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Spatial trend in the physico-chemical characteristics of Ikpa River, Akwa Ibom State, Nigeria

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Abstract
Triplicate water and sediments samples were collected once a month for a period of nine months (June, 2014 to February 2015) in the four sampling Stations; Edem Iyire (I), Ntak Inyang (II), Iba Oku (III) and Nwaniba (IV). Temperature, Hydrogen ion concentration (pH), transparency, conductivity, dissolve oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), salinity, alkalinity, nitrate, sulphate and phosphate in both water and in sediment were all determined following standard methods. The mean ranges in the physico-chemical parameters in water across the stations were as follows: temperature, 24.85 - 26.15 ºC; pH, 5.588 - 6.919mg/kg; transparency, 1.447 - 2.734m; conductivity, 11.32 - 29.72us/cm; DO, 6.654 - 8.042m/l; COD, 2.493 - 5.146mg/l; BOD, 1.94 - 2.617mg/l; salinity, 0.001 - 0.009; alkalinity, 11.94 - 18.695mg/l; nitrate,0.645 - 0.810mg/l; sulphate, 0.558 - 0.698 mg/l; phosphate, 0.003 - 0.066mg/l. The ranges of the result in the sediment are as follows: temperature, 26.62 - 27.95 ºC; pH, 5.833 - 5.862mg/; Conductivity, 33.85 - 54.61Us/cm; Alkalinity, 23.68 - 40.47mg/kg; Nitrate, 2.700 - 3.717 mg/kg; Sulphate, 2.129 - 2.698mg/kg; Phosphate, 1.451 - 1.724mg/kg. All the physico-chemical parameters examined in water and sediment in the four Stations in Ikpa River fell within the permissible limits provided by the Federal Environmental Protection Agency (FEPA) while conductivity and alkalinity showed significant difference ($P<0.05$) across the four Stations.

Keywords: spatial trend, physico-chemical, Ikpa River, Akwa Ibom State

1. Introduction

Water quality connotes the physical, chemical and biological characteristics of water (Dierssing, 2009) [8]. It is a measure of how suitable water is for a particular purpose (USGS, 2012) [23]. According to Johnson *et al.* (1997) [12], it is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose.

In natural water bodies, water quality is very important because the quality of the water influence the whole aquatic community as well as each stage of the life cycle of the organisms and as such plays a major role in structuring that community (Ogar *et al.*, 2013; Anyadiegwu and uwaezuoke, 2015) [17, 5]. Water quality is important for the protection of aquatic ecosystems. Availability of safe and reliable source of water is an essential prerequisite for sustainable development (Adakole *et al.*, 2008) [1]. High levels of contaminants such as phosphorus, dissolved metals and sediment can have an adverse effect on the productivity of aquatic organisms (Boyd, 2002). The higher the water quality, the more applications it can be used for with minimal treatment (USEPA, 2006; USGS, 2012) [23].

Water quality assessment is of immense importance to practices involving the use of water bodies such as: in the management of fisheries, water supply, pollution control, irrigation and sewage reservoir and impoundment (Adakole *et al.*, 2008) [1]. Water quality data are used to characterize waters, identify trends over time, identify emerging problems, determine whether pollution control programs are working, help direct pollution control efforts to where they are most needed and respond to emergencies such as flood and spills (USEPA, 2006) [23].

The most common standards used to assess water quality relate to health of ecosystem, safety to human contact and drinking water. In the setting of standards, agencies make political and technical scientific decisions about how the water will be used (USEPA, 2006) [23]. In the case of natural water bodies, they also make some reasonable estimate of pristine conditions. Different uses raise different concerns and therefore different standards are considered. Natural water bodies will vary in response to environmental conditions. Environmental scientists work to understand how these systems function, which in turn helps to identify the sources and fates of contaminants (Johnson *et al.*, 1997) [12].

Water is one of the most essential and abundant compounds of the ecosystem as all living organisms on earth including humans require water for their survival and growth (Ogar, *et al.*, 2013) [17] Unfortunately, the availability and quality of water have been impacted upon by both natural and anthropogenic sources due to a lot of demographic factors such as increase in human population, demand for food, land conversion and use of fertilizer have led to the contamination of many River sources including Ikpa River. The release of urban, industrial and agricultural wastes has added various harmful chemicals to the water body thereby altering their inherent physico-chemical and biological characteristics which pose a serious threat to aquatic ecosystem and its quality (Etteokon, 2017) [11].

