Original Research Article

SEASONAL EVALUATION OF THE PHYSICOCHEMICAL PROPERTIES OF SOME BOREHOLES WATER SAMPLES IN MILE 50, ABAKALIKI.

ABSTRACT

Water as excellent natural resource is meant to be of good quality to prevent the outbreak of water-borne diseases. The physical, chemical and biological qualities of water constitute groundwater quality. Water of poor physicochemical quality may have adverse effects on human health and the economy. The physicochemical evaluation of fifteen borehole waters in mile 50 Abakaliki was carried out during the rainy and dry seasons to determine their suitability for drinking using standard analytical methods. During the rainy season, the temperature was 28-30 ^{0}C; pH, 6.63-8.51; dissolved solids, 1.04-17.01mg/l; total suspended solids, 0.09-0.66mg/l; total solids, 1.14-17.99mg/l; electrical conductivity, 107-328us/cm; turbidity, 1.27NTU-2.60NTU total alkalinity, 27.68-82.23mg/l; total hardness, 70.20-150.84mg/l; total chloride, 67.30-124.14mg/l; calcium hardness, 24.50-53.58mg/l; magnesium hardness, 39.40-97.26mg/l; sulphate, 30.03-61.88mg/l; phosphate, 0.25-6.71mg/l; potassium, 0.00-8.04mg/l; nitrate, 1.16-8.03mg/l; iron, 0.00-0.26mg/l; lead, 0.00-0.05mg/l; cadmium, 0.00-0.04mg/l; copper, 0.00-0.23mg/l; chromium, 0.00-0.04mg/l and zinc, 0.07-2.15mg/l. During the dry season the temperature was 27-29^{0}C; pH, 6.40-7.75; electrical conductivity, 24-149 us/cm; dissolved solids, 0.10-2.03mg/l; total suspended solids, 0.02-0.29mg/l; total solids, 0.13-2.64mg/l; turbidity, 0.61NTU-1.90 total alkalinity, 19.96-55.97 mg/l; total hardness, 49.61-82.35mg/l; total chloride, 26.31-80.72mg/l; calcium hardness, 5.63-29.30mg/l; magnesium hardness, 30.54-67.30mg/l; sulphate, 13.88-39.18mg/l; phosphate, 0.07-3.18mg/l; potassium, 0.00-4.73mg/l; nitrate, 0.44-4.95mg/l; iron, 0.00-0.16mg/l; lead, 0.00-0.02mg/l; cadmium, 0.00-0.02mg/l ; copper, 0.00-0.15mg/l; chromium, 0.00-0.03mg/l and zinc, 0.02-0.64mg/l during the dry season. From the average 7% of cadmium and 33% of lead in the water samples were above the WHO required limits of 0.03 and 0.01mg/l respectively. Generally, the water from the borehole was of poor physicochemical quality and must be treated adequately before being used by humans.

Keywords: Sanitary risk assessment, Physicochemical and borehole Waters.

INTRODUCTION

Water is an excellent natural resource in the entire world and a critical bond to all spheres ref. The quality of drinking water is a powerful environmental determinant of health (**38**). Water plays an indispensable role in sustenance of life and it is a key pillar of health determinant, since 80% of diseases in developing countries are due to lack of good quality water (**9**). Groundwater is the major source of water supply for agriculture, industrial, and domestic activities ref. Nearly 90% and 50% of water use in rural and urban areas, respectively, is based on groundwater (**4**). However, currently, serious groundwater crisis is prevailing due to contamination (**33**). Water that is meant for drinking should be of high quality.

Groundwater sources are getting contaminated due to human interference, such as waste dumping, effluent and sewage discharge without proper treatment ref. Municipal and industrial wastes, application of fertilizers, herbicides, pesticides, burning of coal, leaching from mining activity further add to contamination of groundwater ref. These different sources of contamination may influence physical, chemical, and biological variables of groundwater (**24**). Physicochemical contaminants include heavy metals, trace metals, total suspended solids, and turbidity and so on (**30**).

Also, water may contain toxic inorganic chemicals which may cause either acute or chronic health effect ref. Acute effects include nausea, lung irritation, skin rash, vomiting and dizziness, sometime death usually occurred ref. Chronic effect, like cancer, birth defects, organs damage, disorder of the nervous system and damage to the immune system are usually more common (**13**). Inorganic chemicals like lead may produce adverse health effect which include interference with red blood cell chemistry, delay in normal physical and mental development in babies and young children, slit deficit in attention span, hearing and learning abilities of children and slight increase in blood pressure in some adults ref. Also, presence of chromium in drinking water had been shown to result in chronic toxic effect (including liver and kidney damage, internal haemorrhage and respiratory disorders) in animal and human by ingestion ref. Although, the sources of metal contaminants of the underground water are uncertain, it may likely be due to natural process and anthropogenic activities (**13**). In addition, rural water also have excessive amount of nitrite from microbial action on agricultural fertilizer, when ingested nitrite compete for oxygen in the blood (**23**).

The unreliable water supply within Abakaliki has forced residents to increasingly depend on shallow wells and boreholes as the source of water for drinking and domestic use ref. These boreholes are dug shallow wells connected to overhead tank and pumped with sume machine many of them are located close to household drainage systems and septic tanks and are therefore susceptible to contamination ref. A good knowledge of the physicochemical properties of water meant for drinking and domestic purposes is crucial to avert a possible health hazard, therefore in this study; the physiochemical properties of some borehole waters in mile 50 Abakaliki were evaluated.

