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Physicochemical Quality of Groundwater Sources in a University Environment

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Abstract

The study aimed to determine the quality of groundwater sources in the Federal University of Agriculture (FUNAAB), Abeokuta, Ogun State, Nigeria. Composite water samples were collected from eight (8) different sources. The temperature and pH were tested in situ and then transported to the laboratory for analysis using standard procedure. Results revealed that the temperature (29.6 – 29.8^oC) across the sources was slightly higher than the WHO thresholds (25-29^oC). The pH (6.41 – 7.75), electrical conductivity (EC) (0.20- 0.83 µS/cm), and total dissolved solids (TDS) (0.10- 0.40 mg/L) across the sources were within the WHO thresholds (6.5-8.5, 1000 µS/cm; <600 mg/L) respectively. The total alkalinity (TA) (2.6 – 6.4 mg/L), total hardness (TH) (120 – 362 mg/L) and chloride ion (Cl^-) (70 – 167 mg/L) across the sources were within the WHO (2011) limit (200; 500; 250 mg/L) respectively. The concentration of calcium (Ca^{2+}) and manganese (Mg^{2+}) in 12.5% and 37.5% of the

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sources exceeded the WHO standard for Ca^{2+} (100–300 mg/L) and Mg^{2+} (60 mg/L) respectively while dissolved oxygen (DO) (1.25– 6.95 mg/L) across the sources was lower than the WHO thresholds (13 – 14 mg/L). Pearson's correlation revealed that EC had a significantly strong relationship with TDS ($r=0.718$, $p<0.05$) and Ca^{2+} ($r=0.874$, $p<0.01$), TDS with TH ($r= 0.763$, $p<0.05$) and Cl ($r=0.812$, $p<0.05$), Additionally, TH with Mg^{2+} ($r=0.750$, $p<0.05$). In conclusion, the studied groundwater sources showed no significant health implications at the time of the study but can result in an unpalatable taste for drinking purposes.

Keywords: Abeokuta, Physicochemical, Groundwater, FUNAAB, University

INTRODUCTION

Water is known as the most essential component amidst the natural resources, which is pivotal for the survival of all living things including humans. There are various cities globally with the challenge of water shortage (Nizel and Islam, 2015; Umoren *et al.,* 2024a). Water quality is usually affected by man-made activities and the declinations due to an increase in urbanization, growth of the population, and change in climate among other factors (Muhammad *et al.,* 2011; Famyiwa *et al.,* 2023).

Groundwater contamination has been a subject of concern to environmental health specialists (Chen *et al.,* 2007; Isa *et al.,* 2013). Generally, the physicochemical qualities of water could be derived from either crustal or man-made sources (Mondal *et al.,* 2010; Muhammad *et al.,* 2011). Groundwater is widely known as a major source of water supply. However, there has been a gradual deterioration in the water quality largely due to various man-made activities which has exposed groundwater resources to the risk of contamination (Tirkey, 2017; Umoren *et al.,* 2024a).

Developing countries including Nigeria have been challenged with various water supply inadequacies, more so some of which are of great significance to public health (Junaidu *et al.* 2011; Famyiwa *et al.,* 2023), The effects of chemical contamination of water are not felt on a short-term basis (except nitrate), their accumulation over a long period in the body has significant health effects (Musa *et al.,* 2014).

Water quality (physicochemical, Heavy metal and Microbial contamination) in various University and campus environments have been examined (Ndububa and Nwafor, 2015; Aduwo and Adeniyi, 2019; Ogeleka and Emegha, 2021). The constant increase in the general population increases the demand for water supply in universities resulting in acute water shortage for sustaining the daily water demand needed by the populace **(**Madani *et at.,* 2016**)**. Most of the activities at the Federal University of Agriculture, Abeokuta alternatively depend on groundwater for various domestic uses (Ige *et al.,* 2020) and sometimes drinking. There is a need to continuously monitor the quality of this water sources to ascertain their status.

MATERIALS AND METHODS

Study Area

The investigation was carried out at the Federal University of Agriculture Abeokuta, (FUNAAB), Ogun State, Nigeria. Located along the Abeokuta-Ibadan road in Alabata, along the Osiele-Abeokuta route, bordering the Ogun-Osun River Basin Development Authority. Its latitude and longitude are 7.20°N–7.24°N and 3.41°E–3.46°E, respectively. Being 30–180 meters above mean sea level, it has clearly defined undulating topography, which is associated with rugged terrain. The amount of rainfall during the rainy season (March to October) is approximately 750–1000 mm, whilst the dry season (November to March) is between 250 and 500 mm. The region has a dendritic drainage pattern, with the Ogun, Oyan, and numerous other tributaries draining the majority of the land. The Precambrian rocks of the Southwest Basement Complex, which include gneisses, migmatite, and granite suites, underlie the study region (Ige *et al.,* 2020). The description of the water sources is given in Table 1.

