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Physicochemical Limnology and Water Quality Assessment of Ten Surface Water Bodies in Edo State, Nigeria

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ABSTRACT: The objective of this paper was to assess the physicochemical limnology and water quality assessment of ten surface water bodies in Edo State, Nigeria to determine their suitability for drinking, provide information on water quality status to the concerned public as well as providing baseline information that can be used as reference for further studies using appropriate standard techniques. Results revealed that pH, colour, turbidity, total dissolved solids, electrical conductivity, total alkalinity, total hardness, calcium, magnesium, dissolved oxygen, biochemical oxygen demand, sulphate, nitrate and phosphate 5.52 – 7.06, 1.0 – 5.5 PtCoU, 3.5 - 23.0 NTU, 11.0 -75.5 mg/L, 21.0 – 152.5µS/cm, 25.0 – 106.5 mg/L, 3.0 – 40.8 mg/L, 0.18 – 7.40 mg/L, 0.13 – 2.77 mg/L, 5.76 – 8.92 mg/L, 3.12 – 6.87 mg/L, 9.5 – 24.5 mg/L, 0.2 – 2.60 mg/L and 0.05 – 0.49 mg/L respectively. From the results of the physicochemical analyses, the water quality index score of the rivers was computed using the Weighted Arithmetic Water Quality Index method and the values obtained indicated that 60% of the sampled rivers were classified as having grade C quality (51 – 75), while 40% were of the grade D category (76 -100). Maximum index score (79.72) was recorded at Eruvbi River while the lowest index value (59.32) was redorded at Ugbogor River. Overall, this study found that the water quality of all chosen rivers is poor and unfit for drinking without previous treatment, although they are appropriate for irrigation and industrial usage.

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Water ranks among the natural resources which are most important on the Earth and it covers 71% of the surface of the Earth. Different types of water bodies are found all around the earth including oceans, rivers, lakes, glaciers and groundwater (Mishra, 2023). Despite the vast quantities of water present on Earth, only an estimated 2.5% is freshwater and this small portion serves human needs for drinking, agriculture and industry while also being essential for the maintenance of ecological balance. Freshwater resources can be classified further into groundwater and surface water (Mushtaq *et al.,* 2020). Surface water is easily accessible, provides for many human needs and is found in reservoirs, lakes and rivers. Groundwater, on the other hand, is stored in aquifers, and serves as a vital drinking water source, particularly in places where there is a scarcity of surface water (Lewandowski *et al.,* 2020). In Nigeria, the socio-economic advancement of many communities is reliant on the presence of surface water bodies. This is because these water bodies supply water for drinking, irrigation, fisheries, industrial activities and recreation

