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A Comparative Study of Physicochemical Characteristics of Sediments of Azuabie and Obufe Creeks in the Upper Bonny Estuary, Niger Delta

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Abstract

Physico-chemical parameters in sediment of the Azuabie and Obufe Creeks were monitored from February 2021 – January 2022. Nine sampling stations (five in Azuabie and four in Obufe) were established along the Creeks based on sources of industrial and human pollutant inputs. Sediment samples were collected with an Eckman grab. Some parameters (pH, Redox Potential and Conductivity) were analyzed in situ using a multiparameter water quality meter (Hanna H19829), while appropriate standard methods were used for total hydrocarbon content (THC), total organic content (TOC), ammonium-nitrogen, nitrate and phosphate in the laboratory. The mean pH in Azuabie Creek was 7.12 (±0.74) while that in Obufe Creek was 7.16 (±0.73). Mean ±SD values for other parameters are as follows: Redox potential in Azuabie Creek (46.05±26.28 mV), Obufe Creek (34.98±19.05 mV).; Conductivity in Azubie Creek (2696±1434), Objufe Creek (2662±1536). THC) in Azuabie (100.40±236.56), Obufe (69.29±196.91) Creek. TOC in Azuabie Creek (4.28±± 1.12), Obufe Creek (3.35±1.63); Ammonium-Nitrogen Azuabie (0.06±0.03 mg/kg) and Obufe (0.08±0.06 mg/kg). Nitrate in Azuabie Creek was 0.22±0.10 mg/kg while that in Obufe Creek was 0.26±0.12 mg/kg; Mean phosphate values in Azubie Creek (0.40±0.78), of Objufe Creek (0.26±0.09). Student's t-tests showed that mean values of pH, Conductivity, THC, nitrate, and phosphate were not significantly different between Creeks. However, Redox Potential and TOC were significantly higher in Azuabie Creek, while ammonium-Nitrogen was significantly higher in Obufe Creek. The THC values in both creeks were higher than the EGASPIN target value of 50mg/kg and are a cause for concern.

Keywords: *Physicochemical Parameters; Azuabie Creek, Obufe Creek; Sediment, Niger Delta*

Introduction

The Okpoka Creek in the upper Bonny Estuary is one of the Niger Delta Rivers System and bifurcates into the Azuabie and Obufe Creeks.. Many human's activities going on within and around this creek include dredging, fishing, boating, navigation, washing, disposal of excreta, bathing and swimming, to mention but a few. Dredging mostly takes place during the dry season than in the wet season due to the reduced volume of water in the creek. Runoffs carry a lot of materials from the surroundings during the rainy season into this creek (Davies, 2008). As an important component of the aquatic ecosystem, sediments serve as habitat and or spawning/breeding grounds for a wide range of aquatic organisms, usually referred to benthic organisms, the maintenance of its health and by extension that of the organism it supports becomes paramount (Wokoma and Friday, 2017). Sediments were extensively studied all around the world and acts as a sinks and sources of contaminants in aquatic systems because of their variable physical and chemical properties. Trace metals can accumulate in the upper sediment. Such accumulation takes place by biological and geochemical mechanisms, and cause significant environmental concentration such as toxic to sediment-dwelling organisms and fish, resulting in decrease survival, reduced growth, or impaired reproduction and lowered species diversity (Praveena *et al*., 2007). The sediments of Bonny Estuary are contaminated with different pollutants and hydrocarbon is the major candidate (Chindah *et al.*, 2004; Izoafuo *et al.*, 2004). The contaminants (organic and inorganic compounds) are from effluents discharges released into the Bonny Estuary. The physicochemical parameters of the sediments such as electrical conductivity, dissolved oxygen, pH, and total organic carbon can control the occurrence and abundance of species distributed in them (McLusky and Elliott, 2004). We present here a comparative study on the physicochemistry and sediment quality of Azuabie and Obufe Creeks in the Upper Bonny Estuary, Niger Delta.

