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RESEARCH PAPER

Limnochemical Characterization of Lotic and Lentic Ecosystems in Agbede Wetlands

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Abstract

Investigation of the physical and chemical characteristics of selected lotic and lentic ecological systems in Agbede wetlands were under taken between December, 2012 and May, 2014 to assess the quality status of the water bodies. Water samples were collected monthly from seven stations which comprised one stream with three sampling points and three ponds with four sampling points. Thirty two (32) physical and chemical characteristics were determined using standard methods. Application of principal component analysis (PCA) revealed that total dissolved solids; total suspended solids and cadmium were the sources of variations among the parameters in the sampled stations owing to the strong component factors. All the physical and chemical characteristics in the surface waters had their mean values within the set limits by Federal Ministry of Environment of Nigeria (FMEnv.) except for turbidity whose value was > 5 NTU, copper (> 1 mgL^{-1}) and zinc (> 1 mgL^{-1}). It can be inferred that the selected surface water bodies were in a semi-pristine condition.

Keywords: Hydrology**,** limnochemistry, water quality, wetlands, Nigeria.

Introduction

Wetlands are areas where land and water meet and are wet for an ecologically significant part of the year. They may be temporary flooded each day as with tidal marshes or be filled seasonally with waters from melting snow (The Volunteer Monitor, 1998). The International Union for the Conservation of Nature (IUCN, 1979) defined wetlands as the areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters.

Global biodiversity is enhanced by wetlands as they are vital for the survival of disproportionately large number of threatened and endangered species (Mitsh & Gossilink, 1993; Biswasroy, Samal, Roy, & Amazumdar, 2011). In the last few decades, aquatic ecologists have focused more of their researches on water quality, resources management and sustainable utilization, which have become more challenging with climate change phenomena. Although: inundation, siltation, agriculture, deforestation, industrialization and urbanization were itemized to pose greater challenges to aquatic regimes in recent times (Olomukoro & Dirisu, 2014). Surface water quality is an essential component of the natural environment and a matter of serious concern today (Liu, Yu, & Chung, 2011).

In Nigeria, wetlands have received very little attention even though they are among the most productive ecosystems in the world comparable to rain forests and reefs. Similarly, despite the numerous lentic and lotic systems in Agbede wetlands, studies on the chemical hydrology are quite few (Olomukoro & Dirisu, 2012; Dirisu & Olomukoro, 2015). This study seeks to document the limnochemical conditions of the selected lotic and lentic ecosystems with a view to assessing the effects of land use on the quality of the water bodies. It is hoped that the research findings would help in the development of a proper management plan for the sustainable use of the wetlands.

Materials and Methods

Study Area

The study area is Agbede wetlands (Figure 1) located in the northern part of Edo State within a rainforest ecosystem and fast becoming a derived savannah; it lies within longitude 006°16.3”E, 006º 18.7”E and latitude 06°52.2”N, 06°55.4”N. The

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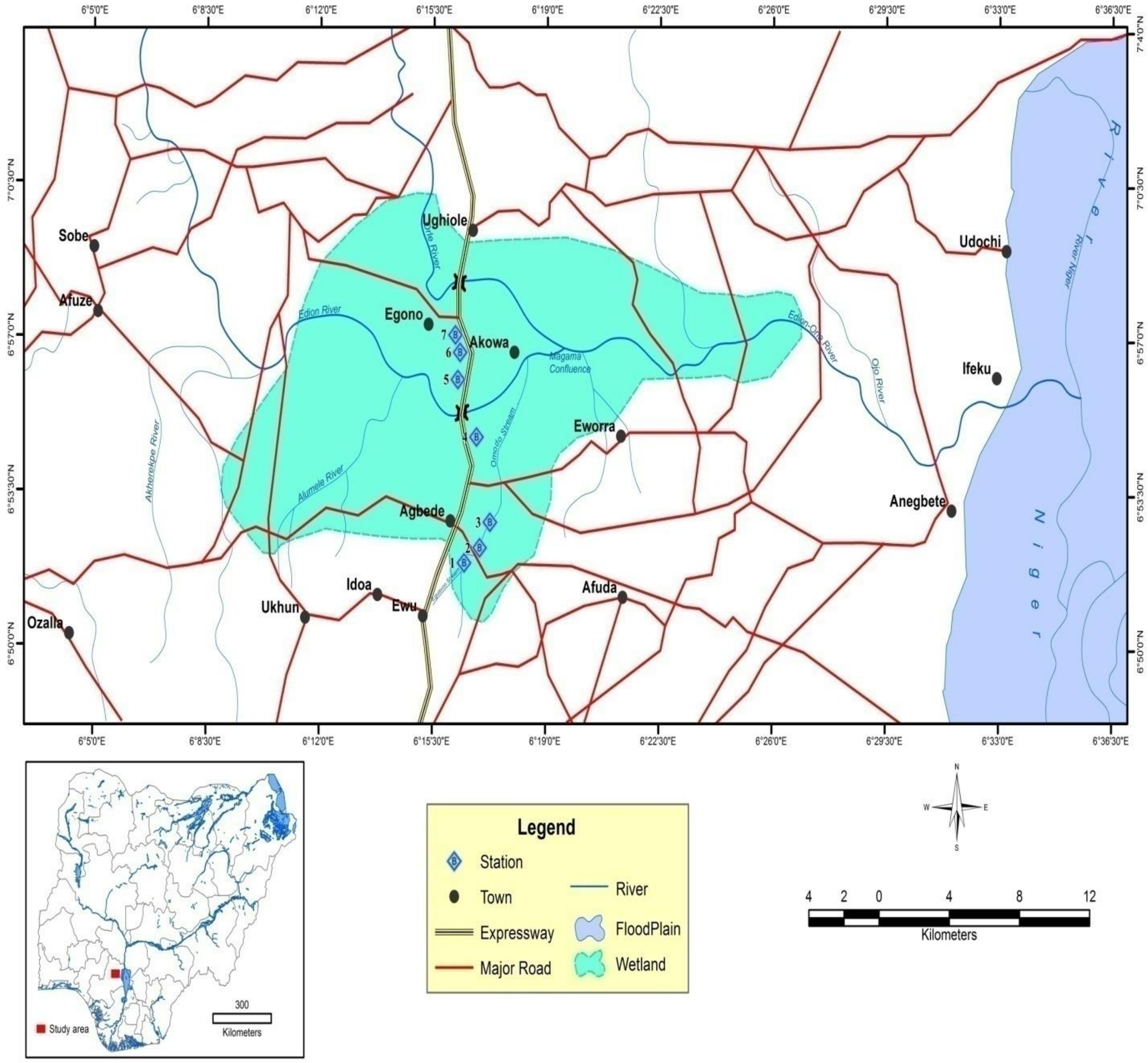

Figure 1. Map of the Study Area.

wetlands are mostly fed by surface run-off from neighboring communities of Auchi, Warrake, Ewu, Ewora, Jagbe and Idoa respectively through a number of streams and rivers. The lentic systems usually become inundated between July and October each year while the lotic systems are permanent in nature. Omodo stream flows in the South– East direction with few tributaries which are seasonal. The climate of Agbede has been previously described (Ikhile & Aderogba, 2011; Olomukoro & Dirisu, 2014). The meteorological data is shown if Figure 2.

