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Full Length Research Article

ASSESSMENT OF THE PHYSICOCHEMICAL CHARACTERISTICS OF WATER IN AN URBAN RIVER IN ABUJA, NIGERIA

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ABSTRACT
The assessment of physicochemical characteristics of water from River Wupa, Abuja, Nigeria was carried out to ascertain its suitability for domestic and industrial usage. Sixty water samples were taken from ten locations along the length of the river in both dry and wet seasons. The samples were analyzed for pH, temperature, EC, TDS, TSS, turbidity, alkalinity, DO, BOD, COD, hardness, sulphate, nitrate, nitrite, phosphate, and chloride using standard methods prescribed by AOAC. The results obtained for these respective parameters pH, temperature, EC, TDS, TSS, turbidity, alkalinity, DO, BOD, COD, hardness, sulphate, nitrate, nitrite, phosphate and chloride were (7.01-7.29), (20.70-22.10ºC), (172.20-293.00 µS/cm), (102.00-207.00 mg/dm^3), (15.90-65.00 mg/dm^3), (11.00-58.00 mg/dm^3), (27.50-38.90 mg/dm^3), (7.00-8.00 mg/dm^3), (10.00-25.00 mg/dm^3), (15.50-60.10 mg/dm^3), (30.40-36.50 mg/dm^3), (39.90-42.70 mg/dm^3), (10.00-15.00 mg/dm^3), (0.05-0.10 mg/dm^3), (1.70-2.70 mg/dm^3) and (37.00-49.00 mg/dm^3) in dry season. In wet season the respective results were (7.24-7.43), (26.70-28.30ºC), (121.60-176.40 µS/cm), (62.00-86.50 mg/dm^3), (287.00-430.00 mg/dm^3), (299.00-492.00 mg/dm^3), (23.70-35.00 mg/dm^3), (7.00-9.87 mg/dm^3), (12.00-20.00 mg/dm^3), (14.60-45.00 mg/dm^3), (28.00-40.00 mg/dm^3), (27.60-30.80 mg/dm^3), (9.00-15.00 mg/dm^3), (0.03-0.09 mg/dm^3), (1.80-2.70 mg/dm^3) and (27.90-38.00 mg/dm^3). These results revealed that the levels of all the physicochemical parameters determined for all sampling locations were below the tolerable limits recommended by NSDWQ and WHO except for turbidity, DO and phosphate values from all sampling locations which were higher compared to tolerable recommended limits. It is concluded that the water from River Wupa cannot be said to be wholly safe for usage by humans because of some health risks that are associated with the parameters with values higher than those of the regulatory bodies. It is, therefore, recommended that the water quality of the river be monitored regularly and the water should be treated to make it safe for use.

Keywords: Assessment, water, physicochemical parameters, water quality, health risk.

INTRODUCTION

The importance of water to life at every stage for all living organisms cannot be over emphasized. Water is needed by all living organisms for growth, development and other physiological activities. The quality of water therefore, is not only very fundamental but also crucial to the existence as well as the quality of life of living organisms (Omonona *et al*., 2019). In a given ecosystem the quality of water resources drives the resources that support life (Rajesh *et al*., 2002). Based on the importance of water to life generally, United nations General Assembly in July 2016 declared that access to clean and safe water for human consumption is a human right (UN, 2016). Water is increasingly in demand and is under threat of factors ranging from contamination to pollution which affects it quality (Janat *et al*., 2019).

Water resources such as rivers, lakes, streams, seas, ocean and groundwater covers about 70% of the earth's surface for which 3% is considered to be fresh water and about 5% of the fresh water is accessible by humans (Usharani *et al*., 2010). The freshwater sources are subjected to enormous pressure because they are readily and easily accessible for disposal of wastewater (Janat *et al*., 2019).

These water sources always serve as points for the discharge of human wastes to highly toxic industrial discharges such untreated wastewater from industries, urban wastes as well as agrochemical wastes (Naseem, 2021). This leads to contamination of water sources and it is always very difficult, economically expensive and even almost impossible to treat such water (Janat *et al*., 2019). Contamination of aquatic ecosystem is on the increase due to rapid growth in population, urbanization, industrialization as well as non-enforcement of existing environmental laws (Ogolo and Abam, 2021). This contamination affects the physical, chemical and microbiological characteristics of water and all these determines the quality of water which basically is a measured of the condition of water relative to one biotic species or to human need and/or purpose (Omonona *et al*., 2019).

Prolonged contamination of freshwater sources causes the water body to become polluted thereby creating health challenges (Gondden and Lohdip, 2015). Water-borne diseases are the recent emerging infectious diseases and have become of serious concern worldwide (Gondden and Lohdip, 2015). The contribute to about 70-80% health challenges in developing countries and have continued to be the source of human mortality and morbidity (Dada *et al*., 2011).

