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Seasonal variation in physicochemical characteristics of Agulu Lake, South Eastern Nigeria

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Abstract

Discharges from natural and anthropogenic sources entering aquatic ecosystem may impair the physicochemical parameters as well as impact the distribution of resident aquatic biota. Seasonal variation in physicochemical characteristics of Agulu was investigated. The physicochemical properties of the lake determined according to the standard methods were temperature, conductivity, pH, alkalinity, dissolved oxygen, phosphates, sulphates, nitrate-nitrogen, carbon dioxide, turbidity, total dissolved solid, total suspended solid and total hardness. Results showed spatial, monthly and seasonal variations in the parameters analyzed. The mean values of the parameters were as follows: Temperature 29 ± 1.67 °C, pH 5.27 ± 1.14 , turbidity 24.15 ± 1.76 NTU, conductivity 9.67 ± 1.71 $\mu\text{s}/\text{cm}$, alkalinity 51.47 ± 5.02 mg/L, total dissolved solids 10.54 ± 1.25 mg/L, total suspended solid 9.51 ± 1.11 mg/L, sulphate 2.71 ± 0.39 mg/L, phosphates 0.91 ± 0.27 mg/L, nitrate-nitrogen 0.90 ± 0.29 mg/L, dissolved oxygen 5.41 ± 0.72 mg/L and carbon dioxide 3.98 ± 0.87 mg/L. In general the physicochemical parameters measured did not vary among the stations but there were significant variations during the rainy and dry seasons ($P < 0.05$). The physicochemical properties found at the sampling stations of the Lake were within the permissible limits recommended by World Health Organization and United States Environmental Protection Agency (USEPA) for lentic ecosystem, indicating that the water from the lake may be suitable for domestic use and conducive for survival of aquatic life.

Keywords: Agulu Lake, physicochemical parameters, sampling, seasonal variations, aquatic life

Introduction

Lakes are dynamic lentic ecosystems which are significant inland water resources for meeting the increasing water demand. However, all these functions depend on the quality of water, which is based on a well-balanced environment in terms of its physical, chemical and biological variables^[1].

Water quality determine to a great extent the success or failure of fish culture operation. Aquatic and terrestrial life require water for support, movement, feeding and for maintenance of body functions. The physical and chemical features of water can directly or indirectly affect aquatic life. The dynamics of water quality may present complex patterns and variability which are dependent on a number of unpredictable factors. Some of these factors may be hydrological, meteorological and anthropogenic^[2].

All over the world, lakes are the most abundantly available substances in nature^[3]. Being stagnant water body, they are prone to pollution than the rivers as self-purification processes are very poor in them^[4]. Any contamination or pollution of lakes affects greatly the flora and fauna and also the human health if the water is used for domestic purposes^[5].

The functioning of an aquatic ecosystem and its stability to support life forms depend, to a great extent, on the physicochemical characteristics of its water. Water quality provides current information about the concentration of various solutes at a given place and time^[6].

The quality of surface water which depends on the equilibrium between the physical, chemical, and biological characteristics of the surrounding environment is constantly changing in response to daily, seasonal, and climatic condition. Variability in physicochemical parameters is responsible for the distribution of organisms in different freshwater habitat according to their adaptation, which allow them to survive in a specific habitat^[7]. Since water is of necessity to man, animals and plants, it is of greater importance to assess its quality so as

to proffer guidelines for its sustainable usage or make corrective steps to ensure its quality [8].

Agulu Lake is very important in the history of Anambra State as a national and international tourist center. The Lake serves for other economic purposes such as fishing and transport. Due to these various activities that take place in the lake, coupled with farming going around the Lake, the lake may be contaminated with these anthropogenic activities including some natural source of pollution that may find its way into this important aquatic ecosystem and deteriorates the quality of the water. Therefore, present study was designed to determine the physicochemical characteristics of Agulu Lake in Aniocha, Anambra state.

Materials and methods

Study area

The study was carried out at the Agulu Lake. The Lake is located in Aniocha Local Government Area of Anambra state, Nigeria. The coordinates are 6°08'N, 7° 02'E

Experimental design and sample collection

Sampling involved both *in situ* measurements and sample collection from four sampling stations in the Lake from April 2014 to March 2015. Sampling for physicochemical parameters was done once monthly for 12 months between 08:00-11:00 hours on each sampling day. Surface water samples for chemical parameters were collected from all sampling stations in 2 L plastic bottles. All the analyses were carried out in Spring Board Research Laboratory, Awka.

