

ASSESSMENT OF PHYSICOCHEMICAL PARAMETERS OF QUA IBOE ESTUARY, NIGERIA

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ABSTRACT

The physicochemical parameters of Qua Iboe estuary were carried out to determine its suitability for fish growth. Three strategic locations were selected and a total of eleven different parameters were investigated using standard methods. The mean values for the physicochemical parameters were 28.22°C (Temperature); 4.04 mg/L (Dissolved oxygen); 7.72 (pH); 14.48‰ (Salinity); 16.91 mg/L (Alkalinity); 20348.95 µs/cm (Conductivity); 13851.11 mg/L (TDS); 0.07 mg/L (Nitrate); 0.66 mg/L (Chloride); 0.17 mg/L (Phosphate) and 7.72 mg/L (Sulphate). The results revealed monthly variation in conductivity, TDS, nitrate and phosphate while spatial variation was noticed in pH, salinity, TDS, chloride and phosphate, suggesting that increased anthropogenic activities and the influx of allochthonous organic and inorganic materials from the surrounding catchments area into the estuary may have altered the water quality. With exception of conductivity and TDS, the values of physicochemical properties were within the standard guideline values for survival, metabolism and physiology of aquatic organisms in a brackish water environment. Thus, there should be concerted effort to maintain the conditions of the estuary in view of its uniqueness and importance in the life cycle of many aquatic species and the livelihood of local fisher-folks.

Keywords: water quality, physicochemical parameters, Qua Iboe estuary

INTRODUCTION

Globally, estuaries are vital resource and significant support for euryhaline organisms and many other aquatic species which are of tremendous importance to fisheries. It is obvious that water quality degradation is an important issue around the world; however, coastal areas bear the most brunt of environmental contaminants. Nigeria which is a maritime state is not left out. Nigerian coastal environment which consists of rich and diverse ecosystems, natural resources and increased human population, has been subjected to different forms of anthropogenic pollution.

The water quality of estuaries is affected by seasons, geographic areas, and activities at the rivers and water bodies flowing into them. When rains come, most of the physicochemical characteristics of tropical rivers are changed because of all ochthonous organic material input from the catchment areas. Runoff is a major non-point source of chemical inputs into the estuaries. Fish growth depends largely on the quality of the water and other ecological conditions. Therefore, important physicochemical parameters influencing the aquatic environment such as temperature, pH, salinity, dissolved oxygen, total dissolved solids, total alkalinity and conductivity need to be monitored. Others like chlorides, nitrates, phosphates and sulphates are nutrients or limiting factors for the survival of aquatic organism. Poor water qualities may also be caused by low water flow, municipal effluents and industrial discharges (Chitmanat and Traichaiyaporn, 2010). The Qua Iboe estuary is

situated close to the Exxon-Mobile oil effluent treatment and discharge plant. The industrial wastes are discharged into the Atlantic Ocean but may recycle into the estuary due to tidal motion. However, the effects of direct discharge of industrial waste into Qua Iboe estuary on the water conditions are not well known. The estuary supports the artisanal fisheries, water ways and cultural values of Qua Iboe community. Hence, the present study was designed to investigate the water quality of Qua Iboe estuary, which empties into the Atlantic Ocean, using some physicochemical parameters. Results obtained will provide additional information to existing data on water quality assessments of this important water body.

Study Area

Qua Iboe estuary is one of the major estuary in the Niger Delta region of Nigeria. It is situated between longitude 7°32' and 7°59' E, and latitude 4°32' and 5°29' N (Figure 1), and is in proximity to Exxon-Mobil crude oil effluent processing and treatment facility. Qua Iboe River is a confluence of rivers from different sources flowing through Eket and Ibeno communities of Akwa Ibom State in to the Gulf of Guinea (Atlantic Ocean). In addition to Exxon-Mobil treatment facility, the river mainly receives municipal wastes, urban runoff, untreated industrial discharges from food processing industries, as well as other solid wastes (garbages, metal scraps, etc.). The river system serves as a major source of water for the

predominantly rural population of the area whose major occupation is commercial fish farming.

