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RESEARCH ARTICLE

APPLICATION OF WATER QUALITY INDEX TO EXAMINE THE SUITABILITY OF BOREHOLE WATER QUALITY FOR DRINKING PURPOSES IN AFIKPO SOUTH LOCAL GOVERNMENT AREA, EBONYI STATE, NIGERIA

*,1,2Ibiam, J. A., [1]Afiukwa, J. N., [2]Oti Wilberforce, J. O., [1]Ezem, S. N. and [1]Ugbo, U. I.

[1]Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, P.M.B. 1007 Afikpo, Ebonyi State Nigeria

[2]Department of Industrial Chemistry, Ebonyi State University, P.M.B 053, Abakaliki, Nigeria

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ABSTRACT

Water quality index (wqi) was applied to study the quality and suitability of the borehole water for drinking purposes in afikpo south local government area. This was carried out by subjecting samples collected from eight locations by analyzing the physico-chemical parameters according to apha (1998) methods. Ten parameters such as the colour, temperature, ph, electrical conductivity (ec), total dissolved solids (tds), total alkalinity (ta), total hardness (th), dissolved oxygen (do), chemical oxygen demand (cod), ci^-, so_4^{2-}, no_3^-, na^+, ca^{2+} and mg^{2+} were calculated for wqi . Results were presented in mean and standard error. The results obtained for wqi varied 121.57 – 186.68 for dry season and 101.59-167.82 for rainy season. The results indicate that borehole water in all the locations were unsuitable for drinking and need treatment. The deterioration of the water quality may have been contributed by the pollutants that were leached from the refuse dumps and agricultural practices which might have concentrated over a period of time and percolated into the aquifer.

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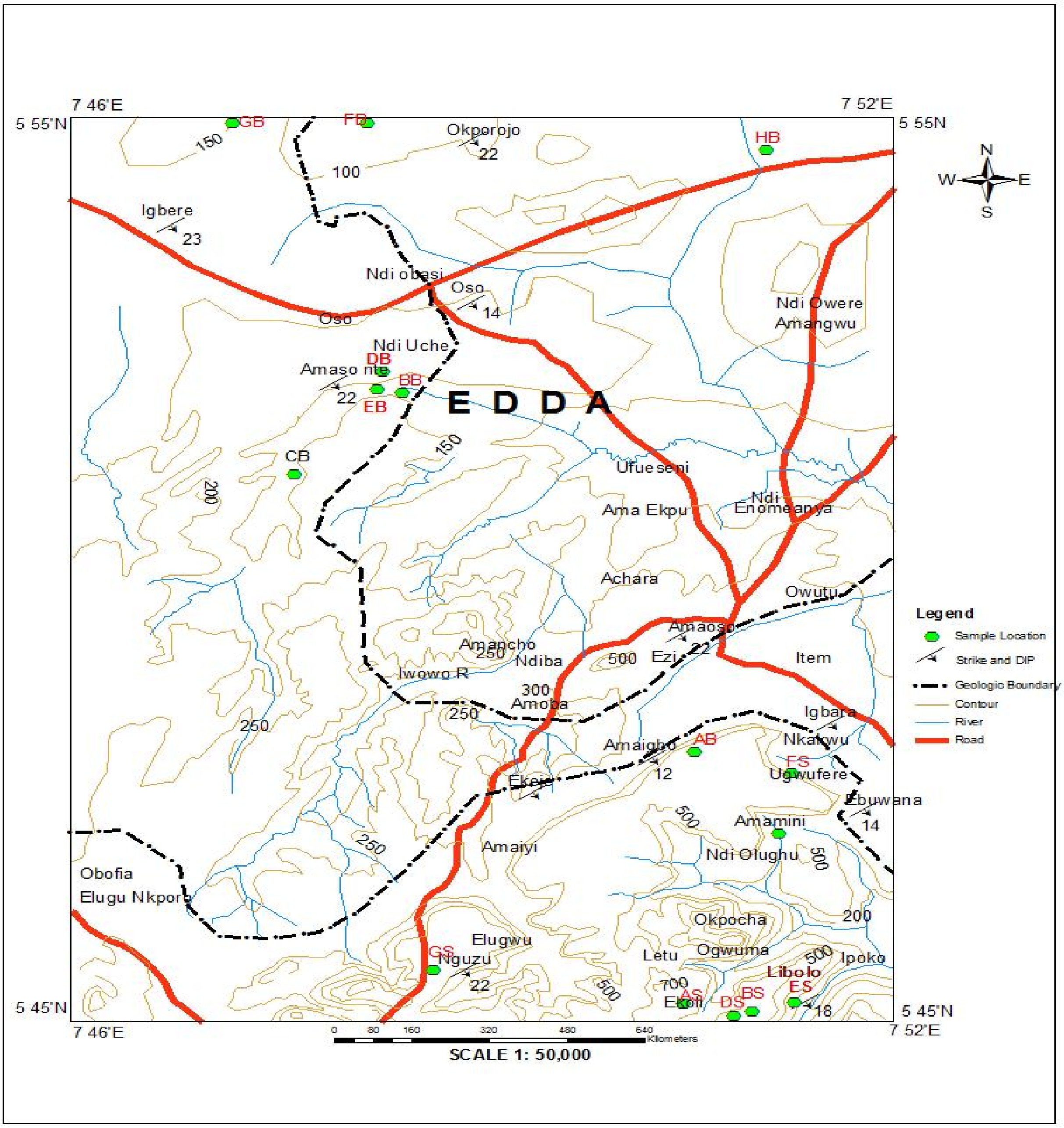
INTRODUCTION

