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Assessment Of The Water Quality From Boreholes And Its Health Implications In College Of Education Akwanga And The Surrounding Areas

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Abstract
The research investigated the water quality of boreholes used as potable water (drinking water and other domestic purposes) in College of Education Akwanga and its surrounding communities that accommodate students. Eleven boreholes were randomly selected from numerous boreholes. Water analyses were carried out for their physicochemical parameters, trace, heavy metal and bacteriological quality using standard procedures. Results obtained for the physiochemical parameters and heavy metals were compared with WHO and NSDWQ standards for potable water. The results showed that the groundwater quality of the selected boreholes was generally below the standards prescribed by WHO and NSDWQ. The calculated water quality index (WQI), showed that the quality of all the eleven boreholes water was very good with a range value of 25.56 - 5.24. Biological parameters (E-coil, clostridium perfringens, fecal streptocci and cryptosporidium occyst.) were not detected, indicating that there was no contamination with these microorganisms. The results for total coliform count were below the standards for coliforms in drinking water which means the water is safe and does not pose significant health hazards to consumers. The ANOVA carried out showed that there was significant difference at $P < 0.05$ in all of the parameter analysed.

Keywords: *borehole, water quality, Physiochemical, Microbiological, Students community, WHO*

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I. Introduction

The ability to maintain water resources and provide safe water and sanitation are important drivers of economic and social development, this offer substantial support for health and education sectors (Misstear *et al*., 2023). Healthy life depends not only on good personal hygiene but also on safe drinking water (Sampson et al., 2014).

The importance of water to human life cannot be over emphasized. This natural substance has been described as the most important nutrient for the survival of man on earth because of its involvement in the various functions of human body (Nicholas *et al*., 2022). One of the complex challenges facing rural communities in Africa is the provision of safe drinking water. Borehole water has been used as a vital source of potable water for many communities.

The rapid increase in number of boreholes dug by individuals, public and private entities in various communities is in a bid to overcome the problem of potable water shortage (Musa and Tukura, 2017; Owarri 2022). According to Ukpong *et al*., 2013, the provision of potable water in the past was a sole responsibility of the government but the government has failed in that aspect. In Nigeria, the National water supply policy admits that water supply is grossly inadequate in some states and aims at an improvement of the present level of 32 liter per capita per day for the rural areas which is far below the WHO standard of 70 and 130 liters for rural and urban area respectively (Ezeh, 2009). According to Titilayo and Dahiru, (2018), about 52% of Nigeria population lack access to safe drinking water. Water quality is affected by an increase in human activities such septic tanks, waste disposal, pit latrines and graves near borehole water and management of other water uses.(Nywanchuku and Onyenechere, 2022).

Human health is threatened globally due to consumption of contaminated water. (Oladipo *et al*., 2023). Water that is contaminated can transmit diseases such as cholera, dysentery, diarrhea, typhoid and polio. In Nigeria several studies on water quality has indicated that ground water is highly susceptible to contamination that has led to outbreaks of water borne diseases (Bashir and Olalekan, 2012).

Borehole is the main sources of water for drinking, laundry and domestic purposes for students in College of Education Akwanga and surrounding areas. Although several studies have been conducted to address water quality in some parts of Akwanga (Musa and Tukura, 2017), no previous studies have been conducted to date addressing borehole water quality of hostels in and around the College of Education campus. A detailed knowledge of water quality in these communities is essential so that drinking water can be adequately treated and the contamination of its sources can be prevented. This work, therefore, aims at examining the physical, chemical and microbiological characteristics on borehole water in selected hostels in and around the campus and to determine whether or not the water is potable. The results will help management of College of Education and decision makers in selecting good water management policies for hostel managers in the study area.

