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EVALUATING THE IMPACT OF CLIMATE CHANGE ON THE QUALITY OF GROUND WATER – CASE STUDY OF A COAL ENRICHED ENVIRONMENT IN ENUGU URBAN

R C Nnaemeka-Okeke[1], P E Eze-Steven[2] and C C Ugwu[3]
[1,3]*Department of Architecture, University of Nigeria, Enugu Campus, Enugu*
[2]*Department of Applied Biochemistry, Enugu State University of Science and Technology*

Climate change has been an issue of focus especially as it affects the quality and quantity of groundwater. This study evaluates the impact of climate change on the quality of groundwater within areas of Independence Layout, Abakpa, and Uwani in Enugu metropolis. A physiochemical analysis of 12 deep wells was carried out from April 2018 to March 2019 using the weighted arithmetic index method was used to transform the parameters into a single indicator value which represents the water quality level. Results showed that the groundwater resources were weakly acidic which might be as a result of pyrite in the weathering of coal and rainfall charged by chloride ions. There was a significant variation in the parameters of the water samples, in dry and rainy seasons. 1% of the well water samples were excellent, 58.3% were good, and 29.1% were poor water while only 8.3% of samples were very poor.

Keywords: climate change, coal, groundwater, water quality index, water supply

INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) estimated that the global mean surface temperature has increased 0.6 o C ± 0.2 o C since 1861and predicted that there will be an increase in temperature from 2 o C to 4 o C over the next 100 years. (P. Kumar, 2016) This disrupts the water cycle as there is an increase in evaporation rate from water bodies directly influencing the quantity, duration and intensity of rainfall. High evaporation and low precipitation reduce the quantity surface water resulting in a higher dependency on groundwater. (J Mallick et al 2018). People living in Enugu Urban increasingly depend on groundwater (hand dug well), as an alternative source of water supply to water from the mains. some resort to the use of private water suppliers' trucks, who seldom supply well water with questionable purity. Since so much of everyday life and planning is

1 rosemary.nnaemeka-okeke@unn.edu.ng
2 peter.ezesteven@esut.edu.ng
3 chiamaka.ugwu@unn.edu.ng

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determined by the hydrological systems, it is important to understand the impact that climate change is having on groundwater supply.

The objectives of the study are as follows:

- To evaluate the quality of water in sample areas using certain parameters in a Physio-chemical analysis.
- To transform the parameters into a single indicator value using Water quality index (WQI) to determine the water quality level.
- To compare the results obtained with the World Health Organization (WHO) standard for potable water.
- To make necessary recommendations based on the findings of the research.

LITERATURE REVIEW

Groundwater is a valuable resource for healthy living, ecosystems and sustainable development. At the global scale, it supplies one-third of total water withdrawal to cater for nearly 85% and 50% of rural and urban needs, respectively (Kumar and Shah, 2006). Since the beginning of the modern era, there has been an increasing threat to the quantity and quality of groundwater both from climatic and non-climatic factors (R.A. Aslam et al 2008). Data from studies show that the water cycle is being impacted by climate change (Buffoni et al. 2002; Labat et al. 2004; Huntington 2006; IPCC 2007). Thus, Water recharged during the dry period will have a higher concentration of salts and higher TDS (total dissolved solids) while during a wet period the reverse may occur (Sukhija et al. 1998). It is also possible to link the occurrence of certain ions in groundwater to water rock processes that occurred during specific past climatic periods.

The change in temperature, the increase of CO2 dissolved in rainwater and the change in rainfall pattern promotes a greater dissolution or precipitation of carbonate minerals in ground water resources. (Oliveira, J.). J. Oliveira further stated that Extreme drought conditions, increases the residence time of groundwater affecting its quality by increasing the reaction time of the water with the rocks.

Coal is often described as a broad name given to stratified accumulations of carbonaceous material derived from vegetation (Dixon and Leighton1969). It comes from organic matter subjected to intense heat and pressure for millions of years. In Enugu, SE Nigeria, coal originates as partly decomposed and macerated vegetation matter mainly as vascular land plants. Several shallow open hand-dug wells as well the deep wells are chosen at random at Independence Layout, Abakpa, Emene, and Uwani areas. the groundwater from the wells at these areas are mainly for domestic purposes. Hence, it is necessary to ascertain the physicochemical characteristics of water from these ground water resources in the coal rich area. This will help to know the quality of water in Enugu Urban.

Water Quality Index (WQI) is used to have summary of the overall quality of water sample (Adeyi and Majolagbe2014). It reduces the number of parameters used in monitoring water quality to a simple expression in order to facilitate interpretation of the data, allowing public access to water quality data. (P. Mădălina & I. G.