Table 1: Description of the groundwater sources

Site	Source	Location	Coordinate
A	Hand-dug well	Comfort Zone Car pack	7°13'42.0"N 3°26'21.3"E
B	Hand-dug well	SSANU Complex	7°13'40.4"N 3°26'19.4"E
C	Borehole	Internal Audit	7°13'50.4"N 3°26'24.3"E
D	Hand-dug well	FUNAAB Cooperative Multipurpose Shopping Complex	7°13'36.7"N 3°26'16.2"E
E	Borehole	Student Union Government (SUG)	7°13'41.2"N 3°25'57.1"E
F	Borehole	New 300 Seaters Lecture Theater opposite SUG	7°13'38.5"N 3°25'58.9"E
G	Borehole	COLAMRUD	7°13'52.2"N 3°26'05.7"E
H	Borehole	Umar Kabir Hall Male Hostel	7°13'59.5"N 3°25'59.6"E

Sample Collection

Eight (8) water samples were collected from the water sources, using a 2L virgin plastic bottle previously treated with 5% trioxonitrate (v) acid (HNO_3) overnight. While sampling, all necessary precautions were considered to prevent contamination (Umoren *et al.,* 2024a; 2024b). The temperature and pH of the samples were determined *in situ*, labelled accordingly and transported in an ice pack to the Chemical Science Unit of Pure Sciences laboratory, Abeokuta, Ogun State, Nigeria for further analysis.

Quality Control and Assurance

The chemicals used for the investigation were of analytical grade while reagent blanks were prepared according to the specifications to evaluate the reagents' purity. To ensure the highest level of instrument accuracy, the water quality meter and laboratory equipment were checked and calibrated according to the manufacturer (Famuyiwa *et al.,* 2023; Umoren *et al.,* 2024b).

Determination of Physiochemical Properties

The physicochemical quality of the water sample was assessed using the standard laboratory methods. The temperature, pH, TDS and EC of the sample were determined using an electronic water quality meter. The total alkalinity, total hardness, chloride ion, Mg^{2+}, Ca^{2+} and DO were determined using titrimetric methods (Umoren *et al.,* 2024b).

Total Alkalinity: The titrant (0.2 M H_2SO_4) was titrated against 100 cm^3 of water sample in a conical flask, using 3 drops each of phenolphthalein and methyl orange as indicators. A peach colouration was obtained indicating the endpoint.

$$Total\ Alkalinity = \frac{Titre\ value \times 0.2 \times 1000}{100}$$

Total Hardness:100 cm^3 of the water sample was measured into a conical flask and 3 drops of Eriochrome Black T was used as an indicator. Ammonium buffer was added to stabilize the pH. The solution was then titrated against 0.001M Ethylene diamine tetraacetic acid (EDTA). A blue colouration determines the endpoint.

$$Total\ Hardness = \frac{Titre\ value \times 1000}{100}$$

Chloride ion:100 cm^3 of the water sample was measured into the conical flask using 1 cm^3 potassium chromate (K_2CrO_4) as the indicator. The solution is then titrated against a 0.01M Silver nitrate ($AgNO_3$). A brick red colouration indicates the endpoint.

$$Chloride\ ion = \frac{Titre\ value \times 1000}{100}$$

Calcium ion: 50 cm^3 of the water sample was measured into the conical flask, and then 2 cm^3 of 2M of sodium hydroxide (NaOH) was added. using a drop of murexide as the indicator. The solution was then titrated against a 0.01M EDTA. A purple colouration indicates the endpoint.

$$Calcium\ ion = \frac{Titre\ value \times 1000}{50}$$

$$\text{Magnesium} = Total\ Hardness - Calcium\ ion$$

Dissolved Oxygen (DO): Water samples for DO were fixed with Winkler's A and B reagents *in situ*. 2 cm^3 of concentrated tetraoxosulphate (vi) acid (H_2SO_4) was added to 100 cm^3 sample, inverted several times to dissolve the flocc. It was then titrated against sodium thiosulphate solution (0.1N $Na_2S_2O_3$) as titrant and 1 cm^3 of starch solution as indicator. The reaction turns from blue-black to colourless to determine the endpoint. The values were expressed using the formula:

$$Dissolved\ Oxygen\ (DO) = \frac{Titre\ value\ \times 0.1\ N}{0.025}$$

Data Analysis

Data was subjected to Microsoft Excel 2016 version for conversion and calculations, results are presented in mean of triplicate samples. Pearson correlation was employed to reveal the association between parameters.

