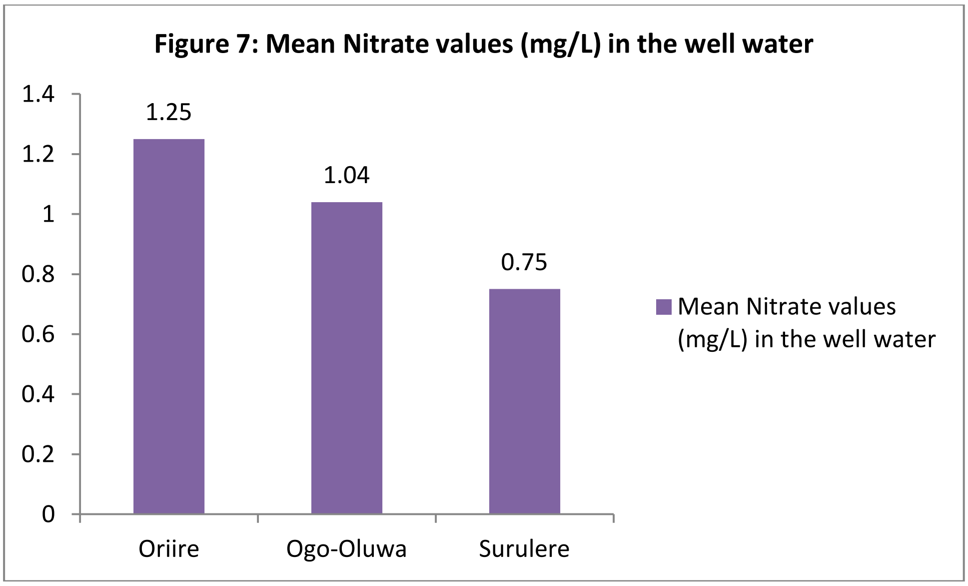
Oxidation Redox Potential (ORP)

ORP is important in many drinking water processes and applications. For instance, the corrosion of distribution system materials, precipitation of iron and manganese compounds, nitrification and microbial disinfection are dependent on O-R reactions. ORP is a tool to monitor drinking water processes such as disinfection effectiveness. WHO (1993) adopted ORP of 700mV for drinking water. ORP of 200mV indicates reduced levels of dissolved oxygen. Generally, most part of the study area had ORP values ranging from 289mV to 294mV indicating that underground water in the study area fall within the permissible limit following the adoption of WHO (1993).