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(Umar, 2020). Edo State is located in southern Nigeria and is blessed with surface water resources, with rivers such as Ovia, Ose, Orhionmwon and Ikpoba rivers, being notable (Osimen and Anagha, 2020). The quality of these water bodies and the hydrological dynamics are affected by the tropical climate and seasons which the state experiences all year round (Ogieriakhi and Ilevbare, 2020). Water quality assesses the status of water relative to the requirements of one or more biotic species and or to any human need or purpose (Boyd, 2019). It is evaluated through the assessment of different physical, chemical and biological properties of water including temperature, pH, electrical conductivity, turbidity, dissolved oxygen, nutrient concentrations, pollutants and microorganisms (Giri, 2021; Uddin *et al.,* 2021). The physicochemical and microbiological parameters of water are vital for the evaluation of the suitability of water for different uses and for the maintenance of healthy aquatic ecosystems. Water of poor quality generally causes detrimental effects to human health and biodiversity (Ejigu, 2021). Water Quality Index (WQI) is a tool which is used by scientists to comprehensively evaluate the quality of water. The WQI refers to a numerical representation which converts the data obtained for various water quality parameters into a single value that members of the public, water managers and policymakers can easily interpret and understand (Kawo and Karuppannan, 2018; Uddin *et al.,* 2021). WQI is derived from several water quality parameters which are assigned weights that reflect their relative importance to the overall value of water quality. The resulting index provides a clear and succinct depiction of the water quality status, assisting in assessing and managing water resources (Kachroud *et al.,* 2019). There are a number of water quality indices which are employed in assessing water quality around the world (Gupta and Gupta, 2021). The most common indices include Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Dinius Water Quality Index (WQI), British Columbia Water Quality Index (BCWQI), National Sanitation Foundation Water Quality Index (NSFWQI) and the Oregon Water Quality Index (OWQI) (Olasoji *et al.,* 2019; Chidiac *et al.,* 2023). The WQI is one of the most effective tools for the communication of information regarding the quality of water to citizens and policymakers (Alum *et al.,* 2021). The importance of monitoring and assessing the quality of surface water bodies cannot be overemphasized. Edo state features a wide range of anthropogenic activities and attendant occurrences such as improper waste disposal, agricultural runoff, industrialisation and urbanisation (Beshiru *et al.,* 2019). All of these are key drivers that affect the quality of surface water in the state. These activities are the source of myriads of pollutants including organic matter, heavy metals, nutrients and pathogens, which potentially decrease the quality of water and pose health risks to humans and aquatic life (Ogbeifun *et al.,* 2019; Ighalo and Adeniyi, 2020). For this reason, a thorough understanding of the physicochemical properties and water quality status of surface water bodies in Edo State is essential for developing effective management strategies and ensuring the sustainable use of these aquatic resources. A number of studies on surface water quality assessment in Nigeria have been documented. Some of the water bodies which have been assessed for WQI in previous investigations include Kontagora Reservoir (Ibrahim *et al*., 2009), Niger Delta Stream (Etim *et al*., 2013), Iguedo River (Udebuana *et al.,* 2014), Ikhueniro and Okhuahue Rivers (Omorogieva *et al*., 2016), Siluko River (Oboh and Agbala, 2017), Saba River (Yusuf *et al*., 2017), Okhaihue River (Egun and Ogiesoba-Eguakun, 2018), Sagbama Creek (Iyam *et al.,* 2019) and Usuma Dam (Ogbodo *et al.,* 2020). However, despite the wide coverage of studies assessing water quality of surface water sources, Edo State lacks research which covers multiple surface water bodies at the same time. Hence, this study aims to assess the physicochemical limnology and water quality of ten surface water bodies in Edo State, Nigeria to, determine their suitability for drinking, provide information on water quality status to the concerned public as well as providing baseline information that can be used as reference for further studies.

MATERIALS AND METHODS

Study Area: The study area encompasses Benin City, Edo state, situated in southern Nigeria. Benin City is located between latitude 06°19' 00" N to 6°21' 00" N and longitude 5°34' 00" E to 5°44' 00" E. It is situated approximately 40 kilometers (25 mi) north of the Benin River and 320 kilometers (200 mi) by road east of Lagos. The Benin region is underlain by sedimentary formation of the South Sedimentary Basin (Ikhile, 2016). It is located in the humid tropical rainforest belt of Nigeria with two major seasons, the rainy season which begins in March/April and ends in October/November, while the dry season begins in November/December and ends in February/March. Rainfalls are of high intensity and usually with double maxima. The city also experiences a dry spell in August which last for about 2 - 3 weeks and a windy harmattan period during December /January. A total of ten rivers spanning five local government areas (Ovia North East, Ovia South West, Egor, Ikpoba Okha and Oredo) were assessed in this study. They include Ovia River, Ugbogor River, Igue-Edo River, Usen-Ada River, Eruvbi River (Iguosa), Ugonoba River, Okhuaihe River, Ikpoba River, Ikpe River and Ogba River as shown in figure 1.

