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"Gheorghe Asachi" Technical University of Iasi, Romania

# A COMPARATIVE ASSESSMENT OF DOMESTIC WATER QUALITY IN RURAL COMMUNITIES OF SOUTHEAST NIGERIA

**Oliver O. Odikamnoro[1], Charles N. Ezugwu[2], Chukwunonye Ezeah[2]*, Okechukwu G. Omunakwe[3], Florin-Constantin Mihai[4]**

[1]*Department of Applied Biology, Ebonyi State University, Abakaliki, Nigeria*
[2]*Department of Civil Engineering, Alex Ekwueme Federal University, Ndufu-Alike, Ebonyi State, Nigeria*
[3]*Department of Civil Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria.*
[4]*Department of Research, Faculty of Geography and Geology, Alexandru Ion Cuza University of Iasi, Romania*

## Abstract

This study is a comparative assessment of domestic water quality collected from 35 sampling points in seven typical rural communities in Abia State, Southeast Nigeria. Physicochemical parameters such as pH, conductivity, turbidity and bacteriological parameters such as plate count and total coliform were analysed in the laboratory using standard World Health Organization (WHO) methodology. Results indicate that there are significant variations ($p<0.05$) in the physicochemical parameters of the water samples analysed. pH values ranged from 6.06 - 6.42 while values of turbidity ranged from 1.00 -7.60. Statistical analysis indicates no significant difference in the levels of bacteriological parameters ($p > 0.05$). In general, results from this study indicate that water sources in the villages studied are not good for drinking as most of the physicochemical parameters of the water samples were above the permissible limits of the WHO. However bacteriological result indicates that levels of parameters investigated were within the WHO limits. The main implication of this finding is that water from rural communities of Southeast Nigeria needs to be protected from the perils of contamination and in many cases do require further treatment before they could be safe for consumption.

*Key words:* drinking water quality, Nigeria, sustainable development goals, rural water supply, water and sanitation

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## 1. Introduction

Improving access to portable water and safe sanitation especially in the developing countries of the world is the main objective of Goal six of the Sustainable Development Goals (SDG6) recently adopted by the UN General Assembly. In sub Saharan Africa however, progress towards achieving the targets associated with SDG6 has been rather slow, and there are doubts whether these targets would be achieved by 2030, especially at the local level (United Nations, 2018). In particular, rural populations of Africa have a limited access to safe drinking water resources (Alhassan and Kwakwa, 2013; Elemide, 2010; Ezugwu, 2015a; NEWater, 2005). Apart from this, there are major regional inequalities with regard to access to potable water and sanitation facilities across sub-Saharan Africa (Ezugwu, 2015b; Oki and Kanae, 2006; Pullan et al., 2014; USEPA, 2002). By global standards, rural regions of Africa are also reported to be some of the most deprived of other important services such as waste services and power (Mihai, 2017; Olayode, 2006).

Water quality can be measured by assessing a number of parameters, for instance, the amount of material suspended in the water (turbidity), bacteria levels, concentration of dissolved oxygen or the amount of salt (or salinity). Other contaminants also measured to determine the quality of water include the concentration of microscopic algae and quantities of

* Author to whom all correspondence should be addressed: e-mail: C.Ezeah2@gmail.com; Phone: +2349033969903

pesticides and herbicides as well as heavy metals concentration (Agbu, 2006; Wu et al., 2018).

Unfortunately, existing published data on water quality and sanitation in developing countries mostly focus on urban areas, in most cases, they provide insufficient information about the quality of water being provided to rural communities (UNEP, 2006). Additionally, surveys on drinking-water quality and sanitation in such communities often adopt different methodologies, thereby making it difficult both to measure the current scope of the problem and to compare results across regions and over time (Aidan et al., 2006; Kunwar et al., 2004; USEPA, 1993; USDA, 1998; Simpson-Hebert et al., 2004; Zamxaka et al., 2004). The deployment of a rapid, low-cost, field-based technique for assessment of water quality is therefore a necessary condition for obtaining comparable data. In response to this need, WHO and UNICEF, with the support of the UK Department for International Development (DFID), undertook pilot studies of such a method, the Rapid Assessment of Drinking-Water Quality (RADWQ), in six countries including China, Ethiopia and Jordan (McDowell, 2000).

