Water Quality and Trophic State of Two Rivers in Edo State

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Abstract: ***The water quality and trophic state of Ovbioti and Owan Rivers in Owan West, Edo State, Nigeria was studied to determine their suitability for drinking and aquaculture. Water samples were collected from two sites in each river monthly from March to June 2015. Water level, air temperature, water temperature, pH, total dissolved solids (TDS), conductivity, total alkalinity, chloride, free carbon dioxide, dissolved oxygen, biochemical oxygen demand, total hardness, calcium, magnesium and phosphate were determined using standard methods. Chlorophyll a was extracted with acetone and determined with spectrophotometry. Carlson's trophic state index (CTSI) model for productivity was employed in the assessment of trophic state of the rivers. With the exception of magnesium, values of the physicochemical parameters did not exceed permissible limits for drinking water quality and tropical aquaculture. There was significant difference ($p<0.05$) in water level, water temperature, TDS, conductivity, dissolved oxygen and total hardness of the two rivers. CTSI based on chlorophyll a determination indicated oligotrophic state (low productivity) of the rivers. The CTSI ranged from 28.41-31.53. This implied low nutrient and poor ionic conditions of the rivers. Nutrients enrichment is required to increase primary production in the rivers in order to improve their fish production.***

Keywords: Physicochemical parameters, Oligotrophic, Carlson's index

1. Introduction

Rivers are fresh waters flowing in a definite course or channel, carrying the one way flow of dissolved and particulate matter from both natural and anthropogenic sources [1], [2]. Rivers may be influenced by a wide range of activities such as commercial leisure, entry of nutrients from agriculture/aquaculture and forestry, and discharge of wastes from industries [3], [4]. These activities can contaminate rivers and alter their water quality [5]. In rural areas in Nigeria with limited access to potable water, rivers are sources of drinking water, laundry, fisheries and other purposes [6]. Due to impact of human activities, rivers are prone to changes in their physicochemical and biological conditions [7]. The deleterious impacts of municipal, industrial and agricultural wastes on receiving rivers in Nigeria threatening environmental sustainability have been reported [2], [8].

Trophic state is the rate of autotrophic or heterotrophic production processes in an ecosystem [9]. Unlike lake trophic state which has been extensively studied [9], defining trophic state in rivers or streams may be more difficult because many river or stream food webs are dominated by carbon inputs from land. Dodds and Smith [10] concluded that stream benthic chlorophyll is significantly correlated to both total nitrogen (N) and total phosphorus (P) in water column because both heterotrophic and autotrophic processes are influenced by the availability of N and P. Dodds [11] divided stream trophic state into autotrophic (relative amount of whole system primary production) and heterotrophic (relative amount of whole system respiration) processes. Rivers are likely to be more dominated by heterotrophic processes because they have more links to terrestrial systems as organic carbon source [9]. Trophic state is important because biotic communities in the aquatic environment rely upon carbon supply to fuel food webs and maintain the organisms that live in them.

On the basis of trophic state, rivers can be classified as oligotrophic, mesotrophic, eutrophic and hypereutrophic [1], [12]. Each category represents the stage of eutrophication which a water body is experiencing at a particular time [11]. Trophic state index (TSI) is a scale of 1-100 used to indicate the relative trophic state of a water body [13]. Measurement of Chlorophyll a can be used in trophic state assessment [14]. Chlorophyll a values are used in the determination of phytoplankton biomass.

Owan West in Edo state, Nigeria, is renowned for production in aquaculture because of the existence of numerous large rivers. Because potable water supply is lacking in the area the inhabitants also rely on river water for drinking and other domestic purposes. Limited information is available on physicochemical conditions and trophic state of rivers in Edo State [15], and no published information is available for rivers in Owan West. The aim of this study was to determine the physicochemical water quality and trophic state of some rivers in Owan West in order to assess the suitability of the river water for drinking and aquaculture.

