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Seasonal Variation in Physicochemical Properties of Water in Onitsha Metropolis, Southeastern, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study area is a metropolitan city with major markets and industries in the heart of Anambra State, Nigeria. A total of thirty (30) samples was collected over two seasons and were analysed for various physicochemical parameters. The result was used to evaluate the seasonal variation in the various water parameters. The results show that there were no significant seasonal variations in the concentration values of pH, EC, NO_3, CO_3, SO_4, Pb and TDS. However, seasonal variations were observed in the concentrations of Mg, Ca, Cl, Mn, Hg, Na, Cd. Cu, Ni and Ag. The concentrations of the physical parameters, the major cations and anions and some of the heavy metals were within the permissible limit of the WHO standard. Furthermore, the concentrations for turbidity, mercury and cadmium in some of the water samples were above the permissible limits in both seasons. The water quality index (WQI) categorized the samples as good, poor, very poor and unfit for consumption while heavy metal pollution index (HPI) classified the water as poor to very poor. The WQI and HPI are season dependent and these ratings indicated that the water sources are heavily contaminated, and should be properly treated before drinking.

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1. INTRODUCTION

Water resource is one of the major components of the environment that are under threat either from over exploitation or pollution, exacerbated by human activities on the earth's surface [1]. Generally, water resource problems are of three main types: too little water, two much water and polluted water [2,3]. In the study area, the problem of water resource is the contamination of potable water due of the various anthropogenic activities in the area which results in the environmental pollution.

Onitsha is a metropolitan city on the eastern bank of the Niger River, in Anambra State, Nigeria and it is known for its river port and as an economic hub for commerce, industry, and education. It hosts the Onitsha Main Market, the largest market in Africa in terms of geographical size and volume of goods (https://en.wikipedia.org/wiki/Onitsha). Due to its metropolitan nature, there is an increase in industrial and human activities coupled with environmental degradation and indiscriminate refuse disposal. The cottage industries (like the paints, insecticides, agrochemicals) and other commercial businesses in this area, empty their waste into drains, with the aim of emptying them into the River Niger [4,5]. The high volume of these activities poses a threat to the various water sources in the area. Amongst the sources of water (rain, surface water and groundwater), groundwater is the most sort after in most cities in Nigeria and this is as a result of the paucity of surface water and the lack of public water supplies, which has led to the increase in the demand of groundwater due to its protective nature and indirect contact with the surface. The inhabitants of the study area rely mainly on groundwater as the primary source of water supply in the area.

The effect of physicochemical parameters on the quality of water is a major environmental challenge in our society today [6] and the seasonality in physical and chemical properties of various water sources is suggested previously by Zheng and Kelogg [7]; Kelly [8]; Kurosawa [9]. As groundwater has a huge potential to ensure future demand for water, it is important that human activities on the surface do not negatively affect this precious resource [10]. Therefore, the study on the seasonal variation in water quality is important in understanding the season which is more prone to pollution and the processes that may be responsible for the changes in concentration with season which will enhance water resources planning and management in the study area hence, the present research.

It has been variously observed that water sources in the study area were polluted by heavy metal especially by wastes from domestic, industrial and other anthropogenic sources but none of the researches compared the seasonal variations in the physiochemical parameters which this research will address.

1.1 Location, Geology and Hydrogeology of the Study Area

The study area is located in the southeastern part of Nigeria and its area extent is approximately 46.65 km^2. It is bounded within Latitudes 6°10´0˝N and 6°7´0˝N and Longitudes 6°46´30´E and 6°48´30˝E (Fig. 1). The major communities in the study area includes; Fegge, Odoakpu, Woliwo, Awada, Obosi, and Okpoko. The major access road is Trunk A roads; through the Bridge Head - Express Way - Onitsha Owerri road, through Trunk B roads.

The study area lies within the Niger Delta basin (Fig. 2), which consists of three lithostratigraphic units, which are the Akata, Agbada, and the Benin Formations respectively. Onitsha metropolis lies predominantly on the Benin Formation which consists of continental sands with lenses of clay/shale and some isolated units of gravel, conglomerate, and sandstones [11]. The formation is Miocene to Pleistocene to recent in age [12].

It is located within the tropics with two prominent seasons (dry and rainy seasons) and an average monthly rainfall of 2000 mm. The mean annual rainfall is between 1,500 mm to 2,500 mm. Temperature ranges between 22ºC to 27ºC and the study area is majorly drained by Nkisi, Anambra and the Idemili rivers which are tributaries to River Niger.

2. METHODOLOGY

Thirty (30) water samples were collected in both dry and rainy seasons from wells, boreholes and surface water. Fifteen samples were collected in wet season and fifteen samples in dry season. The water samples were collected in one-liter plastic sample bottles. The bottles were rinsed three times using the sample water before collecting the samples. For borehole samples, the tap was allowed to run for 5 – 10 minutes before sample collection. This is to ensure that only representative samples from the aquifer were collected. For the surface water the sample bottles were fully submerged in the water before collection to eliminate air and surface influence. After collection, the sample bottles were corked immediately and each sample was properly labeled at the point of collection, stored in ice packs to ensure minimal reactions and transported to the laboratory for analysis.

The collected samples were analyzed for various physicochemical parameters using standard methods [13]. Distilled water was used in the preparation of the solutions and rinsing of all equipment after testing each sample. In-situ measurements carried out include electrical conductivity, pH, and turbidity using an EC meter (HI-99300), pH meter (HI-991300), and turbidity meter (D-336444) respectively. Ion selective electrode method was used to determine nitrate using the ion meter (JENWAY-3345), Ultraviolet-visible spectrophotometer (PO-3000UV) was used to analyze phosphate, flame photometer was used to analyze sodium, Argentometric method was used to determine chloride, volumetric titration against ethylenediamine tetra-acetic acids (EDTA) was used for total hardness, magnesium, calcium ions and total alkalinity. Heavy metals were analysed using (Varian AA 240) Atomic Absorption Spectrophotometer (AAS) machine.

