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SPATIAL AND TEMPORAL VARIATIONS OF PHYSICO-CHEMICAL VARIABLES IN A SMALL 'PRISTINE' STREAM IN NIGER DELTA, NIGERIA

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ABSTRACT

Spatial and temporal variations of physico-chemical variables of Onu-Iyi – Ukwu stream were studied for 12 months from March 2005 to February 2006. Three sampling stations were established along the main stream channel from source to mouth. Spatial variation in physico-chemical parameters indicated that total alkalinity, total hardness, conductivity, and nitrate-nitrogen (NO₃) recorded their highest values at the upper reaches (with values 14.0mg/l, 88.09mg/l, 17.00µscm, and 0.60mg/l respectively). Dissolved Oxygen (DO) and pH had their maximum values of 8.20mg/l and 6.94 at the middle reaches. Turbidity, biochemical oxygen demand (BOD), temperature and phosphate-phosphorus (PO₄) increased steadily from source to mouth. The observed seasonal variation indicated that wet season values were higher for all the parameters except temperature, turbidity, phosphate-phosphorus (PO₄) and total alkalinity although the values were not statistically significant at $p > 0.05$. The correlation coefficient (r) showed no significant relationships $p < 0.05$ between physico-chemical parameters except DO and BOD with correlation values of (0.75 and -0.54) respectively.

INTRODUCTION

Studies on physico-chemical parameters of the rivers, tributaries and streams in eastern Nigeria are few and the available ones are mostly of short term duration and are based on a few specific samples, which are not significant in terms of baseline data necessary for future studies and for monitoring. They include Ekeh; I.B (1988) unpublished, Nwadiaro (1987), Odigi and Nwadiaro (1988), Nwadiaro and Umeham (1985), Nwadiaro (1982).

Both aquatic and terrestrial life requires water for support, movement, feeding and for maintenance of body functions. The physical and chemical properties of water can therefore directly or indirectly affect aquatic life. The movement of water from a high altitude to a lower one is due to its physical properties such as surface tension and viscosity. Movement of water may erode the land over which it flows, carrying along with it large amounts of suspended solids which will affect its ability to support plant and animal life by increasing its turbidity, reducing light penetration and in areas of where the current velocity is slow, the suspended materials settle on the bottom and affect benthic organism. Water is also a good solvent for various chemical compounds required by all aquatic organisms to survive. Two gases, carbon and oxygen exist in water and each dissolves at a different rate and the amount dissolved is affected by temperature.

There is no information concerning the physico- chemical hydrology of Onu-Iyi-Ukwu stream. This study provides preliminary data which can be used for future monitoring and assessment of pollution and degradation of the Onu-Iyi-Ukwu stream.

MATERIALS AND METHODS

Study Area

Onu-Iyi-Ukwu stream is located in Akabor, Ahiara-Mbaise, Imo State Nigeria on approx. latitude 5°30'N and longitude 7°19'E. The stream originates as a spring from a neighbouring Local Government Isiala Mbano in Imo State and joins two other streams Iyi-Uzo-Aku and Uramiriukwa before emptying into the Otamiri River, a major tributary of the Imo River.

Field Procedures

The three sampling stations were sited at lower; middle and upper reaches. Station 1

was located upstream and station 3 downstream.

Water samples for physico-chemical analysis were collected using plastic containers. Samples were collected once a month from March 2005 to February 2006 at the surface and confined to the mid stream water. Samples were analyzed within 48 hours after collection with no preservatives used. Samples for dissolved oxygen and biochemical oxygen demand were collected with 250ml Nestlé's bottles and fixed *in situ*. Water temperature measurements were done at site, using mercury in glass thermometer.

Fig 1: Ahiazu Mbaise Local Govt Area showing Onu-Iyi-Ukwu River and sampled points

Laboratory Procedure

The physico-chemical analysis of water samples followed the standard limnology methods of APHA (1975). pH was measured with a pH meter (model 3015 jenway), using pH buffer solution of 4.0, 7.0, and 9.0. Turbidity was determined using spectro-photometric method at 420 nm. Total alkalinity was determined using titrimetric method (APHA, 1975) with a 0.2n H₂SO₄ and methylated orange indicator. Nitrate-Nitrogen was measured using the brucine method (APHA, 1975) while conductivity was determined using a conductivity meter (Jenway model 4010). Phosphate-Phosphorus was determined by

the ascorbic acid method (APHA, 1975), total hardness by titrimetric method using ethylene diaminetetracetic acid (EDTA) (APHA, 1975). Dissolved oxygen (DO) and biochemical oxygen demand (BOD) were determined using the modified Azide method (APHA, 1975).