Determination of physicochemical parameters

The physical and chemical parameters including temperature, dissolved oxygen, electrical conductivity and pH value were measured directly in the field according to APHA [9].

Temperature

Temperature was determined *in situ*. It was measured using mercury- in-glass thermometer.

pH

pH was measured by electrometric method using the laboratory pH Meter Hanna model HI991300.

Electrical conductivity

The conductivity of water was determined in the laboratory using the Hanna 911 conductivity meter which was standardized with 0.01 N potassium chloride (KCl) solutions APHA [9].

Total dissolved solids

Total dissolved solid was determined in accordance with APHA [9] and was calculated as $TDS = (A-B) \times 103 \text{ mg/l}$

Where A = weight of dish + solids (mg)

B = weight of dish before-use (mg)

Total suspended solids

Total suspended solid was determined by subtracting the result of total dissolved solids from total solid. Total solids (TS) - Total dissolved solids (TDS) = Total Suspended solids (TSS) APHA [9].

Total hardness

Hardness was measured using method of APHA [9]. About 50 cm³ of the water sample was introduced into a beaker and

1cm³ buffer solution of NH₃ added, three drops of solochrome Black T indicator was also added and the solution swirled properly. The mixture was titrated with 0.01 EDTA solutions until the colour changed from wine red to pure blue with no bluish tinge remaining.

$$\text{Total hardness (mg/CaCO}_3\text{)} = \frac{\text{Volume of Titrate} \times 100}{\text{Volume of samples (cm}^3\text{)}}$$

Turbidity

The samples were placed in a clean, dry turbidity vial. It was placed into the AQ4500 sample chamber and covered with vial cap. The measurement keys were pressed, the results were displayed on the instrument (Turbidity meter) and the result was read and recorded in NTU.

Dissolved oxygen

Dissolved Oxygen in water was determined by Winkler Method in accordance with APHA [9].

Phosphates

Briefly, 100 ml of the homogenized and filtered sample was pipetted into a conical flask. The

About 20 ml of the sample was pipette into test tubes, 10 ml of the combined reagent added, shaken and left to stand for 10 minutes before reading the absorbance at 690 nm on a spectrophotometer, using 20 ml of distilled water plus 1 ml of the reagent as reference.

Sulphate

A total of 250 cm³ of the water sample was evaporated to dryness on a dish. The residue was moistened with a few drop of Conc. HCl and 30 cm³ distilled water was added. This was boiled and then filtered. The sulphate was determined according to APHA [9].

Nitrate-Nitrogen

Nitrate was determined using PD303 UV spectrophotometer APHA [9].

Total alkalinity

Total alkalinity was determined by titrimetric method. A volume of 100 ml of water from each tank was collected into a conical flask. Three drops of methyl orange indicator was added. This was then titrated with 0.02 N H₂SO₄ until a greenish-yellow colour became pink orange. Value for alkalinity was obtained using the formula given below:

$$\text{Alkalinity (mg L}^{-1}\text{)} = \frac{\text{Acid added (ml)} \times \text{normality of acid} \times 50,000}{\text{Sample volume (ml)}}$$

Carbon (IV) oxide

Free carbon dioxide was determined by titrimetric method. A volume of 100 ml of water sample was transferred along the side neck of the conical flask to avoid agitation. Ten drops of phenolphthalein indicator was then added. N/44 sodium hydroxide (NaOH) was titrated until a weak pink colouration first appeared that lasted for at least 30 seconds. The procedure was repeated three times for each tank and the mean calculated. Value of free carbon dioxide was obtained using the formula given below:

$$\text{CO}_2 \text{ (mg L}^{-1}\text{)} = \frac{\text{Sodium hydroxide volume (ml)} \times \text{Normality of NaOH} \times 44,000}{\text{Sample volume (ml)}}$$

Statistical Analysis

Means and standard error (mean \pm SE) were computed using SPSS software (version 20) (SPSS, Chicago, IL, USA). One-way analysis of variance was used in estimation of the statistics. Duncan's multiple range tests was used to compare the means of values. The level of statistical significance was set at $P < 0.05$.

Results

Physicochemical parameters

The results of the physicochemical parameters of the Agulu Lake, measured across the sampling locations from April

2014 to March 2015 are shown in Tables 1, 2 and 3.