II. Material And Methods

Study Area: The study area was College of Akwanga and its surrounding communities with students' private hostels, located north western direction and about 3 km from Akwanga town (Fig. 1). It lies between 8°24′ and 23°58′ East longitude and 8°54′ and 38°77′ north latitude. Landscape of the study area varies with an altitude ranging between 437.10 and 445.35 meters above sea level. Akwanga LGA and its environs are built on predominantly basement complex; characterized by near-surface outcrops of underlying basement rocks and shallow overburden including migmatitic gneisses, schists, and various metamorphic and igneous rocks, with evidence of polyphase deformation and ancient tectonic lineaments (Onyeagocha, 1984: Bello *et al*., 2024).

Figure 1: Map of the study area

Sampling points

Table 1: Boreholes Sample Location and GPS Coordinates

S/N	Sample Location	Sample I.D	Longitude	Latitude
1.	Ayi Male Hostel	BHW-1	8.40454	8.93254
2.	New Female Hostel	BHW-2	8.40215	8.96029
3.	New Male Hostel	BHW-3	8.40317	8.93906
4.	DSS Students Hostel	BHW-4	8.40128	8.93308
5.	Mount Zion Students Village	BHW-5	8.40283	8.93839
6.	Hossana Academic Student Village	BHW-6	8.40934	8.92593
7.	Hauwa Female Hostel and Mustapha	BHW-7	8.40317	8.93906
8.	A.P Filling Station Hostels	BHW-8	8.40934	8.92593
9.	A.A Koto Student Hostels A	BHW-9	8.40215	8.92678
10.	A.A Koto student Hostel B	BHW-10	8.40763	8.92016
11.	New Administrative Block	BHW-11	8.40340	8.93489

Samples collection

The samples were collected from 11locations in bottles of 50cl on the 15th day of December, 2024. The bottles were properly washed with hot water and were rinsed three times and taps were allowed to run for at least 5 minutes before the borehole water sample were collected from each hostel and labeled accordantly. Borehole samples were label according to their sources using the code BHW-1 to BHW-11.

Laboratory work / Analysis

The samples collected from different sources were transferred to the analytical laboratory (Kofa Integrated Concept and Services Ltd.) in Jos, Plateau State.

Physicochemical analysis.

Physicochemical parameters such as temperature, hardness, pH, Electrical conductivity (EC) and Total Dissolved Solids (TDS) were performed immediately after sample arrived the laboratory using a Multi-parameter water quality meter (Model HI "HANNA" instruments). Samples were also analyze to determine concentration of chloride, nitrate, sulphate and sodium and fluoride, following the standards protocols and methods of American Public Health Association as described in Olubanjo *et al*. (2019).

Analyses of heavy metals

Appropriate portion of the collected groundwater samples were digested with concentrated HNO_3 for heavy metals analysis according to the method of Sharma and Tyagi (2013). Atomic Adsorption Spectrophotometer (AAS), was used to analyze the metals, (Copper (Cu), Manganese (Mn), Iron (Fe), Chromium (Cr), Cadmium (Cd), Arsenic (As), Nickel (Ni), Zinc (Zn), Lead (Pb) in the water samples and analytical precision was checked by frequently analyzing the standards as well as blanks.

Bacteriological Parameters.

Bacteriological analysis of the water samples was conducted within 6 h of collection as recommended by APHA (2012). Total coli form count, E. coli, clostridium perfringens, fecal streptococci and cryptosporidium occyst., were quantified in each borehole water sample. 1 mL of the sample was pipette into 9 mL of sterile physiological saline and mixed thoroughly by swirling. The mixtures were diluted decimally until appropriate dilution was obtained. The spread plate's method was used in inoculating aliquot portion 0.1 mL of appropriate dilution into a sterilized nutrient agar medium. The samples were incubated at 35 °C for 24- 48 hours for the bacteria and the colonies obtained after incubation were counted and expressed as colony forming units per milliliter of water (CFU/mL). The physiological characteristics of the colonies and their numbers on the culture plates were used as the basis for the counting, taking into consideration their dilution numbers. Counts were made from the plates containing 30-300 colonies. All the parameters were matched with the WHO standards in order to assess whether the samples were unsafe or safe for drinking purposes.