METHODS

COLLECTION OF SAMPLES

Water samples from fifteen borehole waters in SDP, Ebonyi voice, Mile 50 layout, NEPA junction, pastoral centre, Isiuke lane 1, Isiuke lane 2, Ibiam borehole, Ogodo borehole, Alugbara Eze, Amaike Aba road borehole, Obasi borehole Eze and bros junction, Oroeke market and Nkwo Agu borehole were evaluated physicochemically during the rainy and dry seasons. Two-litre plastic containers with screw caps were used to collect the samples. The containers were initially washed with detergent and thereafter rinsed with sterile distilled water. The containers were also rinsed with the water samples at the point of collection. The samples were transported to the Biotechnology Research Centre of Nnamdi Azikwe University Awka where they were analyzed within twenty-four hours of collection.

PHYSICOCHEMICAL ANALYSIS

The physicochemical characteristics evaluated were temperature, pH, electrical conductivity, total dissolved solids, total suspended solids, total solids, total alkalinity, total hardness, total chloride, calcium hardness, magnesium hardness, sulphate, phosphate, nitrate, potassium, iron, lead, cadmium, copper, zinc, and chromium. The evaluation was carried out using standard analytical methods (**5**)

Determination of pH

The pH meter was calibrated using the buffer solutions 4.01, 7.0 and 10.01 as directed by the manufacturer, Samples were introduced into 250ml beakers and the meter censor was submerged into the samples to determine the pH (*in-situ*) it was then allowed to stabilize before recording the value. It was then repeated again and the average recorded.

Determination of Temperature

Temperature was measured *in-situ* with a hand held mercury-in-glass thermometer. The thermometer (or the probe) was rinsed with a portion of the sample and discarded the thermometer was then immersed into a 250ml beaker containing the borehole water sample until the liquid column in the thermometer stopped moving (approximately 1 minute, or longer if the temperature reading has not become constant). Then the reading was recorded.

Determination of Electrical Conductivity

The conductivity meter was calibrated using the buffer solutions 1413 µS/cm and 12.88 mS/cm as directed by the manufacturer. The meter censor was submerged into each sample in 250ml beaker to determine conductivity individually. This was done *in-situ* Values on the display kept varying until a stabilized value was obtained and recorded.

Determination of Total Dissolved solid (Gravimetric method)

Measuring cylinder was washed and dried using the oven at 105^0C and cooled in the desiccators' weight of the filter paper immediately before uses were noted. Then I homogenized the sample and measure out 50ml of sample in the measuring cylinder. The samples were filtered using the weighed filter paper. The filter papers containing the residue were dried in the oven at 105^0C then cooled in the desiccators and the weight noted.

Calculation

$$\text{Total dissolved solid mg/l} = \frac{\text{Residue} \times 1000}{\text{Volume of sample}}$$

Determination of Total Solids (Gravimetric method)

One hundred (100mls) beaker was washed and dried using the oven at 105^0C for 20 minutes and then cooled in the desiccators. The weight of the beaker immediately before use was noted. The borehole water sample was homogenized and 50ml of sample were measured using a measuring cylinder. The samples were heated at 105^0C in an oven until sample gets dried. They were cooled in the desiccators and the weight noted.

Calculation

$$\text{Total Solid mg/l} = \frac{(A-B)}{\text{Volume of sample}} \times 1000$$

A= weight of beaker+ residue

B= weight of beaker

Determination of Total Suspended Solid: (From TS and TDS)

TS mg/l – TDS mg/l = TSS mg/l
Where;
TS = total solid
TDS = total dissolved solid
TSS = total suspended solid

Determination of Turbidity

The turbidity of the samples was determined *in-situ* by table top turbidity meter manufactured by LabScience. Turbidity was expressed as Nephelometric Turbidity Units (NTU).

Determination of Chloride (Argentometric Titration method)

Fifty (50ml) of water sample was measured into 250ml conical flask. 1 mL K_2CrO_4 indicator solution (prepared by dissolving 50 g of K_2CrO_4 in a little distilled water and $AgNO_3$ solution was added until a definite red precipitate is formed. It was left to stand for 12 hours, filtered, and diluted to 1L with distilled water) was added and titrated with (0.0141N) $AgNO_3$ titrant prepared by (Dissolving 2.395g $AgNO_3$ in distilled water and diluted to 1000 mL; 1 mL = 500 µg Cl^- then stored in brown bottle) to a pinkish yellow end point. The titration was repeated with distilled water blank.

Calculation: $\text{Mg } Cl^-/L = \frac{(A-B)\times N\times 35\times 450}{\text{ml of sample}}$

Where: A = ml titration for sample, B = ml titration for blank, N = normality of $AgNO_3$

Determination of Nitrate (Spectrophotometry method)

Fifty (50mls) of water sample was measured into a conical flask**.** 1ml of 0.1mol sodium arsenite prepared by (weighing 1.3g of sodium arsenite into 100ml volumetric flask and dissolved in little distilled water and made up to the mark with distilled water) were added and thoroughly shaked. From the mixture above, 5ml was measured into a separate test tube and 1ml of 0.1mol brucine sulphate was added (2.2g of brucine sulphate was weighed in 50ml volumetric flask and dissolved with little distilled water and made up to the mark.) Ten (10mls) of concentrated sulphuric acid (H_2SO_4) was added and homogenized with the remaining 45mls solution and allowed for colour development for about 30minutes. The absorbance was read with the aid of a SPECTIONIC------20 machines at wave length of 410nm.