Breabăn 2018). Ji et al. (2016) compared seven different models of evaluating Water Quality Index and found out that Nemerow-Sumitomo Water Quality Index (NWQI), though robust, cannot effectively judge surface water quality when the water quality is worse than class 5. He further stated that the SFPI approach can easily provide water quality classification for the assessed water quality indexes. However, it uses the worst water quality classification of the assessed water quality indexes as the final water quality classification and gives biased results as a result.

The Weighted arithmetic index method was used in this research as it categorizes water quality according to the level of purity by using the commonly assessed water quality parameters. This method has been widely used by the various analysts (Chauhan and Singh 2010; Balan et al. 2012; and Hector et al. 2012).

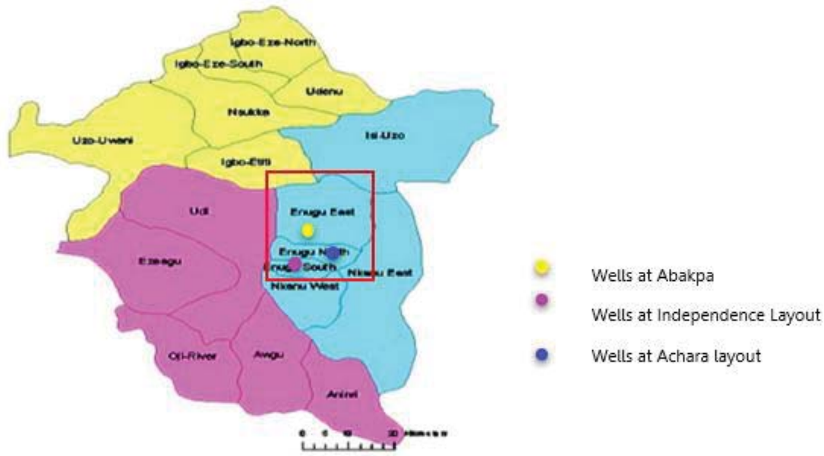

Fig. 1.0: Map of Enugu State, showing Study Area (Enugu Urban).

RESEARCH DESIGN & METHODS

Description of study area:

The Study Area is in Enugu urban which is the capital of Enugu State in South-Eastern Nigeria. It lies at latitude 6021′ to 6030′N and longitude 70 26′ to 7037′E of the equator. The climate of Enugu Urban is warm and humid with its humidity varying from 55-85% but reaches its peak at 75% between March and November. (Source: NIMET, 2017). The mean daily temperature used to be 26°C (80.1°F), but with current climate change phenomena it is now put 270C - 370C (NIMET, 2017). The rainy season lasts approximately from April till August and is accompanied by heavy humidity and heavy rain falls. Heaviest rainfall occurs between June and July, with around 360 mm in July. The annual rainfall in Enugu State is between 1500mm and 2000mm. (Source: NIMET, 2017). The survey of the selected areas at Achara Layout, Independence Layout, and Abakpa was conducted to identify sites for the sample collection.

Sampling and Sample Collection

The samples were collected from 4 sample points each in Achara layout, Independence Layout and Abakpa respectively. They samples were collected at monthly intervals for 12 months. Samples were collected 2 times; first week and last week of every month. The rainy season samples were collected from April 2018 to August 2018 while dry season samples were collected in the months of September 2018 to March 2019. A total of 12 samples were analyzed.

Each sample bottles and glassware were washed with phosphate-free detergent. They were kept in a clean environment with temperature maintained at approximately 4OC. The sample bottles were rinsed with the well water before they were filled. Groundwater samples from 12 wells were collected in a clean sterilized two-liter plastic bottle with tightly fitting covers; wrapped in black polyethylene bags and put in an improvised icebox. The samples for heavy metals were preserved by adding 5mL concentrated HNO3 to prevent metals from adhering to the walls of the containers. The filtration of samples was done using 0.45mm Millipore membrane paper placed in an all glass Millipore filtering system. The membrane filters were washed with 1% HNO3 followed by rinsing in high purity water prior to filtration (Meranger et al., 1997). After sampling, physical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and temperature were measured directly in a flow cell connected to a multi-parameter meter to avoid contact between the ground water and the atmosphere and then in situ using a new Hanna Multi-Meter with replaceable electrodes.

