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Assessment of Household Water Quality from Selected Storage Vessels used in a South-Western Rural Community, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors DBO and OZW designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OA and managed the analyses of the study. Author OAA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Water is an important requirement for life but its contamination via natural and anthropogenic activities is of great concern. This study determined some physicochemical parameters of drinking water from the main source (borehole), and selected storage vessels in Abimbola, Ayedaade Local Government Area, Osun State, Nigeria. About 10 household water samples were collected randomly from the 70 households in the village. The major water storage vessels used by the villagers were clay pots. Only about one-fifth of the households used plastic containers. All the physico-chemical parameters assessed were within permissible limits of the World Health Organization and Standards Organization of Nigeria's drinking water guidelines except for Lead and nitrite. Furthermore, water stored in clay pots had significantly higher levels of Nitrate (p=0.04), Nitrite (p=0.04), Sulphate (p=0.04), Lead (p=0.03), Iron (p=0.04), and Manganese (p=0.04) than

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those stored in plastic containers. Results suggest that the type of storage vessels used could influence the physicochemical quality of the water stored in them. Also, basic water quality monitoring needs to be conducted routinely to ascertain and maintain high quality water supply per time.

Keywords: Water quality; rural community; plastics; clay pots; physicochemical parameters.

1. INTRODUCTION

Water is a basic human need and without it, the survival of people are at risk [1,2]. However, about 2.3 billion people across the globe lack access to clean water, causing 842,000 deaths every year which is a major public health concern [3,4]. In Nigeria, a large percentage of rural communities live without access to clean water [5]. Furthermore, Ali [6] stated that water supplies in Nigeria are not only inadequate but decreasing [6]. Ezenwaji et al. [7] reported that millions of people in the country still depend on unimproved drinking water sources such as shallow wells, springs, rivers, ponds, canals, stored rainwater, etc. for their water needs [7]. Adeleye et al. [8] reported that, in Nigeria, many rural water supply schemes (RWSSs) are not functioning, and most rural dwellers are facing serious and persistent challenges in meeting their water needs [8]. Although, studies done in Osun revealed otherwise as sustainable water supply facilities were made available and accessible to the rural dwellers in the communities [9,10]. This shows that while many rural communities are lacking safe water sources, very few communities are making notable and sustainable progress. However, there has been increase in water need to support the growing rural population [11]. Most people in rural communities in Nigeria have fixed dependence on wells and boreholes for provision of water supplies [12].

Several factors including nutrients, sediments, and other pollutants from point sources and non-point sources, airborne pollutants, contaminated sediments, and physical or habitat degradation are major contaminants of Nigerian rivers, streams, and lakes causing enormous environmental and public health problems [13]. Similar to many sub-Saharan African countries such as Uganda and Ethiopia, surface water sources are leading sources of water in Nigeria [14]. Unfortunately, these water sources are often highly polluted and water quality testing is not performed as often as is necessary to guide users in most developing countries [15]. It is often believed by the rural populace that once a source of water is available, the quantity of water should be given more attention than the quality of water by the users [16].

Due to all these concerns, the need to store water momentarily became one of the most utilized methods to curb the challenges associated with accessibility, and availability of water especially in rural settings. Contamination of drinking water especially at the household level is a great public health concern particularly in developing countries [17]. Reviews showed that significant deterioration occurs in the quality of water stored at home in rural, and urban areas throughout Africa and in other continents [18]. Various studies have been reviewed in Nigeria on water quality and across the globe on the deterioration of water during its collection and storage in homes, but very few works had been done to assess the impact of household storage vessels on the water quality stored in them [19].

Parker et al. [20], Amenu et al. [21] and Schriewer et al. [22], discovered that the quality of household water is usually compromised by their storage methods after water is collected, which in turn increases the proportion of people exposed to contaminated water [20-22]. It has been reported that plastic containers released Bisphenol into stored drinking water which can be linked to early menarche in females, obesity, low sperm count, prostate cancer, breast cancer, and other serious reproductive health challenges [23]. Moreover, galvanized metal storage vessels could leach heavy metals, such as Iron, Lead, Zinc, Manganese, and Nickel to the water stored in the vessels, especially if metal corrosion is imminent [24]. Although, galvanized metal storage vessels are common in urban areas, and utilized more in industries. Storage vessels such as clay pots and plastic containers are commonly used by rural dwellers because they are readily available and affordable. Finding from a study done in a rural community in Bauchi state, Nigeria, revealed that clay/earthen pots, calabash, randa/tulu, hides, gora, salka, jerrycans and gourds are commonly used to store water as a larger percentage of the rural communities make use of both clay pots and plastic containers [25].