A number of research work have been carried out all over the world to assess the physicochemical characteristics of surface water (Ahmed, 2016; Janat *et al*., 2019; Arafat *et al*., 2021) and a host other. Also in Nigeria such researches have been conducted (Ogolo and Abam, 2021; Dada *et al*., 2011; Oluyemi *et al*., 2014) and so many others.

River Wupa originates from the foot of Aso Rock and it transverses the Abuja metropolis down to Wuye and serve different purpose to the inhabitants and there is very scanty or no information on the physical and chemical properties of water from this source. The aim of this study therefore, is to assess the physicochemical

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characteristics of water from River Wupa. Data generated from this research work would be a very good tool for the monitoring and further assessment of the river quality which would eventually determine the degree of pollution and the productivity of the water body.

METHODOLOGY

Study Area

The study area is Abuja and it lies on latitude 8º58'30" to 9º7'30"N and longitude 7º19'30" to 7º31'30"E. River Wupa is located in Federal Capital Territory, Abuja, Nigeria and it originates from Aso Rock in Abuja. During the dry season, the water from the river is used for irrigation agriculture, and fishing also takes place along the river. The river receives heavy inflows of wastes from both point and non-point source discharges most especially during the wet season. Different human activities take place along the river bank from car wash, block moulding, and auto mechanic workshops. Domestic wastes, industrial wastes, and runoff from irrigation farmlands are constantly discharged into the water body.

Sample Collection and Preparation

At each sampling station, three water samples were collected along a North-South transect across the river in all the sample sites. Water samples were collected from River Wupa in Federal Capital Territory, Abuja north central Nigeria in two different seasons: January 2019 for the dry season and September 2019 for the rainy season. A total number of sixty water samples were collected; from ten (10) locations at a distance of about 3 km and the samples were taken using fetcher, 5.0 cm below the water surface (to minimize the contamination of the water sample by surface films) (Opaluwa *et al*., 2020). Each sample was taken into prewashed 1.0 dm^3 plastic bottle. The sample was filtered through 0.4 µm Whatman filter paper using a vacuum pump (Model No.: SP 2 Flat 16455010) to remove particulate matter, and preserved in the refrigerator pending analysis.

Determination of Physicochemical Characteristics

Temperatures, pH, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) were determined at the point of collection of the samples. The temperature was determined using the thermometer. HANNA digital model pH/conductivity/TDS meter (Model No. HI2550 Digital) was used for the determination of pH, EC and TDS. DO was determined using DO meter, DO 150 (Model No. 50150), and a five-day biochemical oxygen demand (BOD) test method 521.0 was used to determine the BOD. Turbidity was determined using a turbidimeter (Model No. HACH2100Q). Total suspended solids (TSS) was determined using the gravimetric method of analysis and total alkalinity, total hardness, Chemical oxygen demand (COD), sulphate, and chloride was determined using the titrimetric method of analysis. Nitrate and nitrite were determined using the spectrophotometric method while phosphate was analyzed with the photometer method. The results obtained from the determinations were compared with standards recommended by Nigerian Standards for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO).

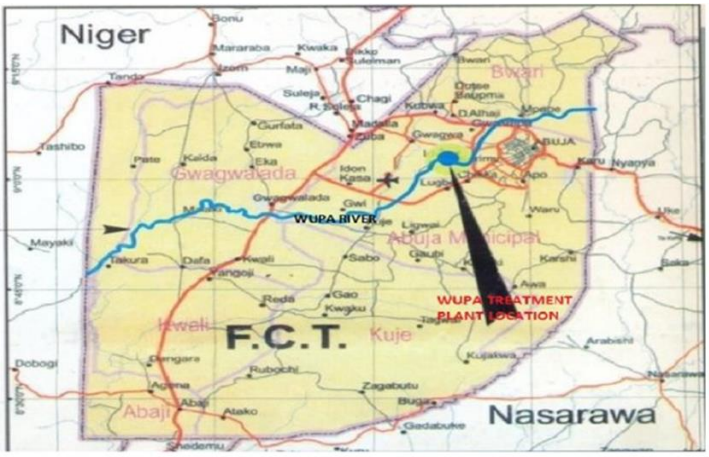

Figure 1: Federal Capital Territory, Abuja showing River Wupa (Source: Akpen *et al*., 2016)

RESULTS AND DISCUSSION

Table 1: Physiochemical Parameters for Water Samples from River Wupa, Abuja during the Dry Season

