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LIMNOLOGICAL EVALUATION IN TERMS OF WATER QUALITY OF OSSIOMO RIVER, SOUTHERN NIGERIA

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Abstract

The main purposes of this study are to characterize the physical and chemical properties of Ossiomo surface water, determine the water quality by identifying the significant source allotment of pollution and evaluate the co-relationship of the parameters across the studied stations. The sampling period spanned from March 2015 to August 2016. Various statistical tools were employed in the analysis of the data collected. The outcome for the evaluation of the concentrations of all the physical and chemical properties of the surface water, showed variations statistically (P<0.05 and P>0.05). Some of the physical and chemical properties were observed to be above the slated national and international standards. The result of the Principal Component Analysis of data, generated 50 variables under 6 components (PC1-PC6) with Eigenvalues >1. The source allotment was established to be traced from organic and inorganic pollutants as the major precursors of the ecosystem deterioration. The results of the measurement of Kaiser-Meyer-Olkin and Barlett's tests of sphericity were 0.83 and 3832.25 respectively, which showed that association existed between each scrutinised variables as well confirmed the correctness of the water data for the PCA extracted. The physical and chemical characteristics at stations 1 and 4 were similar. The findings from this study showed that the designated stations (2-4) in Ossiomo River were perturbed and considered unfit for domestic purposes as at the time of this study. Envirometric models like canonical correspondence analysis (CCA) and ANS (artificial neural network), can be used to predict the likely eco-biological impacts on the ecosystem.

Keywords*: Source allotment; Pollution; Interrelationship; Clusters; Ossiomo; Multivariate.*

Introduction

Aquatic ecosystem is well known for its abundance of natural resources. The quality of river waters can be determined by human activities and some natural factors which impacts on their widely usage, in turn affecting the biota therein.

The evidences of pollution on any aquatic ecosystem and the need to use water quality tools for rapid assessment are significant for the application of ecological management approaches [1-7]. The assessment of water worth is vital to evaluate the healthiness of a river so as to forecast forthcoming pollution.

The physical and chemical components of surface-water and their properties are chiefly controlled by crustal and human impacts which bring about seasonal variations of the water parameters [8-12].

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Environ-metrics or chemo-metrics make available a consistent valuation of water quality in an effort to take account of common water random sampling at various locations and achieve complete examination of water for an enormous number of physical and chemical factors [13-18]. The uses of numerical approaches such as multivariate in the characterization of the spatial, monthly and seasonal changes of the quality of aquatic system consequently of crustal and human influence have been established [19-23].

The purpose of this study are to characterize and assess the physical and chemical components of Ossiomo surface water, determine the water quality by identifying the significant source allotment of pollution and evaluate the co-relationship of the parameters across the studied stations. The design of this work is the first carried on specific regions of the river to in order to characterized its quality and purity.

Experimental Methods

Study Location

Ossiomo Watercourse is situated in the South Eastern part of Edo State, Nigeria. It is the main water body that supports Ologbo, Asabor, Okuku, Ugbenu, Ovade, Egho and Ogbogilete communities. Four sampling stations in the river were designated to show the up-stream and the down-stream points of the river founded on the likely extent of human activities in terms of pollution they received.

The River took its source from the Ishan plateau of Edo state and the geological plain formation (Benin formation) that span the south-central boundary and beyond. It empties its course on the Benin River and finally to the Atlantic Ocean.

Human activities, especially agriculture and crude oil exploration and processing are the dominant hub within this region. The major plants in this ecosytem are Screw pine, Palm tree, Mosquito Fern or Water Velvet, red and blue water lily, Umbrella palm, Water Moss, Antelope grass or Barnyard grass or Cockspur grass and water lettuce, Nile cabbage.

Geographical Location and Climatic Factors

Approximately 2.200km stretch of Ossiomo River (Ologbo axis), were mapped out and assessed with the geographical locations range of Latitude 6°03'1'' N - Longitude 5°40'3'' E (Fig. 1).

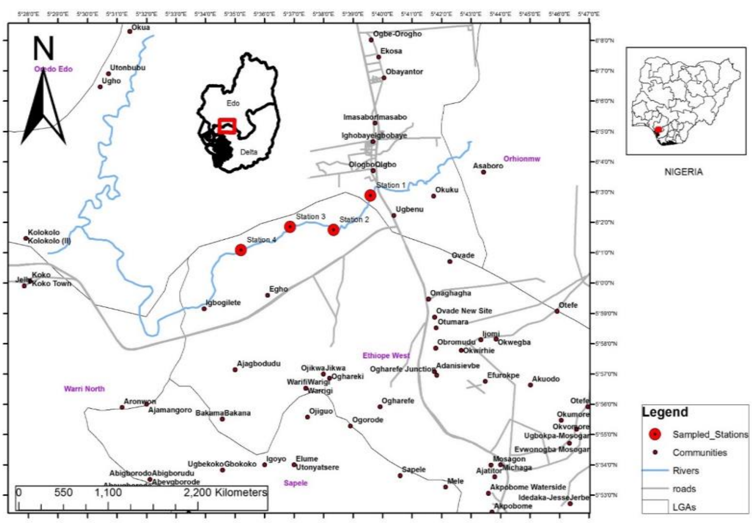

Fig. 1. Map of the study area and sampling stations showing sampled points of Ossiomo River, Edo State

Two separate yearly periods connected with this area: the wet season, which starts in late February and ends in early November and the dry season which begins from late November and ends in early February. Precipitation for 2015 - 2016, fluctuated from 159.0 - 708.50mm with the lowest documented in the month of January 2016 (159.00mm) and the ultimate documented in the month of September 2015 (708.50mm). The average precipitation value was 434.92mm (Fig. 2).

