Influence of Seasonal Variation on Groundwater Quality in parts of Southern Ijaw Local Government Area of Bayelsa State, Southern Nigeria

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Abstract

This work aims at analysing the data of the seasonal variation of groundwater quality in parts of Southern Ijaw Local Government Area of Bayelsa State, Southern Nigeria. The analysis of seasonal groundwater quality in some part of Southern Ijaw is not only appropriate but timely because there is paucity of baseline data on the quality of groundwater in this area, which makes it difficult to ascertain how impaired or degraded the water resources have become over the years. Fifteen (15) communities within the LGA were selected and groundwater from hand-dug well (HDW-15samples) and borehole (BH-15samples) was sourced during the wet season (July) and dry season (March) and analysed for seasonal variations. The difference in the mean of the parameters investigated during the dry and wet season revealed the difference in concentration level as influenced by the season attributes. Paired t-test analysis indicated a strong correlation and no significant difference in the physicochemical properties of both HDW and BH for both seasons. The HDW showed a very strong correlation in wet and dry season physicochemical properties as well as no significant difference in the physicochemical properties of groundwater at both seasons ($r = 0.955$, $p = 0.235$). Also, the results of borehole water sample showed a very strong correlation in wet and dry season physicochemical properties with no significant difference in the physicochemical properties of water at both seasons ($r = 0.992$, $p = 0.175$). The outcome implies that there are similarities in various natural and anthropogenic activities influencing the concentrations during both wet and dry seasons. Irrespective of the season, there is no obvious difference in the physicochemical properties of groundwater sourced from Hand Dug Wells (HDW) and Boreholes (BH). Regular groundwater quality monitoring in the study area is advocated.

Keywords: *Groundwater, Physico-Chemical, Seasonal Variation, Water Quality, Wells, Boreholes*

INTRODUCTION

The need for water for various purposes is increasing at a fast rate. This is due to the continual increase in population, rapid urbanization with the lifestyle change, and growing industrialization (Nwankwoala *et al*., 2011; Gajbhiye *et al.,* 2014: Sharma *et al.,* 2014).

Water quality plays an important role in groundwater protection and quality conservation. Hence it is very important to assess the water quality not only for its present use but also from the viewpoint of a potential source of water for future consumption (Nwankwoala & Omemu, 2019). There is a growing concern about the deterioration of water quality due to geogenic and anthropogenic activities. The quality of water is identified in terms of its physical, chemical, and biological parameters (Abam & Nwankwoala, 2020). Polluted groundwater cannot achieve a balanced ecosystem, in which living things and the environment interact beneficially with one another. Water quality plays a critical role in this relationship (Ntengwe, 2006), as it is key to the maintenance of a well-balanced environment.

The provision of adequate and safe water for drinking is important for sustaining life and the environment because water is an essential ingredient for good health and socio-economic development (Galadima *et al.,* 2011). However, the utility of any water for domestic, industrial and agriculture purpose depends on the physical, chemical, and biological characteristics of such water (Amadi *et al.,* 2012; Sunitha *et al.,* 2012). This is because the status of water affects the health and well-being of humans, animals and plants that make use of it. The quality of water that humans ingest is critical in determining the quality of their lives (Fetter, 1994). It is in line with the above that, the World Health Organization has repeatedly stressed that the single major factor adversely influencing the general health and life expectancy of a population in many developing countries is the ready access to safe drinking water (Hoko, 2005). Therefore, the availability of water does not suffice, rather how qualitative it is, qualifies it as a resource. Consequently, great concern should be given to the quality of water as it is critical for the overall socio-economic development of any society and, should engage the attention of researchers, government, and non-governmental organizations (Adetunde and Glover, 2010). Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is the measure of the condition of water relative to the requirements.

Poor water quality is a significant global issue that is discussed within the scientific community, especially in developing countries, because it is responsible for most diseases and deaths (WHO, 2005). According to Ashbolt (2004), impaired water accounts for over 1.7 million deaths world-wide every year (i.e., 3.1% of all deaths) and 3.7% of all Disability-Adjusted Life-Years (DALYs), which is the measure of overall disease burden expressed as the number of years lost due to ill-health, disability, or death (WHO, 2001). Similarly, Egwari and Aboaba (2002) stressed that about half the world's hospital beds are occupied by patients suffering from water-related diseases and that every fifteen seconds, a child dies from water-related diseases. Chima and Digha (2010) observed that, about 1.8 million children die each year from diarrhoea due to intake of contaminated water. Similarly, Galadima *et al.,* (2011) concluded that, water-related diseases such as cholera, diarrhoea, bilharziasis, etc affect poor local people because of lack of access to quality water.

Assessment of groundwater quality is critical for resource planning and environmental management (Mohamed *et al*., 2019). Water quality status can be described by several physical, chemical, and biological parameters, large amounts of data make assessment and comparison significantly difficult (Mester *et al.,* 2020).

Consequently, the analysis of groundwater quality in some part of Southern Ijaw is not only appropriate but timely because since there is paucity of baseline data on the quality of groundwater in this area, since it can be difficult to ascertain how impaired or degraded the water resources have become over the years. Thus, this research seeks to determine the seasonal variation influence on groundwater quality in the area. The result of this study will strengthen the national and local water quality database by providing necessary information that will aid stakeholders and the people for necessary action on the status of the groundwater used in the study area.

The Study Location

The study area is Southern Ijaw Local Government Area in Bayelsa State, Nigeria. The area lies within Longitude $6^{\circ}00'10''$ N and $6^{\circ}25'15''$ N and Latitude $4^{\circ}40'07''$ E and $5^{\circ}5'20''$ (Figure 2). The study area has a tropical rain forest climate characterized by two seasons, namely the wet or rainy season and the dry season. The rainy season lasts for about 7 months between April and October with an intervening dry period in August. The dry season lasts for about 4 months, between November and March (Udom & Nwankwoala, 2012). The temperature varies between 25 and 32 ^{0}C. The mean annual rainfall is about 4,500 mm; about 85 % of the mean annual rain falls in the wet season (Akpokodje, 1986; Nwankwoala & Omemu, 2019).

Relief and Drainage

The study area consists of alluvial deposits and an extensive, low-lying, typical deltaic plain with essentially flat topography which in conjunction with the high annual rainfall, is responsible for the extremely poor drainage conditions and the widespread development of marshes and back swamps. This area is usually submerged during the wet season where flood waters range from 0.5 to 4 m deep (Akpokodje 1986). There are several perennial streams, oxbow lakes, and rivers in the area e.g., Kolo Creek, Epie Creek, Yenagoa and Nun River, etc. They all form a network which empties to the Atlantic Ocean through Nun River Estuary. These rivers are mostly turbid during the wet season possibly due to discharge of clay and silt (Amadi *et al.,* 1987; Nwankwoala *et al.*, 2013). The natural vegetation of the study area is that of the rain forest, but this has been destroyed by the activities of man such as bush burning, farming, construction, and illegal crude oil refining activities. The vegetation consists of various kinds of evergreen trees, including palms trees and a variety of shrubs. More than 70 % of the inhabitants of the study area are engaged in subsistent farming and fishing.

Geology and Hydrogeology of the Study Area

The geology of the Niger Delta has been described in detail by various authors such as Short and Stauble, I967 & Kogbe, I976). The formation of the Delta started during Early Paleocene and resulted mainly from the build-up of fine-grained sediments eroded and transported by the River Niger and its tributaries. The Tertiary Niger Delta is a sedimentary structure formed as a complex regressive off-lap sequence of clastic sediments ranging in thickness from 9,000m - I2,000m (Abam, 1999; Abam & Nwankwoala, 2020). Starting as separate depocenters, the Niger Delta has coalesced to form a single united system since Miocene. The Niger Delta is a large and ecologically sensitive region, in which various water species including surface and sub-surface water bodies exist in a state of dynamic equilibrium (Abam, I999). The Niger Delta is stratified by three lithologic successions: Benin Formation, Agbada Formation and Akata Formation.