Water Temperature

This varied from 23.00 to 32.10 °C, with a mean of 29.08 °C \pm 0.28 during the study period (Table 1). Values were higher in the dry season (30.73 °C \pm 0.23) than in rainy season (28.10°C \pm 0.68) (Table 2), with an overall peak (31.20 °C) recorded in February 2015, and least values (25.33 °C) recorded in August 2014. There was a significant seasonal variation in water temperature (Table 2), but was not significant ($p > 0.05$) across the sampling stations throughout the study duration (Table 3).

Table 1: Physicochemical Parameters of Agulu Lake, between April, 2014 and March, 2015

Parameters	Minimum	Maximum	Range	Mean \pm SE	NESREA (2011)
Temperature (°C)	22.00	32.10	10.10	29.08 \pm 0.28	NS
pH	4.00	7.34	3.34	5.27 \pm 0.17	6.5-8.5
Hardness (mg/L)	43.50	58.52	15.02	51.86 \pm 0.60	NS
Turbidity (NTU)	16.03	28.70	12.67	24.15 \pm 0.47	
EC (μ S/cm)	5.02	13.10	8.08	9.67 \pm 0.29	NS
Alkalinity (mg/L)	40.00	60.70	20.70	51.47 \pm 0.78	NS
TDS (mg/L)	7.06	13.80	6.74	10.53 \pm 0.22	NS
TSS (mg/L)	6.01	12.05	6.04	9.51 \pm 0.20	0.25
DO (mg/L)	3.22	7.01	3.79	5.41 \pm 0.14	\leq 6.0
NO ₃ -N (mg/L)	0.40	2.01	1.61	0.90 \pm 0.05	9.1
CO ₂ (mg/L)	2.01	6.07	4.06	3.98 \pm 0.14	<20.0
SO ₄ (mg/L)	1.56	4.01	2.45	2.71 \pm 0.07	100
PO ₄ (mg/L)	0.20	1.60	1.40	0.91 \pm 0.04	3.5

SE= standard error, EC= Electric conductivity, TDS= total dissolved solid, DO= dissolved oxygen, TSS= total suspended solid

pH

pH ranged from 4.00 to 7.34, with a mean of 5.27 \pm 0.17 (Table 1). Concentrations were higher in the rainy season (6.86 \pm 0.14) than dry season (6.69 \pm 0.19) of the sampling period (Table 2). There was significant difference ($p < 0.05$) in seasonal variation of mean pH in the sampling stations. The highest pH value of 7.34 was recorded in August 2014, while least value (6.68) was found in February, 2014. No significant differences ($p > 0.05$) in pH concentrations were recorded across the sampling stations (Table 2). The pH concentration correlated significantly at $p < 0.05$ with turbidity, total dissolved solid, and sulphates ions.

Total hardness

This ranged from 43.50 to 58.52 mg/L during the study period, with a mean level of 51.86 \pm 0.60 mg/L (Table 1). The seasonal concentration was higher in dry (54.79 \pm 1.03 mg/L) than the rainy (49.52 \pm 0.98 mg/L) period. There was significant difference ($p < 0.05$) in total hardness levels between the rainy and dry seasons (Table 2), but a significant difference at $p < 0.05$ was recorded in the mean values of total

hardness across the four sampling stations (Table 3).

Turbidity

Values for turbidity of Agulu Lake varied from 16.03 - 28.70 NTU (Table 1). These were higher during the rainy season (23.79 \pm 0.79) than dry season (21.25 \pm 0.08) during the study period (Table 2). There was significant difference ($p < 0.05$) in mean turbidity across the sampling stations (Table 3), whereas, there was no significant difference ($p > 0.05$) in mean turbidity between the rainy and dry seasons (Table 2).

Electrical conductivity

This ranged from 5.02 to 13.10 μ Scm⁻¹ during the study period, with a mean concentration of 9.67 \pm 0.29 μ S cm⁻¹ (Table 1). Higher conductivity concentrations were recorded in the rainy season (10.41 \pm 0.53 μ Scm⁻¹) than dry season (7.20 \pm 0.36 μ Scm⁻¹). There was significant seasonal variation ($p < 0.05$) in conductivity (Table 2). Similarly, there were significant differences recorded at $p < 0.05$ across the sampling stations (Table 3).