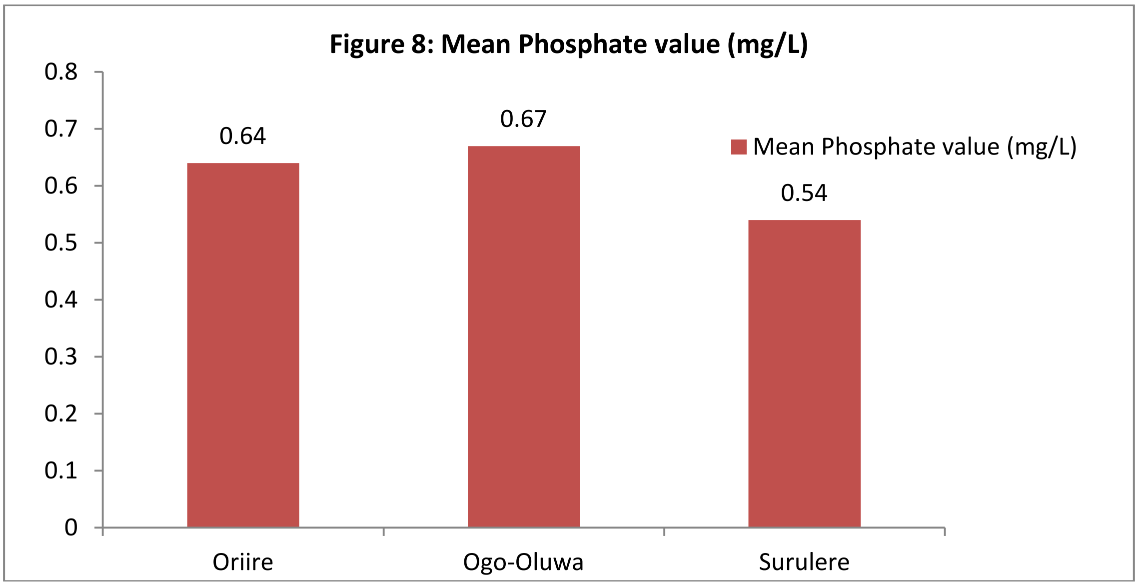
Nitrate

According to Tables 2-4, the contents of nitrate in the well water across the three LGAs are generally low implying that the water is safe for human consumption. For instance, the highest values observed are respectively 2.96mg/L, 1.58mg/L and 1.22mg/L across Oriire, Ogo Oluwa and Surulere LGAs. The mean values shown in Figure 7 are far below the 50mg/L maximum value recommended by both the WHO and NIS indicating the safety of the water for human consumption.



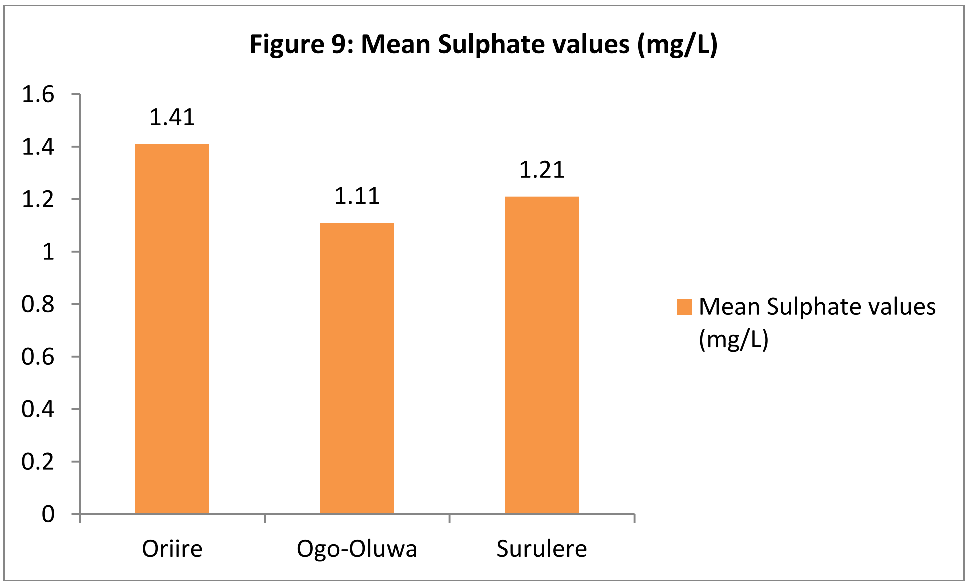
Phosphate

The contents of phosphate in the well water in the villages investigated in the three LGAs according to Tables 2-4 show that the water quality is safe for man's use. The highest value in Oriire LGA is 1.00mg/L, 1.03 in Ogo-Oluwa and 0.83mg/L in Surulere LGAs. These values lower than the WHO and NIS recommended limit of 2.2mg/L. The mean values of this parameter across the three LGAs are as shown in Figure 8.



