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Assessment of Water Quality Index of Groundwater resources from Industrial areas of Anambra, Southeastern, Nigeria

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ABSTRACT

The work determined the physicochemical properties and quality of groundwater samples from Industrial cluster areas of Anambra state, Nigeria using Quality Index method. The samples were collected monthly in rainy season (May–July, 2017) and dry season (November, 2017 to January, 2018). The ranges of the physicochemical parameters in both seasons were temperature (27.0–30.4oC), pH (5.5 – 6.5), electrical conductivity (22.5–178 µS/cm), calcium (1.00–17.67 mg/L), magnesium (0.00–13.33mg/L),total hardness (1.00–27.00 mg/L),chlorides (0.83–16.67mg/L), sulphate (0.33–4.00 mg/L), total alkalinity (0.75–16.67 mg/L), total dissolved solids (13.50–106.67 mg/L), total suspended solids (1.03–9.67 mg/L), total solids (16.00–116.33 mg/L), turbidity (0.00–3.04 NTU), dissolved oxygen (5.67–9.07mg/L), biochemical oxygen demand (0.10–1.27 mg/L) and chemical oxygen demand (5.67–18.33 mg/L). The values were compared with the standard values recommended by World Health Organization (WHO 2017) and Nigerian Standard for Drinking Water Quality (NSDWQ 2007). Statistical analysis (ANOVA) was performed which showed significance variations between the parametric values of the borehole water samples. Levene's t-test indicated significance variations between the rainy season and dry season parametric means. The water quality index (WQI) results in both seasons showed that the water quality status of the samples collected from Uruagu, Nnewichi, Okpoko and Awada were excellent while those collected from Otolo, Umudim, Fegge and Woliwo were good.

Introduction

Water is the most essential resource that is of vital importance to the existence of life (Aralu et al., 2022). It is referred to as one of the indispensable substances in life because of its importance in human health and the general well being of the nation (Okhuebor and Izevbuwa, 2020). Therefore, water serves several purposes such as domestic, municipal, agricultural and industrial purposes. Groundwater is the major source of drinking water in Nnewi and Onitsha which are major metropolitan cities and commercial centers of activities for urban growth and industrialization in Anambra state (Aralu, 2021). Groundwater can be contaminated by anthropogenic and natural activities such as industrial activities, agricultural practices (use of fertilizers, pesticides, herbicides, insecticides, etc), sewage disposal and septic tanks, improper dumping of wastes, vehicular emissions, weathering of rocks, atmospheric depositions, mining, domestic activities, etc (Talabi and Kayode, 2019). Notwithstanding, a reasonable number of the world's population make use of the groundwater as a source of their drinking water and water for municipal uses are derived mainly from groundwater. The borehole water quality depends on various chemical constituents and their concentrations and can also be affected by some other factors like pH, temperature, dissolved oxygen, erosion, runoff and decayed organic materials (Kale, 2016). Untreated water contains impurities which can be hazardous to health and pose threat to life. High intake of these contaminants in drinking water has been associated with various diseases and health problems such as cancer, diarrhea, vomiting, stomach pains, infertility and coronary heart diseases (Jiang et al., 2016). Therefore, this study assessed the quality of groundwater used for drinking purposes in Anambra state as a result of the industrial and other anthropogenic activities.

Initially, Water Quality Index (WQI) was developed in 1965 by Horton in United States to generate a single unit capable of defining general water quality for specific purposes and has been widely applied and accepted in European, African and Asian countries. Many other WQI methods of assessing water quality have emerged and a number of Organisations have developed water quality indices such as National Sanitation Foundation Water Quality Index (NSFWQI), Weight Arithmetic Water Quality Index (WAWQI), Oregon Water Quality Index (OWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) and these methods have been applied for estimation of water quality in a specific area (Chaturvedi and Bassin, 2010).