Water quality index (WQI) is a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water for human consumption Mishra (1998). It is a single number that expresses water quality by aggregating the measurements of water quality parameters such as DO, pH, NO_3^-, Cl^-, total hardness, metals etc. WQI is regarded as one of the most effective way to communicate water quality. Water quality is assessed on the basis of calculated water quality indices Sinha and Ritesh (2006) and Sinha, Saxena and Saxena (2004).The WQI though developed by the Yale Center for Environmental Law and Policy is one of the indicators that make up the environmental Performance Index, Yale Center (2012). The concept of water quality indices is based on the comparison of the water quality parameter with respective regulatory standards. It is proximity-to-target composite of water quality, adjusted for the density of monitoring stations in each country, with a maximum score of 100.Usually the lower score alludes to better water quality (excellent, good) and higher score to degraded quality (bad, poor). Water quality and its suitability for drinking purpose can be examined by determining its WQI. The health and wellbeing of humans and ecosystems depend heavily on the quality of the water resources available. Water quality is at risk from poorly treated municipal waste, industrial effluent, and fertilizer run-off from agriculture.

The standards for drinking water, such as, WHO (2006) and Indian Standard (1992) have been considered for calculation of WQI. Parameters are often then weighted according to their perceived importance to overall water quality and the index is calculated as the weighted average of all observations of interest Liou, Lien and Wang (2004). In this method the weightage for various water quality parameters is assumed to be inversely proportional to the recommended standards for the corresponding parameters Mishra and Patel (2001). This research examined physicochemical parameters and water quality index of borehole water supplies in Afikpo South Local Government area.

****Corresponding author: Ibiam, J. A.***
Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, P.M.B. 1007 Afikpo, Ebonyi State Nigeria.



Source: Cartographic Unit, Depatriment of Geology, Ebonyi State University

Fig. 1. Map of Afikpo South LGA Showing Sample Locations

MATERIALS AND METHODS

Water samples were collected for physico-chemical analysis from Amaukabi (AB), Nde-Okpo (BB), Amaosonta (CB), Nde-Obasi (DB) and Oso-Tech (EB), Okporojo Secondary School (FB), Ogiri (GB) and Ameta (HB) (Fig. 1 and Table 1). Standard methods were observed in the collection of the samples. The samples were collected with one litre plastic bottles and preserved till the parameters were analyzed in laboratory. Water samples were analyzed for colour, temperature, pH, EC, TDS, Total Alkalinity, Total Hardness, Cl^-, SO_4^{2-}, NO_3^-, dissolved oxygen (DO), chemical oxygen demand (COD), Na^+, Ca^{2+} and Mg^{2+} according to APHA (1998) methods.

In this study, calculation of water quality index was based on twelve important physico-chemical parameters. The WQI were calculated using WHO (2006) and BIS (1992) drinking water standards (Table 2).

Table 1. Locations, Codes and GPS Co-ordinates of the sample sites

Sample locations	Codes	Elevation (m)	Latitude (N)	Latitude (E)
Amaukabi	AB	58.00	05°48'37.10"	007°51'10.40"
Nde-Okpo	BB	70.70	05°52'01.700"	007°48'50.30"
Amaosonta	CB	58.00	05°51'21.80"	007° 47'35.80"
Nde-Obasi	DB	70.60	05°52'45.00"	007°48'55.60"
Oso Tech.	EB	59.80	05°52'10.00"	007°47'48.00"
Okporojo Sec. Sch.	FB	40.90	05°55'40.90"	007°48'33.20"
Ogiri	GB	37.00	05°54'56.50"	007°47'37.50"