The monitoring of the quality of water is among the major environmental priorities as it permits direct assessment of the Rivers that are exposed to deleterious anthropogenic factors.

Although few Water quality studies have been investigated in this Rivers, such studies rarely cover the whole length of the River which could have given the baseline on changes caused by natural or anthropogenic processes as the proper understanding of these dynamics is a key to the successful management of any aquatic ecosystem.

Therefore, this study which is first on water quality to cover the whole length of the River (Upstream, Midstream Downstream) from it source in Edem Iyire (Ikono L.G.A.) to its downstream in Nwaniba (Uruan L.G.A) is meant to update information on the trend of some physico-chemical characteristics of Ikpa River with a view of providing necessary information for rational policies that would regulate the state of pollution of the River in order to save this aquatic environment and enhance proper management.

2. Materials and Methods

2.1 Study Area

Ikpa River is situated in Akwa Ibom State (Latitude 05°11′ N and 05°16′N and Longitude E07°55′E and 08°07′E) within the rainforest zone of Southeastern Nigeria (Fig. 3.1). It is a small perennial rainforest River located west of the lower reaches of the Cross River System. It drains a catchment area of 516.5km^2, 76.5km^2 (14.8%) of which is liable to annual flooding. The total length of the main channel (between its source in Ikono and discharge point into the Cross River Creek close to Nwaniba in Uruan L.G.A) is 53.5km. The Cross River finally empties into the Atlantic Ocean. The River drains several parts of Akwa Ibom State including Ikono, Ibiono Ibom, Itu, Uyo and Uruan Local Government Areas of Akwa Ibom State.

The climate of Ikpa River is typical of tropical rainforests, comprising of two main seasons: the wet and the dry season. The wet season is characterized by heavy rains and thunderstorms that last from April to October, while the dry season covers the months of November to March. The monthly distribution of rainfall shows a noticeable fluctuation in the month of August usually termed as the "August break". The mean annual rainfall varies from 2250mm to about 1500mm during the wet and dry seasons. The average minimum and maximum temperature are about 25 °C and 32 °C respectively. The wet season is also characterized throughout the area by relatively low temperatures and a high relative humidity (85 - 95%). The dry season is marked by the dry harmattan winds whose intensity is more felt from late November to early January. The mean annual potential evapo-transpiration (PET) varies from 1425 to 1625mm (Ekpo, 2013) [10].

2.2 Location of Sampling Stations

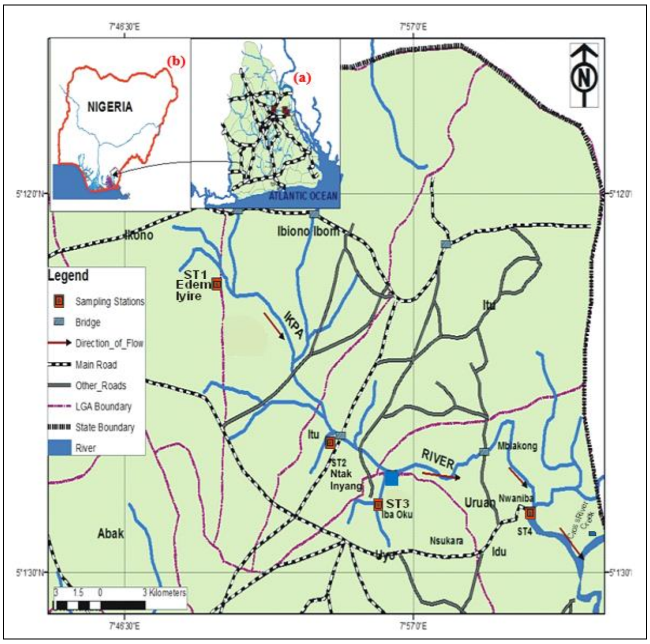
Four sampling Stations (I - IV) were chosen along the River course based on the anthropogenic impact in these Stations. The co-ordinates of the sampling stations were taken using Geographic Positioning System (GPS).

Station I, Edem Iyire is the source of the River (Upstream) located latitude: N007°49'47.6" and longitude: E05°09' 25.0". It is a small headwater stream which is shaded by riparian vegetation. The topography of the catchment is hilly and elevated. The river is fast flowing which may be due to land excavation and dredging activities carried out in the area. The River serves as a source of drinking water for the rural community. Laundry activities are also carried out in the River.