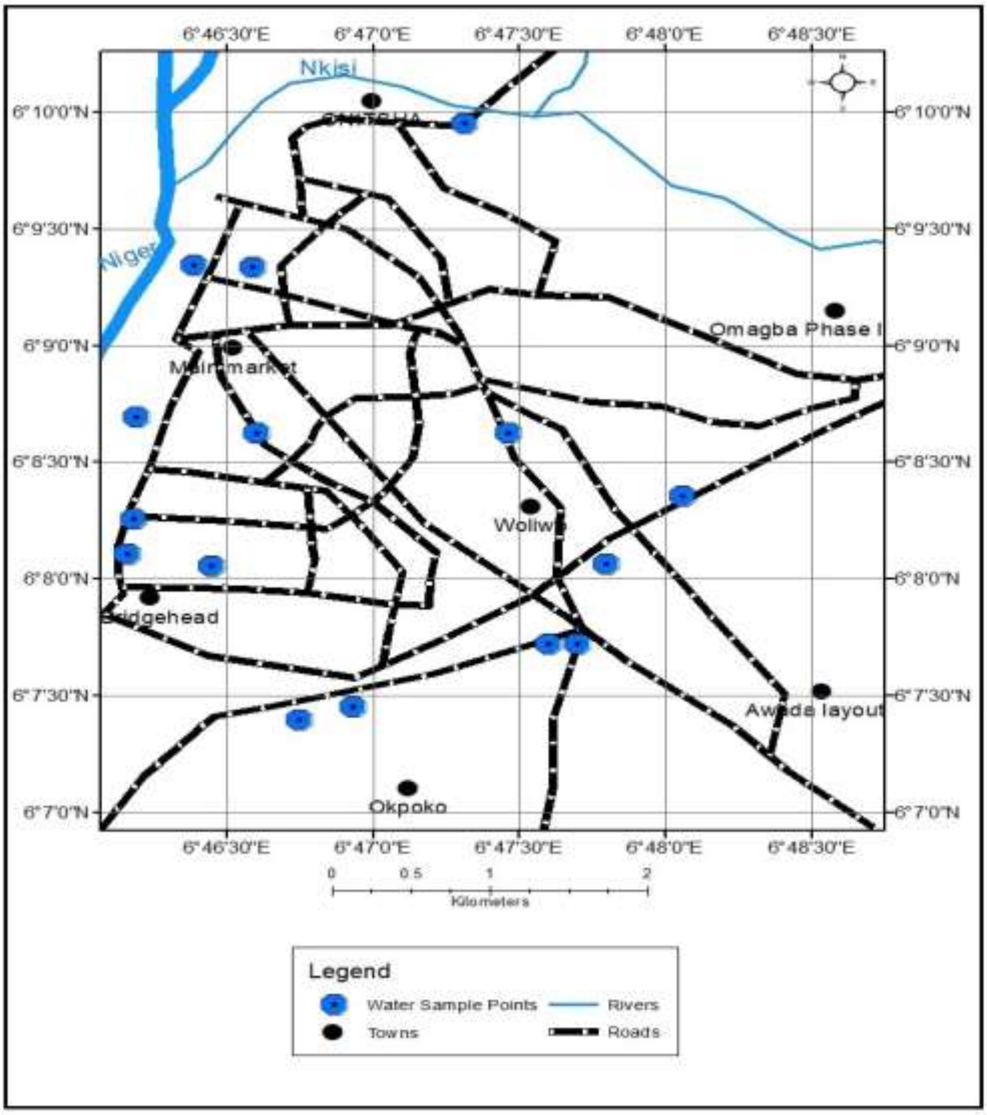

Fig. 1. Location map of the study area showing the various sampling points (GIS map, 2020)