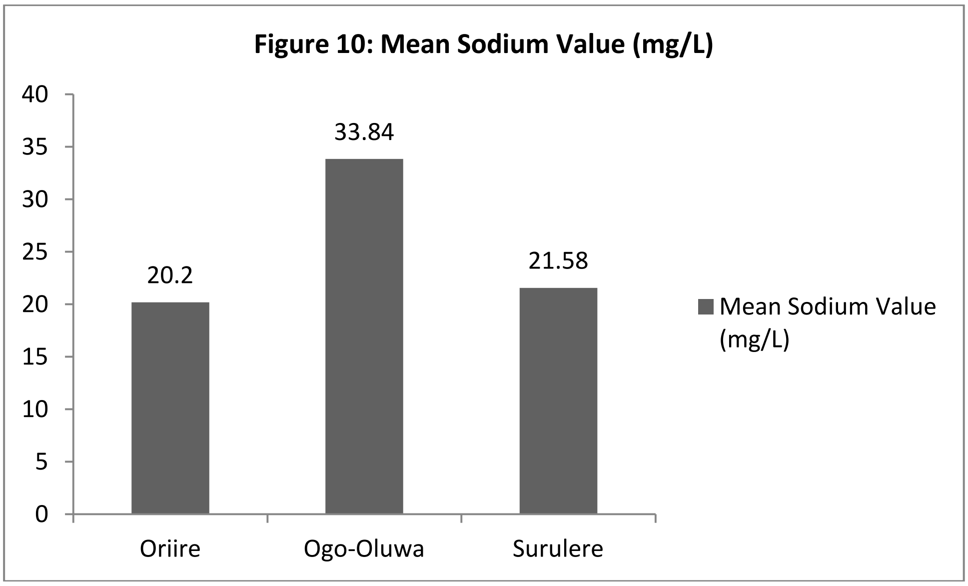
Sulphate

The results of sulphate contents of the well water in the three LGAs as presented in Tables 2-4 indicate that the values are far below the respective 250mg/L and 100mg/L maxima permissible by WHO and NIS. The highest observed in Oriire LGA is 2.26 in Budo-Ode, 2.01 in Pontela (Ogo-Oluwa LGA) and 1.89mg/L in Eleeru (Surulere LGA). The implication of this is that the water is safe for human consumption. Figure 9 shows the mean values across the study area.



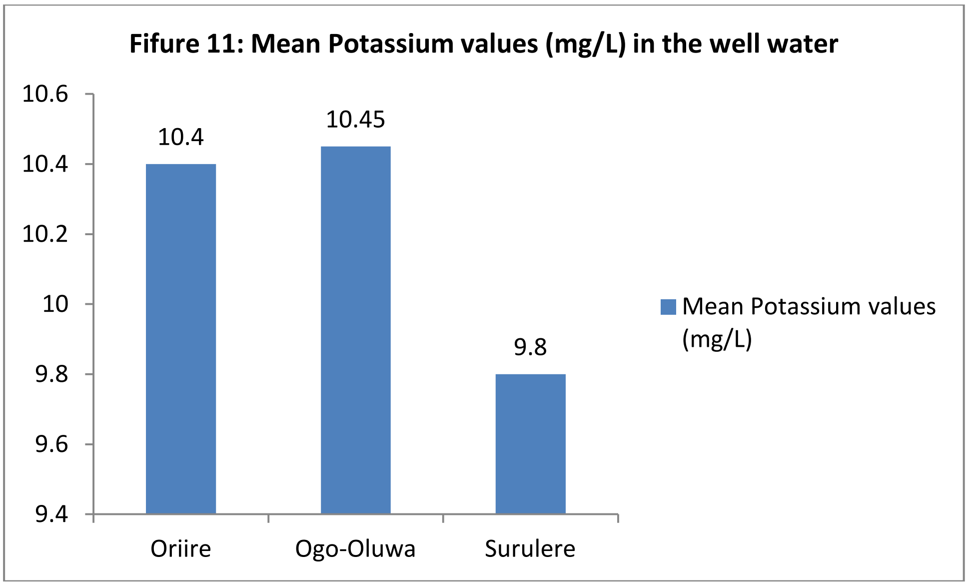
Sodium

Tables 2-4 show that the sodium contents of the underground water across the three LGAs fall below the maxima acceptable by WHO and NSO standards of 50ppm and 200mg/L respectively. It is noted that the highest values in Oriire, Ogo-Oluwa and Surulere are respectively 30.22mg/L (Alaidan), 44.03mg/L (Iwata) and 25.90mg/L (Onipanu). Figure 10 shows the spread of the average values in the study area.