RESULTS AND DISCUSSION

Results

The physicochemical qualities of the groundwater are shown in Table 2., revealing that the temperature of water samples ranging between 29.6 – 29.8 ^oC. with the highest mean temperature recorded in samples C and H and the lowest in sample A. The temperature across the samples was slightly higher than the WHO (2011) threshold (25.0 – 29.0 ^oC). The water samples have a pH ranging between 6.41 – 7.75, with the highest mean pH recorded in sample B and the lowest in sample C. The pH in two (2) of the samples (C-6.44 and D-6.41) was slightly below the WHO (2011) threshold (6.5 – 8.5^oC). The electrical conductivity (EC) of the sample ranged between 0.20 – 0.83 µS/cm with the highest mean EC recorded in sample H and the lowest in sample D. The EC across the samples was within the WHO (2011) limit (1000 µS/cm). Total dissolved solids (TDS) in the sample ranged between 0.10 – 0.40 mg/L with the mean highest TDS recorded in sample E and the lowest in sample D. The TDS across the samples were within the WHO (2011) limit (<600 mg/L). The total alkalinity (TA) of the samples ranged from 2.8 – 6.4 mg/L with the mean highest TA recorded in sample D while the lowest equally in both samples A and H. The concentration of TA across the samples was within the WHO (2011) threshold (200 mg/L). The total hardness (TH) in the samples ranged from 120 – 362 mg/L with the mean highest TA recorded from sample B while the lowest was recorded from sample F. The TA across the samples were within the WHO (2011) threshold (500 mg/L). The chloride ion (Cl) content of the samples ranged from 70 – 167 mg/L with the mean highest Cl recorded in sample H while the lowest in sample D. The Cl content across the samples were within the WHO (2011) limit (250 mg/L). The calcium ions (Ca^{2+}) in the sample ranged from 102 to 320 mg/L with the mean highest Ca^{2+} recorded in sample H and the lowest in sample C. 12.5% of the samples had Ca^{2+} concentration higher than the WHO (2011) threshold (100–300 mg/L). The concentration of magnesium ion (Mg^{2+}) in the sample ranged from 0 – 142 mg/L with the mean highest Mg^{2+} recorded in sample C while the lowest in sample A. 37.5% of the samples had Mg^{2+} concentration higher than the WHO (2011) threshold (60 mg/L). The concentration of dissolved oxygen (DO) in the sample ranged from 1.25 – 6.95 mg/L with the mean highest in sample A and the lowest in sample C. The DO across the samples were lower than the WHO (2011) threshold (13 – 14 mg/L).

Table 2: Physicochemical characteristics of the groundwater

Parameters	**Samples (n=3)**								**WHO (2011)**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
Temp (°C)	29.6	29.7	29.8	29.7	29.7	29.7	29.7	29.8	25.0 - 29.0
pH	6.95	7.75	6.44	6.41	6.96	6.59	7.45	6.87	6.5-8.5
Conductivity (µS/cm)	0.35	0.51	0.33	0.20	0.80	0.29	0.21	0.83	1000
TDS (mg/L)	0.18	0.25	0.17	0.10	0.40	0.15	0.11	0.17	<600
Total Alkalinity (mg/L)	2.8	5.8	5.8	6.4	6.2	5.4	2.6	2.8	200
Total Hardness (mg/L)	125	362	284	146	355	120	175	205	500
Chloride ion (mg/L)	97	70	79	72	167	100	76	97	250
Magnesium (Mg^{2+}) (mg/L)	18	102	182	ND	93	ND	43	ND	60
Calcium (Ca^{2+}) (mg/L)	110	260	102	160	262	128	132	320	100–300
Dissolved Oxygen (mg/L)	6.95	6.30	1.25	5.15	3.10	4.35	5.95	5.75	13–14

Key: ND =not detected

Correlation between parameters

Pearson's correlation coefficient performed between the parameters is presented in Table 3, reveals that EC had a significantly strong relationship with TDS ($r=0.718, p<0.05$) and Ca^{2+} ($r=0.874, p<0.01$). TDS had a significantly strong relationship with TH ($r= 0.763, p<0.05$) and Cl ($r=0.812, p<0.05$). TH had a significantly strong relationship with Mg^{2+} ($r=0.750, p<0.05$)