The Niger Delta has two most critical aquifers, Deltaic and Benin Formations (Ngah & Nwankwoala, 2013). With a regularly dendritic waste system, this very penetrable sands of the Benin Formation enable simple penetration of water to revive the shallow aquifers. Nwankwoala *et al.,* 2014 depicted the aquifers here as an arrangement of various aquifer frameworks stacked on one another with the unconfined upper aquifers happening at the best (Ngerebara *et al*., 2008).

The recharge of aquifers is immediate from invasion of precipitation, the yearly aggregate of which shifts between 5000mm at the drift to about 2540mm landwards. Groundwater in the zone happens in shallow aquifers of overwhelmingly mainland deposits experienced at penetrations of somewhere in the range of 45m and 60m. The lithology contains a blend of sand in a fining up arrangement, rock, and mud. Well yield is phenomenal, with generation rates of 20,000 litres/hour normal and borehole achievement rate is typically high (Amadi *et al.,* 2012).

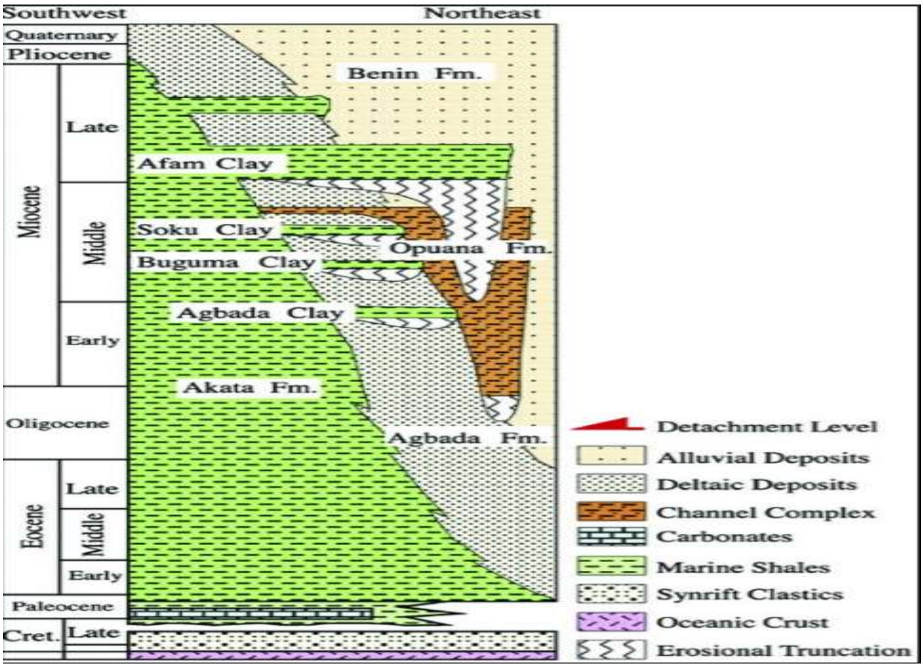

Figure 1: Geological Stratification of the Niger Delta (after Short & Stauble, 1967)

MATERIALS AND METHODS OF STUDY

Sample Collection

The water samples for the study were collected during the dry season (March) and wet season (July) from boreholes and hand-dug wells around the study area. Specifically, water samples were collected from borehole (15) and groundwater (15) during the dry season and the process was repeated during wet season which implies that a total of forty (60) samples were collected for the study during both seasons for the same wells and boreholes. To prevent confusion and mixed up of the water sample, each sample will be tagged according to their sources, and the season they represent and with Roman figure to represent the position of the sample as presented.

i. Borehole (BH) Water during Wet Season (WS) = BHWS I-XIV
ii. Borehole (BH) Water during Dry Season (DS) = BHDS I-XIV

iii. Hand-dug well (HDW) Water during Wet Season (WS) = HDWWS I-XIV
iv. Hand-dug well (HDW) Water during Dry Season (DS) = HDWDS I-XIV

With the aid of labelled bottle, water samples were collected from various designated water source. Prior to the water collection, clean bottles were cleaned in order prevent impurities and other form of contamination. The water samples were collected from each designated point and the bottles were fully filled. Thereafter, the filled bottles were immediately placed in the ice-parked cooling medium to arrest continuous microbial activities and preserve the water before been taken to the laboratory for analysis. The laboratory analysis of APHA standard was used.

Table 1: Analytical methods used for groundwater samples analysis

Analysis	Parameter	Symbol	Unit	Type of Test	Laboratory Standard
Physio-Chemical	pH	pH		In-situ	APHA 4500-H^+B
	Total Dissolved Solids	TDS	mg/L	In-situ	APHA 2540C
	Electrical Conductivity	EC	µS/cm	In-situ	APHA 2510B
	Sodium	Na	mg/L	Laboratory	APHA 3111B
	Calcium	Ca	mg/L	Laboratory	APHA 3111D
	Magnesium	Mg	mg/L	Laboratory	APHA 3111B
	Potassium	K	mg/L	Laboratory	APHA 3111B
	Sulphate	SO4	mg/L	Laboratory	APHA 4500/SO_4-E
	Nitrate	NO_3	mg/L	Laboratory	APHA 4500/NO_3-E
	Chloride	Cl	mg/L	Laboratory	APHA 3111B
	Bicarbonate	HCO_3	mg/L	Laboratory	APHA 3111B
Biological	Total Coliform	TC	(MPN/100ml)	Laboratory	APHA 9221C
Heavy Metals	Iron	Fe	mg/L	Laboratory	APHA 3111B
	Zinc	Zn	mg/L	Laboratory	APHA 3111B
	Manganese	Mn	mg/L	Laboratory	APHA 3111B
	Chromium	Cr	mg/L	Laboratory	APHA 3111D
	Lead	Pb	mg/L	Laboratory	APHA 3111B
	Cadmium	Cd	mg/L	Laboratory	APHA 3111B
	Copper	Cu	mg/L	Laboratory	APHA 3111B