Stations II is Ntak Inyang (Midstream) located centrally along the Calabar-Itu highway. It lies Latitude: N007°53'59.2" and Longitude: E05°05'04.5". The Station is characterized by moderately fast water current. The bottom of the River is prominently sandy and muddy. The topography of the catchments is characterized by gentle slope. Some parts of this water surface are covered with floating leaves of *Azolla* and *Salvinia* species. The riparian zone is dominated by strands of *Raphia hookeri* and *Raphia vinifera.* Sand dredging and fishing are carried out in this Station.

Station III (Iba Oku) is also located centrally (midstream) along Uyo Village road and lies within Latitude: N007°56'11.9" and Longitude: E05°04'10.3". The River is marked with a reduced flow current with a sloppy topography of the catchment attributed to the gully erosion in this area. The erosion site of the University of Uyo, town campus drains into this station while Uyo urban waste usually dumped at the ravine along Eka Street (Uyo) also drains into this tributary. Bathing, laundry and refuse dumping are carried out along the bank.

The lower Ikpa River, Station IV (Nwaniba) is the downstream segment that discharges into Cross River Creek. It is located within Latitude N008°01'15.2" and Longitude: E05°03'25.7"; is tidal and shaded by over hanging canopy of riparian vegetation mostly *Elaeis quineensis, Pandanus candelabrum, Raphia hookeri, R. vinifera* and other tropical forest trees. The predominant aquatic macrophytes are *Nymphae*, *Vossia*, *Utricularia* and *Musanga crinium.* Human activities in the area include fishing, farming, boat building and wood logging.



a) Location of Ikpa River on the Map of Akwa Ibom State
b) Location of Akwa Ibom State on the Map of Nigeria

Fig 1: Location of the Study Stations in Ikpa River Basin. Inset

2.3 Samples Collection

Water and sediments samples were collected once a month between the hours of 9am – 12pm for a period of nine months in the four sampling Stations; Edem Iyire (1), Ntak Inyang (2), Iba Oku (3) and Nwaniba (4). Water was taken in each of the Stations at a depth of 30cm below the surface using one litre plastic containers with screw caps tightly covered to avoid trapping of air. The container was initially rinsed with concentrated HNO_3 and later rinsed with distilled deionized water.

2.4 Physico-chemical Analysis of Samples

Temperature, hydrogen ion concentration (pH), transparency, conductivity, dissolve oxygen, chemical oxygen demand, biochemical oxygen demand, salinity, alkalinity, nitrate, sulphate and phosphate in both water and in sediment were all determined following standard methods (APHA, 2005).

3. Result and Discussion

Mean physico-chemical characteristics of water and sediment samples in the four studied stations are presented in Table 1 and 2 respectively with the national guidelines for water qualities permissible limit for various uses in Nigeria as provided by FEPA for comparison.

Table 1: Spatial variation of the Physico-chemical Concentrations in Water of Ikpa River

	Station I		Station II		Station III		Station IV		FEPA
Parameters	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	
Temp. (º C)	24.85[a]	0.513	25.38[a]	0.537	25.35[a]	0.347	26.15[a]	0.593	Ambient
pH	6.129[a]	0.351	6.469[a]	0.238	6.919[a]	0.342	5.588[a]	0.524	6.5-8.5
Transparency(m)	1.727[a]	0.149	1.812[a]	0.280	1.447[a]	0.57	2.734[a]	0.265	NG
Conductivity(us/cm)	11.32[a]	4.784	18.465[b]	4.65	29.72[a]	1.549	19.18[b]	2.354	1000.00
DO (mg/l)	8.042[a]	0.935	7.47[a]	0.473	7.104[a]	0.431	6.654[a]	0.517	NG
COD (mg/l)	2.493[a]	0.488	3.118[a]	0.456	5.146[a]	0.854	3.277[a]	0.506	NG
BOD (mg/l)	1.941[a]	0.206	2.095[a]	0.274	2.617[a]	0.176	1.991[a]	0.178	NG
Salinity (mg/l)	0.008[a]	0.008	0.001[a]	0.005	0.009[a]	0.006	0.028[a]	0.010	250.00
Alkalinity(mg/l)	14.36[a]	4.463	11.94[b]	3.268	15.21[a]	2.407	18.695[b]	1.076	NG
Nitrate (mg/l)	0.719[a]	0.035	0.658[a]	0.03	0.645[a]	0.016	0.810[a]	0.037	50.00
Sulphate(mg/l)	0.692[a]	0.155	0.558[a]	0.042	0.652[a]	0.027	0.698[a]	0.059	100.00
Phosphate(mg/l)	0.005[a]	0.005	0.066[a]	0.065	0.003[a]	0.003	0.004[a]	0.001	250.00