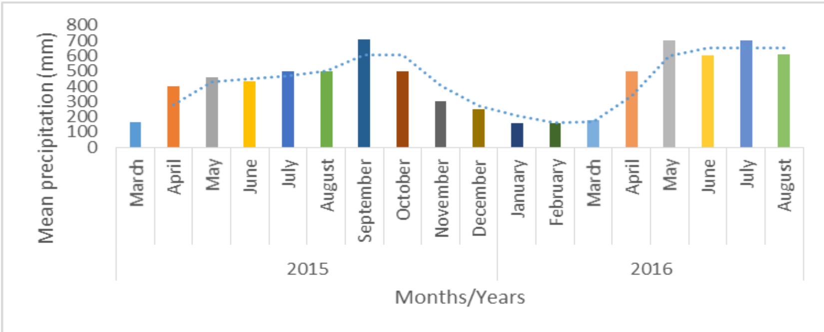

Fig. 2. Precipitation data of Benin City, Edo State, Nigeria, spanning from March 2015 – August 2016. Source: NIMET (Nigerian Meteorological Agency, BENIN) 2015 – 2016.

Sampling periodicity and techniques

The sampling period spanned from March 2015 to August 2016. Samples were collected once every month between the hours of 9.00 and 12.30 hours on each sampling day along the stretch of the river. Each time, sampling began in station 1 and ended in station 4. This was done to reflect the variations of the hydrological seasons (dry season: December- February and wet season: March-November).

A total of Thirty-three (33) water parameters were investigated and a total of 216 composite samples collected. In advance to the sampling, all vessels used for the water collection were carefully washed. At each of the four sampling stations triplicates water samples for physical and chemical analyses were collected and pulled together according to standard procedures [24].

In-situ sampling (field activities)

The water temperature was measured *in situ* with mercury in-glass thermometer. The thermometer was submerged 80 mm underneath the water exterior and left to calm for about 5 min. to become stable. This was done thrice to obtain the mean value in °C.

The air temperature was measured with a field thermometer which contains mercury. It was held upright 60cm above the surface water air for about 5 min. to become stable. This was also done thrice obtain the mean value in °C [25].

The Winkler's solution method using Magnesium sulphate (Winkler's solution I) and another 2mm of Potassium iodide-Sodium Hydroxide (Winkler's solution II) was used in the estimation of the dissolved oxygen (DO) contents in the water.

Extech meter probes (Extsik ii) D 600 produced in China was used in the determination of Hydrogen-ion concentration (pH), total dissolved solids (TDS), electrical conductivity (EC) and salinity in the surface water instantly at the sampling locations. The probe was placed in a glass beaker of the sampled water. After about 5min., the values obtained were recorded

Water sample was collected in a clean, transparent container for heavy metals analysis. About 1mL of HNO_3 was added in order to fix the metal contents therein. Similarly, water sample was collected in a clean, transparent container for the determination of Total hydrocarbon contents.

Ex-situ sampling (laboratory activities)

All samples collected were transported in an ice chess thermo-cooler and taken to the laboratory for further analysis.

In the laboratory, the photo-metric method of [24] was employed with a HACH UV/VIS Spectrophotometer (model DR/2000) in the measurement of Total suspended solids (TSS) in mgL^{-1}. While an HACH Turbidimeter Model 2100p was used in the measurement of Turbidity in NTU. The COD (chemical oxygen demand), DO and BOD_5 (biochemical oxygen demand) based on the modified method of [24]. The argento-metric methods as proposed by [24] and modified by [24] was used to in the determination of Chloride (Cl) content. The HACH Spectrophotometer at 410 nm (Hach UV/VIS Model DR 2000) and HACH Spectrophotometer at 890nm (Model DR 2000) were used in the determination of nitrate and phosphate using the method of [24]. While the turbidi-metric method, using the HACH Spectrophotometer (DR/2000) at 450nm was used in the determination of Sulphate according to the methods of [24]. The trace metal contents were determined using the methods of [24] with the Atomic Absorption Spectrophotometer (AAS) Solaar 969 Unicam Series model.

Statistical analysis

The analysis of variance (ANOVA) set at 0.05 (95%) level of confidence was used to compute the physical and chemical data using the Statistical Package for the Social Scientists (SPSS) version 20.0. Where there is no significant difference in the mean values, a further analysis using Duncan Multiple Regression Test (DMRT) was used to test for differences of mean values across the stations. The multivariate numerical methods; principal component analysis (PCA) and the Euclidean-Ward similarity and distance indices, which were used for the elucidation of dissimilarities and explanation of the river water quality dataset, were done with the SPSS and paleontological statistical software (PAST) version 3.0. The graphical demonstrations were done using Microsoft excel version 2013 and PAST version 3.0.

Results and discussion

The physical and chemical characterization of the surface water in Ossiomo River

Table 1 shows the result of the physical and chemical characteristics, the mean, the standard deviation, the minimum and the maximum values of the surface water parameters. These values were compared with the [26-28] standards for surface water. The concentrations of all the physical and chemical parameters in the surface water varied. Some of the parameters were observed to surpass the national and international thresholds.

Air and Water temperatures

The results of the minimum and maximum air temperatures in stations 1-4 are (28.30 - 30.90, 28.10 – 30.10, 26.10-30.80 and 29.0-31.4°C) respectively. The results of the water temperature were low (26. 60°C) in station 1 and high (27.10°C) in station 4. There was significance differences at $p<0.05$ and $p<0.01$ respectively in the air and water temperatures in station 4 when compared with the other stations after subjection to Duncan multiple range tests. The water temperature strictly followed the air temperature. This similar finding has also been reported in related studies somewhere else in Nigeria internal waters-bodies [29-31].