This region consists of secondary rainforest which has been greatly subjected to deforestation, indiscriminate land cultivation, nomadic Agriculture, use of pesticides and logging. The dominant vegetation now comprises *Heavea brasiliensis*, *Gmelina arborea*, *Tectona grandis and Bambusa vulgaris* tickets. Others include; *Elais guineesis and Anacadium occidentalis.* Several species of shrubs, herbaceous plants and plantation agriculture like Duca nut trees, Plantain and Banana (*Musa* sp) (Dirisu & Olomukoro, 2015) are also observed in the marginal area. Riparian settlements comprise the Hausa/Fulani and the Ibira immigrants, who are mostly peasant farmer.

A total of seven sampling stations were designated for this study and included one river with three (3) stations and three Ponds (3) with four stations. All the stations were carefully chosen based on accessibility particularly during inundation period. A descriptive summary of the sampled stations is given in Table 1.

Sampling Techniques and Samples Analyses

Water samples were collected monthly between December, 2012 and May, 2014 at each of the seven stations between 0900hr and 1200hr every sampling day. A total of 126 composite replicate samples were collected and analysed throughout this study. Before sampling, all containers were thoroughly washed. At each sampling station composite water samples for physical and chemical analyses were collected from the sub-surface into appropriate sample containers and preserved as appropriate for laboratory analysis according to standard procedures (APHA, 2005). Air and water temperatures were measured in-situ using mercury – in – glass thermometer calibrated from 0 – 100°C (Krisson model-59) (Olomukoro & Dirisu, 2012). Air temperature was usually measured before that of water at each station. The floatation method earlier used by Olomukoro and Dirisu (2012) was adopted to determine the velocity of flow and the current was calculated in meters per seconds (ms^{-1}). The water level at specific points in the study stations were measured using a straight stick; which was actually measured using a field tape calibrated in meters (Ogbeibu & Victor, 1995). The pH, Electrical conductivity (EC) and Total dissolved solids (TDS) were measured in-situ using potentiometric method with pH/Conductivity/TDS meter (Hach pH meter sense ion 2 Model). Total suspended solids measured in mgL^{-1} were determined in the laboratory using the photometric method with HACH UV/VIS Spectrophotometer (model DR/2000) (APHA, 2005). Turbidity was measured in the laboratory in NTU, using a HACH Turbidimeter Model 2100p. Dissolved oxygen and Biochemical oxygen demand (BOD_5) and chemical oxygen demand were estimated in the laboratory according APHA (2005). Chloride was determined in the laboratory by the argentometric method (Olomukoro, 1996; APHA, 2005). Nitrate was determined in the laboratory with the Cadmium Reduction method using the HACH Spectrophotometer at 410nm (Hach UV/VIS Model DR 2000) (APHA, 2005). Phosphate was determined in the laboratory with the ascorbic method using the HACH Spectrophotometer at 890nm (Model DR 2000) (APHA, 2005) and Sulphate was determined with turbidimetric method, using the HACH Spectrophotometer (DR/2000) at 450nm (APHA, 2005). Heavy metals namely, Fe, Zn, Cu, Cr, Cd, pb,

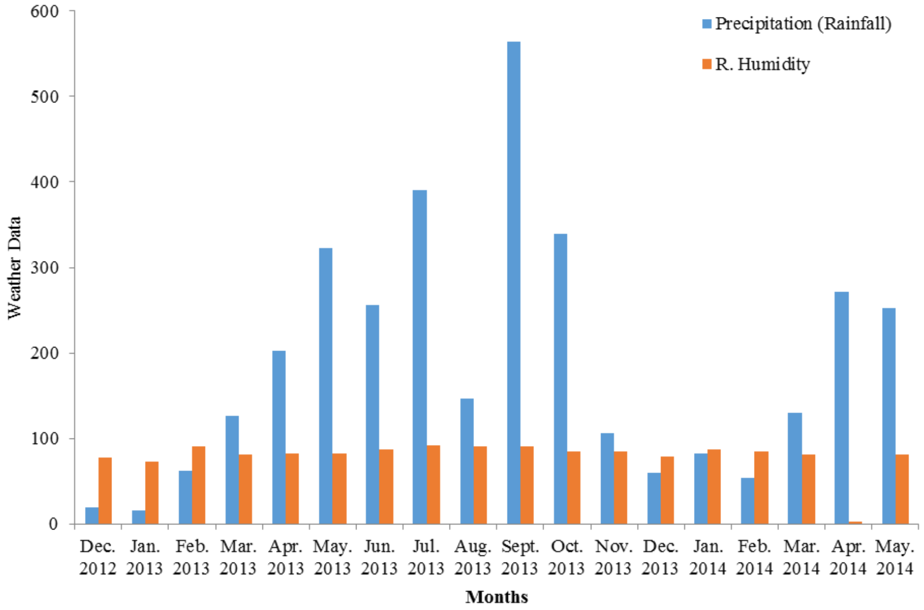

Figure 2. Rainfall and Relative Humidity Patterns during the Sampling Regime (Source: Meteorology Department, Federal Airport Authority of Nigeria, Benin).