Calculation: $$\frac{\text{Concentration}}{\text{Volume of sample used}} \times 1000 \text{ mg/l}$$

Determination of Sulphate (Titrimetric method)

Ten (10ml) of homogenized water sample was measured into a clean conical flask, 5ml of 2mol hydrochloric acid was added. Then 2ml of 0.05mol barium chloride was added to the above and boiled in water bath for five minutes while the test samples were covered with masking foil. The samples were allowed to cool at room temperature and 2ml of concentrated ammonia added. Five (5mls) of 0.01N EDTA was added and boiled for five minutes. Five (5mls) of buffer 10 and three drops of Erichrome black T indicator were also added and titrated with 0.01mol magnesium chloride. Note that colour changes from deep blue to light purple.

Calculation: $$\text{Sulphate mg/l} = \frac{[10-(TV \times 0.93)] \times 96.01464 \text{ mg/l}}{10}$$

Determination of Phosphate (UV Spectrophotometry method)

Ten (10mls) of the neutralized sample was pipette into 50ml volumetric flask and the following added 4ml of ammonium molybdate**,** 4ml of 10N sulphuric acid**,** and 6drops of stannous chloride. The solution was shaked and made up to 50ml. The absorbance was read in a UV (ultra-violet) Spectrophotometer at wave length 650nm.

Determination of Dissolved Oxygen

Dissolved oxygen was determined using dissolved oxygen meter manufactured by Hanna Instruments, USA. Dissolved oxygen was determined at the point of sample collection.

Determination of Total Alkalinity (Titrimetry method)

Ten (10mls) of samples were introduced into a conical flask**,** and then 3 drops of bromocresol green indicator (Prepared by dissolving 100mg bromocresol green salt in 100ml of distilled water) was added and titrated with 0.1N sulphuric acid solution.

$$\text{Total alkalinity, mg } CaCO_3\text{/L} = \frac{B \times N \times 50000}{}$$

Sample volume

Where B= ml titration for blank, N=normality of sulphuric acid

Determination of Total Hardness

Fifty (50mls) of well mixed sample was introduced into a conical flask**, then** 2 ml buffer solution added followed by 1 ml inhibitor. A pinch of Eriochrome black T was added and titrated with standard EDTA (0.01M) till wine red colour changes to blue, then the volume of EDTA required was noted (A). The volume of the reagent blank was analysed and noted (B). The volume of EDTA required by sample, was calculated; C **=** A – B (from volume of EDTA required in steps).

$$\text{Total hardness as } CaCO_3\text{, mg/l} = \frac{C \times D \times 1000}{\text{Volume of sample in 1ml}}$$

C = volume of EDTA required by sample (with EBT indicator)

D = mg $CaCO_3$ equivalent to 1ml EDTA titrant (1ml 0.01M EDTA = 1.00 mg $CaCO_3$)

Determination of Calcium Hardness

Twenty-five (25mls) of well mixed samples were introduced into a 250ml conical flask and 1 ml sodium hydroxide solution 2N was added to raise pH to 12.0 and a pinch of muroxide indicator was added. It was titrated immediately with EDTA 0.01M till pink colour changes to purple. The volume of EDTA used was noted (A_1). Run a reagent blank and note the ml of EDTA required (B_1) and keep it aside to compare end points of sample titrations.

The volume of EDTA required by sample was calculated using C_1 **=** $A_1 – B_1$.

$$\text{Calcium hardness as } CaCO_3\text{, mg/l} = \frac{C_1 \times D \times 1000}{\text{Volume of sample in 1ml}}$$

C_1= volume of EDTA used by sample (with murexide indicator)

D = mg $CaCO_3$ equivalent to 1 ml EDTA titrant

Determination of Magnesium Hardness

Magnesium Hardness = Total hardness as $CaCO_3$, mg/l – Calcium hardness as $CaCO_3$, mg/l.

Determination of Bicarbonate

Calculated from pH and total alkalinity

$$HCO_3^- \text{ as mg } CaCO_3\text{/L} = \frac{T - 5.0 \times 10^{(pH - 10)}}{1 + 0.94 \times 10^{(pH - 10)}}$$

Where T is total alkalinity as mg $CaCO_3$/L

Determination of Carbonate

CO_3^{2-} as mg $CaCO_3$/L = 0.94 ×HCO_3^- × $10^{(pH -10)}$

Where:

T = total alkalinity (Alk-T) as mg$CaCO_3$/L

HCO_3^- = bicarbonate

Determination of potassium (flame photometer)

Reagent: Standard potassium solution (10mg/k)

Fifty (50mls) of the water sample was filtered using Whatmann no.1filter paper to remove suspended solids and the potassium concentration was detected using flame photometer.

Heavy metals (Spectrophotometry)

(Cadmium, lead, chromium, mercury, copper, arsenic, zinc and iron)

Procedure

All metallic elements where determined using Atomic Absorption Spectrophotometer (AAS) manufactured by Buck Scientific. One hundred millilitres of the filtered water samples were introduced into a 250ml conical flask and digested with 2ml of concentrated nitric acid. The digested samples were filtered into a sample bottle and aspirated into the oxyacetylene flame. The absorbance of the aspirated sample was read using the atomic absorption spectrophotometer.

DATA ANALYSIS

The data were subjected to two–way Analysis of variance to determine the level of significance between the physicochemical parameters using SPSS 8.0 package.