Materials and Methods

Study Sites and Sampling Stations

Azuabie and Obufe Creek are tributaries of the Upper Bonny Estuary in the Niger Delta. The Creek receives industrial effluent from the Trans-Amadi Industrial Layout drains, especially, that from the Rivers Vegetable Oil Company (RIVOC). The major vegetation along this Creek is the mangrove forest, mainly of *Rhizophora racemosa*, *Nypa fruticans* and *Avicennia nitida* (Moslen and Daka, 2014), Azuabie Town is found along the Azuabie Creek from where numerous domestic wastes are generated and dumped along the Creek. A major abattoir and some other companies are located upstream of the Azuabie Creek. The Azuabie Creek is open to different kinds of human activities such as dredging, bunkering, fishing, swimming, dumping of waste, etc. which translate into the discharge of various kinds of wastes into the Creek. The frequent discharge of wastes into this Creek can cause a change in the macro-benthic community structure of the Creek (Daka *et al*., 2007, Moslen and Daka, 2014). The Obufe Creek is nearer inland toward, the Elelenwo, Woji and Agpajo axis. The Creek was a narrow estuarine water body that has now widened due to sand mining activities. The Creek receives effluent from oil industries located downstream, boat construction companys and from small abattoirs along the Creek. The major vegetations along the Creek is *Rhizophora racemosa*, *Nypa fructicans* and *Avicennia nitida.* Okujagu and Aberrepele are towns found along the Creek. The activities carried out on

the Creek includes Fishing, dredging, bunkering, swimming, dumping of waste, etc.

Five (5) sampling stations were chosen for Azuabie Creek and four (4) stations in Obufe Creek. The stations include locations with sources of industrial and human pollutant inputs respectively (Azuabie Creek, and Obufe Creek.Stations along the Obufe Creek are, station OBU, OBU2, OBU3, and OBU4, whereas stations located along the Azuabie Creek includes, AZU1, AZU2, AZU3, AZU4 and AZU5. The geographical coordinates of the nine stations were taken with a Global Positioning System (GPSMAP78S GARMIN) and the coordinates and plotted (Fig.1).

