Assessment of Water Quality of Lotic and Lentic Ecosystems in Agbede Wetlands using a Multimetric Approach

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Abstract

In this study, an index method was adopted to grade the water quality of Agbede Wetlands for a period of 18 months (December, 2012 and May, 2014). On monthly basis, water samples were obtained from seven designated stations within the wetlands and analyzed for the classical parameters adopting standard methods. These parameters which included Water temperature, pH, electrical conductivity, turbidity , total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand, chloride, sulphate, phosphate, nitrate, total hydrocarbon content, sodium, potassium, magnesium, calcium, copper, cadmium, iron, lead, chromium, zinc, nickel and manganese contributed invariably to water quality of Agbede Wetlands when keyed into Water Quality Index (WQI). The mean WQI values at stations 1, 2 and 3 were in all cases <30.00, for station 5 and 6, 30< WQI <50 while for stations 4 and 7, 50< WQI <100. Thus based on the parameters characterized in this study while adopting Federal Ministry of Environment standard for surface water, the water quality at stations 1,2,3,5 and 6 were said to be excellent while those of stations 4 and 7 were good. An attempt to x-ray the contribution of individual parameter towards the WQI values showed that the principal parameters were pH, turbidity, dissolved oxygen and heavy metals which include copper, lead, zinc, cadmium and nickel. There is need to ascertain the level of microbial agents, pesticides and herbicides concentrations in Agbede Wetland as the activities witnessed at the watershed are likely to influence them.

Keywords: Principal component Analysis, Wetlands, Watershed, Water Quality Index, Environment, Nigeria.

Introduction

A number of indices have been developed to summarize water quality data in an easily expressible and easily understood format. Water Quality Index (WQI) is believed to have been first developed by Horton between the late 1960s and the early 1970s as a basic mathematical means of calculating a single value from multiple test results. The index results represents the level of water quality in a given water basin such as; river or stream (Miller *et al.*, 1986; Kumar and Dua, 2009; Alam and Pathak, 2010). After Horton a number of workers all over the world have developed WQI based on rating of different water quality parameters (Kumar and Dua, 2009). The index would normally produce numbers 50 ≤ WQI (very good) ≤ 100, 50 ≤ WQII (good water quality) ≤ 100, 100 ≤ WQII (poor) ≤ 200, 200 ≤ WQIII(very poor) ≤ 300 and WQIV (not suitable for consumption)> 300 (Table 1).

Table 1: Water Quality Index (WQI) Statutory Standard

WQI Levels	Description
< 50	Excellent
50 – 100	Good
100 – 200	Poor
200 – 300	Very poor (bad) water
> 300	Unsuitable (unfit)for drinking

Source: (Ramakrishniah *et al.*, 2009)

Aquatic ecologists have variously attempted to investigate and review the water qualities of some water bodies around the globe (e. g. Kumar and Dua, 2009; Saxena and Gangal, 2010; Fagbote *et al.*, 2014; Jeromi and Pius, 2010; Dirisu and Olomukoro, 2015).The quality of water bodies vary widely depending on the location and environmental factors. Some of the factors determining the qualities of surface and ground waters are the chemical composition of the underlying rocks, soil formations and length of time the water body has been trapped underground (Faniran *et al.*, 2001; Fagbote *et al.*, 2014). Fagbote *et al.*, (2014) investigated the water quality index of the ground water of bitumen deposit impacted farm settlements using entropy weighted method. The study revealed that the values obtained for conductivity, pH, turbidity, phosphate ions and total coliform in some of the wells were out of the recommended range for drinking water.

The foremost study carried out on water quality in Agbede wetlands using water quality index (WQI) was the one by Dirisu and Olomukoro (2015) on the investigation of water quality of two Rivers in Agbede wetlands in Southern Nigeria. The water quality condition was observed to be between good and poor as WQI values ranged between 70.942 at station 2 and 10612.020 at station 1 located on the same river. The present study attempts to compare the environmental conditions and the water quality of lotic and lentic ecosystems in the same Agbede wetlands on a long term basis using water quality index model. It will also be regarded as a major baseline archived for streams and ponds in Agbede wetlands for water monitoring projects and modeling in future. The study was also designed to compare the water quality of highly used lotic and lentic ecosystems therein by using water quality index (WQI) and multivariate analyses as standards for comparisons. Hence, this work is of paramount importance as it serves as a major data source for future studies and ecosystems monitoring in Edo – North regarding water quality.

Materials and Methods

Description of Study Area

The study area is located within the latitude 06^{0}52.2″N, 07^{0}00.0″N and longitude (06^{o}16.3″ E, 06^{o} 18.7″E), a part of Agbede town located in Etsako West Local Government area of Edo State (Figure 1). The characteristic features of the locality have been described exhaustively (Dirisu and Olomukoro, 2015). The locality is mostly dominated by agrarian practices including mining and logging activities. A total of seven sampling stations were designated for this study and included one river (with three stations) and three Ponds (with four stations). All the stations were carefully chosen based on accessibility particularly during inundation period which occurs between June and September annually.

Station 1 is on the stretch of Omodo Stream located just by the confluence between Omodo and Egwavo Streams accessible through Ayuele Secondary School. The topography is characteristically steep v-valleys due to high soil erosions experienced in the area when it rains. The area also has dense vegetation dominated by the Bambusa plants (*Bambusa* sp). All forms of human activities which included; bathing, washing of clothes, fermentation of cassava and fishing take place here. Station 2 is located at Odighie village by the bridge linking Agbede and Amah/Idegun towns which is over 1.3km from Station1. Washing of auto-bikes, bathing and washing of clothes are the major

human impact here. Station 3 is about 1.6km from station 2 and is located by the bridge at Egho village unto Rabho- Imes farms district. It is the major source of water for every form of activity like drinking, washing and bathing by the various Farm Camps. Station 4is the pond before Edion
River when transiting to Auchi town by Ogwedi on farm settlements. It is a major source of drinking water to the cattle rearing and nomads and a nesting ground for some bird species like white cattle egret, and weaver birds. It is fed by Edion River during the pick of wet seasons. There is a sparse distribution of rooted macrophytes such as *Nymphae lotus, Sacciolepis africana* and *Chromolenaodorata* in this site. Station 5 is a major but easily accessible pond at Ukatosoma farm district. It is mostly surrounded by cassava (*Manihot* sp) and yam (*Discoria* sp) farms. It is also a major fishery ground which is harvested bi-annually by the commuities. There are lots of macrophytes here (*Nymphae lotus* and *Acroleraszizanoides*) and the banks are surrounded by deciduous trees. Station 6 is about I km away from station 5 while travelling towards Auchi town. It is a major source of drinking water to cattle herds within Ukatosoma farm district in Agbede town. It is mostly surrounded by Gmelina trees (*Gmelina gmelina*) with macrophytes (*Nymphae lotus* and *Sacciolepis africana*). Station 7 is the second station established on the same pond described in station 6 above. It is located at less than 10m away from the high-way. There were yam farms on the west bank. Macrophytes are in abundance here and the dominant species included; *Sacciolepisafricana and Chromolenaodorata*.