Furthermore, a cross-sectional study on determining the water quality index for measuring drinking water quality in rural Bangladesh showed that assessment of drinking water quality is a timely requirement amongst emerging public health problems where availability of safe drinking water is at risk due to natural and man-made activities [26]. Simonne et al. [27] reported in their study to assess the quality of drinking water at Source and Point-of-consumption in Bolivia that there was no significant relationship between the quality of drinking water at the source and the quality of water in drinking cups within the participating households [27]. However, the majority of the surveys conducted in Nigeria on water quality and across the globe were on the deterioration of water during its collection and storage in homes, but very few studies have been done to assess the impact of household storage vessels on the water quality stored in them [20]. Therefore, this study aimed to assess the quality of drinking water at source and storage, and compare the water quality of different household storage containers commonly used in rural communities in Osun State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in Abimbola, which is a rural settlement in Ayedaade Local Government Area, Osun State, Nigeria. The Local Government Area (LGA) shares boundaries with Isokan, Irewole, and Aiyedire LGA to the East, and Ife North to the West; with an area of 1,113 km² and a population of 150,392. It is located at coordinate 7°19’N°21’E 4. Abimbola village is prominently known to produce palm oil and there are about 500 villagers with about 70 households in the area.

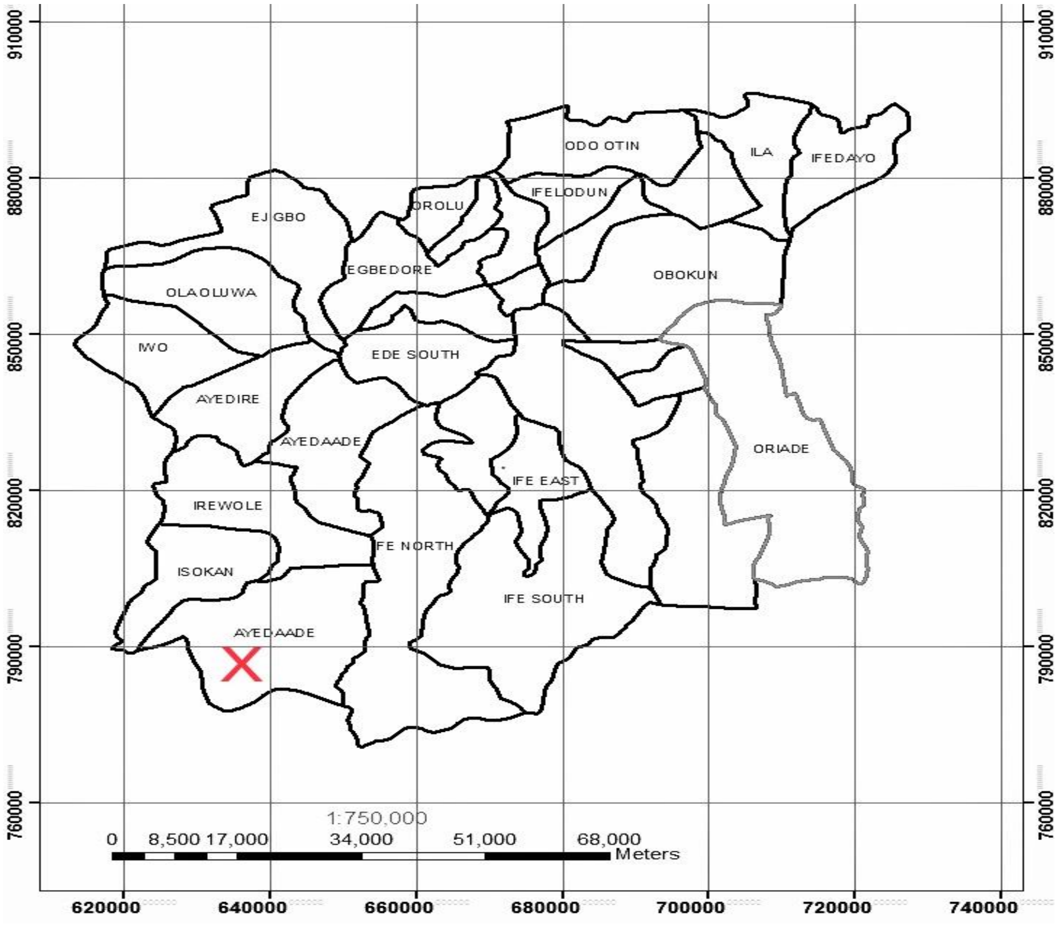

Fig. 1. Map Showing Ayedaade LGA marked X [28]