Results

Surface water temperature during each month showed seasonal variation. All reaches noted peak values in February. Lower values were recorded between August and October. All stations showed definite pattern of increased values from August to February. The seasonal variation

was found with higher readings in the dry season at all the stations (Table 2). These seasonal differences were statistically non-significant at the upper reaches and negatively significant at the middle and lower reaches. Correlation showed non-significant values.

BOD values ranged from 3.8 mg/l - 22.4 mg/l (Table 1). The highest monthly variation occurred in the lower reaches. Higher values were observed in the wet than dry season (Table 2) with non-significant differences at all the reaches. There was a significant positive correlation at the upper reaches and negative correlation at the middle and lower reaches ($r = 0.61, -0.55, -0.54$).

DO values ranged from 2.00 - 8.20 mg/l (Table 1). All the stations showed peak values of 8.0 mg/l in February 2006. The wet season values were slightly higher than dry season value with no significant difference between seasons. There was a positive correlation between the seasons at stations 1 and 3 (Table 2).

pH values peaked in June, July and February at all stations. Variability was highest at the lower reaches and lowest at the upper reaches. The upper and middle reaches recorded higher wet season values than dry season values but no significant difference was found between the seasons. There was a negative correlation at station 1 and 3 (Table 2).

The monthly variation of turbidity was dramatic at the various stations. Periods of low and high values in August and September coincided with all reaches. Values were highest at all stations in November and lowest in March. The pattern of variation recorded dry season maximum against wet season minimum in all the stations with a non-statistical level of significance (Table 2). Correlation coefficient for the two seasons indicated a negative non-significant correlation (Table 2).

Total hardness varied monthly at all the stations. High monthly variation occurred at the upper reaches while low variation

occurred in the lower reaches. Total hardness showed dry season maximum and wet season minimum. However, the lower reaches recorded an increase in wet season value against dry season. These difference were statistically non significant. A non-significant negative correlation was also recorded in all the stations (Table 2).

Total alkalinity peaked in January with values ranged from 0.50-14.40 (Table 1). Alkalinity data showed dry season maximum and wet season minimum values (Table 2), with a non-significant difference between the seasonal values at all the stations. However, the Upper reaches showed a negative correlation, while the middle and lower reaches indicated a positive non-significant correlation.

Nitrate varied independent of season as high and low values occurred at both dry and wet season months. The pattern of fluctuation produced several peak and low values at each station. All stations recorded peak values in the month of July. Wet season values were higher than dry season values by 0.1mg/l but differences were not statistically significant. The correlation coefficient for the seasons showed negative correlation at all the reaches (Table 2).

Phosphate showed a definite pattern as no values were recorded from May 2005 to January 2006. February observed the lowest 0.009mg/l in all the stations and the highest values occurred in April with values of 1.6 and 1.8mg/l in middle and lower reaches. A non significant difference exists at the reaches. Correlation coefficient for the two seasons showed zero correlation.

The monthly variations in electrical conductivity at various stations ranged from 6.00-17.00 μscm^{-1} at the upper reaches. The lowest conductivity value 6.0 μscm^{-1} occurred in March and the highest 17.0 μscm^{-1} in August). Conductivity showed no seasonal variation at all the reaches as wet season maximum value of 8.67 μscm^{-1} and minimum dry of

8.0 μscm^{-1} were obtained at the lower reaches with a non-significant difference between the seasonal values. Correlation (r) showed that upper reaches had a non significant negative relationship while middle reaches, recorded a significant negative correlation and lower reaches recorded no correlation at all (Table 2).

