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QUALITY ASSESSMENT OF WATER FROM DIFFERENT SOURCES IN LAFIA TOWNSHIP, NIGERIA

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Abstract: The role water plays in the survival of plants and animals makes it relevant to investigate its physicochemical facets. This study assessed the physicochemical parameters of different water sources in different locations in the four areas that make up Lafia Township (Shabu, Gandu, Tudun-Amba and Akurba).Water samples were collected and evaluated from sachets, boreholes, hand-dug wells and river water during the dry and rainy seasons for its suitability for human consumption using weighted arithmetic Water Quality Index (WQI) technique. Some physicochemical parameters like temperature, electrical conductivity, dissolved oxygen; pH, total hardness, total dissolved solids, chlorides, total alkalinity, phosphate, biochemical oxygen demand and turbidity were measured using standard methods. The results revealed that all the physicochemical parameters were below the permissible limits for drinking water set by the WHO and NESREA. The water quality indices showed that all the water sources were good in both seasons and can be used for drinking, irrigation and in industries except river water that was poor and can be used only when treated.

Highlights:

- All the physicochemical parameters values were below the WHO and NESREA permissible limits for drinking water.
- The sachet water quality indices for January, March, July and September were 13.26, 29.32, 33.94 and 37.11 respectively.
- The borehole water quality indices for January, March, July and September were 38.61, 39.27, 39.27 and 40.47 respectively.
- The hand dug well water quality indices for January, March, July and September were 40.93, 41.84, 43.13, and 44.44 respectively.
- The river water quality indices for January, March, July and September were 46.17, 51.21, 51.65 and 64.16 respectively.
- The water quality indices for all the water sources were good except river water.

Keywords: Assessment, weighted arithmetic, water quality Index

1.0 Introduction

Unsafe water is a public health threat globally, placing people at risk for a host of diseases as (Hughes and Kaplan, 2005). Most of the water bodies all over the world are getting polluted, thus decreasing the portability of water (Chandra *et.al*.,2012). The importance of water to man and other animals cannot be over emphasized. They can survive longer without food than without water. Man requires it for cooking, washing, sanitation, drinking, irrigations and for industrial purposes. Therefore modern man like his primitive ancestors is heavily dependent on water for his survival.

The provision of good quality water can help in eradicating water-borne diseases and in improving the general sanitation of Nigeria's towns and villages (Ayoade, 1975). Water quality index (WQI) provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of WQI is to turn complex data into information that is understandable and usable by the public. A number of indices have been developed to summarize water quality data in an easily expressible and understood format. The index result represents the level of water quality in a given water body such as lakes, boreholes, hand dug wells, sachets and rivers or streams. The use of water quality index (WQI) simplifies the presentation of results of an investigation related to a water body as it summarizes in one value or concept a series of parameters analyzed. In this way, the indices are very useful to transmit information concerning water quality to the public in general, and give a good idea of the evolution tendency of water quality to evolve over a period of time. A single WQI value makes information more easily and rapidly understood than a long list of numerical values for a large variety of parameters. Additionally, WQI also facilitates comparison between different sampling sites, water sources and events (Stambuk-Giljanovic, 1999). Inadequate management of water resources as directly or indirectly resulted in the degradation of aquatic environment.

Therefore, a continuous periodical monitoring of water quality is necessary so that appropriate steps may be taken for water resource management practices (Etim *et.al*., 2012). The present

study is to serve as a baseline study since there is no literature regarding the water quality index in Lafia metropolis before now assessing the four water sources. The present investigations was carried out to compute the Water Quality Index (WQI) in order to assess the suitability of water from different sources collected from different areas in Lafia metropolis of Nigeria. The main objectives of the study are:

- Collection of water samples from sachet water, borehole water, hand dug well and river water in Lafia metropolis.
- Analysis of water quality parameters *viz*., pH, total alkalinity, chlorides, phosphate, total hardness, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids and temperature.
- Assessment of the water quality using weighted arithmetic water quality index.

2.0 Material and Methods

2.1 Reagents

All the reagents used were analytical grade and were purchased from the Finlab Nigeria Limited plot 38 Port Harcourt Crescent, Garki, Federal Capital Territory, Abuja.

2.2 Water samples collection

Sachet water, borehole water, hand dug wells and river water samples from different sites Shabu,Tudun-Amba,Akurba and Gandu) in Lafia Metropolis of Nigeria were collected (Figure1). All plastics and glasses utilized were pre-treated by washing with dilute HCl (0.05M) and later rinsed with deionized water. They were then air-dried in a free dust environment. Sachet water was obtained from all the sachet water production companies around the sites, borehole and hand dug well water samples were obtained from residential areas or

building while the river water were obtained where people fetch water for domestic and human consumption around the sampled sites. Composite sampling method was adopted. At the collection point, containers were rinsed with relevant samples twice and filled with samples and then corked tightly before taken to the Faculty of Agriculture, Nasarawa state university, Keffi Laboratory for the physicochemical analysis.

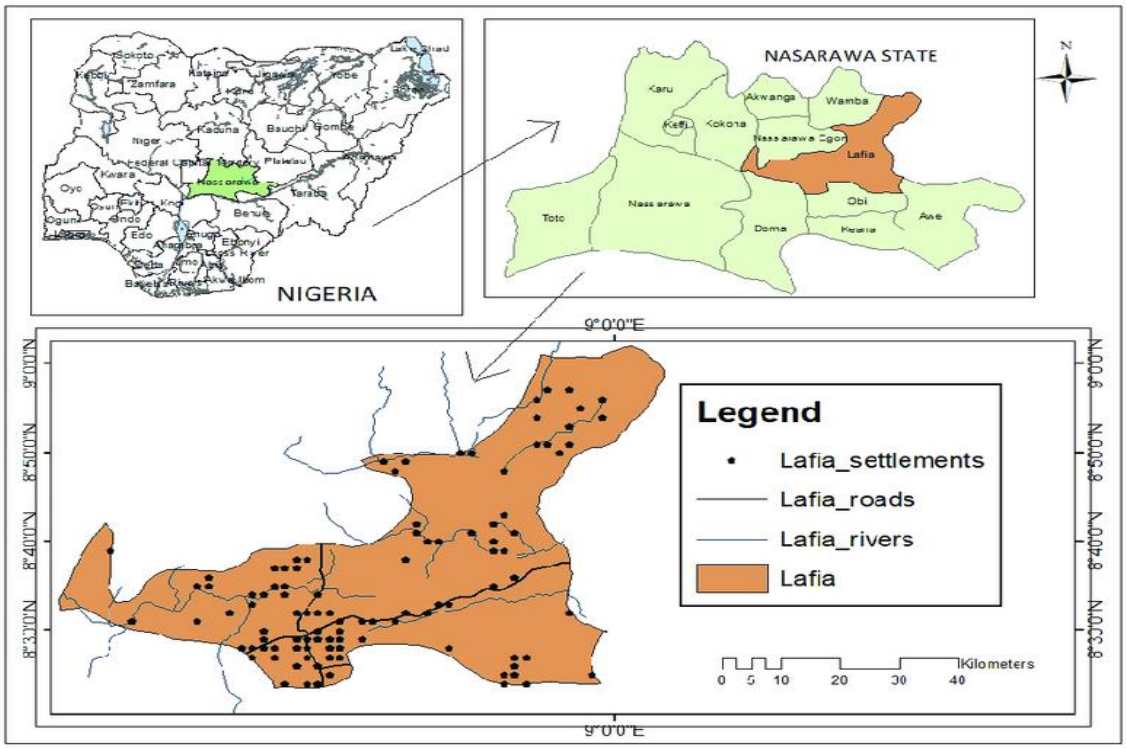

Figure 1: Map of Lafia metropolis showing the sampling points

2.3 Sample analysis

The physiochemical tests of water samples determined include temperature, electrical conductivity, dissolved oxygen, pH, Total hardness, total dissolved solid, chloride, Total Alkalinity, phosphate, Biochemical oxygen demand and Turbidity. pH was measured with a digital pH meter (Thermo Russell instrument, Model RL150). Temperature was measured at the point of water collection using a digital thermometer (Model 275-K). TDS and electrical

conductivity was measured in situ using multipurpose HANNA digital portable model conductivity / TDS meter. All the analytical methods adopted were described by Patel and Parikh, 2013.

2.4 Calculation of Water Quality Index

Water quality index was calculated using eleven important parameters. WQI was calculated using standards for drinking water quality recommended by the World Health Organization (WHO)(2000) and Indian Council for Medical Research (ICMR)(1975). The weighted Arithmetic index method has been used for the calculation of WQI in this study. Further, quality rating or sub index was calculated using the following expression.