Statistical Treatment of Data

Data analysis was conducted with the statistical Programmed for Social Sciences (SPSS) version 20. Data from the laboratory were presented in tables, and descriptive statistics was conducted on the data. Thereafter, inferential statistics was conducted which was used to reach conclusions at 0.05 (5%) level of significance.

III. Results

The results of the physicochemical parameters, WQI, heavy metals and microbiological parameters are presented in table 2-5.

Table 2: Results of Physico-chemical parameters of the Boreholes water in College of Education Akwanga and its Environs.

S/N	Samples Location	I.D	Color TCU	Taste/Odour	Temp. (ºC)	pH	Turb. NTU	TDS (mg/L)	Hardness (mg/l)	EC (uS/cm)	TOC (mg/L)	CL^- (mg/L)	F^{--} (mg/L)	NO_3^- (mg/L)	SO_4^- (mg/L)	Na^+ (mg/L)
1	Ayih Male Hostel	BHW-1	2.50	Odorless	26.50	6.05	0.50	148.20	139.00	296.00	0.12	76.57	0.16	10.85	7.18	22.00
2	New Female Hostel	BHW-2	2.12	Odorless	25.60	6.36	0.35	167.00	143.00	334.00	0.10	45.38	0.47	5.83	9.59	3.55
3	New Male Hostel	BHW-3	2.80	Odorless	26.80	6.25	0.70	171.00	127.00	342.00	0.18	70.17	0.13	8.79	9.25	8.78
4	DSS Students Hostel	BHW-4	2.10	Odorless	26.50	6.50	0.30	65.00	57.00	130.00	0.17	4.96	0.43	3.35	5.32	6.83
5	Hossana Academic	BHW-5	2.10	Odorless	25.80	6.54	0.30	90.00	99.00	180.00	0.12	9.22	0.53	3.60	4.76	5.68

	Studs. Village															
6	Mount Zion Studs. Village	BHW-6	2.10	Odorless	24.80	6.75	0.40	103.00	66.00	206.00	0.16	28.36	0.20	6.75	6.50	8.88
7	Hauwa Female Hostel	BHW-7	2.80	Odorless	25.90	6.40	0.90	162.00	151.00	324.00	0.15	63.82	0.34	9.32	8.73	6.33
8	A.P Filling Station Hostel	BHW-8	2.60	Odorless	26.40	6.61	0.75	108.00	128.00	210.00	0.14	56.80	0.25	12.25	6.17	12.40
9	A.A Koto Students-A	BHW-9	2.15	Odorless	25.40	6.72	0.80	119.50	132.00	300.00	0.11	63.20	0.18	9.62	8.11	15.46
10	A.A KotoStudents Hostel-B	BHW-10	2.70	Odorless	25.90	6.58	0.71	131.20	125.00	125.00	0.15	55.60	0.21	4.71	7.18	7.84
11	New Admin. Block	BHW-11	3.10	Odorless	27.10	6.48	0.45	98.00	140.00	192.00	0.19	48.20	0.18	6.87	10.33	8.64
		Maxim Minim	3.10 2.10		27.10 24.80	6.75-6.05	0.90 0.30	171 65	151 57	342 125	0.19 0.10	76.57-4.96	0.53 0.13	12.25 3.35	10.53-4.76	22.0-3.55
		Mean	2.46		26.06	6.48	0.56	123.9	118.8	239.9	0.145	47.48	0.28	7.5	7.56	9.67
		S.D	0.25		0.67	0.21	0.22	34.89	31..38	81..44	0.295	23.81	0.139	2.95	1.78	5.21
		WHO	15		25-30	6.5-8.5	5.0	500	500	1000	5	250	1.5	50	100	200
		NSD WQ	15		----	6.5-8.5	5.0	500	150	1000	5	250	1	50	100	200

Table 2: Result of Calculated Unit Weights and Quality rating for each Borehole water Samples