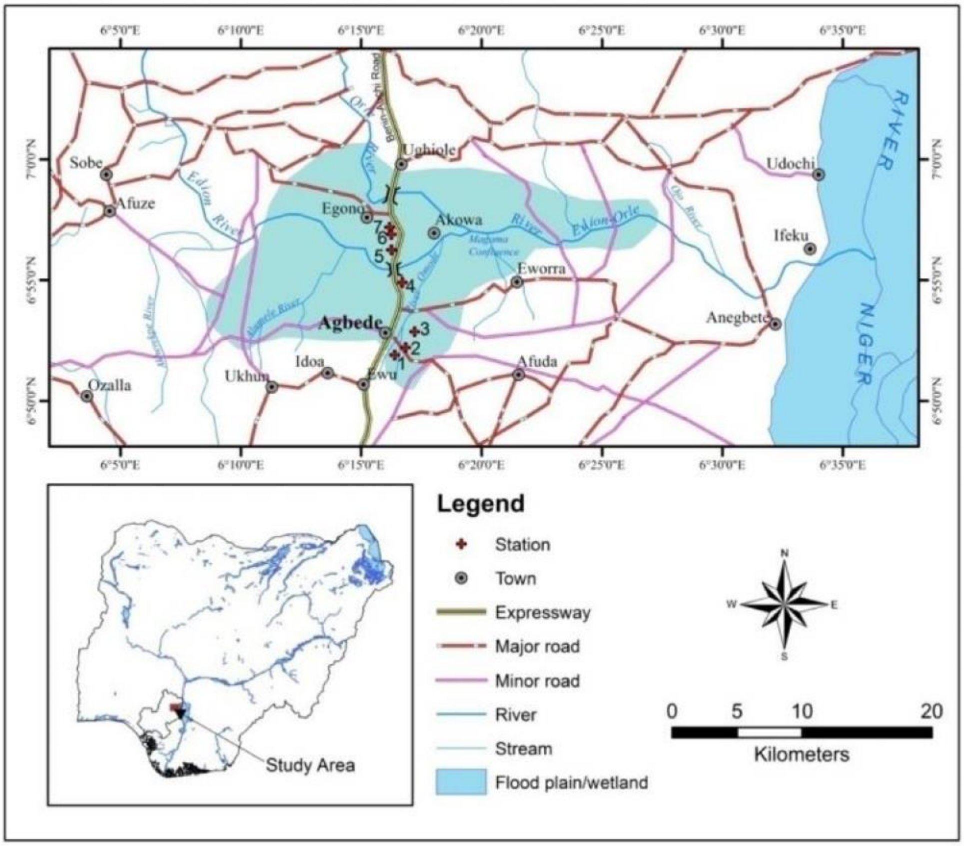

Figure 1: Map of the Study Area

Water Sampling and Analyses

Monthly water sampling was carried between December, 2012 and May, 2014 at each of the seven sampling station between 0900hr and 1200hr every sampling day. A total of 126 composite samples were collected throughout the study period. All sample containers were thoroughly washed before sampling and each sampling station had 18 replicate water sampled for physical and chemical analyses which were collected from the sub-surface into sample containers and preserved as appropriate for laboratory analysis according to standard procedures (APHA, 2005).

Water temperature was measured in-situ using mercury – in – glass thermometer calibrated from 0^{o}C – 100^{o}C (Krisson model-59). 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, Biochemical oxygen demand (BOD_5) and chemical oxygen demand were estimated in the laboratory according to APHA (2005). Chloride was determined in the laboratory by the argentometric method 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). Sodium and potassium cations were determined using a Conning flame photometer IV and Lithium being the references filter. Magnesium and calcium were determined using the EDTA method (APHA, 2005). Heavy metals namely, Fe, Zn, Cu, Cr, Cd, pb, Mn and Ni were determined in the laboratory (APHA, 2005) using the Atomic Absorption Spectrophotometer (Thermol Jarrel Ash Smith Heiftje II Model 757).

Data Analyses

The surface water physico-chemical data were subjected to one – way analysis of variance test (ANOVA) for mean, minimum and maximum values using the SPSS version 20.0. We used Palaeontologial Statistics (PAST 1.99) to carry out multivariate analysis such as principal component analysis (PCA) and multiple regression test (MR). Graphs were plotted using MS- excel for window – 7 and PAST.

Determination of Water Quality Index (WQI)

Calculation of water quality index was to turn complex water quality data into information that is understandable and useable by the public. Therefore, water Quality Index (WQI) is a very useful and efficient method which can provide a simple indicator of water quality and it is based on some very important parameters. The parameters adopted in this study include: Water temperature, pH, electrical conductivity, turbidity , total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand, chloride, sulphate, phosphate, nitrate, total hydrocarbon content, sodium, potassium, magnesium, calcium, copper, cadmium, iron, lead, chromium, zinc, nickel and manganese.

Water Quality Index (WQI) was computed on a programmed Excel sheet by using the Weighted Arithmetic Index method as described by Ramakrishniah *et al.*, (2009) and the values obtained were compared with Table 1. In this model, different water quality components were multiplied by a weighting factor and were then aggregated using simple arithmetic mean.