Table 2: Variations in the physicochemical parameters of Agulu Lake, between April, 2014 and March, 2015

Parameters	Season	Mean \pm SE	T	p-value
Temperature (°C)	Rainy	28.10 \pm 0.68	3.670	0.004*
	Dry	30.73 \pm 0.23		
pH	Rainy	6.86 \pm 0.19	9.457	0.000*
	Dry	6.69 \pm 0.14		
Hardness (mg/L)	Rainy	49.52 \pm 0.98	3.306	0.007*
	Dry	54.79 \pm 1.03		
Turbidity (NTU)	Rainy	23.79 \pm 0.79	1.894	0.085
	Dry	21.25 \pm 1.01		
EC (μ S/cm)	Rainy	10.41 \pm 0.53	5.570	0.000*
	Dry	7.20 \pm 0.36		
Alkalinity (mg/L)	Rainy	52.65 \pm 1.04	4.074	0.002*

	Dry	46.32±1.19		
TDS (mg/L)	Rainy	10.42±0.32	2.272	0.044*
	Dry	9.19±0.37		
DO (mg/L)	Rainy	5.36±0.17	1.463	0.171
	Dry	4.92±0.27		
NO ₃ -N (mg/L)	Rainy	0.86±0.04	4.223	0.001*
	Dry	0.61±0.04		
CO ₂ (mg/L)	Rainy	3.06±0.12	6.902	0.000*
	Dry	4.79±0.16		
SO ₄ (mg/L)	Rainy	2.79±0.05	5.495	0.000*
	Dry	2.48±0.06		
PO ₄ (mg/L)	Rainy	0.95±0.08	2.345	0.039*
	Dry	0.72±0.07		
TSS (mg/L)	Rainy	9.57±0.19	2.996	0.012*
	Dry	8.50±0.31		

SE= standard error, EC= Electric conductivity, TDS= total dissolved solid, DO= dissolved oxygen, TSS= total suspended solid; N.B: Values with superscript * differed significantly at $P<0.05$

Table 3: Spatial variation in Physico-chemical parameters of Agulu Lake, between April 2014 and March 2015

Parameter	Stations			
	1	2	3	4
Temperature (°C)	29.08 ^a	29.27 ^a	28.99 ^a	28.98 ^a
pH	5.11 ^a	5.40 ^a	5.23 ^a	5.36 ^a
Hardness (mg/L)	49.91 ^b	55.03 ^a	52.64 ^{ab}	49.87 ^b
Turbidity (NTU)	21.04 ^b	26.55 ^a	26.84 ^a	22.16 ^b
EC (µS/cm)	8.92 ^b	9.94 ^{ab}	10.68 ^a	9.14 ^{ab}
Alkalinity(mg/L)	49.96 ^a	52.61 ^a	52.04 ^a	51.26 ^a
TDS (mg/L)	9.56 ^b	10.93 ^a	10.30 ^{ab}	11.34 ^a
DO (mg/L)	5.99 ^a	5.97 ^a	5.94 ^a	6.03 ^a
NO ₃ -N (mg/L)	0.77 ^b	0.81 ^b	1.13 ^a	0.90 ^{ab}
CO ₂ (mg/L)	3.71 ^a	3.69 ^a	4.16 ^a	4.37 ^a
SO ₄ (mg/L)	2.75 ^a	2.79 ^a	2.57 ^a	2.73 ^a
PO ₄ (mg/L)	0.97 ^a	0.96 ^a	0.89 ^a	0.82 ^a
TSS (mg/L)	8.83 ^b	9.45 ^b	9.20 ^b	10.55 ^a

EC= Electric conductivity, TDS= total dissolved solid, DO= dissolved oxygen, TSS= total suspended solid N.B: Values with the same superscript along same row are not significantly different at $P<0.05$

Alkalinity

Alkalinity ranged from 40.00 to 60.70 mg/L during the study period, with a mean concentration of 51.47 ± 0.78 mg/L (Table 1). Higher alkalinity concentrations were recorded in the rainy season (52.65 ± 1.04 mg/L) than in the dry season (46.32 ± 1.19 mg/L) of the sampling period (Table 2). A significant difference ($P < 0.05$) in mean alkalinity between the rainy and dry seasons was observed, while there was no significant difference ($p > 0.05$) between the sampling stations.

Total dissolved solids

Total dissolved solid (TDS) concentrations ranged between 7.06 and 13.80 mg/L, with a mean value of 10.53 ± 0.22 mg/L (Table 1). Rainy season concentrations (10.42 ± 0.32 mg/L) were higher than dry season concentrations (9.19 ± 0.37 mg/L). There was significant seasonal variation in mean TDS at $P < 0.05$ (Table 2). Also spatially, TDS differs significantly at $P < 0.05$ across the four sampling stations (Table 3).