2. Materials and Methods

2.1. Study area

The study was conducted between March and June 2015 in two rivers (Ovbioti and Owan) at Uhonmora, Owan West, Edo State, Nigeria. Owan West lies on Latitude 6.9279^{o} N and Longitude 5.8565^{o} E of the Greenwich Meridian. Ovbioti River has its source from Auchi and flows through Sabongida-Ora town in Owan West, Edo state in southern Nigeria. Owan River is a municipal river flowing across two Local Government Areas (Owan East and Owan West). The river takes its source from Otuo (Owan East) and flows southward through major towns like Afuze, Ogute, Uzebba, to join Ule River in Sabongida Ora (Owan West), empting into River Osse in Edo State. Owan West has a tropical climate characterized by two main seasons, wet (April to October) and dry (November to March) seasons. Both rivers are major sources of water for drinking, cooking, and washing, bathing, processing of agro-products, swimming and aquaculture.

2.2. Sampling

Water samples for determination of physicochemical parameters were collected from each river monthly from March to June 2015, between 0800 - 1100 hours, using pre-cleaned labeled plastic bottles and 250 ml glass bottles in triplicates. In the field, the bottles were rinsed with the river water before collection. While some physicochemical parameters were measured directly in the field, the water samples for other parameters were taken to the laboratory for their determination.

2.3. Measurement of physicochemical parameters

In situ measurement of water level, water temperature, pH, total dissolved solids (TDS), and conductivity was carried out. Temperature was measured using mercury-in-glass thermometer; water level, using a graduated pole and a tape while pH, TDS and conductivity were measured with portable pH, TDS and conductivity meters (HANNA Instrument, H196107), respectively. In the laboratory, other parameters were determined using standard methods and procedures described by Radojevic and Bashkin [16] and APHA [17]. Total alkalinity, chloride, free carbon dioxide (CO_2), dissolved oxygen (DO), biochemical oxygen demand (BOD), total hardness, calcium and magnesium were titrimetrically determined. Phosphate was determined using a spectrophotometer (Jenway, UK) at a wave length of 470 nm.

2.4. Determination of trophic state

Trophic state of the rivers was determined with chlorophyll a according to Carlson's model.

Chlorophyll a, a characteristic algal pigment constitutes approximately 1% to 2% (dry weight) of planktonic algal biomass, making it a good indicator of algal biomass [18]. Chlorophyll a was determined using the acetone trichromatic method. Water samples were collected using 1-litre plastic bottles from each river and wrapped immediately with black polythene material to prevent photochemical breakdown of the chlorophyll. Samples were transported in iced box to prevent deterioration. In the laboratory, 50 ml of sample was filtered through a 5 µm membrane filter and vacuum was applied until the sample was dry.0.2 ml of $MgCO_3$ (magnesium carbonate) suspension was added during the final phase of the filtration to prevent phytophytinization. The filter was folded into quarters and placed in a centrifuge tube.10 ml of aqueous acetone was added, covered and placed in a dark box for extraction for 24 h. The clear extract was transferred to a 1 cm cell, using the multi-wavelength mode on the 6715 UV/visible spectrophotometer. The absorbance was measured at 630, 645, and 665 nm for chlorophyll a, b and c, respectively.

Parsons and Strickland's equation [19] was used to extrapolate chlorophyll a as follows:

$$\text{Chla } (\mu g/l) = (11.6D_{665} - 1.31D_{645} - 0.14D_{630})\ vl^{-1}v^{-1}$$

Where Chla, chlorophyll a
V, volume of acetone used (ml)
l, path length of cuvette (cm)
V^{-1}, volume of water filtered for extraction (l).
The values were then substituted in Carlson's equation (TSI – C = 9.81 In (Chla) + 30.6). Where TSI, trophic state index

2.5. Quality assurance and statistical analysis

To achieve validation of data, collected samples and data were replicated (triplicates). The mean and standard deviation of each array of data were computed to determine reproducibility and accuracy of data. Statistical analysis was done using the GraphPad Prism software (version 5.0) Student's t-test was computed to compare the means of data sets.

3. Results

3.1. Physicochemical conditions of rivers

Values of measured physicochemical parameters of the two rivers are presented in Table 1.