Parameters	Sampling Locations										Min	Max
	A	B	C	D	E	F	G	H	I	J		
pH	7.20	7.01	7.12	7.12	7.10	7.14	7.21	7.29	7.04	7.04	7.01	7.29
Temp (^{0}C)	22.00	21.20	21.50	21.50	21.20	20.70	20.90	21.90	22.10	22.10	20.7	22.10
EC (µS/cm)	286.00	172.20	182.30	198.40	293.00	239.00	287.00	272.00	271.0	271.00	172.20	293.00
TDS (mg/dm^3)	206.00	102.00	128.00	103.00	207.00	130.00	186.00	150.00	182.00	174.00	102.00	207.00
TSS (mg/dm^3)	41.00	32.10	32.00	38.90	38.90	15.90	29.90	65.00	20.00	20.10	15.90	65.00
Turbidity (NTU)	31.00	21.00	21.00	30.00	32.00	11.00	23.00	58.00	18.00	17.00	11.00	58.00
T. Alkalinity (mg/dm^3)	27.50	30.00	37.30	33.30	29.80	38.90	37.80	35.80	35.60	38.90	27.50	38.90
D.O (mg/dm^3)	7.90	7.89	7.56	7.63	7.700	8.00	7.90	7.80	7.90	7.00	7.00	8.00
BOD (mg/dm^3)	20.00	18.00	18.00	20.00	20.00	10.00	17.00	25.00	12.00	10.00	10.00	25.00
COD (mg/dm^3)	50.50	45.50	45.50	50.00	47.50	15.50	38.50	60.10	25.50	25.00	15.50	60.10
T. Hardness (mg/dm^3)	32.80	35.90	35.90	34.00	34.70	33.80	32.50	30.40	36.50	30.90	30.40	36.50
Sulfate (mg/dm^3)	41.30	39.90	42.70	41.10	40.00	40.00	42.30	42.10	40.70	40.80	39.90	42.70
Nitrate (mg/dm^3)	10.00	13.00	10.00	12.20	10.00	10.00	12.00	15.00	15.00	14.00	10.00	15.00
Nitrite (mg/dm^3)	0.10	0.06	0.09	0.07	0.08	0.07	0.08	0.10	0.05	0.08	0.05	0.10
Orthophosphate (mg/dm^3)	2.00	1.70	1.90	1.80	2.00	2.40	2.50	2.70	1.90	2.00	1.70	2.70
Chloride (mg/dm^3)	45.00	40.40	39.00	41.00	37.00	40.20	40.00	49.00	40.00	38.00	37.00	49.00

Min: Minimum, Max: Maximum, EC: Electrical Conductivity, DO: Dissolved Oxygen, COD: Chemical Oxygen Demand, BOD: Biochemical Oxygen Deman

Table 2: Physiochemical Parameters for Water Samples from River Wupa, Abuja during the Wet Season

Parameters	Sample Location										Min	Max
	A	B	C	D	E	F	G	H	I	J		
pH	7.27	7.28	7.24	7.24	7.29	7.34	7.43	7.33	7.33	7.36	7.24	7.43
Temp (^{0}C)	27.70	28.30	27.90	26.70	27.80	27.80	28.00	27.70	26.90	27.80	26.70	28.30
EC (µS/cm)	137.00	121.60	127.50	159.90	157.90	176.40	168.40	159.90	157.90	157.80	121.6	176.4
TDS (mg/dm^3)	64.0 0	62.00	64.00	78.60	80.10	86.50	84.60	78.90	65.00	78.80	62.00	86.50
TSS (mg/dm^3)	327.00	300.00	329.00	328.60	345.60	320.60	290.70	430.00	380.00	287.00	287.00	430.00
Turbidity (NTU)	356.00	357.00	367.00	368.00	377.00	299.00	317.00	492.00	318.00	364.00	299.00	492.00
T. Alkalinity (mg/dm^3)	28.70	35.00	25.70	24.40	23.70	30.60	30.90	30.00	30.10	34.00	23.70	35.00
D.O (mg/dm^3)	9.67	9.76	8.88	9.87	8.89	8.36	9.03	8.46	9.56	7.00	7.00	9.87
BOD (mg/dm^3)	19.00	12.00	15.00	18.50	18.50	13.50	12.50	20.00	14.00	14.00	12.00	20.00
COD (mg/dm^3)	30.70	25.00	30.80	35.00	29.50	14.60	27.00	45.00	22.70	22.50	14.60	45.00
T. Hardness (mg/dm^3)	34.50	40.00	28.00	35.30	37.80	34.50	34.20	33.30	38.20	32.40	28.00	40.00
Sulfate (mg/dm^3)	27.80	28.90	29.80	28.70	27.60	28.40	27.60	30.80	28.90	29.70	27.60	30.80
Nitrate (mg/dm^3)	11.00	15.00	10.00	13.20	12.90	12.50	9.00	12.40	12.50	13.80	9.00	15.00
Nitrite (mg/dm^3)	0.03	0.05	0.04	0.07	0.06	0.06	0.08	0.09	0.06	0.07	0.03	0.09
Orthophosphate (mg/dm^3)	1.90	2.70	2.30	1.90	1.80	2.00	1.90	2.70	2.40	1.90	1.80	2.70
Chloride (mg/dm^3)	38.00	35.00	30.50	37.00	28.90	29.00	30.00	27.90	30.00	36.00	27.90	38.00

