International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 11 Nov 2021, pp: 496-509 www.ijaem.net ISSN: 2395-5252

Spatial and seasonal variations in the physico-chemical properties of groundwater in Yenagoa Metropolis, Bayelsa State, Nigeria

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Submitted: 05-11-2021 Revised: 12-11-2021 Accepted: 15-11-2021

ABSTRACT
The study examined the spatial and seasonal variations in the physico-chemical properties of groundwater in Yenagoa Metropolis, Bayelsa State, Nigeria. Six groundwater samples were collected equally from the hand dug well and borehole for both wet and dry seasonsin sterilised plastic bottles and were taken to laboratory for further analysis. Descriptive and inferential statistics were adopted for the data analysis. The total hardness, temperature, colour and turbidity were higher in well water during the dry season than the wet season. The pH in the well water was weakly acidic while the chloride, fluoride, BOD, COD, Na, K, Ca and Nitrite were all higher in well water during the wet season than the dry season. Similarly, the total hardness, and temperature were higher during the dry season than wet season in borehole water. In addition, pH during wet season was more alkaline than the dry season. The EC, nitrate, sulphate, chloride, COD, Fe and Mg were higher during the dry season than the wet season. The study concluded that the water quality of groundwater in the Yenagoa is excellent and good for consumption. The study therefore recommended that the groundwater in Yenagoa Metropolis should be prevented from being affected with pollutants which could degrade the quality of its consumption; and there should be periodic monitoring of groundwater quality in the study location.

Keywords: Borehole, Well, Spatio-seasonal, Physico-chemical properties, water quality index

I. INTRODUCTION

The assessment of groundwater quality is as important as its quantity for various purposes ranging from domestic, industrial and agricultural uses all over the globe (Subramani and Damodarasamy, 2005). The quality of groundwater is characterized by different physico-chemical parameter levels based on the geological structure through which it flows and human activities near the groundwater basin (Hejaz, Al-Khatib, and Mahmoud, 2020). Groundwater contamination has become a great problem due to rapid growth rate of population, industrialization and urbanization in the metropolitan city all over the world (Ganiyu, Badmus, Olurin and Ojekunle, 2018); and the deterioration of groundwater globally has been a serious environmental challenge (Hejaz et al., 2020).

It is believed that water is one of the most important natural resources (Mahler, Smolen, Borisova, Boellstorff, Adams and Sochacka, 2013); and as a result, there is need to improve water quality, increase the efficiency of water use, integrate water management programs, and achieve universal and equitable access to safe drinking water for all by 2030 (United Nations, 2015; Eck, Wagner, Chapagain and Josh, 2019). Regardless of the population of interest, perceptions of water issues, environmental impacts, and the protection and preservation of natural resources play a key role in meeting future national and global water supply needs. For instance, in the West Bank/Palestine, economic and population growth has resulted in raising the groundwater demand, as it isthe major resource of water in Palestine (Hejaz et al., 2020) while Charles, Walker and Geo (2018) noted that the growth in the population of Texas cities between 2015 and 2017 has led to the increasing demand from all sectors of the economy for surface water and groundwater in Texas Cities, USA. In Nigeria, more than 60% of the Nigerian population depend on groundwater for domestic water supply (Omole, 2013). This is due to the fact that most homes rely on self-supply of water at her than municipal water supply (Omole and Ndambuki, 2015).Water of good quality is a basic necessity of life and the need to be sure of the quality of water used by humans has become very intense in the past decade (Olatunji, Abimbola, Oloruntola and Odewade, 2005). It is difficult to imagine any programme for human development that does not require a readily available supply of water.