Water level

Water level varied in Ovbioti and Owan Rivers, ranging from 29.8-35.0m (Figure 1) with significant difference ($p<0.05$) in mean values.

Air Temperature

Air temperature in Ovbioti River ranged from 29.80-32.50 ^{o}C, with a mean value, 31.15 ^{o}C. In Owan River, it ranged from 30.60-32.00 ^{o}C, with a mean value, 31.37 ^{o}C. There was no significant difference ($p>0.05$) between the air temperatures of both rivers (Table 1).

Water temperature

Narrow fluctuation was recorded in the water temperature of both rivers which varied between 26.0 and 29.9^{o}C (Table 1). Generally, the temperature of Ovbioti River was lower than that of Owan River (Figure 2) with significant difference in mean values ($p<0.05$).

pH

The pH condition of both rivers was slightly alkaline with values ranging from 7.2- 8.0 (Figure 3). There was no significant difference ($p>0.05$) in mean pH values of the rivers.

TDS

TDS values ranged from 10-15mg/l for Ovbioti River and 11-15mg/l for Owan River (Figure 4) with significant difference in mean values ($p<0.05$). Monthly variation showed increasing trend with increased rainfall.

Conductivity

Conductivity increased with rainfall for both rivers with values between 25 and 32 µS/cm for Ovbioti River, and 30 and 38 µS/cm for Owan River (Figure 5). The mean values were statistically significant ($p<0.05$).

Total alkalinity

Total alkalinity in both rivers ranged from 10-34 mg/l (Figure 6). The highest value (34 mg/l) was measured in Owan River. However, mean values for both rivers showed no significant difference ($p>0.05$).

Chloride

Measured values of chloride in both rivers ranged from 5-13 mg/l with no significant difference in mean levels ($p>0.05$). Chloride increased with increasing rainfall, and the highest values measured in both rivers were in June (Figure 7).

Free CO_2

The free CO_2 in Ovbioti River showed slight variation during the months of study while irregular fluctuation was observed in Owan River (Figure 8). However, the mean values of free $CO_2$for both rivers were not significant ($p>0.05$).

Dissolved oxygen

Dissolved oxygen in both rivers was between 3.5 and 7.0 mg/l (Figure 9). The mean value of dissolved oxygen in Ovbioti River was significantly higher ($p<0.05$) than that of Owan River.

BOD

BOD values in both rivers which ranged from 0.0-0.2 mg/l were low (Figure 10). There was no significant difference ($p>0.05$) in BOD values for both rivers.

Total hardness

Both rivers had soft water condition with total hardness values ranging from 6-22mg/l (Figure 11). Mean values showed significant difference ($p<0.05$). Total hardness increased with rainfall, particularly in both rivers except in May for Ovbioti River.

Calcium

Calcium values were low. They ranged from 0.20-0.52 mg/l (Figure 12). Difference in mean values for both rivers was significant ($p<0.05$).

Magnesium

Magnesium levels (1.34-5.23 mg/l) which increased with rainfall. However, Owan River had a slight reduction in magnesium in May (Figure 13). Mean levels did not show significant difference between the rivers ($p>0.05$).

Phosphate

Phosphate level in both rivers ranged from 0.04- 0.21 mg/l (Figure 14) with no significant difference in mean values ($p>0.05$).

Table 1: Values of the physicochemical parameters of Ovbioti and Owan Rivers between March and June 2015

