

RESEARCH ARTICLE

QUALITY EVALUATION OF SPRING WATER SOURCES IN SOME RURAL COMMUNITIES IN SOUTHEASTERN NIGERIA

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ABSTRACT

This research work was carried out to evaluate the quality of water from two spring sources in Amurri Community in Enugu State, Southeastern Nigeria. Water samples were obtained from Umu and Ogba springs in dry and rainy seasons, and analysis carried out to estimate physico-chemical and bacteriological indices using standard procedures. Analytical results for both seasons indicated that values for pH, total hardness and total dissolved solids were within World Health Organization (WHO) limits and Nigerian Standard for Drinking Water Quality (NSDWQ) recommendations. Values obtained for iron (Fe) in both dry and rainy seasons (0.90 and 0.80mg/L respectively) in Ogba spring water samples were higher than WHO recommended limit of 0.3mg/L. Fluoride, Cadmium and Nitrate were not detected in any of the water samples in both seasons. Total coliform count in dry and rainy seasons for Umu (9.00 and 140.00 CFU/100ml) and Ogba (10.00 and 150.00 CFU/100ml) spring water sources exceeded the WHO recommended value of 0.00 CFU/100ml; *Escherichia coli* was not detected in both spring water samples in dry and rainy seasons. Findings from this study indicate that while results for most of the physico-chemical parameters were within regulatory limits, iron (Fe) in Ogba spring water samples, and total coliform count in both Umu and Ogba exceeded WHO recommended threshold. It is therefore recommended that treatment and disinfection of water from springs in the study area should precede consumption.

KEYWORDS

Spring Water; Water Quality; Physicochemical parameters; Metals; Regulatory limits

1. INTRODUCTION

Improving access to safe drinking water is necessary to sustain good health conditions (Mofor et al., 2017). Water quality has been directly linked with human welfare (Santosh et al., 2014; Anyanwu and Ihediwah, 2015). Unsafe drinking water has been shown to be responsible for 80% of diseases in the tropics, a situation which has caused more than 30% preventable deaths (Olaoye and Onilude, 2009; Onweluzo and Akuagbazie, 2010). The main water sources are surface water (lakes, streams, rivers & oceans), rainwater and groundwater (springs, wells & boreholes). Spring refers to a natural occurrence where water flows from below the surface on to the surface of the earth (Mofor et al., 2017). Migration of spring to the surface is possibly as a result of a confined aquifer in which the recharge area of the spring water table rests at a higher elevation compared with that of the outlet (Ibeneme et al., 2013). Groundwater becomes surface water as soon as it exits at the spring location. Spring is one of the important sources of fresh water needed for survival. However, surface water gets polluted as it flows over land surface (Okechukwu et al., 2013; Manzoor et al., 2013).

Water pollution occurs when biological, chemical or physical components of water exceed the capacity of water body to metabolize it and thus, detrimental to the aquatic ecosystem (Ukpong and Peter, 2012). Key contaminants of surface water include pesticides, synthetic compounds, organic materials, pharmaceutical compounds, *Cryptosporidium*, *Giardia*, *Escherichia coli* (*E. coli*), viruses. Groundwater contaminants include the

previously mentioned pollutants, heavy metals and metalloids (Chittaranjan and Ravi, 2011; WHO, 2011; UNICEF, 2010).

Water quality investigation provides baseline information on water safety. Drinking water quality has great impact on public health and thus, effective continuous monitoring of public drinking water systems is a required to protect the wellbeing of the public (Li et al., 2009; Afiukwa and Eboatu, 2013; Njoyim et al., 2016). Water quality determination entails comparing the chemical and physical characteristics of water samples with water quality standards. Drinking water quality standards are aimed at providing clean and safe water for human consumption (Okechukwu et al., 2013).

