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Spatial Variation in Physico-Chemical Parameters of Eastern Obolo Estuary, Niger Delta, Nigeria

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Abstract

Aspects of the physicochemical parameters of Eastern Obolo estuary, Eastern Obolo, were investigated for three months at five locations: Okorombokho, Iko, Amadaka, Emereoke and Obianga. Mean concentrations of some of the measured parameters at the five sampling locations showed significant statistical differences: Nickel ($F = 18.48$, df 2,8; $P<0.001$), Potassium ($F = 4.47$, df 2,8; $P<0.05$), Total dissolved solids ($F = 32.26$, df 4,8; $P<0.001$), pH ($F = 21.55$, df 4,9; $P<0.001$), Salinity ($F = 73.15$; df 4,8; $P<0.001$), Dissolved Oxygen ($F = 5.06$, df 2,8; $P<0.05$), Temperature ($F = 10.96$, df 2.8; $P<0.01$), and Conductivity ($F = 71.94$, df 4,8; $P<0.01$). Mean differences of other parameters were not statistically significant. The variability of the concentrations of the parameters during the period of study was lowest for dissolved oxygen (2.2%) and highest for hardness (68.4%). The availability of nickel in these waters indicated crude oil pollution. The mean values of nickel, potassium, total dissolved solids, sodium, copper, zinc, total hydrocarbons and biochemical oxygen demand from all stations exceeded the recommended limits for aquatic life or potable water. Hence, the Eastern Obolo estuary may not be an efficient source of drinking water for the community but it definitely helps flush out anthropogenic pollutants into the sea.

Keywords: estuarine flushing, nickel, potassium, total dissolved solids, sodium, copper, zinc, total hydrocarbons

1. Introduction:

The quality of aquatic bionetworks is vital for the productivity, survival and support of aquatic organisms found in them. It is an index of health and well being of the ecosystem and has direct impact on human health. Physicochemical parameters of water provide nutritional balance and ultimately govern the biotic relationships of organisms in an aquatic ecosystem; including ability to withstand pollution load. Industrialization, urbanization and modern agriculture practices directly impact the water resources quantitatively and qualitatively. Many industries are sited near these bodies of water presumably to facilitate easy discharge of effluents and other pollutants into them. A typical example, is the siting of several flow stations on the territorial waters of the Eastern Obolo with its attendant and often incessant oil spillages, gas flares which eventually leads to acid rains (Udoessien 2003) experienced in the area.

Most of the studies conducted on the monitoring and assessment of river and estuarine water quality in the South-south Nigeria are within the lower and upper Cross River estuary (Lowenberg & Kunzel 1992; Ekwu & Sikoki 2006), Calabar River (Asuquo 1999), and a few in the Bonny estuary (Dubbin-Green 1990), New Calabar River (Ekeh & Sikoki 2003) and Nkoro River (Abowei 2010) in the Niger Delta region. Other studies conducted include those of Lagos Lagoon (Ayoola & Kuton 2009) and Tarkwa Bay (Edokpayi *et al.* 2010), in western Nigeria.

Eastern Obolo estuary is a unique aquatic environment in the tropical belt with marked maritime influence due to riverine inflow, vertical mixing, coastal nutrient enrichment, oil pollution and other anthropogenic sources. It is also one of the ecologically and economically rich marine ecosystems in the Niger Delta region of Nigeria providing breeding grounds for a variety of fish and shrimp species. Numerous activities such as oil exploitation and exploration, laundry, fuel wood exploitation and capture fisheries take place along the estuary/watershed. Small concentrations of anions and cations of heavy metals are continuously present in the drinking water, which could consequently pose health risk to the communities.

This study seeks to provide basic information and to enrich the scientific knowledge of the coastal ecosystem of Nigeria with particular reference Eastern Obolo estuary and other similar water bodies where little or no information is available for its effective management and sustainability; and to prevent further degradation of the area.

2. Materials and Methods

This study was carried out in a stretch of the Eastern Obolo estuary, located (4°33’N - 4°50’ N; 7°45’E - 7°55’E) about 650m above sea level in the tropical mangrove forest belt east of the Niger Delta between the lower Imo and Qua Iboe River estuaries (Figure 1). The tidal range in the area is about 0.8m at neap tides and 2.20m during spring tides with little fresh water input joined by numerous tributaries as they empty into the Atlantic Ocean (NEDECO 1961). The climate of the area is tropical with distinct rainy (April to October) and dry seasons (October to May) with a high annual rainfall averaging about 2500mm (AKUTEC Report 2006; Gibo 1988).