2.2 Study Design and Sampling Procedure

A community assessment was first performed at the household level to determine the common types of storage containers used by households in the village. Upon completing the assessment, it was determined that around 80% of the households used clay pots, while the remainder used plastic containers. Subsequently, 10 households from 70 households were randomly selected via stratified sampling. The households were stratified based on the type of storage containers used. Eventually, 8 households that use clay pots, and 2 households that utilize plastic containers were randomly selected.

2.3 Sampling of Water Samples

Samples of drinking water stored for about three to four days in either plastic containers or clay pots sourced from groundwater (borehole which is the main source of water in the community) were randomly collected from 10 households in the community. The eight (8) samples of water stored in clay pots and two (2) samples of water stored in plastic storage containers were all collected in 500ml bottles which were rinsed three times with the sample water prior to collection and sent to Dana pharmaceuticals laboratory for physicochemical analysis.

Table 1. Instruments and method used for water quality analysis

Water quality	Test Description	Method
Colour	Color is used to describe the true color of water from which turbidity has been removed.	Platinum cobalt (visual comparison) method
Odour	Odor is recognized as a quality factor affecting acceptability of drinking water.	Wide mouth glass stoppered bottle
pH	The measure of acidity or alkalinity in the water.	pH meter (Multiparameter Photometer, HANNA)
Turbidity (NTU)	Turbidity in water is the reduction of transparency.	Turbidity meter
TDS	The measure of the number of particulate solids that are in the water	TDS meter (HANNA)
Electrical conductivity	The measure of the amount of electrical current	Conductivity meter (HANNA)
Chloride	Measurement of chloride amount in water	Titrimetric method
Chromium	Measurement of chromium in water	Ion chromatography
Total hardness	Measurement of calcium and magnesium in water.	Titrimetric method
Nitrate	Measurement of nitrate in water	Spectrophotometric method
Magnesium	Measurement of magnesium in water	Titrimetric method
Lead	Measurement of lead in water	Spectrophotometric method (HACH Atomic Absorption Spectrophotometer)
Nitrite	Measurement of nitrite in water	Multiparameter Photometer, HANNA
Iron	Measurement of iron in water	Spectrophotometric method (HACH Atomic Absorption Spectrophotometer)
Manganese	Measurement of manganese in water	Spectrophotometric method (HACH Atomic Absorption Spectrophotometer)
Silica	Measurement of silica in water	Colorimetric method
Sulphate	Measurement of sulphate in water	Spectrophotometric method

2.4 Physicochemical Analysis of Water Samples

The selected water samples from the different households were analyzed. The physicochemical parameters include odour, colour, pH, turbidity, total dissolved solids (TDS), electrical conductivity, chloride, chromium, total hardness, phenolphthalein alkalinity, total alkalinity, calcium hardness, calcium ion, magnesium hardness, nitrate, magnesium ion, lead, nitrite, iron, manganese, silica, sulphate were analyzed. pH was determined using pH meter, turbidity was determined using a turbidity meter. Other parameters were determined by methods shown in Table .

2.5 Data Analysis

The data obtained from this study were analyzed using SPSS software version 20. Descriptive statistics such as mean and standard deviation were used along with inferential statistics such as ANOVA at 5% level of significance for the data collected in the study.

3. RESULTS

The quality of water samples collected from plastic containers (P1 and P2) and clay pots were colourless, unobjectionable, and not turbid. However, the quality of water samples collected from the main water source had fine particles and slightly coloured as shown in Table 2. The pH values of water samples varied from 5.67 to 6.49, total hardness values ranged from 4.83 mg/L to 84.54 mg/L, concentrations of calcium (0.049 - 30.06 mg/L), magnesium hardness (0.042 - 4.649), and chloride (29.5 mg/L to 125.6 mg/L) are shown in Table 2. Majority of the physicochemical parameters analysed in this study fall below WHO and SON permissible limits. However, total alkalinity for samples from two clay pots (3, and 7) exceeded WHO and SON permissible limits, but the mean total alkalinity was below the permissible limit in both plastic and clay pot storage. Likewise, Nitrite levels found in clay pot 1, 3, 5 and 8, exceeded WHO and SON limits with the rest falling below the permissible limit. The concentration of lead found in all the containers (plastic and clay) and the water source exceeded the WHO and SON permissible limits.