In Nigeria, the rate of urbanization characterised by high population concentration increasing industrial and agricultural activities coupled with environmental pollution, degradation and indiscriminate disposal of all kinds of wastes are perceived to pose serious pollution threats with all its concomitant health hazards on groundwater quality especially in urban areas (Adelana, Abiye, Nkhuwa, Tindinugaya. and Oga, 2008; Eni, Obiefuna.,Oko, and Ekwok, 2011; Ocheri, Odoma& Umar, 2014). One of the critical and fundamental problems facing Nigeria as a developing nation in the last five decades has been inadequate supply of portable and safe water for drinking. In parts of the Niger Delta, the negative effects of groundwater pollution and its attendant problems such as water borne diseases, harm to body organs like nervous system, liver, kidney and various forms of cancer, etc, have reached an alarming rate. Nwankoala and Shalokpe (2008) and Amadi et al., 2012) reported that the Niger Delta region of Nigeria is among the world's largest petroleum provinces and its importance lies on its hydrocarbon resources.

Due to the presence of oil companies and other associated industries, the population has increase enormously and the demand for potable water by individuals and companies has also increased. In Nigeria, the rate of urbanization characterised by high population concentration, increasing industrial and agricultural activities, environmental pollution/degradation and indiscriminate disposal of all kinds of wastes pose serious pollution threats and health hazards on groundwater quality especially in urban areas (Adelana et al.,, 2004; Adelana et al., 2008; Eni et al., 2011; Ocheri et al., 2014).

In developing countries, most people have access to some sort of water supply that is merely sufficient to meet basic needs but may represent risks to their health because of it inadequacy for basic hygiene. The quantity, physical, chemical and biological characteristics of water determine its usefulness for domestic or agricultural purposes (Ariyo and Enikanoselu, 2007; Ganiyu et al., 2018). Consumption of water contaminated by disease causing agents (pathogens) or toxic chemicals can cause health problem like diarrhoea, cholera, typhoid, dysentery, cancer and skin diseases (Pal, et al., 2018). Throughout history, groundwater has been a major source of water for sustaining human life.

Groundwater is one of the largest stocks of accessible freshwater which accounts for about one-third of freshwater consumption globally (Famiglietti, 2014; Gorelick&Zheng, 2015; Chen, et al., 2018). Owing to its relatively stable yield of high-quality water, groundwater has emerged as an extremely important water resource for meeting domestic, industrial, agricultural and environmental demands (Howard, 2015). Although groundwater is often relatively well protected from pollution, poor management has resulted in negative impacts such as declining aquifer heads, groundwater quality deterioration, lower crop yields, ecosystem degradation, and in some cases, land subsidence and seawater intrusion (Schoups et al., 2006; Praveena, et al., 2012; Chen et al., 2018).

Groundwater is a vital source of water which can be very difficult to treat if polluted. Thus, detecting the level of pollution especially in the developing countries is highly essential. Groundwater depletion is an inevitable and natural consequence of withdrawing water from an aquifer. In most regions, groundwater is used for drinking without treatment, the use of groundwater without treatment can lead to physiological and health disorder in life system both in humans, plants and animals. Drinking water source should be monitored to establish the required level of water treatment according World Health Organization (WHO) standards, and detect any contaminants which might not be removed during treatment, or which may interfere with the treatment processes. Excessive depletion is indicated by a persistent and substantial head drop resulting from the pumping of groundwater at a rate higher than replenishment. The scale of the problem has been quantified globally (Konikow andKendy, 2005; Chen et al. 2018).

Human population use water for hygiene purpose such as washing, and recreation e.g. swimming and boating. Some industries require water for manufacturing of goods such as pharmaceutical industries, and other consumable products. When this water source supply is not treated or partially treated. It can cause some health issues on human Irrigation of food crops from a polluted or untreated groundwater source supply can pass through the food chain and be bio-accumulated and have a health hazard on humans. Assessment of water quality examines source environment mental impact of specific activities on groundwater quality. This activity includes run-offs from land that has undergone pollution as a result of mining, effluent discharge from industries. Man is at great risks if waste products are not properly treated before discharge into the environment before it circulates.