Study area

The study area, Nnewi and Onitsha are cities in Anambra state, South-East, Nigeria. Nnewi is drained by River Idemili and River Mmili Eze while Onitsha is drained by River Niger and its many tributaries, notably rivers Anambra (which lends the state its name), Nkissi and Idemili Rivers. The study area is influenced by two major trade winds (South west trade winds from Atlantic Ocean during the rainy season (April–October) and the North East trade wind from Sahara desert during the dry season and dusty harmattan (November–March). Nnewi is located on latitude 6°0′ 08′′ N and longitude 6°55′ 03′′ E while Onitsha is located on latitude 6°8′ 07′′ N and longitude 6°47′ 03′′ E (Ajayi et al., 2009). Fig.1 represents the map of Anambra state showing the study area.

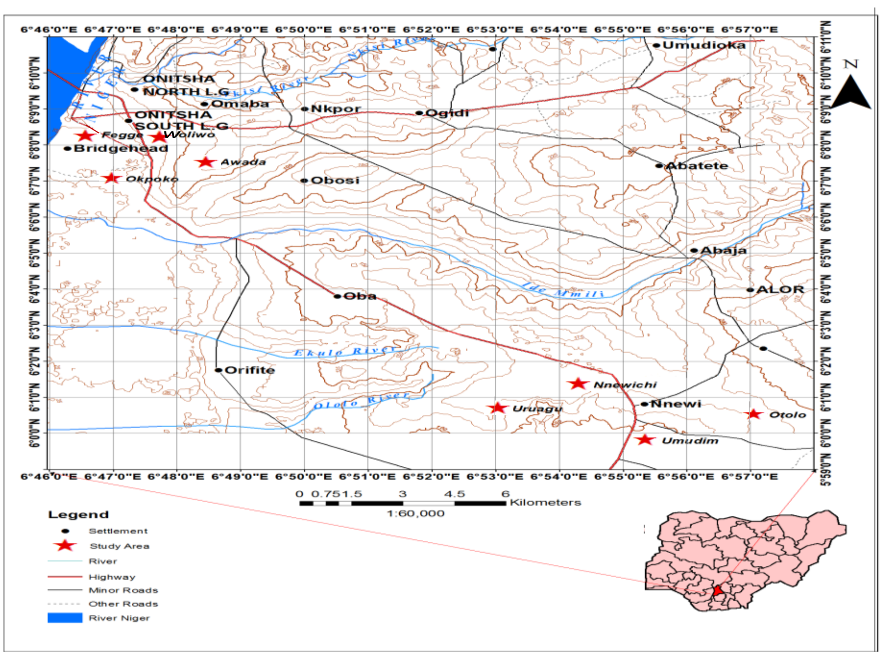

Figure 1. Map of Anambra State showing the Study Area

Sampling

In each of the sampling locations, 5 boreholes were randomly selected and water samples collected and mixed to obtain a composite sample. 8 composite groundwater samples were collected monthly for a period of six months from 8 different sampling locations in rainy season (from May to July, 2017) and dry season (from November, 2017 to January, 2018) and were properly labelled. The samples were collected in 1 litre polyethylene bottles based on the proximity of the boreholes to industrial activities, agricultural activities, mechanic workshops, dumpsites and septic tanks. All the water quality parameters were analyzed in triplicates using standard laboratory methods (APHA, 2005). pH, electrical conductivity (EC), temperature (Temp.) and dissolved oxygen (DO) were analysed insitu using electrometric methods. Sulphate (SO_4^{2-}) was determined using spectrophotometric method. Fluoride (F^-)and nitrite-nitrogen (NO_2-N) were determined using colourimetric method. 5-Day Biochemical oxygen demand (BOD_5) and Chemical oxygen demand (COD) were determined using Winkler's method and COD digester respectively. Total dissolved solids (TDS) was determined using electrometric method. Total suspended solids (TSS) and total solids (TS) were determined by gravimetric method. Turbidity (Turb.) was determined using turbidimeter. Chloride (Cl^-) was determined by Argentometric method. Total alkalinity (TA), total hardness (TH), calcium (Ca) and magnesium (Mg) were determined by titrimetric method. All the chemicals and reagents used were of analytical grade with high percentage purity.