Table 1. Summary of the Sampling Stations with some Characteristic Features in Agbede Wetlands

Station ID	Station/Water Body Type	Macrophytes	Coordinates		Altitude	Farming Activities On the Banks
			Latitude	Longitude		
1	Omodo Stream	Not Present	06^{o}51^{1}53’.6”N	006^{0} 16’ 28’.4”E	121m	Present
2	Omodo Stream	Not Present	06^{0} 52’ 12’. 5”N	006^{0} 16^{1} 50’. 8”E	98m	Present
3	Omodo Stream	Present	06^{0} 52^{1} 51’.6”N	006^{0} 17^{1} 13’. 2”E	109m	Absent
4	Pond 1	Present	06^{0} 55^{1} 01’.0”N	006^{0} 16^{1} 23’.8”E	72m	Present
5	Pond 2	Present	06^{0} 56^{1} 14’. 6”N	006^{0} 16^{1} 15’.4”E	79m	Present
6	Pond 3	Present	06^{0} 56^{1} 53’.2”N	006^{0} 16^{1} 15’.2”E	84m	Present
7	Pond 3	Present	06^{0}56’ 57’.4”N	006^{0} 16^{1} 15’.2”E	82m	Present

Co Mn and Ni were determined in the laboratory (APHA, 2005) using the Atomic Absorption Spectrophotometer (Thermol Jarrel Ash Smith Heiftje IIModel 757).

Data Analyses

Physico-chemical data were subjected to Analysis of Variance (ANOVA) at 95% confidence level using the Statistical Package for the Social Scientists (SPSS 16.0). Principal component analysis (PCA) was carried out with an SPSS and Euclidean similarity test was performed with Paleontological Statistics software (PAST 1.99).

Results

Physical and Chemical Characteristics

The result of the thirty-two (32) physico-chemical characteristics in the surface water is presented below while, the summary containing the minimum, maximum and mean values are presented in Table 2. All the physical and chemical characteristics of the surface waters had their concentrated values within the set limits of the Federal Ministry of Environment of Nigeria (FMEnv.), except for Turbidity, Copper and Zinc whose mean concentrated values were >5mgL^{-1}, >1 mgL^{-1} and 1 mgL^{-1} respectively at stations 4 to 7 (the lentic environments). Very few of the parameters investigated, namely; air temperature, water temperature, flow rate, EC, turbidity, COD, Na, Mg, Ca, Fe, Pb, Cd and Mn showed significant difference ($P<0.05$ and $P<0.001$) amongst the tested mean values across the study stations. Generally, the values obtained for nutrients (Nitrate and Phosphate), alkaline metals (Sodium and Potassium) and alkaline earth-metals (Calcium and Magnesium) were slightly higher in the lentic ecosystems. Meanwhile, the mean concentration values (Table 1) for alkaline metals showed that Sodium had a proportional relationship with Potassium and the former was about 1 fold higher than the latter. The same trend was observed between Magnesium and Calcium. Heavy metals had their mean values across the sampled stations below 1 mgL^{-1} except for Copper, Iron and Zinc which were >1 mgL^{-1} in the lentic systems comparably to the lotic systems.

Dissolved oxygen varied in mean concentrations from station 4 (lentic system) with a low of 4.83mgL^{-1} to station 1 (lotic system) with a high of 7.68mgL^{-1}. Dissolved oxygen concentrations was highest (12.90mgL^{-1}) in December, 2012 and lowest (1.20mgL^{-1}) in March, 2013 at stations 3.

Among the nutrients; Nitrate mean values were between 0.25mgL^{-1} at stations 2 and 0.65mgL^{-1} at station 7. Nitrate values ranged from below detection Limit (BDL) in January, 2013; April, 2013 and April, 2014, to a high of 4.29mgL^{-1} at station 7 in January, 2014. Nitrate monthly values were highest in January, 2014. Sulphate and phosphate did not follow a definite seasonal pattern instead; they exhibited irregular concentrations. Sulphate mean values were highest at station 5 (7.99mgL^{-1}) and lowest at station 1 (0.52mgL^{-1}). Phosphate mean values ranged between 0.32mgL^{-1} at station 4, and 0.54mgL^{-1} at stations 3 and 7 respectively. Spatial and temporal values were between Below Detection Limited (BDL) at stations 1 and 3, and 1.90mgL^{-1} at station 3.

The concentrations of heavy metals throughout the study were considered low thus; seasonal trends showed that the lentic systems recorded higher values than the lotic systems. The concentrations recorded for copper were higher in the lentic environments (stations 4 to 7) than in the lotic environment (stations 1 to 3). The concentrations ranged between Below Detection Limit (BDL) and 6.7100mgL^{-1} at station 2 for the former and station 4 for the latter. Iron minimum and maximum concentrations were between BDL at station 2 and 3, and 5.9300mgL^{-1} at station 4 throughout the study period. Minimum values for Iron were recorded in February and March, 2013 while; maximum value was recorded in July, 2013. Iron concentrations in surface water were fairly higher during the wet season and the observation was not limited to the lentic system (stations 4-7). Spatial and temporal variations for lead ranged from BDL at all the stations (from 1 to 7) to 0.1200mgL^{-1} at stations 4. The maximum values were mostly recorded during the dry seasons of early 2013, (January, February, March and April). Zinc concentrations showed a significant increase towards the wet seasons and higher concentrations were recorded at stations 4 to 7 (lentic environments). Zinc spatial and temporal concentrations in the surface water matrix were between BDL at station 2 and 95.000mgL^{-1} at station 6. It maximum value was recorded in January, 2013 and the minimum value was recorded in December, 2012. Chromium exhibited high rate of fluctuation particularly in 2013. Meanwhile, the spatial and temporal variations ranged between BDL at all the stations in virtually all the months (from December, 2012 to May, 2014 except in April, 2013 where there was no singular value recorded); to a high of 0.1100mgL^{-1} at station 7 in July, 2013. The concentrations of cadmium ranged between BDL at stations 3, 5, 6 and 7 to 0.3700mgL^{-1} at station 7. The values recorded for cadmium were more consistent between December, 2012 and July, 2013. Cadmium value was highest in December, 2012. However, Cobalt ranged in values from BDL across all the study stations (1 to 7) to 0.0100mgL^{-1} at stations 3, 4, 5 and 7. Cobalt did not record any value in December, 2012 as they were all below Detection Limit (BDL) from stations 1 to 7. There were no recorded values for April, 2013, May, 2013, July, 2013, August, 2013, October, 2013, November, 2013, December, 2013 and April, 2014. Values recorded between January and May, 2014 with the exception of April, 2014 were

Table 2. Summary of the Mean, Minimum and Maximum Values of the Physico-Chemical Characteristic of Surface Water of Selected Water Bodies in Agbede Wetlands from December, 2012 to May, 2014