Groundwater studies in some areas in the Niger Delta have shown increased levels in Total Dissolved Solids (TDS) (up to 2900mg/L), high hydrocarbon content–oil and grease (71 mg/L in 2006) are reported to be some of the groundwater problems according to Ayotamuno andKogbara (2007) and Adesuyiet al., (2015). Amajor (1991) had reported iron and chloride elevation as groundwater issues and this was corroborated by Ophori, Gorring, Olsen, Orhua and Hope (2007). Similar problems as reflected in Bayelsa, Delta and AkwaIbom States were also reported by Amangabara and Ejenma (2011) and Amadi et al., (2010). The principal goal of groundwater monitoring and management in developing countries is to assess and manage the water resources that are available. Groundwater is an important source of drinking water for more than half of Nigeria's population and nearly all its rural population. It is generally a very good source of drinking water because of the self-purifying properties of the soil.

Therefore, there is the need for regular monitoring and assessment of these drinking water sources. This is because monitoring provides data on groundwater quantity and quality and it is an integral aspect of groundwater management (Sundaram, et al., 2009). However, the quality assessment of groundwater in selected communities in the Niger Delta is very few in the literature. Hence, the present study is driving its focus along this corridor with a view to providing baseline data that will be used as a guide for future monitoring and to determine the level of contamination by comparing results with local and international standardized limits.

II. MATERIALS AND METHODS

The study was carried out in Yenagoa, Bayelsa State, Nigeria. The study area is located in latitudes between 4^0 51' 30''N and 5^0 13' 30''N and longitudes between 6^0 12' 30''E and 6^0 22' 30''E (Figure 1). The study locations experience a tropical humid climate with lengthy and heavy rainy seasons and very short dry seasons. The heaviest precipitation occurs during September with an average of 370 mm of rain. December on average is the driest month of the year; with an average rainfall of 2000mm. The southwest wind transports its moisture to the region. It blows through Southern Nigeria between the months of February through November. During this period, the region receives its rain. Only the months of December and January truly qualifies as dry season months in the city. The North East trade wind blows through the Sahara desert passes through the core Niger Delta between the months of November through February. During this period the places experience dry season and harmattan. The region is endowed with abundant sunshine and this is because it is located close to the equatorial region. The mean annual temperature of the region is 28^0C and the region records its highest temperature during the month of July and the lowest temperature in January (Adeyemo and Oyegun, 1999). Temperatures throughout the year in the city are relatively constant, showing little variation throughout the course of the year. Average temperatures are typically between 25°C-28°C in the city (Ogbonna et al., 2007). There are two major pressure and wind system in Nigeria. One is generated from subtropical high pressure cell. These cells are called anti–cyclones they generate and drive the north east trade wind and the south west winds.

Relief of the study area is undulating in other words the high and low lands, which characterizes the place. However, Yenagoa is dominated by low lying coastal plains, which structurally belongs to the sedimentary formation of the recent Niger Delta, with an elevation less than 15.24m (Oyegun and Adeyemo, 1999). The low relief of the region results in strikingly gentle slope, which have the effect of making the flow velocity of the rivers very low. This situation results in the formation of well-developed rivers meanders (Umeuduji and Aisuebeogun, 1999).

The study area is underlain by the Coastal Plain sands having its place from the Pleistocenic Formation (Nwakoala and Warmate, 2014). The sediments are deposits comprising of gravel, clays, peats, sands and silt from the River Niger. The depositional order displays vast sandstones superimposing an interchange of sandstones and clays of slightly marine source which has developed to be marine clays. Sands constitute the prevailing and dominant type of rock in the study area.