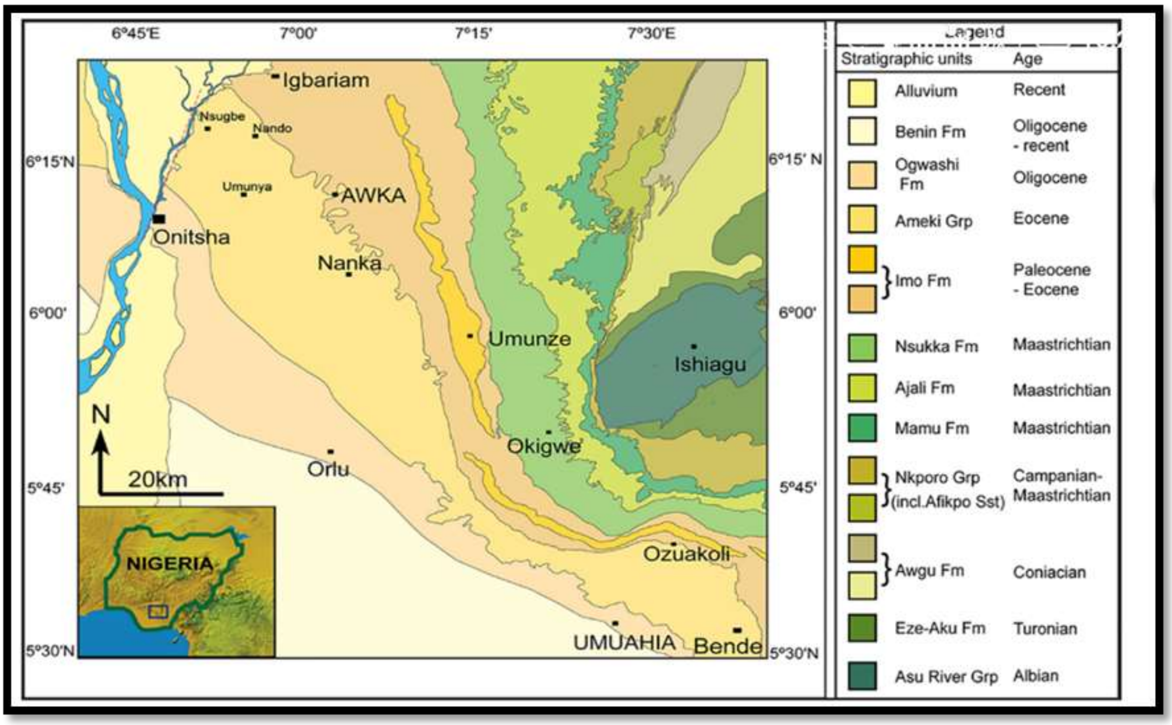

Fig. 2. Geologic map of southeastern Nigeria [12]

WQI was determined using various parameters such as pH, turbidity, chlorides, sulphate, nitrate, electrical conductivity, and total dissolved solids calcium, magnesium, sodium. Water quality index (WQI) provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters [14]. The objective of WQI is to turn complex water quality data into information that is understandable and usable by the public.

The WQI was calculated using standards of drinking water quality recommended by the World Health Organization [15,16]. The weighted Arithmetic index method, [14], was used for the calculation of WQI in this study.

Further, quality rating or sub index was calculated using the equation 1. The water quality rating is shown in Table 4

$$qn = 100[Vn - Vio] / [Sn - Vio] \quad 1$$

where

qn = Quality rating for the n^{th} water quality parameter
Vn = Estimated value of the n^{th} parameter at a given water sampling station
Sn = Standard permissible value of the n^{th} parameter
Vio = Ideal value of n^{th} parameter in pure water. All the ideal values are taken as zero for drinking water except pH which is given the value of 7.0.

The unit weight was calculated by using equation 2.

$$Wn = K/Sn \quad 2$$

Where

Wn is unit weight of n^{th} parameter, and K is the constant of proportionality. K = 1 ($1/V_{S1} + 1/V_{S2} + 1/V_{S3} +$ ……………$1/V_{Sn}$).

Water quality index (WQI) was then computed using equation 3.

$$WQI = \sum_{i=1}^{n} qnWn / \sum_{i=1}^{n} Wn \quad 3$$

The heavy metal pollution index (HPI) is a technique of rating that provides the composite influence of individual heavy metal on the overall water quality. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and inversely proportional to the recommended standard (Si) for each parameter. Water quality and its suitability for drinking purpose can be examined by determining this quality index. The HPI model proposed is given by [17].

The HPI was calculated as follows:

The calculation of weightage of i^{th} parameter, (Wi) and quality rating for each of the heavy metals, *Q*i was obtained and summed to obtain the overall HPI

$$Wi = {}^{K}/_{Si} \quad 4$$

Where Wi is the unit weightage and Si the recommended standard for i^{th} parameter, while K is the constant of proportionality.

Individual quality rating (Qi) is given by the expression (5)

$$Qi = 100\,{}^{Vi}/_{Si} \quad 5$$

Where Qi is the sub index of i^{th} parameter, Vi is the monitored value of the i^{th} parameter in mg/l The Heavy Metal Index (HPI) is then calculated as follows (6)

$$HPI = \sum_{i=1}^{n}(Qi - Wi)/Wi \quad 6$$

Where, n is the number of parameters considered.

3. RESULTS AND DISCUSSION

The results of the physicochemical analysis for the samples in both seasons are presented in Tables 1 and 2. The concentrations of the various physicochemical parameters were compared to the Nigerian Drinking Water Quality (NDWQ, 2017) and WHO [15] to ascertain the quality of the water.

3.1 Physical Parameters

The EC reflects the total concentration of soluble salts in water and it has a direct implication on the ability of current to pass through it. The values of EC range between 33.70 and 79.55 us/cm in both (Fig. 3) season and was observed to be within the permissible limit. Turbidity is the measure of the relative clarity of a liquid and turbidity levels are dependent on the amount of suspended particles present in the water. Suspended particles act as substrate for microorganisms in the water, thus promoting growth in the microbial population [18]. High turbidity level is often associated with higher level of disease-causing microorganisms such as bacteria and other parasites and presence of clay minerals. The turbidity for the samples ranges from 2.30 – 17.90 NTU in both seasons. Samples FGG/W/2, R/NG/3, R/NWA/4, R/NK/6, B/0SE/9, and B/0MA/15 were observed to be above the permissible limit of WHO and NSDWQ in both seasons. The highest concentration was observed in sample R/NG/3 (17.90) which is a river in which solid wastes and effluent wastes are disposed into. However, turbidity in boreholes can be trace to the presence of clay and frequency of drawdown in them [19]. This implies that in 40% of the samples, turbidity exceeded the guideline value while in 60% of the samples it was within the permissible limit. This study recorded that turbidity showed no significant seasonal variation. The present result is in agreement with the findings of Ekundara (2020) who reported that there was no variation in physicochemical parameter with season in a reservoir in Osun state and Okimiji et al. [20] who studied seasonal variation in slum settlement of Lagos Metropolis.