The mean chloride of water stored in clay pots (87.91±26.31 mg/L) was higher than water stored in plastic containers (37.39±17.62 mg/L). The mean magnesium hardness of water stored in the clay pots (8.83±5.99 mg/L) was higher than water stored in the plastic containers (5.14±6.02 mg/L). Also, the mean lead of water stored in the clay pots (0.03±0.01) was higher than water stored in the plastic containers (0.01±0.01 mg/L). The mean lead of water stored in clay pot was above the WHO limits (0.01 mg/L) as shown in Table 3. There was significant difference (at $P<0.05$) in Nitrate ($p=0.04$), Nitrite ($p=0.04$), Sulphate ($p=0.04$), Lead ($p=0.03$), Iron ($p=0.04$), Manganese ($p=0.04$) between water stored in clay pots and plastic bottles.

Table 4 shows significant correlations among the physicochemical parameters. Strong positive correlations were found between Chromium and Nitrate (0.866); Chromium and Lead (0.874); Chromium and Nitrite (0.847); Chromium and iron (0.856); Chromium and Manganese (0.845); Total Hardness and Calcium Hardness (0.99); Total Hardness and Calcium ion (0.99); Total Hardness and Magnesium ion (0.814). Negative correlations exist between Total Alkaline and the majority of the parameters except for Chloride and Sulphate where a weak positive correlation can be seen. Also, Chromium, Nitrate, Nitrite, Lead, Iron, Manganese, Silica, and Sulphate had a negative correlation with pH.

4. DISCUSSION

In this study, water supply facilities were available in the entire community. This confirmed the earlier reports from studies carried out in the community [9,10]. Although, water scarcity is not an issue in the community, and all households were quite close to a functional water facility (handpump borehole), the villagers prefer to store water momentarily. This may be because the villagers desire to ease the stress of going to fetch water at the point-source momentarily. Majority of households in the community use clay pots and plastic containers (buckets and jerrycans) to store water. This is similar with the findings of the study in Kisoro district of Uganda where the water storage containers peculiar to them were jerrycans, and plastic bottles, alongside other storage methods classified into traditional, manufactured, and built-in-place methods [17]. Also, a study conducted in rural communities in Bauchi State, Nigeria, reported that more than half of the people stored water with both clay pots and plastic containers, with about 17% to 23% using clay pots, while 26% to 30% made use of plastic containers to store water [25].

Table 2. Physicochemical analysis results of water samples collected from water stored in clay pots, plastic container s and water source

Parameter	CP_1	CP_2	CP_3	CP_4	CP_5	CP_6	CP_7	CP_8	P_1	P_2	Main source
Turbidity	Not Turbid	Not Turbid	Not Turbid	Not Turbid	Not Turbid	Not Turbid	Not Turbid	Not Turbid	Not Turbid	Not Turbid	Turbid with fine particles
Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
pH	6.405	6.272	6.243	6.271	6.133	6.031	5.874	6.496	6.358	5.67	6.07
Total dissolved solid	74.95	44.225	83.45	130.00	193.5	84.28	5.155	0.193	127.75	8.68	77.38
Electrical conductivity	149.9	88.45	166.9	260.0	387.0	168.56	10.31	0.386	255.5	17.36	154.70
Chloride	74.8	77.3	99.7	124.6	124.6	49.9	49.9	77.7	74.8	24.9	99.7
Chromium	0.0021	0.00033	0.00	0.0011	0.002	0.0020	0.00	0.0001	0.0003	0.00	0.003
Total Hardness	38.65	53.14	19.32	65.41	79.71	14.49	24.15	72.46	84.54	4.83	56.76
Total Alkalinity	62.50	100.00	250.00*	87.5	112.50	50.00	250.00*	150.00	8.875	75.00	105.63
Calcium hardness	29.551	41.342	15.426	51.432	60.675	13.016	21.453	63.542	75.142	3.942	48.631
Calcium ion	0.049	16.5368	6.1704	20.5728	24.27	5.2064	8.5812	25.4168	30.0568	1.5768	19.46
Magnesium Hardness	2.22185	11.7979	3.894	13.978	18.815	1.474	2.7015	8.9215	9.398	0.888	8.13
Nitrate	0.049	0.020	0.024	0.008	0.030	0.021	0.017	0.020	0.011	0.017	0.10
Magnesium ion	0.042	2.8826	0.1975	3.4160	4.649	.3624	0.6636	2.4189	2.3086	0.2172	1.99
Lead	0.074*	0.016*	0.034*	0.019*	0.028*	0.033*	0.011*	0.029*	0.022*	0.007	0.10*
Nitrite	0.056*	0.012	0.026*	0.011	0.026*	0.016	0.014	0.025*	0.013	0.011	0.10
Iron	0.001	0.019	0.053	0.029	0.042	0.046	0.028	0.052	0.036	0.019	0.151
Manganese	0.009	0.004	0.034	0.019	0.018	0.032	0.008	0.032	0.028	0.020	0.119
Silica	0.049	0.004	0.010	0.001	0.006	0.001	0.004	0.004	0.004	0.004	0.03
Sulphate	2.22185	0.001	0.009	0.00	0.0076	0.001	0.0078	0.005	0.003	0.001	0.022