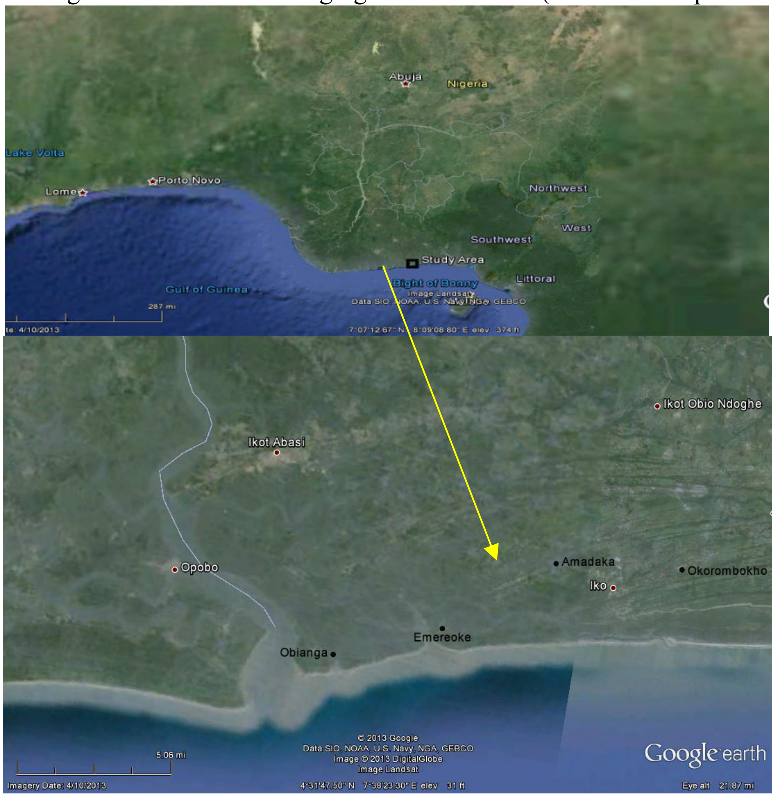

Figure 1: Map of Eastern Obolo estuary showing sampling stations
(*Inset*: Location of site in southeast Nigeria; Source: Google Earth)

The area is characterized by an extensive mangrove swamp with inter-tidal mud flats influenced by the semi-diurnal tidal regime of the estuary. Fishing and farming are the main economic activities in this study area. Oil palm (*Elaeis guineensis*) and coconut palm (*Cocoa nueifera*) are also widely distributed in the surrounding villages. The area is also an oil-producing area with several oil exploration wells.

Water samples were collected during the rainy season months of July, August and September from five locations seaward from Amadaka (AK), Okorombokho (OK), Iko (IK), Emereoke (EK) and Obianga (OB) along the estuary as shown on Figure 1. Five pre-rinsed 5 L plastic tanks and five 800ml bottles were used for collection of water samples.

Water temperature was measured in-situ using mercury-in-glass thermometer. Dissolved oxygen and biochemical oxygen demand (BOD_5) were determined by the Winkler's method (APHA 1998). Hydrogen-ion concentration (pH) and conductivity were measured in-situ with Horiba D – 51 pH meter and conductivity meters, respectively. Salinity was obtained by chlorinity titration (APHA 1998). Total dissolved solids (TDS) and total soluble solids (TSS) were determined gravimetrically (APHA 1998). Emission photometry was used for the determination of sodium and potassium while copper, zinc and nickel, were determined using the Atomic Absorption Spectrophotometer after appropriate treatment and digestion (Allen 1974; APHA 1998). Total hydrocarbon in the water sample was extracted with carbon tetrachloride (CCL_4) in a separating funnel at pH 5 and absorbance read from the fisher Electrophotometer at 450nm wave length (APHA 1998).

Data generated were analysed using one way ANOVA at probability level of $p < 0.05$. In addition variation of the values of these parameters were reported in terms of Mean ± standard deviation and coefficient of variation (CV), which is the standard deviation expressed as a percentage of the mean.