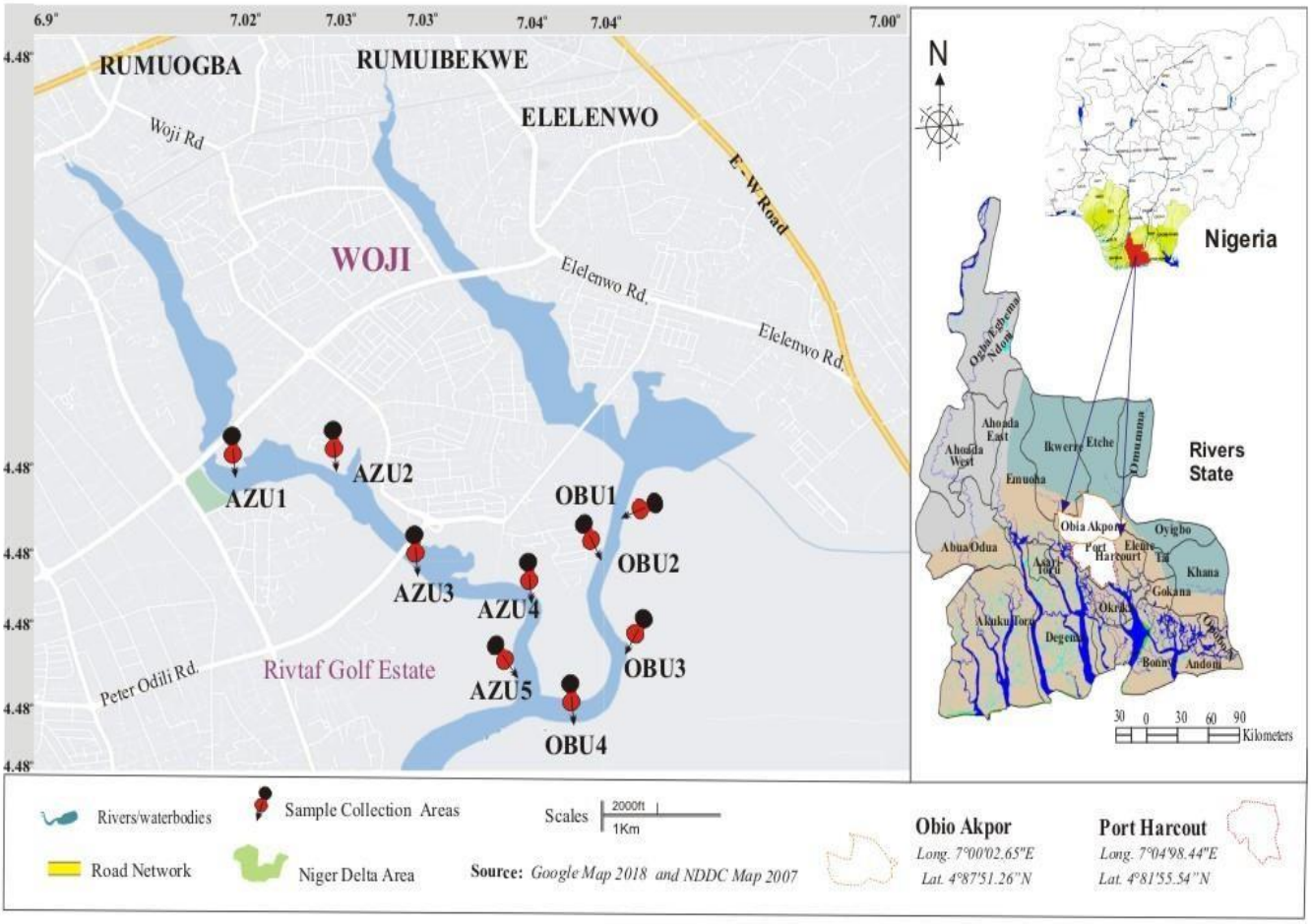

Fig 1: Map Showing the Sampling Sites in the Study Area

Sample collection and analysis

Sediment samples were collected monthly with an Ekman grab (16 cm by 16 cm) at each of the stations for a period of 1 year from February 2021 to January 2022. Samples were collected for physicochemical analysis of the sediment. pH, Redox Potential, and Conductivity of sediment

were determined *in situ* using Hanna 19829 multi-parameter water quality meter where the Sediment samples were placed in a plastic container; the probe was dipped into the sediment and readings were taken after allowing the instrument to stabilize. Samples for the determination of sediment hydrocarbon/ organic content was wrapped in aluminum foil, while those for particle size analysis, and other parameters were kept in black polyethylene bags and transported to the laboratory for analysis. These were transported to the laboratory in ice-cooled boxes. The sediment samples were air-dried, sieved and used to perform the following physicochemical analysis. Total Organic Carbon (TOC) in percentage was determined by the wet combustion method of Walkley and Black (1934). Ammonia concentration was determined by Barium gravimetric technique, Nitrate (NO_3) levels in sediment were determined following the Brucine Method (APHA, 1976, 1998), the total hydrocarbon content of the sediment was determined spectrophotometrically after extraction with toluene (Odu *et al.*, 1985), while available phosphorus was determined by Olsen's extraction method.

Data Analysis

Data collected for the environmental parameters was subjected to statistical analysis using Two-way analysis of variance ANOVA (without replication) was used to test for physico- chemistry variables between stations and time within each Creek. T-tests were used for comparing differences between the two the Creeks. MINITAB for Windows V17 was used for ANOVA while Microsoft EXCEL was t-test.

Results and Discussion

The mean pH values within Azuabie Creek ranged from 6.64 (±0.87) in AZ2 to 7.17 (±0.51) in AZ5 (Table 1) while the range within Obufe Creek was 6.51 (±0.57) at OBU3 to 7.05 (±0.53) at OBU4 (Table 2). In terms of months, the highest pH values in both Creeks were recorded in February and October (Fig 2A). Analysis of Variance (ANOVA) showed that there were no significant differences between stations in either Azuabie Creek (Table 3) or Obufe Creek (Table 4); and also no significant difference between months in the two creeks. Overall mean pH in Azuabie Creek was 7.12 (±0.74) while that in Obufe Creek was 7.16 (±0.73) but there was also no significant difference between the two the Creeks ($t=1.132$, $p=0.259$; Table 5). The range of pH values observed in this study from weakly acidic to weakly alkaline are considered to be suitable for living organisms in sediment. These fall baoadly with the range of values 4.79 to 723 reported previously reported by Moslen (2004) in these Creeks.

The lowest mean monthly values of redox potential in sediment were recorded in January in both creeks, but the highest values were observed in November and December for Azuabie and Obufe Creeks respectively (Figure 2B). There were significant differences between months in both creeks ($p<0.001$). Tukey pair-wise comparisons gave November>December> all other months which were not significantly different in Azuabie Creek, while for Obufe Creek the only clear difference was November > all other months (except June, July and September which were also not different from other months). Mean redox potential in Azuabie Creek ranged from 43.03±22.35 mV in AZU2 to 56.32±18.46 mV in AZU3 but there was no significant difference

between stations (Tables 1 and 3). In Obufe creek the mean was 23.33±16.01 mV in OBU1 and 45.09±18.98 mV in OBU4, and there was significant difference between stations (Tables 2 and 4); OBU 4=OBU3>OBU1. The overall mean redox potential in Azuabie Creek (46.05±26.28 mV) was significantly higher than the Obufe Creek (34.98±19.05 mV) (p=0.016, Table 5).