*Similar letters superscript indicates means that are not significantly different (P<0.05) and vice versa.SE: Standard Error, NG: No Guideline. FEPA: Federal Environmental Protection Agency.

Table 2: Spatial variation in the Physico-chemical Concentrations in sediment of Ikpa River

	Station I		Station II		Station III		Station IV		FEPA
Parameters	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	
Temp(º C)	26.82[a]	0.489	27.95[a]	0.712	27.27[a]	0.957	26.62[a]	1.117	Ambient
pH	5.862[a]	0.418	5.861[a]	0.531	5.835[a]	0.527	5.833[a]	0.500	6.5-8.5
Cond.(us/cm)	35.30[a]	13.56	33.85[a]	13.17	54.61[b]	14.49	49.31[a]	15.01	1000
Alkalinity(mg/kg)	40.47[a]	14.001	23.68[b]	11.490	26.72[a]	10.374	24.77[b]	9.619	NG
Nitrate (mg/kg)	3.277[a]	0.226	3.717[a]	0.285	3.083[a]	0.244	2.700[a]	0.295	50
Sulphate(mg/kg)	2.188[a]	0.012	2.243[a]	0.131	2.698[a]	0.175	2.129[a]	0.187	100
Phospha(mg/k)	1.706[a]	0.091	1.451[a]	0.112	1.724[a]	0.142	1.553[a]	0.163	250

*Similar letters superscript indicates means that are not significantly different (P<0.05) and vice versa. SE: Standard Error, NG: No Guideline. FEPA: Federal Environmental Protection Agency.

The least mean value of water temperature was (24.85± 0.513)ºc recorded in Station I with the highest of (26.15 ± 0.593)ºc in Station IV. There was no significant difference (P<0.05) in the values of temperature between the four studied Stations. Temperature recorded in the sediment varied from (26.62 ± 1.117) in Station IV to (27.95 ± 0.712) with no significant difference in all the Stations. pH recorded its highest mean value (6.919 ±0.342) in Station III with the least (5.588 ± 0.524) in Station IV. There was no significant difference (P < 0.05) in the mean values of pH across the Stations. In the sediment, the least mean values of pH (5.833 ± 0.500) mg/kg was recorded in Station IV and the highest was (5.862 ± 0.418). There was no significant difference in the values of pH in all the Stations.

Transparency value in water was high in Station IV (2.734 ±0.265)m and the least (1.447 ±0.57)m was recorded in Station III. Transparency was not significantly different (P< 0.05) across the Stations. Conductivity in water recorded its highest mean value in (29.72 ± 1.549) u/cm in Station III and the least (11.32 ± 4.784) in Station I. Significant difference was obtained in the mean values of conductivity between Stations II (P< 0.05, 18.465)us/cm and IV (P < 0.05, 19.18) us/cm. In the sediment, Conductivity recorded the lowest mean value (33.85 + 13.17)us/cm in Station II and the highest (54.61 ±14.49) Us/cm which was significantly (P<0.05) higher than other three Stations.

The highest and the least values of Dissolved oxygen in water were recorded in Station I (8.042 ± 0.935)m/l and IV (6.654 ± 0.517)m/l respectively. There was no significant difference (P< 0.05) in the values of Do across the four Stations. In water, COD recorded the least values (2.493 ± 0.488) mg/l in Station I and the highest was in Station III (5.146 ± 0.854) mg/l. There was no significant difference (P< 0.05) in the values of COD in all the Stations. The highest value of BOD was recorded in water in Station III (2.617 ± 0.176) mg/l and the least value in Station I (1.94 ± 0.206) mg/l. BOD was not significantly different across the Stations.