Dissolved oxygen

Dissolved oxygen (DO) ranged from 3.22 to 7.01 mg/L, with a mean concentration of 5.41 ± 0.14 mg/L (Table 1). DO concentrations were higher in the rainy season (5.36 ± 0.17 mg/L) than dry season (4.92 ± 0.27 mg/L) without a significant seasonal differences ($P < 0.05$) (Table 2). Also there was no significant difference ($p > 0.05$) observed in DO concentration across the four sampling stations (Table 3).

Nitrate ions (NO₃²⁻)

Nitrate concentrations ranged between 0.40 and 2.01 mg/L with mean value (0.90 ± 0.05 mg/L) (Table 1). Concentration were higher during the rainy season (0.86 ± 0.04 mg/L) than dry season (0.61 ± 0.04 mg/L) (Table 2); with the maximum concentration of 1.53 mg/L in October 2014 and minimum value of 0.55 mg/L each in March 2015.

Carbon (iv) oxide

Carbon (iv) oxide (CO₂) concentrations of the Lake ranged from 2.01 to 6.07 mg/L, with a mean concentration of 3.98 ± 0.14 mg/L (Table 1). Higher concentrations were recorded during the dry season (4.79 ± 0.16 mg/L) than rainy season (3.06 ± 0.12 mg/L) of the sampling period. There was a significant seasonal difference ($P < 0.5$) in CO₂ concentrations (Table 2); spatially, no significant differences were recorded across the sampling stations (Table 3).

Sulphate ions (SO₄²⁻)

Sulphate ions ranged from 1.56 to 4.01 mg/L, with a mean concentration of 2.71 ± 0.07 mg/L (Table 1). Higher value 2.79 ± 0.05 mg/L was recorded in the rainy season compared with 2.48 ± 0.06 mg/L in the dry season (Table 2), with a significant seasonal difference ($p < 0.05$) between the seasons. However, no significant differences ($p > 0.05$) were recorded in its mean concentration across the sampling station (Table 3).

Phosphate ions (PO₄²⁻)

Phosphate concentrations ranged between 0.20 and 1.60 mg/L, with a mean of 0.91 ± 0.04 mg/L (Table 1). Higher concentration were recorded in the rainy (0.95 ± 0.08 mg/L) than in the dry season (0.72 ± 0.07 mg/L) of the sampling period. There was a significant difference ($P < 0.05$) in mean phosphate ions concentrations between the rainy and dry seasons (Table 2). Whereas, no significant differences ($p > 0.05$) were observed in its mean concentration across the four sampling stations (Table 3)

Total suspended solids

The total suspended solids (TSS) of the Lake varied from 6.01 to 12.05 mg/L, with a mean of 9.51 ± 0.20 mg/L (Table 1). Concentrations were higher in the rainy season (9.57 ± 0.19 mg/L) than in dry season (8.50 ± 0.31 mg/L) during the sampling period, with the highest concentration of 10.91 mg/L recorded in September 2014, while the least concentration of 7.46 mg/L was recorded in March 2015.

Discussion

Water is one of the most important and abundant compounds of the ecosystem. All living organisms on earth need water for their survival and growth. The physicochemical characteristics of Agulu Lake showed spatial, monthly and seasonal variations in the parameters; however quality of the water may be suitable for the beneficial users.

pH

The high pH values of lake water obtained during the rainy season may be associated with the high decomposition activities of biotic and abiotic components of the lake. Further, the lower pH recorded in all the stations during dry season, is probably due to the concentration of dissolved substances as a result of evapotranspiration^[10]. The results obtained for pH in this investigation are comparable to the report of Adefemi and Awokunmi^[11] who studied physicochemical parameters in water samples obtained from Itaogbolu area of Ondo-State, Nigeria.

Total hardness

The total hardness values which ranged from 43.50 to 58.52 found in this present study is lower than the maximum permissible limit for total hardness for drinking water of 600 mg/l^[12] indicating that Agulu lake can support the growth and survival of aquatic biota dwelling in that Lake. Our finding is similar to the report of Olawale^[13] who recorded low hardness during the rainy season and high hardness during the dry season from Asa River, Ilorin, Nigeria.

Turbidity

Similar to the present study, Ikhuoriah & Oronsaye^[14] found high turbidity values during the rainy season and low values during the dry season in Ossiomu River, Ologbo, Benin State, which they attributed to increase of suspended solids loads from point and non-point sources. In general, turbidity concentration found in the investigation is within the maximum permissible limit recommended by WHO and NESREA for samples from freshwater aquatic ecosystem.