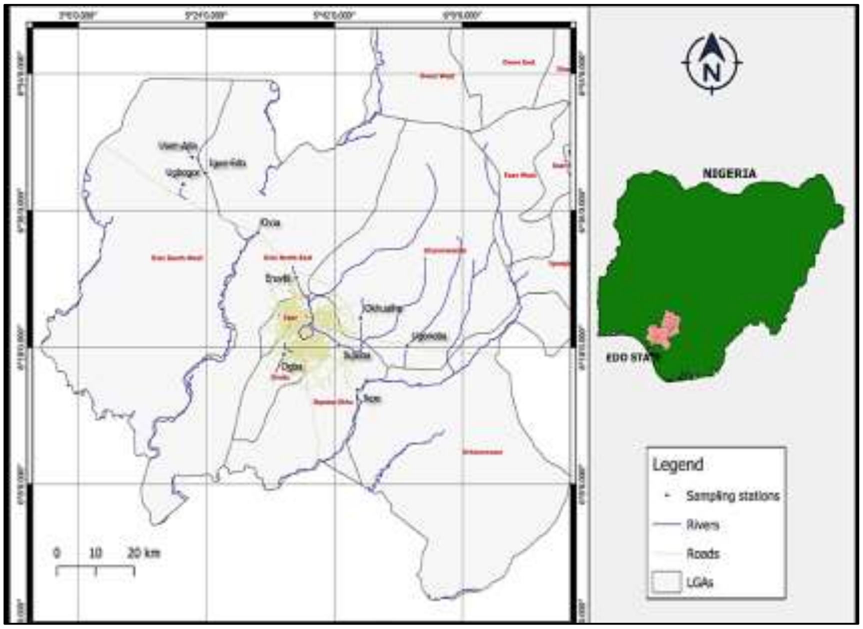

Fig. 1: Map of the study area showing the sampled rivers

Sample Collection and Preparation: Sampling was carried out across the ten rivers in October, 2020. Water samples were collected for both physical and chemical analysis. Water samples were obtained from the subsurface of the rivers into pre-washed sample containers which were rinsed with tap water and the river water sample prior to collection. Water samples for dissolved oxygen (DO) and biological oxygen demand (BOD) were collected in 100 mL oxygen bottles. Dissolved oxygen (DO) the samples were fixed immediately by adding one mL of Winkler A and Winkler B solution respectively while the same was done for the BOD sample after 5 days of incubation in the dark. All samples were properly labelled and were subsequently transferred to the Limnology Laboratory of Plant Biology and Biotechnology department in the University of Benin for analysis.

Physicochemical Analysis: The water samples were analysed for the physicochemical parameters including temperature, turbidity, colour, conductivity, total dissolved solids, pH, total hardness, total alkalinity, dissolved oxygen, biochemical oxygen demand, magnesium, calcium, phosphate, nitrate and sulphate. The temperature and pH of the samples were assessed *in situ* with the aid of a mercury-in-glass thermometer and a HANNAH field pH meter respectively. Turbidity and colour were determined using a HACH DR 2000 spectrophotometer while total dissolved solids and conductivity were measured using a HACH CO 150 TDS/Conductivity meter. Azide modification of Winkler technique was used for the determination of DO and BOD as outlined in APHA (2005). Total alkalinity was estimated by titrimetric method (APHA, 2005) using methyl orange as indicator and 0.02N H_2SO_4 as titrant while phosphate, sulphate and nitrate were estimated by the methods of PhosVer 3 phosphate powder pillows, SulfaVer 4 powder pillows and NitraVer 5 powder pillows respectively, using a HACH DR 2000 spectrophotometer. Total hardness, calcium and magnesium were estimated titrimetrically by the EDTA (Ethylenediaminetetraacetic acid) method with the aid of a HACH digital titrator.