Hydrogen ion concentration (pH) is a measure of the acidity or alkalinity of a sample and it is one of the most important parameters in water chemistry since many of the processes involved in water treatment are pH dependent [21]. pH value was observed to be within the permissible limit and it range from 6.92-7.55 in both seasons. The water can be said to be alkaline. There was no significant variation in pH values for both seasons. The total dissolved solids (TDS) are a measure of the total amount of dissolved minerals in water. It represents the sum of concentrations of all dissolved constituents in water. TDS content is usually one of the factors, which limits or determines the use of water for any purpose [22] and it is an indicator of polluted water and determines the water's palatability and acceptability. The observed values of TDS in this study range from 0.04 – 12.30 mg/l in both seasons and these values are within the permissible limit. The highest and lowest values were observed in R/OSE/5 and B/0GU/14 respectively. The river has boarder with the biggest market in the study area and the part that sells perishable food items dump their wastes in it. On the basis of TDS, the water sources in the study area can be classified as fresh water [23]. The distributions of the physical parameters in both seasons are shown in Fig. 3. However, Igbokwe et al. [24] observed that pH and turbidity

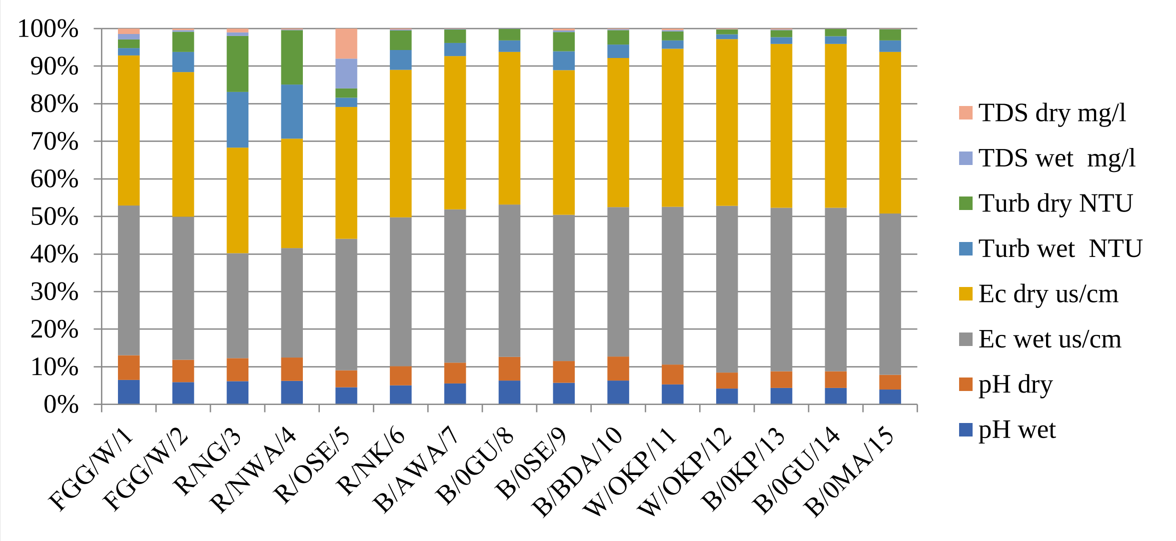

Fig. 3. Seasonal variation in pH, EC and turbidity in the study area

recorded no significant variation with season which in line with the present study while EC, TDS showed significant variation with season which is contrary to the conclusion of the present research. They attributed the increased concentration to runoff into the lake during the wet season.

3.2 Chemical Parameters

The major cations that were analysed were calcium (Ca), magnesium (Mg) and sodium and their concentrations were observed to be within the NDWQ and WHO permissible limits in both seasons. The concentrations of calcium range between 3.433 and 7.543 ppm in the rainy season and 2.893 - 5.278 ppm in the dry season. Magnesium values on the other hand, range from 0.019 - 0.260 ppm in the wet season and 0.398 - 0.988 ppm in the dry season. Higher values of calcium were observed during the wet season than in the dry season while in the dry season, higher values of magnesium were observed. Calcium and magnesium are directly related to hardness and from the obtained values; the water in the area is soft water. Sodium values range from 0.157 - 1.776 ppm in the rainy season and between 0.405 - 1.898 ppm in the dry season. The values were higher in the dry season than in the rainy season and the variation in their concentration may be related to dissolution and leaching during the wet season and concentration during the dry season due to increase in temperature and evaporation which results in reduction in volume. Again, their concentration can be affected by ion exchange reactions [25]. Roshinebegam [26] also noted higher concentrations of Na and Mg during the dry season which shows the same trend with the present research, though they observed higher concentration of calcium in dry season.

The major anion concentrations (chloride, sulphate, and carbonate) were also determined and the observed values range from 11 – 185 mg/l for chloride in the rainy season and 30 – 398 mg/l in the dry season. Chloride is a very crucial parameter of water quality and it exists natural in salt forms such as NaCl, $CaCl_2$ and KCl which may increase the salinity of the soil. Chloride values below the permissible limit are the result of low percolation from surface. So, waste from anthropogenic sources and contribution from geology is not significant, thereby preventing excessive chloride accumulation [26]. The obtained values for chloride were within the permissible limit except for sample R/NWA/4 which was observed to be above the limit in the dry season. Thus, chloride values were observed to be higher in the dry season and this can be attributed to sewage disposal and other anthropogenic activities [27]. Sulphate values range between 41.234 and 75.761 mg/l in both seasons while carbonate values varies between12 and 46 mg/l in wet season and 8 and 30 mg/l in dry seasons. The values are within the permissible limit of the standard for drinking water. The concentration of the anions was observed to be higher in dry season; this could be as a result of hydrodynamic concentration, low volume of water and evaporation.