Min: Minimum, Max: Maximum, EC: Electrical Conductivity, DO: Dissolved Oxygen, COD: Chemical Oxygen Demand, BOD: Biochemical Oxygen Deman

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Table 3: Comparison of Physicochemical Parameter of Water from River Wupa with Standards

Parameters	Mean Values from Present Work		NSDWQ (2007)	WHO (2011)	Health Impact (NSDWQ, 200)
	Dry Season	Wet Season			
pH	7.01 – 7.29	7.24 – 7.43	6.50 – 8.50	6.50 – 8.00	Affects mucous membrane; bitter taste; corrosion
Temp (^{0}C)	20.7 – 22.10	26.70 – 28.3	Ambient	-	None
EC (µS/cm)	172.20 – 293.00	121.6 – 176.4	1000.00	1000.00	Conductivity due to ionizable ions. High conductivity increases corrosive nature of water.
TDS (mg/dm^3)	102.00 – 07.00	62.00 – 86.50	500.00	1000.00	Undesirable taste; gastro-intestinal irritation; corrosion or incrustation
TSS (mg/dm^3)	15.90 – 65.00	287.00 – 430.00	500.00	600.00 – 1000.00	Acceptability problem
Turbidity (NTU)	11.00 – 58.00	299.00 – 492.00	5.00	5.00	Higher level of turbidity are associated with disease causing bacteria
T. Alkalinity (mg/dm^3)	27.50 – 38.90	23.70 – 35.00	100	-	Acceptability problem
D.O (mg/dm^3)	7.00 – 8.00	7.00 – 9.87	5.00	-	Acceptability problem
BOD (mg/dm^3)	10.00 – 25.00	12.00 – 20.00	-	100.00	High BOD decreases level of dissolved oxygen
COD (mg/dm^3)	15.50 – 60.10	14.60 – 45.00		255.00	High COD decreases level of dissolved oxygen
T. Hardness (mg/dm^3)	30.40 – 36.50	28.00 – 40.00	-	200.00	Acceptability problem
Sulfate (mg/dm^3)	39.90 – 42.70	27.60 – 30.80	100.00	250.00 – 1000.00	Taste affected; gastro-intestinal irritation. Calcium sulphate scale
Nitrate (mg/dm^3)	10.00 – 15.00	9.00 – 15.00	50.00	50.00	Cyanosis and asphyxia (blue baby syndrome) in infants under 3 months
Nitrite (mg/dm^3)	0.05 – 0.10	0.03 – 0.09	0.20	0.02	Cyanosis, and asphyxia ("blue-baby syndrome") in infants under 3 months
Orthophosphate (mg/dm^3)	1.70 – 2.70	1.80 – 2.70	-	0.03	Stimulate microbial growth, Rancidity Mold growth
Chloride (mg/dm^3)	37.00 – 49.00	27.90 – 38.00	250.00	200.00 – 300.00	Eye/nose irritation; stomach discomfort. Increase corrosive character of water

Physiochemical parameters for water samples from River Wupa, Abuja during the dry season

Table 1 shows the values of the different physicochemical parameters in the water samples from River Wupa, Federal Capital Territory, Abuja, Nigeria during the dry season.

The pH values of water samples ranges from 7.01 – 7.29 in the dry season. These range values are within the range of values 7.00 – 7.80 recorded for the pH of water from Mullai Periyar River, Tamil Nadu, India in the dry season (Roshinebegam and Selvakumar, 2014). The value from this work is slightly more than the mean pH value 6.11 in the dry season for water from Etche River, Niger Delta, Nigeria (Oluyemi *et al*., 2014). pH from the research work falls within the range of 6.50 – 8.00 recommended as permissible limit by both NSDWQ and WHO.

The temperature range of the water samples was 20.70 – 22.10°C in the dry season. These values are all less than the mean value of 25.67±3.03°C for the mean temperature of water from Nagani/Wubang dam Plateau State, North Central Nigeria in the dry season (Gongden and Lohdip, 2015). However, the temperature values are higher than the range of 3.40 – 8.30 for water sources in Ogbaru communities, Anambra State, Nigeria (Onuorah *et al*., 2019).