Parameters	Ovbioti River			Owan River			tvalue	Significance level
	Mean±SD	Min	Max	Mean±SD	Min.	Max.		
Water level (m)	34.15±1.06	32.80	35.00	30.45±0.76	29.80	31.50	4.54	P<0.05*
Air temperature (^oC)	31.15±1.75	29.80	32.50	31.37±0.67	30.60	32.00	0.23	p>0.05
Water temperature (^oC)	26.52±0.61	26.00	27.40	28.97±0.64	28.50	29.90	2.29	p<0.05*
pH	7.30±0.14	7.20	7.50	7.50±0.34	7.20	8.00	6.82	p>0.05
TDS (mg/l)	12.62±5.57	10.00	15.00	12.75±1.70	11.00	15.00	4.95	p<0.05*
Conductivity (µS/cm)	27.75±3.09	25.00	32.00	33.25±3.40	30.00	38.00	2.31	p<0.05*
Total alkalinity (mg/l)	17.25±4.92	10.00	21.00	23.12±10.53	12.00	34.00	0.32	p>0.05
Chloride (mg/l)	5.75±0.95	5.00	7.00	7.50±3.69	5.00	13.00	0.13	p>0.05
Free CO_2 (mg/l)	1.50±0.57	1.00	2.00	4.00±2.94	1.00	8.00	1.89	p>0.05
DO (mg/l)	6.45±0.58	5.90	7.00	4.20±0.70	3.50	5.10	5.23	p<0.05*
BOD (mg/l)	0.10±0.08	0.00	0.20	0.05±0.04	0.00	0.10	1.36	p>0.05
Total hardness (mg/l)	13.25±6.67	6.00	22.00	13.00±2.44	11.00	16.00	6.82	p<0.05*
Ca hardness (mg/l)	0.62±0.09	0.50	0.70	1.15±0.10	1.00	1.30	6.82	p<0.05*
Mg hardness (mg/l)	12.62±6.87	5.50	21.40	11.85±2.43	9.70	14.80	3.07	p>0.05
Calcium (mg/l)	0.25±0.14	0.20	0.28	0.46±0.05	0.40	0.52	9.00	p<0.05*
Magnesium (mg/l)	3.08±0.06	1.34	5.23	2.88±0.88	2.36	3.61	0.30	p>0.05
Phosphate (mg/l)	0.05±0.03	0.04	0.09	0.10±0.09	0.07	0.21	1.00	p>0.05

*Statistically significant; t, Student's t-test; SD, standard deviation; p, probability; TDS, total dissolved solids; CO_2, carbon dioxide; DO, dissolved oxygen; BOD, biochemical oxygen demand; Ca, calcium; Mg, magnesium.