Table 1: Location of well water samples

Sample Designation	Metropolis
W 1	Achara Layout
W 2	Achara Layout
W 3	Achara Layout
W 4	Achara Layout
W 5	Independence Layout
W 6	Independence Layout
W 7	Independence Layout
W 8	Independence Layout
W 9	Abakpa
W 10	Abakpa
W 11	Akpaba
W 12	Akpaba

W - Well
Source: Author

Procedure

Biochemical oxygen demand (BOD), Chemical Oxygen Demand (COD), and pH was determined using standard method (AOAC, 1990 and Lenore et al., 1999). Temperature was measured using electrometric method (Lenore et al., 1999; G. P. Edwards et al., 1965; Murphy and Riley, 1962; Water quality monitoring, 1996). Total Acidity and Total Alkalinity of the water samples was determined using standard method (Titrimetric method) (AOAC, 1990 and Lenore et al., 1999). Total Suspended Solid (TSS) determined by gravimetric method. (AOAC, 1990 and Lenore et al., 1999). Total Dissolved Solids (TDS) was determined by direct reading using HANNA (Model HI 9811-5) multi-meter pre-calibrated according to manufacturer's instruction 10 mL of water sample was introduced into a 100 mL glass beaker. The probe was dipped into the beaker and the TDS mode activated by gently pressing on the meter's soft touch button. The value displayed at the LCD panel of the meter was left to stabilize before it was recorded. Total Solid (TS) was obtained by calculating the arithmetic sum of the TSS and TDS. Turbidity was determined using standard method (Nephelometric Method) (Lenore et al., 1999).

Sulphate (SO42-) was determined using Turbidimetric Method (AOAC, 1990 and Lenore et al., 1999). Total Hardness was determined using EDTA (Ethylenediaminetetraacetic acid) Titrimetric Method (AOAC, 1990 and Lenore et al., 1999). Electrical Conductivity was determined in accordance with IS 3025 (Part 14) test procedure. (Lenore et al., 1999). Potassium (K) and Sodium (Na) was determined by Flame photometric Method (APHA 3500-K Band APHA 3500-Na B standard methods respectively) (Lenore et al., 1999). Iron (Fe), Lead (Pb) and Zinc (Zn) were determined in accordance with standard procedure (AOAC, 1990 and Lenore et al., 1999):

Data analysis

Data were recorded, organized and summarized in simple descriptive statistics methods using SPSS-PC Statistical Package for Social Scientists (SPSS 20 for windows version).

Table 2: Results (Mean ± SD) and range of the concentrations for rainy season and dry season