The calculation of WQI was made by using the following equation:

$$\mathrm{WQI} = \sum \frac{\mathrm{Q_i W_i}}{\sum \mathrm{W_i}} \qquad Eq\ (1)$$

The quality rating scale ($\mathrm{Q_i}$) for each parameter is calculated by using this expression:

$$\mathrm{Q_i} = 100 \left[\frac{\mathrm{V_i} - \mathrm{V_o}}{\mathrm{S_i} - \mathrm{V_o}}\right] \qquad \mathrm{Eq}(2)$$

$\mathrm{V_i}$ is estimated concentration of ith parameter in the analyzed water

$\mathrm{V_o}$ is the ideal value of this parameter in pure water

$\mathrm{V_o} = 0$ (except pH =7.0 and Dissolved Oxygen = 14.6 mg/L)

$\mathrm{S_i}$ is recommended standard value of ith parameter.

The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$W_i = \frac{K}{Si} \qquad Eq\ (3)$$

Where K= proportionality constant and can also be calculated by using the following equation:

$$\mathrm{K} = \frac{1}{\Sigma\left(\frac{1}{\mathrm{S_i}}\right)} \qquad Eq\ (4)$$

The rating of water quality according to this WQI is given in Table 1.

Table 1: Water rating as per weighted Arithmetic water quality index method

Water Quality Index Value	Grade	Rating of Water Quality	Possible usage
0-25	A	Excellent water quality	Drinking, Irrigation and industrial
26-50	B	Good water Quality	Drinking, Irrigation and industrial
51-75	C	Poor water Quality	Irrigation and industrial
76-100	D	Very Poor water quality	Irrigation
Above 100	E	Unsuitable for drinking purpose	Proper treatment required before use

Spellman, 2017

3.0 Results and discussion

3.1 Physicochemical parameters distribution in the water sources

(i) Temperature

The mean temperature values were consistent within the water sources. During the dry season (January and March) for sachet water, the temperature ranges between 19.80-17.80 ^{o}C and 15.30-14.90 ^{o}C for January and March respectively. The mean values decreases from Shabu to Gandu for both January and March The highest and lowest mean values were recorded in Shabu(19.80 ^{o}C) and Akuruba (15.30 ^{o}C) and the lowest mean values were recorded in Akurba(17.80 ^{o}C) and Gandu(14.90 ^{o}C) in January and March respectively (Tables 2-3). The temperature values showed ambient.

Table 2: Mean Value of the physicochemical Parameters of Sachet water during dry season (January, 2020).

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(^{o}C)	19.80±0.02	18.50±0.01	17.8±0.04	18.10±0.04	18.55	19.80-17.80
Electrical Conductivity	30.20±0.03	20.10±0.08	20.10±0.03	19.40±0.03	22.45	30.20-22.45
DO(mg/L)	0.40±0.01	0.45±0.01	1.20±0.04	1.30±0.08	0.84	1.30-0.40
PH	3.30±0.02	3.40±0.03	3.20±0.01	3.25±0.03	3.29	3.40-3.20
Total Hardness(mg/L)	20.10±0.02	20.20±0.06	20.30±0.02	25.10±0.01	21.45	25.10-20.10
TDS(mg/L)	25.10±0.03	25.10±0.08	22.10±0.03	26.20±0.08	24.65	26.20-22.10
Chloride(mg/L)	10.50±0.11	10.20±0.06	10.20±0.02	10.20±0.01	10.28	10.50-10.20
Total Alkalinity	3.10±0.01	3.20±0.01	3.20±0.01	3.30±0.02	3.20	3.30-3.10
Phosphate(mg/L)	0.45±0.01	0.60±0.04	1.14±0.01	1.50±0.02	0.92	1.50-0.45
BOD(mg/L)	0.15±0.12	0.15±0.01	1.20±0.13	1.30±0.12	0.70	1.30-0.15
Turbidity(NTU)	1.30±0.01	0.42±0.02	1.15±0.02	1.82±0.01	0.17	1.82-0.42

Table 3: Mean Value of the physicochemical Parameters of Sachet water during dry season (March, 2020).

Parameter	Shabu (Mean±S.D)	Tud.-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(ºC)	15.20±0.04	15.10±0.02	15.30±0.02	14.90±0.08	15.13	15.30-14.90
Electrical Conductivity	180.00±0.08	182.00±0.08	181.00±0.08	180.00±0.08	180.75	182.00-180.00
DO(mg/L)	1.80±0.11	1.70±0.11	1.90±0.01	1.80±0.11	1.80	1.90-1.70
pH	4.70±0.02	4.50±0.02	4.60±0.02	4.80±0.02	4.65	4.80-4.50
Total Hardness(mg/L)	62.00±0.06	62.00±0.06	61.10±0.05	63.10±0.05	62.05	63.10-61.10
TDS(mg/L)	2.10±0.01	2.20±0.01	2.30±0.01	2.10±0.01	2.18	2.30-2.10
Chloride(mg/L)	25.10±0.02	25.20±0.01	26.10±0.02	25.10±0.02	25.38	26.10-25.10
Total Alkalinity	2.10±0.01	2.10±0.01	2.20±0.01	2.10±0.01	2.13	2.20-2.10
Phosphate(mg/L)	0.10±0.11	0.10±0.02	0.20±0.03	0.40±0.01	0.20	0.40-0.10
BOD(mg/L)	2.10±0.12	2.00±0.01	2.20±0.01	2.30±0.02	2.15	2.30-2.00
Turbidity(NTU)	0.10±0.01	0.20±0.01	0.30±0.02	0.10±0.01	0.18	0.30-0.10

Tables 4-5 showed mean physicochemical parameters of borehole water for January and March (dry season). Mean January values increases from Shabu to Akuruba while Gandu had same value with shabu. The mean values ranged between 20.30 ºC to 20.10 ºC with Akurba having the highest value and Gandu with the lowest value. In March, the values ranged between 20.40 ºC to 20.10 ºC with Akurba having the highest value (20.40 ºC) and Shabu had the least value(20.10 ºC). The mean values increases from Sabu to Akurba and decreases from Gandu.(Tables 4-5). All the values were below the ambient temperature of 25.0 ºC.

Table 4: Mean Value of the physicochemical Parameters of borehole water during dry season (January, 2020).

Parameter	Shaun (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(°C)	20.10±0.64	20.20±0.13	20.30±0.13	20.10±0.64	20.18	20.30-20.10
Electrical Conductivity	216.00±1.27	321.00±1.79	214.00±1.26	320.00±1.80	267.75	321.00-214.00
DO(mg/L)	4.10±0.06	3.70±0.11	3.60±0.11	4.20±0.06	3.90	4.20-3.60
PH	6.92±0.01	6.44±0.01	6.42±0.01	6.90±0.01	6.67	6.92-6.44
Total Hardness(mg/L)	120.00±1.27	80.00±1.79	80.20±1.80	120.10±1.27	100.08	120.10-80.00
TDS(mg/L)	76.00±3.22	142.00±1.41	142.00±1.41	76.10±3.22	109.03	142.00-76.00
Chloride(mg/L)	42.51±0.02	85.14±0.02	42.50±0.02	85.20±0.02	63.84	85.20-42.50
Total Alkalinity	8.40±0.01	8.10±0.01	8.20±0.01	8.50±0.01	8.30	8.50-8.10
Phosphate(mg/L)	0.70±0.02	1.54±0.01	0.80±0.01	1.55±0.01	1.15	1.55-0.70
BOD(mg/L)	2.10±0.03	1.53±0.11	1.60±0.11	2.20±0.01	1.86	2.20-1.55
Turbidity(NTU)	0.23±0.01	0.84±0.01	0.85±0.01	0.24±0.01	0.54	0.85-0.23

Table 5: Mean Value of the physicochemical Parameters of borehole water during dry season (March, 2020)