3. Results and Discussion

Naturally, the concentration and relative abundance of ions in river or swamp water is highly variable and increases with volume of runoff. Hence, researches into aquatic ecosystems often seek to predict and explain the dynamics of the distribution and species of allochthonous materials and effluents discharged into the system. Results of physicochemical measurements in Eastern Obolo estuary in Eastern Obolo are therefore summarized in Table 1. Wide variations in measured parameters were observed at all stations (Figures 2, 3 and 4). Some of the parameters with high CVs showed no significant statistical differences in their mean values.

The concentration of ions reported in this study tended to increase in sampling stations located seawards, and during drier months. Sampling stations seawards, like Obianga, near the mouth of the estuary experience partial mixing, the salt water slightly being diluted by the seaward inflow of a large volume of mixed water accompanied with a volume of fresh water equivalent to be discharged. The concentration of conservative, non-decaying pollutants and effluents discharged into the estuary will spread out and become modified by means of turbulent mixing and estuarine circulation with the effluent becoming more concentrated in the lower layer upstream and the upper layer downstream of the discharge point. In a salt-wedged estuary, an effluent introduced in the surface layer will be flushed from the estuary before it contaminates the lower layer, because of the poor mixing of fresh water (Wetzel 2001). Consequently, estuaries such as Eastern Obolo estuary also perform the role of diluting and removing pollutants. Total dissolved solids, pH, salinity and conductivity showed significant spatial variations increasing seawards, (Figure 2A, $P<0.001$, n=10). There was no significant spatial difference ($P<0.05$) in the other parameters measured including dissolved oxygen and temperature (Figure 2A-C). Mean values of nickel, potassium, dissolved oxygen and temperature showed significant temporal variations ($P<0.001$, n=10, Figures 3, 4) with a gradual decrease as the rain progressed.

In order to assess the quality of the water at the stations, the mean values of the parameters were compared with international permissible limits for inland waters and for drinking water (Table 1). The mean values of nickel, potassium, total dissolved solids, sodium, copper, zinc, total hydrocarbon and biochemical oxygen demand from all stations exceeded the recommended limits for aquatic life or potable water.

3.1 Total Dissolved Solid (TDS)

TDS is a convenient measure of the total ionic concentration in water. Large amounts of dissolved solids can lead to increased mineralization of the receiving waterway with the consequence of dissolved oxygen depletion (Akpan 1991; Essien-Ibok *et al.* 2010). Concentrations of total dissolved solids (TDS) or non-filterable residue in the study area showed highly significant ($P<0.001$) and wide spatial variations between the sampling stations with the lowest values recorded at Okorombokho (4266.7 mgL^{-1}) and the highest (15966.0 mgL^{-1}) recorded seaward at Iko, a settlement hosting an oil flow station (Fig. 4D). TDS levels increased significantly towards the sea during drier months (Figure 2C). The observed TDS values (20,706.62 mgL^{-1} ±9249.307) are above the permissible limits (500 mg L^{-1}) adopted by WHO (1984), FEPA (1991), and Federal Ministry for Environment, Nigeria (Udoessien 2003) for aquatic organisms. This variation could be explained by the passive loading of ammonia, NH_3 and biological oxygen demand, BOD and decomposition of organic materials by the microbial organisms within the ecosystem. Generally, TDS are common phenomenon in an estuarine environment, where as passive loading of NH_3, and BOD support decomposition of organic materials by the microbial organisms within the ecosystem.

Table 1. Summary of ANOVA situations showing parameters with significant mean differences and Coefficients of variation (CV%) among the five locations in Eastern Obolo estuary, Nigeria

Physico-chemical parameters	Mean ± SD	F-test	df	Prob.	SOV	C.V	Permissible limit
Nickel (mgL^{-1})	0.146±0.027†	18.48	2,8	0.001	Months	16.0	<0.05
Potassium (mgL^{-1})	263.594±90.554†	4.47	2,8	0.05	Months	34.7	75-200
Total Dissolved Solids (mgL^{-1})	20,706.62±9249.307†	32.26	4,8	0.001	Locations	39.9	<500
pH	7.638±0.4644	21.55	4,8	0.001	Locations	5.4	7.5-8.5
Salinity (psu)	1.79±0.8566	73.15	4,8	0.001	Locations	43.8	<10-25
Dissolved Oxygen (mgL^{-1})	7.15±3.4766	5.06	2,8	0.05	Months	2.2	>5
Temperature (˚C)	26.47±1.1487	10.96	2,8	0.01	Months	3.9	<23-33
Conductivity (µS cm^{-1})	28.45±13.1086	71.94	4,8	0.001	Locations	41.3	10-1000
Sodium (mgL^{-1})	5073.78±2787.037†	NS	NS	NS	NS	49.1	5
Copper (mg L^{-1})	0.0848±0.032†	NS	NS	NS	NS	33.8	<0.01
Zinc (mgL^{-1})	0.1436±0.087	NS	NS	NS	NS	52.2	<0.1
Total Hydrocarbon (mg L^{-1})	180.646±171.3953†	NS	NS	NS	NS	10.6	10
Total Suspended Solids (mg L^{-1})	288.654±55.4982	NS	NS	NS	NS	17.2	< 500
Total Hardness (mg L^{-1})	486.486±372.005	NS	NS	NS	NS	68.4	< 500
Biochem. Oxygen $Demand_5$ (mgL^{-1})	0.33±0.0408	NS	NS	NS	NS	14.6	<10