Table 2. WHO (2006) and BIS (1992) Drinking water standards

Parameters	Recommended Agency	Standard
Colour	WHO	15
Temperature	WHO	30
Ph	BIS	6.5-8.5
Electrical conductivity	BIS	250
Total dissolved solids	WHO	500
Total alkalinity	WHO	500
Total hardness	WHO	500
Dissolved oxygen	WHO	4
Chemical oxygen demand	WHO	10
CI-	BIS	250
SO_4^{2-}	WHO	500
NO_3^-	WHO	50
Na^+	WHO	200
Ca^{2+}	WHO	200
Mg^{2+}	WHO	150

$$WQI=\sum_{n=1}^{n}\frac{WiQi}{\sum_{n=1}^{n} Wi}$$ ----- Equation 1

Where Wi = Unit weightage of i^{th} parameters, Qi = sub-index of the i^{th} parameter, n = is the number of parameters considered. Weighted arithmetic index method has been used for calculation of HPI. The unit weight (Wi) has been found out by using formula

$$Wi=\frac{K}{Si}$$ ------Equation 2

Where K = proportionality constant, Si = standard permissible value of i^{th} parameter. The sub-index of (Qi) of the parameter is calculated by

$$Qi=\sum_{n=1}^{n}\frac{|Mi-li|}{Si-li}$$ -----Equation 3

Table 3. Descriptive Statistics of the Physicochemical Parameters of Borehole Water Samples in Afikpo South Local Government Area

Parameters	Season	Range	Mean	SE	CV	Control	WHO Standard (2011)
Colour, mg/l Pt	Dry	5.17 – 9.50	8.69	0.52	0.22	3.58	15
	Rainy	5.20 – 10.15	8.02	0.49	0.17		
Temp, °C	Dry	27.00 – 30.00	29.13	0.41	0.04	27.8	30
	Rainy	29.40 – 33.50	30.74	0.52	0.05		
pH	Dry	5.80 – 6.70	6.11	0.09	0.04	6.30	6.5 – 8.5
	Rainy	5.60 – 6.40	6.10	0.11	0.05		
EC, µS/cm	Dry	54.30 – 2450.00	715.55	246.32	0.97	14.67	250
	Rainy	299.00 – 2120.00	795.88	185.11	0.66		
TDS, mg/l	Dry	178.90 - 1830.00	549.38	176.45	0.90	8.76	500
	Rainy	200.00 – 1530.00	530.63	140.02	0.75		
Turbidity, NTU	Dry	0.50 – 1.50	1.00	0.09	0.25	1.25	5
	Rainy	0.50 – 3.50	1.75	0.33	0.54		
Total Alkalinity, mg/l	Dry	150.00 – 2080.00	791.25	206.78	0.74	18.00	500
	Rainy	64.00 – 1470.00	188.75	43.48	0.65		
Total hardness, mg/l	Dry	18.00 – 170.00	118.75	16.17	0.40	55.00	500
	Rainy	76.00 – 454.00	244.25	43.22	0.56		
DO, mg/l	Dry	5.37 – 7.41	6.73	0.24	0.10	7.43	< 4.0
	Rainy	6.02 – 7.84	6.80	0.18	0.08		
BOD, mg/l	Dry	0.80 – 12.80	4.50	1.19	0.75	0.40	NG
	Rainy	bdl – 2.40	1.09	0.22	0.58		
COD, mg/l	Dry	18.82 – 47.04	29.40	2.97	0.29	2.00	20
	Rainy	bdl – 13.80	6.19	1.17	0.54		
Na^+	Dry	3.25 – 42.32	14.77	4.00	0.86	1.40	200
	Rainy	2.32 – 35.22	11.24	4.00	0.94		
Ca^{2+}	Dry	0.93 – 26.77	6.92	3.10	1.19	0.20	200
	Rainy	1.88 – 13.69	4.16	1.60	1.01		
Mg^{2+}	Dry	0.45 – 6.88	2.61	0.78	0.79	0.10	150
	Rainy	0.15 – 4.45	1.98	0.59	0.79		

Calculation of Pollution Index

The water quality indices are useful and relatively easy way to assess the composite influence of overall pollution. Water quality indices make use of a reproducible series of judgments to compile the effects of all the pollution parameters. For the physicochemical contaminants, the water quality index was calculated by the method developed by Mohan, Nithila and Reddy (1996). The average mean concentrations of the physicochemical parameters such as pH, EC, TDS, total alkalinity, total hardness, Cl^-, SO_4^{2-}, PO_4^{3-}, NO_3^-, Na^+, Ca^{2+} and Mg^{2+} were used for the calculation of water quality index. The critical quality index considered unacceptable is 100.

The WQI is calculated from the equation 1

Where Mi = is the monitored value of i^{th} parameter, li = is the ideal value of i^{th} parameter which is taken from the Indian drinking water specification Indian Standard (1992), IS 10500), Si = is the standard value of the i^{th} parameter, in ppb. The higher the value of WQI the greater the damage to health. Generally, the critical WQI value is 100 (Table 4).