Parameters	Unit	Lotic Stations			Lentic Stations				Limits FMEnv	WHO	p-Value
		Station 1 $\bar{X}$±SD (Min-Max)	Station 2 $\bar{X}$±SD (Min-Max)	Station 3 $\bar{X}$±SD (Min-Max)	Station 4 $\bar{X}$±SD (Min-Max)	Station 5 $\bar{X}$±SD (Min-Max)	Station 6 $\bar{X}$±SD (Min-Max)	Station 7 $\bar{X}$±SD (Min-Max)			
Air Temperature	^{0}C	28.17 ^{b} ±1.96 (23.00-31.50)	28.44 ^{b} ±1.81 (24.00-31.00)	31.67 ^{a} ±1.37 (29.00-33.00)	32.19 ^{a} ±1.72 (29.00-36.00)	31.22 ^{a} ±1.33 (28.50-33.00)	31.92 ^{a} ±1.20 (29.50-33.50)	31.31 ^{a} ±1.63 (27.00-33.50)	NS		0.00
Water Temperature	^{0}C	25.42 ^{d} ±1.77 (20.00-28.00)	25.75 ^{d} ±1.96 (20.00-28.00)	26.58 ^{cd} ±1.78 (22.00-30.00)	29.11 ^{a} ±1.64 (26.00-32.00)	27.36 ^{bc} ±1.46 (24.50-29.00)	28.17 ^{ab} ±1.55 (25.00-30.00)	27.92 ^{c} ±1.57 (25.00-30.00)	<40		0.00
Depth	M	0.30±0.29 (0.10-0.90)	0.30±0.28 (0.10-0.90)	0.26±0.16 (0.12-0.80)	0.32±0.17 (0.16-0.90)	0.31±0.13 (0.13-0.56)	0.28±0.13 (0.12-0.58)	0.26±0.09 (0.13-0.38)	NS		0.42
Flow Rate	ms^{-1}	0.27 ^{b} ±0.06 (0.20-0.50)	0.30 ^{ab} ±0.07 (0.19-0.50)	0.33 ^{a} ±0.12 (0.09-0.50)	0.00 ^{c} ±0.00 (0.00-0.00)	0.00 ^{c} ±0.00 (0.00-0.00)	0.00 ^{c} ±0.00 (0.00-0.00)	0.00 ^{c} ±0.07 (0.00-0.00)	NS		0.00
pH		6.06±0.30 (5.50-6.70)	6.11±0.31 (5.80-6.85)	6.16±0.34 (5.70-7.00)	5.99±0.40 (5.50-7.20)	6.04±0.43 (5.10-6.80)	6.23±0.42 (5.70-7.20)	6.29±0.37 (5.70-7.10)	6 – 9		0.18
Electrical Conductivity	µScm^{-1}	29.78 ^{c} ±13.61 (3.92-48.00)	31.26 ^{c} ±17.00 (3.48-56.00)	35.75 ^{c} ±25.13 (3.54-80.00)	39.63 ^{bc} ±31.04 (3.03-90.00)	37.17 ^{c} ±28.17 (3.11-76.00)	61.33 ^{ab} ±52.36 (2.67-140.00)	62.87 ^{a} ±46.60 (2.76-130.00)	1000		0.01
Turbidity	NTU	4.39 ^{b} ±5.33 (0.00-16.50)	3.34 ^{b} ±5.76 (0.00-18.50)	4.54 ^{b} ±6.07 (0.00-20.50)	6.11 ^{b} ±10.41 (0.00-34.00)	6.06 ^{b} ±12.12 (0.00-39.00)	9.57 ^{b} ±19.24 (0.05-62.00)	21.25 ^{a} ±31.46 (0.04-78.20)	5		0.01
Total Hardness	mgl^{-1}	43.61±13.76 (27.16-68.98)	75.66±57.86 (28.42-168.90)	76.57±66.15 (20.40-189.78)	76.35±57.71 (28.63-182.30)	76.70±50.99 (23.89-184.98)	96.00±72.47 (21.46-210.10)	101.09±83.49 (28.16-235.01)	NS		0.14
Dissolved Oxygen	mgl^{-1}	7.68±2.52 (3.50-14.80)	5.77±2.55 (1.20-8.20)	6.57±2.60 (1.30-12.30)	4.83±2.49 (2.00-10.90)	6.56±4.05 (1.70-14.80)	6.06±3.15 (1.50-11.60)	5.23±2.86 (1.60-12.90)	7.5		0.09
Biochemical Oxygen Demand	mgl^{-1}	3.91±1.60 (1.40-6.80)	2.77±1.69 (0.40-5.20)	2.97±1.24 (0.50-4.80)	1.83±1.41 (0.00-4.30)	3.12±2.78 (0.00-8.20)	3.27±2.36 (0.00-6.80)	2.60±1.46 (0.80-4.80)	30		0.06
Chemical Oxygen Demand	mgl^{-1}	18.80 ^{c} ±5.97 (12.15-30.00)	24.23 ^{bc} ±11.47 (14.83-64.00)	27.42 ^{ab} ±9.12 (13.00-41.52)	34.84 ^{a} ±10.15 (15.00-50.60)	33.29 ^{a} ±19.37 (19.68-96.00)	18.42 ^{c} ±3.72 (15.19-25.80)	28.84 ^{ab} ±11.91 (13.26-48.09)	150		0.00
Total Dissolved Solids	mgl^{-1}	61.18±48.53 (18.85-153.29)	44.42±36.09 (18.50-130.10)	61.49±45.49 (20.25-150.61)	65.52±42.71 (16.17-151.60)	51.32±29.93 (15.45-120.10)	70.48±38.41 (19.22-134.80)	83.45±64.33 (21.31-243.80)	2000		0.20
Total Suspended Solids	mgl^{-1}	16.38±20.61 (0.04-53.40)	10.41±16.53 (0.00-59.20)	14.13±17.01 (0.02-57.40)	13.98±19.13 (0.00-59.80)	12.49±18.26 (0.00-61.20)	17.92±23.01 (0.01-61.20)	27.51±34.78 (0.03-93.80)	30		0.34
Chlorine	mgl^{-1}	19.23±11.15 (9.34-43.17)	19.35±10.00 (10.09-42.12)	18.80±7.41 (8.92-30.55)	19.96±7.69 (9.08-31.45)	19.73±8.47 (9.89-42.17)	23.89±14.63 (5.65-51.15)	23.15±13.83 (8.00-49.92)	600		0.69
Sulphate	mgl^{-1}	0.52±0.86 (0.03-2.37)	2.89±5.08 (0.03-14.95)	2.01±2.84 (0.05-7.67)	1.82±2.39 (0.07-5.41)	7.99±28.13 (0.06-120.45)	0.92±1.41 (0.06-3.91)	3.52±6.98 (0.02-21.98)	500		0.50
Phosphate	mgl^{-1}	0.53±0.44 (0.00-1.25)	0.40±0.41 (0.02-1.50)	0.54±0.49 (0.00-1.90)	0.32±0.32 (0.02-0.94)	0.40±0.29 (0.02-0.95)	0.45±0.34 (0.02-1.00)	0.54±0.55 (0.02-1.87)	5		0.61
Nitrate	mgl^{-1}	0.38±0.79 (0.01-2.22)	0.25±0.51 (0.00-1.71)	0.37±0.76 (0.00-2.09)	0.34±0.70 (0.00-1.92)	0.36±0.75 (0.00-2.01)	0.48±1.00 (0.00-2.71)	0.63±1.37 (0.01-4.29)	20		0.91
Oil & Grease	mgl^{-1}	0.01±0.00 (0.00-0.01)	0.01±0.00 (0.00-0.01)	0.01±0.00 (0.00-0.01)	0.01±0.01 (0.00-0.01)	0.01±0.00 (0.00-0.01)	0.01±0.01 (0.00-0.01)	0.01±0.01 (0.00-0.01)	10		0.20
Sodium	mgl^{-1}	2.38 ^{a} ±0.86 (0.97-3.78)	2.17 ^{a} ±0.85 (0.92-3.40)	2.40 ^{a} ±1.37 (0.87-5.60)	1.58 ^{b} ±0.43 (1.05-2.20)	1.43 ^{b} ±0.52 (0.80-2.23)	1.49 ^{b} ±0.69 (0.52-3.16)	1.58 ^{b} ±0.47 (0.64-2.32)	200		0.00
Potassium	mgl^{-1}	1.16±0.65 (0.26-2.12)	1.40±0.58 (0.84-3.22)	1.11±0.49 (0.02-2.31)	1.32±0.41 (0.79-2.03)	1.39±0.28 (1.00-2.21)	1.37±0.42 (0.71-2.54)	1.34±0.43 (0.53-2.26)	NS		0.40