For assessing the quality of water in this study, firstly, the quality rating scale (Qi) for each parameter was calculated by using the following equation; ø = {[(Å – Ï) / (Ş – Ï)] * 100} 1

Where ø = Quality rating of i^{th} parameter for a total of n water quality parameters

Å = Actual value of the water quality parameter obtained from laboratory analysis

Ï = Ideal value of that water quality parameter can be obtained from the standard Tables. Ï for pH = 7 and for other parameters it is equaling to zero, but for DO, Ï= 14.6 mgL^{-1}

Ş = Recommended Federal Ministry of Environment permissible limits standard of the water quality parameter.

Then, after calculating the quality rating scale (ø), the Relative (unit) weight (Ŧ) was calculated by a value inversely proportional to the recommended standard (Ş) for the corresponding parameter using the following expression;

Ŧ = 1/ Ş 2

Where

Ŧ = Relative (unit) weight for nth parameter
Ş = Standard permissible value for nth
parameter 1 = Proportionality constant.

Finally, the overall WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

WQI = Σ Ŧ ø / Σ Ŧ 3

Where, ø = Quality rating

Ŧ = Relative weight in general,

WQI is defined for a specific and intended use of water. In this study the WQI was considered for human consumption or uses and the maximum permissible WQI for the drinking water was taken as 100 score.

Principal Component Analysis and Multiple Regressions

Principal component analysis (PCA) was applied to summarize the statistical correlation amongst the parameters and further identify the parameter(s) that were most influenced in these aquatic ecosystems. The varimax rotation of the generated PCA results was adopted and a rotation of principal components (PCs) can achieve a simpler and more meaningful representation of the underlying factors by decreasing contributions to PCs by variables with minor significance and increasing the more significant ones. Rotation produces a new set of factors, each involving primarily a subset of original variables with as little overlap as possible, so that the original variables are divided into groups somewhat independent of each other (Sharaf *et al.,* 1986). Although rotation does not affect the goodness of fitting of principal components solution (communalities),the variance explained by each factor is modified (Razmkhah *et al.,* 2010). Thus PCA is designed to transform the original variables into new, uncorrelated variables (axes), called the principal components, which are linear combinations of the original variables. The new axes lie along the directions of maximum variance.

The principal components can be expressed as:

$$Z_{ij}=\alpha_{i1}x_{1j}+\alpha_{i2}x_{2j}+\alpha_{i3}x_{3j}+\ldots+\alpha_{im}x_{mj} \qquad 4$$

Where z is the component score, α is the component loading, x the measured value of variable, i is the component number, j the sample number and m the total number of variables.

Multiple regression (MR) was adopted in order to ascertain the gross influence of the various PC on the variation of WQI output. MR evaluates how multiple independent variables are related to a dependent variable. The WQI value was assigned as the dependent variable while the residual outputs of PCA were adopted as the independent variable.

$$y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots\ldots + \beta_KX_K + \varepsilon \qquad 5$$

Where X_1, X_2 ……. X_K is the independent variable, β_0 is the y-intercept or constant, β_1 β_2 and β_K are the coefficient of first, second and K variables respectively while ε is the residual that cannot be explained by the model.

Results

Environmental Condition

The result of the twenty-seven (27) physico-chemical characteristics in the surface water with the summary containing the minimum, maximum, standard deviation and mean values are presented in Tables 2a and 2b. All the physical and chemical characteristics of the surface waters had their concentration values within the set limits of the Federal Ministry of Environment of Nigeria (FMEnv), except for Turbidity, Copper and Zinc whose mean concentration values were >5mgL^{-1}, >1 mgL^{-1} and 1 mgL^{-1} respectively at stations 4 to 7 (the lentic environments). Generally, the values obtained for nutrients (Nitrate and Phosphate) and alkaline earth-metals (Calcium and Magnesium) were slightly higher in the lentic ecosystems. Also the concentrations of calcium dominated that of magnesium in both the lotic and lentic systems. 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.

 Dirisu and Ezenwa (2016)

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

		Lotic Stations			Lentic Stations				
		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Limits
Parameters	**Unit**	$\bar{X}\pm SD$ (Min-Max)	$\bar{X}\pm SD$ (Min-Max)	$\bar{X}\pm SD$ (Min-Max)	$\bar{X}\pm SD$ (Min-Max)	$\bar{X}\pm SD$ (Min-Max)	$\bar{X}\pm SD$ (Min-Max)	$\bar{X}\pm SD$ (Min-Max)	**FMEnv**
Water Temperature	^0C	25.42 ±1.77 (20.00-28.00)	25.75 ±1.96 (20.00-28.00)	26.58±1.78 (22.00-30.00)	29.11±1.64 (26.00-32.00)	27.36±1.46 (24.50-29.00)	28.17±1.55 (25.00-30.00)	27.92 ±1.57 (25.00-30.00)	35
Flow Rate	ms^{-1}	0.27 ±0.06 (0.20-0.50)	0.30 ±0.07 (0.19-0.50)	0.33±0.12 (0.09-0.50)	0.00±0.00 (0.00-0.00)	0.00±0.00 (0.00-0.00)	0.00±0.00 (0.00-0.00)	0.00 ±0.07 (0.00-0.00)	NS
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)	6.5-8.5
Electrical Conductivity	μScm^{-1}	29.78 ±13.61 (3.92-48.00)	31.26 ±17.00 (3.48-56.00)	35.75 ±25.13 (3.54-80.00)	39.63 ±31.04 (3.03-90.00)	37.17 ±28.17 (3.11-76.00)	61.33 ±52.36 (2.67-140.00)	62.87±46.60 (2.76-130.00)	1000
Turbidity	NTU	4.39 ±5.33 (0.00-16.50)	3.34±5.76 (0.00-18.50)	4.54±6.07 (0.00-20.50)	6.11±10.41 (0.00-34.00)	6.06 ±12.12 (0.00-39.00)	9.57 ±19.24 (0.05-62.00)	21.25 ±31.46 (0.04-78.20)	5
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
Dissolved Oxygen (DO)	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
Biochemical Oxygen Demand (BOD)	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)	0.0
Chemical Oxygen Demand (COD)	mgl^{-1}	18.80 ±5.97 (12.15-30.00)	24.23 ±11.47 (14.83-64.00)	27.42±9.12 (13.00-41.52)	34.84±10.15 (15.00-50.60)	33.29 ±19.37 (19.68-96.00)	18.42 ±3.72 (15.19-25.80)	28.84±11.91 (13.26-48.09)	NS
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)	500
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)	<10
Chloride	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)	200
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
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