*† CP= Clay Pot; P= Plastic; * =above permissible limit*

Table 3. Mean values of physicochemical parameters, F-Values, P-Values, WHO/SON Permissible limits (Values are means ± SD; N = 3)

Parameters	Clay pot	Plastic bottle	F-Value	P-Value	WHO limits	SON limits
pH	6.22±0.20	6.01±0.48	0.7	0.52	6.5-8.5	6.5-8.5
Total Dissolved Solid (mg/L)	76.97±63.94	68.22±84.20	0.0	0.98	500	500
Electrical Conductivity	153.94±127.87	136.43±168.69	0.0	0.98	1000	1000
Total Hardness(mg/L)	45.92±25.36	44.69±56.36	0.1	0.89	500	-
Chloride (mg/L)	87.91±26.31	37.39±17.62	4.3	0.05	250	250
Total Alkalinity	132.81±78.47	41.94±46.76	1.3	0.31	200	-
Calcium Hardness	37.05±20.11	39.54±50.35	0.2	0.85		150
Calcium ion	14.82±8.05	15.82±20.14	0.2	0.85	-	-
Magnesium Hardness	8.83±5.99	5.14±6.02	0.3	0.72		-
Nitrate	0.02±0.01	0.01±0.00	4.3	0.04*	50	50
Magnesium ion	2.10±1.59	1.26±1.48	0.3	0.78	-	0.2
Nitrite	0.02±0.01	0.10±0.09	4.8	0.04*	0.2	0.2
Silica	0.00±0.00	0.00±0.00	3.9	0.06		-
Sulphate	0.01±0.00	0.00±0.00	4.3	0.04*	100	100
Chromium	0.00±0.00	0.00±0.00	1.5	0.27	0.05	0.05
Lead	0.03±0.01	0.01±0.01	4.7	0.03*	0.01	0.01
Iron	0.04±0.02	0.03±0.01	4.3	0.04*	0.3	0.3
Manganese	0.03±0.02	0.02±0.01	4.2	0.04*	0.5	0.2