Hydrogen ion concentration (pH)

The result of the mean pH values of the four stations was observed to be fairly acidic. It ranged between 4.11 and 6.82 respectively in the across the stations. There was no significant difference ($p > 0.05$) across stations 1 to 4. A posterior test further showed that station 1 was significant at $p < 0.01$ from stations 2, 3 and 4. The pH across the stations revealed an acidic state (< 7.0). The low pH observed in this ecosystem may likely increase some of the physicochemical properties in the river. This underpins that the river was highly influenced with lithogenic and anthropogenic activities. Aquatic animals may likely not thrive better with this low level of pH level. This findings is in consonance with the work of [32] in Lativain waters;

[33] in Epie Creek, Niger Delta and [31] in Agbede wetland, Sothern Nigeria who reported that low pH value can reduce aquatic life distribution.

Electrical Conductivity (EC)

The values of the EC obtained in this study ranged between 67.40 to 281.40µScm^{-1} across the stations. There was significance difference ($p < 0.05$) in the EC values across the four stations. A posterior test further showed that station 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$ and $p < 0.05$ respectively. This study recorded gradual fluctuations in increase patterns in the EC values. A relative increase towards the peak of the rains was noticed. The findings of this study are contrary to the work of [25] in Warri River, Nigeria who recorded high values of EC (94.92-135.50µScm^{-1}). The findings also suggest wide-ranging fresh-water characterization depicted by low conductivity levels. Similar findings was reported by [31] for tropical water bodies in Agbede wetland.

Salinity and Colour

The results of the salinity were within the mean range of 0.05 to 0.08gL^{-1}. There was a significant difference ($p < 0.05$) in the values across the stations. A posterior test further showed that station 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$ and $p < 0.05$ respectively. The mean values obtained across the stations (1-4) were 4.87, 6.66, 6.45 and 5.38 Pt.Co respectively. A posterior test further showed that station 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$. The findings obtained in this study indicated that the river is a perfect freshwater ecosystem which has low dissolved salt contents less than 0.005ppm.

Turbidity

The mean value was low (3.93 NTU) in station 1 and high (5.54 NTU) station 2. There was no significant difference ($p > 0.05$) in the turbidity across the studied stations. However, station 2 was significantly higher than stations 1, 3 and 4 at $p< 0.01$ after further subjection to Duncan multiple range tests. A steady upsurge in the values of turbidity in stations 1 and 2 and slight fluctuation in stations 3 and 4 were observed in this study. This possibly may be accredited to the initiation of superficial run-off occasioned by rainfall or seasonal fluctuation. However, the values were within the slated values of [26-28]. Similar report was recounted by [31] in Agbede wetland, Southern Nigeria but contrary with the works of [34] works on surface water near a cement factory, Northern Nigeria.

Total suspended solids (TSS) and Total dissolve substance (TDS)

The highest mean (9.33mgL^{-1}) of the TSS was noticed in station 2, while the lowest (6.15 mgL^{-1}) of the TSS was noticed in station 1. The results of this study are quite similar to the findings of [35] and [36] which showed slightly high TSS values in Asa River (Kwara state). *Osibanjo et al.* [37], reported similar findings for Rivers Ona and Alaro in Ibadan. However, the values were closed to the limit 10mgL^{-1}, set by [26] for TSS. There might be serious concern of TSS elevation in this ecosystem if human activities persist beyond normalcy.

The TDS differed across stations 1 to 4, with the highest mean value 141.30 mgl^{-1} was observed in station 2 and the lowest (90.60mgL^{-1}) in station 1. A DMR tests further showed that stations 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$ and $p < 0.05$ respectively. The TDS recorded in this study ranged from 60.28 to 88.23mgL^{-1} across the stations. While TSS ranged from 6.15 to 9.33mgL^{-1}. The pattern of values recorded was fairly irregular. These values were very low when likened with the [26, 27] and [28] limit of 2000mgL^{-1} and 1000mgL^{-1} for TDS.

Dissolved Oxygen (DO)

The values of DO obtained in this study was low (5.67mgL^{-1}) in stations 2 and 3 respectively, but high (6.23mgL^{-1}) in station 1. There was no significant difference ($p > 0.05$) in the DO parameters across the studied stations. A DMR tests further showed that station 2 was significantly different from stations 1, 3 and 4 at $p < 0.01$ and $p < 0.05$ respectively. This study recorded unequal fluctuation of DO with the highest documented in the rainy season. This is in line with the work of by [33] on the influence of urban overflow on DO quality during the rainy season on the Epie Creek in the Niger Delta. The depletion of oxygen contents in the ecosystem can lead to death of aquatic organisms therein. *Wakawa et al.* [38], recommended that humid water environment should have oxygen concentration of at minimum $5mgL^{-1}$ so as to sustain living organism therein.

Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD)

There were fluctuations in the values of BOD_5 in station 2 and 3. The BOD_5 mean ranged between 2.34 and $3.44mgL^{-1}$ respectively. There was significant difference ($p < 0.05$) in the associated stations (1-4). DMRT further showed that station 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$ respectively.

In this study, the BOD_5 obtained was within the stipulated threshold set by the regulatory bodies. The findings of this study is similar to the work of [31] who reported low BOD_5 range of $0.88\text{-}2.42mgL^{-1}$ in Agbede wetland, [39] who reported low BOD_5 range of $1.51\text{-}2.60mgL^{-1}$. But contrary to the works of [40] who reported high BOD5 ($1.45\text{-}18.00mgL^{-1}$) in Benin River and [41] who reported BOD_5 ($1.45\text{-}18.00mgL^{-1}$) in Warri River. The variation in the BOD_5 values in this study may be as a result of varied human's activity (sawmilling) in the stations. This was noticed in stations 2 and 3 with such activities. *Arimoro et al.* [40], and *Odise et al.* [41] have also reported the influence of sawmilling on the water quality, stating the degenerating impacts on aquatic lives. Tropical River can undergo self-purification under the condition that the BOD_5 does not exceed $4mgL^{-1}$.

On the other hand, the COD mean value was high in station 2 ($18.45mgL^{-1}$) and low in station 1 ($10.68mgL^{-1}$) and there was significant difference ($p < 0.05$) of the range values across the stations. BOD_5 fluctuation might have indirect impact of the chemical oxygen demand for aquatic life forms.