The WQI was used to evaluate the level of purity of all the borehole water samples and was calculated using the expression;

$$WQI = \sum q_n W_n / \sum W_n$$

where, q_n= Quality rating of n^{th} water quality parameter

W_n= Unit weight of n^{th} water quality parameter (Etim et al., 2013)

Results and Discussion

Table 1 represents the results of the borehole water quality parameters obtained during rainy season and dry season. Table 2 shows the results of the water quality index and status in rainy and dry season.

Table 1 Mean values of Borehole water quality parameters in rainy and dry season

Parameter	Season	Sample ID								
		L1	L2	L3	L4	L5	L6	L7	L8	STD
NO_2-N(mg/L)	Rainy season	0.00	0.00	0.00	0.00	0.00	0.00	0.01±0.0	0.01±0.0	#0.06
	Dry season	0.00	0.00	0.01±0.0	0.00	0.01±0.0	0.00	0.01±0.0	0.00	
Temp. (°C)	Rainy season	28.5±0.1	28.6±0.1	28.5±0.1	28.7±0.1	29.1±0.1	29.4±0.1	29.4±0.1	29.3±0.0	*#25
	Dry season	27.0±0.1	28.2±0.1	28.5±0.1	29.1±0.1	30.1±0.1	30.3±0.1	30.1±0.1	30.4±0.1	
pH	Rainy season	6.13±0.1	6.20±0.1	6.40±0.1	6.17±0.1	5.53±0.1	6.13±0.1	6.30±0.1	6.23±0.1	*#6.5-8.5
	Dry season	6.23±0.1	6.47±0.1	6.53±0.1	6.13±0.1	6.53±0.1	6.37±0.1	6.23±0.1	6.43±0.1	
EC (µS/cm)	Rainy season	24.33±0.2	55.37±0.2	31.00±0.4	22.50±0.1	126.67±0.6	135.33±0.6	158.00±2.0	109.00±1.0	*#1000
	Dry season	42.43±0.1	44.13±0.2	39.00±0.3	29.80±0.4	178.00±1.0	111.33±0.6	64.70±0.5	144.67±0.6	
TH(mg/L)	Rainy season	1.00±0.0	4.33±0.6	7.33±0.6	1.00±0.0	12.67±0.6	17.67±0.6	25.33±0.6	21.67±0.6	#150
	Dry season	6.33±0.6	6.33±0.6	15.67±0.6	2.00±0.0	27.00±1.0	9.67±0.6	6.33±0.6	26.67±1.2	
Ca(mg/L)	Rainy season	1.00±0.0	2.33±0.6	7.33±0.6	1.00±0.0	9.33±0.6	8.00±0.0	17.67±0.6	8.33±0.6	*#75
	Dry season	6.00±0.0	4.00±0.0	12.67±0.6	2.00±0.0	16.33±0.6	6.33±0.6	2.67±0.6	17.33±1.2	
Mg(mg/L)	Rainy season	0.00	2.00±0.0	0.00	0.00	3.33±0.6	9.67±0.6	7.67±0.6	13.33±0.6	*#50
	Dry season	0.33±0.6	2.33±0.6	3.00±1.0	0.00	10.67±1.5	3.33±0.6	3.67±0.6	9.33±1.2	