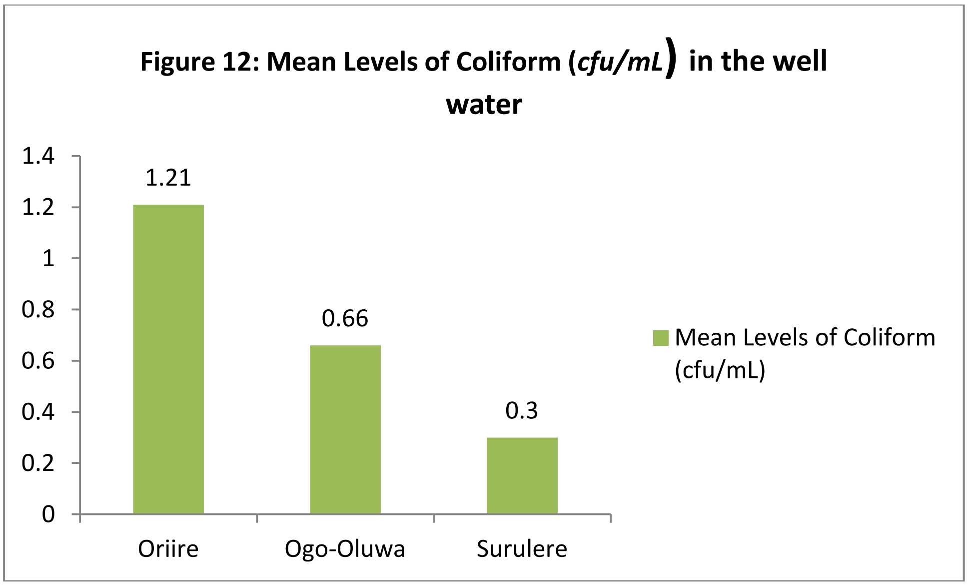
Potassium

Tables 2-4 show that the mean contents of potassium exceed the WHO permissible limit of 10mg/L in Oriire and Ogo-Oluwa LGAs with 10.40mg/L and 10.45mg/L respectively. However, the mean value is 9.8mg/L in Surulere LGA, which is below the recommended standard. However, in Oriire LGA, apart from Olorunda and Aitete communities with 8.5mg/L and 6.5mg/L respectively, the potassium contents in other three rural communities exceeded the acceptable limit. Similarly, the result in Table 3 reveals that the potassium contents of the underground water in three communities in Ogo-Oluwa namely Iwata, Lagbedu and Pontela exceed the maximum standard with 15.00mg/L, 11.50mg/L and 10.75mg/L respectively. However, Opete and Ladanu with 8.01mg/L and 7.01mg/L respectively are within the permissible standard. Apart from Eleeru and Kueke in Surulere LGA that have 11.75mg/L and 10.25mg/L respectively, the values that exceed the maximum permissible, other rural communities such as Igbo-Ile, Idi-Ayin and Onipanu have values within the permissible limit. These are respectively 9.01mg/L, 8.5mg/L and 9.5mg/L. Figure 11 shows the mean values of potassium across the study area.



Coliform

The results in Tables 2-4 show that the contents of coliform across the rural communities in all the LGAs investigated are within the permissible limits of 10cfu/mL recommended by WHO and NSO. This is also depicted in Figure 12. The coliform counts in Oriire LGA ranges from 0.18 in Saamo and 1.80cfu/mL in Olorunda, the range in Ogo-Oluwa LGA is from 0.24 in Iwata to 1.05cfu/mL in Pontela while the coliform counts range from 0.03 to 0.87. The implication of this finding is that the well water is safe for human domestic consumption. However, the results obtained here could have been influenced by the rainy season during which the data were collected. For instance, the contents of some chemical parameters examined like coliform, pH and potassium may have been so as a result of dilution due to rainwater. Thus, it is imperative that further investigation be carried out on the quality of underground water in these areas. Persistent and consistent investigation will help to ascertain those parameters that explain the variation in the quality of water under study.