The range values of electrical conductivity (EC) of the water samples from River Wupa were 172.20 – 293.00 µS/cm in the dry season. This range values are far less than the mean value of electrical conductivity, 11,232.19±2,540.54 µS/cm for the water samples from Ntawogba Stream in Port Harcourt in dry season (Ummunakwe *et al.,* 2020). The values of conductivity from this present research work are also less than the mean value 76,000.20 µS/cm for water from Iko River, Nigeria in the dry season (Usoro *et al.,* 2013). However, the values are far below the recommended permissible limit of 1000 µS/cm by NSDWQ and WHO

The range of total dissolved solids (TDS) for water from Wupa River was 102.00 – 207.00 mg/dm^3 in the dry season. This range is higher than the mean total dissolved solids in the dry season 34.00±0.82 mg/dm^3 for water from Borgu sector of Kainji Lake National Park, Nigeria (Omonona, *et al.,* 2019). However, the range value is less than the range value 1890 – 15,046 mg/dm^3 reported for water sources in the South of Najaf City, Iraq (Ahmed, 2016). The TDS from all the locations are all lower than the recommended values by NSDWQ and WHO which are 500 and 1000mg/dm^3 respectively.

Total suspended solids for the water in the dry season had a range value of. 15.90 – 65.00 mg/dm^3. The values from locations A-E are within the range value, F-J are lower and H is more than the total suspended solids in the dry season for water from River Mkomon, Gwande Local Government Area, Nigeria, 31.30±0.81 – 39.30±0.80 mg/dm^3 (Ioryue *et al.,* 2018). But the values from all locations are higher compared to the mean value of total suspended solids in the dry season14.21±0.75 mg/dm^3 for water from Ajiwa Reservoir, Katsina State, Nigeria (Usman, 2016). The TSS from all the locations are all lower than the recommended values by NSDWQ and WHO which are 500 and 1000mg/dm^3 respectively.

Turbidity of water samples from Wupa River in the dry season had the range value of 11.00 – 58.00 NTU. These values are high and could be attributed to the constant discharge of domestic sewage and industrial effluents which continues to agitate the sediment bed and increase the level of turbidity. These values of turbidity are lower than the mean value of turbidity in the dry season 80.03±1.77

mg/dm^3 reported for water from Ajiwa Reservoir, Katsina State, Nigeria (Ioryue *et al.,* 2018). The values of turbidity for all the locations except for H (the maximum value) are lower compared to the mean of turbidity in dry season 34.43±10.78 mg/dm^3 reported for water from Ntawogba Stream, Port Harcourt (Ummunakwe *et al.,* 2020). The turbidity values from all the sampling locations are higher compared to the NSDWQ and WHO recommended permissible value 5.00 NTU for turbidity of water.

The range values for total alkalinity for water samples from Wupa River were recorded to be 27.50 – 38.90 mg$CaCO_3$/dm^3 in the dry season. The values from all locations except for A, B, and E are slightly higher compared to the mean value of total alkalinity in dry season 33.11±1.35 mg$CaCO_3$/dm^3 recorded for water from Ajiwa Reservoir, Katsina State, Nigeria (Usman, 2016). All the values of total alkalinity in the dry season from this research work are lower compared to the range values of total alkalinity in the dry season 133.27±13.48 – 184.19±17.66mg$CaCO_3$/dm^3 for water sources in Ruiru, Kiambu County, Kenya (Otieno *et al.,* 2015). The values of total alkalinity from all locations fall below the value of 100.00 mg$CaCO_3$ recommended by NSDWQ as the tolerable limit.

The dissolved oxygen (DO) contents of water samples from Wupa River had a range value of 7.00 – 8.00 mg/dm^3 in the dry season. This high DO contents in the dry season could be due to a low level of organic matter. This range value agrees with the mean value of dissolved oxygen in the dry season 7.68±0.61 mg/dm^3 for water samples from the Borgu Sector of Kainji Lake, National Park, Nigeria (Omonona *et al.,* 2019). However, the range value is in contrast with the range of 4.51 – 7.58 mg/dm^3 reported in the dry season as the dissolved oxygen contents in water from Awash River, Ethiopia (Temesgen and Seyoum, 2018). The DO values from all the locations are above the value of 5.00 mg/dm^3 recommended as a tolerable limit by NSDWQ.

Biochemical oxygen demand (BOD) for water samples from Wupa River in the dry season had the range values 10.00 – 25.00 mg/dm^3. The values from all the locations are higher compared to the mean value in the dry season 0.31±061 mg/dm^3 reported for water samples from the Borgu Sector of Kainji Lake, National Park, Nigeria (Omonona *et al.,* 2019). The values are also more than the biochemical oxygen demand range values in dry season 0.70 – 0.90 mg/dm^3 recorded for water sources from Anguwar Liman Area of Samaru-Zaria, Nigeria (Ibrahim *et al*., 2019). However, the BOD values from all the sampling locations are lower compared to the WHO recommended permissible value 100.00 mg/dm^3 for BOD of water.