The electrical conductivity had the same monthly pattern in the two Creeks, with highest values in February, March and April and low values in November to January; (Fig 2C) with significant monthly variation in both Creeks. Tukey tests show that February, March, April and May were significantly higher than other months. There was, however, no significant difference between stations in any of the Creeks - Azuabie (2594±1589 to 2768±1420, p=0.842, Tables 1 and 3); Obufe (2482 ±1539 to 2854.08±1619, p=0.258) Tables 2 and 4). Mean conductivity values in Azubie Creek (2696±1434) was not significantly different from that of Objufe Creek (2662±1536) (p=0.903, Table 5). The monthly variation in conductivity agrees with previous report in the Creeks by Daka *et al.* (2007) who also found spatial gradients within the Creeks as a result of higher precipitation and run-offs during the rainy season.

Table 1: Mean (± SD) of Physiochemical variables of Sediment at Different Stations in Azuabie Creek

	Stations				
Parameter s	**AZU1**	**AZU2**	**AZU3**	**AZU4**	**AZU5**
pH	6.78±0.79	6.64±0.87	6.85±0.67	7.00±0.60	7.17±0.51
Redox Potential (mV)	43.35±36.6	43.03±22.35	56.32±18.46	45.61±25.22	41.96±27.07
Electrical Conductivity (µS/cm)	2594±1589	2665 ±1629	2768±1420	2737 ±1301	2715 ±1452
Total Hydrocarbon Content (mg/kg)	146.73±297.17	53.23±76.82	83.56±101.95	208.34±410.46	10.16±19.84
Total Organic Carbon (%)	4.40±1.43	4.57±1.10	4.52±1.26	4.31±0.85	3.60±0.67
Ammonium-Nitrogen (mg/kg)	0.05±0.02	0.05±0.02	0.07±0.03	0.07±0.03	0.07±0.03
Nitrate (mg/kg)	0.18±0.11	0.20±0.09	0.25±0.11	0.24±0.07	0.23±0.09
Phosphate (mg/kg)	0.83±1.71	0.34±0.07	0.30±0.09	0.26±0.04	0.25±0.04

Table 2: Mean (± SD) of Physiochemical variables of Sediment at Different Stations in Obufe Creek

Parameter s	Stations			
	OBU1	**OBU2**	**OBU3**	**OBU4**
pH	6.86±0.80	6.97±0.90	6.51±0.57	7.05±0.53
Redox Potential (mV)	23.33±16.01	30.46±16.76	41.02±18.20	45.09±18.98
Electrical Conductivity (µS/cm)	2697±1719	2482 ±1539	2613±143	2854.08±1619
Total Hydrocarbon Content (mg/kg)	8.94±18.15	2.18±2.83	27.40±45.81	238.62±348.06
Total Organic Carbon (%)	3.87±1.61	3.61±1.10	2.73±1.45	3.20±2.14
Ammonium-Nitrogen (mg/kg)	0.07±0.05	0.07±0.02	0.09±0.04	0.10±0.09
Nitrate (mg/kg)	0.26±0.14	0.23±0.06	0.28±0.11	0.26±0.13
Phosphate (mg/kg)	0.25±0.09	0.26±0.10	0.25±0.11	0.28±0.06

Table 3: Summary of Analysis of Variance of Sediment Parameters in Azuabie Creek

Parameters	Stations		Months	
	F-Value	**P- value**	**F- Value**	**p- Value**
pH	2.014	5.716	2.588	0.139
Redox Potential	2.34	0.07	15.98	0.001
Electrical Conductivity	0.35	0.842	65.28	0.001
Total Hydrocarbon Content	1.74	0.158	2.48	0.016
Total Organic Carbon	3.6	0.013	7.77	0.001
Ammonium-Nitrogen	2.13	0.093	2.15	0.036
Nitrate	1.8	0.146	4.3	0.001
Phosphate	1.24	0.308	1.08	0.401

Table 4: Summary of Analysis of Variance of Sediment Parameters in Obufe Creek

Parameters	Stations		Months	
	F- Value	p- Value	F- Value	p- Value
pH	1.59	0.212	1.78	0.098
Redox Potential	5.39	0.004	2.61	0.016
Electrical Conductivity	1.41	0.258	45.43	0.001
Total Hydrocarbon Content	5.03	0.006	1.03	0.445
Total Organic Carbon	2.49	0.077	5.87	0.001
Ammonium-Nitrogen	1.12	0.357	1.9	0.075
Nitrate	2.093	0.001	2.891	0.612
Phosphate	0.53	0.664	3.3	0.004