Nigeria exemplifies sub-Saharan African countries with serious inadequacies in terms of clean water and sanitation provision. Estimates put the population of Nigeria in excess of 180 million (NIS, 2007; NRC, 1996) of which approximately 50% live in rural areas. However, some reports suggest that less than 20% of the entire population has access to clean pipe borne drinking water (NIS, 2007). Poor sanitation contributes to water pollution in Nigeria where children under 5 years of age have a 38% higher risk of dying from lack of access to improved sanitation and clean water (Ezeh et al., 2014).

As a coping measure, Nigerians often resort to drilling shallow wells and/or bore-holes as a source of water supply. Although ground water can be a source of clean drinking water (depending on the depth), such untreated water should still be tested and ultimately treated before use. This is because bore holes and wells are easily exposed to heavy metals such as arsenic, cadmium, cobalt, lead etc. These contaminants are reported to be carcinogenic in nature. Due to the prevalence of these contaminants, it is necessary to test and most importantly treat water from such sources before use. Having said this, lack of access to water test kits as well as treatment options, particularly in the poorer rural areas, often demand that citizen consume potentially dangerous untreated water (WHO, 2005).

To improve water supply coverage in the country, there is need for specific legislation, regulation and standards that deal with targets and indicators on service coverage (accessibility, affordability, quantity and quality), as well as community participation in water management and decision making, accountability and monitoring of service provision. In summary, the key objectives of this investigation are threefold:

1. To assess the status of drinking water quality parameters in selected rural cum semi-rural communities in Abia State, South Eastern Nigeria.
2. To compare results from case study locations with national and World Health Organization drinking water quality standards
3. To make appropriate deductions from results and proper recommendations.

## 2. Material and methods

### *2.1. Study area*

Relying on the researcher's expert knowledge of the region vis a vis the outlined research objectives, purposive sampling technique was adopted because it provides a cost effective non-probabilistic method of selecting ideal sampling locations, so as to include a broad range of water sources. For that reason, the study was carried out in seven communities in Obioma Ngwa (Obi Ngwa) Local Government Area (LGA), Abia State, Nigeria (Fig. 1).

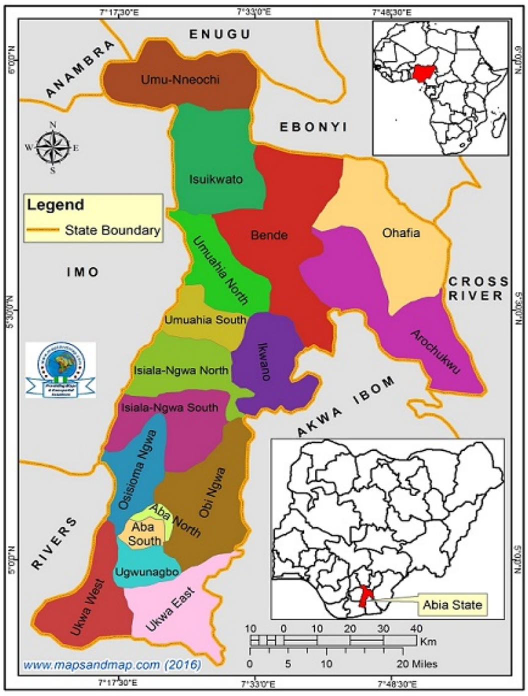


**Fig. 1.** Map of Abia state showing Obingwa local government area (case study area) (Google Maps)

Autonomous communities within this study area include: Onicha Ngwa, Ama Iri N'ato, Umu Opara, Aba Ngwa. Geographically, the study area is located between Latitude 5° 8' 39.4" (5.1443°) N and Longitude: 7° 27' 54" (7.465°) E with Average elevation: 71 meters (233 feet) above sea level. The climate is tropical and humid all the year round. Generally, there are two climatic seasons; the rainy season starts from March to October, while the dry season starts from November to February. Temperature ranges between $22^{0}$C minimum to $31^{0}$C maximum. Vegetation of the study area is mostly lowland rainforest and major crops grown are arable crops (examples cassava, maize, yam). Others include banana, plantain, vegetables etc. Major cash crops grown in the State include oil palm, kola nut, cocoa, and cashew.