SOV - Source of variation   *NS* - not significant ($p > 0.05$) † - *above permissible limit*

3.2 Total suspended solids (TSS)

Mean TSS (288.654±55.4982mg L^{-1}) is below values indicative of pollution (<500mg L^{-1}), but higher than values (0.37 - 5.90mgL^{-1}) obtained in Calabar River estuary by Ekwu & Sikoki (2006).

3.3 Total hardness

TH is indicative of the presence of alkaline earth metals such as magnesium. The most productive waters, however, are those with TH < 500 mgL^{-1} (Wetzel 2001). The highest (2,140 mgL^{-1}) and least (200 mgL^{-1}) TH values in this study were recorded at AK and OK (landwards) in July, with no significant (P>0.05) temporal or spatial variations (Figures 2A, 4D).

3.4 Biochemical Oxygen Demand (BOD)

BOD_5 (after 5 days) indicates the degree of microbial mediated oxygen consumption by contaminants in water, i.e., the amount of dissolved oxygen used in the oxidation process to produce carbon dioxide and

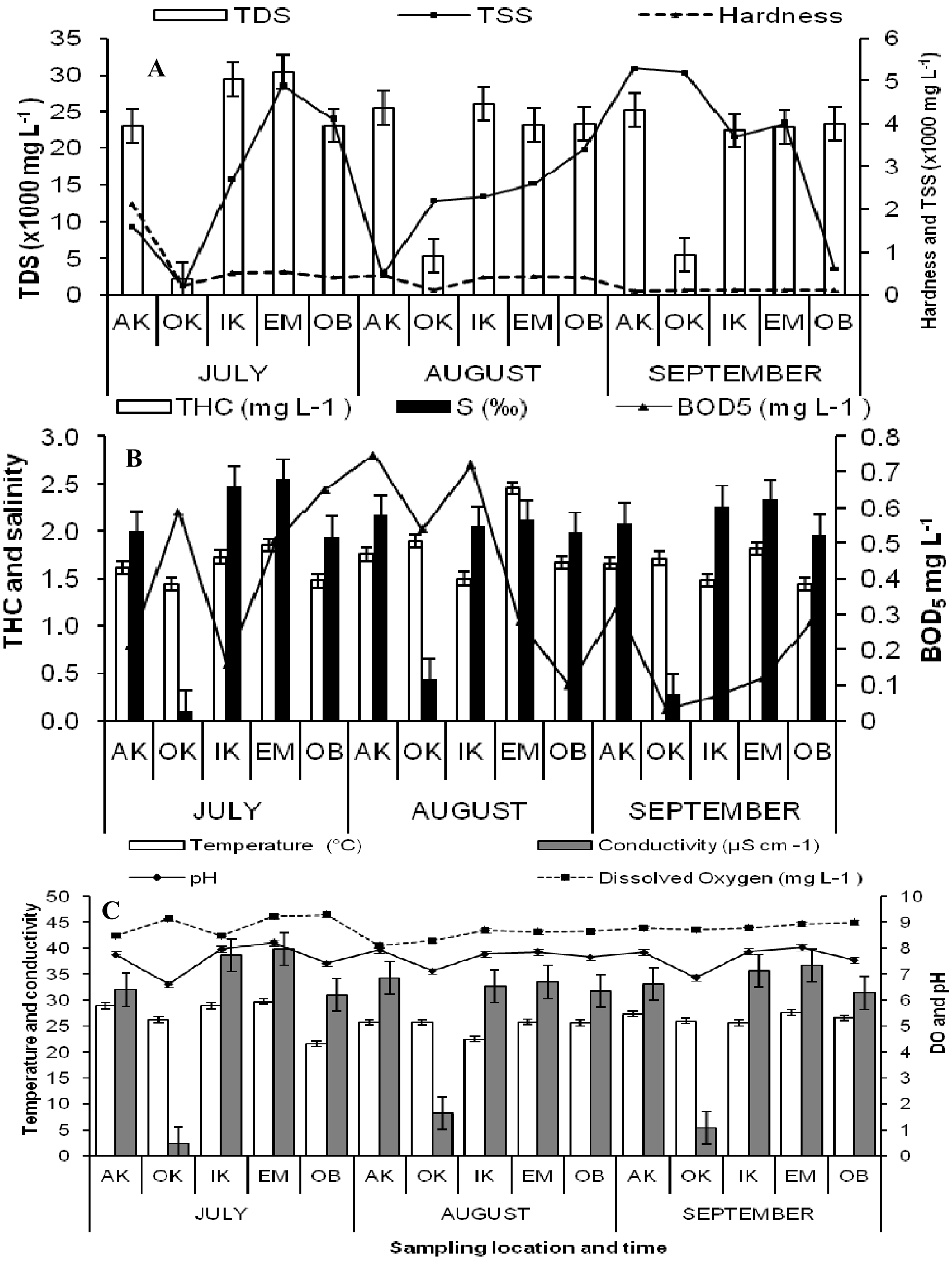

Figure 2: Spatiotemporal variation of some physicochemical parameters of Eastern Obolo Estuary, Nigeria

water. Oxygen depletion brings about the growth of anaerobes which can breakdown organic matter using sulphates and nitrates, in the absence of dissolved oxygen, to release hydrogen sulphide and ammonia gases.

High BOD concentration may be attributed to increased input or import of decaying organic matter, humus, nutrient load and dead macrophytes, through surface runoff from swamps into the river, requiring oxygen for their biodegradation (Akpan & Akpan 1994; Essien-Ibok *et al.