SO_4^{2-}(mg/L)	Rainy season	3.23±0.3	0.67±0.3	0.50±0.0	0.67±0.3	0.33±0.3	0.83±0.3	0.67±0.3	0.83±0.3	#100
	Dry season	0.50±0.0	0.50±0.0	0.50±0.0	0.50±0.0	0.67±0.3	4.00±1.0	1.00±0.0	1.17±0.3	
Cl^-(mg/L)	Rainy season	2.50±0.5	4.17±0.3	1.17±0.3	0.83±0.3	12.50±0.5	14.67±0.6	12.50±0.5	11.17±0.3	*#250
	Dry season	6.50±0.5	5.58±0.3	1.17±0.3	3.33±0.6	21.67±0.6	11.50±0.5	6.17±0.3	14.50±0.5	
TA(mg/L)	Rainy season	4.75±0.3	5.25±0.3	12.43±0.4	1.75±0.3	5.00±0.9	0.75±0.2	6.85±0.0	9.50±0.9	#100
	Dry season	12.67±1.1	5.33±0.6	13.33±1.2	2.00±0.0	4.00±0.0	13.33±1.2	4.67±1.2	16.67±1.2	
TDS(mg/L)	Rainy season	14.60±0.1	33.40±0.3	18.63±0.2	13.50±0.1	76.00±0.4	81.20±0.4	94.80±1.2	65.40±0.6	*#500
	Dry season	25.47±0.1	26.50±0.1	23.40±0.2	17.87±0.3	106.67±0.6	66.80±0.4	38.83±0.3	86.83±0.4	
TSS(mg/L)	Rainy season	2.40±1.0	1.27±0.5	1.03±0.7	2.50±1.1	3.00±1.3	2.80±1.3	1.20±1.1	3.27±0.7	–
	Dry season	1.87±0.6	2.83±0.7	1.23±0.7	1.80±0.4	9.67±1.5	2.53±0.8	1.50±0.6	4.50±1.0	
TS(mg/L)	Rainy season	17.00±1.0	34.67±0.6	19.67±0.6	16.00±1.0	79.00±1.0	84.00±1.0	96.00±1.0	68.67±1.2	*#500
	Dry season	27.33±0.6	29.33±0.6	24.67±0.6	19.67±0.6	116.33±1.5	69.33±0.6	40.33±0.6	91.33±0.6	
Turb. (NTU)	Rainy season	3.04±0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.38±1.0	*#5
	Dry season	0.00	0.00	0.00	0.00	0.63±0.0	0.00	0.00	0.00	
DO(mg/L)	Rainy season	7.13±0.1	8.00±0.1	8.00±0.1	8.40±0.1	8.90±0.2	8.73±0.2	9.07±0.2	7.83±0.2	–
	Dry season	7.12±0.0	8.13±0.0	7.82±0.1	7.57±0.1	8.07±0.0	7.13±0.1	7.52±0.0	6.95±0.1	
BOD(mg/L)	Rainy season	0.17±0.1	0.30±0.1	0.13±0.6	0.10±0.1	0.70±0.2	0.53±0.2	0.53±0.2	0.73±0.2	*#5
	Dry season	0.63±0.1	0.47±0.6	0.85±0.1	0.83±0.1	1.27±0.0	0.13±0.1	0.70±0.1	0.82±0.1	
COD(mg/L)	Rainy season	17.67±3.1	15.67±0.6	17.00±2.3	16.00±2.7	16.00±1.0	17.33±1.5	18.00±2.0	5.67±2.1	*#10
	Dry season	18.33±2.5	8.33±2.1	14.00±1.0	5.67±1.2	6.67±1.1	6.33±1.5	10.33±2.5	6.00±1.0	

L1=Uruagu, L2=Nnewichi, L3=Otolo, L4=Umudim, L5=Fegge, L6=Okpoko, L7=Awada and L8=Woliwo
* Values are given by World Health Organisation (WHO)
# Values are given by Nigerian Standard for Drinking Water Quality (NSDWQ)

Table 2. Water Quality Index and Status of the 8 borehole water samples for Rainy season and Dry season