Hydrogen bi-carbonates (HCO_3)

The mean HCO3 value obtained in this study was high in station 2 ($41.61mgL^{-1}$) and low in station 1 ($20.78mgL^{-1}$). A DMR tests further showed that station 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$ and $p < 0.05$ respectively. Nitrates and phosphate have frequently been referred to as regulating nutrients in water ecosystem and have been generally approved as pointers for low oxygen content (eutrophication) in static aquatic freshwater bodies [42-44].

Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg)

The values of Sodium obtained in this study varied across the various stations with the lowest value of $0.83mgL^{-1}$ (station 1) to the maximum value of $1.12mgL^{-1}$ (station 2). There was no significant difference ($p > 0.05$) in the value of Na across the stations. A DMRT further showed that station 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$.

The result obtained in the mean Potassium was low ($0.14mgL^{-1}$) in stations 1 and 4 and higher ($0.23mgL^{-1}$) in station 2. There was no significant difference ($p > 0.05$) across the stations. A DMR tests further showed that stations 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$.

Amongst the basic metals analysed, Calcium had the highest values which ranged from 1.80 and $1.81mgL^{-1}$ (stations 1 and 4) to 2.69 and $2.54mgL^{-1}$ (stations 2 and 3) respectively. A DMRT further showed that station 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$.

The lowest values of Mg were $0.60mgL^{-1}$ (station 1) the highest was $0.87mgL^{-1}$ (station 2). No significant difference ($p > 0.05$) across the studied stations.

Chlorine (Cl), Phosphate (P), Ammonium Nitrates (NH_4N), Nitrites (No_2) and Nitrates (No_3)

The mean minimum Chlorine concentration value was $23.24mgL^{-1}$ (station 1) and the maximum was $43.31mgL^{-1}$ (Station 4). A DMR tests further showed that stations 2 was significantly higher than stations 1, 3 and 4 at $p < 0.01$.

The mean phosphate was low ($0.65mgL^{-1}$) in station 1 and high ($1.27mgL^{-1}$) in station 2. However, there was no significant difference ($p > 0.05$) of the mean concentrations of P across the stations Phosphate was mostly not detected during the dry season. However, higher values were observed during the rainy season which can be sourced from fertilizers via agricultural processes. Similar findings were also reported by [45]. A comparable result was reported by [46], for Ikpoba River, and [47] but, was contrasted with that of [25] for Warri River and [48] for Ikpoba River.

The NH_4N was low ($0.09mgL^{-1}$) in station 1 and high ($0.20mgL^{-1}$) in station 2. However, there was no significant difference ($p > 0.05$) in the mean NH4N across the stations

The NO_2 was low ($0.05mgL^{-1}$) in station 1 and high ($0.14mgL^{-1}$) in station 2. No significant difference ($p > 0.05$) among the mean NO_2 across the stations.

The NO_3 was low ($1.55mgL^{-1}$) in station 1 and high ($2.96mgL^{-1}$) in station 2. No significant difference ($p > 0.05$) among the mean NO_3 across the studied stations. Nitrates and phosphate have frequently been referred to as the regulating nutrients in water environs and have been generally approved as pointers for low oxygen content (eutrophication) in static aquatic bodies [42-44].

Sulphate (SO_4)

The mean values of sulphate were between 0.63 and $1.07mgL^{-1}$. These values were not significant at $p > 0.05$. A DMR tests further showed that station 2 was much higher than stations 1, 3 and 4 respectively at $p < 0.01$. These values were not also significant at $P>0.05$. A DMR tests further showed that station 2 was much higher than stations 1, 3 and 4 respectively at $p < 0.01$. The values of the sulphate obtained in this study were generally low across the stations. This finding conforms to the work of [49] who reported low fluctuations of sulphate in Ikpoba River, southern Nigeria. This may be as a result of low anthropogenic impacts.

Iron, (Fe), Magnesium (Mn) Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Lead (Pb) and Vanadium (V)

The mean concentrations of Fe, Mn, Zn, Cu, Cr, Cd, Ni, Pb and V in this study, ranged from $0.68\text{-}1.79mgL^{-1}$, 0.07 to $0.16mgL^{-1}$, 0.26 to $0.67mgL^{-1}$, 0.03 to $0.06mgL^{-1}$, 0.01 to $0.04mgL^{-1}$, 0.01 to $0.03mgL^{-1}$, 0.00 to $0.01mgL^{-1}$. 0.00 to $0.04mgL^{-1}$ and 0.00 to $0.01mgL^{-1}$ respectively. No significant difference at $p > 0.05$ of the mean values existed across the studied stations. However, A DMRT further showed that station 2 was much higher than stations 1, 3 and 4 respectively at $p < 0.01$ and $p < 0.05$ respectively.

The heavy metals concentration in the surface water was in this order; Fe>Zn>Mn>Cu>Cr>Pb>Cd>V>Ni. The concentrations of Fe, Mn, Zn, Cu, Cr and Cd recorded in the water were slightly above the slated national and international limits. The concentrations of Ni especially in stations 2 and 3 were at the same range with the national and international standards. The ascendency of iron over other heavy metals in aquatic ecosystem had been reported by [50-53]. Iron in most Nigeria water has been reported to be usually abundant than WHO standard of $0.3mgL^{-1}$ [54]. This can be liken to industrial releases, weathering of iron and steel materials from buildings, leachates from dumpsites and vehicular effluents [45, 55]. Results from this study indicated that the metals where sourced from anthropogenic activity such as farming and lithogenic impacts.

The concentrations of Mn, Zn and Fe recorded in this study were similar to values documented by [31, 55], in related environment and [39] and [57] in a similar but different stretch of Ossiomo River.