* 2010). The range of BOD levels (0.30 - 0.43mg L^{-1}) obtained is below values indicative of pollution (<10mg L^{-1}), similar to the observations of Ubong & Gobo (2001) but differs with the values (1.32 – 6.8mg L^{-1}) obtained in New Calabar River (Ekeh & Sikoki 2003). Generally, BOD depends on temperature, extent of biochemical activities, concentration of organic matter and such other related factors.

3.5 Dissolved Oxygen (DO)

DO is essential to all forms of aquatic life and varies with temperature, turbulence, atmospheric pressure and photosynthetic activity of algae and plants. Coastal waters typically require a minimum of 4.0 mgL^{-1} but do better with 5.0 mgL^{-1} of oxygen to provide for optimum ecosystem function and highest carrying capacity (UNESCO/WHO (1978). The dissolved oxygen range in the current study was within the acceptable ranges and displayed significant temporal differences. Mean DO was 7.15±3.4766 mgL^{-1} with a dip at Emereoke (0.94 mgL^{-1}). The spatial difference in dissolved oxygen values was however not significant (P<0.5). Higher DO values (8.25 mgL^{-1} to 9.93 mgL^{-1}) were also reported for Woji Creek (Hart & Zabbey 2005; Davies *et al.* 2008) and in Okpoko River (Abowei & George 2009) in the Niger Delta area of Nigeria.

3.6 Total hydrocarbon (THC)

THC in surface water was 1.6 mgL^{-1} (Amadaka) to 383.3 mgL^{-1}(Emereoke) and below detectable limit in Okorombokho and Iko throughout the study. The result is different from the THC level reported for the Cross River system - 2.3 mgL^{-1}THC (Lowenberg & Kunzel 1992) and 0.76 - 8.25 mgL^{-1} in Ibeno, west of Eastern Obolo estuary (Akpan 2003). Though these values are below the WHO standard of 10mgL^{-1} allowed in natural waters, Akpan (2004) notes that their sublethal concentrations maybe indicative of chronic oil pollution the area.