3.3 Heavy Metals

Heavy metals are metallic elements that are toxic and have a high density, specific gravity, or atomic weight. They are found naturally in the earth's crust, but due to indiscriminate human activities, their geochemical and biochemical balance has become drastic. Essential heavy metals that the human body requires in trace amounts are cobalt, copper, zinc, and manganese but their excessive intake can be detrimental to human health because they tend to bioaccumulate. These metals can enter the water supply system through industrial and other waste types, acid rain and other anthropogenic activities [28]. Thus, their presence in water depends on the local geology, hydrogeology and geochemical characteristics of the aquifer and human activities [29].

Amongst the analysed heavy metals, lead, copper and nickel were not detected in water samples in wet season. However, copper and nickel were detected in the dry season. Their concentrations vary between 0.144 and 0.250 ppm and 0 and 0.022 ppm respectively in water samples. Mercury concentration ranges from 0 - 0.190 ppm in the wet season and 0.027 - 0.218 ppm in the dry season. The concentration in 33% of the samples in wet season exceeded the permissible limit while the remaining 67% were within the recommended limit and in 100% of the dry season samples the standard was exceeded. For cadmium, the values range from 0.004 – 0.027ppm in the wet season and 0.002 - 0.015 ppm in the dry season. Hence, in 100% of the water samples in the wet season cadmium concentration was above the acceptable limit. However, in dry season in 73% of the water samples cadmium concentration were above the recommended limit and the remaining 27% were found to be within the acceptable limit. In wet season silver concentration in samples ranged from 0 – 0.018 ppm and in dry season 0.01 – 0.148 ppm with higher values observed in dry season. The distributions of the heavy metals with seasons are shown in Fig. 4. Hydrodynamic concentration has a higher influence more than dissolution on the accumulation of heavy metals in hydrologic systems in the study area. The higher values in dry season can also be attributed to gentle flow during dry season and reduced volume of water making dissolution of metals higher, leading to higher concentration in liquid phase (Ellku and Leta, 2018). However, increased concentration in wet season can be due to influx from waste as infiltrating contaminated surface water enter the groundwater zone.