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)	10

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

		Lotic Stations			Lentic Stations				
		Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**	**Station 7**	**Limits**
Parameters	**Unit**	**$\bar{x}$±SD (Min-Max)**	**$\bar{x}$±SD (Min-Max)**	**$\bar{x}$±SD (Min-Max)**	**$\bar{x}$±SD (Min-Max)**	**$\bar{x}$±SD (Min-Max)**	**$\bar{x}$±SD (Min-Max)**	**$\bar{x}$±SD (Min-Max)**	**FMEnv**
Sodium	mgl^{-1}	2.38 ±0.86 (0.97-3.78)	2.17 ±0.85 (0.92-3.40)	2.40 ±1.37 (0.87-5.60)	1.58±0.43 (1.05-2.20)	1.43±0.52 (0.80-2.23)	1.49±0.69 (0.52-3.16)	1.58±0.47 (0.64-2.32)	200
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
Magnesium	mgl^{-1}	7.73±2.80 (5.05-18.07)	7.97±5.06 (1.46-25.09)	8.71±4.71 (5.68-23.07)	15.22±7.22 (9.34-32.09)	17.86±6.60 (8.61-30.07)	19.21±9.39 (10.46-40.02)	20.11±10.71 (9.73-50.00)	NS
Calcium	mgl^{-1}	10.24 ±2.72 (8.80-20.95)	14.33±6.87 (8.80-38.08)	15.91±9.25 (10.01-48.57)	19.47±8.19 (10.59-40.08)	27.22±7.90 (15.50-48.05)	31.16±7.18 (22.21-52.15)	30.13±7.50 (22.56-56.08)	NS
Copper	mgl^{-1}	0.5049±0.2980 (0.0100-0.9900)	0.3667 ±0.3438 (0.0000-0.9800)	0.6648±0.3337 (0.0310-0.9900)	2.1471±1.7335 (0.0400-0.7100)	1.1686±0.8236 (0.0300-2.4300)	1.2739 ±0.7280 (0.0180-2.5120)	1.3930±0.6821 (0.0790-2.6200)	0.1
Iron	mgl^{-1}	1.2620±0.4211 (0.4100-1.9200)	0.9128±0.6612 (0.0000-1.9800)	1.2138±0.6233 (0.0000-2.0900)	2.8258±1.9531 (0.0100-5.9300)	2.2537 ±0.9010 (0.6000-3.6230)	2.2761±0.8486 (0.8300-3.4200)	2.7929±1.0691 (0.8200-4.4400)	10
Lead	mgl^{-1}	0.0126±0.0150 (0.0000-0.0500)	0.0100±0.0115 (0.0000-0.0400)	0.0176 ±0.0183 (0.0000-0.0500)	0.0357±0.0309 (0.0000-0.1200)	0.017611±0.0152 (0.0000-0.0600)	0.0185±0.0166 (0.0000-0.0500)	0.0207±0.0225 (0.0000-0.0700)	0.05
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
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)	0.05

Cadmium	mgl^{-1}	0.0464±0.0668 (0.0010-0.1900)	0.0116 ±0.0122 (0.0010-0.0400)	0.0370 ±0.0547 (0.0000-0.1700)	0.0423±0.0493 (0.0010-0.1300)	0.1144 ±0.12250 (0.0000-0.3100)	0.0981±0.1285 (0.0000-0.3500)	0.1039±0.1234 (0.0000-0.3700)	0.01
Nickel	mgl^{-1}	0.0744±0.0801 (0.0010-0.2800)	0.0558±0.0670 (0.0010-0.2000)	0.0402 ±0.0356 (0.0010-0.1000)	0.4746±0.7804 (0.0010-2.8500)	0.1052±0.1705 (0.0010-0.6100)	0.2574±0.4229 (0.0000-1.2500)	0.4429 ±0.6134 (0.0010-1.8300)	0.05
Manganese	mgl^{-1}	0.3757±0.1012 (0.2100-0.6100)	0.3428 ±0.2192 (0.0300-0.9500)	0.3868 ±0.6080 (0.0210-1.7600)	0.9896±0.8270 (0.0500-2.8500)	0.3933±0.3138 (0.0400-0.9300)	0.3498 ±0.3532 (0.0100-0.9000)	0.3468 ±0.3983 (0.0300-1.1600)	0.05

NS = implies not specified

Water Quality Index (WQI)

Water quality index was performed and used as a reliable tool to better assess the quality or suitability of the surface waters in the wetlands throughout the eighteen months sampling regime. The trends in the spatial and temporal variations in WQI values are presented in Figures 2 and 3.