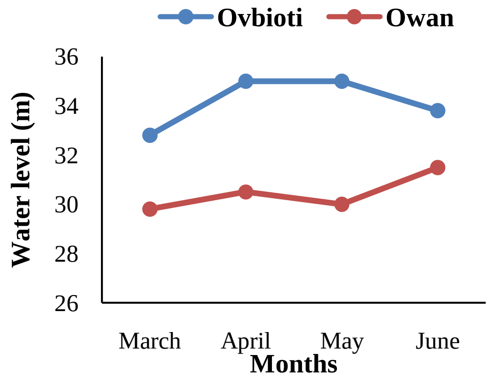

Figure 1: Monthly variation in river water level

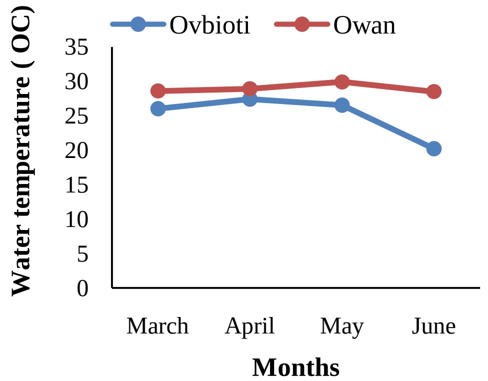

Figure 2: Monthly variation in river temperature

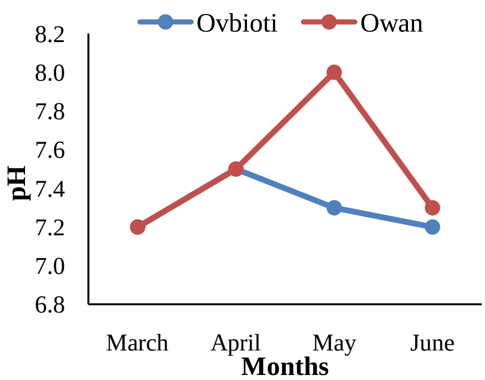

Figure 3: Monthly variation in river water pH

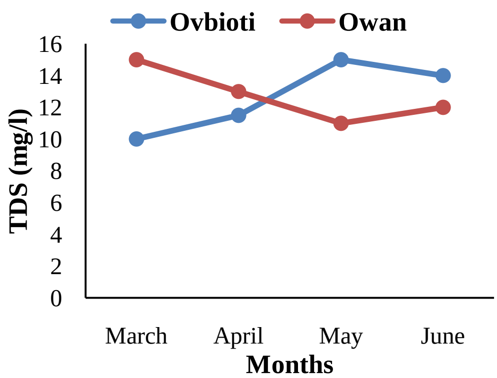

Figure 4: Monthly variation in river TDS (total dissolved solids)