Table 5: T-tests for Differences in Mean Sediment Parameters between Azuabie and Obufe Creeks

Parameters	Azuabie		Obufe		t-Value	p-Value
	Mean	SD	Mean	SD		
pH	7.12	0.74	7.16	0.73	1.132	0.259
Redox Potential	46.05	26.28	34.98	19.05	2.449	0.015
Electrical Conductivity	2696	1434	2662	1536	0.121	0.903
Total Hydrocarbon Content	100.40	236.56	69.29	196.91	0.73	0.466
Total Organic Carbon	4.28	1.12	3.35	1.63	3.507	0.001
Ammonium-Nitrogen	0.06	0.03	0.08	0.06	2.451	0.015
Nitrate	0.22	0.10	0.26	0.12	1.735	0.085
Phosphate	0.40	0.78	0.26	0.09	1.212	0.227

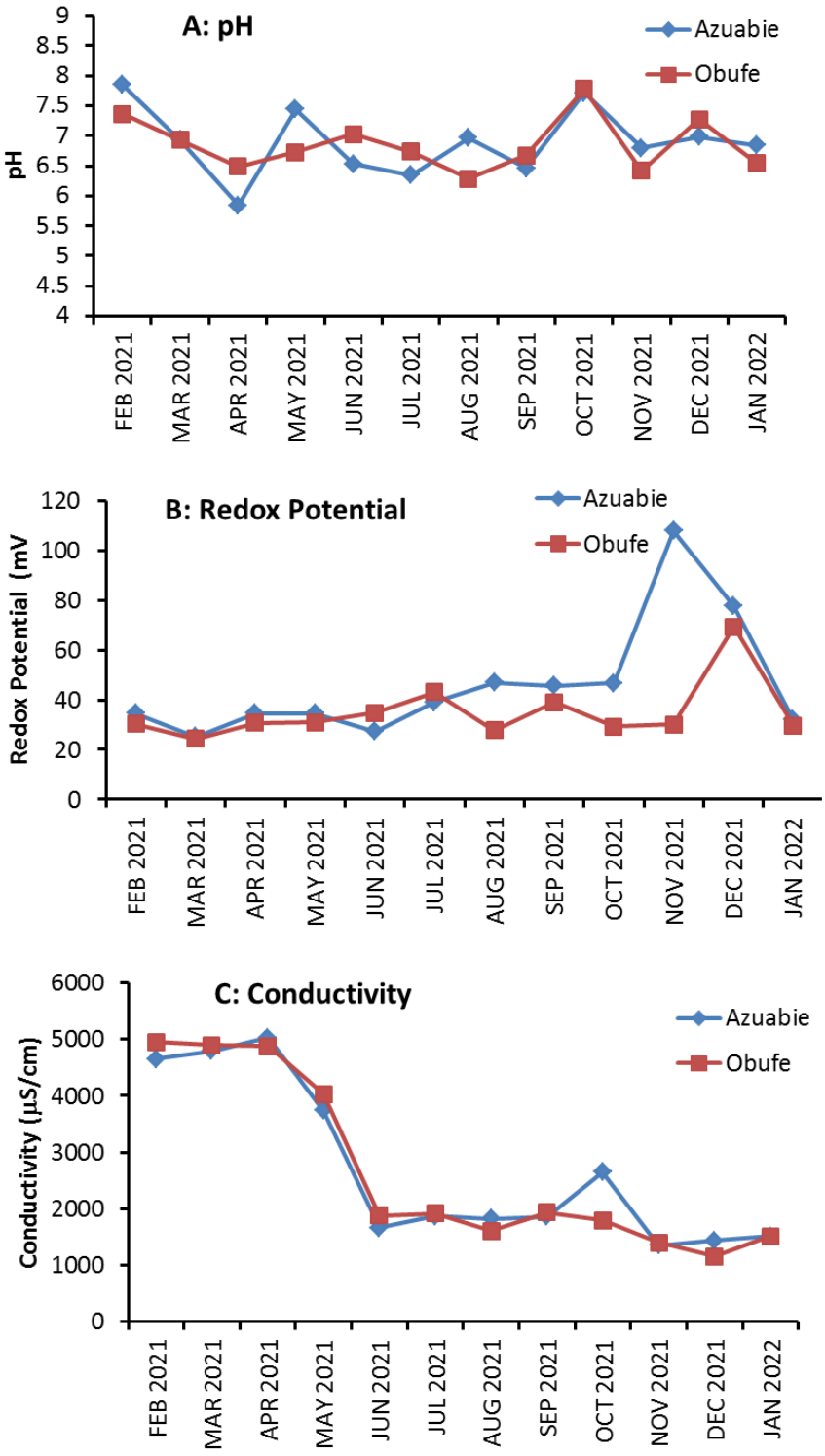

Figure 2: Temporal Variations of pH, Redox Potential and Conductivity in Azuabie and Obufe Creeks