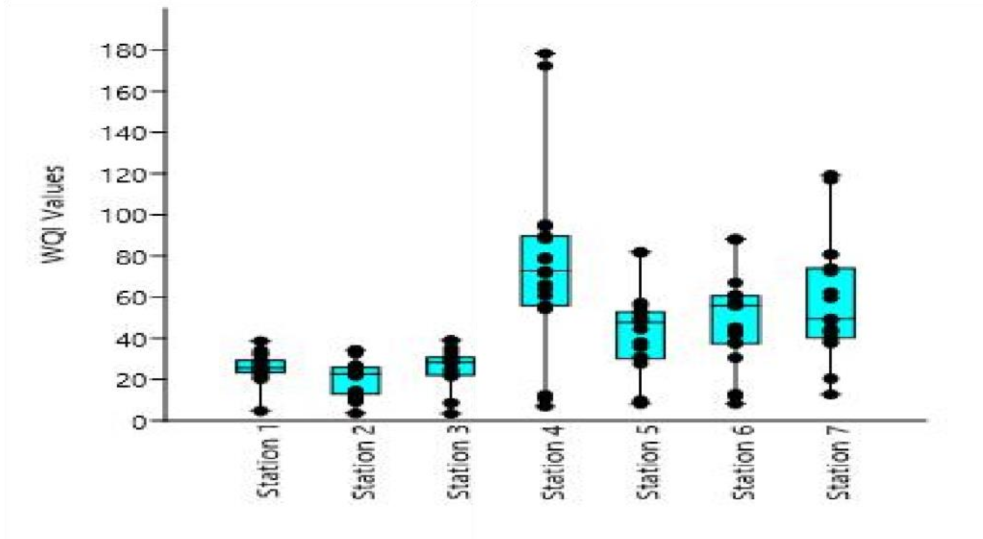

Figure 2: Box and Jitter Plot of Water Quality Index Trends across the Stations

Table 3 presents the summary of the mean, standard deviation, minimum and maximum values of WQI across the study stations. The mean WQI values ranged between 20.02 at station 2 and 75.05 at station 4. Minimum and maximum WQI values were between 3.38 at station 3 and 178.28 at station 4 respectively. Generally, water quality index was excellent amongst stations 1 through 3 (the lotic systems) and only read excellent at station 5 (lentic system) (Table 3). The temporal and spatial variations of WQI across the study area revealed series of fluctuations (Figure 3). Temporally variations within the lotic system maintained closed ranges when compared to that of lentic systems, similarly the mean values of lotic systems were relatively similar. During the beginning of this study, stations 4 and 7 (lentic systems) had high values of WQI which were beyond the bench mark of 100, and indicating poor quality of water.

Table 3: Summary of the Mean (± SD**) for Water Quality Index across the Sampled Stations. (Values in parenthesis are minimum and maximum values)**

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
WQI	25.84±7.17 (4.73-38.65)	20.02±9.15 (3.60-34.14)	25.87±10.07 (3.38-39.05)	75.05±45.55 (6.87-178.28)	42.38±21.33 (8.22-81.92)	47.86±22.89 (8.23-88.22)	58.06±28.78 (12.81-119.18)

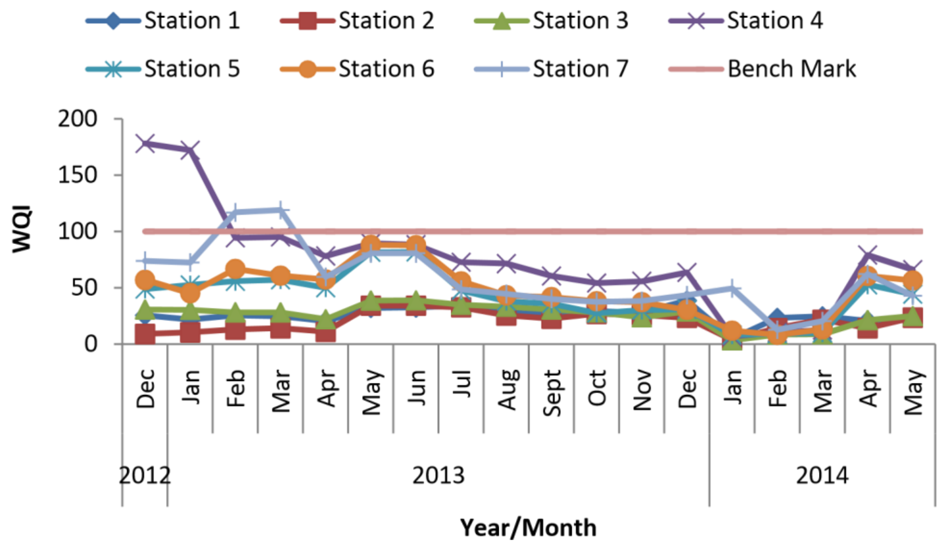

Figure 3: Spatial and Temporal Variations in Water Quality of Agbede Wetlands

Principal Component Analysis and Multiple Regression Approach

Principal component analysis was performed on the data set individually for the lotic and lentic systems. The screen plots (Figures 4 and 5) were used to identify the number of principal components (PCs); even though it has been suggested to use all the PCs up to and including the first one after the brake, again default software criteria of Eigen values greater than unity was used for determining the number of PCs to be retained. Projection of the original variables on the subspace of the PCs are called loading, this coincides with the correlation coefficients between PCs and variables (Vega *et al.*, 1998; Razmkhah *et al.*, 2010). And the component loadings were used to determine the relative importance of a variable as compared to other variables in a PC; these do not reflect the importance of the component itself (Ouyang *et al.*, 2006).

The screen plot (Figure 4) showed gradual change of slope after the 8th eigen value but seven principal components were retained, which had eigen values greater than unity and explained 78.13% of the variance or information contained in the original data set (Table 4). PC 1 accounting for 17.94% of the total variance in the data sets of the water showed strong loadings for TDS, TSS, chloride, cadmium and nickel, a moderate and inverse loading was related to COD. PC 2 that accounted for 14.64% of the total variance had strong loadings for magnesium, calcium and chromium, moderate loading for EC and moderate negative loading for vanadium. PC 3 which accounted for 10.01% of the variance had strong loading for BOD_5 and DO and moderate loading for zinc. PC 4 accounted for 9.56% of the total variance had strong loading for turbidity, moderate loading for lead and sodium and strong negative loading for pH. PC 5 associated to 9.15% of the total variance loaded strongly for copper and moderately for phosphate; the component had negative strong load for nitrate. PC 6 accounted for 8.48% of the total variance and had strong loading for sulphate and manganese, and moderate negative loading for iron while PC 7 which accounted for 8.35% of the total variance showed strong loadings for temperature and THC.