Potability of groundwater in the study area

Factor analysis extracted four physico-chemical parameters namely electrical conductivity (EC), nitrate (NO^-_3), coliform and phosphate (PO^-_4) with eigenvalues of 1.00 and above as extracted from the SPSS-generated rotated matrix. This is presented in Table 5. The four water quality parameters explain the entire 100% variations in the quality of water in the study area indicating that the water is unsafe for human consumption. Electrical conductivity has the highest percentage of variance of 27.06 followed by Nitrate (25.64%). Coliform and Phosphate respectively have 23.88% and 23.41% of variance.

Table 5: Water Quality Parameters, their respective, eigenvalues, loadings and % of Variance

S/N	Chemical Parameter	Loading[a]	Eigenvalue[b]	% of Variance[b]	Cumulative %[b]
1.	Electrical Conductivity	0.989	4.17	27.06	27.06
2.	Nitrate	0.966	3.34	25.64	52.70
3.	Coliform	0.946	2.29	23.88	76.59
4.	Phosphate	0.991	1.20	23.41	100.00

Source: [a] Extracted from SPSS-generated Rotated Component Matrix and [b]Table of Total Variance Explained

Similar observations were made by Ishaku et al. (2011) in which Nitrate, Phosphate, and Electrical Conductivity among other physico-chemical parameters were found to contribute 76.04% to the variation in the underground water. The implication of the results of factor analysis is that the underground water in the study area is susceptible to both air- and water-borne contaminants. Thus, efforts should be made to check the concentration of the parameters observed for the quality of the water to be sustained. One of the remedial solutions is that wells should be cited away from the possible source/s of these parameters to subdue their concentrations. The contribution of coliform to the poor quality of well water could be attributed to the closeness of wells to septic tank or latrines, home or industrial effluents or refuse dumps. Apart from this, one of the sources of nitrates is chemical fertilizers used in agricultural practices in the rural areas (see Hamilton and Helsel, 1995; Bolke , 2002; Levison and Novakoski, 2009). Wells should be sited away from farm plots to avoid leaching of such chemicals and also other organic wastes into underground water. Sources of phosphates in well water include human and animal wastes, fertilizer, soil erosion which are peculiar to rural areas (see Schröider et al (2004). Thus, in order to get rid of the concentration of phosphates in well water, efforts should be made to checkmate the aforementioned sources. In the same vein, the contribution of electrical conductivity to the quality of underground water is also closely related to surface runoff which releases pollutants into the well.

CONCLUSION

The study of the quality of underground water in the rural areas of Ogbomoso zone has been conducted. The descriptive analysis generally revealed the potability of the underground water in the study area. However, factor analysis extracted four chemical parameters which dominate the variation in the quality status of underground water in the study area. These are electrical conductivity, nitrate, coliform and phosphate. Thus, by implication, the well water under investigation is not safe for human consumption except it undergoes treatment especially by boiling. The parameters generally have common source such as human and animal wastes, chemical fertilizers, home and industrial effluents which needs to be checked if the quality of the well water in the rural areas will be made safe for human consumption.

Water resource management in the study area should therefore include putting control measures to checkmate the concentration of these quality parameters in the well water. The measures should among others include concretizing the well area and, also the circumference be raised above the surface of the earth to checkmate surface runoff and direct leaching into the well. Also wells/boreholes should be cited away from the possible sources of pollutants such as farm plots, latrines and erosion channels and should be protected among others. Further research on water quality determinants on seasonal basis is suggested for comparative purposes and conformity with the acceptable standards.

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