This study adopted experimental research and cross sectional research designs in an attempt to answer the questions previously raised for the investigation. Experimental research is undertaken when a researcher wishes to trace cause-and-effect relationships between defined variables (Tarner, 2018). Experimental research is any research conducted with a scientific approach, where a set of variables are kept constant while the other set of variables are being measured as the subject of experiment (Mitchell, 2015).The functional boreholes and hand-dug wells were located and captured using a global positioning system (GPS). It was used to register the coordinates (longitude and latitudes) of the boreholes/hand-dug wells which were brought into the ArcGIS environment to determine their spatial distribution within the study area. The study locations were Yenagoa. Enugu State though not a Niger Delta region is also chosen as a study location as the control for the study. Three boreholes and three hand dug wells were purposively collected in the study locations (Table 1). The criteria for selection of boreholes/hand-dug wells included boreholes that are 140ft and above; hand-dug wells that are 30ft and above; they were 100m apart; accessibility by the owners; and security of the area.

Table 1: Coordinates of Groundwater selected for the study

S/N	Groundwater	Y_Coordinates	X_Coordinates
1	Well1	4.93611	6.28472
2	Well2	4.93496	6.27288
3	Well 3	4.98387	6.28217
4	Borehole 1	4.94578	6.33688
5	Borehole 2	4.94122	6.31723
6	Borehole 3	4.91017	6.29717