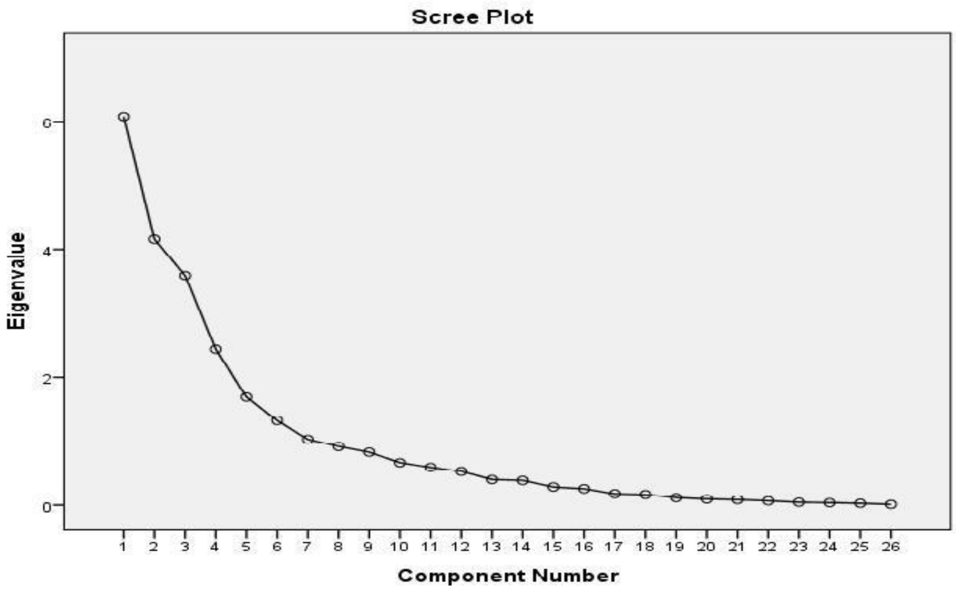

Figure 4: Screen plot of Eigen values in the Lotic System

For the lentic systems, the eight PCs which had eigen values greater than unity (Figure 4) accounted for approximately 77.47% of the total variance in the original water data sets (Table 5). The PCs 1, 2, 3, 4, 5, 6, 7 and 8 accounted for 19.80%, 15.06%, 10.75%, 7.18%, 6.83%, 6.75%, 6.36%, and 4.75% of the variance respectively. PC 1 associated strong loadings to EC, BOD, magnesium, calcium and chromium and moderate negative loading to manganese. PC 2 loaded strongly for TDS, phosphate and nickel and moderately for TSS and copper. PC 3 associated strong and moderate negative loadings to pH and nitrate respectively; the same component loaded strongly and moderately to chloride and iron respectively. Turbidity was strongly loaded in PC 4 whereas in PC 5, vanadium loaded strongly while DO together with lead loaded moderately. In PCs 6 and 7, strong loading and negative loadings were attributed to COD and water temperature respectively. Also in PC 7, moderate loading was attributed to sulphate while, zinc in PC 8 loaded strongly.

Table 4: Principle component matrix of the Various Lotic Systems' Principal Components

Parameters	Principal Components						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Water Temperature	-0.009	0.116	-0.207	0.072	0.194	0.167	0.853
pH	-0.067	-0.100	0.017	-0.778	-0.083	0.335	-0.091
EC	-0.573	0.562	0.098	-0.100	0.024	-0.336	0.229
Turbidity	-0.136	-0.326	0.224	0.806	-0.099	0.027	0.196
DO	0.100	-0.088	0.868	0.069	-0.087	-0.162	-0.202
BOD_5	-0.442	0.294	0.720	0.111	0.016	0.026	-0.059
COD	-0.561	0.135	0.094	-0.181	0.531	0.104	-0.113
TDS	0.773	-0.206	0.210	0.282	0.067	0.148	-0.307
TSS	0.853	-0.231	0.006	-0.001	-0.047	0.072	-0.261
Chloride	0.811	0.267	-0.217	-0.075	0.090	0.240	0.114

Sulphate	0.088	-0.034	-0.356	-0.138	-0.267	0.726	0.200
Phosphate	0.437	-0.092	0.267	-0.291	0.612	0.049	0.252
Nitrate	-0.391	-0.141	0.199	-0.312	-0.758	0.014	0.079
THC	-0.207	-0.127	-0.168	0.043	-0.135	0.089	0.796
Sodium	0.286	-0.377	-0.299	0.507	0.282	0.175	-0.135
Magnesium	0.013	0.888	0.032	-0.148	0.085	-0.086	-0.087
Calcium	-0.168	0.858	0.011	-0.103	0.028	-0.016	-0.026
Copper	-0.095	0.363	0.062	0.263	0.739	-0.191	0.070
Iron	-0.382	0.352	0.322	0.058	0.294	-0.518	-0.108
Lead	0.095	-0.075	0.447	0.682	0.260	-0.012	-0.201
Zinc	-0.042	0.258	0.564	0.167	0.238	0.095	-0.357
Chromium	-0.121	0.754	0.203	0.094	0.303	-0.240	-0.103
Cadmium	0.714	-0.142	0.120	-0.057	0.130	0.092	-0.143
Nickel	0.756	0.088	-0.236	0.019	0.071	0.010	0.175
Vanadium	-0.117	-0.660	0.061	0.055	-0.085	-0.445	-0.306
Manganese	0.172	-0.084	0.170	-0.076	0.128	0.821	0.052
Eigen values	4.663	3.805	2.602	2.486	2.380	2.205	2.173
Proportion (%)	17.935	14.635	10.006	9.561	9.153	8.480	8.358
Cum. Proportion (%)	17.935	32.570	42.576	52.137	61.290	69.770	78.127

To complement the WQI with PCA, we used multiple regressions (stepwise method) to order the variations in water quality to PCA axis. In the lotic system, variations in water quality were attributed to PCs 5, 4, 3 and 2. PCs 5, 4, 3 and 2 all regressed highly significantly ($p<0.01$) in influencing the quality of water in the lotic system. According to the model summary of the analysis, these PCs accounted for 81.3% of the water quality variations in the lotic system and their coefficients were positive. In the lentic system, variations in water quality were mostly associated with PCs 2, 3, 1, 4, 6 and 7 and they altogether accounted for 87.7%of the water quality variations in the system. The various PCs as indicated as major factors influencing the water quality of the lentic system regressed highly significantly ($p<0.01$). Excluding PC 1, the other PCs indicated positive coefficient.