Water Quality Index (WQI): In this study, eleven important physicochemical parameters were selected for the calculation of water quality index. The WQI was computed by using standards of drinking water quality as recommended by WHO (2011) and ICMR (1975). The Weighted Arithmetic Index method by Brown *et al.* (1972) was used for computation of WQI in this study as shown in the equation (1)

$$WQI = \sum W_i Q_i \quad (1)$$

Where W_i = Weightage of the ith parameter; Qi = Sub index of the ith parameter; $\sum$ = Summation
Furthermore, the Weightage was calculated using the expression:

$$W_i = wi/(\sum wi) \quad (2)$$

Where W_i = Weightage of the ith parameter; w_i = Unit weightage of the ith parameter; $\sum$ = Summation

The unit weightage (w) was calculated by a value inversely proportional to the recommended standard value S_i of the corresponding parameter.

$$w_i = K/(S_i) \quad (3)$$

Where w_i = Unit weightage of the ith parameter; S_i = Recommended standard permissible value for the ith parameter; K = Proportionality constant

The constant K was calculated by the expression:

$$K = 1/\sum\left(\frac{1}{Si}\right) \quad (4)$$

Further, the quality rating or sub-index (Q_i) was calculated using the following mathematical expression:

$$Q_i = 100 \times \frac{[(Vi-Vo)]}{[(Si-Vo)]} \quad (5)$$

Where Q_i = Sub index or quality rating of the ith parameter; V_i = Measured value of the ith parameter at a given water sampling station; V_o = Ideal value of the ith parameter in pure water; S_i = Recommended standard permissible value for the ith parameter

All the ideal values (V_o) are taken as zero for drinking water except for pH which is = 7.0 and dissolved oxygen which is = 14.6 mg/L (Tripaty and Sahu, 2005).

Table 1: Water quality index and water quality status as per WAWQI method

Water Quality Index Level	Water Quality Status
0 – 25	Excellent water quality
26 – 50	Good water quality
51 – 75	Poor water quality
76 – 100	Very poor water quality
> 100	Unsuitable for drinking

RESULTS AND DISCUSSION

Physicochemical parameters: Spatial variation in the physicochemical parameters of the studied rivers is as shown in table 2. In this study, air temperature ranged from 26^0C to 30^0C while water temperature ranged from 25^0C to 28^0C both of which are within the permissible limit (<40^oC) established by WHO (2008). The air temperature was generally higher than the corresponding water temperature for the same river with the exception of Igue-Edo River and this is invariably linked to the fact that the specific heat capacity of water is greater than that of air which means that much heat is required to raise the temperature of a given volume of water as opposed to that of air. The air temperature measurement recorded in this study is in agreement with the results of Nwonumara (2018) who also recorded an air temperature range of 26^0C to 39.6^0C for Idumayo River in Ebonyi State. Turbidity values for all the selected water bodies exceeded the standard of 5.0 NTU set by WHO (2008) and SON (2007) with the exception of Okhuaihe River which recorded mean turbidity value of 3.5±0.28 NTU. The highest turbidity value of 23.0±1.73 NTU was recorded at Eruvbi River and this is connected to the fact that the river receives a large influx of effluent from a nearby bottling company together with a large number of runoff from the surrounding hinterland as the river is situated downslope. The turbidity values obtained in this study were in congruence with the results of Singh and Sharma (2016) who conducted a similar study on the physicochemical parameters of Baldi River in India and reported turbidity values ranging from 2 NTU – 115 NTU.