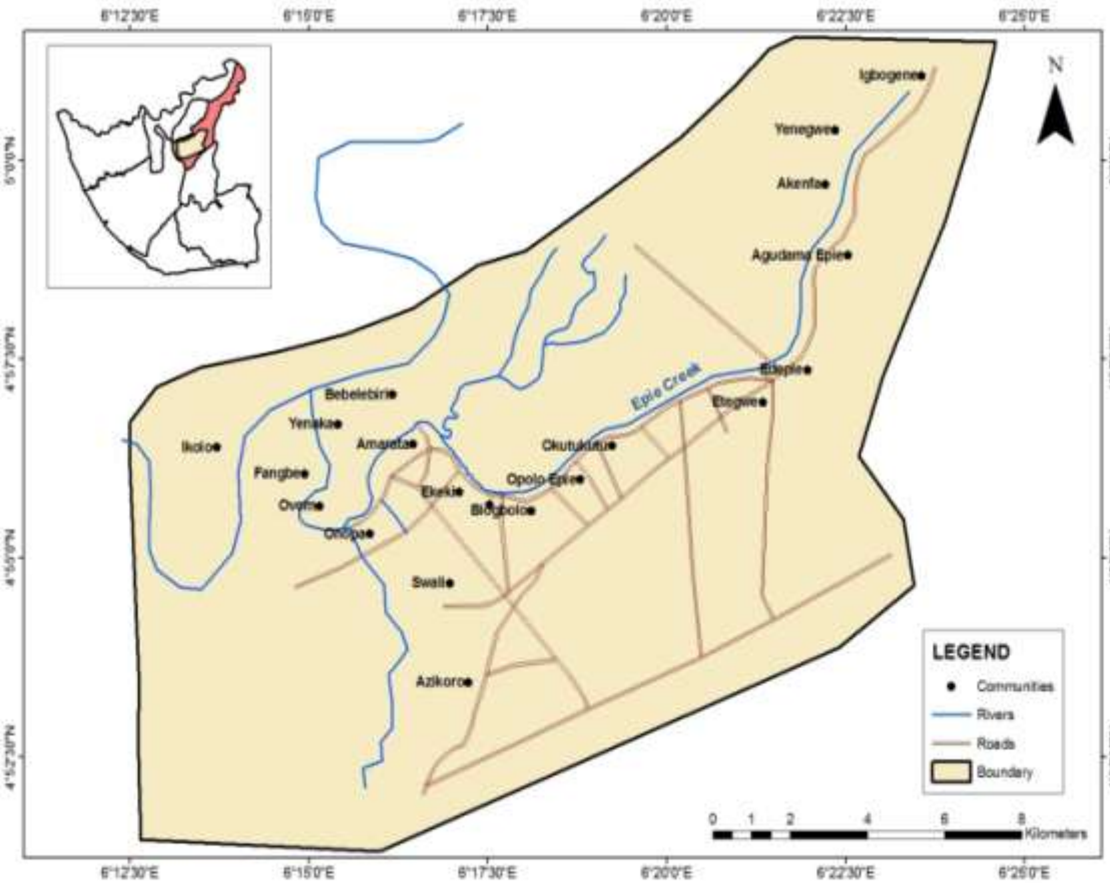

Figure 1: Yenagoa Metropolis showing road and communities

Water Sampling Methods and Laboratory Analysis

The data collection was carried out in the dry (November 2020-February 2021) and wet seasons (July 2021- August 2021). Groundwater samples were taken from the selected boreholes in Yenagoainto distilled jars. The jars were properly labelled for heavy metals test and polycyclic aromatic hydrocarbon test. The water samples were stored in ice packed coolers at a temperature below 4^oC to preserve the quality and pre-treated with 2mls of hydrochloric acid (HCl) in order to stabilize the samples and thereafter, the water samples were taken to laboratory.All results from the water samples from boreholes were subjected to the World Health Organization Standard for potable water to determine its suitability for domestic and industrial uses.Water Quality Index (WQI) was applied in this study. WQI is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers (Amadi et al., 2012). It is an important parameter for the assessment and management of surface water and can be applied in groundwater as well. WQI is a scale used to estimate an overall quality of water based on the values of the water quality parameters (Amadi, 2011). It is a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point view of the suitability of groundwater for human consumption (Amadi, Olasehinde and Yisa, 2010; Njenga, 2010). The WQI was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter qi was calculated by using the expression in Equ. 2:

qi = (Ci / Si) x 100 ………………………………………………………………….. Equation 3.3.

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100.

Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter (Equation 3.4):

Wi = 1/Si ……………………………………………………………………… (Equation 3.4)

The overall WQI was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly.

Where:

Qi = the quality of the ith parameter,

Wi = the unit weight of the ith parameter and

n = the number of the parameter considered.

Generally, WQI was discussed for a specific and intended use of water. In this study the WQI for drinking purposes is considered and permissible WQI for the drinking water is taken as 100 (Amadi, Olasehinde, Yisa, Okosun, Nwankwoala and Alkali, 2012).The calculation of WQI was made using weighed Arithmetic index method (Brown et al, 1972) in the following steps:

Let there be in water quality parameters and quality rating (qn) corresponding to nth parameter is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible value. qn values are given by the relationship.

qn=100 (vn-vi) / (vs-vi)

vs = Standard value,

vn = observed value

vi = ideal value

In most cases vi=0 except in certain parameters like pH, dissolved oxygen etc.

Calculation of quality rating for pH & DO (vi≠ 0)

In most cases, vio=0 except for pH and DO

For pH, vio=7; For DO, vio=14.6mg/l

q pH = 100 (v pH – 7.0) / (8.5 – 1.0) and

q DO = 100 (VDO – 14.6) / (15.0-14.6).

The suitability of WQI values for human consumption according to Mishra & Patel, (2001) and Oni and Fasakin (2016) are rated as follows.

0-25 .... .Excellent

26-50 .... Good

51-75 ....Bad

76-100 .... Very Bad

100 & above ....Unfit and Unsuitable for Drinking

In the data analysis, descriptive analysis was used to describe the mean values of groundwater parameters. In the data analysis, descriptive analysis was used to describe the mean values of groundwater parameters.

III. RESULTS AND DISCUSSIONS

Spatial and seasonal variations in the physico-chemical properties of Well Waterin Yenagoa

The spatial analysis of groundwater from the study locations are discussed in this section. It is shown that Table 2 displays the seasonal variation of the physical properties of well water in the dry and wet seasons in Yenagoa City. In the dry season, it is revealed that the total dissolved soilds was 0.47 mg/l, total hardness was 11.14 mg/l while the temperature was 28.33°C, the colour was 3.67 Hz and turbidity was 15.67 mg/l. In the wet season, it is shown that total dissolved solids was 0.66 mg/l, total hardness was 10.00 mg/l, temperature was 27.47°C while colour of the water was 2.33 Hz and the turbidity was 13.67 NTU. This result showed that the total dissolved solid was higher in the wet season than the dry season while the temperature, colour and turbidity were higher during the dry season.