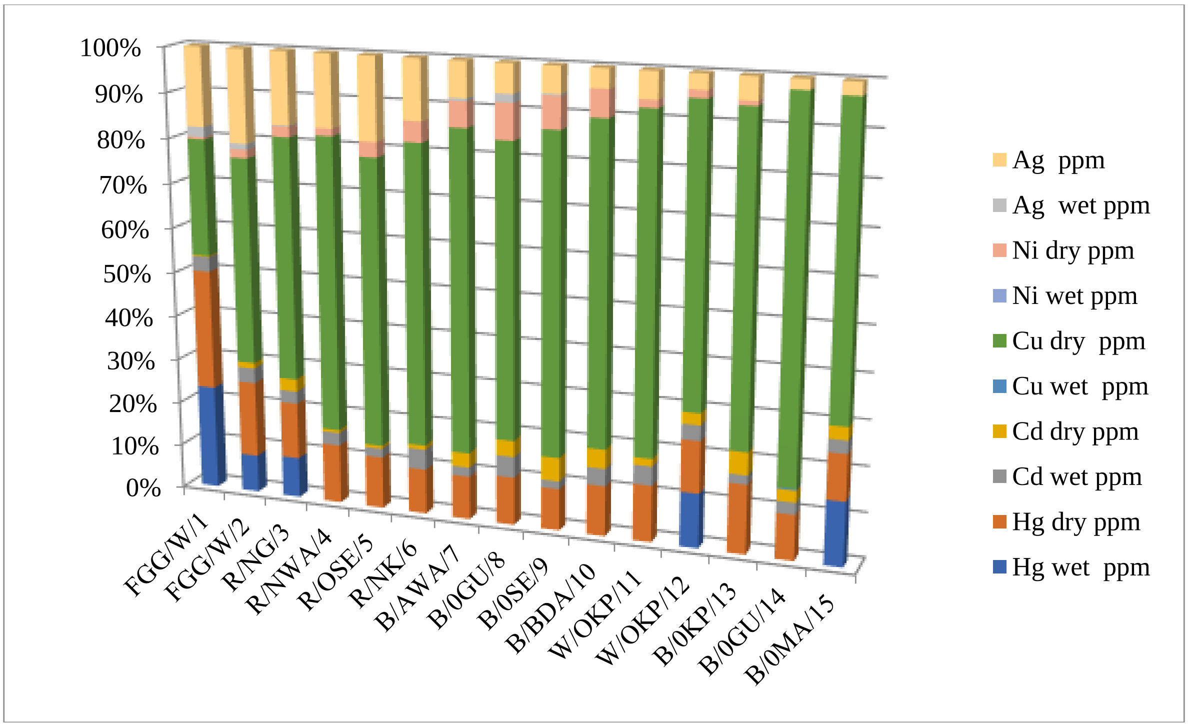

Fig. 4. Distribution of heavy metals in rainy and dry seasons samples

Table 1. The physiochemical parameters of water samples in rainy season

Samples	pH	Ec us/cm	Turb NTU	NO_3 mg/l	CO_3 mg/l	SO_4 mg/l	TDS mg/l	Cl mg/l	Mn ppm	Hg ppm	Mg ppm	Na ppm	Pb ppm	Cd ppm	Cu ppm	Ni ppm	Ag ppm	Ca ppm
FGG/W/1	7.24	44.10	2.50	5.175	22	41.234	1.60	20	0.00	0.190	0.260	1.776	0.00	0.027	0.00	0.00	0.018	3.433
FGG/W/2	7.18	46.60	6.50	3.257	8	52.469	0.50	40	0.00	0.040	0.118	0.771	0.00	0.016	0.00	0.00	0.006	3.866
R/NG/3	7.41	33.80	17.90	11.053	30	65.418	1.20	113	0.00	0.039	0.055	0.339	0.00	0.012	0.00	0.00	0.001	5.755
R/NWA/4	7.23	33.70	16.70	12.334	10	65.349	0.25	185	0.052	0.00	0.059	0.490	0.00	0.009	0.00	0.00	0.00	4.875
R/OSE/5	6.97	54.10	3.80	6.236	12	54.719	12.30	47	0.004	0.00	0.027	0.424	0.00	0.006	0.00	0.00	0.00	4.899
R/NK/6	7.01	54.20	7.20	9.551	22	62.469	0.34	46	0.138	0.00	0.102	0.372	0.00	0.014	0.00	0.00	0.00	6.754
B/AWA/7	7.35	54.30	4.80	5.241	16	70.699	0.16	39	0.00	0.00	0.019	0.291	0.00	0.007	0.00	0.00	0.002	7.543
B/0GU/8	6.98	44.70	3.40	7.834	12	56.173	0.04	68	0.165	0.00	0.105	0.230	0.00	0.013	0.00	0.00	0.005	6.383
B/0SE/9	6.77	45.0	5.90	4.830	16	44.115	0.56	15	0.00	0.00	0.053	0.267	0.00	0.005	0.00	0.00	0.001	4.787
B/BDA/10	7.22	45.10	4.40	6.055	16	75.761	0.24	25	0.00	0.00	0.096	0.259	0.00	0.011	0.00	0.00	0.00	5.876
W/OKP/11	6.98	55.5	3.10	12.916	10	45.349	0.52	35	0.00	0.00	0.035	0.261	0.00	0.010	0.00	0.00	0.00	6.784
W/OKP/12	7.55	79.55	2.30	7.346	16	48.230	0.24	11	0.010	0.036	0.039	0.293	0.00	0.010	0.00	0.00	0.00	6.784
B/0KP/13	6.92	68.92	2.90	4.473	8	64.938	0.34	95	0.00	0.00	0.084	0.290	0.00	0.004	0.00	0.00	0.00	6.083
B/0GU/14	6.93	68.93	3.20	3.311	10	43.704	0.04	17	0.00	0.00	0.027	0.255	0.00	0.008	0.001	0.00	0.00	5.744
B/0MA/15	7.20	79.20	5.60	5.451	18	63.704	0.14	132	0.00	0.045	0.022	0.157	0.00	0.009	0.00	0.00	0.00	6.559
NDWQ	6.5 -8.5	1000	5.00	50	-	250	500	250	0.2	0.001	150	200	0.01	0.003	1	0.02		75

Table 2. The physiochemical parameters of water samples in dry season

Samples	pH	Ec us/cm	Turb NTU	NO_3 mg/l	CO_3 mg/l	SO_4 mg/l	TDS mg/l	Cl mg/l	Mn ppm	Hg ppm	Mg ppm	Na ppm	Pb ppm	Cd ppm	Cu ppm	Ni ppm	Ag ppm	Ca ppm
FGG/W/1	7.24	44.10	2.50	5.175	22	41.234	1.60	60	0.082	0.218	0.478	1.898	0.00	0.002	0.212	0.004	0.143	3.892
FGG/W/2	7.18	46.60	6.50	3.257	8	52.469	0.50	90	0.041	0.081	0.398	1.655	0.00	0.006	0.219	0.009	0.098	3.982
R/NG/3	7.41	33.80	17.90	11.053	30	65.418	1.20	398	0.098	0.055	0.893	0.987	0.00	0.012	0.233	0.010	0.069	4.783
R/NWA/4	7.23	33.70	16.70	12.334	10	65.349	0.25	293	0.015	0.041	0.456	0.490	0.00	0.002	0.204	0.005	0.050	4.893
R/OSE/5	6.97	54.10	3.80	6.236	12	54.719	12.30	122	0.011	0.035	0.787	0.787	0.00	0.002	0.193	0.010	0.055	4.092
R/NK/6	7.01	54.20	7.20	9.551	22	62.469	0.34	63	0.033	0.031	0.745	0.987	0.00	0.003	0.206	0.014	0.041	2.893
B/AWA/7	7.35	54.30	4.80	5.241	16	70.699	0.16	54	0.00	0.033	0.675	0.783	0.00	0.011	0.242	0.019	0.027	2.982
B/0GU/8	6.98	44.70	3.40	7.834	12	56.173	0.04	114	0.029	0.030	0.454	0.478	0.00	0.010	0.182	0.022	0.018	5.278
B/0SE/9	6.77	45.0	5.90	4.830	16	44.115	0.56	43	0.0038	0.027	0.988	0.673	0.00	0.015	0.203	0.020	0.017	5.092
B/BDA/10	7.22	45.10	4.40	6.055	16	75.761	0.24	34	0.010	0.032	0.565	0.564	0.00	0.012	0.200	0.017	0.012	4.892
W/OKP/11	6.98	55.5	3.10	12.916	10	45.349	0.52	68	0.021	0.030	0.766	0.478	0.00	0.004	0.175	0.004	0.014	4.293
W/OKP/12	7.55	79.55	2.30	7.346	16	48.230	0.24	33	0.064	0.034	0.988	0.782	0.00	0.008	0.193	0.005	0.010	4.982
B/0KP/13	6.92	68.92	2.90	4.473	8	64.938	0.34	109	0.094	0.031	0.578	0.478	0.00	0.010	0.144	0.002	0.010	3.902
B/0GU/14	6.93	68.93	3.20	3.311	10	43.704	0.04	30	0.047	0.031	0.844	0.499	0.00	0.008	0.250	0.00	0.007	4.117
B/0MA/15	7.20	79.20	5.60	5.451	18	63.704	0.14	233	0.048	0.032	0.622	0.405	0.00	0.009	0.211	0.00	0.009	4.893
NDWQ	6.5 – 8.5	1000	5.00	50	-	250	500	250	0.2	0.001	150	200	0.01	0.003	1.0	0.02		75