RESULTS

Table 1: Physical characteristics of borehole water during rainy season

Borehole Location	Temp (°C)	pH	EC (µs/cm)	TSS (mg/l)	TS (mg/l)	DS (mg/l)	Turbidity (NTU)
SDP	29	7.27	250	0.26	6.54	6.28	1.98
Ebonyi voice	28	7.08	243	0.22	2.33	2.11	1.93
Mile 50	28	7.37	203	0.19	1.99	1.80	1.77
NEPA	29	8.51	225	0.26	5.46	5.20	1.81
Pastoral	28	7.74	107	0.09	1.81	1.72	1.36
Isiuke lane 1	28	7.76	190	0.33	7.53	7.20	1.50
Isiuke lane 2	29	7.72	171	0.17	1.77	1.60	1.71
Ibiam	29	6.63	159	0.14	1.18	1.04	1.66
Ogodo	30	7.94	328	0.98	17.99	17.01	2.60
Alugbara eze	28	7.18	178	0.13	1.27	1.14	1.42
Amaike Aba	30	8.21	304	0.66	11.66	11.00	2.52
Obasi	28	7.62	183	0.21	3.38	3.17	2.45
Eze & bros	29	7.32	288	0.52	9.78	9.26	2.50
Oroke market	28	8.09	231	0.30	5.58	5.28	2.31
Nkwo agu	29	7.92	135	0.10	1.14	1.04	1.27
WHO(2006)	**25-32**	**6.5-8.5**	**1000**	**-**	**500**	**500**	**5**

Table 2. Physical characteristics of borehole water during dry season

Borehole Location	Temp (^oC)	pH	EC (µs/cm)	TSS (mg/l)	TS (mg/l)	DS (mg/l)	Turbidity (NTU)
SDP	27	7.06	97	0.18	0.55	0.37	1.62
Ebonyi voice	28	6.80	72	0.13	0.38	0.25	1.57
Mile 50	27	6.84	60	0.08	0.22	0.14	1.31
NEPA	28	7.75	65	0.09	0.23	0.14	1.40
Pastoral	27	6.54	24	0.02	0.13	0.11	0.61
Isiuke lane 1	27	6.95	50	0.09	0.26	0.17	0.84
Isiuke lane 2	28	6.85	51	0.08	0.26	0.18	1.21
Ibiam	27	6.40	40	0.06	0.27	0.21	0.75
Ogodo	28	7.12	149	0.61	2.64	2.03	1.90
Alugbara eze	27	6.86	47	0.04	0.17	0.13	0.93
Amaike Aba	29	7.74	117	0.29	1.16	0.87	1.84
Obasi	27	6.64	54	0.11	0.40	0.29	1.30
Eze & bros	28	6.91	103	0.21	0.75	0.54	1.67
Oroke market	27	7.09	68	0.11	0.36	0.25	1.49
Nkwo agu	28	7.12	36	0.03	0.13	0.10	0.69
WHO(2006)	**25-32**	**6.5-8.5**	**1000**	**-**	**500**	**500**	**5**

Table 3.Chemical characteristics of borehole water during rainy season

Borehole Location	Chloride (mg/l)	Phos. (mg/l)	Total alkalinity (mg/l)	Total hardness (mg/l)	Cal. Hardness (mg/l)	Mg. hardness (mg/l)	Bicar. (mg/l)	Car. (mg/l)	Nitrate (mg/l)	K (mg/l)	Sul. (mg/l)	DO (mg/l)
SDP	84.76	0.42	74.28	95.00	24.50	70.50	74.08	0.202	1.16	2.39	45.20	7.44
Ebonyi voice	69.92	0.31	58.74	118.00	33.80	84.20	58.56	0.185	3.18	0.00	47.39	6.78
Mile 50	98.84	0.62	61.02	84.00	24.70	59.30	60.80	0.219	6.05	8.04	49.60	7.22
NEPA	72.84	0.38	56.47	79.80	28.20	51.60	56.34	0.131	1.44	2.07	41.44	6.27
Pastoral	101.41	0.28	48.17	111.16	47.84	63.32	48.09	0.072	1.56	1.39	37.05	8.01
Isiuke lane 1	98.71	0.27	70.09	85.60	30.70	54.90	69.83	0.262	1.40	2.04	40.01	7.87
Isiuke lane 2	102.76	0.43	63.24	70.20	30.80	39.40	63.09	0.141	1.22	4.02	38.50	6.85
Ibiam	124.14	0.47	30.53	72.80	25.50	47.30	30.47	0.065	5.87	5.93	43.28	7.89
Ogodo	77.30	6.71	66.15	137.20	47.00	90.20	66.05	0.098	7.32	6.35	61.88	6.73
Alugbaraeze	67.30	0.36	64.86	116.40	42.10	74.30	64.71	0.153	4.12	1.87	47.67	7.50
Amaike Aba	81.30	4.68	82.23	150.84	53.58	97.26	82.06	0.169	8.03	0.21	51.21	5.81
Obasi	112.76	0.27	51.37	93.60	36.90	60.70	51.11	0.259	5.56	0.00	45.31	7.80
Eze & bros	68.16	2.37	27.68	122.70	51.47	71.23	27.55	0.132	5.98	0.97	39.62	6.82
Oroke market	107.62	0.48	75.80	129.25	49.96	79.29	75.56	0.241	5.62	0.19	45.17	7.02
Nkwo agu	114.71	0.25	78.09	100.67	32.29	68.38	77.99	0.094	1.74	0.27	30.03	6.57
WHO(2006)	**250**	**0.5**	**250**	**250**	**75**	**50**	**-**	**-**	**10**	**5**	**250**	**>5**

Key: Bicar = Bicarbonates. Car = Carbonates. Phos = Phosphate. Sul = Sulphate.