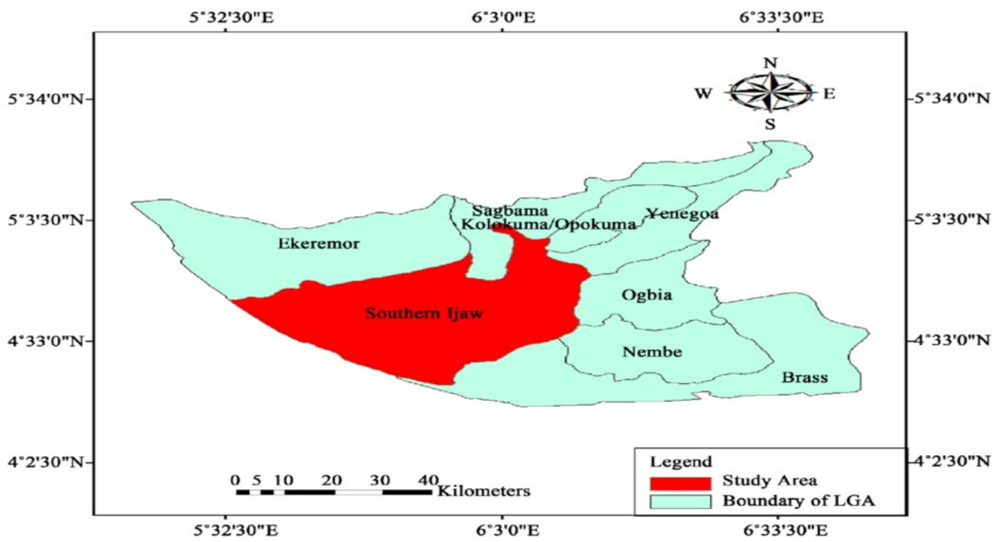

Figure 2: Overview of the Study Area

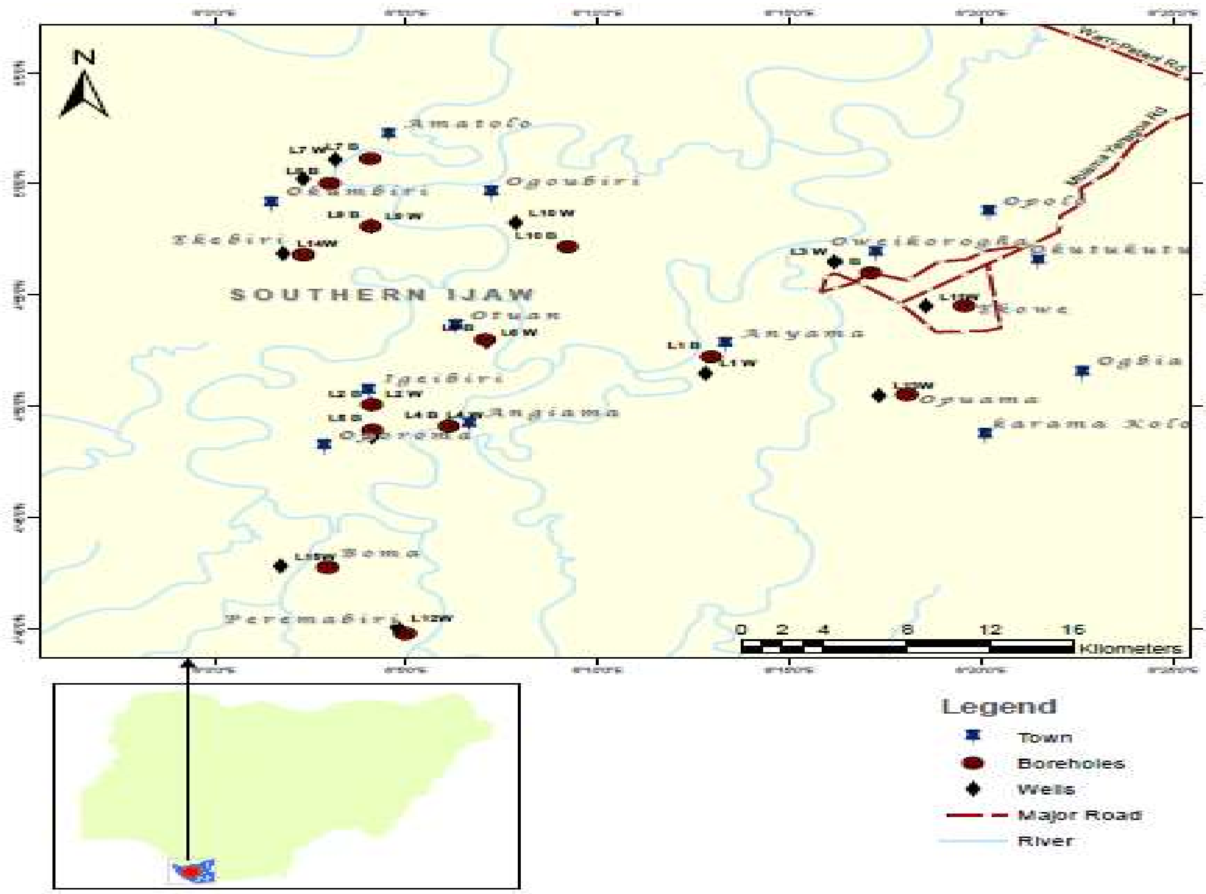

Figure 3: Map of the Study Area showing various sampling points

RESULTS AND DISCUSSION

i. pH

The mean pH values of the HDW during the wet and dry season showed 6.62 and 7.00 respectively at variation of 0.38 while the BH showed pH mean values of 7.20 and 6.81 during the wet and dry season respectively at variation of 0.39. However, the pH mean values of the water sources at different seasons are within the permissible limit of WHO (2012) of 6.5-8.9. The finding corroborated with that of Ganiyu *et al*., (2018) and Afolabi *et al.,* (2021) where the pH of the groundwater in their study was within the permissible limit, even though dry season is the season of maximum pH concentration (Pearson *et al*., 1971). The variation in value showed no abnormal change and low value pH has no harmful effect (Mohamed & Zair, 2017; Awan *et al.,* 2012).

ii. EC

The Electrical conductivity (EC) showed a value range of 674.67 to 522.27µS/cm during the wet and dry seasons for HDW and 169.95 to 158.05µS/cm for BH during the seasons respectively. The EC values for HDW during the wet season indicated that it exceeded the permissible limit of 600µS/cm while the concentration is within the permissible limit of WHO (2012) during the dry season. The finding outcome differs from the outcome of Afolabi *et al*., (2021) and Mohamed and Zair (2017) where both seasons showed EC concentration exceeding the WHO limit. However, the EC values for BH are within the permissible limit during the wet and dry seasons. The finding showed similarity with the outcome of Sharma and Chhipa (2016). According to Nnaji *et al.,* (2019) and Hameed *et al*., (2010), the extent of EC can be influence by natural weathering as well as anthropogenic activities and it's directly proportional to the TSS. From the Seasonal variation of electrical conductivity of Boreholes and Hand-dug wells it shows that seasonal variation has less effect on the Boreholes than the Hand-dug wells. The results obtained in this study also suggest that electrical conductivity (EC) of Boreholes and Hand-dug wells in this area does not follow a particular pattern but rather depends wholly on human activities and natural geographical formation of a specific location. High level of EC mean values of Hand-dug wells were because of run-off, infiltration, percolation from dumpsite, Agricultural activities, abattoir, domestic waste, industrial waste, leachates etc. located near the wells and rivers, also, natural phenomena such as erosion, flood, high temperature, soil type etc. This is possible because of the shallow nature of the Hand-dug wells (Temuagee *et al.,* 2020)

iii. TDS

The TDS values for HDW at dry and wet seasons were 329.47mg/L and 252.67mg/L with variation of 76.8mg/L respectively, while BH values during the dry and wet seasons were 87.06mg/L and 72.63mg/L with variation of 14.43mg/L. The TDS values of all the seasons are within the permissible limit of 500mg/l (WHO, 2012). The finding showed similarities with the study conducted by Adebayo *et al.,* (2015); Ganiyu *et al.* (2018). The TDS value of less than 1000mg/l implies that the water samples can be classified as freshwater. High TDS concentration in water could lead to laxative or constipation effects (Leelavathi *et al*., 2016; Afolabi *et al*., 2021) and the concentration can be influence by anthropogenic activities such as untreated wastewater and industrial discharge (Mohamed and Zair, 2017).

iv. TSS

The mean TSS values of the HDW during the wet and dry season showed 4.10mg/l and 3.87mg/l respectively while the BH showed TSS mean values of 3.87mg/l and 3.64mg/l during the wet and dry season respectively. The TSS mean values of the water sources at different seasons are within the permissible limit of 5mg/l (WHO, 2012). However, the outcome differs from the similar study conducted in Niger Delta communities (Woke and Babatunde, 2015; Woke and Umesi, 2018) where their values exceeded the permissible limit except the study conducted by Afolabi *et al*., (2021). High value of TSS (mg/l) is an implication for the presence of silt, decaying plants, and animal matter (Elenwo *et al.,* 2019).

v. TC

The mean Total Coliform (TC) values of the HDW during the wet and dry season showed >1600MPN/100ml and >1600MPN/100ml respectively with no variation at both seasons while the BH showed TC mean values of 840.0MPN/100ml and 823.50MPN/100ml during the wet and dry season respectively at variation of 16.5MPN/100ml. The finding showed that TC value was higher during the wet season for both HDW and BH than the dry season; however, all the values exceeded the permissible limit of 0/100mh/l (WHO, 2012). The finding showed similarity with the study conducted in Niger Delta communities (Woke and Babatunde, 2015; Dick *et al*., 2018 and Afolabi *et al*., 2021) where the TC values exceeded the acceptable limit for drinking water. This finding indicated that the water from the communities irrespective of the sources and seasons have been contaminated with microbes and possible pathogenic microorganisms (Elisante & Muzuka, 2016) which its source could be linked to human or animal origin. As noted by Woke and Babatunde (2015), high coliform counts seem to be attribute of rural areas water quality in Nigeria. The highest TC counts were significantly higher ($p < 0.05$) during the wet than the dry season owing to rising of water table and leaching during rainy season. Water sources that were located within 10 m of pit latrines had the highest coliform counts relative to those located beyond 10 m. Similarly, the highest coliform counts were observed in all shallow wells that (i) had low well head above the ground, (ii) were not covered, (iii) had casing materials which were not concrete and (iv) utilised traditional pumping (bucket/pulley) systems. This was due to contaminated storm water access, inoculation of microbes by exposed buckets and inefficiency of the casing material. Furthermore, the counts decreased with depths of boreholes and shallow wells during the two seasons probably due to retention and die-off (Elisante & Muzuka, 2016).