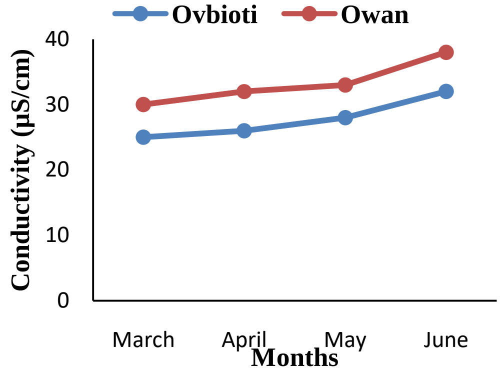

Figure 5: Monthly variation in river water conductivity

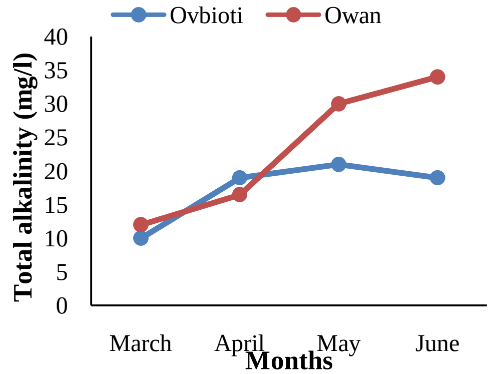

Figure 6: Monthly variation in river total alkalinity

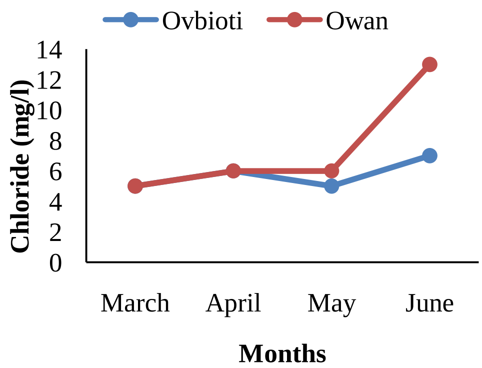

Figure 7: Monthly variation in river water chloride

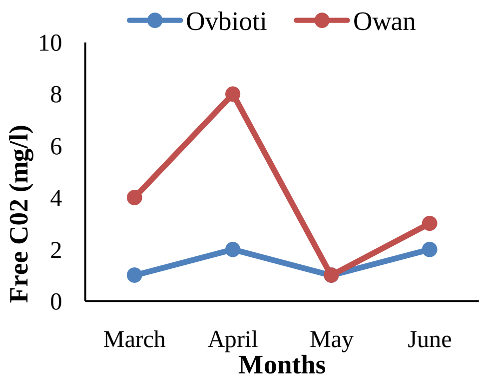

Figure 8: Monthly variation in free CO_2 (carbon dioxide) in river water

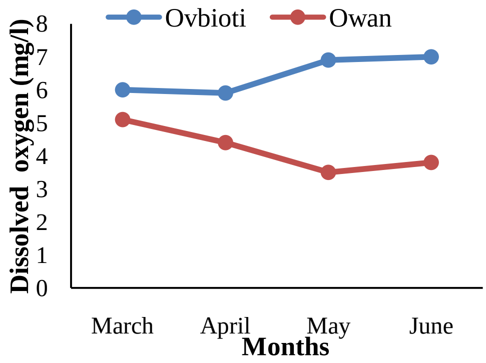

Figure 9: Monthly variation in river dissolved oxygen

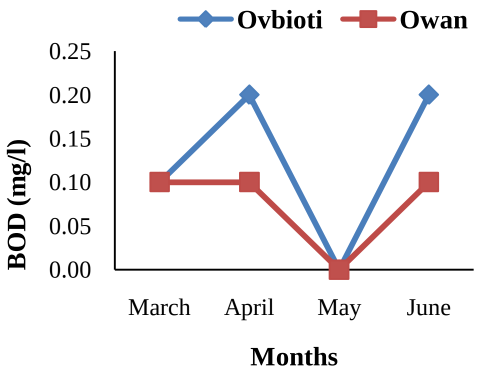

Figure 10: Monthly variation in river BOD (biochemical oxygen demand)

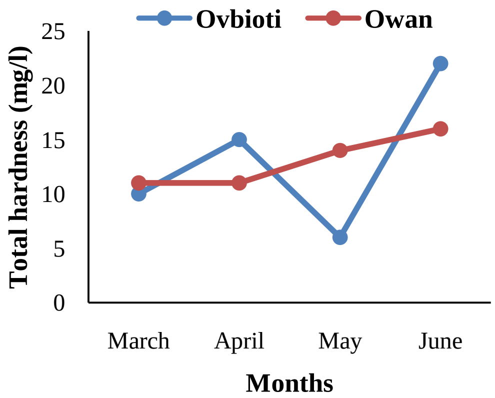

Figure 11: Monthly variation in total hardness of river water

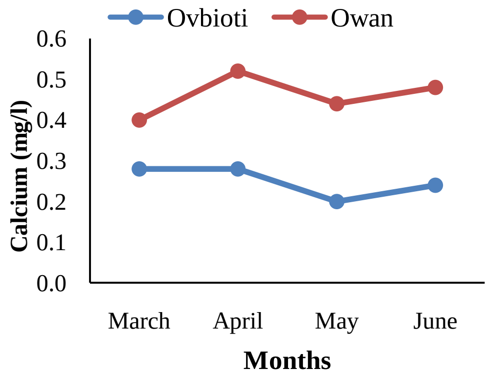

Figure 12: Monthly variation in calcium in river water

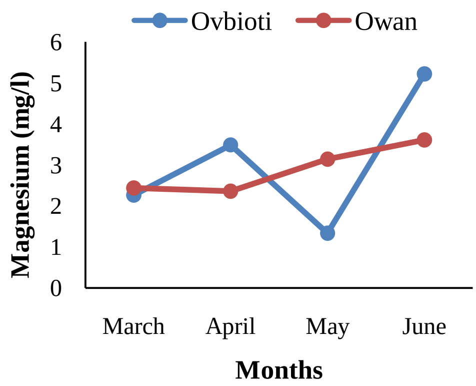

Figure 13: Monthly variation in magnesium in river water

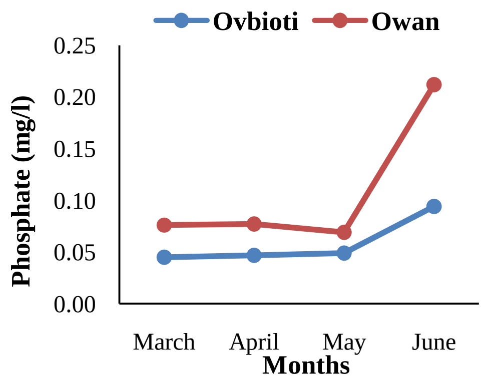

Figure 14: Monthly variation in phosphate in river water

3.2. Trophic state of rivers

Chlorophyll a levels in the rivers ranged from 0.80-1.13 µg/l (Table 2 and Figure 15) and the mean values were not significantly different ($p>0.05$). Chlorophyll b levels in both rivers ranged from 0.10-1.70 µg/l while chlorophyll cvalues were between 0.20 and 3.00 µg/l (Table 2). Carlson's trophic state index **(**CTSI) in Ovbioti River varied between 28.41 and 31.53 (Table 2 and Figure 16). Maximum CTSI value (31.53) in Ovbioti River occurred in May, indicating oligotrophic state which reduced to minimum in June. In Owan River, CTSI ranged from 29.56-30.60 (Table 2 and Figure 16), indicating oligotrophic state throughout the study. Mean values of CTSI for the rivers were not significantly different ($p>0.05$).