The existence of trace and heavy metals in the water ecosystem beyond standard limits, are key concern, because of the possible harmful risk they portend to flora and fauna existence and the natural ecological balance [58-70]. The relatively elevated levels of heavy metals recorded in this aquatic ecosystem may be sourced from anthropogenic and farming wastes washed down via runoff [71, 72]

Total Hydrocarbon contents (THC)

The mean concentration of THC in this study ranged from 0.11 to 0.09mgL^{-1}. The minimum value (0.11mgL^{-1}) at station 2 and maximum value (0.09mgL^{-1}) at station 3. A significant difference ($p < 0.05$) existed across all the four stations. However, A DMR tests further showed that station 2 was much higher than stations 1, 3 and 4 respectively at $p < 0.01$ and $p < 0.05$. The mean concentrations of THC attained in the surface water, were similar to the values obtained by [35, 37, 45, 52] at concentration <1 mgl^{-1} at the Niger Delta mangrove creek. THC < 1.00mgL^{-1} in surface water denotes unpolluted water body. However, this water body was uncontaminated by THC as at when the samples they were collected. But, on the contrary, since the average concentrations of THC in the water were above the value of 0.05mgL^{-1}stipulated by [26] the water was said to be contaminated by THC. [73], attributed the occurrence of THC to anthropogenic activities like transportation and oil spill from speed boats which is a common factor along the studied stretch of this river. However, the THC obtained this study when compared to other studies may be accredited to environmental factors such as natural and human inputs such as urban run-off from auto repair workshop and petroleum depot.

Note: Unit of measurement: pH has no unit, Electrical conductivity (EC); µScm^{-1}, Salinity; g^{-1}, Turbidity; NTU and Color; Pt.Co. Most of the parameters were measured in mgL^{-1}; $p < 0.05$ – Significant difference; $p > 0.05$ – No significant difference. NS: indicates not specified and N/A; indicates not available. FMEnvN indicates; Federal Ministry of Environment Nigeria, WHO; World Health Organisation and NIS indicates Nigeria Industrial Standards. Superscript (^{a}) means that p is significant at 0.05 ($p < 0.05$) and Superscript (^{b}) means that p is significant at 0.01 ($p < 0.01$).

Multivariate approach in assessing surface water quality

Principle component analysis (PCA)

The result of the PCA matrix of the physical and chemical parameters is expressed in Table 2. The PCA was performed on the data sets contained 33 components analysed in the water samples (Fig. 2). In this study, PC1-PC4 contributed the largest percentage respectively, of the loadings of heavy metals in the surface water PCA. The parameters of importance cover the 6 components. The source allotment could be traced from organic and inorganic pollution as the major point source of contamination [74-78].

The data sets yielded 50 variables with Eigenvalues >1. These variables explained 84.18% of the total variance in water quality respectively. Eigenvalues of one (1.0) or >1, are considered significant [79]. By implication, the highest eigenvalue is taken to be the most significant and should be one or greater for proper considerations during PCA [80].

The contributions were as follows; component 1, 2, 3, 4, 5 and 6 accounted for the proportion as follows: 34.91, 14.09, 12.23, 11.34, 6.31 and 5.30% respectively (Table 2). The parameters of importance in each component were: 1; EC, salinity, TSS, HCO3, Na, K, Ca, Mg, Cl, P, NH4N, NO3, SO4, Fe, Mn, Zn, Cu, Cr, Pb and THC 2; K, Ca, Mg, P, NH4N, Fe, Cu, Cr, Cd, Ni, Pb, V and THC 3; COD, NH4N, NO2, Ni and V 4; pH, colour, turbidity, TSS, Mn and THC 5; BOD5, COD, HCO3 and Mn and 6; water temperature and salinity. Factor loadings values of >0.75, between 0.5-0.75 and 0.3-0.5 are classified as strong, moderate and weak respectively, based on their absolute values. The eigenvalues gotten in this study indicated PC1-PC6 to have strong absolute values. These also revealed that parameters in PC1-PC6 components had strong influence in the ecosystem.

Table 1. Summary of the physical and chemical Characteristics of surface water in Ossiomo River collected from designated stations from March 2015 - August 2016