vi. Bicarbonate

The mean Bicarbonate values showed that HDW had 105.33mg/l and 95.71mg/l during the wet and dry season respectively with variation of 9.62mg/l while the BH had 63.10mg/l and 59.57mg/l for the same seasons with variation of 3.53mg/l. The highest value of bicarbonate was recorded at HDW during dry season; however, none of the values exceeded the permissible limit of 150mg/l (WHO, 2012) including that of the HDW during the wet season. The extent of bicarbonate in water can be influenced by the activities of atmospheric CO_2 and CO_2 from decomposed organic materials (Umapathy, 2011).

vii. Chloride

The mean values of Chloride are found in the range of 17.85mg/l and 27.0mg/l for HDW during the wet and dry seasons at variation of 9.15mg/l. The Chloride values for BH ranged from 7.51mg/l and 6.20mg/l for wet and dry season at variation of 1.31mg/l. The highest chloride value was recorded during the dry season of HDW; however, none of the water samples exceeded the permissible limit of

250mg/l (WHO, 2011). The finding showed similarities with the study conducted for Niger Delta communities by Ngah & Nwankwoala, 2012; Afolabi *et al.,* (2021), Dick *et al.,* (2018) and that of Mohamed and Zair (2017). According to Omole *et al*., (2017), chloride in drinking water is comparatively harmless. However, the extent of chloride in water could be influenced by natural and anthropogenic activities such as salt formation (Rehman & Rehman, 2014), application of inorganic fertilizer and industrial effluents (Bundela *et al*., 2012; Afolabi *et al.,* 2021).

viii. Sulphate

The mean value of Sulphate showed that HDW had 20.43mg/l and 30.87mg/l during the wet and dry season with variation of 10.44mg/l while BH had 126.87mg/l and 18.05mg/l with variation of 108.82mg/l. The outcome showed that the highest value of sulphate was recorded during the dry season for HDW and wet season for BH with obvious variation between the season concentrations; however, none of the values exceeded the permissible limit of 250mg/l (WHO, 2012). The finding corroborated with that of Omole *et al*., (2017). Higher values of sulphate could lead to intestinal disorder and odour under aerobic condition (Rehman and Rehman, 2014).

ix. Nitrate

The mean Nitrate value of 1.56mg/l and 1.28mg/l was recorded for HDW during the wet and dry seasons while 0.35mg/l and 0.45mg/l was recorded for BH during the wet and dry seasons. All the values are within the permissible limit of 45mg/l (WHO, 2012). The study found similarities with that of Ganiyu *et al*., (2018) and Mohamed and Zair (2017). Naturally, nitrate is found in soil and water; however, the concentration can increase because of anthropogenic activities such as industrial waste and domestic waste (Jameel and Hussain, 2011).

x. Calcium

The mean value of Calcium for HDW during the wet and dry season was 31.14mg/l and 38.28mg/l with variation of 7.14mg/l while BH has mean values of 3.01mg/l and 3.40mg/l during the wet and dry season. All the values are within the permissible limit of 200mg/l (WHO, 2012). The outcome corroborated with similar study conducted in Niger Delta communities (Dick *et al*., 2018; Afolabi *et al.,* 2021) while the high concentration during the dry season of HDW could be attributed to reduction in water level attributed to high sunshine resulting in an increase concentration of calcium.

xi. Magnesium

The mean value Magnesium for HDW during the wet and dry season was 8.44mg/l and 8.00mg/l while BH has mean values of 4.84mg/l and 5.20mg/l during the wet and dry season. All the values are within the permissible limit of 150mg/l (WHO, 2012). The outcome corroborated with similar study conducted in Niger Delta communities (Dick *et al*., 2018).

xii. Potassium

The mean value potassium for HDW during the wet and dry season was 4.72mg/l and 7.50mg/l with a seasonal variation of 2.78mg/l while BH has mean values of 2.16mg/l and 2.39mg/l during the wet and dry season. All the values are within the permissible limit of 20mg/l (WHO, 2011). The outcome corroborated with similar study conducted by Ganiyu *et al*., (2018) and Afolabi *et al.,* (2021).

xiii. Phosphorus

The mean value of phosphorus ranged from 0.05mg/l and 0.07mg/l for HDW during the wet and dry seasons and 0.06mg/l and 0.05mg/l for BH during the wet and dry seasons. All the values are within the permissible limit of 0.1mg/l (WHO, 2012). The low values in phosphorus corroborate with the report of Ezeribe *et al.,* (2012) and that reported for Niger Delta communities Afolabi *et al.,* (2021). The concentration of phosphorus in groundwater can be influenced by natural and anthropogenic activities such as weathering and percolation of domestic sewage (Mohamed and Zair, 2017).

Descriptive Statistics

Table 2 and Figure 4 presented the arithemetical variation and spatial-temporal variation among various parameters during the dry and wet season based on the water sourced from HDW and BH. The difference in the mean of the parameters investigated during the dry and wet season revealed the difference in concentration level as influenced by the season attributes.

The HDW showed a very strong correlation in wet and dry season physiochemical properties as well as no significant difference in the physiochemical properties of groundwater at both seasons ($r = 0.955$, $p= 0.235$). Also, the BH showed a very strong correlation in wet and dry season physiochemical properties with no significant difference in the physiochemical properties of water at both seasons ($r = 0.992$, $p= 0.175$). The outcome showed similarity with the study conducted by Afolabi *et al*., (2021). The outcome implies that there are similarities in various natural and anthropogenic activities influencing the parameters concentration during both wet and dry seasons. Therefore, irrespective of the season, there is no obvious difference in the physiochemical properties of groundwater sourced from HDW and BH.

Table 2: Seasonal Variation of Groundwater Quality Parameters during the Seasons

		Hand Dug Well			Borehole		
S/N	Parameters	Wet Season	Dry Season	AV*	Wet Season	Dry Season	AV*
1	pH	6.62	7.00	0.38	7.20	6.81	0.39
2	Temperature (°C)	31.77	31.79	0.02	30.59	31.77	1.18
3	EC (µS/cm)	674.67	522.27	152.4	169.95	158.05	11.9
4	TDS (mg/L)	329.47	252.67	76.8	87.06	72.63	14.43
5	TSS (mg/L)	4.10	3.87	0.23	3.87	3.642	0.22
6	TC (MPN/100ml)	1600.0	1600.0	-	840.00	823.50	16.5
7	Bicarbonate (mg/L)	105.33	95.71	9.62	63.10	59.57	3.53
8	Chloride (mg/L)	17.85	27.00	9.15	7.51	6.20	1.31
9	Sulphate (mg/L)	20.43	30.87	10.44	126.87	18.05	108.82
10	Nitrate (mg/L)	1.56	1.28	0.28	0.35	0.45	0.1
11	Calcium (mg/L)	31.14	38.28	7.14	3.01	3.40	0.39
12	Magnesium (mg/L)	8.44	8.00	0.44	4.84	5.20	0.36
13	Potassium (mg/L)	4.72	7.50	2.78	2.16	2.39	0.23
14	Phosphorus (mg/L)	0.05	0.07	0.02	0.06	0.05	0.01