Table 2: Trophic state indices of Ovbioti and Owan Rivers between March and June 2015

Parameters	Ovbioti River			Owan River			t value
	Mean±SD	Min.	Max.	Mean±SD	Min.	Max.	
Chlorophyll a (μg/l)	0.93±0.19	0.80	1.20	0.93±0.15	0.80	1.13	0.26
Chlorophyll b (μg/l)	0.63±0.60	0.10	1.40	0.76±0.81	0.20	1.70	0.45
Chlorophyll c (μg/l)	0.33±0.49	0.20	0.30	1.10±1.60	0.20	3.00	1.62
CTSI	29.97±2.21	28.41	31.53	30.08±0.74	29.56	30.60	-0.22

SD, standard deviation; CTSI, Carlson's trophic state index; t, student's t-test (p = 0.05)

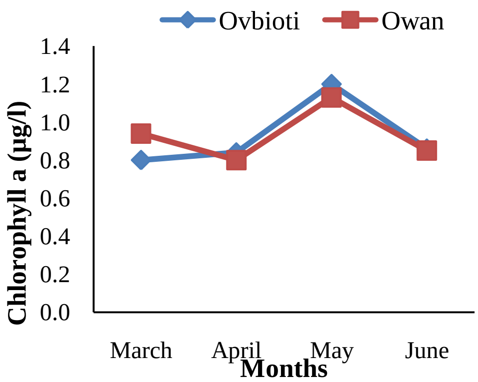

Figure 15: Monthly variation in river chlorophyll a

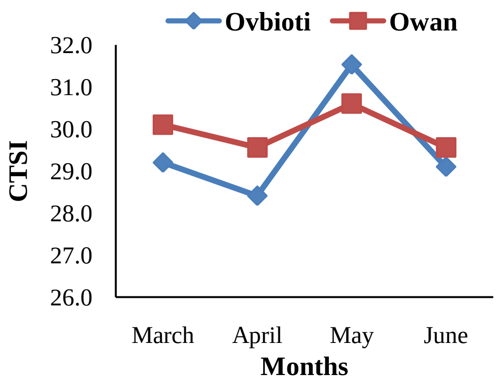

Figure 16: Monthly variation in CTSI in rivers (CTSI, Carlson trophic state index)

4. Discussion

4.1 Physicochemical parameters of rivers

Water level and air temperature measured in this study reflected tropical condition. Regulatory limits for physicochemical parameters in drinking water are presented in Table 3. In both rivers, all the measured physicochemical parameters (except magnesium) did not exceed the regulatory limits for drinking water. However, some physicochemical parameters showed significant difference between the two rivers. This was probably due to microhabitat factor. Water temperature is an indispensable ecological factor that regulates the physiological behavior and the distribution of aquatic organisms. Air and water temperature did not vary widely, and this is typical of tropical waters [20]. The pH in the rivers during the study was slightly alkaline. Similarly, Indabawa [21] reported a mean pH of 7.2 in Challawa River in Kano State, Nigeria.

Low TDS (10-15 mg/l) was measured in both rivers. The low level of TDS may be attributable to low runoff of debris from land into the rivers. In River Benue, Akaahan et al. [22] measured a higher TDS value of 29.63 mg/l. TDS can reduce water solubility of gases like oxygen and the palatability of water, and enhance eutrophication in water bodies [23]. The conductivity in both rivers was low (25-38 μS/cm). This was probably due to low dissolved ions in the rivers. However, Agbaire and Obi [24] observed higher conductivity (73-98 μS/cm) in River Ethiope, Abraka, Nigeria. The range of total alkalinity (10-34 mg/l) in both rivers was within the recommended level for freshwaters. Tolerable alkaline level for freshwater system is 5-500 mg/l [25]. Chloride is one of the important parameters used in assessing water quality. Higher concentration of chloride in water indicates higher degree of organic pollution. The level of chloride measured in both rivers was low, indicating less organic pollution. Eneji et al. [26] reported low chloride content in River Benue in Nigeria.