Station 1 is located in Ukpenekang, an area considered to be heavily perturbed by human activity. Station 2 is at the mouth of Stubbs Creek, about 1,300 km from Station 1 which could be considered to be minimally impaired by human activity and Qua Iboe Terminal (Station 3) is about 1,100 km from station 2 where human activity is also minimal but the station is closest to the processing plant of Exxon-Mobil crude oil treatment

facility. The estuary substratum consists mainly of fine sand mixed with mud and occasionally with coarse sand. Decaying macrophytes and debris also form part of the substratum. The climate of the area, although comparatively stable, is not uniform. A rhythm of rainfall occurs in conjunction with movements of the southwest Monsoon winds across the Atlantic Ocean and the timing of these movements varies from year to year (Oze *et al.*, (2006).

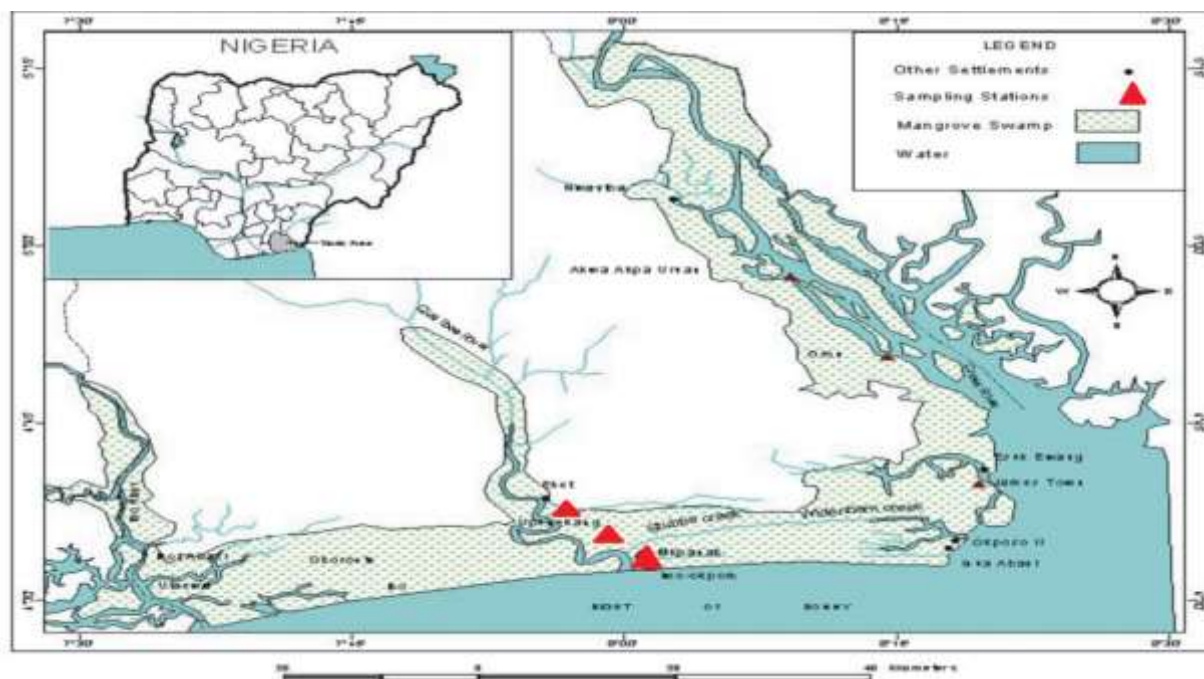


Figure 1. Map of study area showing the mangrove ecosystem of the Qua Iboe estuary and the associated creeks.