RESULTS AND DISCUSSION

The result of the physicochemical parameters of the borehole water samples are presented in Table 3. The result showed that colour during the dry and rainy seasons ranged 5.17 ± 0.24 - 9.50 ± 0.42 mg/l Pt and 5.20 ± 0.094 - 10.15 ± 0.07 mg/l Pt, respectively and they were below the WHO (2011) standard for drinking water (15 mg/l Pt). The result implies that there is an absence of decomposed vegetative, colloidal and organic materials.

Table 4. Water Quality Index and Quality of Water Asuquo and Etim (2012)

Water Quality Index Level	Water Quality Status
0-25	Excellent
25-50	Good
51-75	Poor
76-100	Very poor
>100	Unsuitable for drinking

temperature enhances the growth of microorganisms Okoye and Okoye (2008). The results of the pH were outside the range of WHO (2011) drinking water standard of 6.5 - 8.5 with exception of Okporojo Secondary School. The results were in accord with the mean values of 5.70 and 6.12 findings of Ayedun *et al.* (2011) and Omoboriowo *et al.* (2012), respectively. It is reported in Afiukwa (2010) that pH levels below 6.0 show sign of acidity and are not potable.

Table 5. WQI calculations of Borehole water samples during dry season based on WHO drinking water standards

	Locations							
Parameters	AB	BB	CB	DB	EB	FB	GB	HB
Colour	0.067	3.05	2.76	2.31	2.31	3.65	3.2	4.24
Temp	3.3	3.3	2.97	3.3	3.33	3.33	3.08	3.08
Ph	7.98	8.53	8.12	8.4	8.4	9.8	8.12	8.12
EC	0.087	0.69	0.43	1.29	0.16	3.92	1.04	1.04
TDS	0.15	11.72	0.072	0.22	0.092	0.73	0.18	0.18
DO	33.56	40.44	48.25	40.44	40.38	43.19	44	44
COD	28.22	23.52	28.22	37.63	23.52	18.82	47.01	47.01
TA	2.75	0.048	1.5	4.95	7	20.8	9.4	9.4
TH	0.054	0.058	0.037	0.063	0.074	0.007	0.058	0.058
Cl^-	0.2	0.17	0.2	0.14	0.17	1.68	0.11	0.11
SO_4^{2-}	0.021	0.035	0.032	0.035	0.01	0.052	0.032	0.032
NO_3^-	0.063	0.06	0.1	0.008	0.058	0.055	0.063	0.063
Na^+	0.023	0.082	0.046	4.55	0.053	4.55	0.1	0.1
Ca^{2+}	0.053	0.17	0.07	14	0.075	0.007	0.12	0.12
Mg^{2+}	0.061	0.017	0.029	0.022	0.016	0.005	0.061	0.061
$WQI = \frac{\sum WiQi}{\sum Wi}$	$= \frac{\sum 76.59}{0.63}$	$= \frac{\sum 91.89}{0.63}$	$= \frac{\sum 92.84}{0.63}$	$= \frac{\sum 117.36}{0.63}$	$= \frac{\sum 85.65}{0.63}$	$= \frac{\sum 110.60}{0.63}$	$= \frac{\sum 116.57}{0.63}$	$= \frac{\sum 117.61}{0.63}$
	= 121.57	= 145.86	= 147.37	= 186.29	= 135.95	= 175.56	= 185.03	= 186.68

Table 6. WQI calculations of Borehole water samples during rainy season based on WHO drinking water standards

	Locations							
Parameters	AB	BB	CB	DB	EB	FB	GB	HB
Colour	3.75	0.017	3.84	2.32	4.53	4.09	3.22	3.35
Temp	3.32	0.032	3.69	3.32	3.26	3.33	3.63	3.31
Ph	7.71	8.67	7.85	8.81	8.4	8.81	8.81	8.81
EC	0.8	0.88	0.48	1.14	1.37	3.39	1.1	1.1
TDS	0.13	14.96	2.67	0.2	0.08	0.61	0.19	0.19
DO	37.63	37.63	39.38	43	45.25	42.25	41.75	41.75
COD	13.8	13.8	5.1	3.6	21.5	0	43.84	43.84
TA	0.64	0.64	0.66	1.26	6.8	0.15	2.4	2.4
TH	0.092	0.092	0.03	0.18	0.064	0.036	0.16	0.16
Cl^-	0.16	0.28	0.11	0.36	0.13	0.012	0.17	0.17
SO_4^{2-}	0.009	0	0.015	0.021	0.003	0.046	0.008	0.008
NO_3^-	0.11	0.17	0.006	0.004	0.11	0.14	0.12	0.12
Na^+	0.018	0.046	0.079	4.14	0.026	4.14	0.081	0.081
Ca^{2+}	0.028	0.028	0.082	0.16	0.046	0.005	0.094	0.094
Mg^{2+}	0.029	0.013	0.005	0.01	0.025	0.002	0.042	0.042
$WQI = \frac{\sum WiQi}{\sum Wi}$	$= \frac{\sum 68.23}{0.63}$	$= \frac{\sum 77.26}{0.63}$	$= \frac{\sum 64.00}{0.63}$	$= \frac{\sum 68.53}{0.63}$	$= \frac{\sum 91.59}{0.63}$	$= \frac{\sum 67.01}{0.63}$	$= \frac{\sum 105.62}{0.63}$	$= \frac{\sum 105.43}{0.63}$
	= 108.94	= 122.63	= 101.59	= 108.78	= 145.38	= 106.37	= 167.62	= 167.35