S/N	Parameter	S_n	$K=(1/S_n)^{-1}$	$Wi=K/S_n$	BHW-1 Q_i	BHW-2 Q_i	BHW-3 Q_i	BHW-4 Q_i	BHW-5 Q_i	BHW-6 Q_i	BHW-7 Q_i	BHW-8 Q_i	BHW-9 Q_i	BHW-10 Q_i	BHW-11 Q_i
1	PH	8.5	2.765	0.325	63.33	42.67	50.00	33.33	30.67	16.67	40.00	26.00	18.67	42.67	50.00
2	TDS	500	2.765	0.006	27.60	33.40	34.20	13.00	18.00	20.00	32.40	21.60	23.90	33.40	34.20
3	Hardness	150	2.765	0.018	92.67	95.33	84.67	38.00	66.00	44.00	100.67	85.33	88.00	95.33	84.67
4	EC	1000	2.765	0.003	29.60	33.40	34.20	13.00	18.00	20.60	32.40	21.00	30.00	33.40	34.20
5	TOC	5	2.765	0.553	2.40	2.00	3.60	3.40	2.40	3.20	3.00	2.80	2.20	2.00	3.60
6	CL	250	2.765	0.011	30.63	18.15	28.07	1.98	3.73	11.34	25.53	22.72	25.28	18.15	28.07
7	NO_3	50	2.765	0.055	21.70	11.66	17.58	6.70	7.26	15.50	18.64	24.50	19.24	11.66	17.58
8	SO_4	100	2.765	0.028	7.18	9.59	9.25	5.32	4.76	6.5	6.17	6.17	8.11	9.59	9.25
				$\sum w=1.00$											

Table 3: Summary of WQI of the borehole water in College of Education and its Evirons.

S/N	Borehole	Sample I.D	WQI	Rating
1	Ayih Male Hostel	BHW-1	25.56	Good
2	New Female Hostel	BHW-2	17.17	Excellent
3	New Male Hostel	BHW-3	21.63	Excellent
4	DSS Student Hostel	BHW-4	14.05	Excellent
5	Hosanna Academic Stud. Village	BHW-5	13.24	Excellent
6	Mount Zion Stud. Village	BHW-6	9.05	Excellent
7	Hauwa Female Hostel	BHW-7	5.24	Excellent
8	A.P Filling Station Hostel	BHW-8	11.99	Excellent
9	A.A Koto Students Hostel-A	BHW-9	10.66	Excellent

10	A.A Koto Students Hostel-B	BHW-10	13.43	Excellent
11	New Administrative. Block	BHW-11	16.50	Excellent

Table 4: Result of Heavy Metal Analysis of the Borehole

S/N	Sample Location	Sample I.D	CU mg/L	Fe mg/L	Zn mg/L	Pb mg/L	Cd mg/L	As mg/L	Ni mg/L	Cr mg/L	Hg mg/L
1	Ayih Male Hostel	BHW-1	0.035	0.217	0.067	0,003	0.000	0.000	0.000	0.000	0.000
2	New Female Hostel	BHW-2	0.041	0.165	0.068	0.002	0.000	0.000	0.000	0.000	0.000
3	New Male Hostel	BHW-3	0.277	0.051`	0.085	0.004	0.000	0.000	0.000	0.000	0.000
4	DSS Student Hostel	BHW-4	0.031	0.038	0.104	0.003	0.000	0.000	0.000	0.000	0.000
5	Hossana Academic Stud. Village	BHW-5	0.277	0.051	0.085	0.004	0.000	0.000	0.000	0.000	0.000
6	Mount Zion Stud. Village	BHW-6	0.030	0.052	0.115	0.000	0.000	0.000	0.000	0.000	0.000
7	Hauwa Female Hostel	BHW-7	0.025	0.097	0.316	0.001	0.000	0.000	0.000	0.000	0.000
8	A.P Filling Station Hostel	BHW-8	0.015	0.118	0.069	0.011	0.000	0.000	0.000	0.000	0.000
9	A.A Koto Students Hostel-A	BHW-9	0.015	0.118	0.020	0.006	0.000	0.000	0.000	0.000	0.000
10	A.A Koto Students Hostel-B	BHW-10	0.022	0.080	0.050	0.008	0.000	0.000	0.000	0.000	0.000
11	New Admin. Block	BHW-11	0.081	0.053	0.075	0.002	0.000	0.000	0.000	0.000	0.000
		Maxim. Minim.	0.277 0.015	0.217 0.038	0.316 0.020	0.011 0.000	0.000	0.000	0.000	0.000	0.000
		Mean	0.077	0.095	0.958	0.004	0.000	0.000	0.000	0.000	0.000
		S.D	0.100	0.054	0.077	0.003	0.000	0.000	0.000	0.000	0.000
		WHO	1	0.3	3	0.01	0.003	0.01	0.02	0.05	0.001
		NSDWQ	1	0.3	3	0.01	0.003	0.01	0.02	0.05	0.001