*Arithmetic Variation in the season

Table 3: Descriptive Statistics of the Water Sourced during Wet and Dry Season

		Hand-dug Well (HDW)				Borehole (BH)					
		Wet Season		Dry Season		Wet Season		Dry Season			
S/N	Parameters	Means	SD	Means	SD	Means	SD	Means	SD	WHO*	NSDWQ*
1	pH	6.62	0.68	7.00	0.46	7.20	0.26	6.81	0.39	6.5-8.9	6.5-8.5
2	Temperature (°C)	31.77	4.30	31.79	0.25	30.59	0.71	31.77	0.10	Amt*	Amt*
3	EC (µS/cm)	674.67	294.21	522.27	227.82	169.95	65.73	158.05	39.48	600	500.00
4	TDS (mg/L)	329.47	167.04	252.67	115.48	87.06	20.91	72.63	20.72	1000	1000.0
5	TSS (mg/L)	4.10	0.71	3.87	0.62	3.642	0.61	3.621	0.58	5	NA
6	TC (MPN/100ml)	1600.00	.00	1600.00	.00	840.00	1074.8	823.50	1098.13	0/100	NA
7	Bicarbonate (mg/L)	105.33	30.52	95.71	66.65	63.10	12.77	59.57	16.12	200	50.00
8	Chloride (mg/L)	17.85	8.58	27.00	18.26	7.51	6.70	6.20	5.76	250	200.00
9	Sulphate (mg/L)	20.43	17.07	30.87	21.95	126.87	292.33	18.05	28.65	250	250.00
10	Nitrate (mg/L)	1.56	1.04	1.28	0.547	0.35	0.2	0.45	0.2	45	NA
11	Calcium (mg/L)	31.14	15.28	38.28	22.55	3.01	1.42	3.40	1.74	200	NA
12	Magnesium (mg/L)	8.44	2.94	8.00	2.25	4.84	1.38	5.20	1.31	150	0.30
13	Potassium (mg/L)	4.72	3.20	7.50	3.13	2.16	1.14	2.39	0.99	20	3.00
14	Phosphorus (mg/L)	0.05	0.02	0.07	0.02	0.06	0.02	0.05	0.01	0.1	1.00

*WHO (2012) * NSDWQ (2007), * Ambient, NA-Not Available

Table 4: Paired-Samples T-test of the Water Sourced during Wet and Dry Season

	Paired Correlations	Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
	Correlation				Lower	Upper			
HDW(WS) – HDW(DS)	.955	14.97143	45.00459	12.02798	-11.01345	40.95631	1.245	13	.235
BH(WS) – BH(DS)	0.992	11.04429	28.78605	7.69340	-5.57628	27.66486	1.436	13	.175

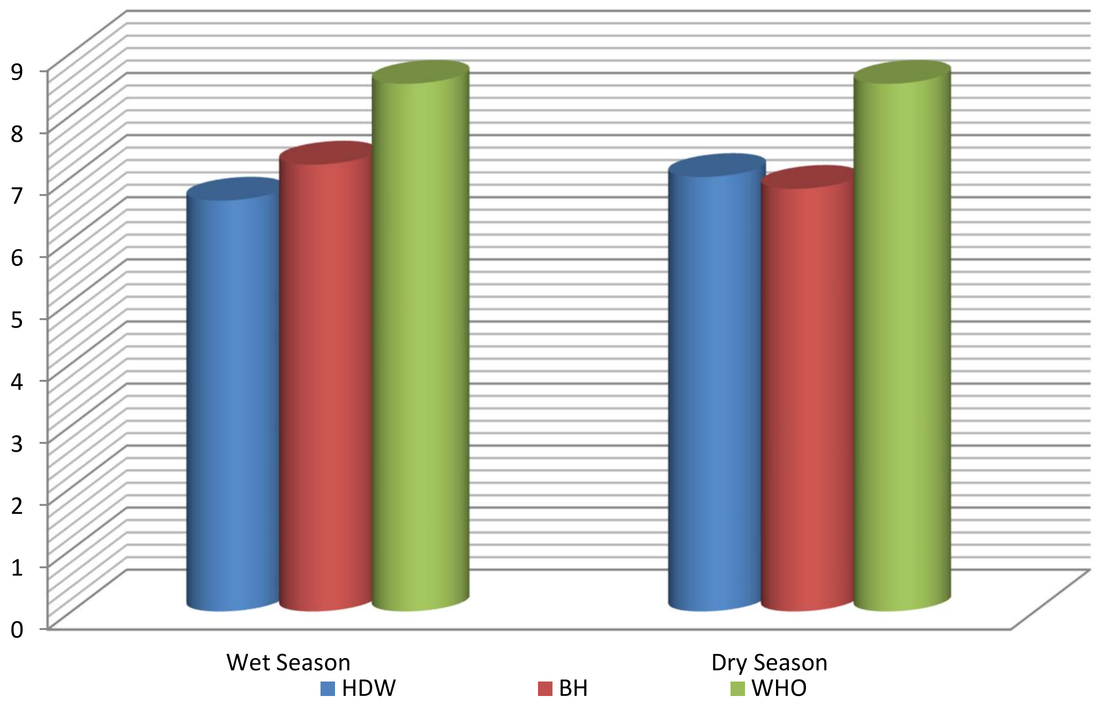

Figure 4: pH concentration from HDW, BH during Wet and Dry as Compared with WHO

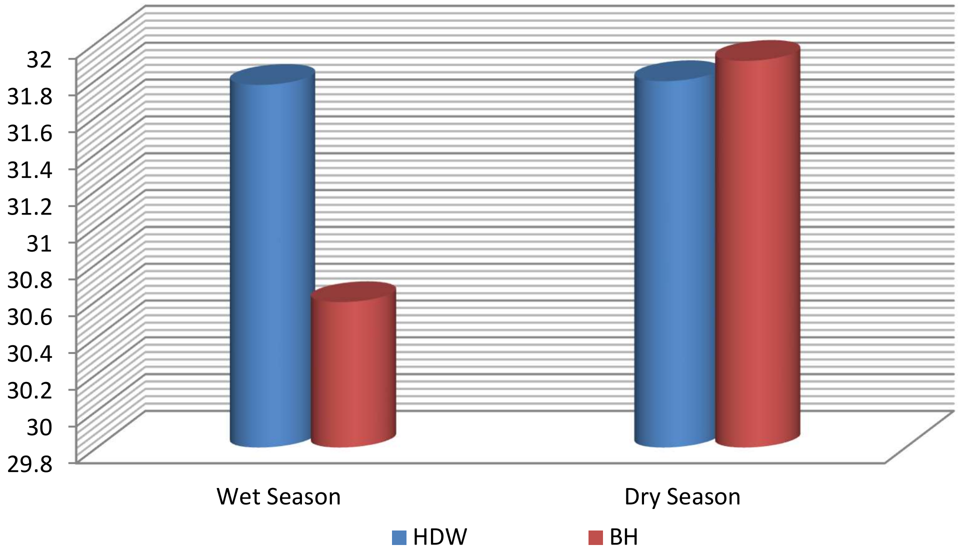

Figure 5: Temperature (°C) concentration from HDW, BH during Wet and Dry as Compared with WHO

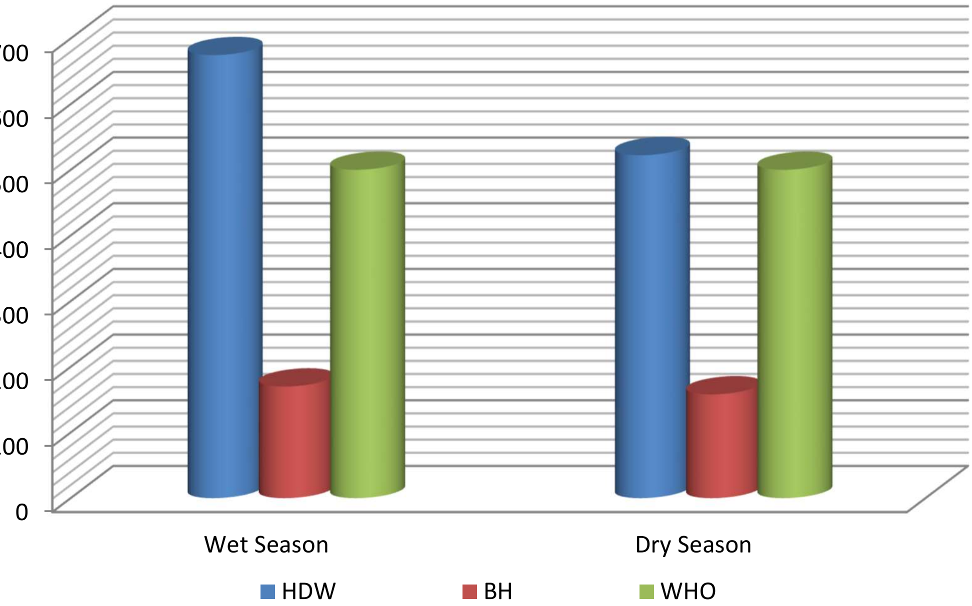

Figure 6: EC (µS/cm) concentration from HDW, BH during Wet and Dry as Compared with WHO