Table 4: Chemical characteristics of borehole water during dry season

Borehole Location	Chloride (mg/l)	Phosphate (mg/l)	Total alkalinity (mg/l)	Total hardness (mg/l)	Calcium hardness (mg/l)	Magnesium hardness (mg/l)	Bicarbonate (mg/l)	Carbonate (mg/l)	Nitrate (mg/l)	K (mg/l)	Sulphate (mg/l)	DO (mg/l)
SDP	41.43	0.11	30.55	70.20	09.87	60.33	30.47	0.076	1.01	0.98	30.29	6.19
Ebonyi voice	28.81	0.10	22.76	80.84	13.54	67.30	22.69	0.063	0.44	0.00	27.18	6.34
Mile 50	46.52	0.15	35.63	49.61	11.42	38.19	35.58	0.052	2.92	4.73	29.20	6.73
NEPA	33.73	0.10	55.97	50.20	12.10	38.10	55.93	0.041	1.09	1.09	32.51	5.98
Pastoral	63.71	0.09	41.25	66.78	24.62	42.16	41.18	0.069	1.05	0.99	28.62	6.13
Isiuke lane1	50.52	0.07	42.80	60.09	17.36	42.73	42.75	0.049	0.86	1.01	23.11	6.48
Isiuke lane2	53.38	0.12	40.92	58.15	14.94	33.21	40.84	0.085	0.76	1.44	18.07	6.23
Ibiam	80.72	0.13	19.96	50.66	20.12	30.54	19.95	0.013	2.61	3.27	21.37	7.42
Ogodo	35.39	3.18	25.97	74.60	29.30	45.30	25.89	0.071	4.08	3.25	39.18	5.85
Alugbaraeze	31.63	0.08	47.62	60.89	21.28	39.61	47.58	0.038	0.92	1.07	18.07	6.93
Amaike Aba	38.49	2.16	53.18	70.82	05.63	65.19	53.09	0.087	4.95	0.11	29.91	5.25
Obasi	67.51	0.08	38.09	74.53	17.35	57.18	38.03	0.059	1.11	0.00	23.24	6.09
Eze and bros	26.31	1.10	23.48	82.35	27.53	54.82	23.45	0.032	1.24	0.21	13.88	6.42
Orokemarket	64.47	0.14	51.36	65.65	27.38	38.27	51.28	0.079	1.27	0.09	29.73	6.93
Nkwo agu	67.62	0.07	46.19	72.48	18.97	53.51	46.16	0.029	1.04	0.13	16.73	6.17
WHO(2006)	**250**	**0.5**	**250**	**250**	**75**	**50**	**-**	**-**	**10**	**5**	**250**	**>5**

Table 5. Heavy metal characteristics of borehole water during rainy season

Borehole location	Zn (mg/l)	Fe (mg/l)	Cu (mg/l)	Hg (mg/l)	Cd (mg/l)	Pb (mg/l)	Cr (mg/l)
SDP	0.28	0.00	0.00	0.00	0.01	0.01	0.00
Ebonyi voice	2.02	0.04	0.08	0.00	0.02	0.03	0.03
Mile 50	0.19	0.00	0.00	0.00	0.03	0.02	0.02
NEPA	0.20	0.00	0.00	0.00	0.00	0.03	0.00
Pastoral	0.18	0.03	0.07	0.00	0.00	0.01	0.00
Isiuke lane 1	0.16	0.00	0.06	0.00	0.00	0.00	0.02
Isiuke lane 2	0.18	0.10	0.08	0.00	0.01	0.01	0.03
Ibiam	0.14	0.00	0.02	0.00	0.02	0.01	0.01
Ogodo	2.15	0.26	0.15	0.00	0.04	0.05	0.05
Alugbaraeze	0.36	0.00	0.04	0.00	0.00	0.00	0.03
Amaike Aba	1.27	0.21	0.23	0.00	0.03	0.04	0.04
Obasi	0.30	0.00	0.01	0.00	0.01	0.00	0.00
Eze & bros	0.13	0.08	0.05	0.00	0.02	0.00	0.00
Oroke market	0.10	0.15	0.11	0.00	0.00	0.01	0.02
Nkwo agu	0.07	0.04	0.07	0.00	0.01	0.00	0.01
WHO (2006)	**3.0**	**0.3**	**2.0**	**0.001**	**0.03**	**0.01**	**0.05**

Table 6: Heavy metal characteristics of borehole water during dry season

Borehole location	Zn (mg/l)	Fe (mg/l)	Cu (mg/l)	Hg (mg/l)	Cd (mg/l)	Pb (mg/l)	Cr (mg/l)
SDP	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Ebonyi voice	0.13	0.02	0.03	0.00	0.00	0.01	0.01
Mile 50	0.10	0.00	0.00	0.00	0.01	0.00	0.00
NEPA	0.11	0.00	0.00	0.00	0.00	0.01	0.00
Pastoral	0.09	0.00	0.04	0.00	0.00	0.00	0.00
Isiuke lane 1	0.08	0.00	0.02	0.00	0.00	0.00	0.01
Isiuke lane 2	0.07	0.04	0.03	0.00	0.00	0.00	0.02
Ibiam	0.03	0.00	0.00	0.00	0.01	0.00	0.00
Ogodo	0.57	0.16	0.09	0.00	0.02	0.01	0.03
Alugbaraeze	0.22	0.00	0.02	0.00	0.00	0.00	0.01
Amaike Aba	0.64	0.13	0.15	0.00	0.01	0.02	0.02
Obasi	0.18	0.00	0.00	0.00	0.01	0.00	0.00
Eze & bros	0.03	0.03	0.01	0.00	0.01	0.00	0.00
Oroke market	0.02	0.10	0.05	0.00	0.00	0.00	0.00
Nkwo agu	0.05	0.01	0.02	0.00	0.01	0.00	0.00
WHO(2006)	**3.0**	**0.3**	**2.0**	**0.001**	**0.03**	**0.01**	**0.05**

DISCUSSION

Groundwater has been considered as a safe source of drinking water. However, nowadays, the quality of drinking water is deteriorating (**39**). Therefore, the present study focuses on physicochemical properties of the groundwater (borehole) samples collected from mile 50 Abakaliki and was compared with world health standard.