Parameters	Units	Station 1 $\overline{X}$±SD (Min-Max)	Station 2 $\overline{X}$±SD (Min-Max)	Station 3 $\overline{X}$±SD (Min-Max)	Station 4 $\overline{X}$±SD (Min-Max)	FMEnvN (2003)	WHO (2008)	NIS (2007)	Significant values
Water Temp	^{0}C	26.19±1.09 (26.60-28.10)	26.73±0.87 (24.90-28.00)	26.99±0.58 (26.10-28.00)	27.69±0.58 (24.4-29.10) ^{ab}	<40	NS	N/A	P<0.05
pH		5.80±0.56 (4.94-6.82) ^{b}	5.48±0.59 (4.11-6.12)	5.72±0.52 (4.84-6.50)	5.64±0.50 (4.70-6.24)	6-9	6-8	N/A	P>0.05
EC	µSc m^{-1}	120.29±35.46 (67.40-80.06)	172.81±46.98 (112.40-283.4) ^{ab}	166.26±44.95 (98.60-251.8)	134.64±34.33 (64.80-195.7)	3	NS	N/A	P<0.05
Salinity	g^{-1}	0.05±0.02 (0.03-0.08)	0.08±0.02 (0.05-0.13) ^{ab}	0.08±0.02 (0.05-0.11)	0.06±0.02 (0.03-0.09)	NS	NS	N/A	P<0.05
Colour	Pt Co	4.87±2.40 (1.70-10.40)	6.66±3.95 (2.30-15.30) ^{b}	6.45±3.49 (1.70-13.70)	5.38±3.09 (1.40-11.50)	15	NS	N/A	P<0.05
Turbidity	NTU	3.93±2.14 (1.20-8.40)	5.54±3.69 (1.80-13.90) ^{b}	4.95±2.65 (1.10-10.50)	4.29±2.42 (0.90-7.80)	5	5	N/A	P>0.05
TSS	mg l^{-1}	6.15±2.60 (2.80-12.50)	9.33±4.45 (4.70-19.40) ^{b}	8.48±3.92 (2.80-16.30)	7.06±3.17 (2.10-14.00)	10	NS	N/A	P>0.05
TDS	mg l^{-1}	60.28±17.70 (33.90-90.60)	88.23±23.30 (57.00-141.30) ^{ab}	82.10±22.43 (50.10-25.50)	67.26±17.09 (32.00-97.10)	2000	1000	N/A	P<0.05
DO	mg l^{-1}	6.23±0.54 (5.40-7.10) ^{b}	5.67±0.69 (4.80-6.90)	5.67±0.70 (4.10-6.70)	5.87±0.38 (5.20-6.40)	NS	NS	N/A	P>0.05
BOD_5	mg l^{-1}	2.34±0.57 (1.60-3.20)	3.44±0.70 (2.30-4.70) ^{b}	3.00±0.82 (2.10-4.40)	2.44±1.11 (1.10-4.00)	30	NS	N/A	P<0.05
COD	mg l^{-1}	10.68±3.90 (6.20-18.60)	18.45±7.86 (10.40-35.40)	15.63±9.18 (7.50-38.30)	12.62±6.17 (4.30-(21.10	NS	NS	N/A	P>0.05
HCO_3	mg l^{-1}	20.78±12.70 (12.20-54.20)	41.61±11.93 (24.40-61.00) ^{ab}	39.50±13.79 (24.40-59.20)	29.18±15.13 (6.10-54.90)	200	NS	N/A	P<0.05
Na	mg l^{-1}	0.83±0.42 (0.46-1.82)	1.12±0.44 (0.59-2.19) ^{ab}	1.04±0.45 (0.55-1.95)	0.93±0.42 (0.41-1.78)	200	NS	N/A	P<0.05
K	mg l^{-1}	0.14±0.07 (0.05-0.27)	0.23±0.11 (0.09-0.42) b	0.19±0.10 (0.05-0.41)	0.14±0.04 (0.09-0.21)	75-200	NS	N/A	P>0.05

Table 1 (cont.). Summary of the physical and chemical Characteristics of surface water in Ossiomo River collected from designated stations from March 2015 - August 2016

Parameters	Units	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)	FMEnvN (2003)	WHO (2008)	NIS (2007)	Significant values
Ca	$mg\ l^{-1}$	1.80±0.79 (0.82-3.35)	2.69±1.27 (1.27-5.13) ^{b}	2.54±1.35 (1.19-5.16)	1.81±0.72 (0.79-3.10)	NS	NS	N/A	P>0.05
Mg	$mg\ l^{-1}$	0.60±0.37 (0.25-1.37)	0.87±0.38 (0.21-1.60) ^{b}	0.72±0.36 (0.35-1.64)	0.58±0.26 (0.21-1.05)	NS	NS	N/A	P>0.05
Cl	$mg\ l^{-1}$	23.24±18.78 (7.00-73.20)	43.31±39.51 (15.20-150.30) ^{b}	38.57±34.94 (11.50-26.90)	26.88±18.95 (10.70-82.80)	600	500	N/A	P>0.05
P	$mg\ l^{-1}$	0.65±0.42 (0.12-1.30)	1.27±1.06 (0.33-3.28) ^{b}	1.26±0.90 (0.35-3.17)	0.84±0.59 (0.16-1.95)	5	NS	N/A	P>0.05
NH_4H	$mg\ l^{-1}$	0.09±0.05 (0.02-0.16)	0.20±0.10 (0.05-0.34) ^{b}	0.18±0.16 (0.06-0.59)	0.12±0.05 (0.03-0.19)	1	NS	N/A	P>0.05
NO_2	$mg\ l^{-1}$	0.05±0.03 (0.01-0.12)	0.14±0.18 (0.04-0.69) ^{b}	0.13±0.19 (0.02-0.71)	0.08±0.05 (0.01-0.17)	1	NS	N/A	P>0.05
NO_3	$mg\ l^{-1}$	1.55±0.59 (0.74-2.48)	2.96±1.75 (0.93-6.27) ^{b}	2.86±1.64 (0.77-5.10)	1.77±0.72 (1.11-3.19	20	50	N/A	P>0.05
SO_4	$mg\ l^{-1}$	0.63±0.35 (0.27-1.49)	1.07±0.48 (0.53-2.30) ^{b}	0.96±0.40 (0.47-1.84)	0.82±0.39 (0.21-1.71)	500	500	N/A	P>0.05
Fe	$mg\ l^{-1}$	0.68±0.48 (0.19-1.85)	1.79±1.22 (0.57-4.12) ^{ab}	1.50±1.27 (0.27-4.12)	0.90±0.50 (0.25-1.90)	20	0.4	0.3	P<0.05
Mn	$mg\ l^{-1}$	0.07±0.05 (0.01-0.17)	0.16±0.08 (0.06-0.32) ^{ab}	0.11±0.07 (0.01-0.22)	0.09±0.04 (0.03-0.19)	0.05	NS	0.2	P<0.05
Zn	$mg\ l^{-1}$	0.26±0.16 (0.09-0.55)	0.67±0.33 (0.24-1.35) ^{b}	0.59±0.36 (0.09-1.29)	0.39±0.22 (0.11-0.81)	<1	3	3	P>0.05
Cu	$mg\ l^{-1}$	0.03±0.03 (0.01-0.09)	0.06±0.04 (0.01-0.13) ^{b}	0.06±0.05 (0.01-0.18)	0.04±0.03 (0.00-0.10)	<1	0.05	1	P>0.05
Cr	$mg\ l^{-1}$	0.01±0.01 (0.00-0.05)	0.04±0.03 (0.00-0.13)	0.04±0.05 (0.00-0.18) ^{b}	0.02±0.03 (0.00-0.09)	<1	0.03	0.05	P>0.05
Cd	$mg\ l^{-1}$	0.01±0.01 (0.00-0.04)	0.03±0.02 (0.00-0.08)	0.03±0.04 (0.00-0.15) ^{b}	0.03±0.02 (0.00-0.07)	<1	0.01	0.003	P>0.05
Ni	$mg\ l^{-1}$	0.00±0.00 (0.00-0.02)	0.01±0.02 (0.00-0.04) ^{b}	0.01±0.02 (0.00-0.05)	0.00±0.01 (0.00-0.02)	0.05	NS	0.02	P>0.05
Pb	$mg\ l^{-1}$	0.01±0.02 (0.00-0.08)	0.04±0.04 (0.00-0.12) ^{b}	0.04±0.04 (0.00-0.17)	0.01±0.01 (0.00-0.04)	<1	0.01	0.01	P>0.05
V	$mg\ l^{-1}$	0.00±0.00 (0.00-0.01)	0.01±0.01 (0.00-0.03) ^{b}	0.01±0.02 (0.00-0.05)	0.00±0.00 (0.00-0.01)	0.01	NS	N/A	P>0.05
THC	$mg\ l^{-1}$	0.04±0.03 (0.00-0.09)	0.11±0.04 (0.07-0.18) ^{ab}	0.09±0.06 (0.02-0.24)	0.07±0.03 (0.03-0.12)	0.05	NS	N/A	P<0.05