Table 2. Continued.

Parameters	Unit	Lotic Stations			Lentic Stations				Limits FMEnv	WHO	p-Value
		Station 1 $\bar{X}$±SD (Min-Max)	Station 2 $\bar{X}$±SD (Min-Max)	Station 3 $\bar{X}$±SD (Min-Max)	Station 4 $\bar{X}$±SD (Min-Max)	Station 5 $\bar{X}$±SD (Min-Max)	Station 6 $\bar{X}$±SD (Min-Max)	Station 7 $\bar{X}$±SD (Min-Max)			
Magnesium	mgl^{-1}	7.73^{b} ±2.80 (5.05-18.07)	7.97^{b} ±5.06 (1.46-25.09)	8.71^{b} ±4.71 (5.68-23.07)	15.22^{a} ±7.22 (9.34-32.09)	17.86^{a} ±6.60 (8.61-30.07)	19.21^{a} ±9.39 (10.46-40.02)	20.11^{a} ±10.71 (9.73-50.00)	200		0.00
Calcium	mgl^{-1}	10.24^{d} ±2.72 (8.80-20.95)	14.33^{cd} ±6.87 (8.80-38.08)	15.91^{bc} ±9.25 (10.01-48.57)	19.47^{b} ±8.19 (10.59-40.08)	27.22^{a} ±7.90 (15.50-48.05)	31.16^{a} ±7.18 (22.21-52.15)	30.13^{a} ±7.50 (22.56-56.08)	200		0.00
Copper	mgl^{-1}	0.5049^{d} ±0.2980 (0.0100-0.9900)	0.3667^{d} ±0.3438 (0.0000-0.9800)	0.6648^{cd} ±0.3337 (0.0310-0.9900)	2.147^{a} 1±1.7335 (0.0400-6.7100)	1.1686^{bc} ±0.8236 (0.0300-2.4300)	1.2739^{b} ±0.7280 (0.0180-2.5120)	1.3930^{b} ±0.6821 (0.0790-2.6200)	<1		0.00
Iron	mgl^{-1}	1.2620^{b} ±0.4211 (0.4100-1.9200)	0.9128^{b} ±0.6612 (0.0000-1.9800)	1.2138^{b} ±0.6233 (0.0000-2.0900)	2.8258^{a} ±1.9531 (0.0100-5.9300)	2.2537^{a} ±0.9010 (0.6000-3.6230)	2.2761^{a} ±0.8486 (0.8300-3.4200)	2.7929^{a} ±1.0691 (0.8200-4.4400)	20		0.00
Lead	mgl^{-1}	0.0126^{b} ±0.0150 (0.0000-0.0500)	0.0100^{b} ±0.0115 (0.0000-0.0400)	0.0176^{b} ±0.0183 (0.0000-0.0500)	0.0357^{a} ±0.0309 (0.0000-0.1200)	0.017611^{b}±0.0152 (0.0000-0.0600)	0.0185^{b} ±0.0166 (0.0000-0.0500)	0.0207^{b} ±0.0225 (0.0000-0.0700)	<1		0.01
Zinc	mgl^{-1}	0.7575±0.3948 (0.0810-1.7500)	0.5780±0.5580 (0.0000-2.0300)	0.6353±0.4095 (0.0210-1.1500)	2.4329±1.3876 (0.0090-5.3700)	1.2024±0.5930 (0.0870-1.9100)	6.5197±22.0936 (0.0800-95.0000)	1.3139±0.5645 (0.1810-1.8850)	<1		0.33
Chromium	mgl^{-1}	0.0095±0.0146 (0.0000-0.0600)	0.0104±0.0127 (0.0000-0.0500)	0.0163±0.0184 (0.0000-0.0500)	0.0158±0.0192 (0.0000-0.0600)	0.0146±0.0174 (0.0000-0.0500)	0.0157±0.0199 (0.0000-0.0500)	0.0213±0.0285 (0.0000-0.1100)	<1		0.61
Cadmium	mgl^{-1}	0.0464^{bcd} ±0.0668 (0.0010-0.1900)	0.0116^{d} ±0.0122 (0.0010-0.0400)	0.0370^{cd} ±0.0547 (0.0000-0.1700)	0.0423^{bcd} ±0.0493 (0.0010-0.1300)	0.1144^{a} ±0.12250 (0.0000-0.3100)	0.0981^{abc} ±0.1285 (0.0000-0.3500)	0.1039^{ab} ±0.1234 (0.0000-0.3700)	<1		0.00
Cobolt	mgl^{-1}	0.0003±0.0005 (0.0000-0.0010)	0.0003±0.0005 (0.0000-0.0010)	0.0014±0.0032 (0.0000-0.0100)	0.0013±0.0032 (0.0000-0.0100)	0.0019±0.0038 (0.0000-0.0100)	0.0002±0.0004 (0.0000-0.0010)	0.0008±0.0023 (0.0000-0.0100)			0.23
Nickel	mgl^{-1}	0.0744^{b} ±0.0801 (0.0010-0.2800)	0.0558^{b} ±0.0670 (0.0010-0.2000)	0.0402^{b} ±0.0356 (0.0010-0.1000)	0.4746^{a} ±0.7804 (0.0010-2.8500)	0.1052^{b} ±0.1705 (0.0010-0.6100)	0.2574^{ab} ±0.4229 (0.0000-1.2500)	0.4429^{a} ±0.6134 (0.0010-1.8300)	<1		0.00
Vanadium	mgl^{-1}	0.0009±0.0006 (0.0000-0.0020)	0.0008±0.0004 (0.0000-0.0010)	0.0008±0.0004 (0.0000-0.0010)	0.0007±0.0006 (0.0000-0.0020)	0.0007±0.0005 (0.0000-0.0010)	0.0007±0.0005 (0.0000-0.0010)	0.0007±0.0005 (0.0000-0.0010)	<1		0.85
Manganese	mgl^{-1}	0.3757^{b} ±0.1012 (0.2100-0.6100)	0.3428^{b} ±0.2192 (0.0300-0.9500)	0.3868^{b} ±0.6080 (0.0210-1.7600)	0.9896^{a} ±0.8270 (0.0500-2.8500)	0.3933^{b} ±0.3138 (0.0400-0.9300)	0.3498^{b} ±0.3532 (0.0100-0.9000)	0.3468^{b} ±0.3983 (0.0300-1.1600)	5		0.00