*2.2. Sample collection*

A total of thirty-five samples each were collected in October, 2014 and October, 2018. Physicochemical parameters like pH, conductivity, turbidity and bacteriological parameters such as plate count and total coliform test were assessed in the Department of Applied Biology laboratory, Ebonyi State University, Nigeria (Table 1). Changes in water quality over time was evaluated by comparing initial parameter values with more recent data from an ongoing longitudinal water quality survey and found no significant variation. Results were further validated using secondary data from literature.

*2.3. Collection procedures*

Water samples were collected with 1 liter sized cans which had previously been washed in the laboratory to avoid contamination. For river samples, they were collected from the opposing flow ends at a depth of approximately 50cm from water surface. The cans were not standing up stream during collection but slanted. The caps of the bottles were removed and slowly covered into the water, pointing them up stream until the lower tips of the opening submerged.

For borehole samples, they were collected from the borehole by keeping cans (suspended from a pole) at an angle.

The cans were allowed to fill gradually avoiding any turbulence, which would add oxygen to the samples. When the water level in the can had stabilized, cans were slowly turned upright and allowed to overflow for 1 or 2 minutes to ensure that no air bubbles were trapped. Collected samples were transported same day to the laboratory for analysis. In all cases, samples were collected twice during the sampling period from the same location and mean values of parameters determined.

## 3. Results and discussion

Within the study area, water samples from boreholes, wells, rivers, streams, lakes were collected from five villages in each of the communities and then analysed. The result of the physical, chemical and bacteriological analysis of samples from each community is represented in Tables 2-5 with the mean and standard deviation.

*3.1. Physical characteristics of water samples*

The result of physical analysis indicates that all the water sample were odourless. The pH value ranged from 6.06 - 6.42, hence within the permissible WHO standard which is between 6-8.5. The values of turbidity ranged from 1.00-7.60. Samples B, D, E were above the WHO standard while samples A, C, F fell below the WHO standard with an exception in sample G which was within the permissible WHO standard.

The electrical conductivity of all water samples fell within the permissible level of the WHO standard, which indicates the capacity of these water samples to conduct electric current as shown in Table 2.

*3.2. Chemical parameters of water samples*

The alkalinity of all the water samples were significantly lower than the WHO standard range. This is responsible for the inability of the water to resist pH changes. The implication of that is that pH values will constantly fluctuate, changing from acidic to basic fairly rapidly. Water with low alkalinity is usually corrosive and irritates the eyes. The iron content of all the water samples fell below the WHO standard. Significant amounts of iron in water give it an unpleasant metallic taste. Other key chemical parameters studied such as total dissolved/suspended solids, sulphates and chlorides also fell below the permissible level of the WHO standard (Table 3).

**Table 1.** Outline of samples collected

| ***S/No*** | ***Sample Name*** | ***Sample Code*** | ***S/No*** | ***Sample Name*** | ***Sample Code*** |
|---|---|---|---|---|---|
| 1 | Onicha Ngwa well water | $A_1$ | 21 | Sample name | $E_1$ |
| 2 | Onicha Ngwa borehole | $A_2$ | 22 | Iyi Amude | $E_2$ |
| 3 | Umu-Uwaoma stream | $A_3$ | 23 | Iyi Obeama | $E_3$ |
| 4 | Mbarekpe borehole | $A_4$ | 24 | Iyi Onicha Onicha | $E_4$ |
| 5 | Abala well water | $A_5$ | 25 | Onicha Onicha II | $E_5$ |
| 6 | Iyi ngwu (Akanu okpulo) | $B_1$ | 26 | Iyi Ntigha | $F_1$ |
| 7 | Iyi Akanu Afagha | $B_2$ | 27 | Umu opara egbelu | $F_2$ |
| 8 | Iyi Umuobiakwa | $B_3$ | 28 | Iyi Umuogbala | $F_3$ |
| 9 | Iyi Umuakatawo | $B_4$ | 29 | Umuogbala borehole | $F_4$ |
| 10 | Agburuke stream | $B_5$ | 30 | Iyi Alaoji | $F_5$ |
| 11 | Osa ukwu borehole | $C_1$ | 31 | Iyi Umuola | $G_1$ |
| 12 | Iyi nwangu | $C_2$ | 32 | Water side (Aba) | $G_2$ |
| 13 | Osa oke well water | $C_3$ | 33 | Owo borehole water | $G_3$ |
| 14 | Ohuru isimmiri | $C_4$ | 34 | Owo well water | $G_4$ |
| 15 | Ohuru Umuekwensu | $C_5$ | 35 | Itukpa well water | $G_5$ |
| 16 | Iyi umuoru | $D_1$ | | | |