The colour units obtained in this study ranged from 0.5 PtCoU to 5.5 PtCoU. The high colour unit observed at Ikpe River may be attributed to decaying organic matter and inorganic matter around the river. In all the sampled rivers the colour unit was far below the recommended standard of 15.0 PtCoU. The TDS values fluctuated between 11.0±0.57 mg/L to 75.5±0.28 mg/L which fell within the 500mg/L permissible limit for TDS established for drinking water by WHO (2006) and USEPA (2002). This is in conformity with the results of Ogbodo *et al*. (2020) for the ower Usuma Dam but is at variance with the results of Gebreyohannes *et al*. (2015) for river Elala in Ethiopia, Oboh and Agbala (2017) for Siluko River in Edo state, Nigeria and Kodom *et al*. (2018) for Volta Lake in Ghana. Electrical conductivity measures of the ability of a solution to carry or conduct an electrical current is positively correlated to the amount of dissolved solids in the water. In this research values obtained for this parameter ranged from a minimum of 21.0±0.58 µS/cm to a maximum of 152.5±1.44µS/cm. The maximum value was recorded at Ovia which also had the highest value for total dissolved solids thus corroborating the linkage between electrical conductivity and the concentration of dissolved solids. Range of values obtained in this study were generally lower than 295 µS/cm – 426.9 µS/cm range reported by Sharifinia *et al*. (2019) for Zarivar lake in Iran, and falls within the range of 76.2µS/cm – 124.09µS/cm reported by Kodom *et al*. (2018) for Volta lake in Ghana. In general, the values fell within the 750 µS/cm permissible limit for electrical conductivity established for drinking water by WHO (2008). Expectedly, electrical conductivity and TDS followed a similar spatial trend in this present study, and this is because these parameters are directly related.

pH is one of the most important parameters of water quality and it measures the acidity or basicity of a solution. pH values recorded in this study ranged from 5.52 – 7.06. Most of the rivers were outside the permissible range of 6.5 – 8.5 recommended by WHO (2008) except for Ugbogor and Ovia rivers which had a value of 6.66 and 7.06 respectively. The low pH in most of the sampled rivers is indicative of the presence of weakly ionizing acids, a high level of CO_2 and oligotrophic water body. More so, the decomposition of accumulated organic matter such as leaf litter is also contributive to the low pH recorded at these sites. Decomposition of organic matter by microbial oxidation release CO_2 and other products such as amino acid which ultimately results to lower pH. The range of values obtained in this study were generally lower than 7.28 – 8.35 reported by Sharifinia *et al*. (2019) for Zarivar lake in Iran, and falls within the range of 5.53 – 5.75 reported by Udebuana *et al*. (2014) for Igue-Edo River in Edo state.

Dissolved oxygen (DO) which is a measure of how much oxygen is dissolved in water is considered to be one of the most important parameters of water quality in aquatic ecosystems. Dissolved oxygen values obtained in this research ranged from 5.76 mg/L to 8.92 mg/L. In contrast, lower DO values were described for other rivers in Edo State including Eruvbi River (3.18 mg/L – 3.27 mg/L), Siluko River (4.35 mg/L – 4.82 mg/L) and downstream portion of Ikpoba River (1.84 mg/L – 5.22 mg/L) reported by Ogbeibu and Edutie (2002); Imoobe and Koye (2011) and Oboh and Agbala (2017) respectively. The low level of DO recorded at Ugbogor could be as a result of reduced water movement which consequently reduces aeration and also as a result of lots of organic matter on the surface of the river, decomposition of which by microorganism consumes lots of dissolved oxygen. Overall, DO values in this study were more or less within the 4 – 8mg/L range stipulated in WHO (2018) aggregated from their global overview of national regulations an standards for drinking water quality.

Biochemical Oxygen Demand (BOD) a measure of oxygen needed by aerobic decomposers for the breakdown of organic materials in water (Mezgebe *et al*., 2015). This demand for oxygen is directly proportional to increasing input of organic wastes in water. BOD values recorded in this research ranged from 3.12 mg/L at Ikpe River to 6.87 mg/L at Ovia River. According to the ranking of Moore and Moore (1976), BOD < 1.0 mg/L are considered clean, 1 – 2 mg/L fairly clean, 5.0 mg/L doubtful and 10 mg/L definitely bad and polluted. On the basis of this ranking, a good number of the sampled rivers were found to be polluted. Although no direct health implication on man exists for BOD, it is an important indicator of overall water quality (IEPA, 2001). High BOD levels found at Ovia River could be ascribed to the presence of lots of leaf litter on the surface of the river, which requires lots of oxygen for its decomposition by aerobic decomposers thus creating increased demand for dissolved oxygen and consequently a higher BOD level. The findings of this study is similar to the work of Yusuf *et al*. (2017) who reported high BOD range of 6.43 mg/L – 6.73mg/L for Saba river in Osun State, but contrary to the work of Ekhator *et al.* (2015) who reported low BOD range of 1.66 mg/L – 3.71 mg/L for Osse river in Edo State and Enuneku *et al*. (2017) who also reported a range of 1.23 mg/L – 1.93 mg/L for Obueyinomo River in Edo State. The variation in BOD values in this study may be as a result of site specific conditions.