S/N	Parameter	Seasons	Samples											
			W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
1	Temp	DS	30.8	31.8	31.3	30.	30.1	30.7	29.7	29.6	28.9	30.1	31.0	30.0
	(C)	WS	29.1	30.1	31.8	30.1	29.9	30.9	30.9	29.98	28.0	29.97	31.05	30.3
2	E.C.	DS	23.33	20.0	40.00	60.00	16.67	66.7	130.0	190.0	180.0	170.0	200.0	240.0
	(8µS/cm)	WS	63.33	23.3	123.3	236.7	20.00	236.7	305.4	202.7	201.6	200.9	244.6	300.6
3	pH	DS	5.01	5.01	4.90	5.3	5.2	5.4	6.9	6.6	7.2	7.1	7.2	7.5
		WS	4.63	5.01	5.17	4.1	4.9	4.8	4.7	6.0	5.0	5.2	5.8	6.3
4	TDS	DS	10.00	0.00	10.00	20.0	0.00	20.00	60.0	110.0	210.0	90.0	100.0	120.0
	(mg/L)	WS	93.33	3.3	43.3	53.33	6.66	220.0	200.0	111.8	216.7	100.0	183.3	135.0
5	TSS	DS	250.0	120.0	190.0	150.0	70.00	130.0	190.0	250.0	160.0	70.00	120.0	270.0
	(mg/L)	WS	256.7	130.0	200.0	173.3	103.3	140.0	247.2	260.0	166.7	153.3	130.0	273.3
6	TS	DS	260.0	120.0	200.0	170.0	70.0	150.0	250.0	360.0	370.0	160.0	220.0	390
	(mg/L)	WS	350.0	133.3	343.3	226.7	110.0	360.0	447.9	371.8	383.3	256.0	313.3	408.3
7	T/Ac	DS	0.357	0.153	0.237	0.067	0.203	0.327	0.237	0.355	1.233	0.203	0.167	0.603
	(mg/L)	WS	8.447	0.167	0.497	0.103	0.217	0.403	10.37	0.288	1.101	0.247	10.17	0.663
8	T.Al	DS	28.03	40.0	36.08	52.10	47.03	34.03	34.97	28.09	28.11	17.04	37.04	38.81
	(mg/L)	WS	26.03	29.0	30.07	52.03	47.00	28.67	15.37	26.75	28.00	20.03	20.17	25.00
9	SO42-	DS	21.18	20.1	22.13	20.11	22.16	24.18	21.14	21.16	23.20	22.00	20.14	22.40
	(mg/L)	WS	26.23	20.5	24.33	26.27	37.20	82.63	24.54	21.27	33.50	25.73	29.17	29.667
10	BOD	DS	5.07	5.7	5.9	5.607	5.973	4.893	4.6	4.2	4.27	3.14	5.56	5.40
		WS	4.17	5.1	4.1	4.647	5.760	4.037	3.95	3.94	3.79	4.22	4.37	3.67
11	COD	DS	6.883	7.190	9.587	7.380	7.393	8.670	6.4	5.87	6.430	6.617	7.673	7.257
		WS	5.007	6.550	4.937	5.447	7.047	4.947	4.9	4.81	4.847	5.327	5.260	4.567
12	Fe	DS	0.068	0.079	0.280	0.762	0.002	0.456	0.066	0.06	0.096	0.092	0.828	1.608
	(mg/L)	WS	0.077	0.023	1.324	1.087	0.000	1.651	0.072	0.04	0.124	0.095	0.048	0.066
13	Pb	DS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(mg/L)	WS	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	Zn	DS	2.640	0.02	0.861	0.010	0.021	2.392	2.449	13.84	0.031	0.156	3.000	2.858
	(mg/L)	WS	2.857	0.03	2.120	0.081	0.025	3.387	2.817	14.10	0.045	0.172	2.931	2.858
15	Na	DS	10.02	3.31	12.32	2.037	6.013	3.123	10.01	1.43	10.18	17.01	13.96	18.62
	(mg/L)	WS	12.20	3.42	13.34	2.137	6.077	4.153	12.02	2.33	15.19	17.12	14.10	19.04
16	K	DS	6.006	1.907	7.080	8.370	0.630	0.000	6.00	9.27	12.01	9.270	6.533	8.063
	(mg/L)	WS	10.12	2.087	11.14	11.03	1.327	12.02	10.10	13.21	11.01	10.04	11.19	14.00±
17	Turb.	DS	8.70	4.27	5.05	4.50	3.45	4.75	8.70	8.90	8.95	4.70	4.74	50.00
	(NTU)	WS	8.86	4.29	5.86	4.86	3.83	4.82	8.81	10.90	10.03	4.98	4.86	55.67
18	T/Hard(mg/	DS	126.0	130.1	140.0	120.1	125.0	100.0	125.9	100.4	100.11	105.19	130.1	110.0
	L)	WS	110.0	120.0	126.7	110.0	120.0	100.0	100.0	100.0	19.9	7.2	101.7	97.5

Source: Author
Legend:
Turb. = Turbidity. NS =Not Stated. Temp.= Temperature. TDS = Total Dissolved Solids. TSS= Total Suspended Solids.
TS= Total Solids. BOD= Biochemical Oxygen Demand. COD= Chemical Oxygen Demand. E.C. = Electrical Conductivity. T/Ac. = Total Acidity. T/Al. = Total Alkalinity. T/Hard. = Total Hardness. BH= Borehole

Results were analyzed using this statistical software analyses and presented in descriptive statistics such as Analysis of Variance (ANOVA) in office excel, twofactor analysis to determine significance at p (0.05), Dunnett's t-test (Post Hoc test) of multiple comparison and Pearson correlation measures at (0.05 and 0.01 significant levels).

Table 2.2: Total Parameter Mean and Range of The Concentrations in The Samples for Rainy Season and Dry Season