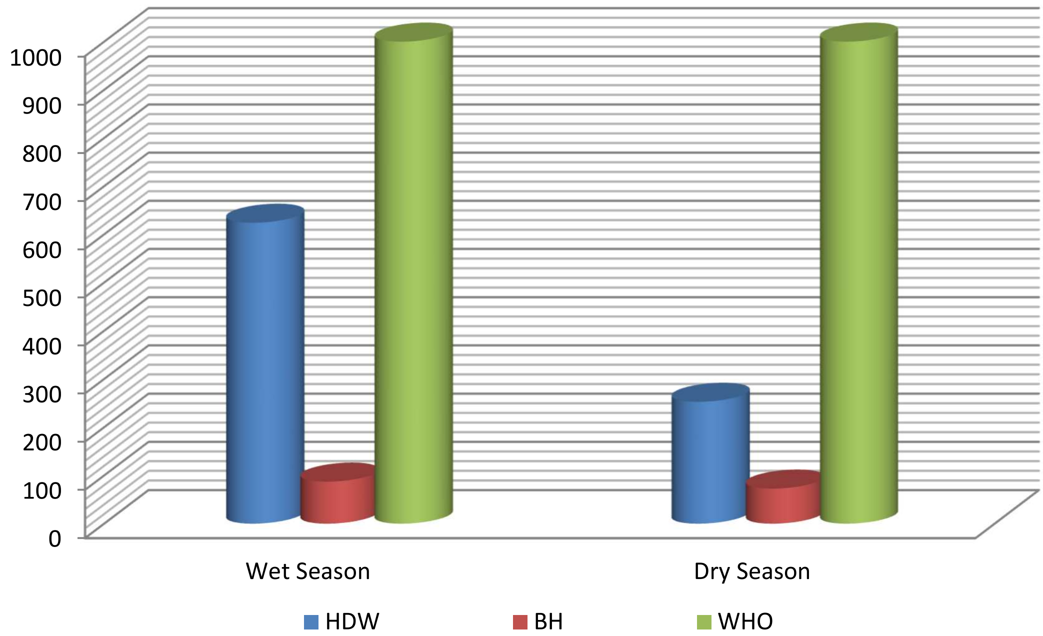

Figure 7: TDS (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

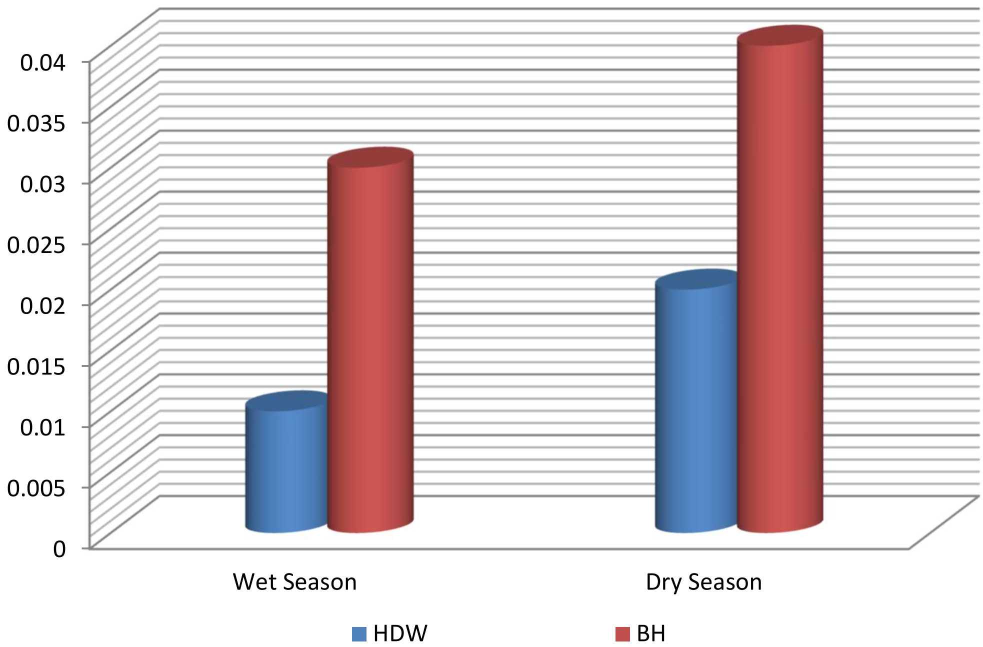

Figure 8: TSS (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

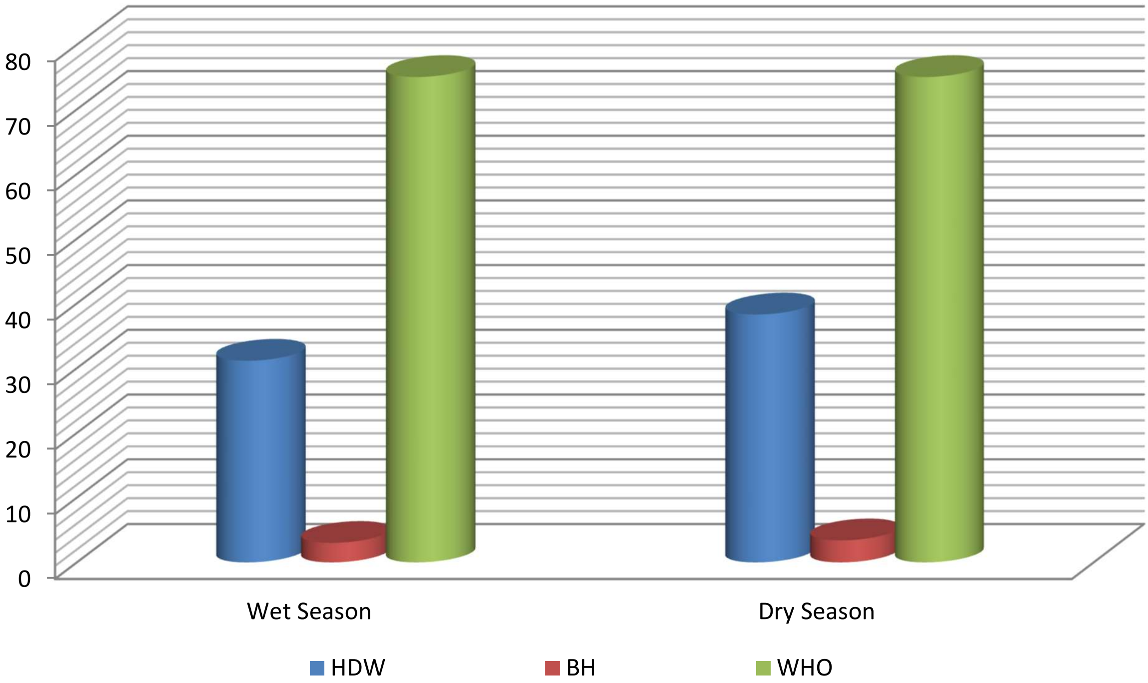

Figure 9: Ca (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

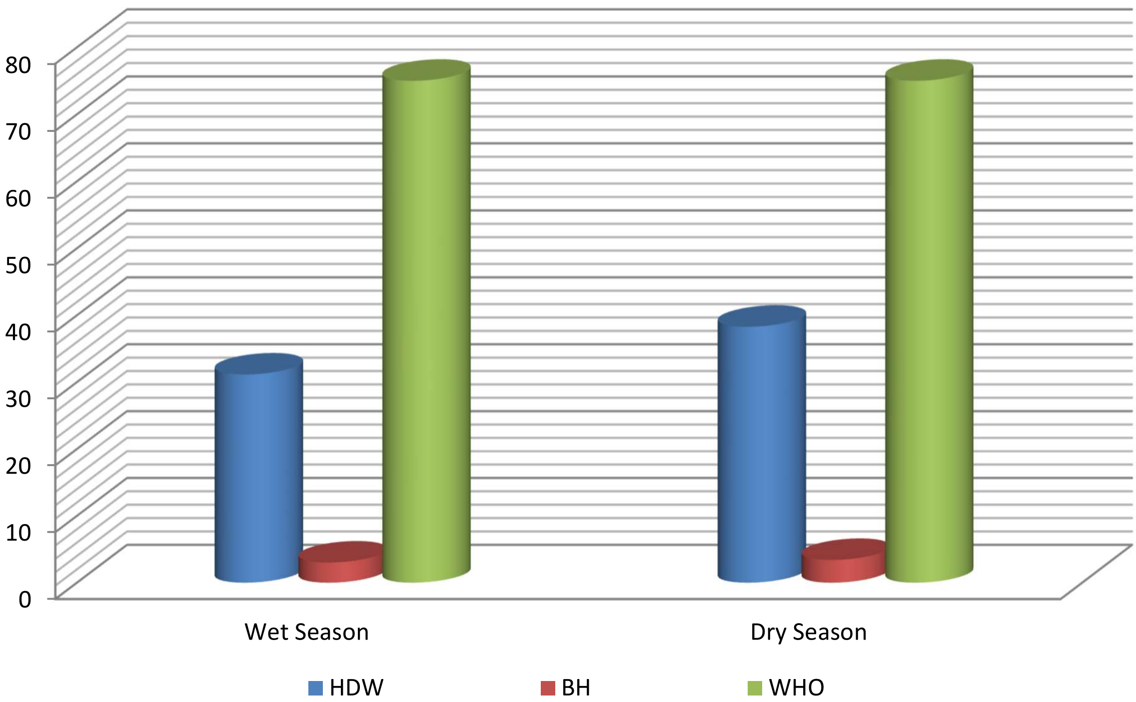

Figure 10: Mg (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

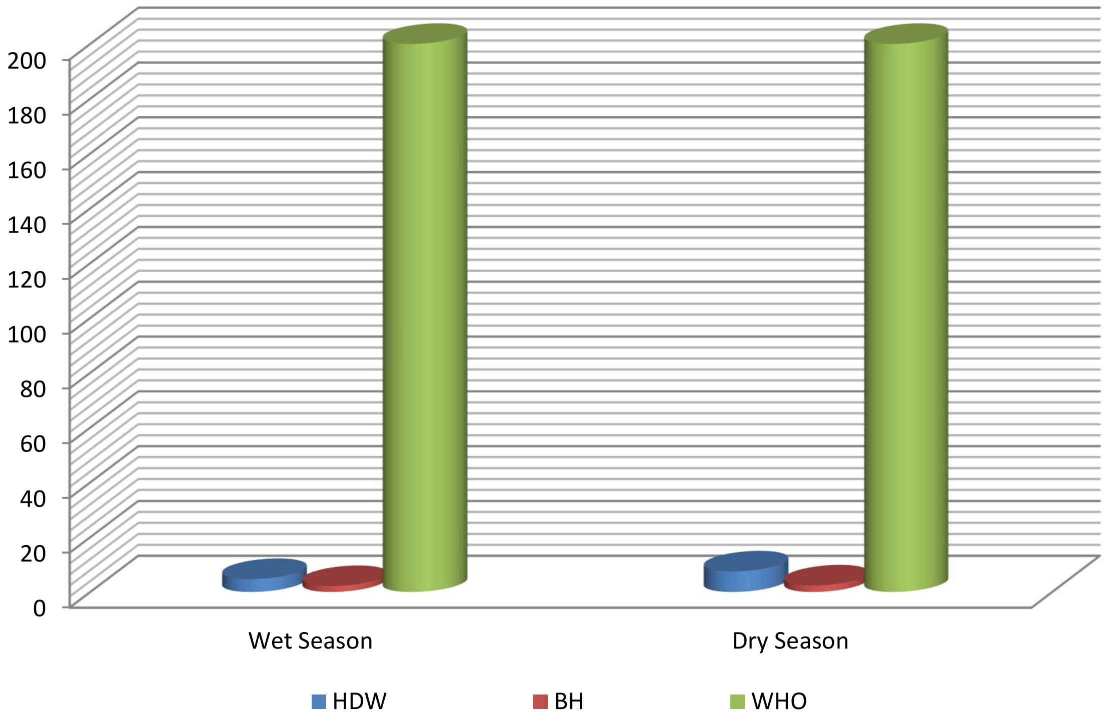

Figure 11: K (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

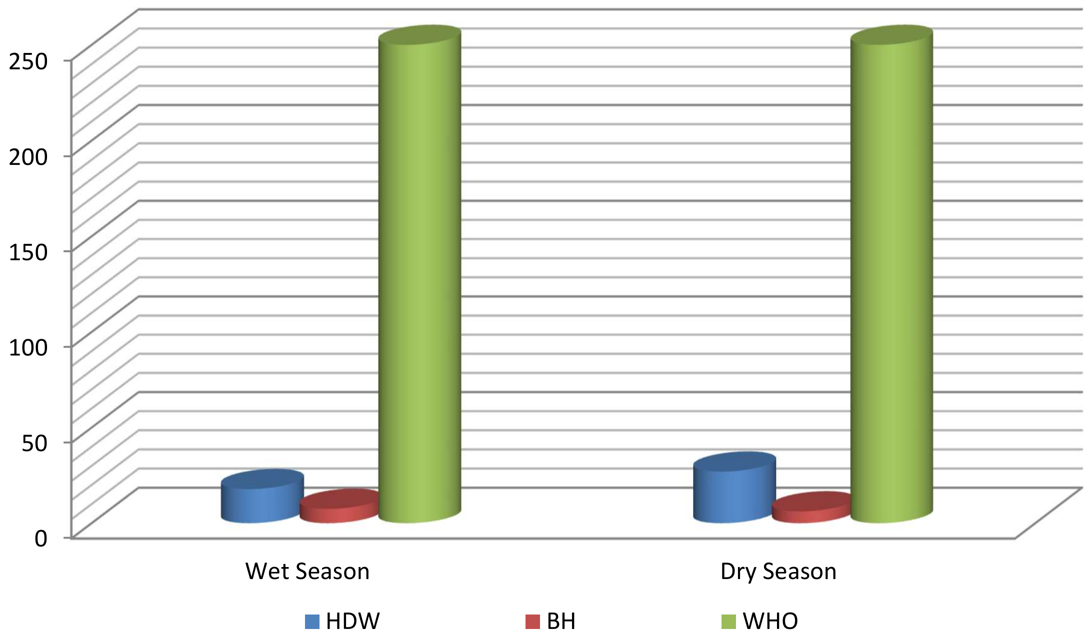

Figure 12: Cl (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

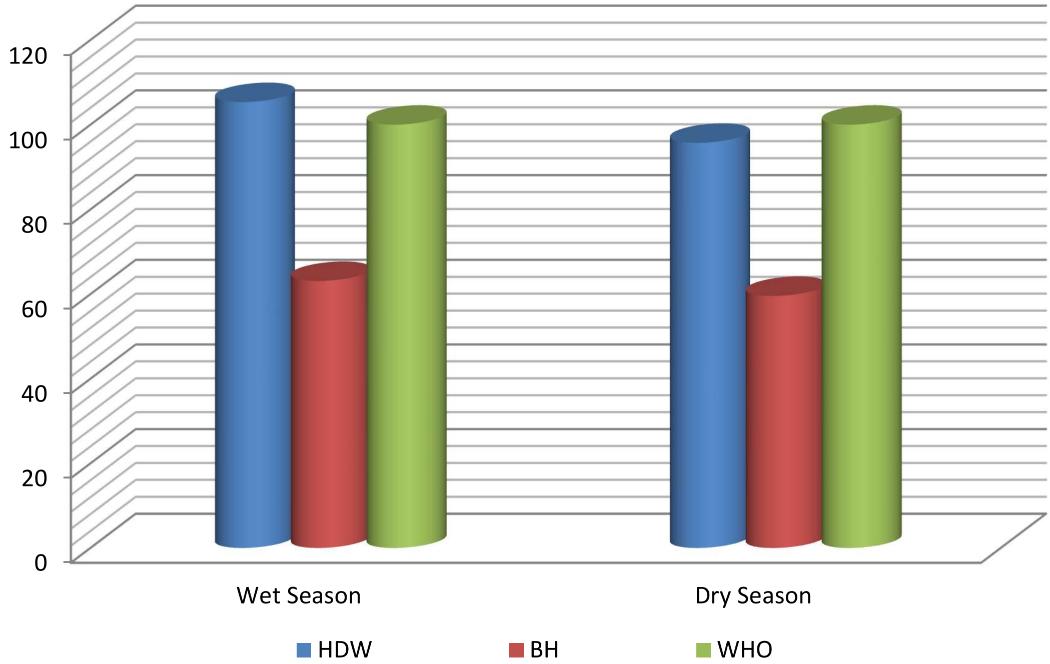

Figure 13: BC (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

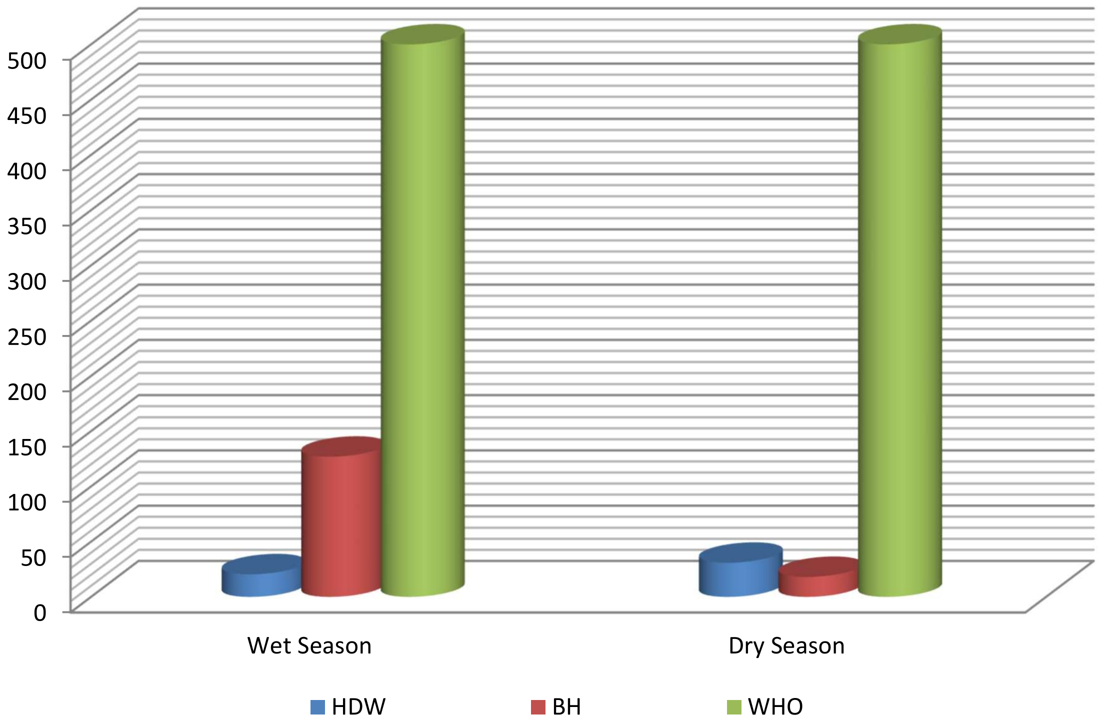

Figure 14: SO_3 (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

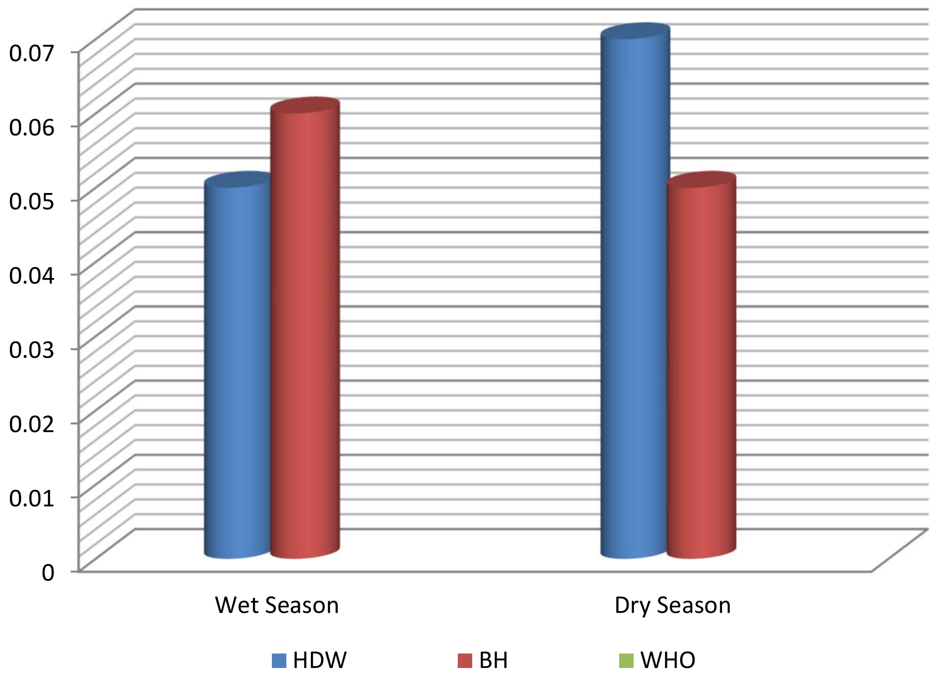