It is reported in (USGS, 2012) that colour in water may not make it harmful but may certainly render the water unappealing. The Temperature ranged 27.00 ± 0.13 – 30 ± 0.16°C and 29.4 ± 0.19 - 33.5 ± 0.25°C with mean concentrations of 29.13 ± 0.41°C and 30.74 ± 0.52°C for dry rainy seasons, respectively. The results vary with the submission of Afiukwa (2011) which ranged 29.3 – 30.4°C.

Cool water are generally more potable and palatable for drinking purposes than warm water, while high water

The low pH could be attributed to the geologic formation of the area which has a high limestone deposits and this can lead to acidosis. Acidic water has the capacity to attack geological materials and leach toxic trace metals into the water. Metals tend to be more toxic at lower pH because they are more soluble (USGS, 2012). The EC ranged 54.3 ± 2.06 – 2450 ± 4.32 and 299 ± 4.7– 2120 ± 8.17 µS/cm with mean levels of 715.54 and 795.88 µS/cm for dry and rainy seasons, respectively. The results of the analysis showed that the EC level in the dry season were generally higher than rainy season.

Table 7. Correlations between Physicochemical Parameters during Dry Season

	Colour	Temp	pH	EC	TDS	TSS	TS	Turbidity	Salinity	Acidity	TA	TH	DO	BOD	COD
Colour	1														
Temp	0.051	1													
pH	0.408	-0.131	1												
EC	0.340	0.283	0.622*	1											
TDS	0.310	0.169	0.660**	0.991**	1										
TSS	0.428	-0.040	0.576(*)	0.601*	0.60*	1									
TS	0.325	0.160	0.671**	0.990**	0.99**	0.641*	1								
Turbidity	-0.163	-0.018	-0.762**	-0.691**	-0.721**	-0.650**	-0.734**	1							
Salinity	-0.261	0.022	0.067	0.305	0.333	0.178	0.331	-0.074	1						
Acidity	0.158	0.027	0.218	0.010	-0.001	0.578*	0.036	-0.369	-0.179	1					
TA	0.428	0.117	0.687**	0.911**	0.918**	0.821**	0.933**	-0.759**	0.339	0.249	1				
TH	0.134	-0.024	0.467	0.125	0.126	0.588*	0.158	-0.584*	-0.121	0.781**	0.277	1			
DO	0.409	0.048	0.509	0.460	0.436	0.705**	0.464	-0.377	0.097	0.529*	0.583*	0.518*	1		
BOD	0.323	0.290	0.245	-0.035	-0.072	-0.192	-0.082	0.036	-0.445	0.196	-0.093	0.031	0.010	1	
COD	-0.423	-0.307	-.551(*)	-0.307	-0.273	-0.061	-0.266	0.364	0.333	0.043	-0.265	-0.094	-0.244	-0.564(*)	1

Table 8. Correlations between Physicochemical Parameters during Rainy Season

	Colour	Temp	pH	EC	TDS	TSS	TS	Turbidity	Salinity	Acidity	TA	TH	DO	BOD	COD
Colour	1														
Temp	0.271	1													
pH	-0.003	0.651**	1												
EC	0.497	0.403	0.572*	1											
TDS	0.369	0.372	0.533*	0.964**	1										
TSS	0.130	0.337	0.494	0.627**	0.623**	1									
TS	0.362	0.379	0.544*	0.965**	0.999**	0.662**	1								
Turbidity	0.482	0.191	-0.053	-0.032	-0.195	-0.166	-0.196	1							
Salinity	0.309	0.357	0.518*	0.935**	0.995**	0.618*	0.994**	-0.247	1						
Acidity	0.305	0.440	0.508	0.676**	0.764**	0.573*	0.767**	-0.019	0.737**	1					
TA	0.458	0.401	0.583*	0.963**	0.929**	0.754**	0.940**	-0.029	0.901**	0.757**	1				
TH	0.044	0.552*	0.580*	0.327	0.311	0.408	0.325	0.012	0.320	0.745**	0.321	1			
DO	-0.274	-0.820**	-0.384	-0.447	-0.433	-0.340	-0.438	-0.197	-0.425	-0.180	-0.395	-0.434	1		
BOD	0.209	-0.038	-0.293	-0.104	-0.063	0.023	-0.055	0.019	-0.033	-0.185	-0.130	-0.267	-0.181	1	
COD	0.236	-0.089	-0.316	-0.056	-0.019	0.001	-0.018	-0.015	0.010	-0.210	-0.148	-0.186	-0.200	0.965**	1