Similar Superscript Row-wise – No Significant Difference
$P<0.05$ = indicates significant difference
$P>0.05$ = indicates no significant difference
NS = implies not specified

mostly less than 0.001mgL^{-1}. Nickel temporal and spatial values ranged from BDL at station 6 to 2.8500 mgL^{-1} at station 4. The minimum value was recorded in March, 2013 and the maximum value was recorded in December, 2012. Vanadium showed no specific pattern in the temporal and spatial variations, there was fluctuation in the concentrations across the stations in the various seasons. Vanadium concentrations were mostly not detected in February and March, 2013. Manganese did not show regular trends in the temporal and spatial variations from stations 1 to 7. The minimum and maximum values of manganese ranged between 0.0100 and 2.8500mgL^{-1} at stations 6 and 4 respectively. The minimum value was recorded in November, 2013 while; the maximum value was recorded in December, 2012.

Principal Component Analysis for Surface Water Parameters

The physico-chemical characteristics of the surface waters were further subjected to principal component analysis (PCA) to better ascertain the parameters influencing the health status of the waters. The Eigen value for component 1 was 4.509 and was closely followed by component 2 (Table 3). Meanwhile the varimax rotation of the generated PCA result revealed very strong factors for three parameters which were greater than 0.75 (>0.75) along component 1. The existing relationship between total dissolved solids (TDS), total suspended solids (TSS) and Cadmium could be read along load 1, indicating that as TSS was increasing so, TDS and Cd. These sources of variations were tied to stations 1, 2, 4, 5, 6 and 7 respectively between February and April, 2013, and April, 2014.

Euclidean Similarity and Distance Indices

The performance of similarity and distance indices (Table 4) showed that stations 6 and 7 were closed to each other in terms of the values obtained as well as stations 2 and 3. Apparently, station 1 was different from all others (stations 2 to 7).

Table 3. Principal Component Analysis for Physicochemical Characteristics

Parameters	Components									
	1	2	3	4	5	6	7	8	9	10
Air Temp.	0.082	0.049	0.837	-0.098	0.004	0.064	0.024	0.021	0.061	0.094
Water Temp.	-0.037	0.159	0.767	0.091	-0.164	0.060	-0.034	0.031	0.154	-0.102
Depth	-0.087	0.051	-0.194	0.003	0.089	0.017	-0.751	-0.023	-0.057	-0.080
Flow rate	-0.313	-0.543	-0.512	0.077	0.014	-0.069	0.244	-0.211	0.110	-0.112
pH	0.121	0.275	-0.093	-0.672	-0.072	-0.119	0.180	-0.097	0.254	-0.157
EC	-0.494	0.698	-0.016	0.206	0.034	0.235	-0.104	0.083	-0.139	-0.113
Turbidity	0.069	0.028	0.144	0.116	0.053	0.921	-0.069	-0.001	-0.083	0.008
Total Hardness	-0.295	0.508	-0.090	0.624	0.066	0.241	-0.088	0.203	-0.060	-0.003
DO	0.021	0.171	-0.369	0.137	0.717	-0.040	-0.168	-0.252	-0.014	-0.151
BOD	-0.436	0.465	-0.465	-0.063	0.383	0.013	-0.138	-0.122	0.097	-0.037
COD	-0.232	0.208	0.065	0.020	0.030	0.008	0.102	0.738	0.092	-0.106
TDS	0.821	-0.083	-0.068	0.196	0.076	0.282	0.164	-0.118	0.084	0.023
TSS	0.844	-0.208	0.042	-0.072	0.053	0.161	0.125	-0.215	0.052	0.087
Chloride	0.196	0.276	0.035	0.688	-0.125	-0.005	0.098	-0.150	-0.029	-0.255
Sulphate	0.208	-0.130	0.022	-0.358	-0.423	0.551	0.179	-0.015	0.162	-0.074
Phosphate	0.400	0.195	-0.252	0.151	-0.009	0.197	0.405	-0.214	0.397	0.000
Nitrate	-0.297	-0.057	0.185	-0.713	-0.008	0.189	-0.199	0.035	-0.243	-0.095
THC	-0.648	-0.181	0.339	-0.068	-0.013	0.157	0.208	-0.210	0.147	0.135
Sodium	-0.020	-0.224	-0.351	-0.013	0.042	-0.040	0.654	0.089	-0.294	-0.130
Potassium	0.043	0.289	-0.469	-0.064	-0.230	-0.069	-0.241	0.466	0.077	0.185
Magnesium	-0.084	0.877	0.115	-0.190	-0.060	-0.104	0.051	0.167	-0.109	-0.040
Calcium	0.072	0.893	0.171	0.087	-0.107	0.017	-0.135	0.005	-0.071	0.082
Copper	0.394	0.154	0.314	0.439	0.005	0.170	-0.121	0.384	0.366	0.121
Iron	0.210	0.552	0.180	0.343	0.204	0.176	-0.189	0.249	0.017	0.099
Lead	0.319	0.152	0.113	0.176	0.577	-0.180	0.126	0.372	-0.166	0.089
Zinc	0.068	0.043	0.012	0.025	0.010	-0.015	0.017	-0.040	-0.028	0.937
Chromium	-0.192	0.743	-0.234	0.289	0.119	-0.235	0.062	0.074	0.065	0.002
Cadmium	0.802	-0.020	0.160	0.079	-0.223	-0.086	-0.061	-0.166	0.057	-0.031
Cobolt	0.076	-0.147	0.103	-0.055	-0.160	-0.036	-0.053	0.053	0.685	-0.054
Nickel	0.624	0.015	0.231	-0.033	0.072	0.053	0.079	0.201	0.344	0.129
Vanadium	-0.157	-0.291	0.011	-0.241	0.688	0.110	0.001	0.061	-0.169	0.087
Manganese	0.495	-0.350	0.215	0.027	-0.090	-0.122	-0.042	0.222	0.498	0.051
Eigen values	4.509	4.489	2.923	2.667	1.933	1.702	1.662	1.633	1.573	1.218
Proportion (%)	14.090	14.027	9.135	8.336	6.039	5.320	5.195	5.102	4.917	3.806
Cum. Proportion (%)	14.090	28.117	37.253	45.588	51.627	56.948	62.143	67.245	72.162	75.967