Communities in Amurri clan in Enugu State, Southeastern Nigeria, depend on groundwater from spring sources as the main alternative water supply for domestic uses. Despite the fair distribution of springs in the area, provision of potable water to meet the need remains an unsolved problem. As a standard, water supply for human consumption must be devoid of contaminants, physically clear and appealing to taste so as to ensure safe public health (WHO, 2011). This study focused on evaluating the overall physical, chemical and biological qualities of water from these spring sources. These springs serve as water sources for residents of the area who utilize the water for their daily activities. Hence it is pertinent to investigate the quality of the spring water and make necessary recommendations.

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2. MATERIAL AND METHODS

2.1 Study Area

Amurri clan is in Nkanu West Local Government Area, Enugu state, Nigeria (Figure 1). The area lies within latitudes 060 25' 00" N to 060 38' 00" N and longitudes 0070 13' 00" E to 0070 24' 00" E with an estimated area of 489.4sqkm.

2.2 The Spring Sources

Umu and Ogba Springs are located at different areas within Amurri. Both springs possess different features. However, the common feature among them is that both water sources discharge underground water all year round. Both springs are major sources of water supply to residents of the host community.

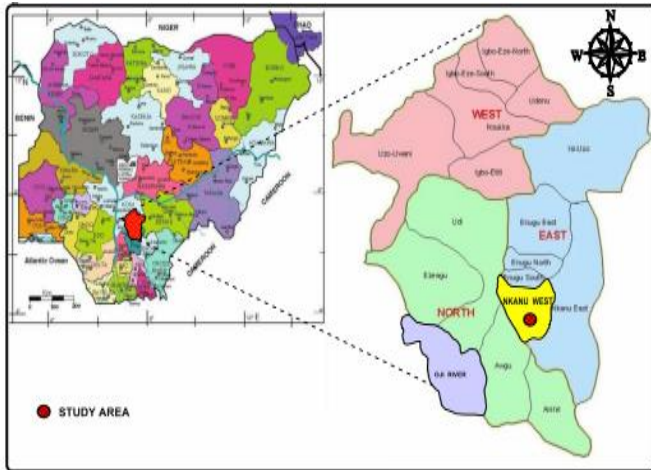


Figure 1: Map showing location of the study area in Enugu State Nigeria. (Insert: Map of Nigeria) Source: (Okonkwo et al., 2016)



Plate 1: Front view of Umu Spring



Plate 2: Front view of Ogba Spring

2.3 Sample Collection

Spring water samples were obtained in both dry and rainy seasons in Nigeria using labeled amber bottles, ensuring that there were no air bubbles. Before sample collection, bottles were thoroughly washed and rinsed with test water samples to avoid any possible contamination in bottling; each step was carefully taken. Commercial bottle water was also purchased from the study area for analysis as control sample. Samples collected were refrigerated at 4°C before analysis.

2.4 Analytical Methods

Determination of pH was carried out using the ASTM D 1293 method (Bates, 1973). Electrical Conductivity (EC) was measured using the conductometric method (Khopkar, 1993). The Titrator method was used to ascertain levels of chloride in water samples (Cotlove, 1961). Determination of Biological Oxygen Demand (BOD) was carried out using the APHA 5210B method (Young, 1973). The USEPA 5220D method was used to determine Chemical Oxygen Demand (COD) while Electrical Conductivity was measured using the Potentiometric method (Winter, 1971; Khopkar, 2007). Metals in water (Sodium, Calcium, Potassium, Copper, Zinc, Cadmium and Iron) were determined using Atomic Absorption Spectrophotometer method (Smith, 1983). Water samples were analyzed for microbial parameters according to APHA standard methods (APHA, 2005). Determination of Nitrite levels was done by the colorimetric method (visible spectrophotometric) (Nerdy and Putra, 2018). Calcium and total hardness were determined by standard methods using ethylene diaminetetraacetic acid (EDTA) complexometric titration, while the magnesium hardness was estimated by computing the difference between the total water hardness and calcium hardness (Ademoroti, 1996; Mendham et al., 2000; Ming-Ho, 2001; Afiukwa, 2012). Gravimetric method was used to determine Total Solids (AMBL, 2017).