MATERIALS AND METHODS

Sample collection

The study was carried out between January and June 2016 from the three stations. Fifty-four (54) surface and underlying water samples were obtained separately in triplicates from each location for six months. Physicochemical parameters were measured using appropriate procedures (APHA, 1998). Since the physicochemical properties of a lotic system could vary with time, sampling was done at regular and specific time intervals in the late-morning hours between 10:00 and 11:00 hours. At each sampling location, the surface water samples were collected close to the middle of the river and stored in 250cm³ standard glass bottles that have been pre-washed with nitric acid, thoroughly rinsed with deionized water and rinsed severally with the brackish water. During collection, measures were taken to avoid air bubbles and were carefully stoppered below water surface to avoid contact with air. Parameters such as salinity, conductivity and total dissolved solids, dissolved oxygen, pH, and

temperature were measured in the field. Other water samples were preserved in cooler box and immediately transported to the laboratory and stored at 4°C in the refrigerator prior to chemical analysis. The chemical analysis was performed at the Akwa Ibom State Water Corporation Central Laboratory, Uyo.

Determination of Physicochemical Parameters

The temperature values of water samples were recorded using mercury-in-glass thermometer, dissolved oxygen values were determined using Hach model Sension 6 Portable Dissolved Oxygen meter, and pH values were measured using HACH model Sension 3 Portable pH meter; while salinity, conductivity and total dissolved solid values were determined and calculated using HACH model Sension 5 Portable Conductivity meter. Alkalinity value was determined by standard titrimetric method.

Determination of Nutrients

The chloride values were determined by standard titrimetric method, and nitrate values were determined using cadmium reduction method with a spectrophotometer model HACH DR/2010. Determination of phosphate values were carried out using Molybdenum blue method with a spectrophotometer (HACH DR/2010 model), while values of sulphate were measured using ion chromatography method by 850 Professional IC Anion (Metrohm model)

Statistical Analysis

The results obtained were subjected to statistical evaluation using Minitab© version 15. Parameters were reported as mean, while one-way Analysis of variance (ANOVA) was used to evaluate significant difference in mean values. Mean separation was carried out using the Turkey test. Correlation coefficient was used to determine the interdependence of sets of data in physicochemical properties. Correlations were performed in a pair wise fashion employing Pearson correlation procedure. Coefficient of variation (CV) was used to evaluate the intra-monthly and intra-station variability.

RESULTS

The mean values of physicochemical parameters determine in this study are reported in Table 1 for the three sites. The values in the parenthesis represent the range values for the entire sampling period (January – June, 2013). The water temperature ranged between 25.5 and 30.0°C across the stations, with overall mean value of 28.22±1.35°C. Temperature at the three sites varied more in January, February and April (CV=1.76%) than in March, May and June with coefficient of variation of 0.00, 1.74 and 0.97% respectively. There were no significant ($P>0.05$) difference in mean water temperatures across the three stations thus giving a steady trend of water temperature in all stations (Table 1). Temperature values were relatively stable across stations. Lowest temperature of 25.5°C was recorded in June, while the maximum temperature of 30°C was observed in the month of March. Significant difference ($P<0.05$) in temperature was observed in all sampling months.

In this study, dissolved oxygen was as low as 0.7 and as high as 6.9 mg/L, with the overall mean value of 4.04±1.87 mg/L. The lowest DO value was recorded during the month of June and highest during the month of January, with significant ($P<0.05$) variation noticed during months of sampling. DO recorded greater variability in the month of June (CV=17.83%) than other months, but the month of May recorded the least variability with 2.92%. The mean and range values of 3.94±1.89 (0.7-6.7), 4.10±1.92 (1.0-6.9) and 4.08±1.79 (1.2-6.4) mg/L were recorded for Stations 1, 2 and 3

respectively (Table 1). The variations did not differ significantly ($P>0.05$) across the stations.

The hydrogen ion concentration (pH) in Qua Iboe Estuary ranges from 6.18 in the month of February in Station 1 to 8.41 in the month of April in Station 3, with the overall mean value of 7.72±0.56. Coefficient of variation showed higher intra-monthly variation during February with 11.67% while June recorded the lowest with 1.30%. The monthly and spatial variations of pH were minimal, but significant ($P<0.05$). The mean values of 7.48±0.69, 7.71±0.44 and 7.98±0.36 were recorded for Stations 1, 2 and 3 respectively (Table 1).