Chemical oxygen demand (COD) for water samples from Wupa River in the dry season had the range values to be 15.50 – 60.10 mg/dm^3. The COD values from all locations are higher compared to the mean COD in dry season 5.35 mg/dm^3 recorded for water from Iko River, Nigeria (Usoro *et al.,* 2013). The values are however lower compared to the mean value of COD in dry season 76.82 mg/dm^{3}for water samples from Awash River, Ethiopia (Temesgen and Seyoum, 2018). All the COD values from the present work fall below the tolerable limit 255.00 mg/dm^3 recommended by WHO.
The range total hardness values for Wupa River were recorded to be 30.40 – 36.50 mg/dm^3 in the dry season. The mean value 65.19 mg/dm^3 in the dry season reported by Ocheri and Ahola (2012) is higher than all the values obtained from the current research work. The range values are far less than the range value 265.00 – 387.00 mg/dm^3 recorded for water in Laxima Taal, Jhansi, India (Tirthesh and Ramendra, 2016). All the total hardness values from the present work fall below the tolerable limit 200.00 mg/dm^3 recommended by WHO.

Sulphate in water samples from Wupa River in the dry season had a range value 39.90 – 42.70 mg/dm^3. The sulphate values from all the locations are far more than the mean value 0.42 mg/dm^3 for sulphate in water from the river Katsina-ala Catchment Area of Northern Nigeria (Ajon *et al.,*2014). However, the mean value is far lower compared to the sulphate contents 541.80 mg/dm^3 in the dry season for water from Etche River, Niger Delta Area, Nigeria (Oluyemi *et al.,* 2014). The sulphate values from all the sampling locations fall below the recommended limits by NSDWQ and WHO.
Nitrate in water from Wupa River during the dry season had a mean value of 10.00 – 15.00 mg/dm^3. The values from all location are higher compared to the mean level of sulphate 0.73±0.05 mg/dm^3 in the dry season for water from Ajiwa Reservoir, Katsina State, Nigeria (Usman, 2016). The values are far higher compared to the mean value of 0.98 mg/dm^3 for river water samples in the dry season (Tukura *et al.,* 2012). Nitrate values from all locations fall below recommended tolerable limits by NSDWQ and WHO.
Nitrite had a range value 0.05 – 0.10 mg/dm^3 in the dry season for water samples from Wupa River. The values agree with the range values for nitrite contents in water from Ottawa River to the St. Lawrence River (Frenette and Ali, 2018). The values are higher compared to the mean nitrite level 0.009 mg/dm^3 in water Weihe River in the semi-arid area (Ying *et al.,*2016). However, nitrite values from all the locations fall below the recommended limits by NSDWQ and WHO.

Phosphate in water from Wupa River in dry season had a range 1.70 – 2.70 mg/dm^3. The annual mean value for phosphate 0.36 mg/dm^3 in water from Al-Gharraf River, southern Iraq (Ewaid and Abed, 2017) is lower compared to the values for phosphate from all the locations in the current research work. However, the values are all lower compared to 33.30±2.90 mg/dm^3 recorded for water sources in the suburban area in Kikwit, the Democratic Republic of the Congo during the dry season (Nienie *et al*., 2017). Phosphate levels from all locations are higher than the recommended limit by WHO.

The range chloride level in water samples from Wupa River during the dry and wet seasons was 37.00 – 49.00 mg/dm^3. The range is higher compared to the range values of 5.70±0.70 – 15.20±1.00 mg/dm^3 for chloride in water sources from selected areas in Ado Ekiti, Nigeria (Dada *et al.,* 2011) but lower than the mean chloride value of 94.52 mg/dm^3 reported by Opaluwa *et al.* (2016). It is also lower than the mean value of 102.5 mg/dm^3 for stream water samples in the dry season reported by Aremu *et al.* (2014). Chloride concentrations from all locations are below the recommended limit by NSDWQ and WHO.