2.3 Statistical Analysis

Results in this study are expressed as Means \pm Standard Error Mean (SEM). One-way ANOVA was used to test for differences between the groups in this study using SPSS version 20. Results were considered significant at p-values of less than 0.05, that is, at 95% confidence level.

3. RESULTS

Table 1 describes the various groups in this study. The result of chemical, physical and microbiological analyses of spring water samples collected from the study area in dry and rainy seasons are presented in Tables 2 to 5. Results obtained for spring water samples were compared with that of commercial bottle water sold in the locality which served as control, and World Health Organization (WHO) / Nigerian Standard for Drinking Water Quality (NSDWQ) values. Mean values of physical parameters of Umu & Ogba spring water samples in both dry & rainy seasons are presented in Table 2. Values for analyzed physical parameters namely pH, Temperature ($^{\circ}$ C), Electrical Conductivity (EC) (μ S/cm), Total Suspended Solids (TSS) (mg/l), Total Dissolved Solids (TDS) (mg/l) and Total Solids (TS) (mg/l) were below WHO acceptable limits. pH values of 6.95 ± 0.27 and 6.66 ± 0.45 for Umu and Ogba spring water samples in the rainy season decreased to 6.77 ± 0.30 and 6.16 ± 0.07 respectively in the dry season. Seasonal changes in weather resulted in increases in values for EC from 104.70 ± 5.93 and 85.80 ± 0.28 , to 121.30 ± 0.14 and 118.95 ± 0.07 in the rainy season. Also, values for TSS (mg/l) and TS (mg/l) showed increases in the rainy season for both Umu and Ogba Spring water samples.

Mean levels of chemical indices for Umu & Ogba spring water samples in dry & rainy seasons are reported in Table 3. Total Hardness values for both spring water samples were 17.16 ± 5.60 mg/l and 17.80 ± 5.20 mg/l in the dry season, but increased to 18.00 ± 1.41 mg/l and 21.00 ± 1.41 mg/l respectively in the rainy season. Biochemical Oxygen Demand (BOD) values for Umu and Ogba spring water samples also increased from 7.80 ± 0.84 mg/l and 8.95 ± 0.21 mg/l to 12.70 ± 0.56 and 13.05 ± 0.35 respectively in the rainy season. Nitrate and fluoride were not detected in both seasons in the spring water under study. Table 4 shows mean metal concentrations in Umu & Ogba spring water in dry and rainy seasons. Values recorded for potassium, sodium, zinc, cadmium and copper in Umu and Ogba spring water in both dry and rainy seasons were below the respective WHO permissible limits. However, iron (Fe) values in both dry and rainy seasons (0.90 and 0.80 mg/L respectively) for Ogba spring were higher than the WHO permissible limit of 0.3 mg/L.

Results presented in Table 5 indicates that total Coliform in both spring water samples to be higher than WHO permissible limits; Umu Spring recorded 9 CFU/ml and 10 CFU/ml in the dry and rainy seasons respectively while Ogba Spring water samples recorded 140 CFU/ml and 150 CFU/ml in both seasons respectively. *Escherichia coli* was not detected in both spring water samples in the two seasons.

Table 1: Spring water investigated in this study

Group Name	UMU	OGB	CBW
Description	Umu Spring water sample	Ogba Spring water sample	Commercial Bottle water

Table 2: Mean values for physical parameters of Umu & Ogba spring water in dry & rainy seasons