Table 2. Eigenvectors and Eigenvalues of the various components of surface water parameters in Ossiomo River sampled from March 2015 – August 2016

Parameters/Components	PC1	PC2	PC3	PC4	PC5	PC6
Air temperature	0.10	0.12	-0.41	-0.50	-0.15	-0.05
Water temperature	0.17	0.16	-0.13	-0.13	-0.06	**0.74**
pH	-0.44	0.00	-0.32	**0.51**	-0.24	-0.20
EC	**0.89**	0.12	0.20	0.08	0.06	0.28
Salinity	**0.72**	-0.05	0.15	0.17	0.11	**0.33**
Colour	0.16	-0.04	0.07	**0.95**	0.03	-0.01
Turbidity	0.19	0.01	0.04	**0.92**	0.10	-0.01
TSS	0.30	-0.04	-0.02	**0.86**	-0.07	0.14
TDS	**0.90**	0.12	0.18	0.08	0.07	0.28
DO	0.10	0.06	-0.19	-0.20	-0.17	-0.81
BOD_5	0.22	0.16	0.19	0.06	**0.89**	0.09
COD	0.15	0.04	**0.69**	-0.07	**0.64**	-0.07
Hydrogen bicarbonate	**0.56**	0.15	0.31	0.12	**0.53**	0.19
Na	**0.84**	0.28	0.10	-0.02	0.08	-0.17
K	**0.74**	**0.45**	0.05	0.07	0.13	-0.08
Ca	**0.87**	**0.41**	0.01	0.00	0.05	-0.05
Mg	**0.74**	**0.40**	0.09	0.10	0.03	-0.24
Cl	**0.92**	0.08	0.03	-0.12	0.16	0.01
P	**0.79**	**0.41**	0.04	0.27	0.02	-0.15
Ammonium Nitrates	**0.40**	**0.33**	**0.73**	0.15	0.22	0.08
Nitrite	-0.03	0.07	**0.93**	0.16	0.08	0.03
Nitrate	**0.78**	0.20	0.25	0.30	-0.10	0.00
Sulphate	**0.87**	0.05	-0.01	0.11	0.29	0.07
Fe	**0.82**	**0.46**	0.10	0.07	0.07	0.01
Mn	**0.68**	0.26	-0.03	**0.39**	**0.34**	-0.10
Zn	**0.88**	0.26	0.18	0.12	0.14	0.07
Cu	**0.68**	**0.51**	0.24	-0.07	-0.16	0.10
Cr	**0.37**	**0.86**	0.21	-0.02	0.02	0.06
Cd	0.23	**0.87**	0.25	-0.10	0.19	0.01
Ni	0.28	**0.52**	**0.76**	-0.09	0.04	0.01
Pb	**0.41**	**0.83**	0.14	-0.13	0.05	0.08
V	0.26	**0.48**	**0.80**	-0.06	0.05	0.02
THC	**0.44**	**0.56**	0.27	**0.37**	0.22	0.08
Eigenvalues	11.53	4.65	4.04	3.74	2.83	1.75
Proportion (%)	34.91	14.09	12.23	11.34	6.31	5.30
Cum. Proportion (%)	34.91	48.99	61.22	72.56	78.87	84.17

NB: Bolded values exceeded standards. According to [81], loadings > 0.71 are typically regarded as excellent, and loadings < 0.32 very poor. However, [80] stated that the component with the highest Eigenvalue is taken to be the most significant and should be one or greater for proper considerations during PCA. Factor loadings values of > 0.75, between 0.75–0.5 and 0.5–0.3 are classified as strong, moderate and weak respectively, based on their absolute values.

Figure 3 shows the scatter plot and the relationship of the physicochemical parameters in Ossiomo River. The relationship of the parameters as shown in the scatter plot indicated similar cluster between the following Cl, HCO3, COD, EC, TDS, K and V in components 1 and 2. This denotes strong interrelationship between the chemical constituents and the aquatic environment and their impacts negatively and positively.

Table 3 shows the Kaiser-Meyer-Olkin and Bartlett's test of sphericity. The results of the measurement of sampling adequacy/Kaiser-Meyer-Olkin (KMO) and Barlett's tests of sphericity (BTS) were 0.83 and 3832.25 respectively. Both the measurements of sampling adequacy and sphericity showed significant difference at $p < 0.05$ respectively. The KMO and the BTS values obtained in this study demonstrated that there is a relationship and importance of individuality amongst the PCA variables, which is a superb grade of evaluating the competency of the PCA. This confirms the correctness of the water data for the PCA extracted [82].