| | | | | | |
|---|---|---|---|---|---|
| 17 | Iyi Umuokpo 1 | $D_2$ | | | |
| 18 | Umu iroma borehole | $D_3$ | | | |
| 19 | Iyi olive | $D_4$ | | | |
| 20 | Umu iroma well water | $D_5$ | | | |

**Table 2.** Physical analysis

| | *A* | *B* | *C* | *D* | *E* | *F* | *G* |
|---|---|---|---|---|---|---|---|
| Odour | Nil | Nil | Nil | Nil | Nil | Nil | Nil |
| Turbidity | 3.00±2.55 | 6.20±3.19 | 2.40±2.60 | 6.00±3.08 | 7.60±1.02 | 1.00±0.00 | 5.60±6.31 |
| pH | 6.42±0.08 | 6.58±0.13 | 6.22±0.13 | 6.20±0.33 | 6.32±0.29 | 6.06±0.39 | 6.26±0.32 |
| Electrical conductivity | 144.60±4.58 | 151.6±118.6 | 166.16±5.80 | 151.92±6.41 | 187.08±7.50 | 224.74±8.99 | 179.62±6.23 |

*Note: SAMPLE A = ONICHA NGWA; SAMPLE B = AKANU; SAMPLE C = OSA UKWU; SAMPLE D = AMA IRI N'ATO; SAMPLE E = NTIGHA-UZO; SAMPLE F = UMUOPARA; SAMPLE G = ABA NGWA*

**Table 3.** Chemical analysis

| | *A* | *B* | *C* | *D* | *E* | *F* | *G* |
|---|---|---|---|---|---|---|---|
| Alkalinity | 7.22± 4.93 | 9.90±5.94 | 9.90±5.94 | Nil | 20.80±24.08 | 10.80±5.59 | 18.18± 22.31 |
| Total solids | 110.41± 9.85 | 142.50± 9.40 | 142.50± 16.40 | 11.10±4.97 | 121.80±12.88 | 146.18± 18.93 | 99.85± 10.81 |
| Total dissolved solids | 91.58± 6.29 | 44.13±6.33 | 44.14± 6.34 | 85.14± 95.32 | 121.77± 12.69 | 146.13± 18.93 | 47.94± 40.47 |
| Total suspended solids | 0.23± 0.19 | 0.24±0.16 | 0.24±0.06 | 50.69±38.08 | 0.15±0.10 | 0.05±0.00 | 0.25± 0.15 |
| Calcium | 7.02± 3.94 | 7.7±5.58 | 7.74±5.58 | 0.3700±0.13 | 8.96±6.27 | 4.72±3.30 | 4.40±2.16 |
| Magnesium | 0.58± 0.06 | 0.73±0.62 | 0.73±0.42 | 6.60±6.21 | 0.60±0.37 | 0.36±0.25 | 4.76±7.39 |
| Total hardness | 15.10± 8.90 | 15.10± 8.91 | 15.10±8.90 | 0.33±0.10 | 24.40±16.86 | 13.00±9.22 | 8.62±4.07 |
| Calcium hardness | 12.94± 8.08 | 12.94± 8.08 | 12.94±8.08 | 8.36±4.66 | 22.40±15.66 | 11.80±8.40 | 9.32±4.10 |
| Magnesium hardness | 2.42± 1.73 | 2.42±1.73 | 2.42±1.73 | 32.00±50.12 | 11.00±12.43 | 1.20±0.84 | 2.52±2.31 |
| Iron | 0.17± 0.06 | 0.17±0.06 | 0.17±0.05 | 1.76±2.09 | 0.21±0.04 | 0.23±0.05 | 0.20±0.04 |
| Chlorides | 66.40± 4.70 | 66.40± 10.70 | 66.40± 4.70 | 0.00±0.00 | 18.29±13.30 | 18.29± 11.31 | 81.07± 13.53 |
| Chlorides as sodium chlorides | 26.64± 2.68 | 26.65±2.68 | 26.65± 21.68 | 11.17±4.63 | 30.18±22.11 | 30.19±18.65 | 23.18± 14.59 |
| Sulphate | 19.97± 8.85 | 19.97±8.9 | 19.97± 18.85 | 10.21±7.15 | 12.99±5.81 | 17.55±7.61 | 8.65± 1.04 |
| Nitrate | 1.47± 0.70 | 1.47±0.70 | 1.47±0.69 | 0.28±0.18 | 0.18±0.04 | 0.17±0.05 | 0.36± 0.21 |