Salinity values ranged between 4.6 and 27.6‰. The highest and lowest salinity values (27.6 and 4.6‰) were both recorded at station 1 in May and February respectively (Fig. 2), monthly variations were significant ($P<0.05$). There was greater variability in the month of February (CV=65.15%) while January, March, April, May and June had CV Values of 12.93, 33.94, 37.18, 34.15 and 19.57% respectively. Variation in salinity differed significantly ($P<0.05$) across the three stations. The overall mean salinity for the study period was 14.48±6.58‰.

Alkalinity values ranged from 6.9 to 52.9 mg/L. The mean values were 14.93±5.50, 15.62±5.05 and 20.17±15.34 mg/L for Stations 1, 2 and 3 respectively (Table 1). Coefficient of variation showed higher intra-monthly variation during February (CV=50.43%) more than other months. The overall mean was 16.91±10.12 mg/L for the estuary. Significant variation ($P<0.05$) in the values of alkalinity was observed in months.

Conductivity values observed during the study period ranged between 9.58 and 151200 µs/cm across the stations, the minimum and maximum values were obtained in February and June respectively (Fig. 3), with the mean composite value of 20348.95±46414.17 µs/cm. The mean values of 25174±56241, 15746±35160 and 20127±44933 were recorded for Stations 1, 2 and 3 respectively (Table 1). Monthly and spatial variations in conductivity were significant from one sampling location to another.

The total dissolved solids ranged between 4470 and 26600 mg/L in the months of May and February in station 1 (Table 1). Coefficient of variation showed higher intra-monthly variation during February (CV=64.68%) while January had the lowest (12.49%). The mean dissolved solids were 13014±7638 (Station 1), 11640±3693 (Station 2) and 16899±5658 mg/L (Station 3) (Table 1). The overall mean value was 13851.11±6294.67 mg/L. Significant difference ($P<0.05$) in means were noticed in all sampling months and across the stations.

Nitrate ranged from 0 to 0.13 mg/L, with the overall mean value of 0.07±0.03 mg/L. No

significant difference ($P>0.05$) was observed across the stations. The mean values were 0.06 ± 0.03 , 0.06 ± 0.02 and 0.08 ± 0.03 mg/L for stations 1, 2 and 3 respectively (Table 1). Coefficient of variation showed higher intra-monthly variation during February (CV=72.17%) more than other sampling months. NO_3^- values showed significant difference ($P<0.05$) in months.

Chloride was observed in the range of 0.0 to 1.9 mg/L, with the highest value (1.9 mg/L) observed during the month of May. Coefficient of variation showed higher intra-monthly variation during February with 119.31% while January recorded 15.96% as the lowest. The mean composite value for the estuary was 0.66 ± 0.41 mg/L. There were significant variations ($P<0.05$) in months and across the stations.

Phosphate ranged between 0.0 mg/L in the month of May at Station 3 and 0.92 mg/L in the month of June at Station 1 (Table 1), with the mean composite value of 0.17 ± 0.13 mg/L. The coefficient of variation depicted a greater variability in the month of May (CV=98.36%) than other months.

Variations in sampling stations differed significantly ($P<0.05$), while no significant difference ($P>0.05$) occurred in the months of sampling.

Sulphate ranged between 2.0 mg/L in the month of March at Station 1 and 18.0 mg/L in the month of February at Station 2 (Table 1), with the mean composite value of 7.72 ± 3.38 mg/L. There was greater variability during March (CV=46.87%) than other months for all stations. The mean values of 7.11 ± 2.87 , 8.11 ± 4.64 and 7.83 ± 2.09 were recorded for Stations 1, 2 and 3 respectively, with no significant difference ($P>0.05$) across them (Table 1). Monthly variations were significant ($P<0.05$) throughout the study period.