Group	pH	Temperature (°C)	E. C. (µS / cm)	TDS (mg / l)	TSS (mg / l)	Total Solids (mg / l)
DRY SEASON						
UMU	6.95 ± 0.27 ^a	26.95 ± 0.07 ^a	104.70 ± 5.93 ^c	66.75 ± 0.77 ^c	15.80 ± 2.82 ^b	82.55 ± 3.60 ^c
OGB	6.66 ± 0.45 ^a	26.90 ± 0.70 ^a	85.80 ± 0.28 ^b	52.05 ± 0.63 ^a	18.85 ± 0.21 ^c	70.90 ± 0.84 ^b
RAINY SEASON						
UMU	6.77 ± 0.30 ^b	30.00 ± 0.00 ^b	121.30 ± 0.14 ^c	60.50 ± 0.00 ^c	19.50 ± 0.00 ^b	85.40 ± 0.00 ^c
OGB	6.16 ± 0.07 ^a	30.00 ± 0.70 ^b	118.95 ± 0.07 ^b	59.40 ± 0.00 ^b	20.60 ± 0.00 ^b	71.50 ± 0.00 ^b
CONTROL/REGULATORY VALUES (BOTH SEASONS)						
CBW	7.02 ± 0.21 ^b	26.90 ± 0.28 ^a	81.45 ± 1.34 ^a	54.20 ± 5.93 ^b	12.05 ± 0.63 ^a	61.25 ± 1.76 ^a
WHO/ NSDWQ	6.5 - 8.5	30	400	500	25	500

Values are mean ± standard deviation of triplicate determinations. Values with different superscripts (a-c) on the same row differ significantly ($p < 0.05$) when compared with control.

Table 3: Mean levels of chemical parameters of Umu & Ogba spring water samples in dry & rainy seasons

Group	Total Hardness (mg/l)	Ca Hardness (mg/l)	Mg Hardness (mg/l)	Total alkalinity (mg/l)	BOD (mg / l)	COD (mg / l)	SO ₄ ⁻ (mg / l)	Cl ⁻ (mg / l)	Nitrate (mg / l)	CO ₂ (ppm)	F ⁻ (mg/l)
DRY SEASON											
UMU	17.16 ± 5.60 ^b	11.71 ± 4.57 ^a	6.13 ± 2.04 ^b	1.60 ± 0.56 ^b	7.80 ± 0.84 ^b	19.50 ± 2.12 ^b	15.00 ± 1.14 ^a	11.50 ± 2.12 ^b	ND	0.90 ± 0.14 ^a	ND
OGB	17.80 ± 5.20 ^c	11.96 ± 4.74 ^b	5.21 ± 1.58 ^a	1.85 ± 0.49 ^c	8.95 ± 0.21 ^c	24.50 ± 2.12 ^c	50.00 ± 14.1 ^b	4.00 ± 1.41 ^a	ND	1.10 ± 0.14 ^c	ND
RAINY SEASON											
UMU	18.00 ± 1.41 ^b	11.45 ± 0.21 ^b	5.75 ± 0.21 ^b	1.20 ± 0.28 ^a	12.70 ± 0.56 ^b	22.50 ± 0.70 ^b	5.00 ± 1.14 ^a	0.75 ± 0.21 ^a	ND	1.25 ± 0.21 ^a	ND
OGB	21.00 ± 1.41 ^c	14.70 ± 0.14 ^c	7.40 ± 0.14 ^c	2.10 ± 0.85 ^b	13.05 ± 0.35 ^c	22.50 ± 0.70 ^b	7.50 ± 2.12 ^b	0.60 ± 0.28 ^a	ND	2.30 ± 0.14 ^b	ND
CONTROL/REGULATORY VALUES (BOTH SEASONS)											
CBW	16.50 ± 5.00 ^a	10.96 ± 4.50 ^a	5.00 ± 1.50 ^a	1.15 ± 0.07 ^a	3.20 ± 0.56 ^a	8.00 ± 1.41 ^a	15.00 ± 1.41 ^c	11.50 ± 2.12 ^b	ND	1.00 ± 0.14 ^a	ND
WHO/ NSDWQ	500	75	30	1000	Nil	Nil	250	250	5	50	1.5

Values are mean ± standard deviation of triplicate determinations. Values with different superscripts (a-c) on the same row differ significantly ($p < 0.05$) when compared with control. ND- Not Detected.