Table 5: Result of Microbiological Analysis of Borehole water Samples

S/N	Sample Location	Sample I.D	Clostridium perfringens (CFU/ML)	Escherichia coli (CFU/ML)	Fecal streptococci (CFU/ML)	Total coliform count (10CFU/ML)	Cryptosporidium occyst.
1	Ayih Male Hostel	BHW-1	0.00	0.00	0.00	1.00	0.00
2	New Female Hostel	BHW-2	0.00	0.00	0.00	0.00	0.00
3	New Male Hostel	BHW-3	0.00	0.00	0.00	2.00	0.00
4	DSS Student Hostel	BHW-4	0.00	0.00	0.00	0.00	0.00
5	Hossana Academic Stud. Village	BHW-5	0.00	0.00	0.00	4.00	0.00
6	Mount Zion Stud. Village	BHW-6	0.00	0.00	0.00	2.00	0.00
7	Hauwa Female Hostel	BHW-7	000	0.00	0.00	1.00	0.00
8	A.P Filling Station Hostel	BHW-8	0.00	0.00	0.00	8.00	0.00
9	A.A Koto Students Hostel-A	BHW-9	0.00	0.00	0.00	1.00	0.00
10	A.A Koto Students Hostel-B	BHW-10	0.00	0.00	0.00	2.00	0.00
11	New Admin. Block	BHW-11	0.00	0.00	0.00	1.00	0.00
	WHO Standard limit		0	0	0	10	3 log reduction or
	NSDWQ Standard limit		0	0	0	0	Inactivation

IV. Discussion

The values of the physicochemical, WQI, microbiological and heavy metal parameters shown in the table are further discussed. This section considers all the parameters evaluated for all locations and assesses the water quality thereof, in comparison to WHO and NSDWQ standards.

Physicochemical Parameters

Color: Natural color reflects the presence of complex organic molecules derived from vegetable (humic matter) such as peat, leaves, and branches and so on. It effects are also increased by the presence of suspended matter. Natural color might also arise from the presence of colloidal iron/manganese but organic matter is the major contributing factor (EPA, 2009). All the water samples analyze were below WHO and NSDWQ maximum permissible levels (15 TCU). The total mean value obtained for color is 2.46 TCU.

Temperature: The mean temperature of all the water samples of the study area was 27.90 °C and in the range of 27.10–24.80 °C. Temperature in this study was found within permissible limit of WHO and NSDWQ (25-30 °C), except that of Mount Zion Students Hostel whose temperature was below permissible limit (24.80 ^{o}C).