Table 4. Correlation Coefficients of all the physicochemical parameters

		pH	TDS	EC	Cl	Cr	TH	TA	CaH	Cation	MagHard	Nitrate	Magion	Pb	Nitrite	Fe	Mn	Silica	SO$_4^{2-}$
pH	**R**	1	0.246	0.246	0.086	-0.128	0.642	-0.106	0.638	0.638	0.501	-0.195	0.475	-0.094	-0.152	-0.117	-0.139	-0.262	0.183
	P value		0.440	0.440	0.791	0.693	0.025	0.742	0.026	0.026	0.097	0.544	0.119	0.778	0.637	0.717	0.666	0.412	0.570
TDS	**R**		1	1.000	0.392	0.326	0.505	-0.341	0.438	0.438	0.672	0.017	0.610	0.080	0.027	0.038	0.022	0.008	0.017
	P value			0.000	0.207	0.301	0.094	0.278	0.155	0.155	0.017	0.957	0.035	0.804	0.932	0.907	0.945	0.981	0.957
EC	**r**			1	0.392	0.326	0.505	-0.341	0.438	0.438	0.672	0.017	0.610	0.080	0.027	0.038	0.022	0.008	0.017
	P value				0.207	0.301	0.094	0.278	0.155	0.155	0.017	0.957	0.035	0.804	0.932	0.907	0.945	0.981	0.957
Cl	**r**				1	0.262	0.244	0.402	0.158	0.158	0.565	0.228	0.500	0.230	0.249	0.213	0.154	0.229	0.283
	P value					0.410	0.444	0.195	0.625	0.625	0.056	0.476	0.098	0.473	0.435	0.506	0.632	0.474	0.372
Cr	**r**					1	-0.033	-0.353	-0.097	-0.097	0.256	0.866	0.267	0.871	0.847	0.856	0.845	0.762	0.779
	P value						0.919	0.261	0.765	0.765	0.423	0.000	0.402	0.000	0.001	0.000	0.001	0.004	0.003
TH	**r**						1	-0.265	0.990	0.990	0.793	-0.087	0.814	-0.025	-0.038	-0.045	-0.072	-0.074	-0.056
	P value							0.405	0.000	0.000	0.002	0.788	0.001	0.939	0.906	0.890	0.823	0.818	0.862
TA	**r**							1	-0.257	-0.257	-0.236	-0.111	-0.307	-0.136	-0.087	-0.104	-0.170	-0.006	0.085
	P value								0.420	0.420	0.460	0.731	0.332	0.673	0.789	0.747	0.598	0.986	0.792
CaH	**r**								1	1.000	0.700	-0.118	0.728	-0.048	-0.064	-0.064	-0.086	-0.096	-0.079
	P value									0.000	0.011	0.715	0.007	0.883	0.844	0.842	0.790	0.766	0.808

		pH	TDS	EC	Cl	Cr	TH	TA	CaH	Cation	MagHard	Nitrate	Magion	Pb	Nitrite	Fe	Mn	Silica	SO_4^{2-}
Cation	**r**									**1**	**0.700**	**-0.118**	**0.728**	**-0.048**	**-0.064**	**-0.064**	**-0.086**	**-0.096**	**-0.079**
	P value										**0.011**	**0.715**	**0.007**	**0.883**	**0.844**	**0.842**	**0.790**	**0.766**	**0.808**
MagHard	**r**										**1**	**0.073**	**0.987**	**0.084**	**0.084**	**0.055**	**0.009**	**0.041**	**0.057**
	P value											**0.823**	**0.000**	**0.796**	**0.795**	**0.866**	**0.978**	**0.900**	**0.861**
Nitrate	**r**											**1**	**0.074**	**0.983**	**0.994**	**0.985**	**0.976**	**0.951**	**0.967**
	P value												**0.820**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Magion	**r**												**1**	**0.078**	**0.082**	**0.053**	**0.010**	**0.026**	**0.041**
	P value													**0.808**	**0.799**	**0.871**	**0.976**	**0.935**	**0.900**
Pb	**r**													**1**	**0.991**	**0.997**	**0.990**	**0.945**	**0.955**
	P value														**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Nitrite	**r**														**1**	**0.995**	**0.986**	**0.962**	**0.976**
	P value															**0.000**	**0.000**	**0.000**	**0.000**
Fe	**r**															**1**	**0.994**	**0.953**	**0.966**
	P value																**0.000**	**0.000**	**0.000**
Mn	**r**																**1**	**0.943**	**0.945**
	P value																	**0.000**	**0.000**
Silica	**r**																	**1**	**0.955**
	P value																		**0.000**
SO_4^{2-}	**r**																		**1**
	P value																		

Clay pots were more in use in the community to store water across the households compared to plastic containers. It may be because of the readily available materials to make clay pots, the cost to afford plastic containers, and clay pots help to reduce the water temperature [29]. Although, plastic containers are used more to fetch the water from the point-water sources. However, plastic containers had been linked to pose serious health effects, such as impaired immunity, reproductive health challenges, and birth disorders, among others due to their ability to leach bisphenol A (BPA), and phthalates into the water, which was used to produce plastics [25].

The pH values obtained in this study are less than the WHO set allowable limits which is like other studies that have been carried out in Maiduguri, Nigeria with pH values generally <6.5 and in Ondo State, Nigeria with a mean pH value of 6.35 ± 0.036 [30,31]. The pH values are higher in the stored containers than in the source (5.961). According to a previous study done, the increase in the pH value of the stored water could be because of the death of microorganisms present which results in the release of inorganic substances [32]. The slightly acidic pH values could be an indication of contamination of either organic matter or microorganisms [33]. Even though some studies say that pH has no direct impact on human health, its indirect action on the physiological process cannot be overemphasized [34], it is important to note that water with pH values below the required standards values results in the indirect health risk of metallic leaching of plumbing systems, due to the presence of acidic water within domestic and municipal plumbing lines [33].