Table 4: Mean levels of metal concentrations of Umu & Ogba spring water samples in dry & rainy seasons

Group	K (mg / l)	Na (mg / l)	Fe (mg / l)	Zn (mg / l)	Cd (mg / l)	Cu (mg / l)
DRY SEASON						
UMU	4.50 ± 2.12 ^b	7.00 ± 1.41 ^a	0.05 ± 0.07 ^a	0.76 ± 0.93 ^c	ND	0.03 ± 0.028 ^a
OGB	6.60 ± 1.40 ^c	11.00 ± 1.41 ^b	0.90 ± 0.14 ^b	0.63 ± 0.79 ^b	ND	0.09 ± 0.002 ^a
RAINY SEASON						
UMU	1.30 ± 0.14 ^a	9.50 ± 0.71 ^b	0.20 ± 0.00 ^b	0.27 ± 0.04 ^b	ND	0.09 ± 0.02 ^a
OGB	1.60 ± 0.14 ^b	13.00 ± 1.41 ^c	0.80 ± 0.00 ^c	0.13 ± 0.03 ^a	ND	0.46 ± 0.002 ^b
CONTROL/REGULATORY VALUES (BOTH SEASONS)						
CBW	1.65 ± 0.49 ^b	7.00 ± 1.41 ^a	0.00 ± 0.00 ^a	0.50 ± 0.70 ^c	ND	0.48 ± 0.028 ^b
WHO/ NSDWQ	10	200	0.3	5.0	0.003	1.6

Values are mean ± standard deviation of triplicate determinations. Values with different superscripts (a-c) on the same row differ significantly ($p < 0.05$) when compared with control. ND- Not Detected.

Table 5: Mean microbial load in Umu & Ogba spring water samples in dry & rainy seasons

Group	<i>E. coli</i> (CFU/100ml)	Total Coliform (CFU/ml)
DRY SEASON		
UMU	0	9
OGB	0	140
RAINY SEASON		
UMU	0	10
OGB	0	150
CONTROL/REGULATORY VALUES (BOTH SEASONS)		
CBW	0	0
WHO/ NSDWQ	Nil	Nil

4. DISCUSSION

The levels of physico-chemical indices, biological parameters and selected metals in spring water samples, in both dry and rainy seasons, were compared with NSDWQ and WHO limits for drinking water to establish if water from the spring sources investigated is safe for human consumption (NSDWQ, 2015; WHO, 2017). The results indicate that most parameters assayed were within NSDWQ and WHO recommended limits except for microbial content and Fe level in Ogba Spring, which indicated high levels of contamination. Also, it was observed that values for Electrical Conductivity, Total Suspended Solids, Total hardness and sodium were higher in the spring water samples during rainy season as compared with dry season. Generally, higher turbidity could result from high levels of suspended sediments and organic matter from surrounding farmlands, as the water source lies in close proximity to agricultural fields (Gurung et al., 2019). High turbidity in drinking water harbors pathogen, pollutants and nutrients, and thus capable of creating health issues (WHO, 2017). However, a group researcher noted that water turbidity is more of an aesthetic contaminant than a health problem (Gurung et al., 2019).

pH is an indicator of water's acidic or alkaline status. WHO recommended permissible limit for pH ranges from 6.5 to 8.5. Water pH values in the current investigation were within the range of WHO standards and similar to a previous report by (Aremu, 2011). The amount of dissolved carbon dioxide (CO₂), which forms carbonic acid in water is a major determinant of water pH. At low pH, heavy metals such as cadmium, lead and chromium dissolve more easily and pose serious threat to life (WHO, 2017). Generally, changes in pH, in either direction from neutral indicates the presence of pollutants in spring sources (Cirino, 2018). Temperature measurement for spring water from the study area showed values ranging from 26.90 – 26.95°C in the dry season and stood at 30.00°C in the rainy season. Water temperature was found to be within WHO permissible level of 30 °C. Temperature affects the amount of Dissolved Oxygen (DO) in the water. Increases in water temperature causes decreases in solubility of oxygen in water (McCaffrey, 2018).

Electrical conductivity (EC) is determined by the level of dissolved solids in water. EC of water is enhanced by increase in ions concentration. A group researcher reported that the major positively charged ions, including calcium (Ca²⁺), sodium (Na⁺), magnesium (Mg²⁺) and potassium (K⁺) contribute to conductivity of water (Deshwal et al., 2016). WHO standards recommend that EC value should not exceed 400 µS/cm. The present water quality study indicates that EC values were within Regulatory limits in both dry and rainy season. These results mean that water in the study area is not considerably ionized, an indication of low-level ionic concentration. Meride and Ayenew noted that high conductivity could be as a result of high amount of Ca²⁺ and Mg²⁺ (Meride and Ayenew, 2016).