	Parameter	Seasons	Total Parameter Mean	Total Parameter Range	Standard Permissible level
1	Temp	DS	30.4	29.0 - 31.9	25.0(ambient)
	(C)	WS	30.32	29.00 - 31.90	
2	E.C.	DS	133.9	10.00 - 410.0	#1000
	(8µS/cm)	WS	189.6	10.00 - 360.0	
3	pH	DS	6.13	4.90 - 7.50	†*#8.5
		WS	5.40	4.00 - 7.20	
4	TDS	DS	62.50	0.000 - 210.0	†#500.0
	(mg/L)	WS	127.4	0.000 - 260.0	
5	TSS	DS	164.2	70.00 - 270.0	NS
	(mg/L)	WS	186.7	100.0 - 280.00	
6	TS	DS	226.7	70.00 - 390.0	†#500.0
	(mg/L)	WS	311.8	110.0 - 560.0	
7	T/Ac	DS	0.347	0.060 - 1.240	ª 0.300
	(mg/L)	WS	2.739	0.100 - 10.50	
8	T.Al	DS	36.48	28.00 - 22.10	80.00
	(mg/L)	WS	29.07	10.00 - 52.10	
9	SO42- (mg/L)	DS	21.78	20.10 - 24.34	†*#200.0
		WS	31.27	0.000 - 100.0	
10	BOD	DS	5.155	3.140 - 6.370	†*3.000
		WS	4.288	2.880 - 6.100	
11	COD	DS	7.541	5.840 - 10.51	†*294.0
		WS	5.207	3.490 - 7.450	
12	Fe	DS	1.244	0.000 - 11.03	#0.300
	(mg/L)	WS	1.499	0.000 - 12.29	
13	Pb	DS	0.000	0.000 - 0.000	†#0.010
	(mg/L	WS	0.000	0.000 - 0.000	
14	Zn (mg/L)	DS	1.317	0.010 - 3.000	†*#3.000
		WS	1.437	0.020 - 3.610	
15	Na	DS	11.81	0.000 -22.44	#200.00
	(mg/L)	WS	11.97	0.000 - 21.28	
16	K	DS	6.408	0.000 - 12.03	ª 10.00
	(mg/L)	WS	10.17	1.320 - 15.11	
17	Turb.	DS	9.743	3.450 - 50.00	†#5.000
	(NTU)	WS	10.80	3.800 - 56.00	
18	T/Hard	DS	111.7	100.0 - 140.1	#150.0
	(mg/L)	WS	118.9	100.0 - 130.0	

Source: Author
Legend:
Turb. = Turbidity. NS =Not Stated. Temp.= Temperature. TDS = Total Dissolved Solids. TSS= Total Suspended Solids.
TS= Total Solids. BOD= Biochemical Oxygen Demand. COD= Chemical Oxygen Demand. E.C. = Electrical Conductivity. T/Ac. = Total Acidity. T/Al. = Total Alkalinity. T/Hard. = Total Hardness. BH= Borehole
† Values are given by World Health Organization.
**Values are given by National Agency for Food and drugs Administration and Control.*
 # Values are given by Nigerian Standard for Drinking Water Quality (NSDWQ).
ª Value is given by the European Union (EU).

Water quality grading method

The weighted arithmetic WQI method was applied to assess water suitability for drinking purposes. (Yisa J. 2010, Nwachukwu R. et al 2019). In this method, water quality rating scale, relative weight, and overall WQI were calculated by the following formulae:

$qi=(Ci/Si) \times 100$

where q i, = quality rating scale

C i, = concentration of i th parameter

S i = standard value of I th parameter

Relative weight was calculated by $wi=1/Si$,

where the standard value of the i parameter is inversely proportional to the relative weight.

WQI was calculated according to the following expression:

$WQI=\sum qi\, wi/\sum wi$ where:

WQI = water quality index;

Qi = sub index for the i th water quality parameter;

Wi = weight associated with the i th water quality parameter; n = number of water quality parameter.

Table 3: shows the Water Quality Index (WQI) and quality ratings of the 12 well water samples

S/N	Well Samples	WQI (Dry Season)	Quality Rating	WQI (Wet Season)	Quality Rating
1	W1	26.31	Excellent Water	88.18	Good Water
2	W2	51.29	Good Water	99.35	Good Water
3	W3	93.51	Good Water	99.35	Good Water
4	W4	85.26	Good Water	91.6	Good Water
5	W5	61.68	Good Water	87.56	Good Water
6	W6	82.00	Good Water	105.60	Poor Water
7	W7	64.32	Good Water	122.54	Poor Water
8	W8	97.46	Good Water	102.60	Poor Water
9	W9	150.08	Poor Water	234.58	Very Poor Water
10	W10	100.53	Good Water	163.94	Poor Water
11	W11	82.6	Good Water	135.35	Poor Water
12	W12	150.08	Poor Water	234..58	Very poor water

Source: Author

There was a significant difference between the overall physicochemical water quality index of the study are during dry season and rainy season.

Table 4: Water Quality Index (WQI) range and percentage of different water types

S/N	WQI Range	Type of Water
1	< 50	Excellent water
2	50-100	Good water
3	100-200	Poor water
4	200-300	Very poor water
5	>300	Unsuitable

RESULTS AND DISCUSSION

Temperature

The highest temperature value of 31.9OC observed, was the same for both dry season (in W2) and rainy season (W3) seasons. Lowest temperature recorded was 29.0OC during dry season (W9) and rainy season (W1 and W9). The mean temperatures were 30.4±0.7 and 30.3±0.8 during dry season and rainy season respectively indicating moderate temperature stability in the ground water aquifers and a slight decrease at rainy season due to seasonal changes. The slightly elevated values of temperature during dry season could be due to thermal storage of solar energy. Temperature values obtained in this study were also above ambient level (250C) of the Nigerian Standard for Drinking Water Quality (NSDWQ) recommended by the Standard Organization of Nigeria (SON) (Nigeria Industrial Standard, 2007) indicating thermal pollution.