The alkalinity of water is its acid-neutralizing capacity, comprised of the total of all titratable bases (APHA, 2005) and is mainly caused by the presence of hydroxide ions (OH^-), bicarbonate ions (HCO_3^-), and carbonate ions (CO_3^{2-}), or a mixture of two of these ions in water. In this present study, alkalinity fluctuated between 25.0±1.73 mg/L at Ugonoba River to 106.5±0.87 mg/L at Ovia River. The high value recorded at Ovia River is an indication that the water has a high acid buffering capacity and as such the river may be less sensitive to acidic inputs. This is substantiated by the pH measurements which fall within the alkaline range.

The capacity of water to precipitate insoluble calcium and magnesium salts of higher fatty acids from soap solutions is referred as the hardness and the two main cations that cause hardness are magnesium (Mg^{2+}) and calcium (Ca^{2+}) Harharan and Kayani (2014).The majority of water's hardness and capacity to create scale is caused by these ions. The total hardness values of this present research varied from 3.0 to 40.8 $CaCO_3$mg/L. Though there is no set guideline value as per WHO, The total hardness values obtained here did not surpass the 100 – 1000 $CaCO_3$mg/L stipulated in WHO (2018) for drinking water based on the regulatory requirements of 57 out of 104 countries/territories with set guideline values.

The concentration of calcium and magnesium ion in this study ranged from 0.18 – 7.40 mg/L and 0.15 – 2.77 mg/L respectively. This negates the findings of Udebuana *et al*. (2014) who reported lower values ranging from 0.12 – 0.2 mg/L and 0.23 – 0.32 mg/L for calcium and magnesium respectively for Iguedo River in Edo State and the findings of Ekhator *et al*. (2015) who reported a higher value of calcium and magnesium for Osse River in Edo State. This variation could be attributed to the geomorphology of the area and other site specific conditions. Generally, the calcium and magnesium ion levels fell below the maximum permissible limit of WHO. Furthermore, the concentration of calcium was higher than that of magnesium in this study and thus accounted for more of the total hardness recorded in this study. This is easily comprehendible bearing in mind that calcium is found in the earth's crust in much higher amounts compared to magnesium - 3.63% for calcium and 2.09% for magnesium (Helmenstine, 2020).

Phosphorus is often the most limiting nutrient for algal development in many aquatic ecosystems, and it is measured in the dissolved form. Phosphate, along with other nutrients such as nitrate, is the primary contributor to water quality degradation caused by the creation of algal blooms, which leads to eutrophication. Phosphate concentrations in this research fluctuated between 0.05 mg/L and 0.49 mg/L. This range is much lower than that reported by Egun and Ogiesoba-Eguakun (2018) for Okhuaihe River. Among the rivers sampled, none exceeded the permissible value of 1 mg/L for drinking water quality as per by WHO (1999) but were above the 0.1mg/L acceptable limit with the exception of Igue Edo River.