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(°C)	20.30±0.13	20.40±0.13	20.10±0.12	20.50±0.12	20.33	20.50-20.10
Electrical Conductivity	215.10±1.28	324.10±1.92	215.10±1.28	325.10±1.89	269.85	325.10-215.10
DO(mg/L)	4.20±0.01	3.90±0.01	4.30±0.01	4.50±0.01	3.38	4.50-3.90
pH	7.10±0.01	6.90±0.01	6.80±0.01	6.70±0.01	6.88	7.10-6.70
Total Hardness(mg/L)	125.20±1.27	84.30±1.60	85.10±1.60	110.00±1.27	101.15	125.20-84.30
TDS(mg/L)	72.10±1.52	142.10±1.31	142.20±2.31	134.20±1.37	122.65	142.20-72.10
Chloride(mg/L)	43.20±0.02	86.14±1.62	64.20±1.92	42.50±0.02	59.01	86.14-42.50
Total Alkalinity	8.50±0.01	8.10±0.01	8.30±0.01	8.40±0.01	8.33	8.50-8.10
Phosphate(mg/L)	0.70±0.01	1.64±0.01	1.62±0.01	1.63±0.01	1.39	1.64-0.70
BOD(mg/L)	1.30±0.01	1.60±0.01	1.40±0.01	1.20±0.01	1.38	1.60-1.20
Turbidity(NTU)	0.43±0.01	0.86±0.01	0.76±0.11	0.90±0.01	0.73	0.90-0.43

Temperature mean values for hand dug well water for January showed values between 20.50 °C and 20.10 °C with the highest value at Gandu(20.50 °C) and the least value at Akurba (20.10 °C). the values increases from Shabu to Tudum-Amba and decreases from Akurba and increases from Gandu. The increase and decrease in temperature values may be as a result of the intensity of sunlight at the sampled points while the March values ranged between 21.80 °C to 21.50 °C with the highest value at Shabu (21.80 °C) and the least at Gandu(21.50 °C). The values decrease uniformly from Shabu to Gandu (Tables 6-7).

Table 6: Mean Value of the physicochemical Parameters of Hand dug well water during dry season (January, 2020).

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(^{o}C)	21.80±0.08	21.70±0.02	21.60±0.02	21.50±0.02	21.65	21.80-21.50
Electrical Conductivity	39.80±0.03	40.10±0.04	41.10±0.04	42.10±0.04	40.78	42.10-39.80
DO(mg/L)	0.70±0.01	2.70±0.01	2.40±0.01	0.60±0.01	1.60	2.70-0.60
pH	6.40±0.08	6.50±0.01	6.60±0.01	6.70±0.01	6.55	6.70-6.40
Total Hardness(mg/L)	41.80±0.08	41.70±0.04	41.60±0.04	41.50±0.13	41.65	41.80-41.50
TDS(mg/L)	53.20±0.05	54.30±0.05	55.10±0.05	55.90±0.15	54.63	55.90-53.20
Chloride(mg/L)	17.20±0.18	17.30±0.02	19.30±0.12	20.20±0.02	18.50	20.20-17.20
Total Alkalinity	6.60±0.01	6.40±0.01	6.20±0.01	6.10±0.01	6.33	6.60-6.10
Phosphate(mg/L)	1.40±0.01	1.30±0.12	1.10±0.11	1.30±0.11	1.28	1.40-1.10
BOD(mg/L)	0.30±0.01	1.30±0.01	1.20±0.01	0.30±0.21	0.78	1.30-0.30
Turbidity(NTU)	1.82±0.11	1.62±0.02	1.25±0.01	0.82±0.11	1.38	1.82-0.82

Table 7: Mean Value of the physicochemical Parameters of Hand dug well water during dry season (March, 2020).

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(°C)	21.80±0.02	21.70±0.08	21.60±0.02	21.80±0.02	21.73	21.80-21.60
Electrical Conductivity(mg/L)	41.50±0.25	40.26±0.04	43.10±0.04	42.30±0.04	41.78	43.10-40.26
DO(mg/L)	1.20±0.01	1.40±0.01	2.10±0.02	3.20±0.01	1.98	3.20-1.20
pH	6.47±0.25	5.57±0.29	5.47±0.25	6.40±0.01	5.98	6.47-5.47
Total Hardness(mg/L)	53.20±0.05	54.40±0.05	52.10±0.05	51.20±0.05	52.73	54.40-51.20
TDS(mg/L)	70.33±0.07	70.60±0.07	67.17±1.60	70.77±0.07	69.72	70.77-67.17
Chloride(mg/L)	26.40±0.16	26.60±0.28	25.83±0.05	27.43±0.29	26.57	27.43-25.83
Total Alkalinity	6.70±0.08	6.80±0.01	6.60±0.01	6.90±0.01	6.75	6.90-6.60
Phosphate(mg/L)	2.90±0.11	2.76±0.01	2.80±0.02	2.40±0.01	2.70	2.90-2.40
BOD(mg/L)	0.60±0.04	0.70±0.04	1.05±0.01	1.60±0.01	0.99	1.60-0.60
Turbidity(NTU)	2.70±0.08	2.40±0.02	2.60±0.24	2.80±0.02	2.63	2.80-2.40

The River water mean temperature values during the dry season (January and March) were presented in Tables 8-9.

January mean temperature values ranged between 21.80 °C to 21.60 with the highest values recorded in River Gandu and River Shabu with a uniform value of 21.80 °C and the least value was recorded in River Akurba (21.60 °C) .The values decreases from River Shabu uniformly to River Akurba with Gandu and Shabu having same value. In March,the values ranged between 27.80 °C to 27.20 °C with the highest value recorded in Gandu(27.80 °C) and the least value in Gandu (27.20 °C) .All the values in march in all the sampled points were above ambient(25 °C).

Table 8: Mean Value of the physicochemical Parameters of River water during dry season (January, 2020).

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	**Mean**	**Range**
Temperature(^{o}C)	27.80±0.08	27.50±0.08	27.30±0.08	27.20±0.08	27.45	27.80-27.20
Electrical Conductivity(mg/L)	34.40±0.16	34.20±0.09	32.30±0.22	31.43±0.17	33.08	34.40-31.43
DO(mg/L)	3.20±0.08	2.80±0.02	2.65±0.05	2.73±0.05	2.85	3.20-2.65
pH	5.50±0.08	5.80±0.03	5.70±0.08	5.70±0.12	5.68	66.80-60.20
Total Hardness(mg/L)	66.80±0.02	65.60±0.12	63.40±0.16	60.20±0.08	64.00	18.80-15.47
TDS(mg/L)	18.80±0.04	18.30±0.08	16.33±0.12	15.47±0.25	17.23	46.30-43.60
Chloride(mg/L)	44.90±0.60	45.90±1.10	46.30±0.04	43.60±0.30	45.18	7.40-7.10
Total Alkalinity	7.40±0.01	7.30±0.01	7.20±0.01	7.10±0.01	7.25	2.90-2.70
Phosphate(mg/L)	2.90±0.04	2.80±0.04	2.70±0.08	2.70±0.08	2.78	2.90-2.70
BOD(mg/L)	1.30±0.03	1.40±0.03	1.45±0.02	1.50±0.03	1.41	1.50-1.30
Turbidity(NTU)	4.30±0.05	4.2±0.04	4.10±0.12	3.90±0.12	4.13	4.30-3.90

Table 9: Mean Value of the physicochemical Parameters of River water during dry season (March, 2020).

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(°C)	17.20±0.02	16.80±0.03	16.90±0.18	17.30±0.02	17.05	17.30-16.80
Electrical Conductivity(mg/L)	200.00±1.64	201.00±2.16	203.00±0.15	204.00±0.15	202.00	204.0-200.0
DO(mg/L)	2.10±0.01	1.90±0.02	2.20±0.06	1.90±0.03	2.03	2.20-1.90
pH	5.60±0.01	5.30±0.01	5.50±0.01	5.40±0.01	5.45	5.60-5.30
Total Hardness(mg/L)	82.30±0.64	80.00±0.11	82.30±0.64	80.00±0.11	81.15	82.30-80.00
TDS(mg/L)	4.20±0.07	4.10±0.06	4.20±0.07	4.10±0.06	4.15	4.20-4.10
Chloride(mg/L)	31.10±0.06	30.00±0.05	31.10±0.06	30.00±0.05	30.55	31.10-30.00
Total Alkalinity	4.10±0.05	4.20±0.01	4.10±0.05	4.20±0.01	4.15	4.20-4.10
Phosphate(mg/L)	0.20±0.01	0.20±0.01	0.20±0.01	0.20±0.01	0.20	0.20-0.20
BOD(mg/L)	3.20±0.02	3.20±0.02	3.20±0.02	3.20±0.02	3.20	3.20-3.20
Turbidity(NTU)	0.10±0.01	0.10±0.11	0.10±0.01	0.10±0.11	0.10	0.10-0.10

During the rainy season (July and September) the mean temperature ranges between 17.30 ^{O}C to 16.80 ^{O}C for Sachet water in July with the highest and least temperature recorded from Gandu (17.30 ^{O}C) and Tudun-Amba (16.80 ^{O}C) respectively. In September, the mean temperature ranged between 20.30 to 20.10 with the highest mean value recorded in Akurba (20.30 ^{O}C) and the least in Shabu (20.10 ^{O}C) .Both the values in july and September were below ambient temperature (Tables 10-11).