Table 2 shows the correlation matrix between some physicochemical parameters and further revealed the significant ($P<0.05$) relationships within each other. The pH showed a significant positive relationship with salinity ($r=0.730$) and TDS ($r=0.725$); While Salinity on the other hand, showed a significantly positive correlation with TDS ($r=0.999$).

Table 1: Physicochemical Properties of Water in Qua Iboe Estuary

Parameters	Station 1	Station 2	Station 3	Permissible Limits WHO (1998)	DPR (2002)
	$\bar{X}\pm SD$ (Min – max)	$\bar{X}\pm SD$ (Min – max)	$\bar{X}\pm SD$ (Min – max)		
Temperature (°C)	28.42 ± 1.43^a (25.5-30)	28.08 ± 1.37^a (25.5-30)	28.17 ± 1.21^a (26-30)	-	30
DO (mg/l)	3.94 ± 1.89^a (0.7-6.7)	4.10 ± 1.92^a (1-6.9)	4.08 ± 1.79^a (1.2-6.4)	-	20
pH	7.48 ± 0.69^a (6.18-8.4)	7.71 ± 0.44^b (7.2-8.3)	7.98 ± 0.36^c (7.45-8.41)	6.5-8.5	6-9
Salinity (‰)	13.62 ± 7.93^a (4.6-27.6)	12.19 ± 3.93^b (6.2-17.2)	17.63 ± 5.96^c (8.8-26.8)	-	-
TDS (mg/l)	13014 ± 7638^a (4470-26600)	11640 ± 3693^b (6000-16540)	16899 ± 5658^c (8460-25400)	-	2000
Conductivity (µs/cm)	25174 ± 56241^a (9.58-151200)	15746 ± 35160^a (12.64-94500)	20127 ± 44933^a (16.2-120600)	2000	-
Alkalinity (mg/l)	14.93 ± 5.50^a (8.1-24)	15.62 ± 5.05^a (11.78-26.4)	20.17 ± 15.34^a (6.9-52.9)	600	-
NO_3^- (mg/l)	0.06 ± 0.03^a (0.01-0.13)	0.06 ± 0.02^a (0-0.1)	0.08 ± 0.03^a (0-0.11)	50-100	20
Cl^- (mg/l)	0.7 ± 0.52^a (0-1.9)	0.47 ± 0.31^b (0-1.2)	0.83 ± 0.28^c (0.5-1.3)	200	-
PO_4^{3-} (mg/l)	0.23 ± 0.21^a (0.08-0.916)	0.101 ± 0.05^b (0.01-0.18)	0.17 ± 0.08^c (0-0.31)	-	5
SO_4^{2-} (mg/l)	7.11 ± 2.87^a (2-13)	8.11 ± 4.64^a (3-18)	7.83 ± 2.09^a (5-11)	200-400	50-200

abc= mean values in the same row with different superscript are significantly different at $\alpha= 0.05$. DPR- Department of Petroleum Resources (2002) limits for substances discharge into water for domestic use in Nigeria.

Table 2: Correlation matrix between some physicochemical properties in water of Qua Iboe estuary

	Temp.	DO	pH	Salinity	TDS	Cond.	Alkal.	NO ₃	Cl ⁻	PO ₄	SO ₄
Temp.	1										
DO	0.573*	1									
pH	0.317	0.360	1								
Salinity	-0.068	-0.048	0.730*	1							
TDS	-0.069	-0.055	0.725*	0.999*	1						
Cond.	-0.832*	-0.698*	-0.283	0.165	0.171	1					
Alkal.	-0.032	-0.332	0.202	0.256	0.261	-0.147	1				
NO ₃	-0.093	-0.011	0.482	0.568*	0.570*	0.019	0.448	1			
Cl ⁻	-0.127	0.056	0.427	0.551*	0.547*	0.200	-0.028	0.593*	1		
PO ₄	-0.309	-0.245	0.077	0.434	0.434	0.396	0.255	0.278	0.377	1	
SO ₄	-0.164	-0.323	-0.183	-0.084	-0.075	-0.025	0.511*	0.305	-0.028	0.106	1

*Significantly correlated at P=0.05

DISCUSSION

Temperature was influenced by influx of freshwater, and ebbing and flowing of the adjoining neritic waters. The study revealed that the water temperatures were uniform and within the acceptable levels for survival, metabolism and physiology of aquatic organisms (DPR 2002). Pearson correlation coefficient indicates a negative but strongly significant ($P < 0.05$) relationship between temperature and conductivity ($r = -0.832$) indicating that an increase in temperature leads to a corresponding decrease in conductivity.