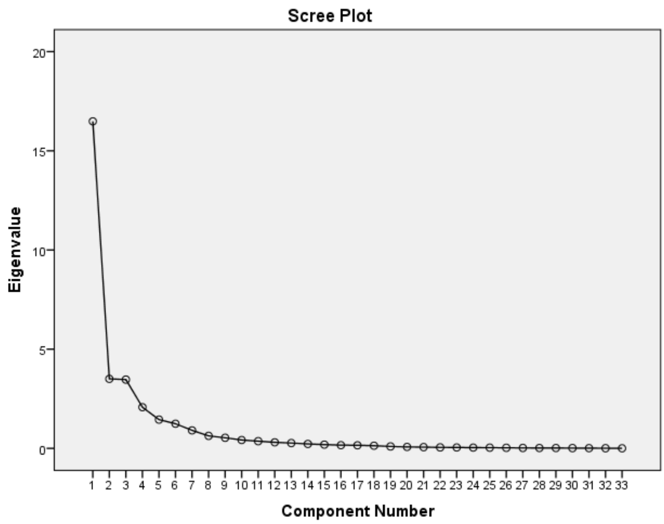

Fig. 3. Scree plot for surface water PCA of Ossiomo River

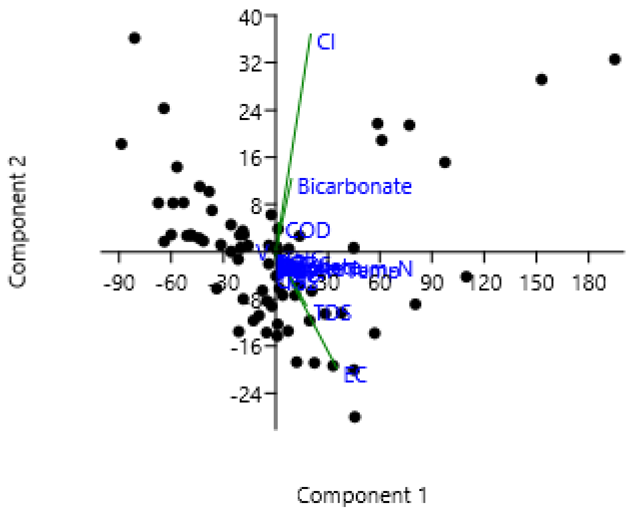

Fig. 4. Scatter plot for based on the positive and negative relationship of all the parameters

Table 3. Kaiser-Meyer-Olkin and Bartlett's test of sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.83
Bartlett's Test of Sphericity	3832.85
Degree of freedom	528.00
Significant value	0.00
P-value	p<0.05

Cluster analysis, Ward-Euclidean similarity and distance indices

Table 4 shows the similarity and dissimilarity as defined by the Euclidean distance and the combination of cluster by the Ward method as shown by the dendrogram (Fig. 4), based on the concentrations of all the parameters analysed from the surface water. According to the combinations of the clusters, the physical and chemical characteristics of stations 1 and 4 were similar. Furthermore, the Ward method indicated that the prevailing physical and chemical characteristics at stations 2 and 3 were similar. According to Euclidean distance, the physical and chemical characteristics at stations 1 and 2 were most dissimilar while the same characteristics at 4 and 3 came in between them figure 5. The indication of this is that there is a possible auto-purification capacity of this aquatic body after the perturbation at stations 2 and 3 which were brought about most of the environmental variations in the ecosystem. This auto-purification capacity of this aquatic body was further X-rayed by the state of no significant differences recorded visually in all the parameters in stations 1 and 4. It can be established that the designated stations were perturbed and considered unfit for domestic use and consumption.

Table 4. Euclidean similarity and distance indices across the stations

Stations	1	2	3	4
1	0.00			
2	63.03	0.00		
3	55.61	8.40	0.00	
4	19.09	44.50	36.97	0.00

Ward-Euclidean: 0 and < 1; complete dissimilarity, ≥ 1; complete similarity, critical level of significance (C) = 0.05.

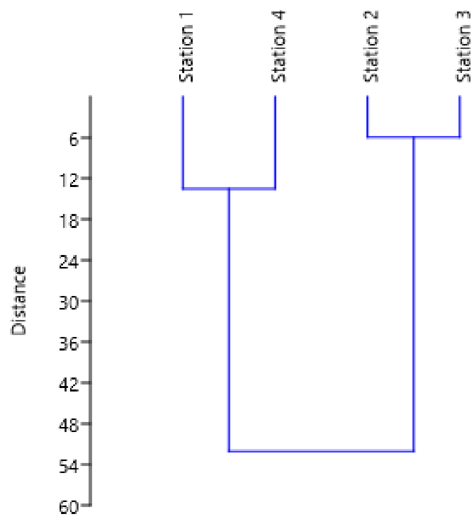

Fig. 5. Dendogram for cluster analysis based on distance indices on sampled stations

Conclusion

In this study, the characterization and assessment of the physical and chemical components of Ossiomo surface water as well as the determination of the water quality via source allotment of pollution were screened. The physical and chemical properties evaluated in this ecosystem was highly influenced by lithogenic and anthropogenic activities. Aquatic animals and plants may likely not thrive better in this ecosystem. The PCA analysis revealed that the physical and chemical components in PC1-PC6, had strong influence in the ecosystem. It can be established that the designated stations were perturbed and considered unfit for domestic use and consumption. It is promising to use various envirometric models like canonical correspondence analysis (CCA), ANS (artificial neural network), Kriging interpolation and CERI (comprehensive environmental risk indices) to compare and predict the possible impact of the water variables on both plant and animals.

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