According to WHO, the maximum allowable limit for conductivity is 1000 µS/cm, the results showed available amounts in clay pots ranging from 0.386-387.0 mg/L and its mean value as 153.94 ± 127.87 while the values for plastic bottles ranged from 17.36-255.5 mg/L while its mean value is 136.43±168.69. According to the WHO guidelines, the taste of drinking water should be non-objectionable to consumers; all water samples tested were unobjectionable. Hardness in drinking water is mainly due to carbonates, bicarbonates, sulphates, and chlorides of Ca and Mg. The mean value of total hardness from clay pots and plastic bottles are 45.92±25.36 and 44.69±56.36, respectively. This shows that all water samples fell below WHO stated maximum level and this suggests that [25].

Most heavy metals tested had their concentrations below WHO permissible limits and this is like a study done in a rural community in Kwara State, Nigeria but quite contrary to that of a study in a rural community in Gombe state that reported more heavy metal contamination of groundwater point-source [35,36]. Chloride in water was noticed to be generally below WHO maximum level of 250mg/L. Chloride can be present in water sources naturally but may also be present due to the local use of de-icing salt or saline intrusion [37]. Higher values of chlorine in water were found in CP_4 and CP_5, this could be linked to the possible use of chlorine for water treatment by the households. Low to moderate concentrations of chloride can add palatability to water; however, an excess of chloride can render water unpleasant to drink [38]. The mean concentrations of chromium in water were far lower than the WHO maximum level of 0.05mg/L, this is like a study conducted in Ibeju Lekki, and Epe Local Government Areas in Lagos state with low chromium levels in the water tested which may be due to lack of mining and industrial activities in that area [39]. Manganese, Iron, Silica, Sulphate, and Lead were detected in limits lower than the WHO maximum levels, and their presence, however, could be due to the pickup of a wide range of compounds, such as magnesium, calcium, and chloride, arsenate, fluoride, nitrate, and iron as groundwater moves through sedimentary rocks, and soils [40]. Nitrate was below the WHO acceptable limit which could be because the people's sewage facilities were not close to the water source and opposed to the review by Nath et al. (2006) that quality of drinking water is a problem in developing countries [41]. However, Olawade et al. (2020) stated that the quality of rural water supply in Osun state was commendable as they recorded physicochemical parameters that are below WHO permissible limits which are like the results of this study [36].

The majority of the physicochemical parameters had significant positive correlations which is an indication that most of the parameters influence other parameters. An increase in Chromium, for example, will lead to an increase in Lead (Pb), Nitrate, Nitrite, Manganese, Silica, and Sulphate. A highly significant positive correlation exists between TDS and EC which further solidifies the fact that EC depends greatly on the number of dissolved ions in water. This is in agreement with findings from previous studies [42,43]. Also, positive correlations were found between hardness, and each of Calcium ion, and Magnesium ion; TDS and Hardness which agrees with results from other studies [42-44]. On the other hand, there was a negative correlation between total hardness and nitrate which is quite predictable in light of the fact that the impact of nitrogen-fixing microorganisms diminishes with expanding water hardness [45].

5. CONCLUSION

It has been a Herculean task for Africa to balance supply with the increasing water demands and to provide safe water for its population [37]. However, the quality of drinking water both at source and stored are of good quality, and there is little difference between the water quality of the different households in Abimbola. There may not be adequate facilities necessary to process water to make it fit for human consumption, but natural springs can be made abundant to provide water to make up for activities of daily living in poor rural areas with little, or no water treatment resources. Also, there is a need for constant monitoring of water supply in rural areas, education on water treatment to members of the rural community.

Water from protected sources may not be contaminated to necessarily pose a public health risk, but contamination can come from the handling of water in transportation to various homes and a drop in water quality is also possible by its storage pattern, which may pose a significant risk to public health at individuals, households, and community levels. Some previous interventions in communities on waterborne diseases have made provisions for pipe-borne water to augment major water sources in the study area. However, study reports on water crisis with its associated public health problems reveal to authorities the need for prompt intervention.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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