The dissolved oxygen values in this study was similar to those reported for many other Nigerian waters including 4.00-7.50 mg/l for Luubara creek in Niger Delta (Deekae *et al.*, 2010), 4.58 – 5.81 mg/l in Upper and Lower Reach of the New Calabar River in Niger Delta (Dienye and Woke 2015). Low values of DO was observed at the estuary, which is attributed to the increased anthropogenic activities such as high organic content from faecal matter, decayed plant materials and domestic wastes that found their way into the estuary through site 1. Similar low Dissolved oxygen (DO) levels were obtained in Nta Wogba Creek (Tony *et al.*, 2018) and Mbo River (Essien-Ibok *et al.*, 2010). According to USDA (1992), the level of oxygen depletion depends primarily on the amount of waste added, the size, velocity, and turbulence of the stream and water temperature.

pH range of 6.18 – 8.41 documented for Qua Iboe estuary could be considered to be within the range considered as normal for unpolluted aquatic environment (Fakayode, 2005). It is characteristics of a tidal brackish water environment as noted by the International Joint Commission, IJC (1977). Most natural water bodies are known to have a pH range of 5–10 (Tepe *et al.*, 2005). The variation in pH could probably be due to evapo-transpiration process, rainfall and the chemical and biological processes in the water (Mama and Ado, 2003). This is consistent with the report of Akpan (2004), and Tony *et al.*, (2018). The generally lower pH values at station 1 than at stations 2 and 3 may

have resulted from decaying of the domestic wastes and high organic content at station 1 (upstream) contributing to the acidic nature of the water. The significant positive correlation between pH and TDS ($r = 0.725$) and salinity ($r = 0.730$) show that an increase in these parameters result in a corresponding increase in pH.

The salinity from this study showed Qua Iboe estuary as a brackish water environment. The salinity profile for Qua Iboe estuary showed a gradual increase of salinity values from the upstream to downstream along the brackish water creek. Higher salinities were recorded across the stations during the rainy season and high tide, a situation traceable to the incursion of sea water from the ocean.

A minimum level of alkalinity is desirable because it is considered a “buffer” that prevents large variations in pH. Moderately alkaline water (less than 350 mg/l), in combination with hardness, forms a layer of calcium or magnesium carbonate that tends to inhibit corrosion of metal piping (Wright and Welbourn 2002). High alkalinity (above 500 mg/l) is usually associated with high pH values, hardness and high dissolved solids. Water with low alkalinity (less than 75 mg/l), especially some surface waters and rainfall, is subject to changes in pH due to dissolved gases that may be corrosive to metallic fittings. Boyd, (1982), recommended suitability of alkalinities between 20 and 50 mg/l for plankton production for fish culture. Alkalinity is used in the classification of waters especially lakes according to nourishments (Kara *et al.*, 2004). In the absence of sufficient carbonic acid, the bicarbonate ion in the water dissociates to form additional carbon dioxide (Baird, 2010). Algae readily use this carbon dioxide for their photosynthetic needs, at the cost of allowing a build-up of hydroxide ions making the water alkaline. Qua Iboe estuary in this study is classified as rich in terms of nourishments. The nourishments are necessary for photosynthetic activity and plant growth. The values are consistent with those reported for some tropical water bodies;

Amadi-ama Creek (Olufunmilayo, and Enitou, (2018).Epie Creek (Izonfuo and Bariweni, 2001).