Salinity in the water ranged from (0.001 ± 0.005) mg/l in Station II to (0.009 ± 0.006) and was not significantly different (P<0.05) across the Stations. The mean value of Alkalinity in water was significantly higher (P <0.05, 18.695 ± 1.076) mg/l in Station IV and a significantly difference was recorded in Station II (P<0.05, 1.94 ± 3.268) mg/l. Station III although not significantly different was slightly higher (15.21 ± 2.407) mg/l than Station I (14.36 ± 4.463) mg/l. The mean value of Alkalinity in sediment varied from (23.68 ± 11.490) mg/kg in Station II to (40.47 ± 14.001) mg/kg in Station I. There was a significant difference in the mean values of Alkalinity between Stations II (P<0.05, 23.68) and Station IV (P <0.05, 24.77 which were significantly lower than Stations I and III.

Nitrate recorded the highest mean value (0.810 ±0.037) mg/l in Station IV and the least (0.645 ± 0.0016) mg/l in Station III. In the sediment, the lowest mean values (2.700 ± 9.619) mg/kg of Nitrate was recorded in Station IV and the highest (3.717 ± 0.285) mg/kg was in Station II. The mean values of nitrate in both water and sediment was not significantly different (P <0.05) across the Stations. The highest mean value of sulphate was recorded in Station IV (0.698 ± 0.059) and the lowest (0.558 ± 0.042) mg/l was recorded in Station II. In the sediment, Sulphate recorded its lowest mean values (2.129 ± 0.187)mg/kg in Station IV and the highest (2.698 ± 0.175) mg/kg in Station III. Sulphate was not significantly different (P <0.05) across the Stations in both water and sediment.

The mean values of phosphate in water ranged from the lowest (0.003 ± 0.003) mg/l in Station III to the highest (0.066 ± 0.065) mg/l in Station II while in the sediment, Phosphate varied in its mean concentration (1.451 ± 0.112) mg/kg in Station II to (1.724 ± 0.142) mg/kg in Station III. No significant difference (P<0.05) was recorded in the mean values of phosphate across the Stations in water and sediment. In all the physico-chemical parameters examined in water and sediment in the four Stations in Ikpa River, only conductivity and alkalinity showed significant difference (P<0.05) across the four Stations.

Temperature is an essential parameter in any established system as it controls the rate of all chemical reactions (Etteokon, 2017) [11]. Although water temperature in this study showed no significant difference among the stations, highest mean value was recorded in Station IV with the least in Station I. The least value recorded at Station I could be attributed to the location of this Station as the headstream which is characterized by the high riparian vegetations that prevent the direct sunlight heat radiation on the water compared to other Stations. This is in line with the observation of Allan (1995) [3] that temperature can be influenced by the amount of shading, climate and elevation.

In this study, pH concentration although not significant (P<0.05) among the Stations in both water and sediment fell within the slightly acidic condition, typical of a tropical forest River. The values of pH recorded in this study fell within the range (5.55 – 7.91) recorded by Ogbeibu and Omoigberale (2007) in Osse River. The low pH value recorded in Station IV shows that the water was acidic and the acidity may be related to the intense degradation of organic matter, since low water acidity is derived from ions released during decomposition (Shimabukuro and Henry, 2011) [19].

Dissolve oxygen content of any water body depends on the mixing and aeration of water, water temperature, duration of sunlight received and altitude of the studied area (Etteokon, 2017) [11]. Dissolved oxygen showed no significant difference in water among the study Stations but the concentration in Station I was higher than other Stations and this could be linked to the abundance of riparian vegetation in Station I over other Stations which serve as a canopy which covers the water and helps to reduce the amount of sunlight radiation on water which would have increased the water temperature. According to Chapman and Kimstach (1996) [7], high temperature and dissolve oxygen are inversely related as dissolve oxygen declines with increase in temperature. Also, the low DO obtained in other Stations may be traced to the abundance of decaying organic matter from different sources along the River which uses oxygen in its decomposition (Ukogo and Onyedineke, 2012; Kuma and Khan, 2013) [21, 15].

BOD is an essential parameter as it measures the effects of pollution on a receiving water body (Edokpayi *et al.*, 2010) [9]. In this study, although no significance difference was evident among the Stations, Station III was slightly higher in concentration over other Stations. This is indicative of high organic content which could be linked to the relative shallowness of this stream, the usual dumping of urban domestic and other forms of waste. The BOD concentration recorded in the Stations falls within the range (1.23-3.74) recorded in Ogba River, Benin, Nigeria by Uqwu *et al.* (2008).