Table 10: Mean Value of the physicochemical Parameters of Sachet water during rainy season (July, 2020).

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(^{o}C)	20.10±0.13	20.20±0.13	20.30±0.13	20.12±0.13	20.18	20.30-20.10
Electrical Conductivity(mg/L)	216.00±1.27	321.00±1.92	214.00±1.28	320.00±1.89	267.75	321.0-214.0
DO(mg/L)	4.10±0.01	3.70±0.11	3.80±0.11	4.20±0.01	3.95	4.20-3.70
pH	6.92±0.01	6.44±0.01	6.52±0.02	6.90±0.02	6.69	6.92-6.44
Total Hardness(mg/L)	120.00±1.27	80.00±1.79	85.00±1.60	115.00±1.27	100.00	120.0-80.00
TDS(mg/L)	76.00±1.69	142.00±1.41	140.00±1.32	130.00±1.32	122.00	142.00-76.0
Chloride(mg/L)	42.51±0.16	85.14±0.02	65.10±1.92	41.50±0.23	58.56	85.14-41.50
Total Alkalinity	8.40±0.01	8.10±0.01	8.20±0.03	8.30±0.02	8.25	8.40-8.10
Phosphate(mg/L)	0.70±0.01	1.54±0.01	1.52±0.01	1.53±0.01	1.32	1.54-0.70
BOD(mg/L)	1.20±0.11	1.50±0.01	1.30±0.01	1.10±0.01	1.28	1.50-1.10
Turbidity(NTU)	0.23±0.10	0.84±0.21	0.74±0.01	0.82±0.01	0.66	0.84-0.23

Table 11: Mean Value of the physicochemical Parameters of Sachet water during rainy season (September, 2020)

Parameter	**Shabu (Mean±S.D)**	**Tudun-Amba (Mean±S.D)**	**Akurba (Mean±S.D)**	**Gandu (Mean±S.D)**	**Mean**	**Range**
Temperature(°C)	20.10±0.02	20.20±0.02	20.40±0.02	20.12±0.02	20.23	20.40-20.10
Electrical Conductivity(mg/L)	42.10±0.04	41.10±0.04	40.10±0.04	39.90±0.03	40.80	42.10-39.90
DO(mg/L)	0.60±0.01	0.70±0.01	2.40±0.11	2.70±0.01	1.60	2.70-0.60
pH	6.60±0.01	6.70±0.13	6.50±0.12	6.45±0.11	6.56	6.70-6.45
Total Hardness(mg/L)	40.21±0.04	40.50±0.04	40.60±0.04	50.10±0.05	42.85	50.10-40.21
TDS(mg/L)	55.10±0.05	54.30±0.05	55.90±0.05	53.20±0.05	40.85	55.90-53.20
Chloride(mg/L)	20.10±0.02	20.20±0.02	20.40±0.02	20.50±0.02	20.30	20.50-20.10
Total Alkalinity	6.10±0.01	6.20±0.01	60.40±0.06	6.60±0.01	6.33	60.40-6.10
Phosphate(mg/L)	0.72±0.01	1.56±0.14	1.14±0.01	1.50±0.11	0.31	1.56-0.72
BOD(mg/L)	0.30±0.01	0.30±0.01	1.20±0.12	1.30±0.21	0.78	1.30-0.30
Turbidity(NTU)	1.66±0.02	0.84±0.11	1.25±0.21	1.80±0.01	1.39	1.80-0.84

The borehole water mean temperature values during the rainy season (July and September) were presented in Tables 12-13.

The July means temperature values ranged between 20.40 ^{O}C to 20.10 ^{O}C with the highest value recorded in Akurba (20.40 ^{O}C) and the least in Shabu (20.10 ^{O}C). The mean values increases from Shabu to Akurba and decreases from Gandu. In September the temperature ranged between 21.40 ^{O}C to 21.10 ^{O}C with the highest and lowest values recorded in Shabu (21.40 ^{O}C) and Gandu (21.10 ^{O}C) respectively. The mean values decreases uniformly from Shabu to Gandu. Both in july and September in all the sampled points the mean temperature values were below ambient temperature of 25 ^{O}C.

Table 12: Mean Value of the physicochemical Parameters of borehole water during the rainy season (July, 2020).

Parameter	**Shabu (Mean±S.D)**	**Tudun-Amba (Mean±S.D)**	**Akurba (Mean±S.D)**	**Gandu (Mean±S.D)**	**Mean**	**Range**
Temperature(^{o}C)	21.40±0.13	21.30±0.13	21.20±0.13	21.10±0.01	21.25	21.40-21.10
Electrical Conductivity	301.00±2.53	571.00±0.63	300.00±2.20	301.00±2.52	368.25	571.0-300.0
DO(mg/L)	4.90±0.06	4.80±0.11	4.60±0.11	4.50±0.01	4.70	4.90-4.50
pH	6.84±0.01	6.38±0.01	6.28±0.01	6.38±0.01	6.47	6.84-6.28
Total Hardness(mg/L)	120.00±1.26	160.00±1.79	120.00±1.26	160.00±1.79	140.00	160.0-120.0
TDS(mg/L)	165.00±2.22	327.00±1.26	165.00±2.22	327.00±2.72	246.00	327.0-165.0
Chloride(mg/L)	42.55±0.02	85.16±0.02	42.55±0.02	84.12±0.02	63.59	85.16-42.55
Total Alkalinity	8.10±0.06	7.90±0.01	8.20±0.06	7.60±0.01	7.95	8.20-7.60
Phosphate(mg/L)	0.72±0.01	1.56±0.01	0.81±0.01	1.42±0.01	1.13	1.56-0.72
BOD(mg/L)	2.45±0.03	2.40±0.11	2.20±0.03	2.30±0.11	2.34	2.45-2.20
Turbidity(NTU)	1.66±0.01	0.84±0.01	1.50±0.01	0.82±0.01	1.21	1.66-0.82

Table 13: Mean Value of the physicochemical Parameters of borehole water during the rainy season (September, 2020).

Parameter	**Shabu (Mean±S.D)**	**Tudun-Amba (Mean±S.D)**	**Akurba (Mean±S.D)**	**Gandu (Mean±S.D)**	**Mean**	**Range**
Temperature(^{o}C)	21.40±0.02	21.30±0.02	21.50±0.02	22.00±0.02	21.55	22.00-21.30
Electrical Conductivity(mg/L)	301.00±1.88	571.00±4.10	450.00±1.42	320.00±1.32	410.50	571.0-301.0
DO(mg/L)	4.90±0.01	4.80±0.02	4.82±0.12	5.00±0.01	4.88	5.00-4.80
pH	6.84±0.01	6.38±0.03	6.92±0.02	6.42±0.13	6.64	6.92-6.38
Total Hardness(mg/L)	120.00±1.16	160.00±1.79	180.00±1.82	161.00±1.60	155.25	180.0-120.0
TDS(mg/L)	165.00±2.22	327.00±1.89	350.00±1.27	164.00±1.62	251.50	350.0-164.0
Chloride(mg/L)	42.55±0.04	85.16±0.08	90.00±0.09	45.50±0.04	65.80	90.00-42.55
Total Alkalinity	8.10±0.11	7.90±0.01	8.00±0.11	7.80±0.01	7.95	8.10-7.80
Phosphate(mg/L)	0.72±0.01	1.56±0.01	1.80±0.01	0.82±0.01	1.23	1.80-0.72
BOD(mg/L)	2.45±0.01	2.30±0.01	2.31±0.01	2.50±0.01	2.38	2.50-2.30
Turbidity(NTU)	1.66±0.01	0.84±0.21	1.52±0.12	1.80±0.11	1.46	1.80-0.84

The Mean temperature values during the rainy season (July and September) for hand dug well water were presented in Tables 14-15.

The July mean value ranged between 22.00-21.30 ^{O}C with the highest and lowest value recorded was 22.00 ^{O}C and 21.30 ^{O}C at Gandu and Tudun-Amba respectively. The values decrease from Shaun to Tudun-Amba and increases from Akurba to Gandu. In September the mean value ranged between 23.20 ^{O}C to 21.20 ^{O}C with Gandu and Shabu having the highest and least values respectively. The values increase uniformly from Shaun to Gandu. Both the July and September values are below the ambient temperature, Tables 14-15.