Table 5: Principle component matrix of the Various Lentic Systems' Principal Components

	Principal Components							
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Water Temp.	-0.335	-0.086	-0.053	0.188	-0.110	-0.045	-0.741	-0.157
pH	0.300	0.367	-0.739	-0.122	-0.065	-0.048	-0.132	-0.102
EC	0.779	-0.255	0.203	0.288	0.016	0.213	-0.146	-0.039
Turbidity	-0.036	0.159	0.107	0.865	0.054	-0.034	0.092	-0.102
DO	0.373	-0.043	0.294	-0.079	0.648	-0.398	-0.054	-0.197
BOD_5	0.787	-0.213	-0.046	0.038	0.300	-0.176	-0.087	-0.021
COD	0.064	-0.152	0.109	-0.045	0.052	0.805	0.094	-0.109

TDS	-0.266	0.758	0.210	0.112	-0.001	-0.247	0.269	-0.138
TSS	-0.441	0.618	-0.066	0.029	0.084	-0.307	0.454	-0.066
Chloride	0.291	0.110	0.780	-0.023	-0.052	0.043	-0.088	-0.140
Sulphate	-0.153	0.104	-0.142	0.255	-0.157	0.108	0.622	0.055
Phosphate	0.219	0.770	0.079	0.168	-0.162	-0.195	0.205	-0.084
Nitrate	-0.081	-0.493	-0.634	0.166	0.105	0.163	0.145	-0.087
THC	0.046	-0.380	-0.159	0.421	-0.058	0.234	-0.144	0.483
Sodium	0.454	0.052	-0.391	-0.379	0.070	0.346	0.229	-0.186
Magnesium	0.819	-0.147	-0.265	-0.203	-0.031	0.247	0.060	-0.059
Calcium	0.849	0.048	0.183	-0.043	-0.145	-0.142	0.187	0.057
Copper	-0.256	0.599	0.488	0.115	-0.045	0.261	-0.195	0.125
Iron	0.317	0.329	0.544	0.127	0.194	0.137	0.062	-0.019
Lead	-0.008	0.213	0.199	-0.406	0.635	0.259	0.080	0.030
Zinc	-0.036	0.068	0.052	-0.131	0.085	-0.153	0.192	0.836
Chromium	0.832	0.053	0.256	-0.268	0.031	0.143	-0.065	0.016
Cadmium	-0.384	0.470	0.120	-0.200	-0.329	-0.392	0.285	-0.190
Nickel	-0.280	0.796	-0.088	-0.081	0.076	0.099	-0.047	0.134
Vanadium	-0.090	-0.163	-0.248	0.256	0.760	0.075	-0.055	0.163
Manganese	-0.672	0.475	0.046	-0.285	-0.021	0.100	-0.126	0.064
Eigen values	5.147	3.915	2.796	1.866	1.776	1.754	1.654	1.235
Proportion (%)	19.796	15.056	10.752	7.178	6.830	6.747	6.360	4.750
Cum. Proportion (%)	19.796	34.852	45.604	52.782	59.612	66.360	72.719	77.469

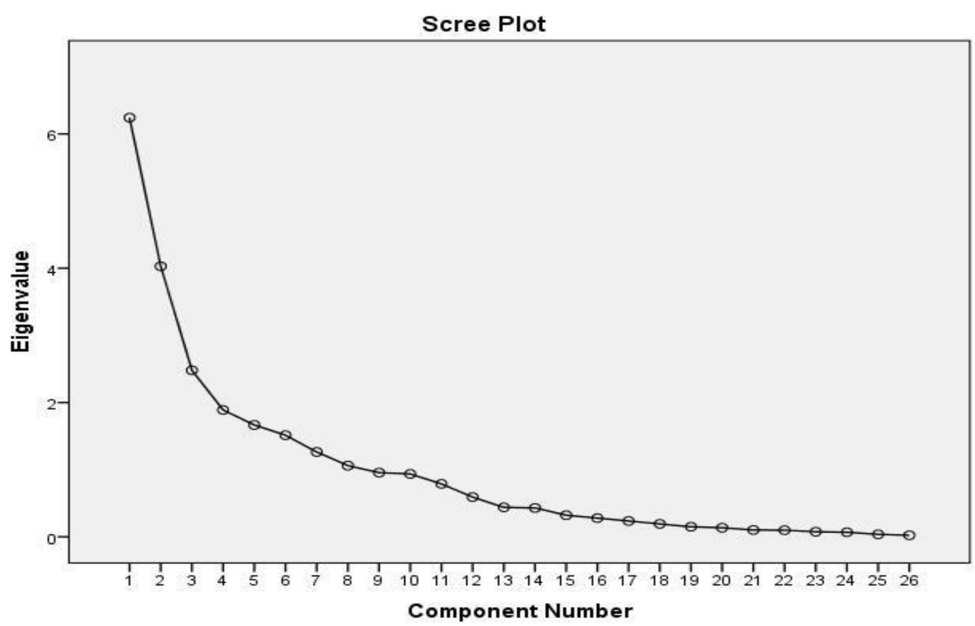

Figure 5: Screen plot of Eigen values in the Lentic System

Discussion

Water Quality

Water quality condition was better amongst the lotic ecosystem (stations 1 to 3) with WQI values below 50 which was an indication of excellent water (Ramakrishniah *et al.* 2009). The lentic ecosystems had values between >50 and <200 with station 4 far above the bench mark of 100 (Ramakrishniah *et al.*, 2009), particularly during December, 2012 and January, 2013, and thereafter maintained a gradual improvement between February, 2014 and March, 2014. Station 7 had an abrupt increase in WQI values in February and March, 2014. Apparently, stations 6 and 7 had its water quality as good (between 50 and 100). The temporal variations as stated above are generally controlled by precipitation and the influence of precipitation on WQI values has widely been documented (Yogendra and Puttaiah, 2008; Ashwani and Anish, 2009; Khwakaram *et al.*, 2012).

It is important to note that the characteristics that played dominant role in the overall variations in the water quality of Agbede wetlands include; pH, turbidity, dissolved oxygen and heavy metals such as copper, lead, zinc, cadmium and nickel. The products of the quality rating (ø) and relative weight – (Ŧ) showed that the impacts of the parameters listed above were more felt in the lentic systems than the lotic system. These differences can be attributed to the fact that lentic systems serve as a sink as well as a reservoir and also its rate of exchange is minimal compare to lotic systems. Relationships among these characteristics listed above accordingly can be explained as follows: increase in turbidity reduces light penetration into the water and hence hampers the rate of photosynthesis which in turn reduces the released oxygen in the system. Hence, the inclusion of dissolved oxygen as one of the principal characteristics contributing to the overall water quality of the ecosystems. In relation to heavy metals enumerated above, their availability can be influenced by the pH of the system. The solubility of heavy metals is influence by pH, thus low pH increases the solubility of heavy metals (Radojevic and Bashkin, 1999).