pH: pH is an important parameter in evaluating the acid–base balance of water. It is also the indicator of acidic or alkaline condition of water status. WHO and NSDWQ has recommended maximum permissible limit of pH from 6.5 to 8.5. The current investigation range was 6.75–6.05. The results of pH from DSS students hostel, Mount Zion student village, AP filling station hostel, A.A. Koto students hostel A and A.A. Koto students hostel B were within the range of WHO and NSDWQ standards while the results of Ayih male hostel, New female hostel, Hauwa female hostel and New Admin block, were below the standard limit set by WHO and NSDWQ. The sample locations with low pH (<6.5) values observed in this study may be attributed to several factors such as percolating carbon dioxide that produced weak carbonic acid (Napacho and Manyele, 2010), mineral composition as well as differential weathering intensity of the various bed rocks around the study area (Talabi and Ogundana, 2014). The consumption of such acidic water could have adverse effect on health and may also lead to corrosion of water pipes as the case maybe. Furthermore, acidic water causes leaching of soil nutrients. Extreme pH values affect the palatability of water. The low pH (<6.5) obtained from some locations in this work agrees with the report of Abba and Suleiman, (2022), Okoro, (2016), Wokem and Lawson-jack, (2015) in a similar findings in Nigeria.

As a remedy for this shortfall of water with pH value of <6.5, pH value can be increase by employing a neutralizing filter made up of calcium carbonate or synthetic magnesium oxide. Calcium carbonate is used when the pH of the borehole is above 6 while synthetic magnesium oxide is used for pH below 6.

Electrical conductivity

The mobility of ions in solution has been found to be closely related to its total alkalinity, which in turn increases electrical conductance ability in water. The conductivity values of all the different water samples all fall below the maximum permissible level of WHO and NSDWQ. The mean conductivity value of 239.9µS/cm was obtained from the study. Conductivity values obtained in this study agrees with the mean value of 179.4 µS/cm reported in a similar work by Musa and Tukura, (2017) on evaluation of heavy metals concentrations in boreholes water near solid waste dumpsites in Akwanga Local Government Area.

Water Hardness: Water hardness in boreholes of the study area varies from 57.0-151 mg/L with mean value of 118.8 mg/L. None of the sample exceeded the recommended value of 500 mg/L for drinking provided by WHO. However, NSDWQ recommended a total hardness of 150 mg/L for drinking water in Nigeria. Borehole water from Hauwa female hostel (BHW-7), hardness value (151mg/L) was slightly above the NSDWQ standard. Hardness in the water is a natural occurrence implying that there is a lot of calcium, magnesium carbonate, hydrogen carbonate and sulphate ions present in the water (Bashir and Olalekan, 2012). The incidences of water hardness in BHW-7 may be as a result of the dissolution of calcium carbonate associated with the sandstone that underlies the area. This suggests that the water hardness may be a natural occurrence.

Turbidity

Turbidity in water arises from the presence of very finely divided solids which are not filterable by routine methods (Sampson *et al*., 2024). Turbid water loses acceptance in the eyes of the consumer. The mean turbidity values of all the borehole water samples were found to be below WHO and NSDWQ maximum permissible levels of 5 NTUs.

Total dissolved solids

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These minerals produced un-wanted taste and diluted color in appearance of water. This is the important parameter for the use of water. The water with high TDS value indicates that water is highly mineralized (Luvhimbi *et al*., 2022). WHO and NSDWQ recommended TDS value of 500 mg/L for drinking Water. In this Study, the mean TDS value was 123.9 mg/L with a ranged of 65 – 167 mg/L. However the total dissolved solids concentration of all water samples are below the standard limit set by WHO and NSDWQ. Okoro *et al*. (2016), reported similar values from their findings on Quality of ground water sources in Owerri, Imo state, Nigeria. High values of TDS in ground water are generally not harmful to human beings, but high concentration of these may affect persons who are suffering from kidney and heart diseases.

Nitrate

Nitrate in soils may be from soluble nitrate compounds or from runoff inorganic fertilizers that may leach into ground water deposits (WHO, 2006). Bacterial oxidation and fixing of nitrogen by plants can also produce nitrate. Nitrate concentration in all the water samples of the study area were below the NSDWQ and WHO permissible levels (50 mg/L), hence show safe levels of nitrate (Table 2).