Table 14: Mean Value of the physicochemical Parameters of hand dug well water during the rainy season (July, 2020)

Parameter	Shabu (Mean±S.D)	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Temperature(°C)	21.20±0.02	21.40±0.02	21.60±0.02	23.20±0.08	21.85	23.20-21.20
Electrical Conductivity (mg/L)	301.10±1.88	302.00±1.89	446.70±2.55	321.00±1.82	342.70	446.7-301.10
DO(mg/L)	4.80±0.01	4.30±0.01	4.70±0.08	5.20±0.01	4.75	5.20-4.30
pH	6.80±0.01	6.20±0.08	6.80±0.08	6.44±0.12	6.56	6.80-6.20
Total Hardness(mg/L)	134.37±1.34	160.10±1.60	180.20±1.80	160.40±1.60	158.77	180.20-160.1
TDS(mg/L)	165.43±1.62	328.10±1.33	350.40±1.35	164.60±1.62	252.13	350.40-164.6
Chloride(mg/L)	42.70±0.04	86.40±0.08	90.60±0.09	45.70±0.04	66.35	90.60-42.70
Total Alkalinity	8.40±0.01	7.80±0.08	8.40±0.02	7.80±0.01	8.10	8.40-7.80
Phosphate(mg/L)	1.60±0.02	1.53±0.02	1.70±0.01	0.84±0.01	1.42	1.70-0.84
BOD(mg/L)	2.60±0.18	2.40±0.01	2.50±0.01	2.63±0.11	2.53	2.63-2.40
Turbidity(NTU)	1.70±0.01	0.80±0.01	1.70±0.11	1.80±0.11	1.50	1.80-0.80

Table 15: Mean Value of the physicochemical Parameters of hand dug well water during the rainy season (September, 2020)

Parameter	River Shabu (Mean±S.D)	River Amba (Mean±S.D)	RiverAkurba (Mean±S.D)	River Gandu (Mean±S.D)	Mean	Range
Temperature(°C)	29.20±0.08	29.90±0.08	29.50±0.82	27.90±0.08	28.88	29.90-27.90
Electrical Conductivity(mg/L)	39.40±0.80	34.10±1.80	31.30±0.84	34.20±0.84	34.74	39.40-31.30
DO(mg/L)	3.00±0.01	2.80±0.01	2.90±0.07	2.70±0.07	2.85	3.00-2.70
pH	5.60±0.19	5.90±0.03	5.70±0.03	5.60±0.03	5.70	5.90-5.60
Total Hardness(mg/L)	66.70±0.80	45.70±0.82	114.60±12.5	46.70±0.82	68.43	114.60-45.70
TDS(mg/L)	17.10±0.82	16.70±0.81	18.80±0.09	18.90±0.09	17.88	18.90-16.70
Chloride(mg/L)	43.60±0.30	46.30±0.04	45.90±1.10	44.90±1.00	45.18	46.30-43.60
Total Alkalinity	7.10±0.01	7.20±0.01	7.30±0.01	7.40±0.01	7.25	7.40-7.10
Phosphate(mg/L)	2.70±0.08	2.70±0.04	2.90±0.07	2.80±0.06	2.78	2.90-2.70
BOD(mg/L)	1.50±0.03	1.40±0.03	1.45±0.02	1.30±0.03	1.41	1.50-1.30
Turbidity(NTU)	3.90±0.12	4.20±0.04	4.30±0.11	4.10±0.12	4.13	4.30-3.90

The River water mean temperature values for July ranged between 29.50-27.90 ^{O}C with the highest and lowest mean value recorded at River Akurba (29.50 ^{O}C) and River Gandu (27.90 ^{O}C). The values decrease from River Shaun to River Amba and from River Akurba to River Gandu. The September mean values ranged between 21.90 ^{O}C to 21.40 ^{O}C with the highest and lowest values recorded at River Amba (21.90 ^{O}C) and River Shabu (21.40 ^{O}C) respectively. All the values in July were above ambient temperature while September values were below ambient (Tables 16-17).

Table 16: Mean Value of the physicochemical Parameters of River water during the rainy season (July, 2020)

Parameter	River Shabu (Mean±S.D)	River Amba (Mean±S.D)	RiverAkurba (Mean±S.D)	River Gandu (Mean±S.D)	Mean	Range
Temperature(°C)	21.40±0.02	21.90±0.02	21.60±0.02	21.70±0.02	21.65	21.90-21.40
Electrical Conductivity(mg/L)	44.10±0.04	42.10±0.04	43.10±0.04	44.20±0.04	43.38	44.20-42.10
DO(mg/L)	1.20±0.01	0.90±0.01	2.80±0.03	3.10±0.01	2.00	3.10-0.90
PH	7.60±0.19	7.70±0.01	7.50±0.04	7.42±0.12	7.56	7.70-7.42
Total Hardness(mg/L)	52.30±0.04	52.40±0.21	53.10±0.05	52.42±0.05	52.56	53.10-52.30
TDS(mg/L)	70.10±0.07	70.90±0.07	71.20±0.07	70.50±0.07	70.68	71.20-70.10
Chloride(mg/L)	25.10±0.02	26.10±0.02	25.20±0.02	26.90±0.02	25.83	26.90-25.10
Total Alkalinity	6.90±0.01	6.80±0.01	6.70±0.01	6.60±0.11	6.75	6.90-6.60
Phosphate(mg/L)	2.10±0.01	2.30±0.01	2.20±0.01	2.40±0.02	2.25	2.40-2.10
BOD(mg/L)	2.90±0.01	2.90±0.01	2.76±0.02	1.21±0.01	2.44	2.90-1.21
Turbidity(NTU)	2.20±0.01	2.50±0.01	2.40±0.01	3.10±0.01	2.55	3.10-2.20

Table 17: Mean Value of the physicochemical Parameters of River water during the rainy season (September, 2020)

Parameter	River Shabu (Mean±S.D)	River Amba (Mean±S.D)	RiverAkurba (Mean±S.D)	River Gandu (Mean±S.D)	Mean	Range
Temperature(^{o}C)	21.40±0.02	21.90±0.02	21.60±0.02	21.70±0.02	21.65	21.90-21.40
Electrical Conductivity(mg/L)	44.10±0.04	42.10±0.04	43.10±0.04	44.20±0.04	43.38	44.20-42.10
DO(mg/L)	1.20±0.01	0.90±0.01	2.80±0.03	3.10±0.01	2.00	3.10-0.90
PH	7.60±0.19	7.70±0.01	7.50±0.04	7.42±0.12	7.56	7.70-7.42
Total Hardness(mg/L)	52.30±0.04	52.40±0.21	53.10±0.05	52.42±0.05	52.56	53.10-52.30
TDS(mg/L)	70.10±0.07	70.90±0.07	71.20±0.07	70.50±0.07	70.68	71.20-70.10
Chloride(mg/L)	25.10±0.02	26.10±0.02	25.20±0.02	26.90±0.02	25.83	26.90-25.10
Total Alkalinity	6.90±0.01	6.80±0.01	6.70±0.01	6.60±0.11	6.75	6.90-6.60
Phosphate(mg/L)	2.10±0.01	2.30±0.01	2.20±0.01	2.40±0.02	2.25	2.40-2.10
BOD(mg/L)	2.90±0.01	2.90±0.01	2.76±0.02	1.21±0.01	2.44	2.90-1.21
Turbidity(NTU)	2.20±0.01	2.50±0.01	2.40±0.01	3.10±0.01	2.55	3.10-2.20

The mean water temperatures values were high and nearly uniform in both seasons. Higher temperature values were recorded during the rainy season and lower values during dry season**.** This lack of differences in trends between water temperatures is consistent with findings of Obire *et al.*,(2003) who observed a similar trend in Elechi Creek in Port Harcourt, Nigeria. Akpan (1994) working on tropical fresh water bodies in Uyo, also noted the seasonal difference in temperature which he attributed to the effect of the prevailing air-masses. Considering the ANOVA Values for dry and rainy seasons, there is no significant variation.