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

Okporojo Secondary School (FB) in both dry and rainy seasons showed very high EC of 2450 ± 4.42 and 2120 ± 8.17 µS/cm, respectively. This high EC in Okporojo Secondary School may have been caused by the presence of highly dissolved solids especially since there is this suspicion of salt intrusion from Uburu salt deposit. This high value is an indication that the water is not fresh and potable. The TDS ranged 178 ± 3.40 – 1830 ± 17.00 mg/l and 200 ± 2.36 – 1530 ± 2.36 mg/l with mean concentrations of 549.38 and 530.63 mg/l for dry and rainy seasons, respectively. Apart from Nde-Obasi (DB) and Okporojo Secondary School (FB) that recorded high concentrations of TDS, all other locations were below the WHO (2011) drinking water standard of 500 mg/l.

The results are in agreement with the findings of Osibanjo and Majolagbe (2012). It is reported in EU (1998) that water with a TDS above 500 mg/l is not recommended for drinking and other sophisticated applications. TDS concentration above 500mg/l decreases palatability and may cause gastrointestinal irritation and constipation effects Maiti (2001). Total dissolve solids are introduced into the borehole from the rocks and soil through which water percolates (WHO, 2006). The turbidity level ranged 0.50 ± 0.05 - 1.50 ± 0.08 and 0.50 ± 0.02 - 3.50 ± 0.08 NTU with a mean level of 1.00 and 1.75 for dry and rainy seasons, respectively. Turbidity values in all the water samples were generally low when compared with WHO (2011) recommended drinking water standard of 5 NTU Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. The total alkalinity for dry and rainy seasons ranged 150.00 ± 2.36 – 2080.00 ± 4.71 mg/l and 64.00 ± 0.82 – 470 ± 0.94 mg/l with mean concentrations of 791.25 and 188.75 mg/l. The values in Oso Tech (EB), Okporojo Secondary School (FB), Ogiri (GB), Ameta (HB) were above WHO (2011) drinking water standard of 500mg/l. The results showed that the concentrations of total alkalinity were high in dry season than in rainy seasons in all the locations. This high total alkalinity may be due to the dissolution of limestone which is prevalent in the study area. The alkalinity of water is caused mainly due to OH^-, CO_3^{2-} and HCO_3^- ions. Aturamu (2012) also reported similar results in borehole analysis in Ikere which was above the maximum allowable contamination value of 100 mg/l. The total hardness in the water samples during dry and rainy seasons ranged 18.00 ± 0.82 – 170.00 ± 0.90 and 76 ± 1.41 – 454.00 ± 1.89 with mean concentrations of 118.75 and 244.25 mg/l, respectively.

The results of the analysis in all the locations showed that the water samples did not exceed the WHO (2011) drinking water standard of 500 mg/l. Several reports Aturamu (2012) and Provin and Pitt (2002) have shown that the borehole contain high concentration of hardness. The results vary with the findings of Afiukwa (2010). In the classification of water according to its hardness by Spellman (2007), showed that Amaukabi (AB), Nde-Okpo (BB), Nde-Obasi (DB), Ogiri (GB) and Ameta (HB) with concentrations 136, 92, 158,146 and 170 mg/l, respectively are hard water while the rest are either soft or moderately hard. Groundwater exceeding the limit of 300 mg/l is considered to be very hard Naganathan and Sankar (2014). The total hardness in borehole water samples recorded higher concentration in the rainy season than dry season. Water hardness is imparted mainly by the calcium and magnesium ions, which apart form sulphates, chlorides and nitrates are found in combination with carbonates Lorraine (2000).