Sulphate concentration in was found to be between 6 mg/L – 24.5 mg/L. This fell outside the range of 0.01 mg/L to 7.24 mg/L reported by Etim *et al.* (2013) for stream water in Nigeria's Niger Delta region. The relatively high concentration of sulphate observed at Okhuaihe River in this study is far higher than the maximum value of 1.05 mg/L reported for the same river by Egun and Ogiesoba-Eguakun (2018). This could be ascribed notably to the laundry activities observed at the site as at the time of sample collection since sodium sulphate is an important ingredient in the production of detergents. Similar activities were also observed at Ikpe River where mean sulphate concentration of 23.0±0.05mg/L was recorded and this could be attributed partly to laundry activities and may also be due to leaching of natural deposits of sodium or magnesium sulphate (Davis and David, 2008). Overall, the sulphate concentrations of the selected rivers in this study were below the 250mg/L maximum permissible limit as per WHO (2008). Nitrogen is one of the limiting macronutrients and is essential in water quality assessment. The concentration of nitrate in water indicates the amount of this macronutrient in water bodies and the ability to support plant growth. Nitrate concentrations recorded in this research varied between 0.20 mg/L to 2.60 mg/L. Concentrations obtained in this research were at variance with those reported by Ekhator *et al.* (2015) for Osse River in Edo State, but was in consonance with the 0.96 mg/L – 1.44 mg/L range of nitrate reported by Enuneku *et al.* (2017) for Obueyinomo River in Edo State. Generally, the value of nitrate recorded in this study fell below the 45 mg/L maximum permissible limit as stipulated in WHO (2008).

Table 2: Physicochemical Parameters of the Sampled Rivers (Mean ±.S.E.)

Parameters	Eruvbi	Igue-Edo	Ikpe	Ikpoba	Ogba	Okhuaihe	Ovia	Ugbogor	Ugonoba	Usen-ada
AT (^OC)	29.5±0.29	27±0.58	29.5±0.29	29.0±0.58	30.0±0.00	29.0±0.57	28.0±1.15	28.5±0.29	28.0±0.00	28.0±0.00
WT (^OC)	28.0±0.00	28.0±0.00	26.5±0.29	26.5±0.29	27.5±0.29	26.50.29	25.5±0.9	26.0±0.00	26.5±0.29	26.5±0.00
Turbidity (NTU)	23.0±1.73	5.5±0.87	19.5±0.28	14.5±0.87	10.0±0.58	3.5±0.28	5.5±0.28	10.5±0.29	7.0±0.57	7.5±0.0.28
Colour (PtCoU)	1.5±0.28	1.0±0.00	5.5±0.29	2.0±0.58	1.5±0.29	4.5±0.29	2.5±0.29	3.5±0.29	1.0±0.00	1.0±0.00
TDS (mg/L)	45.5±0.28	31.0±1.73	14.0±0.57	28.0±0.58	45.5±2.02	11.0±0.58	75.5±0.28	38.5±0.28	11.0±0.57	57.0±1.15
Cond. (µS/cm)	92.0±1.15	68.0±1.15	30.0±2.89	56.5±0.87	98.0±1.73	21.0±0.58	152.5±1.44	81.5±0.87	21.0±0.58	118±3.46
pH	6.03±0.02	6.04±0.04	5.52±0.03	5.92±0.02	5.56±0.05	5.58±0.01	7.06±0.05	6.66±0.10	5.83±0.04	6.46±0.05
DO (mg/L)	8.66±2.11	8.40±1.96	7.64±0.21	8.82±2.21	8.92±1.69	8.82±2.43	8.90±2.25	5.76±0.32	6.36±0.21	8.76±2.78
BOD (mg/L)	6.75±0.49	5.91±0.11	3.12±0.05	5.52±0.15	4.40±0.23	5.42±0.08	6.87±0.44	3.43±0.13	4.65±0.55	5.88±0.07
TA (mg/L)	70.0±5.77	60.0±2.88	43.5±2.02	35.0±2.31	50.0±2.89	40.0±4.04	106.5±0.87	45.0±2.88	25.0±1.73	65.0±2.30
TH ($CaCO_3$mg/L)	3.0±1.15	8.4±0.23	3.1±1.09	3.2±0.46	16.2±2.19	8.5±2.59	36.2±2.19	11.2±0.69	7.2±1.62	40.8±5.31
Ca (CO_3mg/L)	0.18±0.01	1.49±0.03	0.34±0.01	0.67±0.01	3.10±0.06	0.98±0.01	5.86±0.49	3.39±0.17	0.88±0.04	7.40±0.34
Mg ($CaCO_3$mg/L)	0.15±0.00	1.23±0.03	0.13±0.02	0.23±0.01	1.20±0.07	0.36±0.02	2.77±0.60	1.04±0.15	0.60±0.00	2.43±0.23
Phosphate (mg/L)	0.17±0.01	0.05±0.01	0.48±0.06	0.13±0.02	0.49±0.06	0.27±0.02	0.12±0.02	0.32±0.03	0.35±0.03	0.49±0.01
Sulphate (mg/L)	6.0±0.58	14.0±0.57	23.0±0.50	16.0±1.15	12.0±0.58	24.5±0.29	14.5±1.44	10.0±0.57	9.5±0.87	20.0±1.15
Nitrate (mg/L)	1.25±0.03	2.60±0.06	0.9±0.06	0.55±0.09	1.05±0.03	1.90±0.06	0.20±0.05	0.25±0.03	2.05±0.03	0.75±0.03