Table 3: Correlation Matric between parameters

	Temp	pH	EC	TDS	TA	TH	Cl^-	Mg^{2+}	Ca^{2+}	DO
Temp	1									
pH	-0.267	1								
EC	0.329	0.184	1							
TDS	-0.072	0.267	**0.718***	1						
TA	0.143	-0.311	-0.035	0.357	1					
TH	0.319	0.416	0.558	**0.763***	0.460	1				
Cl^-	-0.111	-0.097	0.643	**0.812***	0.161	0.318	1			
Mg^{2+}	0.370	0.096	0.079	0.403	0.409	**0.750***	0.039	1		
Ca^{2+}	0.340	0.359	**0.874****	0.518	0.022	0.529	0.347	-0.093	1	
DO	-0.567	0.555	-0.067	-0.270	-0.580	-0.377	-0.309	-0.673	0.181	1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

The temperature of the sample is the degree of its coldness and hotness, the slight increase in the samples can be due to the atmospheric temperature at the collection time (Umoren *et al.,* 2024a). The pH of the sample is the hydrogen ion concentration, an extreme pH can alter the normal physiology of the human body (Isa *et al.,* 2013), the slightly low pH recorded in some of the samples can be attributed to the presence of organic acids, and hydrolysing salts such as iron (II) sulphate and aluminium sulphate (WHO, 2011). This is similar to the report in a borehole study in Kenya by Hinga (2016). Electrical conductivities of water are physical properties of water utilised in estimating the potential of a water sample to conduct electric charge due to an occurrence of certain dissolved inorganic solids (Umoren *et al.,* 2024a). The conductivity recorded in the study is extremely low due to the presence of an extremely low amount of inorganic dissolved solids in the sample. This is in contrast to the high EC recorded in groundwater studies in Kwame Nkrumah University of Science and Technology (KNUST) campus, Ghana (104 µS/cm) (Hayford and Appiah-Adjei, 2022) and Kano (93.3 – 2760 µS/cm) (Abubakar and Sa'id, 2022). Total dissolved solids are water properties used for evaluating the amount of solid substances in a water sample (WHO, 2011). The TDS from the study is extremely lower than the report from the KNUST campus, Ghana (51.96 mg/L) (Hayford and Appiah-Adjei, 2022). The total alkalinity (TA) is the concentration of titratable bases in the water sample (Boyd *et al.,* 2016). The TA reported from this study is lower than the report from boreholes in Kano (16.3 mg/L) (Abubakar and Sa'id, 2022). The total hardness of a water sample occurs as a result of alkaline earth metallic cations (Ca^{2+} and Mg^{2+}) in water (WHO 2011). A moderate TH was reported across the sample in the study, but higher than the report from the KNUST campus, Ghana (58.8 mg/L) (Hayford and Appiah-Adjei, 2022). An extreme concentration of chlorine in water leads to a salty taste of the water and makes it unpalatable for drinking (Azizullah*et al.,* 2011). The Cl content reported from the study is in the normal range and compliance with WHO guidelines.

Magnesium (Mg^{2+}) and calcium ions (Ca^{2+}) are some of the major cations responsible for water hardness (Hayford and Appiah-Adjei, 2022). The Mg^{2+} was not detected or below detectable level in 38% of the samples. Furthermore, 38% of the samples were above the standard threshold while the high concentration of Ca^{2+} across the samples may either be due to its abundance in the earth's crust or release as a weathering product of feldspars, amphibole and pyroxenes in the environment (Ayodele and Aturamu, 2011). This is not in agreement with Nicholas *et al.* (2018)'s report of a low Ca^{2+} concentration from underground water study in Lagos, Nigeria. The concentration of DO in the study shows a reduced amount of living organisms in the water sample, since a reduced DO, cannot support the microbial reduction of nitrate to nitrite and sulfate to sulfide.

CONCLUSION

The study determined the quality of eight (8) groundwater sources in the Federal University of Agriculture (FUNAAB), Abeokuta, Ogun state, Southwest Nigeria. The majority of the studied parameters were within the WHO (2011) standard except for a slight temperature increase, Ca^{2+} and Mg^{2+} in 12.5% and 37.5% of the sources respectively. The water sources showed no significant health implications but can result in an unpalatable taste for drinking purposes. Therefore, close monitoring of the water is required to avoid disagreeable taste, further research should conduct heavy metal analysis and microbial contaminations.

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