Electrical Conductivity

A decrease in conductivity values during the dry season and an increase during the rainy season was recorded in the present study. The increase in conductivity during rainy

season could be attributed to increase in concentration of salts, organic and inorganic substances in the lake, emanating from runoff from domestic and other anthropogenic sources into the lake during rainy season. The variability in the conductivity of water recorded in this study coincided with the studies of Edokpayi and Osimen^[15] who found higher conductivity in Ibiekuma stream (Southern Nigeria) during the rainy season and lower conductivity in the dry season.

Total alkalinity

The total alkalinity of the Lake is an indication of its carbonates and bicarbonate contributes with the possibility of silicates and phosphates contributing to it. Higher concentration of total alkalinity found in the Agulu Lake during the rainy season could be attributed to higher carbon dioxide concentration and release of bicarbonates ions by sediments. The mean range of the total alkalinity (40-60) compared favourably with the range given for lakes by USEPA^[16]. Sugunam^[17] reported that total alkalinity above 40 mg/L is indicative of high productivity.

Total dissolved solids

The data reported showed that the total dissolved solids value was below the maximum recommended limit by the WHO and NESREA. Similar findings showing more concentration of total dissolved solid in rainy season than dry season have been reported by many researchers^[18, 10, 19, 14].

Dissolved oxygen

During rainy season, as the water level increases, the flow velocity increases and there is bound to be an increase in the dissolved oxygen content^[14]. High content of dissolved oxygen found in the rainy season in the stations of Agulu lake is comparable with the studies of Izonfuo and Bariweni^[20] of Epie Creek in Niger Delta, Adedeji *et al.*^[8] of Lake Ribadu in Adamawa state, Nigeria.

Nitrate ions

The concentration of nitrate found during the wet season could be due to surface run-offs as well as the decomposition of organic matter or it could be attributed to the many allochthonous inputs emanating from the lake catchment areas^[21]. Comin *et al.*^[22] noted that a high nitrate concentration in river or lake is related to inputs from agricultural lands. The levels of nitrate recorded in this study were higher than the report of Enuneku *et al.*^[23] who found 0.47 – 0.55 mg/l nitrate concentrations from Owan River, Edo State.

Sulphate ions

The high values of sulphate may be due to the fact that this ion is washed into the river during the wet season. Significant amount of sulphate may be introduced into the lake as a result of industrial and domestic activities. The sulphate values obtained in this study were however higher than those of^[23] who recorded sulphates values in the range of 0.69 - 0.88 mg/l from River Owan, Edo State, Nigeria.

Phosphate ions

Mean value of phosphate recorded in Agulu Lake, was above the recommended maximum concentration. The significance of phosphorus in river is principally in regard to the phenomenon of eutrophication (over enrichment) of lakes and to nitrate, promotes the growth of algae and other plants leading to blooms, littoral slimes, diurnal dissolved oxygen

variations of great magnitude and related problems EPA [24]. High phosphate levels have been observed to be associated with organic pollution [25]. Similar to what is obtainable in most Nigerian inland waters; peak values were observed in rainy season months when allochthonous phosphorus containing materials are introduced by surface run-off. Different phosphate values in Nigerian rivers had also been reported; 0.17- 0.59 mg/l in Ossiommo River [26]. Omoigberale and Ogbeibu [27] reported higher values of 0.28 mg/l to 3.52 mg/l for Osse River.

Total suspended solids

The total suspended solids (TSS) determination is particularly useful in the analysis of sewage and other waste waters and is as significant as BOD determination. It is used to evaluate the strength of domestic wastewaters and efficiency of treatment units. Suspended solids are objectionable in aquatic systems for many reasons. Suspended Solids containing much organic matter may cause putrefaction and consequently, the stream may be devoid of dissolved oxygen.

TSS of the lake and river comprise mainly of silt and clay particles, its low concentration may not be a limiting factor to aquatic production. The significant differences in the TSS values obtained for the sampled stations of this study may also be due to the different anthropogenic influence on the stations. Similar to this finding, Madu [21] found high concentration of total suspended solids during the rainy season compared to dry season at lower River Niger at Idah, Kogi State, Nigeria.

In Conclusion, there was seasonal, spatial and monthly variation in the physicochemical characteristics of Agulu Lake as observed from this study. However, the variations in the parameters are within the acceptable limits recommended by national and international organization including National Environmental Standards and Regulations Enforcement Agency NESREA [28] and World Health Organization [29] standard. Further studies should be conducted to identify specific sources of pollution, monitor seasonal changes in bacterial incidences and correlate this to outbreaks of waterborne diseases in the community using the Lake.

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