*Note: SAMPLE A = ONICHA NGWA; SAMPLE B = AKANU; SAMPLE C = OSA UKWU; SAMPLE D = AMA IRI N'ATO; SAMPLE E = NTIGHA-UZO; SAMPLE F = UMUOPARA; SAMPLE G = ABA NGWA*

**Table 4.** Bacteriological analysis

| | *A* | *B* | *C* | *D* | *E* | *F* | *G* |
|---|---|---|---|---|---|---|---|
| Total coliform | 17.50±1.88 | 30.64±36.05 | 17.50±9.89 | 17.50±9.89 | 21.40±1.67 | 12.60±11.59 | 15.10±8.69 |
| Total plate count | 89.14±5.86 | 39.24±46.92 | 89.14±51.87 | 89.14±51.87 | 103.40±25.26 | 80.40±53.31 | 59.84±55.55 |
| *E. coli* | Nil | Nil | Nil | Nil | Nil | Nil | Nil |

Table 4 shows the bacteriological level of the water samples as *E. coli* was not found in all the analysed water samples from sample A to G (Onicha Ngwa, Akanu, Osa Ukwu, Aba Ngwa, Ntigha-Uzo, Umuopara and Ama Iri N'ato).

### *3.3. Discussions*

Although significant amounts of money are said to have been spent on portable water supply projects across developing countries such as Nigeria, a large proportion of these projects, usually targeted at urban water supply, are yet to translate into concrete results (Hussan et al., 2005). As such, significant proportions of the population (mostly the poor) still suffer from some form of water-related diseases – diarrhoea, cholera, guinea worm, hookworm, typhoid fever, etc – because of inadequate provision of clean water (Ajayi, 2008; Aidan et al., 2006). Since water quality assurance is an integral part of environmental management, it is believed that efficient potable water supply and wastewater management strategies are vital for water quality management. Through an integrated and sustainable management of all environmental aspects, the main threats from human activities can be effectively controlled (Ezeah et al., 2009).

At regional and national levels, the morbidity and mortality burden associated with either total lack or limited access to safe drinking-water and poor hygiene practices also undercuts the economic vitality and future of these nations (Aribigbola, 2009; Ijaiya et al., 2011). To reduce the burden from infectious diarrhoeal diseases, there is an urgent need to improve the current situation with regard to drinking-water and sanitation.

Such improvements must include the quality and availability of water, excreta disposal, and personal as well as environmental hygiene. In addition, it is also critical to have an effective quality control mechanism in place to monitor and manage the potential for epidemic outbreaks. This is particularly so because a contaminated public drinking-water supply is an efficient pathway for transmission of pathogens especially in densely populated areas (Fewtrell and Colford, 2004; Keeley and Scoones, 2003). Results of Analysis of Variance (Anova) in this study (Table 6) indicate that there were significant variations in the examined samples. Fig. 2 indicates significant variations in the results of certain physicochemical parameters of water samples from the studied seven communities (Onicha Ngwa, Ama iri n'ato, Umu Opara, Aba Ngwa, Obete Ukwu, Umuokahia, Nnwaigwe) of Obioma Ngwa L.G.A. Abia State, Nigeria. Samples were collected from five villages in each of the communities with physicochemical parameters of the water samples varying significantly between samples as shown in Tables 2-5. A comparison of physicochemical characteristics of samples from the studied water sources has also been made with WHO standard (WHO, 2018).