Figure 15: P (mg/l) concentration from HDW, BH during Wet and Dry as Compared with WHO

CONCLUSION

Considering the importance of groundwater in the life and activities of human being and its influence on their wellness, this study examined the seasonal variation of groundwater quality of communities in Southern Ijaw Local Government Area of Bayelsa State, Southern Nigeria. The physiochemical properties of the water from HDW and BH are found to be within the permissible limit set by WHO and NSDWQ. However, Total Coliform (TC) exceeded the permissible limit. Due to the TC concentration, the water is deemed unsafe for human-related actives; hence, the groundwater from both HDW and BH in the communities of studied LGA is contaminated. There was statistically strong correlation in the physiochemical properties of both HDW and BH during the wet and dry season; however, there was no significant difference in the physiochemical properties of water at both seasons. This study concluded as follows:

i. The mean values of parameters such as pH, TDS, TSS, Bicarbonate, Cl, SO_3^4, NO_2, Ca, Mg, K and P of groundwater sourced from HDW and BH during the wet and dry seasons are within the permissible limit of WHO and NSDWQ.
ii. The EC of the groundwater was within the permissible limit of WHO and NSDWQ except for HDW during the wet season.
iii. The finding showed that TC value was higher during the wet season for both HDW and BH than the dry season; however, all the values exceeded

the permissible limit of WHO and NSDWQ.

This study recommended that groundwater in the area be treated against coliform contamination prior to utilization as potable water. There is need for continuous monitoring of the water quality in the communities to improve the wellbeing of the people in the area.

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