DISCUSSION

The water temperature range of 25.5 - 29.2°C, falls within the range noted in some tropical rivers. Alabaster and Lloyd (1980), recorded 25°C - 35°C, Egborge and Jolomi (1986) observed 25°C - 31°C, Ekeh and Sikoki (2003), recorded 23.2°C - 31°C in New Calabar River. The increased temperature values towards lower reaches have also been reported in other tropical rivers. The dense tree canopy at the upper reaches which shades the water from solar radiation is partly responsible for the observed temperatures at the upper reaches.

The range of turbidity values (0.00- 4.00 nm) reported in the study agrees with the observed ranges in New Calabar River where Ekeh (1998) recorded a range of 0.4 - 3.32 as well as the observed values with ranges of 30.0 - 101.5 cm recorded at Mfang-Mfang stream. The minimum turbidity at the upper reaches agrees with the finding of Ekeh (1998) at New Calabar River. Maximum turbidity at lower reaches is attributed to high input of allochthonous material during the period of high water and also due to human activities.

The observed range of BOD (3.84 - 22.40 mg/l) in the study is higher than some tropical rivers studied. Ekeh and Sikoki (2003) recorded 0.2 - 6.8 mg/l values in the New Calabar River. Odokuma and Okpokwasili (1996) recorded 0.25 - 4.20 mg/l at the middle of New Calabar River. The higher range of 22.4 mg/l observed could be attributed to increase decay of organic matter from anthropogenic sources particularly at the lower reaches. This agrees with level of 6.25 mg/l BOD at Njaba River near its deltaic end (Nwadiaro

et al, 1982). The observed value of BOD at the lower reaches of the study depicts the River as clean in the upper reaches but polluted in the lower reaches. However, the highest BOD recorded in the study exceeds the limits of international standard for water quality. The difference observed between the stations could be attributed to high organic load from human perturbations and influx of allochthonous materials from surrounding environment through erosion.

The observed range of Dissolved Oxygen 2.0 - 8.2 mg/l indicated low oxygen level which agrees with findings of low oxygen level in New Calabar River (Ekeh and Sikoki, 2003). The range is similar to values obtained from other studies such as New Calabar River 4.5 - 9.9 mg/l (King and Nkata, 1991) 3.5 - 7.5 mg/l in Bonny River (Chinda and Pudo, 1991), 6 - 8 mg/l in Densu River (Biney, 1991) and 7.29 mg/l in some rivers in the Niger Delta (Nwadiaro *et al*, 1982). The low Dissolved Oxygen observed is probably due to organic detritus and human interferences particularly at the lower reaches. The variation of DO along the stream indicated that, the lower values at the lower reaches could be due to shading by surface by surface floating aquatic macrophytes such as *Tania sp*, *Pistia sp* and *Azolla sp*. Pennak (1971), reported that shading by macrophytes reduce photosynthesis in water as well as dissolved oxygen value. The low DO obtained at the lower reaches of Onu-Iyi-Ukwu stream is chiefly caused by high BOD probably due to organic matter from human activities (such as washing off melon, bread fruit etc) and also due to influx of allochthonous materials during the periods of high water. The pH concentration (Hydrogen ion concentration) range from 4.47 - 6.94 depicts acidic water conditions. The observed pH range is similar to the range recorded in other studies of Nigerian rivers. Ogan (1982) recorded pH of 5.6 - 6.0 in some rivers in Port Harcourt. Nwadiaro *et al* (1982) recorded 5.7, in Imo

River, 6.1 Obigbo, and 5.7 Aluu. The result of hydrogen ion concentration in this study depicted the stream is a clear acidic water type. Similar observations of acidic fresh water have been reported by Moses (1979) in Cross River systems and Ekeh (1988) in Nworie stream.

The range of total alkalinity observed can be referred to as soft water with low total alkalinity values of 0.50 - 14.4 mg/l. The values in this study could be regarded as low, with consequent low biological production. Nwadiaro *et al* (1982) reported similar low value of 10 - 17.5 mg/l in Imo River at Obigbo. Ekeh, 1998 (unpublished data) recorded low values of total alkalinity of 1 - 15 mg/l at the upper reaches of New Calabar River. The high values of total alkalinity at the upper reaches agrees with results obtained in Cross River Systems (Moses, 1979) who reported that total alkalinity was higher in the upper reaches than lower reaches.