Water samples from all the study areas were found to be odourless, which is in line with the expectations of WHO Guidelines for Drinking Water Quality (GDWQ) that water is an odourless liquid. Turbidity in water is mainly caused by the presence of suspended matter. Most common causes of turbidity include clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. It can also be caused by finely divided air bubbles. The values of the turbidity from results of this study range from 1.0 - 7.60. High turbidity values were observed at sample B, D, E which is above the WHO standard and low turbidity values were observed in samples A, C and F of the locations while sample G from the locations is in line with the WHO standard (Table 3).

pH is an indication of the intensity of acidic or basic character of a liquid sample at a given temperature. Measurement of pH is one of the most common tests used in determining water quality. Every aspect of water treatment such as acid-base neutralization, water softening, precipitation, coagulation, disinfection, corrosion control etc. is pH dependent.

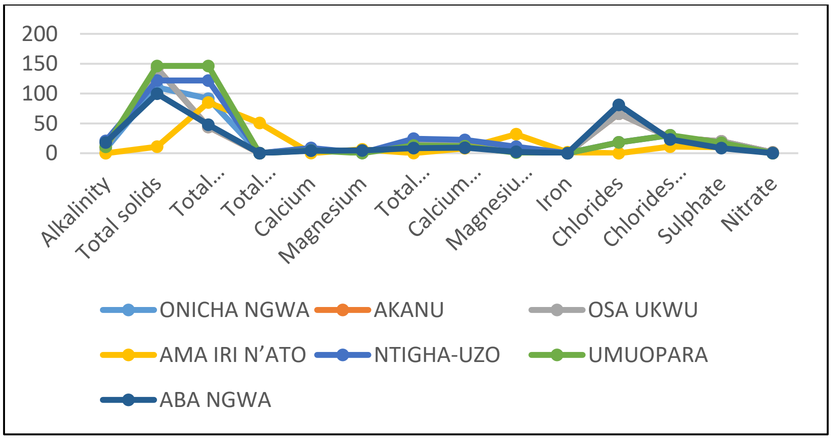


**Fig. 2.** Chemical analysis plot

**Table 5.** Anova of chemicals parameter of water sample a

| ***ANOVA***[a] | | | | | | |
|---|---|---|---|---|---|---|
| ***Model*** | | ***Sum of Squares*** | ***df*** | ***Mean Square*** | ***F*** | ***Sig.*** |
| 1 | Regression | 97.168 | 4 | 24.292 | | .[b] |
| | Residual | .000 | 0 | | | |
| | Total | 97.168 | 4 | | | |

*Note: [a]Dependent Variable: Alkalinity; [b]Predictors: (Constant), nitrate, Magnesium hardness, Total hardness, magnesium*

**Table 6.** Model coefficients for chemical parameter

| Coefficients | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Model*** | | ***Unstandardized Coefficients*** | | ***Standardized Coefficients*** | ***t*** | ***Sig.*** | ***Correlations*** | | |
| | | ***B*** | ***Std. Error*** | ***Beta*** | | | ***Zero-order*** | ***Partial*** | ***Part*** |
| 1 | (Constant) | 17.715 | 0.000 | | | | | | |
| | Magnesium | -1.609 | 0.000 | -0.184 | | | -0.091 | -1.000 | -0.126 |
| | Total hardness | -0.271 | 0.000 | -0.490 | | | -0.391 | -1.000 | -0.354 |
| | Magnesium hardness | -2.426 | 0.000 | -0.853 | | | -0.887 | -1.000 | -0.817 |
| | Nitrate | 0.275 | 0.000 | 0.150 | | | 0.231 | 1.000 | 0.135 |

*Note: [a]Dependent Variable: Alkalinity*

The pH of the analysed water samples ranged from 6.06-6.42 which indicates that the water samples from these location are acidic in nature and require further treatment. The maximum permissible limit of pH as prescribed by WHO is 7.0 to 8.50. All the water samples have pH values outstide the desirable and suitable range.