(ii) Electrical Conductivity (EC)

EC of the water sample during the dry season ranged between 325.10-19.40 µs/cm (Tables 2-9) for all the water samples. The highest (325.10 µs/cm) and lowest (19.40 µs/cm) values were both recorded in January at GANDU for hand dug well (Table 6) and sachet water (Table 2)

respectively. During the rainy season values ranged between 571.00-31.30 µs/cm for all the samples. The Highest values were recorded in borehole (571.00 µs/cm) and hand dug well (571.00 µs/cm) water both at TUDUN-AMBA in September and July respectively. This indicates that during the rainy season the borehole and hand dug well waters has the highest amount of dissolved ionic salts responsible for the conductivity in the water since the same potential pollution sources. Comparison of EC results of this study with EC values reported by other researchers, EC values for Sachet water obtained in this study both dry and rainy seasons was lower than the 283 µs/cm value reported by Adika *et al*.,(2018) in the assessment of water quality in Kenya. Also the research is in lined with the work of Farringoro and Ndor (2019) where they accessed the physicochemical properties of water used in lafia metropolis for domestic purposes and concluded that the values were all below the WHO values. The electrical conductivity values for all the water sampled both dry and rainy are below the standard limit of 1000 µs/cm set by the WHO and NESREA (Figures 2 and 3 and Table 18).

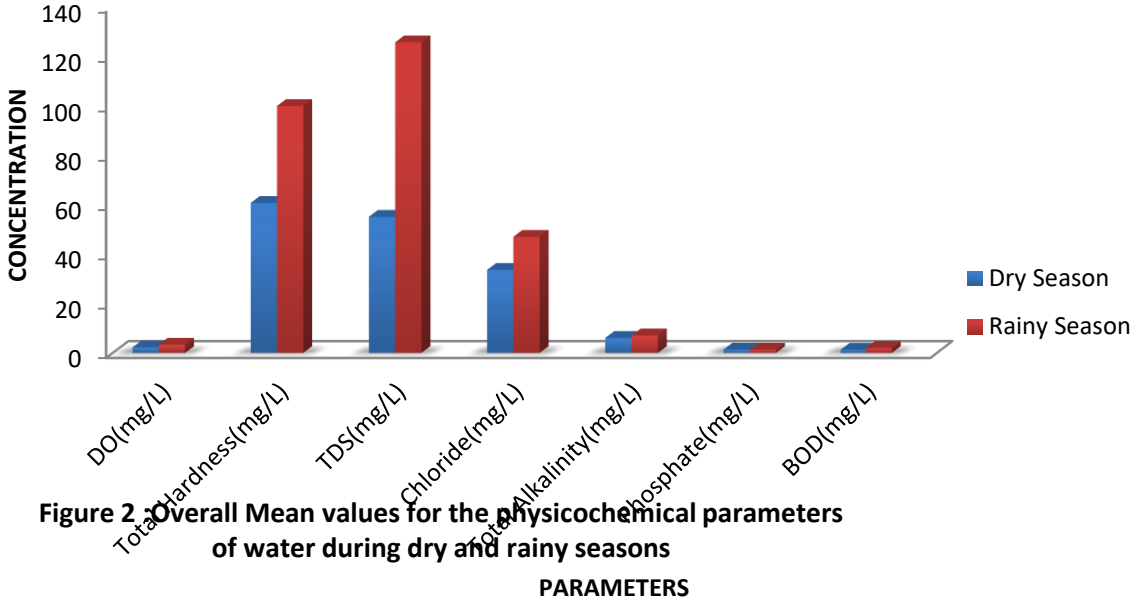

Figure 2 :Overall Mean values for the physicochemical parameters of water during dry and rainy seasons

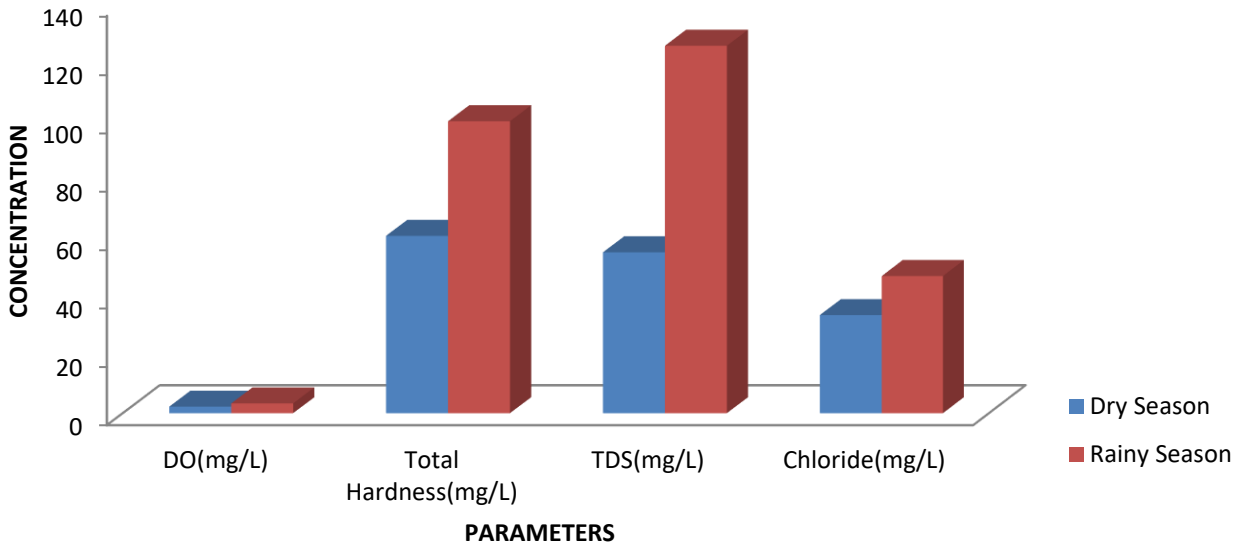

Figure 3:Overall Mean values for the physicochemicalparameter of water during dry and rainy seasons…

Table 18: Overall Mean values for the physicochemical parameters of water during dry and rainy seasons

Parameter	**Dry season**	**Rainy season**
Temperature(°C)	20.66	21.58
EC(µS/cm)	112.16	213.77
DO(mg/L)	2.24	3.34
PH	5.78	6.45
Total Hardness(mg/L)	60.74	99.88
TDS(mg/L)	55.11	125.65
Chloride(mg/L)	33.63	47.02
Total Alkalinity(mg/L)	6.08	7.09
Phosphate(mg/L)	1.34	1.33
BOD(mg/L)	1.26	2.05
Turbidity(NTU)	1.52	1.63

(iii) Dissolved Oxygen (DO)

The dissolved oxygen levels were lower during the dry season (January and March) with mean values of 0.84 mg/L and 1.80 mg/L for sachet, 3.90 mg/L and 1.60 mg/L for borehole, 3.38 mg/L and 1.60 mg/L for hand dug well, 1.98 mg/L and 2.85 mg/L for river water respectively. The highest value for dry season was recorded in hand dug well water in January at GANDU (4.50 mg/L) and the least was recorded in Sachet water in January at SHABU (0.40 mg/L). The rainy season (July and September) values are higher than the dry season values. The highest value was recorded in hand dug well water in

September at GANDU (5.20 mg/L) and the least was recorded in borehole water at SHABU (0.60 mg/L) in July. Both the dry and rainy season values are lower than the permissible limits set by the WHO of 5.0 mg/L. Higher levels of dissolved oxygen recorded in rainy season in all the sampling points in all the water sources is consistent with the work of Izonfuo and Bariweni (2001), in Niger Delta, while working in Epie Creek.

(iv) pH

The pH of water is an important indicator of the quality of water and the extent of pollution in the water (Kumar *et al.,* 2000). The pH of all the water sources was consistent and falls within the same range for each water sources in all the sampling points during the dry season (January and March). The ranged was 7.10-3.20 for all the sampled water. During the rainy season (July and September) the ranged was 7.70-5.45 for all the water samples. The pH values for all the water sources were within the permissible level set by WHO and SON that is 6.5 to 8.5. The lower pH values recorded in all the stations in all the water sources during dry season is probably due to the concentration of dissolved substances. The pH increased during the rainy season was as a result of dilution effect.

(v) Total Hardness

Hardness of water is mainly contributed by bicarbonates, sulphates and chlorides of calcium and magnesium.Total hardness of water quality is a parameter used to describe the effect of dissolved minerals (Ca and Mg), determining suitability of water for domestic, industrial and drinking purpose. In this study the total hardness of the water samples during the dry season ranged between 125.20-20.10 mg/L.The highest and lowest values during the dry season was recorded in hand dug well and Sachet water both in January at SHABU with values of 125.20 mg/L and 20.10 mg/L respectively. During the rainy season (July and September) the values ranged between 180.20-40.21 mg/L. The highest and lowest values was recorded in hand dug well water in September at AKURBA and borehole water in July at

SHABU with values of 180.20 mg/L and 40.21 mg/L respectively. All the values in all the Water sources were below the standard limit value of 500 mg/L by the WHO. In 1964 Durfor and Becker classified water as soft (0-60mg/L), Moderate (61-120 mg/L), hard (121-180 mg/L) and very hard (>181 mg/L). With the mean values recorded during dry and rainy season, Sachet and river water were moderate both during dry and rainy seasons, borehole and hand dug well water were moderate during the dry season and hard during the rainy season.