pH:

Most of the water samples indicated acidic pH values. In dry season, the pH range recorded was 4.9 - 7.5 in all the 12 boreholes water samples with a mean value of 6.13±1.0. During rainy season, pH ranged from 4.00- 7.20 with a mean value of 5.403±0.854 indicating a seasonal decrease in pH which may be due to increased infiltration of aquifers with water containing chemical fertilizers, municipal and industrial wastes. A physicochemical and microbial analysis of potable water sources in Enugu Urban in early 2015 revealed similar acidic pH values of 2.1, 4.3, 2.0, 4.2, 4.8 and 5.0 in five boreholes (Engwa et al., 2015). The mean values obtained in this study during dry season and rainy season fall outside the highest desirable level of 7.00- 8.50, maximum permissible level of 6.5-9.2 set by WHO guidelines for drinking water quality (WHO, 2008; WHO, 2006) and maximum tolerance level of 6.50 – 8.50 recommended by NAFDAC (NIS, 2007) and the NSDWQ (NAFDAC, 1999) by SON. Hence, indicating unsafe acidic drinking water capable of leaching metal ions such as Cu, Pb and Zn from plumbing fixtures, and aquifers.

Electrical conductivity:

Electrical Conductivity ranged from 10.000- 410.0 µS/cm in water samples studied during dry season and 10.00- 360.0 µS/cm during rainy season study. The mean values for dry season and rainy season studies were 133.9±120.3 µS/cm and 189.6±107.7 µS/cm respectively, indicating a seasonal change in electrical conductivity (an increase in rainy season conductivity mean value) which may be due to a rise in the content of ionizable materials transported into the groundwater. Generally, all the water samples showed electrical conductivity values below the standard maximum permissible level of 1000 µS/cm (NIS, 2007) recommended for potable water.

TDS, TSS and TS

As shown in Table 2.0, TDS ranged from 0.000- 210.0 mg/L with a mean value of 62.50±64.97 mg/L in dry season. The rainy season TDS results range was 0.000- 260.0 mg/L with a mean value of 127.4±81.13 mg/L indicating an increase in total dissolved solid in the rainy season water samples which may be due to increase in the concentration of soluble species from the environment entering the water. In 2011, Ani et al characterized industrial effluents in Enugu, Nigeria and recorded high concentrations level of total dissolved solids in effluents from beverage and fibre-cement plants. The values of TDS obtained in this study were all below the recommended value of 500 mg/L for TDS in potable water set by standard bodies (NIS, 2007; WHO, 2008; WHO, 2006). The range of values for total suspended solid (TSS) during dry season was 70.00-270.0 mg/L with a mean concentration of 164.2±67.62 mg/L. During the rainy season, TSS range was 100.0- 280.0 mg/L with a mean concentration of 186.7±60.03 mg/L. Total Solids (TS) during dry season ranged from 70.00 - 390.0 mg/L and had a mean concentration of 226.7±103.1 mg/L but had a concentration range of 110.0 - 560.0 mg/L and mean of 311.8±120.7 mg/L during rainy season indicating a seasonal increase in TS content. However, the mean value obtained for the TS in this study were below the standard value of 500 mg/L (WHO, 2008; WHO, 2006) recommended by W.H.O. but above the NAFDAC set value of 100 mg/L (WHO, 2008) recommended for drinking water quality.

Turbidity
Turbidity at dry season ranged between 3.450- 50.00 NTU with a mean value of 9.743±12.86. At rainy season the range was 3.800- 56.00 NTU and mean of 10.80±14.37 NTU, indicating a very slight (perhaps due to relative decrease in ground water flow rate) increase in turbidity. The increase in TSS and turbidity may be due to increase in silt and clay carried into groundwater by rainfall runoff on the landscape. The mean turbidity values were higher than the highest desirable level of 5 NTU recommended by standard bodies (NIS, 2007; WHO, 2008; WHO, 2006).

Sulphate (SO42-)
SO42- range between 20.10- 24.34 mg/L at dry season and 0.000- 100.0 mg/L in rainy season. The mean SO42- contents were 21.78±1.267 mg/L and 31.27±16.95 mg/L during dry season and rainy season respectively showing an increase in sulphate concentration. The concentration of sulphate during both seasons was below the recommended value of 200 mg/L (NAFDAC, 1999; WHO, 2008) set by standard regulatory bodies. Studies in other parts of South-east Nigeria and Enugu in the past agree with the similar finding that sulphate content in a borehole water content is below the recommended value (Okoye et al., 2010; Edeonovo, 2010; Onunkwo and Uzoije, 2011).