W=Well samples; R=River samples; B= Borehole samples

3.3.1 Water Quality Index (WQI)

The values for the estimated WQI using equations 1, 2, and 3 are shown in Table 3. The ratings using Brown et al. [14] (Table 4) are here discussed.

The results of the computed WQI shows that three categories of water was observed in the study area and they are; Good (53.3 % in rainy season and 47% in dry season), Poor (33.3% in the rainy season and 40% in the dry season) and Unfit for drinking (13.3% in the rainy season and 13% in the dry season). Thus, samples R/NG/3 and R/NWA/4 (Rivers samples) were unfit for consumption without proper treatment and the high concentration observed in these rivers can be attributed to the various anthropogenic activities in the area. WQI indicates that the rivers in the study area are polluted thus some of the groundwater sources needs pre-use treatment. The pie charts (Fig. 5) show that water quality was more in dry season, thus, water quality in the study area is affected by the seasons.

3.3.2 Heavy Metal Pollution Index (HPI)

The critical pollution index value is 100 and HPI values < 100 indicates that the water is safe for drinking and it is free from heavy metal pollution while HPI values > 100 indicates that the water is contaminated or polluted with heavy metals. The HPI was estimated using equations 4, 5, and 6. The values obtained are shown in Table 5 and the HPI rating is shown in Table 6.

The results of the computed HPI shows that water quality ranges from poor – very poor. The ratings indicate deterioration in water quality as result of the heavy metals in both seasons though none of the values was greater than 100. Thereby, indicating that water samples are contaminated with heavy metals. This poor water quality can be attributable to the various human activities in the area such as poor sanitation system, effluents from industries and the indiscriminate dumping of solid wastes in the environment. The higher percentage of very poor-quality water during the wet season could be attributed to dissolution and leaching of the wastes into the surface water and groundwater resources. However, the HPI of sample B/0MA/15 was observed to be higher in the dry season than in the rainy season and this can be attributed to the reduced water volume in the dry season which will result in hydrodynamic concentration of elements. This is in line with the various studies in different locations [30-32] who reported that the concentrations of metals investigated were higher in dry season when compared with the wet season. Again flow rate is reduced leading to increased contact time and reducing mobility of the elements. The distribution of the ratings of the HPI is shown in Fig. 6 [33-35].

Table 3. Results of the WQI of the various samples in both seasons

Samples	WQI (Rainy)	WQI (Dry)
FGG/W/1	30.38	30.71
FGG/W/2	68.38	68.77
R/NG/3	185.95	187.97
R/NWA/4	171.16	171.93
R/OSE/5	39.41	40.33
R/NK/6	72.87	72.99
B/AWA/7	55.32	60.32
B/0GU/8	35.53	42.12
B/0SE/9	63.37	67.35
B/BDA/10	49.02	52.66
W/OKP/11	32.87	33.16
W/OKP/12	34.81	38.36
B/0KP/13	31.68	37.79
B/0GU/14	33.93	37.05
B/0MA/15	60.88	73.05

Table 4. Water quality index rating [14]

WQI	Water Quality Status	No. of Samples		% Samples	
		Rainy	Dry	Rainy	Dry
0 – 25	Excellent	0	0	0	0
26 – 50	Good	8	7	53.4	47
51 – 75	Poor	5	6	33.3	40
75 – 100	Very Poor	0	0	0	0
>100	Unfit for consumption	2	2	13.3	13