There were variable profiles of Total hydrocarbon concentration in Azuabie and Obufe Creeks (Fig 3A). In Azuabie Creek, a spike from February levels in March was followed by a progressive reduction in subsequent months with significant difference between months; Oscillatory values were observed in Obufe Creek with no significant difference between months. On the other hand there was no significant difference between stations in Azuabie Creek (10.16±19.84 mg/kg at AZ5 to 208.34±410.46 mg/kg at AZ4, p=0.158), while significant spatial difference was found in Obufe Creek (2.18±2.83 at OBU2 to 238.62±348.06 at OBU4, p=0.006 with Tukey showing OBU4>OBU3=OBU1=OBU2. Mean THC values were higher in Azuabie (100.40±236.56) than Obufe (69.29±196.91) Creek but there was no significant difference. The amount of variation from the means suggests occasional pollution incidents. These values were lower than the range reported a range of 3584.62 - 19981.42µg/g recorded by Ebere (2002) from a chronically polluted creek with inputs of effluents from a petroleum refinery. The values however conformed with the lower limits of the range of 305 – 2865µg/g recorded by Daka et al. (2007) in Azuabie/Obufe Creek and . 134.71 - 5052.29µg/g by Anyanwu *et al*. (2018) in Okpoka Creek. The THC values in both Creeks were higher than the EGASPIN target values of 50mg/kg which is a cause for concern.

Monthly mean levels of total organic carbon are presented in Figure 3B and there were significant differences ($p<0.001$, Tables 3 and 4). There was significant difference in TOC values between stations in Azuabie Creek ($p=0.013$) which was reflected between the lowest value **of** 3.60±0.67 % at AZU5 and the highest value of 4.57±1.10 % at AZU2. However, no significant difference was observed amongst stations in Obufe Creek with values of 2.73±1.45 at OBU3 to 3.87±1.61 at OBU1. The overall mean value of TOC in Azuabie Creek (4.28±± 1.12) was significantly higher ($p<0.001$, Table 5) than that of Obufe Creek (3.35±1.63). This values in this study corresponds with the range of 3.68 – 26%. (Ugbomeh, 1987), 2.7 – 16% (Umesi, 1999). 0.97 – 8.37% (Daka *et al*., 2007) and 1.0 – 18.5% (Anyanwu *et al*., 2018) reported in the upper Bonny estuary.