Total acidity
The range of concentration of total acidity was between 0.060- 1.240 mg/L at dry season and 0.100- 10.50 mg/L at rainy season. There was seasonal variation in total acid contents in the borehole water as the mean acidity concentration increased from 0.347±0.311 mg/L at dry season to 2.739±4.222 mg/L at rainy season. This increase in acidity loading could be due to flushing and percolation of water containing dissolved acidic radicals into the groundwater. The range of total acidity in borehole water in Enugu State, Nigeria as observed by a previous study (Engwa et al., 2015) showed similarities in acid content with the range of total acidity concentrations observed in the dry season result of this study. The mean total acid content of the water samples in this study during dry season and rainy season were within standard guideline values for total acidity in drinking water (WHO, 2011).

Total alkalinity
The respective ranges of total alkalinity during dry season and rainy season are 28.00- 22.10mg/L and 10.00 - 52.10 mg/L. As acidity increased, there was a

corresponding drop in the mean total alkalinity contents from 36.48±7.398 mg/L during dry season to 29.07±10.56 mg/L at rainy season. This noticeable seasonal variation in alkalinity may be due to chemical processes in the groundwater resulting from farming activities. The range of values as well as mean total alkalinity content obtained in the water samples of this study were within the standard recommended guidelines values (NAFDAC, 1999; WHO, 2011). Similar findings were made in the study of total alkalinity in borehole water samples in Enugu and parts of South-east (Okoye and Adiele,2014) as well as some other parts of Nigeria (Edeonovo, 2010) during dry season and rainy season (Amangabara and Ejenma 2011).

Total hardness

Total hardness remained fairly the same at both seasons. Its dry season range recorded was 110.1- 110.2 mg/L with a mean of 110.1±0.058 mg/L and rainy season results ranged between 100.0- 110.0 mg/L with a mean value of 118.9±15.27 mg/L. The similarity in total hardness in all the samples could be due to the general hydrogeology, geochemistry and soil conditions of the area. The range and means of total hardness concentrations in all the water samples obtained during dry season and rainy season were below the recommended guideline value of 150 mg/L as contained in the NSDWQ (NIS, 2007). Past data also showed lower hardness concentrations in borehole water in Enugu state and some parts of south-east Nigeria when compared to the recommended guideline value (Okoye et al., 2010; Onunkwo and Uzoije, 2011) but was above the set guideline value in some borehole water samples in Ebonyi area of Nigeria (Omaka et al., 2015)

BOD5

In the dry season, the lowest BOD5 value of 3.140 mg/L was recorded in the water samples from W 10 and the highest value of 6.370 mg/L was recorded in W 3. The mean BOD5 value for all the 12 boreholes water during dry season period was 5.155±0.822. During rainy season, BOD5 ranged from 2.880 mg/L in W 7 to 6.100 mg/L in W 5. The mean BOD5 value for all the 12 wells during rainy season period was

4.288±0.703 as shown in Table 2. The higher BOD mean value of 5.155±0.822 and. 288±0.703 during dry season could be due to percolation of biodegradable organic matter and leaching of inorganic iron and/or manganese into groundwater aquifers. From the BOD5 results in this study, it can be concluded that the ground water in the area studied is generally polluted due to high biochemical oxygen demand during dry season and rainy season periods and may be unfit for drinking since the range of BOD5 values is above the maximum permissible level of 3.00 mg/L recommended by National Agency for Food and drugs Administration and Control (NAFDAC) (NAFDAC, 1999). and World Health Organization (WHO) (WHO, 2008).

COD

As shown in Table 2, the mean COD content was higher during dry season (7.541±1.085) than in the rainy season (5.207±0.879 mg/L) with values ranging from 5.840 mg/L (lowest in W 8) to 10.51 mg/L (highest in W 7) at dry season and 3.490 mg/L (lowest in W 7) to 7.450 mg/L (highest in W 5) at rainy season. The higher mean COD content at dry season may be due to prolong accumulation of seeped organic leachates into the aquifers.

Fe

The levels of Fe in the water samples during dry season and rainy season were in the range between 0.000 - 11.03 mg/L and 0.000 - 12.29 mg/L respectively. The dry season and rainy season Fe mean concentrations were 1.244±2.978 mg/L and 1.499±3.448 mg/L indicating a slight rise in iron content during rainy season; and these were above the recommended guideline value of 0.30 mg/L (NIS, 2007). Similar findings include Nwachukwu et. al (2014) that recorded higher iron concentrations in shallow hand dug wells, lake/ponds and rivers in some rural regions of South-east Nigeria, Uzoije, et al., (2014) recorded high Fe content in shallow aquifers (hand-dug wells and springs of the discharge farmland settlement) and some deep aquifers (boreholes) in Nsukka south-east (Uzoije et al., 2014).