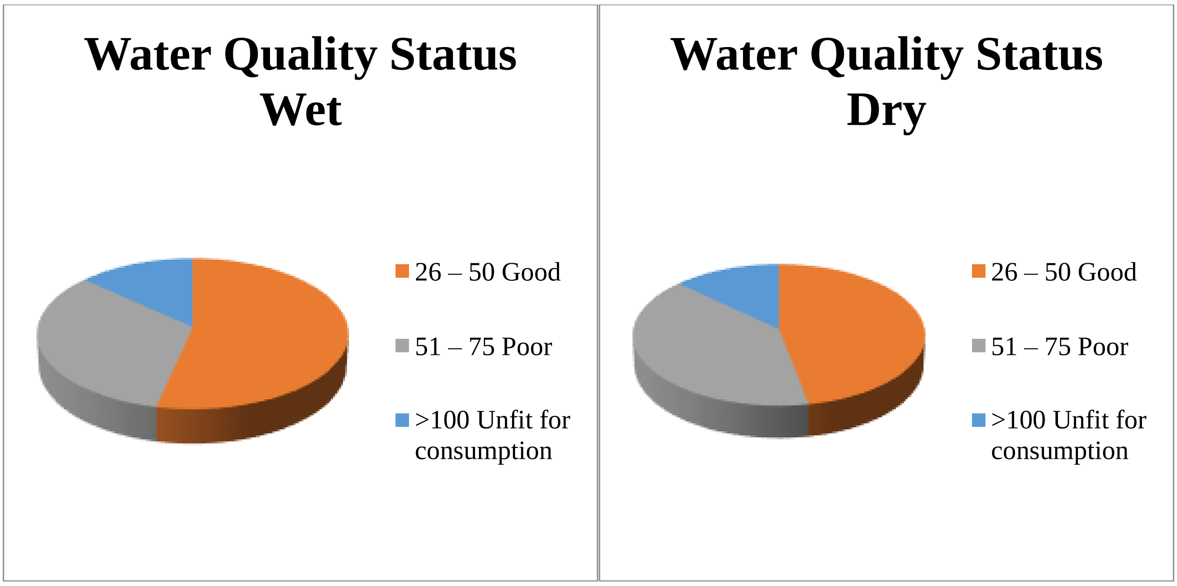

Fig. 5. The distribution of the ratings of water quality status in the study area

Table 5. Heavy metal pollution index for the various samples in both seasons

Samples	HPI (Rainy season)	HPI (Dry season)
FGG/W/1	85.29	86.71
FGG/W/2	93.03	96.10
R/NG/3	95.22	74.54
R/NWA/4	96.21	98.65
R/OSE/5	96.58	98.69
R/NK/6	96.82	98.59
B/AWA/7	96.59	98.68
B/0GU/8	96.79	98.61
B/0SE/9	96.91	98.70
B/BDA/10	96.64	98.63
W/OKP/11	96.86	98.64
W/OKP/12	96.57	76.42
B/0KP/13	96.73	98.72
B/0GU/14	96.75	98.67
B/0MA/15	96.75	70.88

Table 6. Heavy metal quality rating according to Mohan et al. [17]

HPI	Classification	No. of Samples		% Samples	
		Rainy	Dry	Rainy	Dry
<25	Excellent	0	0	0	0
26 – 50	Good	0	0	0	0
51 – 75	Poor	0	2	0	13
75 – 100	Very Poor	15	13	100	87
>100	Unsuitable for consumption	0	0	0	0

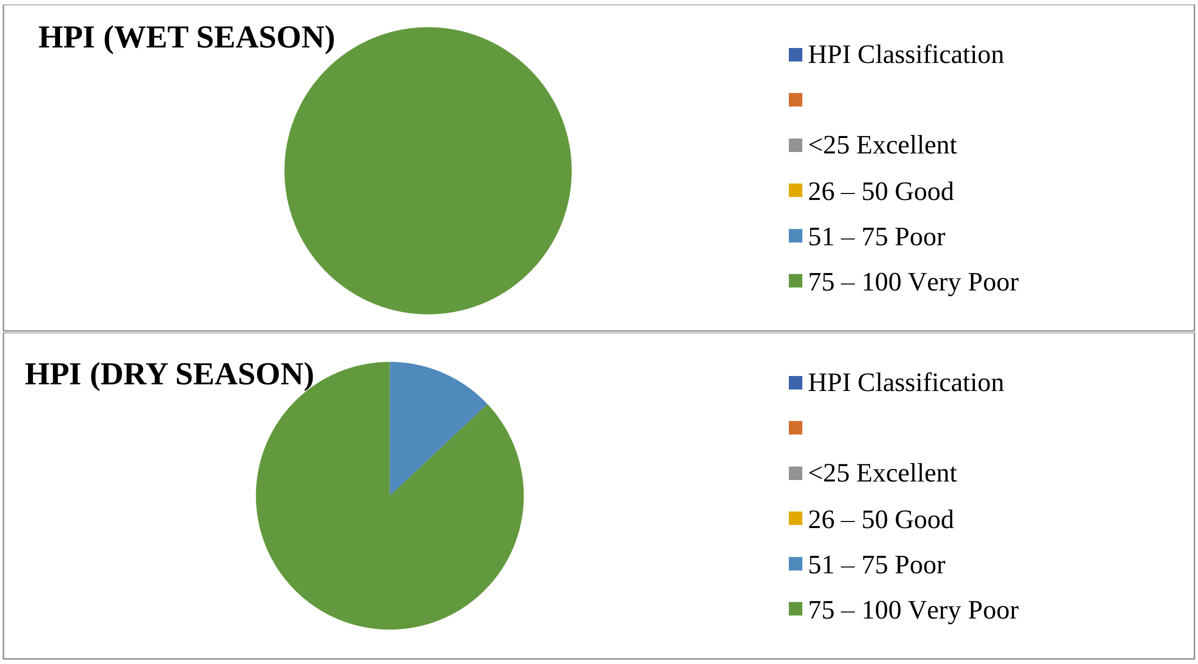

Fig. 6. The distribution of HPI ratings for both seasons in the study area

4. CONCLUSION

This study assessed the seasonal variation in the various physicochemical parameters of water in the study area. It was observed that seasonal changes affected some of the parameters monitored, while others were unaffected. There was no significant difference in the concentrations of pH, EC, NO_3, CO_3, SO_4. Pb, and TDS with season. However, it was observed that seasonal changes influenced the concentrations of turbidity, Mg, Ca, Cl, Mn, Hg, Na, Cd. Cu, Ni and Ag. Parameters such as turbidity, mercury and cadmium were observed to have higher concentration than the permissible limits. The WQI indicated that the surface water bodies were polluted while the HPI indicated that they were heavily contaminated. Generally, the WQI and HPI indicated seasonal influence affected their status. Hence, there is need for pre-use treatment before drinking and measures to improve quality and prevent further deterioration in quality of water should be put in place in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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