Sulfate

Sulfate mainly is derived from the dissolution of salts of sulfuric acid and abundantly found in almost all water bodies. High concentration of sulfate may be due to oxidation of pyrite and mine drainage etc. Sulfate concentration in natural water ranges from a few to a several 100 mg/L, but no major negative impact of sulfate on human health is reported. WHO has established 100 mg/L as the highest standard limit of sulfate in drinking water. In this study, concentration of sulfate in all the water samples was (7.56 mg/L) lower than the standard limit set by WHO and NSDWQ and it may not be harmful for human health.

Fluoride: Fluoride mean concentrations in all the borehole water samples (0.28 mg/L) was below the standard limit of 1.5 mg/l set by WHO/ NSDWQ. Excess amounts of fluoride ions in drinking water can cause dental fluorosis, skeletal fluorosis, arthritis, bone damage, osteoporosis, muscular damage, fatigue, joint-related problems, and chronicle issues.

Sodium: Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension (WHO, 2011). However excess sodium in the body can increase the risk of developing a high blood pressure, cardiovascular diseases and kidney damage (Strazzullo and Leclercq, 2014). The recommended sodium value set by WHO/ NSDWQ for drinking water is 200 mg/L. In this study the sodium concentration ranged between 3.55-22.0 mg/L. Hence the sodium concentration for all the water samples is far below the set standard by WHO and NSDWQ.

Chloride: The concentration of chloride in water samples from the study ranges from 4.96-76.57 mg/L with a mean value of 47.48 mg/L. This is within the recommended limits of 250 mg/L for drinking water set by WHO/ NSDWQ (Table 2). The concentrations of chloride obtained in this work agree with the result of the findings of Oladipo *et al*., (2023) on quality analysis of borehole water in federal Polytechnic Ado Ekiti hostels. Drinking water with small amounts of chloride does not cause harmful health effects and provides protection against waterborne disease outbreaks.

Water Quality Index (WQI)

The results of calculated WQI can allow the researcher to differentiate pollution levels to know water quality and to implement corrective or preventive measures (Rubio- Arias *et al*., 2013). In this study, the WQI of all the borehole water are presented in table 2

The results were 25.56, 17.17, 21.63, 1405, 13.24, 9.05, 5.24, 11.99, 10.66, 13.43 and 16.50 respectively. The WQI was classified based on the table used by Musa and Wuana, (2022) and Etim *et al*, (2013). The results indicated that all the borehole water samples analyzed falls under Good and Excellent or very good water quality as the rating shows low WQI values (Table 5). This result suggests that the boreholes water is safe for human consumption and other domestic's purposes. The results obtained from the study disagree with the high WQI values reported from findings of Ugwoha and Nwike, (2018) on the assessment of water quality in Chobe Campus hostel of the University of Port Harcourt, Nigeria.

Heavy Metals Analysis

The presence of the toxic metals in drinking water higher than a certain concentration can be detrimental to human health.

Copper: Copper is present naturally within Iron deposits but more often, its presence in water is due to attack on copper pipes. Rarely, its occurrence may be to its use as an algaecide (EPA, 2009). A copper level above 2 mg/L in drinking water causes adverse effects, 1 mg/L in stringent cases. In this work, the concentration of copper in all the water samples (0.077 mg/L) was below WHO and NSDWQ maximum permissible levels of 1 mg/L. The results obtained from this study were lower than the 0.190 mg/L result presented by Oladipo *et al*., (2023) on quality analysis of borehole water in federal polytechnic Ado Ekiti Hostel in Ekiti State, Nigeria. High level of copper in drinking water causes anemia, digestive disturbances, liver and kidney damages etc. (NSDWQ, 2015). Staining of laundry and sanitary occurs at copper concentration above 1 mg/L. At levels above 2.5 mg/L, copper imparts an undesirable bitter taste to water and its color (WHO, 2008).