(vi) Total dissolved solids (TDS)

Total dissolved solids values obtained for the water samples in this study during the dry season ranged between 142.20-2.10 mg/L with Hand dug well and borehole water having the highest TDS values during the dry season. During the rainy season, sachet water ranged between 350.0-4.10 mg/L. The highest values were recorded in both Hand dug well and borehole water in AKURBA, GANDU and TUDUN-AMBA in July, September and September with values of 350 mg/L, 327 mg/L and 327 mg/L respectively. The lowest value was recorded in sachet water at TUDUN-AMBA and GANDU in July both with the value of 4.10 mg/L respectively. TDS values from this study are higher during the rainy season than the dry season. The higher values during the rainy season might be due to anthropogenic activities within and around the water sources. Both the dry and rainy season values are within the 1000 mg/L maximum permissible limits recommended for safe drinking and pose no health problem on the humans and animals. Similar findings have been reported by Garg *et al., (*2010), Kirubavathy *et. al.,* (2005), Fasae and Omolaja (2014).

(vii) Chloride

Chloride occurs naturally in all types of water sources with a very low concentration. The values ranged between 86.14-10.20 mg/L. The highest and lowest values were recorded in hand dug well and sachet water at TUDUN-AMBA and AKURBA both in January with values of 86.14 mg/L and 10.20 mg/L

respectively. The values are uniform in all the water sources. Higher values in hand dug well and river water was as a result of availability of chloride sources near and within the water sources or as a result of domestic sewage which contains a good amount of chloride. During the rainy season values ranged between 90.60-20.30 mg/L. values recorded during the rainy season are higher than the dry season. High values were recorded for hand dug well and sachet water due to the materials or equipment used to draw the water from the well which contains chloride or chloride sources and for sachet water is as a result of treatment of the water source with excess chlorine. The chloride result of the study is below the WHO, SON and NESREA permissible limit of 200 mg/L and 250 mg/L.

(viii) Total Alkalinity

Total alkalinity measures the amount of carbonate, bicarbonate and hydroxide present in terms of calcium carbonate. Alkalinity is the capacity to neutralize acids, and the alkalinity of natural water is derived principally from the salts of weak acids. Hydroxide carbonates, and bicarbonates are the dominant source of natural alkalinity. During the dry season (January and March) the values for sachet water ranged between 8.50-2.10 mg/L. The values in all the water sources were uniform and consistent in all the sampling points during the dry season. The highest and lowest values were recorded for hand dug well and sachet water both at SHABU in January and March with values of 8.50 mg/L and 2.10 mg/L respectively. During the rainy seasons the values ranged between 8.40-4.10 mg/L. The highest values were recorded in sachet and hand dug well water both in SHABU in September and the lowest value was recorded in July in sachet water at SHABU and AKURBA with the values of 4.10 mg/L respectively. Both the dry and rainy season values are below the 200 mg/L permissible limits recommended by the WHO.

(ix) Phosphate (PO_4^{3-})

The trend of phosphate was similar in all the water sources both during the dry and rainy seasons with close values in all the sampling sites. The phosphate concentration was higher during the rainy season than the dry season in almost all the water sources. This could be attributed to concentration effect as a result of reduced water volume during the dry season, while the mean value recorded in the rainy season could be due to the dilution effect of rains. The highest values were recorded both in River SHABU in January and March with values of 2.90 mg/L and the lowest values were recorded in Sachet water in March at SHABU and TUDUN-AMBA with values of 0.10 mg/L respectively. High value in River SHABU could be attributed to domestic waste waters, particularly those containing detergents and fertilizer runoff from various sources to the river. During the rainy season, the highest and lowest concentration values were noticed in River AKURBA in July and Sachet water in July at SHABU, TUDUN-AMBA, AKURBA and GANDU with values of 2.90 mg/L and 0.20 mg/L respectively. The highest value in River AKURBA was as a result of domestic waste waters, particularly those containing detergents and fertilizer runoff from various sources to the river. Both the concentrations during the dry and rainy season were within the WHO, SON and NESREA permissible limit for drinking water of 6.5 mg/L.

(x) Biochemical Oxygen demand (BOD)

It is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand (Abida and Harikrishna, 2008). The average concentration of BOD in the study during the dry season ranged between 2.30-0.15 mg/L. The highest and lowest values were recorded both in Sachet water in GANDU and SHABU in March and January with values of 2.30 mg/L and 0.15 mg/L respectively. Lower values of BOD in all the sampled sites and water samples indicated higher DO values which mean

more oxygen remains in water. Rainy season ranged between 3.20-0.30 mg/L.The highest values during the rainy season was recorded in Sachet water in July in all the sampled points with a uniform value of 3.20 mg/L and the lowest value of 0.30 mg/L was recorded both at SHABU and TUDUN-AMBA in July in borehole water. Both the dry and rainy season BOD values were below the permissible limit for BOD of 5 mg/L prescribed by WHO and NESREA. Similar trend was also reported by so many researchers like Ahipathi and puttaiah (2006).

(xi) Turbidity

In the present study, water turbidity during dry and rainy season ranged between 4.30-0.10 NTU. The highest and lowest values during the dry season were recorded in River SHABU (4.30 NTU) and in Sachet water at SHABU and GANDU (0.10 NTU) both in March. The highest and lowest values during the rainy season were recorded in River water at River AKURBA (4.30) in July and in all the sampled points in July with uniform values of 0.10 NTU. Both the dry and rainy season values recorded were below the permissible limits of 5.0 NTU.

3.2 Water quality index (WQI)

3.2.1 Water quality indices during dry season (January and March)

The results of the Weighted Arithmetic WQI obtained from sachet, borehole, hand dug wells and river water sampled at Shabu, Tudun-Amba, Akurba and Gandu in January were found to be 13.26, 38.61, 40.93 and 46.17 respectively (Figure 6). The WQI was classified based on the table used by Etim *et.al* (2013) and Kangabam *et.al*,(2017). Results indicated that water samples analyzed from sachet water falls under excellent and Grade A water quality as it shows low water quality index value. The result suggests that sachet water is safe for human consumption, irrigation, industrial and for other domestic purposes. The borehole, hand dug well and river water falls under Good and Grade B water quality as it has values between 26-50 water quality index values (Table 1). The results suggest that borehole, hand dug well and river water are safe for drinking, irrigation and industrial purposes in January.

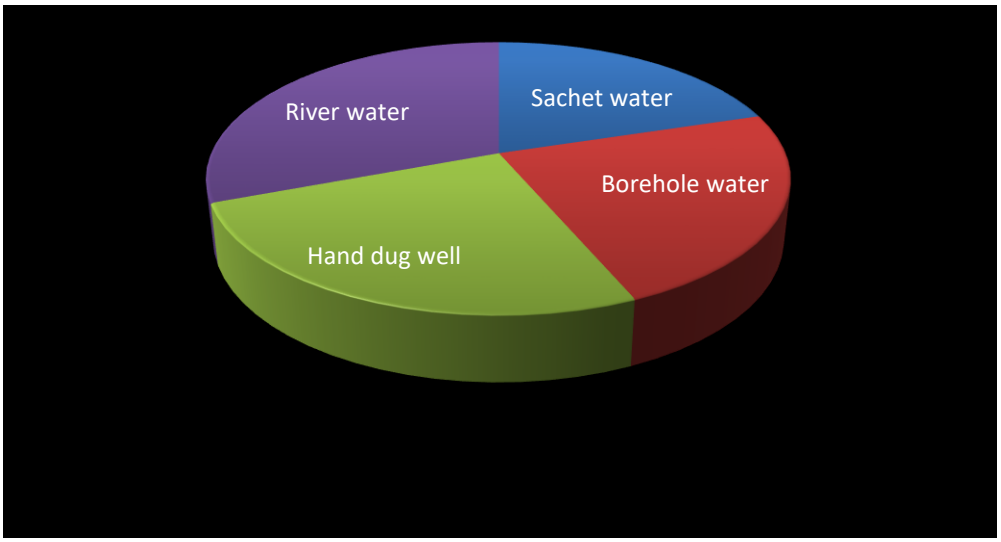

Figure 4: Water quality index during the dry season (January, 2020)

Results in March revealed that sachet, borehole, hand dug well and river water has values of 29.32, 39.27, 41.84 and 51.21 respectively (Figure 5). The results showed that sachet, borehole and hand dug well water falls under Good and Grade B and are safe for drinking, irrigation and industrial purposes while River water falls under Poor and Grade C water quality which is unsafe for drinking purposes and can only be used for irrigation and industrial purposes.