COD measures the amount of dissolved oxygen required to cause chemical oxidation of the inorganic material in water (Etteokon, 2017) [11]. It is one of the key indicators of the environmental health of surface water. In this study, a higher concentration of COD was recorded in Station III over other Stations. This indicates high soluble inorganic compounds in the Station which could be as a result of urban refuse dump in parts of this Station. Also, its nearness to road may have also contributed to the high concentration of COD in Station III as this could serve as a source of hydrocarbon from passing vehicles as well as vehicles and tricycle usually washed along the River bank. According to Williams and Feltmate (1992) [24], vehicles impose an additional urban related stress in environment as higher values of COD in urban surface waters result due to hydrocarbons leaked from all automobiles (i.e oil and gas).

A significantly and non significantly higher mean values of Alkalinity recorded in Stations IV and III respectively were linked with the higher volume of water in Station IV which according to Ali *et al.* (2007) [4], aids in diluting the water. While the observed trend in Station III was traced to the shallowed with a reduced volume of water in Station III as well as leaching from carbonate soils and rocks into the River as reported by Haag *et al.* (2010) [14] that natural events such as floods can lead to the resuspension of the contaminants out of deeper sediment layers into water column. A significantly and non significantly (p<0.05) low concentrations of Alkalinity in Stations II and I respectively were attributed to much of the anthropogenic activities as well as intense degradation which raises the acidity of water resulting in a corresponding low alkalinity in these Stations. This is in line with Galdean *et al.* (2000) [13] report that increasing amounts of acid in a water body decreases the buffering capacity of the water resulting in a low alkalinity.

Transparency showed no significant difference among the Stations but Station IV showed a higher mean value over other Stations and was traced to the reduced suspended particles in water in this Station over other Stations.

Conductivity of a water body is an index of the total ionic content, it is useful in determining the freshness or otherwise of the water. A significantly (P<0.05) lower concentration of conductivity in Stations II and IV over Station III was recorded. Although the concentration of conductivity recorded across the Stations were low compared to what was recorded in a Nigerian River by Omoigberale and Ogbeibu (2010) [18]. According to Edokpayi *et al.* (2010) [9], the conductivities are much less than 500us/cm at the peak of dry season many inland water bodies. This low conductivity indicates low ionic concentration of the water during the study period which is typical of a tropical River and could be traced to a low salinity content in the River as Nkwoji *et al.* (2010) [16] have identified salinity and conductivity as associated factors with synergistic relationship. Therefore the low (zero) salinity recorded in Ikpa River may have been responsible for the corresponding low conductivity in this study. The higher concentration of conductivity in Station III could be traced to the shallowness of the Station as well as the location of a refuse dump site along the River which tends to concentrates the water thereby increasing the concentration of conductivity due to the additional chloride, phosphate and nitrate ions (Ali *et al.*, 2007) [4].

The insignificant range of salinity recorded in water across the Stations during the period of study is typical of a fresh water condition. According to Alagoa and Alleleye (2012) [2], fresh water habitats are defined as having salinities of less than 1 ppt (parts per thousands) or 1 gram of total dissolved solids per liter of water and most are usually considerable less than 1ppt.

The nutrient parameters of nitrates (PO_3-N), phosphates (PO_4-P) and sulphate (SO_4^{2-}) in water were generally low in concentration throughout the study period and there was no significant difference ($P<0.05$) in the parameters across the four Stations. A low nutrient level of this nature has been reported for Niger Delta region (Alagoa and Alleleye, 2012) [2]. This oligotrophic nature of Ikpa River can be attributed to high activity rate of organisms and their ability to quickly use up the nutrient in the water column as soon as it is released and the poor nutrient status of the substratum.

4. Conclusion

The results of the physico-chemical analysis of the study reveals that Temperature, hydrogen ion concentration (pH), transparency, conductivity, dissolve oxygen, chemical oxygen demand, biochemical oxygen demand, salinity, alkalinity, nitrate, sulphate and phosphate in both water and in sediment fell within the permissible limits provided by the Federal Enviromental protection Agency (FEPA) and standards for water qualities while conductivity and alkalinity showed significant difference ($P<0.05$) across the four Stations in all the physico-chemical parameters examined in water and sediment in Ikpa River.

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