Conductivity (electrical conductance), is strongly influenced by the concentration of dissolved constituents. Results from this study compared favorably with the results of Abowei and George, (2009) on Okpoka creek, Essien-Ibok *et al.*, (2010) on Mbo River, and Davies, *et al.*, 2008, on Trans-Amadi (Woji) creek) in Niger Delta. A possible explanation for high value for conductivity in June may be due to the influx of allochthonous organic and inorganic materials from the surrounding catchments area during the rains. Conductivity gave a significant negative correlation with temperature, DO and pH, indicating that an increase in these parameters leads to a corresponding decrease in conductivity. The significant negative correlation with these variables strongly signifies that they have a major influence on the ionic composition of the river.

TDS was higher than 2000mg/l recommended for drinking water and aquatic life by DPR (2002). This may be due to salt intrusion from the sea and is influenced by organic sources such as leaves, silt, plankton, and industrial waste and sewage. This result is similar to the report of Essien-Ibok *et al.*, (2010) where they observed a high in TDS in Mbo River, attributing it to evapo-crystallisation process and low precipitation signifying low dilution. Fatoki *et al.*, (2002), also noted an increase in total dissolved solids in Umtata River (South Africa) from runoff during the summer rains.

Mean nitrate value of 0.07 ± 0.03 was far below the Permissible Limits of WHO (1998) and DPR (2002). The present study agrees with the work reported by Olufunmilayo, and Enitou, (2018). The period of high concentration of chloride recorded in the estuary coincided with the period when the salinity level was quite high and, thus, monthly concentration had significant difference ($P < 0.05$). This observation is consistent with that of Akintola *et al.*, (2011) who affirmed that chloride is usually the major anion in water of high salinity, and further noted the importance in the culture of brackish water or marine species. Furthermore, Lewis and Morris (1986), stated that concentrations of chloride greater than 20 mg/l are desirable in intensive freshwater fish culture systems. Chloride showed a significant ($p < 0.05$) positive correlation with salinity ($r = 0.551$); TDS ($r = 0.547$) and NO_3^- ($r = 0.593$) indicating that a rise in these parameters results in a corresponding rise in the level of chloride.

There was significant difference in values of phosphate recorded for the stations. The observed phosphate value might be due to the regeneration and release of total phosphorus from bottom mud into the water column by turbulence and mixing, or from runoff water into the estuary. Akintola *et al.*, (2011), reported similar observation for the level of phosphates in Epie creek. The levels of phosphates

were found to be below the range recommended for drinking water and aquatic life by DPR (2002). Phosphates and nitrates are important ingredients to plant blooms and the eutrophication of lakes and streams.

The sulphate concentration was below 200-400mg/l recommended for drinking water and aquatic life by DPR (2002). Spatial variations were not significant but monthly variation was significant ($P < 0.05$) for sulphate. The influence of runoff is of importance in the level of sulphate concentration in the estuary. This observation is similar to that obtained for Badagry Creek by Akintola *et al.*, (2011); and Bodo creek by Vincent-Akpu, *et al.*, (2015). There was a positive significant correlation between sulphate and nitrate indicating that a rise in nitrate value results in a corresponding rise in sulphate level.

CONCLUSION

The water quality properties in terms of its physicochemical parameters from the water of Qua Iboe estuary were investigated. Values obtained for the temperatures, DO, pH, salinity, conductivity, alkalinity, nitrate, chloride, phosphate and sulphate were within the standard guideline for survival, metabolism and physiology of aquatic organisms in a brackish water environment. The pollution status of Qua Iboe estuary is low comparable to some other water bodies in Niger Delta region. With the exception of Conductivity and TDS, all parameters examined did not exceed the WHO maximum permissible levels for drinking water. Therefore, there is need maintain this trend and also introduce domestic waste treatment methods so that only treated wastes will be discharged into the neighbourhood of the estuary. Above all, there should be concerted effort to conserve the conditions of the estuary in view of its uniqueness and importance in the life cycle of many aquatic species of tremendous importance to both local and international fisheries.

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