The results of DO ranged 5.37 ± 0.009 - 7.41 ± 0.005 mg/l and 6.02 ± 0.01 - 7.84 ± 0.02 mg/l with mean concentrations of 6.73 mg/l and 6.80 mg/l for dry and rainy seasons, respectively. The DO in all the samples analyzed were higher than the WHO (2011) < 4.0. It was observed that the dissolved oxygen was generally higher in the rainy season than in dry season. This value is high when compared with literature Ibrahim *et al.* (2013). Low DO may result an anaerobic conditions that result obnoxious odour. Depletion of DO in water supplies can encourage the microbial reduction of nitrate to nitrite and sulphate to sulphide WHO (2006). The COD ranged 18.82 ± 0.94 - 47.04 ± 0.019 and bdl - 13.80 ± 0.094 mg/l with mean concentration of 29.40 and 6.19 mg/l for dry and rainy seasons, respectively. The COD were higher than the WHO (2011) recommended drinking water standard of 10 mg/l. The COD concentrations were higher than the findings in the literature Mahananda *et al*. (2010); Kalra *et al.* (2012). The results showed that the COD concentrations in the dry season were higher than that of the rainy season. The high COD values in the water samples might be due to infiltration of organic matter in the water body. The Cl^- concentrations during dry and rainy seasons ranged 71.00 ± 0.82 – 1047.00 ± 0.25 and 40.00 ± 0.47 – 746 ± 2.49 mg/l with mean concentrations of 250.63 and 191.00 mg/l, respectively. Apart from Okporojo Secondary School (FB) with mean concentrations of 1047.30 ± 0.245 and 746.00 ± 2.49 mg/l in dry and rainy seasons, respectively, every other location has a value that is below WHO (2011), 250 mg/l, threshold limit of drinking water. However, it was observed that the concentrations of Cl^- in dry season were higher than that of the rainy season. The findings are at variance with the work of Sivakumar *et al.* (2011). High concentration of Cl^- gives an undesirable taste to water and beverages. A taste threshold for the chloride ion depends on the associated cations.

No health-based guideline value is proposed for chloride in drinking water. That notwithstanding, chloride concentrations in excess of about 250 mg/l can give rise to detectable taste in water and laxative effect in human beings Bhadram *et al.* (2004). The Sulphate concentrations during dry and rainy seasons ranged 53.07 - 129.53 and bdl - 57.33 ± 0.009 mg/l with mean concentrations of 86.03 and 30.76 mg/l, respectively. Though various levels of concentration of SO_4^{2-} were found in the analyzed water samples but the levels were below the WHO 500 mg/l limit of drinking water of 2011. The concentrations of SO_4^{2-} were higher in the dry season than in the rainy season. The results of NO_3^- during dry and rainy seasons ranged 1.37 ± 0.03 - 2.69 ± 0.05 and 2.84 ± 0.01 - 4.51 ± 0.00 mg/l with mean concentrations of 1.94 and 3.44 mg/l, respectively. The concentrations of NO_3^- were below the maximum permissible limit of (WHO, 2011) which recommended 50 mg/l as the threshold limit. This low level is an indication that there is low infiltration of nitrate into the groundwater body and the results were in accord to the findings of Kalra *et al.* (2012), Agrawal (2009) and Afiukwa (2011).

It was reported that NO_3^- level above the WHO limit was dangerous to children below the age of 6 and pregnant women as it has the potential of causing metheglobenamia. Methemoglobinemia is actually an excess of methemogobin in the blood and it can cause cyanosis (blue skin) of limbs, weakness and rapid heart rate. The Na concentrations ranged 9.28 ± 0.00 – 1820.00 ± 0.67 and 7.11 ± 0.008 to 1655 ± 2.36 mg/l with mean concentrations of 272.53 and 237.92 mg/l, respectively, for dry and rainy seasons. Apart from Okporojo Secondary School (FB) every other location was within the maximum permissible limit of 200 mg/l stipulated by WHO (2011) drinking water standard. The high concentration of Na in Okporojo Secondary School (FB) can be attributed to the closeness of the borehole to Ohaozara which has a very large deposit of common salt. Though there is no health guideline for sodium but high intake of Na, according to study conducted by Basavaraddi *et al.* (2012) can cause hypertension and must be avoided by people having heart problem. Humbarde, Panaskar and Pawar (2014) reported that groundwater concentration exceeding 50 mg/l is not suitable for domestic use. The concentrations of Ca during dry and rainy seasons ranged 2.87 ± 0.019 to 67.60 ± 0.19 and 2.11 ± 0.012 to 64.30 ± 0.024 mg/l with mean concentrations of 36.93 and 26.22 mg/l, respectively. The concentrations in all the locations were within the permissible limit of WHO (2011) drinking water standard of 200 mg/l. These results were in accordance with the findings in the literature. Calcium in drinking water may have many beneficial effects such as the hardening of the bones and teeth, but at very high levels can have some negative health effect. Razowska-Jaworek (2012) reported that high concentrations of calcium may adversely affect the absorption of essential minerals in the body. It is reported Kozisek (2003) that osteoporosis and osteomalacia are the most common manifestations of calcium deficiency and a less common but proved disorder attributable to Ca deficiency is hypertension. The concentrations of Mg during dry and rainy seasons ranged 0.98 ± 0.01 – 13.17 ± 1.21 and 0.51 ± 0.01 – 8.93 ± 0.01 mg/l with mean concentrations of 7.36 and 4.27 mg/l, respectively. The levels of magnesium in all the locations for borehole waters were below the permissible limit of WHO (2011) drinking water standard of 150 mg/l. Magnesium deficiency increases risk to humans by developing various pathological conditions such as vasoconstrictions, hypertension, cardiac arrhythmia, atherosclerotic vascular disease, acute myocardial infarction, eclampsia in pregnant women, possibly diabetes mellitus of type II and osteoporosis Rude (1998) and Saris *et al* (2000). It is reported in Razowska-Jaworek (2012) that magnesium in drinking water can have a laxative and diuretics effects and can also affect the taste of water and it is a major contributor to water hardness.