3.7 pH

Mean pH value was highest seawards at Emereoke (8.04) compared to other locations like Okorombokho (6.87). The mean pH values are were well within the acceptable range for drinking water (6.5 to 8.5), optimal aquatic productivity (6.5 to 9.0) and livable range of 5.5 to 10 (Wetzel 2001). Similar trends (6.2 – 7.5 and 6.0 – 8.5) were reported in the Calabar River (Asuquo 1999; Akpan 2000), Cross River (Lowenberg & Kunzel 1992), New Calabar River (Ekeh & Sikoki 2003) and Andoni River (Ansa 2005) all in the Niger Delta area of Nigeria. The pH values obtained are characteristic of tidal brackish water environment (Dublin-Green 1990; Ajao & Fagade 2000). Significant decrease in pH values were also observed during the wet months, in sampling stations closer to the sea due to increased input of humic materials from the associated swamps and creeks, dilution of ionic concentrations by rain water and poor

buffering capacity of flood waters (Akpan 2000; Akpan *et al.* 2002), thereby causing a general drop in pH throughout the system. The pH values of rain can be as low as 5.6 due mainly to dissolved CO_2 (Udoessien 2003). Levels below 6.5 may be corrosive.

3.8 Salinity

The result of this study showed significant differences in salinity between stations ($P \leq 0.05$), because the estuary is highly vulnerable to external perturbations and mixing of freshwater with marine (Atlantic ocean). Salinity (Fig. 2A) was highest seawards at Emereoke (2.34 practical salinity units, psu) and lowest at Okorombokho (0.28 psu). However, salinity at Iko, Amadaka and Emereoke were not significantly different from each other. Similar observations were made by Lowenberg & Kunzel (1992), for the Cross River while Abowei & George (2009) and Abowei (2010), differ in their report of no significant difference in salinity between sampling stations, ($P \leq 0.05$), along Okpoka Creek and Nkoro River, respectively; largely due to the fact that water at these sampling stations were from same source (linear in nature). Salinity changes in estuaries are also mainly controlled by freshwater discharge and precipitation. The high freshwater discharge during the wet months is responsible for the absence of spatial variation in estuary in Eastern Obolo. During the dry season, rainfall recedes and discharges from most creeks cease thereby increasing marine influence and salt water intrusion in salinity towards the sea. Lowenberg & Kunzel (1992) reported a change of salinity from 0.5 psu during the wet season to 12 psu during the dry season.