Physiochemical parameters for water samples from River Wupa, Abuja during the wet season

Table 2 shows the values of the different physicochemical parameters in the water samples from River Wupa, Abuja, Federal Capital Territory, Nigeria during the wet season.
The range pH values of water from Wupa River during the wet season was 7.24 – 7.43 and it is very clear that the values from all

locations are, however; higher compared to pH value of 6.76 recorded by Ahmed (2016) but agrees with pH value recorded by Zubia *et al.* (2015). The values from all locations are also higher than the mean value of 5.67 for water samples from a river in the wet season (Oluyemi, *et al.,* 2014) but are all slightly lower than the value of 7.50 for water samples in the wet season reported by Ugwu and Wakawa (Ugwu and Wakawa, 2012). The pH values fall within the tolerable limits recommended by NSDWQ and WHO.
The range temperature value for the water samples during the wet season was 26.70 – 28.30 ˚C. The values from all locations are, however; lower than the value of 30 ˚C obtained from the analysis of physicochemical parameters of water from Rawal Dam Islamabad (Zubia *et al.,* 2015). The results agree with the mean values of 27.73˚C, 27.00˚C, and 28.80˚C in different surface water samples during the wet season [Agaire and Obi, 2009; Tukura *et al.,* 2012; Aremu *et al*., 2014)] respectively.

The electrical conductivity (EC) values for the water samples during the wet season were 121.60 – 176.40 µS/cm. The values from all locations are lower compared to the annual mean value of electrical conductivity 1043.00 µS/cm of water from Al-Gharraf River, southern Iraq (Ewaid and Abed, 2017). The EC values from all locations are also far lower compared to the mean value 3,090.80±568.40 of EC during the wet season for water from Ntawogba Stream, Port Harcourt (Ummunakwe *et al.,* 2020). The EC values fall within the tolerable limits recommended by NSDWQ and WHO.
Total dissolved solids (TDS) and total suspended solids (TSS) in the wet season for water samples from Wupa River had 62.00 – 86.50 and 287.00 – 430.00 mg/dm^3 recorded as the range values respectively. The values for TDS are higher and that of TSS are lower, all compared to the values recorded for TDS and TSS by Uzoekwe and Oghonsanine (2011) which were 10.60 mg/dm^3 and 575.15 mg/dm^3 respectively. The values for this work are also higher than mean values of 8.40 mg/dm^3 and lower compared to 316.00 mg/dm^3 in a river in the wet season recorded for total suspended solids and total dissolved solids respectively by Ugwu and Wakawa (2012). The TSS and TDS values fall within the tolerable limits recommended by NSDWQ and WHO.

The range turbidity values for water samples from Wupa River were 299.00 – 492.00 NTU during the wet season. Turbidity is supposedly higher during the wet season due to runoffs that carry dissolved pesticides, herbicides, and fertilizer as well as silt, clay, and other suspended particles. The values of turbidity from all locations are far higher compared to the mean turbidity value 27.09 NTU in the wet season reported for water sources in Benue State (Ocheri and Ahola, 2012]. The values in the present research work are also higher compared to the range values of turbidity 4.47 – 9.41 NTU reported for water samples from Ottawa River water in St. Lawrence River (Frenette and Ali, 2018). The turbidity values are higher than the tolerable limits recommended by NSDWQ and WHO.

The range value 23.70 – 35.00 mg/dm^3 was recorded as total alkalinity in water samples from Wupa River during the wet season. The values from all the locations except for locations B and J are lower compared to the mean total alkalinity value 33.11±1.35 mg/dm^3 in the wet season recorded for water samples from Ajiwa Reservoir, Katsina State, Nigeria (Usman, 2016). Total alkalinity values from all the locations are lower than the range values 162.00 – 175.00 mg/dm^3 reported as total alkalinity in water sources from LaxmiTaal, Jhansi, India (Tirthesh and Ramendra, 2016). The total alkalinity values fall within the tolerable limits recommended by NSDWQ.

Dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) of water samples from Wupa River in the wet season had range values of 7.00 – 9.87, 12.00 – 20.00 and 14.60 – 45.00 mg/dm^3 respectively. The mean values of DO and BOD are higher compared to the mean values 4.50±0.20 and 1.01±0.08 mg/dm^3 in the wet season for dissolved oxygen and biochemical demand respectively in water samples from Ajiwa Reservoir, Katsina State, Nigeria (Usman, 2016) and the range value of COD is far lower than the range value 212.30 – 215.30 mg/dm^3 reported for water sources from Laxmi Taal, Jhansi, India (Tirthesh and Ramendra, 2016). The values for DO, BOD, and COD from the locations in the present study are also higher compared to the mean values 6.01, 3.39, and 5.31 mg/dm^3 in the wet season reported for the respective parameters in water from Iko River, Nigeria (Usoro *et al.,* 2013). DO from all the locations had values that are above the NSDWQ recommended tolerable limit. Increased DO is, however, good for the health of the river. It is higher in the rainy season due to increased current flow which allowed for diffusion and mixing of atmospheric oxygen. BOD and COD values from all locations fall below the recommended tolerable limit by WHO.
The range value of total hardness for water samples from Wupa River during the wet season was recorded to be 28.00 – 40.00 mg/dm^3. The values from all locations are lower compared to the wet season range values 57.40±0.32 – 133.70±3.01 mg/dm^3 reported for water samples from Mkomon River, Kwande Local Government Area, Nigeria (Ioryue *et al.,* 2018). They are also outside the range values 265.00 – 387.00 mg/dm^3 reported for the total hardness of water from Laxmi Taal, Jhansi, India (Tirthesh and Ramendra, 2016). The total hardness values from all locations fall within the tolerable limits recommended by NSDWQ.