Sample ID	WQI (Rainy)	Water quality status	WQI (Dry)	Water quality status
L1	0.3184	Excellent	0.2316	Excellent
L2	0.2210	Excellent	0.2396	Excellent
L3	42.5055	Good	44.9773	Good
L4	42.4502	Good	33.9302	Good
L5	34.0099	Good	44.9567	Good
L6	0.2145	Excellent	0.1904	Excellent
L7	2.5999	Excellent	2.6282	Excellent
L8	36.3663	Good	34.0903	Good

results of the borehole water quality parameters shown on Table 1 above have been successfully discussed below. The mean of temperatures were 28.9±0.38°C and 29.2±1.16°C in rainy season and dry season respectively. The temperatures were all above the permissible limit (ambient or 25 °C) in all the groundwater. Table 1 shows the seasonal variation of temperature in the groundwater samples. The high temperatures may be from anthropogenic heat generation, surface heat input and heat energy from sun radiation. High temperature depletes the dissolved oxygen content of the water. Similar data were obtained from groundwater quality in Kaduna state, Northwestern, Nigeria and Ebonyi state, Southeastern, Nigeria (Musa et al., 2020 and Njoku and Ngene, 2015). The mean pH values were 6.14±0.26 and 6.37±0.15 in rainy season and dry season respectively. The pH of most of the water samples were low indicating acidity of the groundwater samples. The seasonal variation of pH in all the groundwater samples is shown in Table 1.The acidity of the samples may be from the infiltration of the groundwater aquifers with acid rain, industrial effluents and agricultural chemicals. Acidic water is corrosive and can cause the leaching of heavy metals into the aquifers. A similar result was obtained from the study of groundwater located at Ota state, Southeastern, Nigeria (Ekute, 2021). The EC means were 82.78±52.98 µS/cm and 81.76±53.41 µS/cm in rainy season and dry season respectively. The EC of all the water samples were within the WHO (2017) acceptable limit (1000 µS/cm). The electrical conductivity measures the ability of water to conduct electricity due to dissolved salts or ions present in the water. EC depends on the geology and the hydrogeology of the area. The results of data obtained in this study on EC agree with the results obtained on drinking water sources from Okoroetter community, Eastern coast of Nigeria (Inam, 2017).

The total hardness means were 11.38±9.03 mg/L and 12.50±9.25 mg/L in rainy and dry season. The total hardness concentrations of all the boreholes were below the guideline value (150 mg/L). Total hardness depends on the levels of calcium and magnesium minerals present in the groundwater as a result of the geology of the location which include the type of aquiferous rocks, minerals and soil. The groundwater samples in this study can be classified as soft water (USGS, 2016). A similar work on physicochemical analysis of groundwater in Ogun state, Southwestern, Nigeria also showed low total hardness level. (Ojekunle et al., 2020).

The levels of calcium and magnesium were below the permissible limits of 75 mg/L and 50 mg/L respectively in both seasons. Similar results were also obtained from the analysis of groundwater from Gwagwalada Area Council Abuja, Nigeria (Ephraim et al., 2021). The sulphate level was highest in dry season (4.00 mg/L) at L6 and lowest in rainy season (0.33 mg/L) at L5. The sulphate values in all the groundwater samples were below the guideline value (100 mg/L). Sulphates in groundwater could be from acid rain, industrial effluents and leachates from environment. The chloride mean value of 7.44±5.55 mg/L and 8.83±6.42 mg/L were observed in rainy season and dry season respectively. The high levels of chlorides observed from L5–L8 in both seasons may be due to the geology and hydrogeology of the locations. The chloride levels of all the water samples were below the permissible limit (250 mg/L).Similar results were reported in groundwater from Maiduguri, Nigeria (Usman, 2016). Chlorides are added in drinking water during water treatment processes to help kill bacteria. Chlorides in groundwater may be from dissolution of chloride salts, discharges of industrial effluents, sewage and chemical weathering of bedrocks.

There was a significant variation in the total alkalinity mean contents of the groundwater samples as it increased from 5.79±3.68 mg/L (rainy season) to 9.00±5.36mg/L (dry season). Total alkalinity depends on the concentrations of basic salts and carbonate minerals in the groundwater aquifers. The total alkalinity contents of all the borehole water samples shown in Table 1were below the permissible limit (100 mg/L).