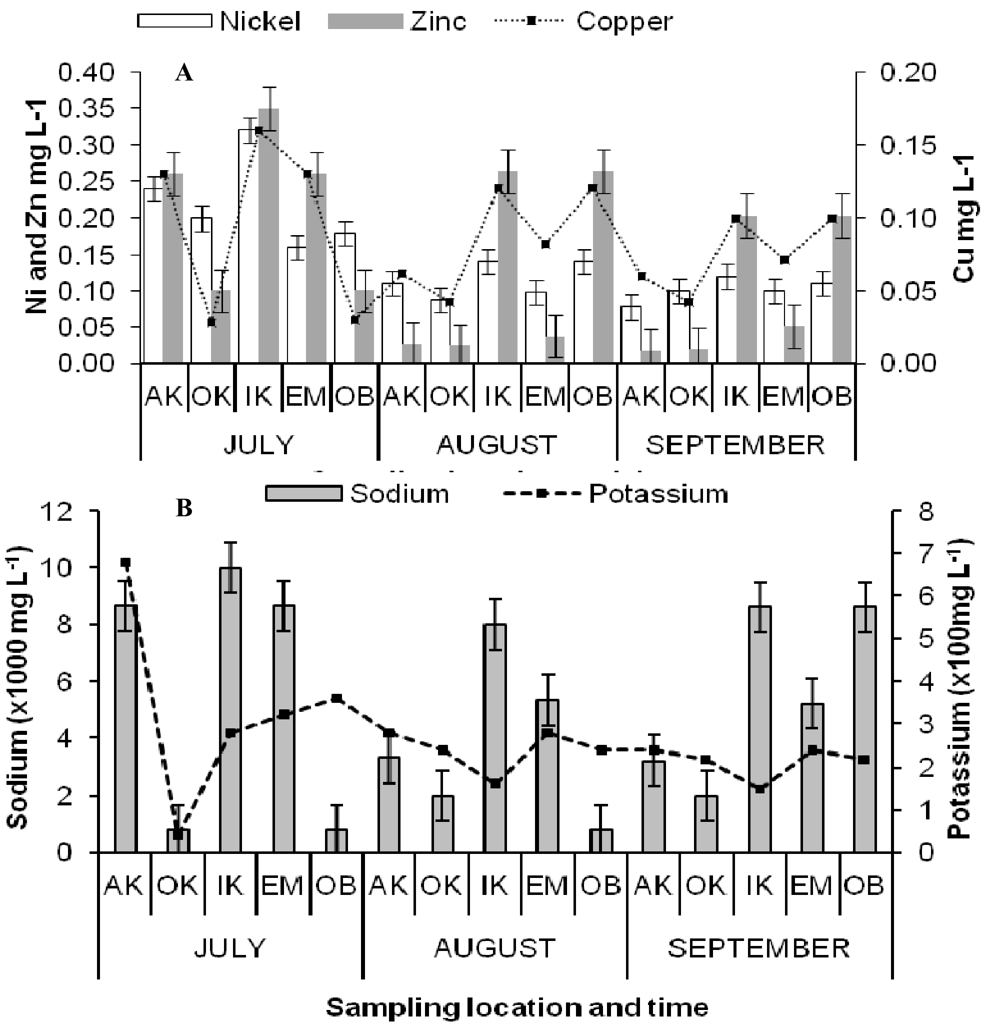

Figure 3: Spatiotemporal variation of some metals in Eastern Obolo Estuary, Nigeria

3.9 Conductivity

Okorombokho had the least conductivity value of 5.31 µS cm^{-1} while Emereoke had the highest value of 36.7 µS cm^{-1}. Mean conductivity values (Figures 2C, 4D) at Amadaka, Iko and Emereoke were not significantly different ($P>0.05$) from each other but were significantly different ($P<0.05$) from the values at Obianga and Okorombokho.

3.10 Temperature

The sub-surface water temperature ranges from 25.1^{0}C to 28.2^{0}C (26.47^{0}C±1.1487) observed across the stations are considered normal since the area falls under humid/semi-hot equatorial climate (NEDECO 1961). This finding agrees with earlier reports of 25 to 27.8^{0}C in the Niger Delta waters (Etim & Akpan 1991; Dibia 2006). However, the result differs from reports of Hart & Zabbey (2005) (25.8 to 30.4^{0}C) and Abowei & George (2009) (27 - 31^{0}C). The observed seasonal variation is directly attributed to the climate of the study area which is usually characterized by a hot dry season and cold wet season (Akpan 1999, 2000). The variation in water temperature, between and within the area, was due to the large tidal fluctuation in the estuary, with cold incoming seawater and warm outgoing freshwater.