Note: The varimax rotation of the generated PCA results can readily be interpreted. Varimax factor correlation coefficient of >0.75, 0.74-0.50 and 0.49-0.30 are considered as strong, moderate and weak factor loading respectively (Liu *et al.,* 2003).

Cluster Analysis

Dendongram for cluster analysis revealed two major arms; a (stations 6 and 7) and b (stations 3 and 4) of very close correlated relationship based on the concentration of values for the parameters (Figure 3). There was invariably no significant variation(s) amongst the characteristics trend in the study stations. Meanwhile, the trends in the chemical characteristics of station 1 out rightly differed significantly (P<0.05) from stations 2, 5, 3 and 4 along the cluster.

Discussions

Wetlands harbouring lotic and lentic ecosystems, and particularly located within a flood plain are governed by a number of factors which include the type of human dominated activities, inundation, hydrogeochemical processes and the prevailing local climatic conditions. Documented and available information on Agbede wetlands (Olomukoro & Dirisu, 2012; Olomukoro, Osamuyiamen, & Dirisu, 2013; Dirisu & Olomukoro, 2015) have it that inundation, hydrogeochemical processes and the prevailing local climatic conditions are the major players influencing the water quality conditions or the limnochemical status.

The spatial and temporal variations in air and water temperatures were primarily governed by the prevailing local climatic conditions, volume of available water particularly during inundation periods,

Table 4. Euclidean similarity and distance indices across the stations

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Station 1	0.000						
Station 2	37.470	0.000					
Station 3	35.392	18.816	0.000				
Station 4	40.600	27.712	12.876	0.000			
Station 5	43.405	21.412	19.011	17.082	0.000		
Station 6	67.133	51.157	40.535	37.020	40.630	0.000	
Station 7	77.482	65.071	51.383	45.581	52.879	23.905	0.000

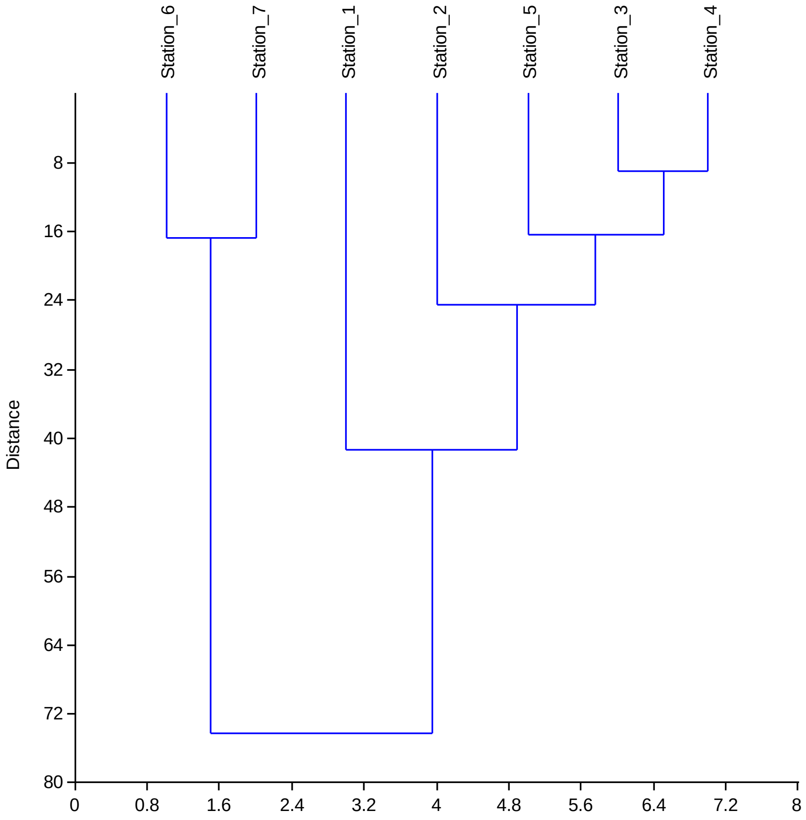

Figure 3. Dendogram for cluster analysis based on the concentrations of all the parameters.

the time of sampling and the amount of exposure to the sun's rays across the stations. Ambient temperatures were generally higher than those of water. The mean temporal and spatial values of temperatures were higher in the lentic systems (Stations 4 to 7) which could be due to their non-flow status as well as their width. The temperature values are typical of Agbede wetlands (Olomukoro & Dirisu, 2012; Olomukoro *et al*., 2013) and for inland environments in Nigeria (Ogbeibu & Victor, 1995) for Okomu Sanctuary, but slightly higher than what was recorded for a tropical forest River in Benin (Imoobe & Ohiozebau, 2009).

pH concentrations in the surface water exhibited fluctuations from a slightly acidic state to slightly alkaline condition. The acidity in pH as particularly recorded for the lotic system can be attributed to the poor carbon sequestration caused by the canopy effect and the poor macrophytes conditions. This was also applicable to the lentic environments. The poor photosynthetic effect by macrophytes resulting in acidic pH was reported (Ogbeibu & Victor, 1995). Meanwhile the pH values were typical for tropical water bodies (Olomukoro & Egborge, 2003/2004; Imoobe & Ohiozebau, 2009, Olomukoro & Dirisu, 2012) and was within FMEnv 1991 limit.