The range concentration of sulphate in water samples from Wupa River in all locations was 27.60 – 30.80 mg/dm^3 during the wet season. These concentration values of sulphate obtained for all locations in the wet season are far below the value range of sulphate 154.33± 1.02 – 252.21±1.32 mg/dm^3 reported by Singh *et al.* (2012). The values are also lower than the mean value of 101.30 mg/dm^3 and 619.20 mg/dm^3 in water samples during the wet season reported respectively by (Ugwu and Wakawa, 2012; Oluyemi *et al.,* 2014). Sulphate concentrations from all the sampling locations fall below the tolerable limits recommended by NSDWQ and WHO.
Nitrate and Nitrite in water samples from Wupa River in the wet season had range concentrations of 9.00 – 15.00 and 0.03 – 0.09 mg/dm^3 respectively. The values of nitrate are all higher and those of the nitrite are all (except for locations A and C) higher compared to the mean values 1.91 and 0.42 mg/dm^3 in wet seasons reported for the respective parameter in water samples from Iko River, Nigeria (Frenette and Ali, 2018). However, all the nitrate and nitrite values from all locations are far more than the mean values 8.60 and 0.009 mg/dm^3 recorded for nitrate and nitrite respectively for water samples from semi-arid river basins, Weihe River watershed, China (Ying *et al.,* 2016). However, nitrate and nitrite values for all sampling locations are within the tolerable values recommended by NSDWQ and WHO.

Phosphate in water samples from Wupa River had a range concentration 1.80 – 2.70 mg/dm^3 during the wet season. All the values are higher compared to the phosphate range values 0.01 – 0.52 mg/dm^3 for water from Narmada River, Madhya Pradesh, India and the mean value 0.019 mg/dm^{3}in wet season for water from Etche River, Niger Delta Area, Nigeria reported by [Oluyemi *et al.,* 2014; Gupta *et al*., 2017) respectively. However, phosphate contents in water from River Wupa in all locations are higher compared to the tolerable limit recommended by WHO and this could to stimulated microbial growth, rancidity, and mould growth.
Chloride in water samples from Wupa River during the wet season had a range concentration to be 27.90 – 38.00 mg/dm^3. The values are far lower compared to the mean value 205.00 mg/dm^3 recorded for chloride in water from Al-Gharraf River southern Iraq (Ewaid and Abed, 2017). The range concentration is also lower than the concentration of chloride in range values 54.80±1.17 – 57.30±4.03 mg/dm^3 for water from Mkomom River, Kwande Local Government area, Nigeria (Ioryue *et al.,* 2018). Chloride concentrations in water from all locations have concentrations that fall below the tolerable limit recommended by NSDWQ and WHO.

The implication of the quality parameters of water from River Wupa on domestic and industrial usage

Water quality is determined by these physicochemical characteristics and the quality of water is directly linked to the health of the water body and human health. Water from River Wupa in both dry and wet seasons had mean values of turbidity, DO and phosphate higher than their standard values recommended by NSDWQ and WHO. This affects the quality of water. Higher turbidity is associated with disease-causing bacteria and this is likely to affect humans as well as animals. Increased DO is, however, good for the health of the river and aquatic organisms. Water with higher contents of phosphate gives rise to algal bloom which causes risks to humans as algal produces toxins that damage the neurological systems and can also lead to depletion in dissolved oxygen in the water. If the water from River Wupa is to be used for industrial purposes the high levels of turbidity and phosphate (which promotes algae growth) will lead to the blockage of pipes.

Conclusion

The following physicochemical characteristics of water from River Wupa; pH, temperature, EC, TDS, TSS, turbidity, alkalinity, DO, BOD, COD, hardness, sulphate, nitrate, nitrite, phosphate, and chloride were assessed in two seasons in 2019 to ascertain its suitability for domestic and industrial purposes. All the physicochemical parameters from all the sampling locations had values that were lower compared to tolerable limits recommended by NSDWQ and WHO in both dry and wet seasons except for turbidity, DO, and phosphate values from all sampling locations which were higher compared to tolerable recommended limits. Therefore, it is concluded that water from River Wupa is not safe for domestic and industrial usage except it is treated.

Conflict of Interest

The authors declared that there is no conflict of interest.

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