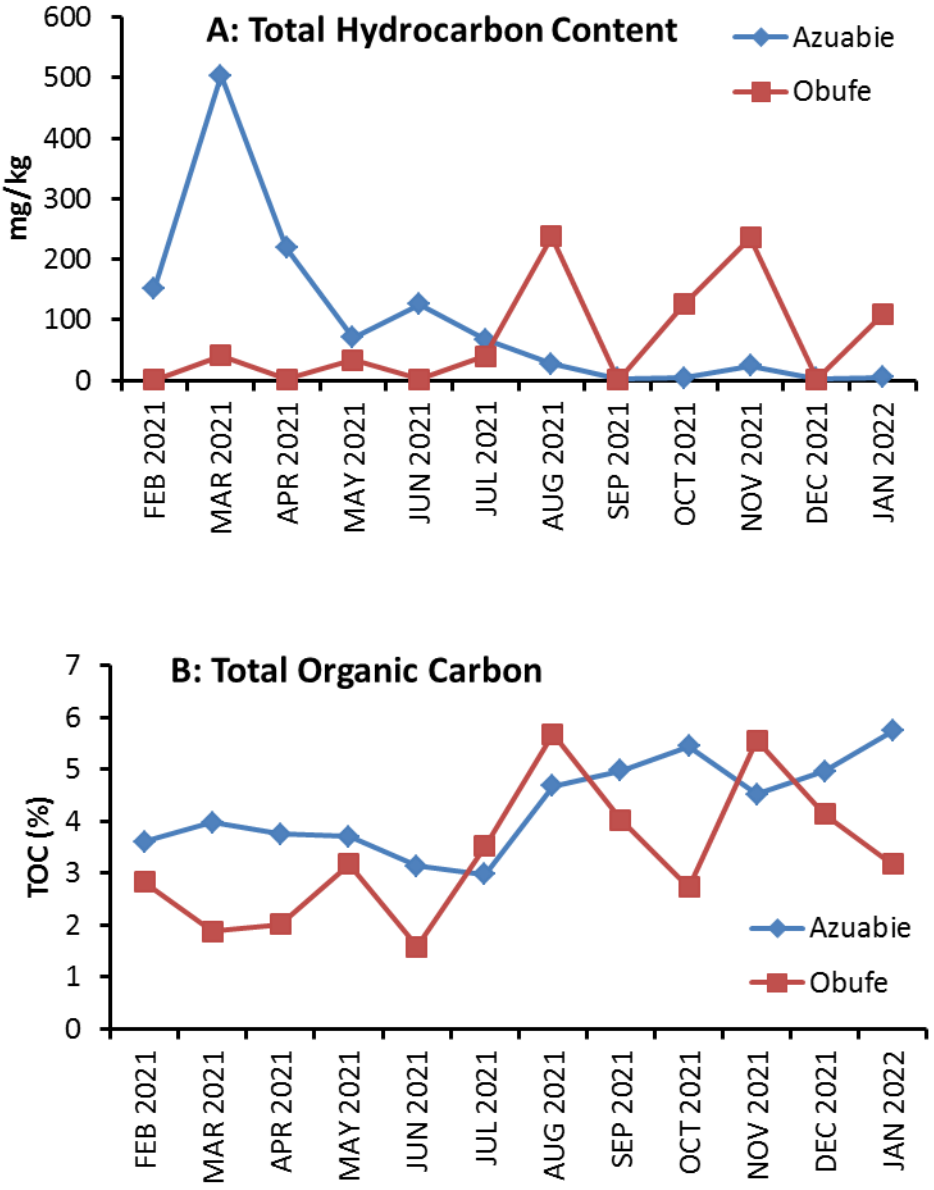

Figure 3: Temporal Variations of Total Hydrocarbon Content and Total Organic Content in Azuabie and Obufe Creeks

The mean concentrations of Ammonium-Nitrogen ranged from 0.05±0.02 to 0.07±0.03 in Azuabie Creek (Table 1) and from 0.07±0.02 to 0.10±0.09 in Obufe Creek (Table 2) with no significant difference between stations in any of the creeks (Tables 3 and 4). Also, no significant monthly variation (Fig 4A) was observed in Obufe Creek and the putative difference in months in Azuabie creek generated by ANOVA could not be separated by Tukey tests. A comparison of means between Azuabie (0.06±0.03 mg/kg) and Obufe (0.08±0.06 mg/kg) showed a significant difference (p=0.015, Table 5). The mean nitrate values within Azuabie Creek ranged from 0.18±0.11 in AZ1 to 70.25±0.11 in AZ3 (Table 1) while the range within Obufe Creek was 0.23±0.06at OBU2 to 0.28±0.11at OBU3 (Table 2). In terms of months, the highest nitrate values in the Creeks were recorded in October for Obufe and November in Azuabie October (Fig4B). ANOVA) showed that there were no significant differences between stations in Azuabie but significant difference in months (Table 3). On the other hand there was significant difference amongst months but not between stations in Obufe Creek (Table 4); Overall mean nitrate in Azuabie Creek was 0.22±0.01 mg/kg while that in Obufe Creek was 0.26±0.12 mg/kg but there was no significant difference between the two the Creeks (p=0.085; Table 5). These ranges were lower than 1.03 – 2.53µg by Daka et al (2007) in Azuabie/Obufe Creek, . 3.07 – 6.47µg/g by Umesi, (1999) in Elechi Creek.

The concentrations of phosphate had the similar monthly patterns in both creeks with an outlier in Azuabie Creek in October (Fig 4C). ANOVA gave significant monthly variation in Obufe Creek only with Tukey tests showing clear difference between November and April. There was, however, no significant difference between stations in any of the Creeks - Azuabie (0.26±0.04 to 0.83±1.71 mg'kg, p=0.308, Tables 1 and 3); Obufe (0.25±0.09 to 0.28±0.06, p=0.664, Tables 2 and 4). Mean phosphate values in Azubie Creek (0.40±0.78) was not significantly different from that of Objufe Creek (0.26±0.09) (p=0.227, Table 5). Higher values have been reported by other authors (Daka et al. 2007: 1.7 – 3.6µg/g; Umesi, 1999: 0.2 – 4.18µg/g; Ebere 2002: 4.95 – 14.73µg/g; Anyanwu *et al*., 2018: 7.02 - 94.74mg/kg in the upper Bonny Estuary.