Total hardness in this study, 4.0 - 80.09 falls within the range recorded by other workers. Total hardness in surface waters is largely attributed to the calcium and magnesium carbonates. Ekeh and Sikoki (2003) recorded 1.0 - 1872 mg/l in New Calabar River. Hall *et al* (1977) observed range of 40 - 50 mg/l CaCO_3 in River Zambesi which agrees with the high value in the present study. Ogan (1988) noted low range of 0.01 - 0.25 mg/l in rivers in Port Harcourt in contrast. The high values of total hardness at the upper reaches and low value at the lower reaches agreed with observations of Moses (1979) in Cross River systems.

The electrical conductivity range of 6.0 - 17.0 μscm is lower than values recorded in the New Calabar River (Ekeh and Sikoki, 2003). However, the observed range agrees with results of some tropical Rivers. Sikoki and Veen (2004), recorded values 3.8 - 10.0 $\mu\text{mhos/cm}$ in Shiroro Lake. Grrerarth and Deny, (1979) 8.1 μscm for coastal lakes at Sierra Leone, while Moses, (1979) reported 6-25 μscm in Cross River Systems. The Longitudinal variation in

conductivity showed higher values in the upper reaches than lower reaches. This result did not conform to observations of Moses, (1979) in Cross River Systems and Ekeh and Sikoki (2003) in New Calabar River who reported low conductivity value at the upper reaches and high values at the lower reaches.

The 0.00 - 0.6 mg/l range of Nitrate-Nitrogen concentration observed conforms to values of other African Rivers. Sikoki and Veen 2004, recorded values ranging from 0.9 - 86 mg/l in Shiroro Lake; Soko River, 0.1 - 0.44 mg/l (Holden and Green, 1960), River Zambesi, 0.1 - 0.30 mg/l (Hall *et al*, 1977), 0.00 - 0.10 mg/l in some rivers in Port Harcourt (Ogan, 1988), 0.0 - 0.3 mg/l in at Warri River (Egborge and Jolomi, 1986) and 0.0 - 0.21 at New Calabar River (Ekeh and Sikoki, 2003). Nitrate concentration in the stream showed variation with maximum values occurring at the upper reaches and minimum at the lower reaches. This agrees with observations of Akpan and Offem (1993) in Cross River, with reduced values towards lower reaches. This contrasts with Ekeh and Sikoki (2003) in New Calabar River. This could be due to decayed organic matter.

Phosphate is one of the principal nutrients that limit productivity of tropical waters (Raymont, 1980; cited in Ekeh, 1998). The occurrence of phosphate-phosphorus in low concentrations in Onu-Iyi-Ukwu stream is in line with the concentrations in other unpolluted tropical waters. Ogan (1988) recorded values of 1.0 mg/l in Port Harcourt River. Adeniyi (1979) noted 1.9 mg/l in Lake Kainji, Nwadiaro and Umeham (1985) recorded trace to less than 1.0 mg/l in Oguta Lake while Hall *et al* (1977) recorded 0.11 - 0.37 mg/l in River Zambesi. Also Sikoki and Veen (2004) recorded low values in Shiroro Lake.

The high phosphate values observed at the middle and lower reaches with very low value at the upper reaches agrees with the findings of Ekeh (1998) in New Calabar

River and Akpan and Offem, (1993) in Cross River.

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Table 1: Mean and Standard Deviations of Physico-Chemical Parameters for Stations 1-3 of the Onu-Iyi-Ukwu Stream March-February 2006