In Table 3 where the chemical properties of water in the well are displayed, it is revealed that the pH in the dry season was less alkaline than the wet season while the electrical conductivity was higher in the dry season than the wet season. It is shown that the Nitrate, Sulphate, Phosphate, Chloride and and Nitrite were higher during the wet season than the dry season. The analysis showed that the DO was 4.67 mg/l, BOD 1.63 mg/l and COD 6.00 mg/l in the well in Yenagoa during the dry season. These water properties were higher during the dry season than the wet season. The cations (Na, K, Mg and Ca) were higher during the wet season than the dry season. Furthermore, the haevy metals were not found in the well water except Fe, Zn, Cd, Cr and Mn which are found in a very low content within the well water.

Table 2: Seasonal Variation of Well Physical Properties in the Dry and Wet Seasons in Yenagoa

Physical Properties	Dry Season		Wet Season	
	Mean	Std. Deviation	Mean	Std. Deviation
Total Dissolved Solids (mg/l)	0.47	0.05	0.66	0.21
Total Hardness (mg/l)	11.14	1.32	10.00	1.32
Temperature (°C)	28.33	0.57	27.47	0.15
Colour (Hz)	3.67	0.57	2.33	0.58
Turbidity (NTU)	15.67	3.06	13.67	3.21

Table 3: Seasonal Variation of Well Chemical Properties in the Dry and Wet Seasons in Yenagoa

Chemical	Dry Season		Wet Season	
Properties	Mean	Std. Deviation	Mean	Std. Deviation
pH	6.63	.15	6.74	.19
EC (um/	239.00	35.93	220.67	93.72
Nitrate	0.07	.02	.21	.07
Sulphate	0.03	.01	.03	.01
Phosphate	0.04	.02	.04	.05
Chloride	77.00	10.39	83.33	23.46
DO	4.67	1.15	3.33	1.53
BOD	1.63	.21	2.03	.06
COD	6.00	1.00	5.83	2.28
Na	8.20	2.15	8.25	6.07
K	1.48	.37	3.16	.36
Mg	1.95	.74	4.60	.71
Ca	19.33	8.46	32.24	4.15
F	0.023	.02	.15	.03
Nitrite	0.027	.01	.12	.05
Carbonate	0.00	.00	.00	.00
Fe	0.10	.03	.16	.06
Pb	0.0	.00	.00	.00
Zn	0.01	.003	.01	.003
Cd	0.01	.00	.00	.00
Cr	0.04	.03	.00	.00
Mn	0.04	.01	.01	.006
Co	0.00	.00	.00	.00
Cu	0.01	.001	.001	.002
$K2SO_4$	0.01	.004	.012	.004
HCO_3	10.50	1.80	11.50	8.79

Spatial and seasonal variations in the physico-chemical properties of Borehole Water in Yenagoa

Table 4 displays the seasonal variation of the physical properties of borehole water in the dry and wet seasons in Yenagoa Metropolis. During the dry season, the total dissolved solids was 4.667 mg/l, total hardness was 15.37 mg/l while the temperature was 28.33°C, the colour was 3.33 Hz and turbidity was 14.00 NTU. In the wet season, it is shown that total dissolved solids was 7.4667 mg/l, total hardness was 11.33 mg/l, temperature was 27.53°C while colour of the water was 8.33 Hz and the turbidity was 44.00 NTU. This result showed that the total dissolved solids, total hardness, and temprature were higher during the wet season than the dry season. In Table 5, the chemical properties of water in the borehole are displayed; it is revealed that the pH in the dry season was less alkaline than the wet season by having 7.1233 while the electrical conductivity was higher in the wet season than the dry season. It is shown that the Nitrate and Sulphate were higher in the dry season than the wet season. The water analysis showed that the DO was 4.666 mg/l, BOD 1.866 mg/l and COD 7.333 mg/l in the well in Yenagoa during the dry season. The water properties were higher during the dry season than the wet season except the COD that was higher during the wet season. The cations were higher during the dry season than the wet season. However, the heavy metals were not found in the well water except Fe, Zn, Mn, and Cu which are very low in quantity and most of them were higher during the dry season.