Different forms of inorganic and some organic minerals or salts can dissolve in water. High Total Dissolves Solids (TDS) indicates that water is highly mineralized. WHO recommended limits for TDS in potable water is 500 mg /l. TDS in analyzed water samples was observed to be significantly lower than WHO recommended limits. The medical significance of high values of TDS in drinking water lies in its detrimental effects on persons suffering from kidney and heart diseases (Sasikaran, 2012).

In the present study, values for Calcium, Magnesium, Chloride, Sulfate, Sodium, Potassium and Nitrate were lower than the various standard limits, and thus may not be harmful to the health of humans. For both spring water sources, values of total hardness fell within the permissible

limit (500mg/L). a group researcher reported that there exists an inverse relationship between water hardness and cardio-vascular diseases (Batool et al., 2018). Also, water hardness was reported to affect the taste of water due to increase in TDS. Iron (Fe) level in water from Ogba Spring showed exceedances with respect to WHO standard value of 0.3 mg/L. This could be as a result of rainfall on land surface and water seeping through the iron-bearing soil and rocks at the location, thus iron is dissolved into the spring water from this source.

Generally, metals (magnesium, sodium, calcium, iron, copper, and zinc) are detected by the taste buds in the oral cavity. High levels of trace elements in water could be an indication of higher dissolution of minerals due to variations in geo-chemical parameters or as a result of human activities (Okoro et al., 2021). WHO noted that water taste is affected above iron levels of 300 µmg/L in water (WHO, 2017). Detection of nitrate in drinking is an indication of organic pollution of water through agriculture, industrial effluents and domestic wastes (Batool et al., 2018). Nitrate is a key disease-causing parameter, particularly responsible for blue baby syndrome in infants. WHO allows maximum levels of 5 mg/l nitrate in drinking water. Interestingly, nitrate was not detected in the spring water studied.

Previous studies have shown drinking water to be a recognized pathway of exposure to heavy metals (Chowdhury et al., 2016). Zinc concentration was within permissible WHO limits. Cadmium was not detected in both water sources. The observed seasonal variation in copper concentrations may be due to associated water properties such as hardness, pH, anion concentration, oxygen concentration and temperature (Boulay and Edwards, 2001). High levels of copper in drinking water may be associated with health effects such as kidney damage, liver necrosis and gastrointestinal distress (Sundaraman and Manisha, 2022; Azeh Engwa et al., 2019).

Total coliform count in the present study was observed to be higher than WHO / NSDWQ permissible limits of 0.00CFU/100ml for potable water. Total coliform is a primary indicator bacterium for the presence of disease-causing organisms in drinking water. It provides guidance on suitability of water for consumption. The presence of large numbers of coliforms in water is an indication that other pathogenic organisms are present (Meride and Ayenew, 2016; Malcolm et al., 2017; Ukpong and Abaraugu). Microbial (bacteriological, protozoan viral, etc.) contamination is responsible for the great majority of evident water-related health problems (Gwimbi, et al., 2019; Ayenew, 2004; Ashbolt, 2015).

5. CONCLUSION

Spring water has been adjudged to be good quality potable water especially if it is free from chemical and microbial contaminants. This study revealed bacterial contamination of water obtained from both spring water sources, as well as, high levels of iron (Fe) in Ogba Spring water. It is suspected that the activities of residents in the area such as open and unhygienic defecation, farming activities, and other factors such poor water drainage systems resulting in surface runoff after rainfall and water seeping through iron-bearing soil and rock, continuously affect quality of water from the spring sources, making it unfit for human consumption. Therefore, treatment and disinfection are sustainable measures required to rid Umu and Ogba spring water of microbial contamination and high levels of iron before consumption.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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