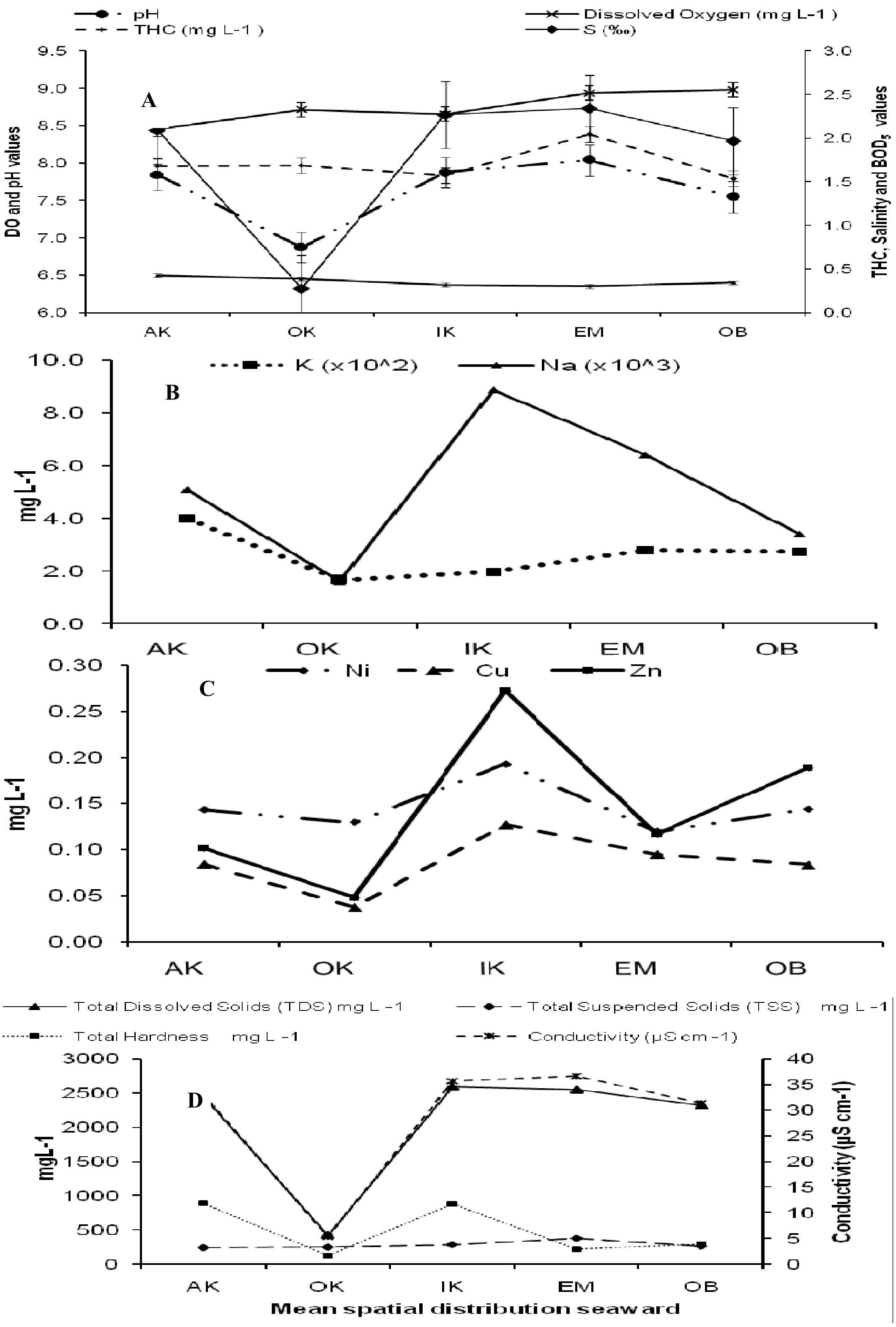

Figure 4: Mean spatial distribution of physic-chemical parameters seaward in Eastern Obolo Estuary

3.11 Metals

Mean values of nickel, potassium, dissolved oxygen and temperature showed significant temporal variations ($P<0.001$, $n=10$, Figs. 3B, 4B, 4C) with a gradual decrease as the rain progressed. Pooled mean values of nickel was highest in July (8.22 mgL^{-1}) compared to August (0.11 mgL^{-1}) and September (0.1 mgL^{-1}). A similar temporal trend was observed in potassium, as values decreased from 376.0 in July, 240.0 in August to 214.2

mgL^{-1} in September.

3.12 Impacts on the community

The Eastern Obolo community depends largely on its forests, swamps and river for sustenance. The community is blessed with abundant physical and human resources, including good agricultural land, large forest areas for lumbering, rich fisheries, as well as coastal transport system. Lots of fishes and shrimps are caught during the flood season to enhance their livelihood. Industrialization, oil exploitation, urbanization and population growth have contributed to the loss of water quality, swamp forest and destruction of nursery/spawning ground for fish with its attendant loss of fisheries resources, fish habitat modification, decrease in fish yield and a declining livelihood of local inhabitants experienced in the study area. This problem is critical due to lack of alternative sources of livelihood and water source to the local inhabitants; thus a large number of youths, men and women, are forced to re-adjust to a new lifestyle of fending for themselves outside agriculture and hunting; and generating social ills and insecurity, including illegal oil bunkering activities. Reversing and mitigating all wrong-doings and restoration of the environment would assuage the fears of the community and enhance sustainable and diversified livelihoods.

4. Conclusion

The present study summarizes the spatiotemporal fluctuations in Cu, Ni, Zn, Na and in various physico-chemical parameters in the waters of Eastern Obolo. Total dissolved solids, pH, salinity and conductivity showed significant ($P<0.001$, $n=10$) spatial variations increasing seawards (Figure 2A). There was no significant spatial difference ($P<0.05$) in the other parameters measured including dissolved oxygen and temperature (Figure 2A-C). Mean values of nickel, potassium, dissolved oxygen and temperature showed significant ($P<0.001$, $n=10$) temporal variations with a gradual decrease as the rain progressed (Figure 3, 4). The temperature ranges represented a typical humid/semi-hot equatorial region as noted by (NEDECO 1961). The mean values of nickel, potassium, total dissolved solids, sodium, copper, zinc, total hydrocarbons and biochemical oxygen demand from all stations exceeded the recommended limits for aquatic life or potable water. There were also minor fluctuations in water quality from one sampling station to the other. The Eastern Obolo estuary may not be an efficient source of drinking water for the community but it definitely helps flush out anthropogenic pollutants into the sea.

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