Free CO_2 levels in both rivers ranged from 1-8 mg/l. Owan River had the highest free CO_2 concentration probably due to greater metabolic activities by the biota. The oxygen content of a water body is important for direct need of many organisms. It is one of the most significant parameters affecting the productivity of aquatic systems [1]. Dissolved Oxygen was higher in Ovbioti River than Owan River. The range of values of dissolved oxygen in this study is similar to the findings (3.2-7.3 mg/l dissolved oxygen) of Abowei [27] for Nkoro River, Niger Delta, Nigeria. The desirable concentration limit for BOD in freshwater is 0.29mg/l [28]. BOD varied slightly in both rivers during the study. In both rivers, the range was 0.0-0.2mg/l, indicating low water pollution with organic matter.

Total hardness in both rivers ranged from 6-22 mg/l with magnesium accounting for greater contribution to the hardness than calcium. Low calcium level (0.2-0.52 mg/l) was measured for both rivers. However, Akoteyon et al. [6] observed a higher mean concentration of 54 mg/l in Owo River, Nigeria. The level of magnesium (1.34-5.23 mg/l) measured in both rivers exceeded the regulatory limit (0.20 mg/l) [29] for drinking water. High concentration of magnesium in the rivers may have been influenced by the background level of magnesium in the surrounding area. Phosphate concentration in both rivers which ranged from 0.04-0.21 mg/l was low. Phosphate is a nutrient in rivers. Welch et al. [30] observed that a water body may be classified as eutrophic if total phosphate value ranged from 20-30 mg/l. Values of measured physicochemical parameters in this study were within the range of water quality requirements for aquaculture in the tropics [28], [31].

Table 3: Guideline values for physicochemical parameters in drinking water

Physicochemical Parameter	Maximum Permissible Limit	Reference
Temperature	Ambient	[29]
pH	6.5-8.5	[29], [32]
TDS	500 mg/l 600-1000 mg/l	[29] [32]
Conductivity	1000 µS/cm	[29]
Total alkalinity	n. s.	
Chloride	250 mg/l	[29], [32]
Free CO_2	n. s.	
Dissolved oxygen	n. s.	
BOD	n. s.	
Hardness (as $CaCO_3$)	150 mg/l 100-300 mg/l	[29] [32]
Calcium	100-300 mg/l	[32]
Magnesium	0.20 mg/l	[29]
Phosphate	n. s.	

n. s., not stated; TDS, total dissolved solids; CO_2; carbon dioxide; BOD, biochemical oxygen demand

4.2. Trophic state of rivers

CTSI based on chlorophyll a parameter indicated oligotrophic state (low productivity) of Ovbioti and Owan Rivers throughout the period of study. Similar results were reported by Kadiri and Omozusi [33] (Ogba, Ologbo and Ogbeze Rivers in Edo State, Nigeria) and Chaurasia and Karan [34] (Mandakini River). The poor ionic state of the rivers reflected by the low TDS and conductivity also indicated oligotrophic status.

5. Conclusion

Physicochemical water quality and trophic state of Ovbioti and Owan Rivers in Edo State, Nigeria was studied. The results indicated that values of the physicochemical parameters (except magnesium) of the rivers did not exceed relevant regulatory limits for drinking water. In addition, values of the parameters were within acceptable limits for aquaculture in tropical freshwaters. CTSI based on chlorophyll a determination indicated oligotrophic state of the rivers. This implied low nutrient and poor ionic conditions of the rivers. The information provided by this study may be useful in the evaluation of rivers for compliance with drinking water quality and productive use for aquaculture. In order to have comprehensive information, there is need to expand the scope of study on the water quality of the rivers.

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