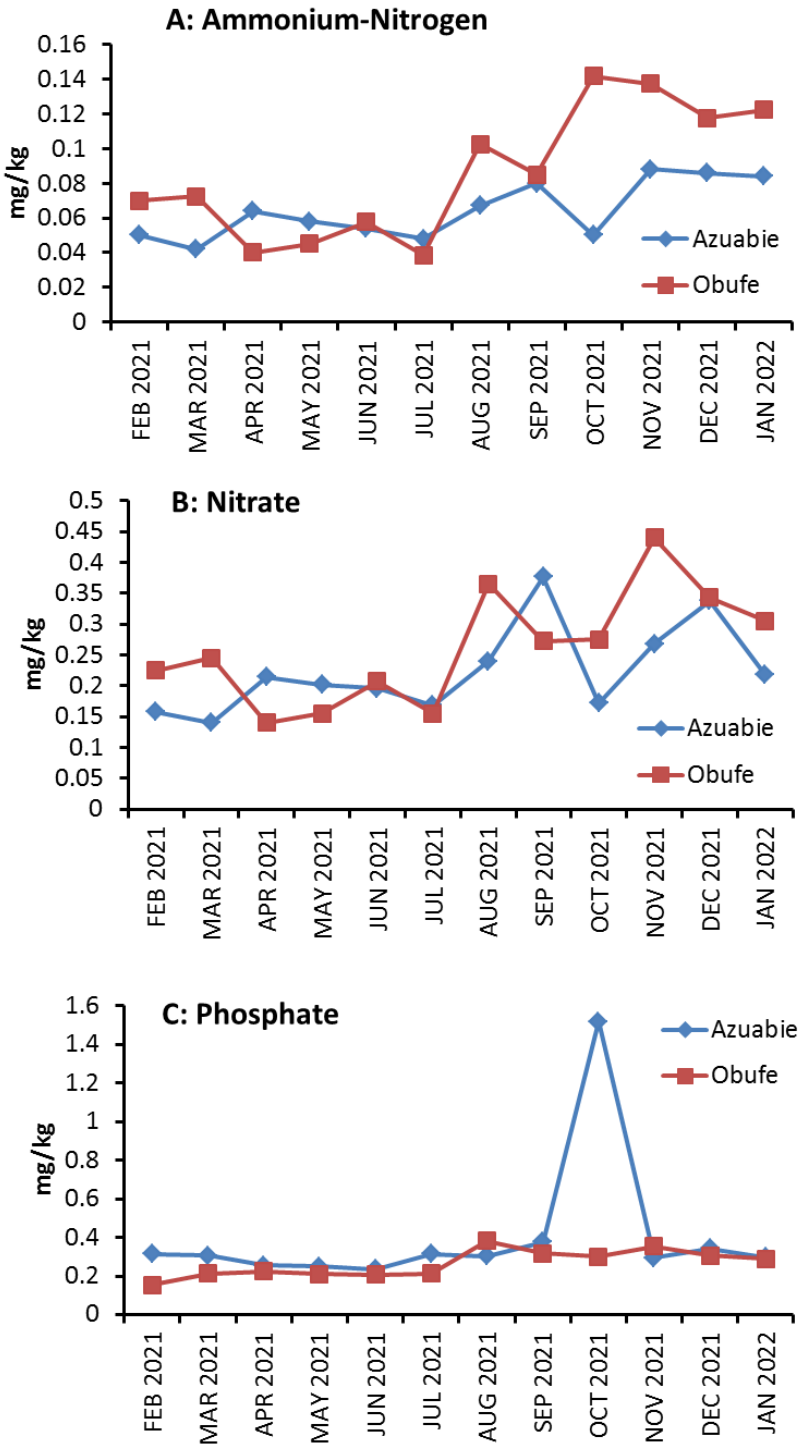

Figure 4: Temporal Variation of Ammonium-Nitrogen, Nitrate and Phosphate in Sediments from Azuabie and Obufe Creeks

Conclusion

Some parameters (pH, conductivity, THC and phosphate did not show significant differences between Azaubie and Obufe Creeks, while redox potential, ammonium-nitrogen and TOC were significantly different between the two creeks. Higher TOC values in Azuabie Creek may be as a result of wastes from abattoir and pier latrines. The THC values in both creeks were above the regulatory target value of 50mg/kg of EGASPIN and are a cause for concern.

Acknowledgments

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