Zn:

Zn content was in the range between 0.010- 3.000 mg/L during dry season and 0.020- 3.610 mg/L in rainy season. The mean Zn content slightly increased from 1.317±1.251 mg/L recorded in dry season to 1.437±1.422 mg/L in rainy season. The mean Zn content was below the maximum permissible level of 3.00 mg/L set by WHO (WHO, 2008; WHO, 2006; WHO, 2011) NAFDAC (NAFDAC, 1999) and SON (NIS, 2007). This low content of Zn in most of the water samples could be due its low solubility in water but Zn is used in some fertilizers which may leach into groundwater. Similar studies also recorded low Zn content in borehole water from Enugu urban (Edeonovo, 2010) and Imo State (Okoye and Adiele 2014).

Na:

Na concentration ranged between 0.000- 22.44 mg/L and between 0.000- 21.28 mg/L during dry season and rainy season respectively. The mean Na contents during both seasons are considerably comparable: a dry season value of 11.81 ± 6.608 mg/L and a rainy season value of 11.97±6.193 mg/L. The mean values were below the recommended maximum permissible level of 200 mg/L set by SON (NIS, 2007) and the European Union (EU) (EU, 2014). Similar results were recorded in Imo (Okoye and Adiele, 2014) and Nsukka south-east (Uzoije et al., 2014).

K:

During dry season the range of potassium in the water samples was 0.000-12.03mg/L and in rainy season, it was 1.320-15.11 mg/L. The mean content of K increased from 6.408±3.711 to 10.17±4.240 mg/L. This may be due to the leaching of dissolved potassium from fertilizers into groundwater during the rainy season planting season. The content of potassium in some hand-dug wells and springs of discharge farmland settlement in Nsukka south-east were in the range of 0.000-10.0 mg/L (Uzoije et al., 2014) while another report showed a range of 1.00 – 12.00 mg/L potassium in borehole water from Imo State (Okoye and Adiele 2014).

CONCLUSION

The findings of this study revealed a significant difference in the quality of the 12 cluster groundwater samples studied in dry and rainy season. The Water Quality

Index (WQI) of the water samples study are arranged from 26.31 to 150.08 in dry season and 87.56 to 234.58 in rainy season. In both seasons, the WQI status was excellent to very poor in ranking. The groundwater samples in areas like Achara layout are most suitable compared to areas like Independence Layout and Abakpa. The groundwater was generally acidic in both seasons but decreased during the rainy season with a corresponding pH drop. Turbidity in some samples was above the guideline value. Total hardness and sulfate also increased during rainy season.

The change in frequency, intensity and patterns in rainfall, as well as change in temperature has implications for replenishment of groundwater storage. However, groundwater-residence times can range from days to tens of thousands of years or more, which delays and disperses the effects of climate and challenges efforts to detect responses in the groundwater to climate variability and change. Hence, understanding the potential effects of climate change on groundwater is more complex than it is on surface water. The decrease in annual rainfall will translate to a reduction in of ground water recharge. the sea-level rise that comes with climate change will reduce the freshwater supply in many areas, by infiltrating groundwater making it undrinkable without excessive treatment. This shows that the impact of climate change on groundwater may be in terms of quality such as deterioration of water by saline intrusion or in terms of reduction of ground water quantity.

It is important to conserve vegetation, particularly forests as these reduce greenhouse gas emissions as well as surface water runoff, thus reducing groundwater recharge. climate Change can be said to affect ground water resources indirectly by reducing recharge, discharge and the water quality.

Based on the findings of this study, the following recommendations are made:

1. Since the BOD of the water samples from all the 12 boreholes were above standard limits, contamination may be due to biological or microbial sources, hence, a study of bacteriological parameters should be conducted in Enugu Urban.
2. Before using water from borehole sources in the study area for drinking, it should be assessed and/or treated for their content of BOD, nitrate, phosphate, pH, iron, potassium and possibly content of bacteriological parameters.
3. Since there are seasonal fluctuations in the ground water quality parameters in Enugu urban, regular water quality tests need to be conducted to measure the trends of variability of the water quality parameters. This will also help to further ascertain the causes and permanence of spatial variability of the borehole water quality as well as contribute to establishing the geochemical features of the area.
4. The government should also collaborate with relevant institutions to regularly conduct seasonal and routine studies of water quality from various sources, especially ground water.

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