Temperature is an important factor which influences the chemical, biochemical and biological characteristics of waters (**19**) the temperature values of the various water samples analyzed during the rainy season ranged from 28-30^{o}C 46.7% having the lowest value of 28^{o}C and 13.3% having the highest value of 30^{o}C. (Table 1) During the dry season, the temperature value of the borehole water samples ranged from 27-29^{o}C with sample 11 having the highest value of 29^{o}C. (Table 2) The average temperature value obtained from both season ranged from 27.5-29.0^{o}C and were within the (25^{o}C – 32^{o}C) W.H.O. standards for drinking water quality. The results showed that the boreholes water temperature values were satisfactory for drinking and domestic water usage. These findings are in accordance with that of Josiah, *et al.*, 2014 who recorded a temperature range of 26 -32^{o}C of the water samples. This may be attributed to the intensity of the sunlight and to the insulating effect of increased nutrient load resulting from industrial discharge. Cool water is more potable for drinking purposes, because high water temperature enhances the growth of microorganisms (**22**).

The pH is a measure of acidity or alkalinity of the water substances (**29**). The pH of the water samples ranged from 6.63-8.51 during the rainy season (Table 1) and 6.40-7.75 in dry season (Table 2). The average pH value obtained from both season ranged from 6.52-8.13 and were within the WHO standard of 6.5 to 8.5 (**35**). pH of all the water samples in the study area were within the limits indicating that water was between slightly acidic and slightly alkaline. The variation in pH of the water samples might be due to the site of sample collection. The results showed that the boreholes water pH values were satisfactory for drinking and domestic water usage. These findings were similar to the works presented by (**18**). The high pH in the rainy season may be due to the presence of limestone in the aquifer formation that dissolved to release $CaCO_3$ into the water. The low pH in the dry season may have been caused by high temperatures that increased the concentration of H^+ ions, hence decreasing the pH of the borehole water. The sedimentary rocks are sources of Calcium ions which might have increased the pH of borehole water during rainy season.

Electrical conductivity is the ability of a solution to conduct an electrical current that is governed by the migration of ions in solutions which is dependent on the nature and numbers of the ionic species in that solution (**32**; **6**). It is a useful tool to assess the purity of water. Conductivity indicates the presence of dissolved solids and contaminates especially electrolytes but does not give inspiration about specific chemicals. The electrical conductivity of the water samples from the boreholes varied from 107-328 µS/cm during the rainy season, (Table 1) while it varied from 24.00-149.00 µS/cm during the dry season (Table 2). The mean conductivity during the both season ranged from 65.5-238.5 µS/cm. The conductivity of the water samples was within the acceptable standard for drinking water. These findings are similar to the work presented by (**10**) who stated that all the values obtained were below the WHO 2006, maximum permissible limit of 1000µS/cm for drinking water. The higher values obtained during the wet season could be ascribed to high concentrations of ionic constituents in the water bodies resulting from surface runoff into the ground water or attributed to the presence of organic matter pollution and run-off with high suspended matter content into the wells.

All water samples indicate the availability of contaminants as shown by the level of the determined values of total suspended solids (TSS). All measurements were within the permissible limits of W.H.O. 0.09-0.98mg/l values were obtained during the rainy season and 0.02-0.61mg/l values were obtained during the dry season they were all below 1.0mg/l. The presence of TSS in water samples indicated the presence of suspended matters in the water samples. The total solids determined had sample 9 and 11 with the highest value of 17.99 and 11.66mg/l respectively in rainy season, with sample 9 having values of 2.64mg/l in dry season among other samples.

Turbidity stems from the reduction of transparency due to the presence of percolate matter such as clay silt, finely divided organic matter etc. The turbidity imparted in the groundwater might be due to the suspended particles and undesirable substances (**21**). The turbidity values obtained during the rainy season ranged from 1.27-2.60 NTU with that of dry season ranging from 0.61-1.84NTU. The average turbidity values for both seasons ranged from 0.98-2.25NTU and are within the W.H.O. standard of 5 NTU. These findings are similar to the work presented by (**10**) who stated that all the values obtained were below the WHO 2006, maximum permissible limit of 5 NTU for drinking water. However the turbidity values were generally lower during the dry season. The increased values during the rainy season could be attributed to surface runoff and erosion carrying soil and partially dissolved/ un-dissolved organic matters. The low recharge in the dry season may have resulted in lower turbidity of the borehole water.

The physical parameters were analyzed using two-way analysis of variance on the data obtained which showed that there was significant difference ($p < 0.0001$) between the various drinking water samples in both rainy and dry season. (Appendix iv)

Chlorine is an active chemical which has disinfecting capabilities. The average values of total chloride investigated during the both season ranged from 47.24-102.43 mg/l and is within the WHO permissible limit of 250mg/l for drinking water. Chloride in drinking water originates from natural sources (dissolving rocks) sewage and industrial effluents; urban runoff containing de-icing salt and saline intrusion (**7**) high level of chloride makes water unpalatable for drinking by imparting salty taste and may harm metallic pipes (**6**). A similar study conducted by (**28**) reported that the chloride ions ranged between 97 and 108 mg/L.