The data obtained from total alkalinity contents in this study were lower than the results on groundwater analysis from Abakiliki, Ebonyi state, Nigeria (Iyabo, 2015). TDS are the concentrations of soluble organic and inorganic species in the water. The mean values were 49.69±31.77 mg/L in rainy season and 49.05±32.02 mg/L in dry season. The TDS mean values were lower than the results on groundwater analysis from Sokoto, Nigeria (Grema et al., 2020). The amount of dissolved salts in the groundwater aquifers also depends on the geology and hydrogeology of the locations. The TDS values of the groundwater samples were below the guideline value (500 mg/L).TSS mean values were 2.18±1.19 mg/L and 3.24±2.76 mg/L in rainy season and dry season respectively. The suspended solids could be from silts and organic particles from the environment. TS mean values were 51.88±31.97 mg/L and 52.29±34.34 mg/L in rainy season and dry season respectively. These values also were below the recommended value (500 mg/L). Table 1 shows the seasonal variation of TS in the groundwater samples.

The turbidity mean values were 0.38±1.03 NTU and 0.08±0.21 NTU in rainy season and dry season indicating a significant decrease in turbidity value in dry season which could be due to decrease in the suspended organic and inorganic particles present in the groundwater samples. The turbidity values were within the recommended value (5 NTU). High turbidity value can stimulate the growth of bacteria because the suspended particles protect the bacteria from the effects of disinfectants. Turbidity value ranging from 1.7–2.4 NTU was reported in groundwater from Kano State, Nigeria (Bernard and Ayeni, 2012). DO is the amount of oxygen dissolved in water. The DO means were 8.26±0.63 mg/L and 7.54±0.43 mg/L in rainy season and dry season respectively. DO level > 6 mg/L indicate the water is free from organic pollution (Basavaraddi et al., 2012).There was a significant difference between the rainy season and dry season DO mean values. Five day BOD measures the amount of oxygen required for all the biodegradable materials to be decomposed completely by bacteria. The mean values of $(BOD)_5$ were 0.40±0.27 mg/L and 0.71±0.32 mg/L in rainy season and dry season respectively. The BOD levels were below the permissible limit set by WHO and NSDWQ (5 mg/L) and low BOD values indicate low levels of biodegradable materials (Usharani et al., 2010). The BOD values showed similarities with the results obtained from the assessment of groundwater located in Mbanabor area, Southeastern Nigeria (Aganigbo, 2016). COD measures the amount of oxygen required for the chemical oxidation of both organic and inorganic pollutants in the water. The COD mean values were 15.42±4.23 mg/L in rainy season and 9.46±4.59 mg/L in dry season. The seasonal variation could be due to increase in the percolation of inorganic pollutants into the groundwater aquifers during the rainy season. The COD of some of the groundwater samples exceeded the permissible limit (10 mg/L).Similar values were reported in groundwater from Ebubu Community, Eleme, Rivers state, Nigeria (Sokpuwu, 2017).

Water Quality Index Assessment

From Table 2, the WQI of the groundwater samples in rainy season showed that 50% of the total groundwater samples were rated excellent and the other 50% are good. Also, the WQI of the borehole water samples in dry season showed that 50% of the total groundwater samples are excellent while 50% are good (Etim et al., 2013). Therefore, the overall ranking of the 8 borehole water samples in order of decreasing water quality status in rainy season was; $L_6 > L_2 > L_1 > L_7 > L_5 > L_8 > L_4 > L_3$ while in dry season, it was ranked thus; $L_6 > L_1 > L_2 > L_7 > L_4 > L_8 > L_5 > L_3$.

Conclusion

The results of this study revealed that temperature, COD and NO_3-N of some groundwater samples were above the set limits and also the pH of most of the water samples were acidic indicating unsafe drinking water which may pose some danger to human health. Therefore, there is need for consistent monitoring and pre-treatment of the groundwater even though the water quality index (WQI) results gave positive ratings for all the groundwater. There is also need for governmental and non-governmental organization to set up water managers and planners to subject the affected boreholes to treatment measures such as reverse osmosis and ion exchange process.

Conflict of interest

The author declares that there was no conflict of interest.

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