Water Quality Index, (WQI)

The WQI of the water samples are shown in Tables 5 and 6. The WQI ranged 121.29 – 186.68 and 101.59 - 167.62 for dry and rainy seasons, respectively. The results of the analysis revealed that the WQI of the water samples were above the critical water quality index value of 100. It is reported in (Asuquo and Etim, 2012) that any water with a WQI greater than 100 was unsuitable for drinking and other domestic uses. Such water needs treatment for its quality to be enhanced. Generally the result of the analysis showed that the borehole water has high water quality index thereby making the borehole water being poor quality water as there were high pollution indicators that impacted on the borehole.

Relationship between Physicochemical Parameters

The correlation coefficient analysis was done using SPSS 15.0 statistical tools and the correlations among the physicochemical parameters are presented in Tables 7 and 8. Correlation analysis gives quick idea of the water quality. The analysis suggested that some of the parameters have either weak or strong positive correlations or weak and strong negative correlations. In the physicochemical analysis of the borehole water quality, total alkalinity, salinity and acidity were significantly correlated (r = 0.70) with TDS, and that the distribution of TDS, total alkalinity, salinity and acidity were significantly correlated (r = 0.70) with EC. There were strong positive correlation value (r = 0.965) of COD with BOD in the rainy season. Very poor correlations were observed among acidity, total hardness, BOD and COD (r = 0.10) with colour, TDS and temperature (r = 0.169); EC, TDS and BOD (r = 0.10) with pH (r = 0.218) and there was almost no correlation observed in dry season between salinity and temperature (r = 0.022), acidity and temperature (r = 0.036), BOD and total hardness (R = 0.031), BOD and DO (r = 0.01) and for rainy season between total hardness and colour (r = 0.044), total hardness and turbidity (r = 0.012), COD and salinity (r = 0.01). There was also poor positive correlation between total hardness and EC (r = 0.125), total hardness with TDS (r = 0.126). There was also poor correlation between total hardness (r = 0.277) with total alkalinity. In the dry season there is almost no correlation between temperature and colour (R = 0.051); salinity and temperature (r = 0.022); salinity and pH (r = 0.067); acidity and EC (r = 0.01); COD and acidity (r = 0.043); BOD and total hardness (r = 0.031). It was observed in the rainy season that there was also no correlation coefficient between total hardness and colour (r = 0.044); total hardness and turbidity (r = 0.012); BOD and turbidity (r = -0.691), turbidity and TDS (r = -0.721); total alkalinity and turbidity (r = -0.759) while there was low negative correlation between pH and temperature (r = -0.0131); turbidity and colour (r = -0.163); turbidity and temperature (r = -0.018); salinity and colour (r = -0.261), salinity and turbidity (r = -0.074); acidity and TDS (r = -0.001); acidity and turbidity (r = -0.121); BOD and EC (r = -0.035), BOD and TDS (r = -0.072); BOD and total alkalinity (r = -0.093). COD forms negative correlations with almost all the physicochemical parameters in the dry season except turbidity, salinity and acidity and forms negative correlations with all the physicochemical parameters in the rainy season except salinity. There was low correlation between SO_4^{2-} and NO_3^- (r = 0.071) in the dry season while there was low negative correlation between Cl^- and NO_3^- (r = -0.107).

Conclusion

The WQI serve as a veritable tool to have a quick interpretation of the quality of water. The physicochemical assay of groundwater quality showed the presence of different levels and concentrations of some physicochemical parameters. The deterioration of the water was as a result of human activities such as the dumping of refuse and agricultural practices within the vicinity of the borehole. Systematic study of the contaminant levels of the groundwater sources in the study area should be carried out regularly and stringent measure should be applied by government and her agencies so as to protect these boreholes from mismanagement by the people.

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