Table 4. Seasonal Variation of Borehole Physical Properties in the Dry and Wet Seasons in Yenagoa

Physical Properties	Dry Season Mean	Std. Deviation	Wet Season Mean	Std. Deviation
Total Dissolved Solids	4.6667	.61101	7.4667	1.45029
Total Hardness	15.3700	3.70215	11.3333	3.61709
Temperature	28.3333	.57735	27.5333	.05774
Colour	3.3333	.57735	8.3333	1.52753
Turbidity	14.0000	2.00000	44.0000	10.53565

Table 5. Seasonal Variation of Borehole Physical Properties in the Dry and Wet Seasons in Yenagoa

Chemical Properties	Dry Season Mean	Std. Deviation	Wet Season Mean	Std. Deviation
pH	6.8333	.11547	7.1233	.15275
EC	255.3333	19.03506	352.6667	137.86346
Nitrate	.2197	.06086	.1473	.08903
Sulphate	.0503	.00971	.0263	.00874
Phosphate	.0290	.00458	.0120	.00755
Chloride	173.3333	11.54701	163.3333	12.58306
DO	4.6667	.57735	9.0000	1.00000
BOD	1.8667	.15275	2.2667	.15275
COD	7.3333	1.15470	6.0667	2.72274
Na	14.7000	3.02655	27.3000	10.21959
K	3.0633	.19757	1.6900	.61879
Mg	11.1000	2.40000	10.0700	3.17596
Ca	21.1000	15.28921	21.0100	18.26738
F	.0733	.01155	.8700	.14422
Nitrite	.1297	.03153	.0897	.05248
Carbonate	.0000	.00000	.0000	.00000
Fe	.1700	.06557	.1067	.04163
Pb	.0000	.00000	.0000	.00000
Zn	.0097	.00252	.0427	.02230
Cd	.0233	.00577	.0000	.00000
Cr	.0233	.00577	.0000	.00000
Mn	.0380	.00700	.3213	.38270
Co	.0000	.00000	.0000	.00000
Cu	.0037	.00058	.0000	.00000
$K2SO_4$	.0127	.00351	.0103	.00462
HCO_3	9.6667	2.08167	22.1667	11.57944

Water quality index inYenagoa Metropolis

The water quality index in the selected study locations in wells and boreholes is displayed in Table 6. The analysis revealed that all the groundwater sampled in the study locations are within the permissible limit. The decision on the water quality was excellent except the well which was categorisedgood. The general groundwaterin Table 7, revealed all groundwater to be excellent.

Table 6.Spatio-seasonal Variation in WQI in the Selected Study Locations in Wells and Boreholes

Locations	Seasons	Well	Water Quality Decision	Borehole	Water Quality Decision
Yenagoa	Dry	6.397943	Excellent	5.167093	Excellent
	Wet	0.675038	Excellent	27.13858	Good

Table 7. General Groundwater QI in Yenagoa in Wells and Boreholes

Locations	Seasons	Groundwater	Water Quality Decision
Yenagoa	Dry	5.782518	Excellent
	Wet	-464.417	Excellent

IV. CONCLUSION AND RECOMMENDATIONS

It can be concluded that the water quality of groundwater in the Yenagoa is excellent and good for consumption. Although the parameters especially the turbidity, and total dissolved solids are higher in the wet season. Based on findings, the study therefore recommended that the groundwater in Yenagoa Metropolis should be prevented from being affected with pollutants which could degrade the quality of its consumption; there should be periodic monitoring of groundwater quality in the study location; people should be informed that the level of groundwater could only be affected by seasons and the parameters like total dissolved solids and turbidity should be controlled and improved.

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