Conductivity is the measure of water capacity to convey electrical current. The values of electrical conductivity ranged from 144.60-224.74. High conductivity values were observed at locations of samples E, F, G. Very low values were observed at locations of samples A, B, C and D and is well below the WHO permissible level. Electrical conductivity is considered to be a good measure of dissolved solids. Conductivity is an important criterion in determining the suitability of water for certain industrial uses. However, studies on the physical analysis showed that there was no significant difference among the values obtained ($p<0.05$).

Alkalinity is a measure of the ability of liquids such as water to neutralize acids. In essence, alkalinity measures the presence of carbon dioxide, bicarbonate, carbonate, and hydroxide ions that are naturally present in water. At normal drinking water pH levels, bicarbonate, and carbonate are the main contributors to alkalinity. From the results, the alkalinity ranged from 7.22- 20.80 for all the water samples and outside the WHO standard range, therefore since the alkalinity of these samples were too low, the ability of the water to resist pH changes decreases. This implies that the pH value will constantly fluctuate, changing from acidic to basic fairly rapidly. Water with low alkalinity tends to be corrosive and irritates the eyes. Hardness of water though not a pollution parameter, is an important indicator of water quality particularly in terms of $Ca^{2+}$ and $Mg^{2+}$ expressed as $CaCO_3$ (Ezenne et al., 2010). Total hardness for the studied samples was found to be in the range of 0.33-24.40 for all the water samples which is much lower than the permissible WHO limit. Total hardness is mainly due to the presence of calcium and magnesium ion. Water that has less hardness is desirable for drinking purposes. According to Jacobs et al. (1998) all values above 64mg/L comes under the category of hard water. Hard water reduces lathering of soaps and water flow in hot water distribution pipes due to scales build up, gray staining of washed clothes, and accumulation of whitish-gray scale in tea kettles and other containers used to boil water. The most common sources of calcium in natural water are various types of rocks, industrial wastes and sewage. There is evidence that hard water plays a role in heart diseases (Mehta et al., 1999). Assessed hardness level was found to be in the range of 1.32 mg/L to 24.40 mg/L indicating a lower than permissible limit as prescribed by WHO. Though this value is lower than the prescribed WHO limit, it is higher than the permissible limit prescribed by NSDWQ.

The value of chloride was found to be in the range of 18.29 mg/L to 81.07 mg/L, which is below the permissible limit prescribed by the WHO. Chloride may occur naturally in water or it may be added in controlled amounts. Some chlorisis may occur when the chloride level exceeds the recommended limits. Iron is an important aspect of human nutrition. When present in drinking water, it helps in preventing fatigue and anaemia. The water may be discoloured and appear brownish and it may even contain sediment. Large amounts of iron in drinking water give it an unpleasant metallic taste. Iron will leave red/ orange rust stains in the sink, toilet and bathtub. There were variations in the iron content of the different sampling locations compared to the WHO standard. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. Discharge of industrial wastes and domestic sewage tends to increase its concentration.

**Table 7.** ANOVA of bacteriological parameters of water sample A

| ANOVA[a] | | | | | | |
|---|---|---|---|---|---|---|
| ***Model*** | | ***Sum of Squares*** | ***df*** | ***Mean Square*** | ***F*** | ***Sig.*** |
| 1 | Regression | 19.667 | 1 | 19.667 | 0.159 | 0.717[b] |
| | Residual | 371.333 | 3 | 123.778 | | |
| | Total | 391.000 | 4 | | | |

*Note: [a]Dependent Variable: Total coliform; [b]Predictors: (Constant), Total plate count*

**Table 8.** Model coefficients for bacteriological parameter

| Coefficients[a] | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 21.311 | 10.778 | | 1.977 | 0.142 |
| | Total plate count | -0.043 | 0.107 | -0.224 | -0.399 | 0.717 |

*Note: [a]Dependent Variable: Total coliform*

The sulphate concentration in all the samples analyzed ranged from 8.65-19.97 mg/L, which is below the permissible limit set by WHO. However, from the above chemical analysis conducted, it can be implied that there was a statistically significant difference in the levels of sulphate for samples analysed ($p<0.05$).