Where TA = Total Alkalinity; TH = Total Hardness; WT = Water temperature; AT = Air temperature; Cond. = Conductivity

Water Quality Index (WQI): Water quality index score is as illustrated in table 3. The values obtained ranged from 59.32 – 79.72. From the result, most of the sampled rivers with the exception of Igue-Edo, Ugonoba, Okhuaihe and Eruvbi fell between the 51 – 75 water quality index level corresponding to poor water quality or a grade C water quality which connote water suitable for irrigation and industrial use but not suitable for drinking. The water quality index scores were higher at Eruvbi River> Okhuaihe River>

Ugonoba River > Igue-Edo River and fell within the of 76 – 100 range of water quality index level corresponding to very poor water quality or a grade D water suitable for only irrigation and not for drinking. The reason for the higher water quality index scores and consequently a poorer water quality status is invariably linked to the disparity between the measured value of BOD, DO and pH obtained for this river and the ideal value of those parameters in pure water. This is quite understandable due to the high weightage assigned to these parameters as per the weighted arithmetic water quality index method. Also, Eruvbi River which recorded the highest WQI score is a recipient of industrial effluents from a nearby carbonated drink-producing industry. The water quality results obtained in this study are in conformity with the 55.05 – 84.94 range reported by Etim *et al*. (2013) for stream water samples in the Niger Delta region of Nigeria.

Table 3: Water Quality Index (WQI) of the sampled rivers

Rivers	WQI Score	Grade	Water Quality Status	Possible Usage
Eruvbi	79.72	D	Very poor water quality	Irrigation
Igue-Edo	75.24	D	Very Poor water quality	Irrigation
Ikpe	65.64	C	Poor water quality	Irrigation and industrial
Ikpoba	72.10	C	Poor water quality	Irrigation and industrial
Ogba	69.43	C	Poor water quality	Irrigation and industrial
Okhuaihe	76.09	D	Very poor water quality	Irrigation
Ovia	68.88	C	Poor water quality	Irrigation and industrial
Ugbogor	59.32	C	Poor water quality	Irrigation and industrial
Ugonoba	75.97	D	Very Poor water quality	Irrigation
Usen-Ada	68.64	C	Poor water quality	Irrigation and industrial

Conclusion: In conclusion, the water quality assessment of the ten rivers assessed revealed that all the rivers were unfit for drinking unless without prior treatment, but were however suitable for irrigation and industrial use. The analysis of the water quality status using physicochemical parameters further reinstate the significance of WQI in water quality assessment and monitoring. It is recommended that regular water quality assessments and monitoring be carried out to ascertain the quality of water prior to its intended use and to also inform policies geared towards protection of surface water systems. Finally, there should be strict regulations in place to ensure that effluents are pre-treated before being released into the environment and that the discharge of effluent into surface waters complies with recommended standards for effluent discharge. Anthropogenic activities near surface water should be closely monitored to detect any activities that negatively impact water quality.

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