The value of phosphate fluctuates from 0.25 mg/l to 6.7 mg/l during rainy season and ranged from 0.07mg/l – 3.18mg/l during dry season. The high values of phosphate during the rainy season are mainly due to rain, surface water runoff, and agriculture run off could have contributed to the inorganic phosphate content. The average phosphate level of the water samples ranged from 0.16- 4.95 mg/l with all the samples being within the WHO acceptable limit of 0.5mg/l and sample 9 and 11 having the highest value of 4.95 and 3.42mg/l respectively above the standard. (**20**) Reported a low phosphate concentrations ranging from 0.09 to 0.347 mg/l and within the WHO standard of 0.5mg/l these could be as a result of low Agricultural activities in such area. Phosphate like any other nutrient is harmless in lower concentrations but become harmful only in higher doses. Higher doses of Phosphate are known to interfere with digestion in both humans and animals. Phosphate enrichment of water bodies contributes to ecological impacts and their presence in water bodies contributes to eutrophication of natural waters. (**36**, **27**)

The total alkalinity of water is its acid neutralizing capacity. The alkalinity of groundwater is mainly due to carbonates and bicarbonates (**31**). The average total alkalinity obtained from both season ranged from 25.25-67.71mg/l the maximum value 67.71mg/l was recorded in sample 11and sample 8 had the minimum value of 25.25mg/l increase in total alkalinity of water is due to bicarbonates in such water (**19**) These findings are similar to the work presented by (**8**) whose value ranged between 74.3 - 88.2 mg/l and were below the WHO 2006, maximum permissible limit of 250mg/l for drinking water. Based on the values of total alkalinity of the sampled waters, it can be inferred that the water is safe for drinking.

Hardness of water may not have any health implications but may affect the taste of water as well as influence its lathering ability when used for washing. The average value of total hardness ranged from 61.73- 110.83mg/l for the analysis conducted in both seasons. The highest values of 110.83mg/l were recorded in sample 11 and the lowest values of 61.73mg/l recorded in sample 8. All the water samples analyzed were below the WHO standard of 100mg/l except for sample 9, 11 and 13 which exceeded 100mg/l. World health organization international standard for drinking water (1998) classified water with total hardness of less than 50mg/l as soft water, 50-150mg/l as moderately hard water and water above 150mg/l as hard water. Based on this, all water samples were moderately hard water and suitable for domestic use in terms of hardness. This finding is similar to the work of (**25**) which stated that all the water samples analysed were moderately hard. The high mean total hardness of the borehole samples in the wet season may be due to dissolution of metallic ions such as Mg^{2+}, Ca^{2+} ions from limestone and sedimentary rocks by rainwater percolation in the soil. The ions may have originated from run-offs that infiltrated into the soil, causing leaching and weathering of limestone and feldspars in the soil. The result is the precipitation of Ca^{2+} and Mg^{2+} ions and other mineral constituents in the soil that can also increase the total hardness of groundwater. The low total hardness in the dry season may be as a result of low aquifer recharge, hence less dissolution of the mineral composition of the aquifer.

The values of calcium hardness obtained from the investigation of the borehole water samples during the rainy season ranged from 24.50-53.58mg/l (Table 3) while the values obtained from the analysis conducted during the dry season were from 05.63- 27.53mg/l (Table 4) the average values of the calcium hardness ranged from 17.19-39.50mg/l. These values are below the 75mg/l stipulated by WHO (2006) and are therefore considered fit for drinking in terms of calcium content. Ca ions occur in groundwater through the decomposition of sulphate, phosphate, and silicate materials and due to the dissolution of carbonate minerals (**11**). Calcium ion when in suitable concentration is known to regulate a number of neuron-muscular excitability, blood coagulation, enzyme reactions, secretary processes and intracellular action of a number of hormones. Calcium, which is essential for nervous system and for the formation of bones, is commonly present in all water bodies where it usually comes from the leaching of rocks (**2**).

The values of magnesium hardness obtained from the investigation of the borehole water samples during the rainy season ranged from 39.40-97.26 mg/l (Table 3) while the values obtained from the analysis conducted during the dry season were from 30.54-67.70mg/l (Table 4) the average values of the magnesium hardness ranged from 36.31-81.23 mg/l. These values were above the 50 mg/l stipulated by WHO (2006) and are therefore considered unfit for drinking. Calcium and magnesium are among the elements essential for human health and metabolism and should be available in normal drinking water (**17**). However, if one or more of these elements occur in the water above certain limits the water may become objectionable to consumers and even become hazardous to health (**25**). High level of magnesium in drinking water could result to kidney problem or bladder stone formation.

Bicarbonates are the dominant anion in most surface and ground waters. The weathering of rocks contributes to bicarbonates content in water. Mostly bicarbonates are soluble in water and concentration in water is related to pH. Bicarbonates are usually less than 500mg/L in ground water (WHO, 2004). In this study, bicarbonates ranged from 27.55-82.06 mg/L during the rainy season and from 19.95-55.93 mg/L during dry season, while carbonate ranged from 0.065-0.262 mg/L during the rainy season (Table 3) and from 0.013- 0.087mg/l during dry season. (Table 4)The average value for both season ranged from 0.039-0.160mg/l. The bicarbonate and carbonate content of the ground water were within the acceptable limit.