Coliforms are normally found growing in the intestine of humans and other mamals. Where that is the case, a key indication is from the fecal waste of their host (Cahoon et al., 2016). Coliform presence is therefore an important indicator that entero-pathogens could be present in water environments (Cheema et al., 2018; Choudhury et al, 2016). Riverine communities in Nigeria are predominantly in rural areas and use a hanging toilet system over water bodies, so that human wastes are disposed inside the water (Abubakar, 2017). Coliforms can also be found in other 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 harmful to human health.

Positive presence of coliforms in treated water, which is usually coliform-free, may indicate treatment ineffectiveness. The result obtained for the preliminary test showed that all resulted negative for the presence of *E. coli*.

However, 16 out of the 35 samples turned out to be positive for coliforms (cfu/mL) though within the NSDWQ and WHO standards (Tables 7 and 8). Therefore all water samples were fit for consumptions. It was also statistically verified that there was no significant difference in the bacteriological results of the samples from the case study area ($P > 0.05$). Having said that, continuous monitoring of drinking water quality particularly in the rural area is crucial, so as to provide reliable data for addressing public health and environmental risks associated with rural water management particularly in developing countries. In response to this need, the authors undertook to monitor the quality of drinking water from the case study in a seven year longitudinal survey.

Recently efforts have been made in such directio across rural Ethiopia, Ghana, Kenya, and Zambia investigating the role of community management by water service providers (Anthonj et al., 2018; Hossain et al., 2017; Kelly et al., 2018) or highlighting the water system breakdowns in Liberia, Nigeria, Tanzania, and Uganda (Klug et al., 2018). Also, modeling techniques could provide useful information for improvement of water services and better management and policy in this sector (Cronk and Bartram, 2017; USEPA, 1995).

## 4. Conclusions

Rural communities of Nigeria are facing public health and environmental threats associated with the lack, poor or unreliable drinking water systems. Overall, result from this study indicates that water sources of villages that make up the communities of the study area is not good for drinking as most of the physicochemical parameters of the water samples were above or below the permissible limits of WHO. The values of the turbidity range from 1.0 - 7.60. High turbidity values were observed at sample B, D, E which is above the WHO standard and low turbidity values were observed in samples A, C, and F of the locations while sample G from the locations is of the WHO standard as shown in Table 3. The pH of the analyzed water samples ranged from 6.06-6.42 which indicates that the water samples from this location are acidic in nature and require further treatment.

The values of electrical conductivity ranged from 144.60- 224.74 but very low values were observed at locations of samples A, B, C and D which is well below the WHO permissible level. The alkalinity ranged from 7.22- 20.80 for all the water samples and outside the WHO standard range, therefore since the alkalinity of these samples were too low, the ability of the water to resist pH changes decreases. Total hardness for the studied samples was found to be in the range of 0.33-24.40 for all the water samples which is much lower than the permissible WHO limit. The value of chloride was found to be in the range of 18.29 mg/L to 81.07 mg/L, which is below the permissible limit prescribed by the WHO, but higher than the permissible limit prescribed by NSDWQ. The sulphate concentration in all the samples analyzed ranged from 8.65-19.97 mg/L, which is below the permissible limit set by WHO. The bacteriological result was found to be within the limits of WHO standard. However, 16 out of the 35 samples turned out to be positive for coliforms (cfu/mL) though within the NSDWQ and WHO standards

Based on the results of analysis, effort should be made towards addressing identified deficiencies in the physiochemical content of water from the case study locations. In addition, it is recommended that a vigorous public awareness programme should be put in place, for users of both surface and ground water in rural communities of the case study area to treat their water for both domestic and industrial uses.

Adequate water treatment before use will bring huge economic and health benefits to most rural dwellers in the entire Southeast region of Nigeria. It is recommended that similar studies should be carried out in other rural regions of Nigeria to provide a country-level assessment of current situation and to examine the prospects of achieving SDG6 targets by 2030.

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