Furthermore, lower values of WQI in the lotic system characterized physicochemically which of course marked good water quality could be better explained by the theory of self purification. Now, the lotic environment is able to distribute and redistribute its water temperatures and also gain dissolved oxygen faster while the stream was running. Hence, the recovering from the induced stresses caused by human activities majorly such as bathing, washing of clothes and automobiles, herds' activities and the recipient of run-offs. It is obvious that water quality was better in the lotic environments with WQI values below 50 the bench mark (excellent water) while the lentic systems had it good in terms of water quality values (between 50 and 100). However, high intra-variations in WQI value of station 4 were occasioned by high variability in the levels of pH, zinc, cadmium and nickel. Based on physicochemical parameters characterized in this study, water quality of Agbede Wetlands was rated fit for agricultural and domestic consumptions in this study (see values in Table 3 and Figures 2 and 3 respectively).

Principal Component Analysis (PCA)

Most recently, source identification of potentially toxic pollutants is mostly conducted by index methods (Xu *et al.,* 2014; Luo *et al*., 2015), or by means of multivariate analysis to group natural and key anthropogenic input types (Yuan *et al.,* 2004; Mamat *et al.,* 2014; Luo *et al.,* 2015; Soltani *et al.,* 2015). With the aid of PCA, multiple signatures of natural and human activities on the watershed are clearly reflected in these studied aquatic ecosystems physically and chemically. The first component (PC 1) having TDS and TSS together with chloride, cadmium, nickel and COD reflect natural impact involving seasonal variation in precipitation and anthropogenic activities that lead to turbulence of the system. The solids that gain entrance into this ecosystem occurs inform of organic and inorganic. Organic mirrored by COD and inorganic reflected by other parameters order than TDS and TSS having strong loadings in PC 1. Further insight (with the aid of Pearson's correlation analyses) revealed that COD showed inverse relationships with cadmium and nickel. This infers that increase in the cadmium and nickel reduces the level of organic constituents or inhibits their oxidation, this is further buttress the state of inverse relationship between BOD and cadmium and nickel. PC 2 with high and positive loadings for magnesium, calcium and chromium reflects common origin for these elements such as dissolution of limestone, marl and gypsum in water (Razmkhah *et al.,* 2010). Moderate loading accrued to EC in PC 2 denotes that these metals occurred in forms that were partially oxidized in this aquatic ecosystem while the inverse condition of vanadium reflects an antagonistic condition or a state of displacement reaction with the alkaline earth metals. PC 3 which had significant attributes for BOD_5 and DO reflect organic pollution and moderate loading for zinc implicate it as one the byproducts of the breakdown of the organic compounds. The condition in PC4 which exhibited strong loading for turbidity, moderate loading for lead and sodium reflect the anthropogenic input. The inverse relationship with pH reflects physicochemical source of variability, Yang and Ma (2006) and Yang *et al.,* (2009) also maintained similar record. PC 5 which loaded strongly for copper, moderately for phosphate and inversely for nitrate further reflect physicochemical variability and nutrient enrichment involving the use of fertilizer; the inverse shows the influence of nitrate on pH which in turn affects the solubility of metals in water. Inasmuch as iron is the most dominant heavy metals in this lotic owing to its abundance in the earth crust, its inverse relationship with sulphate and manganese depicts direct or indirect displacement reactions in PC 6. The parameters listed in PC 6 represent anthropogenic source of variation while PC 7 which showed strong loadings for temperature and THC reflects a physical source of variation. Increase in water temperature will in turn influence the solubility of THC.

The lentic systems (ponds) sampled in Agbede wetlands attributed different parameters to the various principal components. PC 1 which associated significant loadings to EC, BOD, magnesium, calcium and chromium and manganese. The cluster of elemental parameters in PC 1 points to a common origin while the inclusion of BOD and EC depict organic pollution. This organic factor can be interpreted as influences from point sources such as discharges from domestic wastewater and processing of farm produce. PC 2 which loaded strongly for TDS, phosphate and nickel and moderately for TSS and copper reflects both anthropogenic processes involving weathering, agricultural activities, solid waste disposal and natural activity such as surface run-off. PC 3 is associated with variations in physicochemical parameters which brought about variability in the pH; this can be explained taking into account that increases in nitrate cause decrease in pH of the water. The pH which is also affected by chloride in turn influences the solubility of the iron. Thus PC 3 is strongly associated with nutrient load involving use of fertilizer and chloride laden substances. The other PCs in the lentic system is associated with the variation in the water to organic and heavy metal pollutions. Although the proximity between the lotic and lentic ecosystems in Agbede wetland is not high, variations in the associated principal components could most be associated with variations in the oxidation potential which would be higher in the lotic than lentic ecosystem.

Integration of the PCs into the WQI revealed that PCs 5, 4, 3 and 2 were the best predictors reliable for most variations in the water quality of this lotic ecosystem. These principal components were highly loaded with parameters such as pH, EC, turbidity, BOD_5, DO, nitrate, sodium, magnesium, calcium, copper, lead, zinc, chromium and vanadium. Variations attributable to these parameters as already shown above are functions of multiple factors. Thus variation in water quality of the lotic ecosystem in Agbede wetland is as a result of synergistic effects of both anthropogenic and natural processes. Unification of the PCs into the WQI in the lentic system showed that variations in water quality were best explained by PCs 2, 3, 1, 4, 6 and 7. These PCs associated high loading to water temperature, pH, EC, BOD, TDS, TSS, turbidity, COD, sulphate, phosphate, nitrate, chloride, magnesium, calcium, iron, manganese, nickel, chromium and copper. These parameters are also products of combined influence of the anthropogenic and natural processes. PCs 5 and 2 of the lotic and lentic ecosystems respectively which are accorded high level of input in the overall quantification have in common phosphate. The implication of heavy metal contamination in this aquatic ecosystem types did not maintain the condition. All these remarks laid credence that change in the water quality of Agbede wetland is mostly associated with nutrient enrichment, the resident time of the various parameters and oxidation potential of the ecosystem types.

Conclusion and Recommendation

The application of water quality index together with the physico-chemical environment proved moderate water quality amongst the investigated ecosystems. There is need to ascertain the levels of microbial agents and pesticides concentrations of water bodies in Agbede Wetlands as the activities witnessed at the watershed are likely to influence them. The impact of heavy metals on the integrity of any ecosystem can never be overemphasize while considering their health implications thus the need to identify the sources of heavy metal input into these aquatic ecosystems.

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