PARAMETERS	UPPER REACHES			MIDDLE REACHES			LOWER REACHES		
	Mean $\pm$ SD	Min	Max	Mean $\pm$ SD	Min	Max	Mean $\pm$ SD	Min	Max
BOD (mg/l)	10.28 $\pm$ 2.17	6.40	14.40	9.85 $\pm$ 3.90	6.40	20.00	9.51 $\pm$ 5.49	3.84	22.40
DO (mg/l)	5.90 $\pm$ 1.61	2.00	8.00	5.72 $\pm$ 1.86	2.40	8.20	5.80 $\pm$ 1.63	2.00	8.00
pH	6.19 $\pm$ 0.55	5.30	6.76	6.15 $\pm$ 0.75	4.47	6.94	6.06 $\pm$ 0.65	4.90	6.93
TURBIDITY (nm)	0.44 $\pm$ 0.87	0.00	3.00	0.59 $\pm$ 0.84	0.00	3.00	0.70 $\pm$ 1.10	0.00	4.00
TOTAL ALK.(mg/l)	3.67 $\pm$ 3.62	1.20	14.40	2.78 $\pm$ 1.84	0.75	7.20	2.85 $\pm$ 1.71	0.50	7.20
TOTAL HARDNESS (mg/l)	22.81 $\pm$ 28.95	5.60	88.09	26.13 $\pm$ 23.41	4.40	80.08	24.44 $\pm$ 22.60	4.00	80.08
NITRATE (mg/l)	0.24 $\pm$ 0.17	0.00	0.60	0.13 $\pm$ 0.10	0.00	0.33	0.16 $\pm$ 0.13	0.00	0.47
PHOSPHATE (mg/l)	0.00	0.00	0.01	0.13 $\pm$ 0.46	0.00	1.60	0.15 $\pm$ 0.52	0.00	1.80
CONDUCTIVITY(μ scm)	9.75 $\pm$ 3.41	7.00	17.00	8.42 $\pm$ 1.08	7.00	10.00	8.33 $\pm$ 1.67	6.00	
TEMPERATURE ($^{\circ}$ C)	27.27 $\pm$ 1.06	25.50	29.10	27.61 $\pm$ 1.04	25.50	29.20	27.61 $\pm$ 1.05	25.50	

Table 2: Mean Wet and Dry Season values of the Physico-Chemical Parameters, Standard Deviation (in bracket), t-test and Correlation Co-efficient (r)

PARAMETER	UPPER REACHES				MIDDLE REACHES				LOWER REACHES			
	WET	DRY	t-test	R	WET	DRY	t-test	R	WET	DRY	t-test	r
BOD	10.54(2.52)	10.03(1.97)	0.61	0.61	11.53(4.81)	8.20(1.88)	1.4	-0.55	12.0(6.40)	7.06(3.31)	1.40	-0.54
DO	6.37(0.96)	5.43(2.16)	1.75	0.88	6.48(1.44)	4.96(2.04)	1.74	0.29	6.32(1.13)	5.29(1.99)	1.85	0.75
pH	6.22(0.54)	6.15(0.60)	0.16	-0.78	6.34(0.57)	5.93(0.90)	1.20	0.34	6.40(0.52)	5.72(0.61)	2.08	-0.02
TURB.	0.24(0.44)	0.65(1.17)	-0.76	-0.15	0.39(0.45)	0.79(1.11)	-0.82	-0.01	0.4(0.47)	1.00(1.49)	-0.92	-0.05
T. ALK.	3.17(1.44)	4.17(5.11)	-0.41	-0.56	2.58(1.03)	2.99(2.50)	-0.40	0.17	2.6(0.15)	3.1(2.46)	-0.50	0.14
T. HAR.	11.83(4.77)	33.80(39.14)	-1.36	-0.03	19.41(11.13)	32.84(31.21)	-0.87	-0.49	27.86(15.17)	21.02(29.42)	0.43	-0.49
NITRAT.	0.29(0.12)	0.19(0.21)	0.97	-0.21	0.19(0.09)	0.074(0.07)	2.01	-0.71	0.19(0.15)	0.13(0.11)	0.68	-0.27
PHOSPH.	0.00(0.00)	0.0015(0.004)	-1	0	0.00(0.00)	0.267(0.65)	-1.00	0	0.00(0.00)	0.3003(0.73)	-1.00	0
CONDU.	9.83(3.76)	9.67(3.39)	0.08	-0.13	8.5(1.38)	8.33(0.81)	0.21	-0.53	8.67(1.63)	8.30(1.79)	0.67	0
TEMP.	26.61(0.62)	27.97(0.99)	-2.48	-0.33	26.77(0.69)	24.45(0.48)	-4.00	-0.56	28.38(0.56)	28.38(0.56)	-3.36	-0.26