Iron: The mean concentrations of iron obtained from this study, ranged from 0.04 to 0.22 mg/L and were below the recommended concentration of 0.3 mg/L set by WHO and NSDWQ for drinking and domestic use. The low iron concentration obtained from this work agrees with the result presented by Ugwoh and Nwike (2018) from a similar work in Choba Campus Hostel of the University of Port Harcourt.

Lead: The concentrations of Pb in all the borehole locations were significantly lower than 0.01 mg/L standard limit set by WHO and NSDWQ (Table4). The mean concentrations in all the borehole is 0.004 mg/L and ranged between 0.000 to 0.01 mg/L. Pb concentration obtained from this studies agrees with the concentration presented by Udongwo and Sambo, (2022) and Musa and Tukura (2017), in a similar studies in Uyo Metropolis, Akwa Ibom and Akwanga, Nasarawa state, Nigeria. Research has shown that chronic Pb exposure can cause anaemia and high blood pressure especially in older and middle age groups (Wani et al., 2015). Exposure to high concentration could also cause kidney and brain damage in male, while water with 0.01 to 0.05 mg/L concentration of Pb could have slight risk of behavioral changes and possibility of neurological impairment in fetuses and young children developing their brain tissues (Collin et al., 2022).

Zinc: The human body needs zinc for normal cell growth and the repair of damaged tissues (WHO, 2017).

In addition, zinc supports the immune system in controlling inflammation in healing wounds (Kiouri et al., 2023). Zinc concentration in all the borehole locations was below WHO and NSDWQ permissible limit (3 mg/L) for drinking water. The mean concentration in all the boreholes is 0.165 mg/L with a ranged concentration of 0.02-0.315 mg /L. The Zn concentrations obtained from this study agrees with the concentrations reported by Musa and Tukura (2017) in a similar work in Akwanga, Nasarawa state.

Microbiological Analysis of Borehole Water Samples

Escherichia Coli (E-Coli)

The results of the microbiological analysis of all the borehole water samples investigated revealed total absence of Escherichia coli. The results obtained complied with WHO and NSDWQ water quality standards limit which required total absence of E.coli in drinking water (Table 3).

Total Coli form Count

The concentration of total coliform obtained ranged from 0 - 8cfu/mL in samples BHW 1, 3, 5, 6, 7, and 8 were within WHO and NSDWQ standard of 10 cfu /100 mL for drinking water. Total coliform was not detected in samples BHW 2, 4, 9, 10 and 11. This means that the water samples from all the eleven borehole sources were hygienic for drinking and other domestic uses.

Fecal Streptococci / Clostridium perfringens / Cryptosporidium occyst.

In this study, all the borehole water samples were not detected of Fecal Streptococci, Clostridium perfringens or Cryptosporidium occyst. The result obtained complied with WHO and NSDWQ water quality standards limit.

V. Conclusion

In College of Education Akwanga and the surrounding communities, the most frequent water source is ground water (borehole). The result of the physico-chemical parameters and heavy metal concentrations of all the 11 water samples showed that the parameters fall below the maximum permissible limits set by WHO and NSDWQ. The calculated water quality index (WQI) for all locations ranged from 5.24 to 25.56 rated as very good water quality to good water quality which indicates that the water is suitable for drinking purpose. The result of the biological parameters showed that there is no biological pollution in any of the sample. The total coli form count results obtained complied with the standard set by WHO and NSDWQ for coli forms in drinking water, implies that the water in the study area is safe and does not posed significant health hazards to the consumers. The ANOVA carried out showed that there was significant difference at $P < 0.05$ in all of the parameter analysed.

VI. Recommendations

It is recommended that appropriate regulatory agencies and routine checks should be carried out on all the boreholes on regular bases to assess the quality level of the water.

It is also recommended that borehole owners should analyse the quality of their water Government must ensure that professionals analyse already existing boreholes and enforce corrective measures so as to safeguard the public health of the citizens of the state and prevent contamination of the aquifer.

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