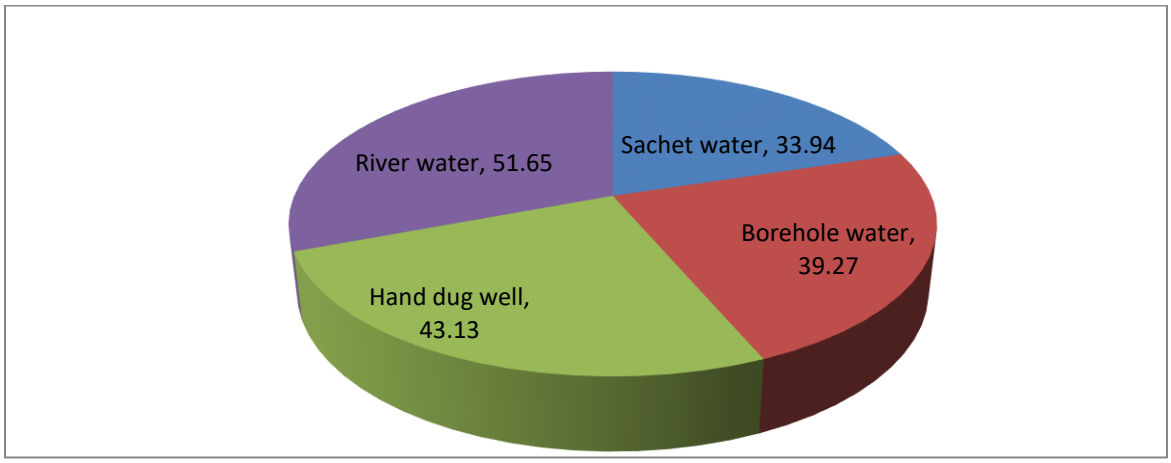

Figure 5: Water quality index during the dry season (March, 2020)

2.2 Water quality indices during rainy season (July and September)

The results of the Weighted Arithmetic WQI obtained for sachet, borehole, hand dug wells and river water sampled at Shabu, Tudun-Amba, Akurba and Gandu in July and September were presented in Figures 6 and 7. The results showed that sachet, borehole, hand dug well and river water has values of 33.94, 39.27, 43.13, 51.65 and 37.11, 40.47, 44.44, 64.16 respectively (Figures 6 and 7).

The result suggests that sachet; borehole and hand dug well water both in July and September falls under Good and Grade B and were safe for human consumption, irrigation, industrial and for other domestic purposes except river water both in July and September that falls under poor and Grade C which are unsafe for consumption except for irrigation and industrial purposes. The high values of WQI for river water may be due to regular discharge of effluents and the use of fertilizers and chemical including pesticides in farm lands around the river increases the pollution of the water. The result obtained for WQI in this present study agrees with the finding of Etim *et.al*.(2013) on assessment of water quality from different sources in the Niger Delta region of Nigeria. The water quality in all the water sources were higher during the rainy season than the dry season value which is contrarily to the findings of Wan *et.al*,(2013) on Bertam River in Cameron Highlands, Malaysia where the WQI value was higher during the dry season than rainy season.

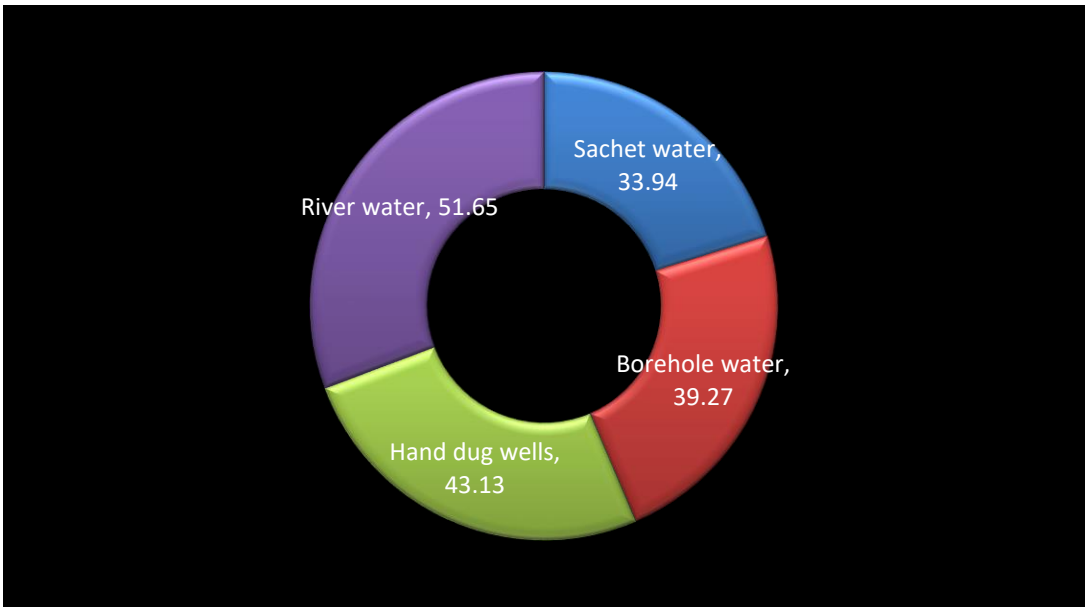

Figure 6: Water quality index during the rainy season (July, 2020)

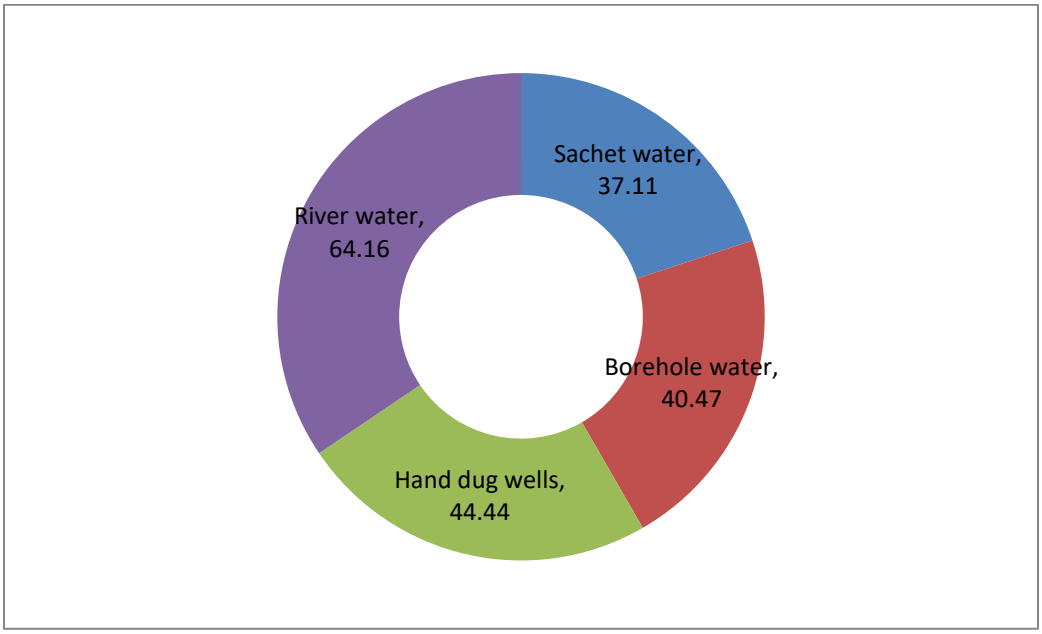

Figure 7: Water quality index during the rainy season (September, 2020)

4. Conclusion

Water issues in Nigeria focus more on water quality than quantity and more studies are needed to identify the causes and extent of pollution. This study was carried out with an aim of assessing the water quality indices of different water sources from Lafia metropolis.

The assessment of the physicochemical parameters from sachet, borehole, hand dug well and river water showed no variation among the different locations in most of the measured parameters. It can be seen that the physicochemical parameters of the different water sources were all lower than the permissible limits for drinking water by the WHO and NESREA. The water quality indices of sachet borehole, hand dug well and river water in January, March, July and September showed that sachet, borehole and hand dug well water was good and can both be used for drinking, irrigation and in industries except river water. This showed that the river water can be used sufficiently only when treated.

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