Electrical Conductivity which is a measure of the waters' capacity to conduct electricity (heat) through the available ions in solution (dissolved solids), showed much seasonal variations throughout the study across the sampled stations. The higher concentrations of conductivity in the dry season maybe due to the high rate of evaporation, coupled with increased mineralization of organic matter. These findings conform to earlier works on inland waters (Ogbeibu & Victor, 1995, Adakola, Abulode, & Balamabe, 2008). The values were over nine folds far below the 1000mgL^{-1} limit stipulated by the Nigeria Federal Ministry of Environment (1991).

Turbidity concentrations did not follow any definite seasonal pattern. The values obtained at the lentic stations were slightly above the bench mark of 5 NTU issued by FMEnv of Nigeria. However, the mean values obtained in lotic stations were slightly below 5 NTU. The increase in turbidity during the wet seasons was attributed to the influx of run-offs and the disturbance caused by Nomads, mostly around the lentic environments during grazing. This finding did not conform to the report for Edion River in Agbede wetlands (Olomukoro & Dirisu, 2012). The solubility of dissolved oxygen is mostly affected non-linearly by temperature of the surface water. Other environmental factors that could influence the amount of dissolved oxygen in the water bodies with particular reference to the lentic systems, appears to be the aquatic plants, organic pollution level, densities of fauna distribution and of course rainfall pattern (Ogbeibu & Victor, 1995). Both the lotic and lentic systems were well oxygenated when compared to the benchmark of 7.5mgL^{-1} by Federal Ministry of Environment of Nigeria. Biochemical Oxygen Demand mean values for both lotic and lentic stations did not follow any regular pattern but was similar to the trends observed for dissolved oxygen. BOD was higher during the wet season of 2013 (May to October) and during May 2014. The BOD values were far below the limit of 30mgL^{-1} set by the Federal Ministry of Environment of Nigeria and were within what have been documented for tropical inland waters (Imoobe & Ohiozebau, 2009; Olomukoro *et al*., 2013). The low BOD values may be due to the low organic pollution in both ecological types.

The mean chloride concentrations ranged of between 18.80 and 23.89mgL^{-1}indicate the freshwater status of the water bodies. The lentic environments had higher mean concentrations than the lotic stations. Excess chloride in water is known to impact the taste and could cause laxative effect in people who are not used to the water type (Jerome & Pius, 2010). The sources of chloride in Agbede wetlands include the use of soaps or detergents containing chlorides and the free chloride from geochemical weathering of the bearing rocks. The slightly high concentrations in the lentic systems could be due to their lentic characteristic like non-flow status. The lentic environments had lowest levels of oil and grease in the surface water. Abu and Egenonu (2008) reported similar values for Calabar River in the Niger Delta region of Nigeria which were much lower than what was reported by Otokunefor and Obiukwu (2005) for water bodies in the same Niger Delta.

Alkaline metals (Sodium and Potassium) are metals found in the group 1 of the periodic table, and are mostly associated with rocky geology of the study area. Even though, the mean values were low, the source of contamination is through geochemical impact of the soil's mineral compositions via run-offs. The alkaline earths metals (calcium and magnesium) cations are known to be commonly associated with surface water located at or near rocks rich in marble. Magnesium concentrations in the water bodies appear to be lower than that of calcium, indicative of the predominant mineral composition of the bearing rock materials. Alkaline earth metals may have also found their ways into the surface water via precipitation of the suspended rock particles around quarries found in neighboring towns like Auchi, Ikpeshi and Uzuare clan.

Phosphates and nitrates have often been widely adopted as indicators for Eutrophication in Lakes, ponds, reservoirs and Rivers (Ovie, 1997; Erhunmwunse, Dirisu, & Ogbeibu, 2013; Dahanayaka, Perera, Wijeyaratne, & Tonooka, 2016). The mean concentrations of phosphate, sulphate and nitrate did not show any significant difference ($P>0.05$) amongst the stations. Mean concentrations of phosphate were much below the bench mark of 5mgL^{-1}. Likewise, the values obtained for sulphate and nitrate that were 200mgL^{-1} and 20mgL^{-1} respectively. Nutrients concentrations were generally higher in the lentic systems than in the lotic systems. This fact may be due to the level of organic decomposition of the dead tree leaves and the submerged macrophytes. On the other hand, the low concentrations of nutrients in the surface water could be as a result of very low use of inorganic fertilizer, a finding similar to what was reported for a study in Agbede wetlands (Dirisu & Olomukoro, 2015).

In conclusion, this study has revealed that the physical and chemical characteristics in the surface water did not follow any definite seasonal pattern. Instead, there was series of fluctuations in the concentration values across the sampled stations and seasons. All the physical and chemical characteristics in the surface waters had their mean values within the set limits by Federal Ministry of Environment of Nigeria (FMEnv.) except for turbidity whose value was >5 NTU, copper (> $1mgL^{-1}$) and zinc (>$1mgL^{-1}$). However, we predict that human impact through agricultural activities and urbanization pose some future challenges to the quality of water bodies in Agbede wetlands. Also, hydrogeochemical weathering does have some moderate negative impacts on the water quality during surface run-offs; such was evident in turbidity, some cations like alkaline and alkaline-earth metals, chloride and zinc in some instances during this study. We strongly recommend that the entire Ogwedion and Ukatosomwa floodplains should be declared a sanctuary by the Edo State Ministry of Environment and should be afforested as well. Deforestation and unauthorised agricultural practices in any form should be grossly prevented within these districts indefinitely to allow the attainment of a sanctuary.

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