Nitrate concentrations ranged from 0.99 to 6.49mg/l and were within the acceptable limit prescribed by WHO (2006) limit of 10.0. The presence of nitrates can be a source of concern because consumption of water with high nitrate concentrations can cause blood disorders (known as methemoglobinemia) as well as cancer in humans (**26**). Nitrogen is present in soils which are normally fixed by nitrogen fixing bacteria. Nitrogen may exist as nitrates and nitrites. These traces of nitrate could result from the close proximity of animal shelters and sewage disposal systems to boreholes, as it infiltrates in underground water after rainfalls. Nitrogen like any other nutrient is harmless in lower concentrations but become harmful only in higher inter-convertible organic nitrogen. Being loosely bound to soils, nitrate is expected to be more in runoff and hence its concentration increases during rainy seasons. These findings are consistent with that of (**16**). The higher nitrate levels during rainy season can be attributed to leachates from nitrogen fertilizers widely used in agricultural practice, waste, notably sewage effluents, animal excrement and manure and municipal waste due to increase recharge of the water. Nitrate values in the water were within the WHO set limits for drinking water and similar with the work reported by (**3**).

Sulphate is a non-toxic anion present in natural water. The average sulphate levels of the water samples for both seasons ranges from 23.38 to 50.53 mg/l and were within the WHO (2006) limit of 250 mg/l. Sulphate gets into ground water through the dissolution of rocks containing sulphur and mine drainage waste. Water with sulphate levels above 500 mg/l can have a laxative effect until an adjustment to the water is made. A similar study conducted by (**14**) reported a sulphate level within the WHO limit of 250mg/l the low concentration of sulphate could be attributed to the absence of sulphate anthropogenic factors in the location of the wells. The presence of sulphate in drinking water can also result in a noticeable taste, the lowest taste threshold concentration for sulphate.

Dissolved oxygen is the measure of the amount of gaseous oxygen dissolved in aqueous solution (**12**). The value of dissolved oxygen (DO) fluctuates from 5.81 mg/l to 8.01 mg/l during the rainy season (Table 3) and ranged from 5.25-7.42mg/l during the dry season (Table 4).The average DO value obtained from both season ranged from 5.53-7.66mg/l which were within the WHO limit of 5mg/l these disagree with the findings of **25** whose values ranged from 29.4 to 33.5 mg/l above WHO permissible limit of >5mg/l. These may be attributed to high temperature and high microbial load in the area. According to UNESCO/WHO/UNEP (1992), Dissolved oxygen is of much more limited use as an indicator of pollution in groundwater, and is not useful for evaluating the use of groundwater for normal purposes.

The chemical parameters of the borehole water samples for both rainy and dry season were analyzed using two-way analysis of variance at Alpha level of 0.05 which showed that there was extreme significant difference ($p < 0.0001$) between the water. (Appendix iv)

Heavy Metals are defined as chemical elements with specific gravity that is at least 5 times the specific gravity of water. A heavy metal is also defined as any metallic chemical element that has a relative high density and is toxic or poisonous at low concentration. These heavy metals are natural components of the earth crust that cannot be easily degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air.

The average lead content of all the borehole water samples investigated during rainy and dry seasons showed that samples 2, 3, 4, 9 and 11 had highest value of more than 0.01mg/l against the WHO (2006) standard in drinking water. This result agreed with that of (**1**) that reported a lead concentration of 0.09 mg/l in water in a major abattoir in Ibadan, Nigeria. High level of lead in water can lead to cancer, interference in vitamin D metabolism, adverse effects in mental development in infants and toxicity to the central and peripheral nervous systems.

Zinc in the samples ranged from 0.2 to 0.864 mg/l and were within the WHO acceptable limit of 3.0. The seasonal variation in the level of the metal was however very minimal.

The concentration of copper in the ground water varied from 0.00-0.23mg/L during the rainy season and from 0.00-0.15mg/L during dry season. The results obtained for copper were below the WHO maximum value of 2.00mg/l (WHO, 2006). Chromium content of the ground water samples varied from 0.00-0.05 mg/L during the rainy season and from 0.00- 0.03 mg/L during the dry season. All the water samples for chromium were within the recommended WHO value of 0.05mg/L (WHO, 2006). The average concentration of cadmium ranged from 0.00mg/l -0.04mg/l. With sample 9 having the highest value of 0.04mg/l little above the WHO (2006) limit of 0.03mg/l. High level of cadmium in water could be toxic to the kidney.

The sources of iron in water include magnetite and biotite. The concentration of Iron in the ground water varied from0.00- 0.26mg/L during the rainy season and from0.00- 0.16mg/L during dry season. None of the values for Iron obtained exceeded the WHO standard of 0.3mg/L WHO, (2004). These values were higher than that of (**8**) whose value range was 0.00 – 0.05 mg/l. the high values may be attributed to the fact that the well covers were made of rusted sheets which infiltrates into the water during and after rain fall. Generally, there was an increase in the iron concentration during the rainy season compared to dry season. Anthropogenic sources of iron in the environment could be washed into the ground water during rainy season. Iron has no health significance but it affects the anaesthetics of the water and causes the consumer to reject the supply.

The heavy metal of the borehole water samples for both rainy and dry season were analyzed using two-way analysis of variance at Alpha level of 0.05 which showed that there was extreme significant difference ($p < 0.0001$) between the water. (Appendix iv)

CONCLUSION

These studies reveal that most of the physical parameters of the selected borehole water samples in the studied area were within the acceptable limits by WHO standards for drinking water. Some of the chemical parameter were above the WHO standards making the water unfit for consumption.

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