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Physicochemical Characteristics of Surface Water and Sediment in Tidal Flood Plain in Selected Oil Producing Areas of Akwa Ibom State During Wet Seson

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Abstract

Tidal flood plain sediments play very important roles in the survival of the aquatic ecosystem. Sediments serve as a sink for several chemical compounds which include but not limited to heavy metals. The sediments of tidal flood plains harbor quite a good number of fauna and flora and these have some have some sorts of supports for human wellbeing. Thus, their status have serious effects on humans as well as other components of the environment. However, the various anthropogenic activities that take place in and around our environment affect the status of the sediments in the aquatic ecosystem in particular because the wastes from such activities eventually find their ways into the surrounding surface water bodies and the coastlines where the sediments form and get deposited. Such activities include oil exploration and production for which Akwa Ibom State is partly known for. It therefore, becomes important to determine the status of the surface water and the arising sediments. This gave rise to the current investigation to determine physicochemical characteristics of both the surface water and sediments of the tidal flood plains of some oil producing area, using Akwa Ibom State as area of study. To ascertain this, sediment and water samples were collected from five different locations namely; Ibeno, Eket, Esit-Eket, Ikot-Abasi and Eastern Obolo for analyses using appropriate laboratory techniques. Results show that all physicochemical characteristics of surface water and sediment exhibited a significant difference ($p<0.05$) between the five sampling locations in the study area. The highest mean concentration of physicochemical parameters across all water and sediment samples were 7.35 (pH), 105.15mg/l (Cl), 0.62mg/l (K), 2.59mg/l (PO_4), 0.06mg/l (F), 36.70mg/kg (P), 0.028% (N), 0.59% (OC), 1.019% (OM), 4.60mg/kg (Ca), 3.00mg/kg (Mg), 0.174mg/kg (K), 0.138mg/kg (Na), 2.80 (EA), 10.26 (ECEC), 89.94% (BS), 0.54mg/kg (Zn), 26.97mg/kg (Ni), 11.00mg/kg (Mn), 7.00mg/kg (Fe), 0.84mg/kg (Cu), 0.87mg/kg (Cr) and 0.72mg/kg (Cd). Physicochemical parameters were generally higher in sediments samples than in the corresponding surface water samples. This study recommends regular assessments of surface water and sediment quality to evaluate the effectiveness of pollution control measures. It further recommends public awareness and advocacy in line with regulations and protocols for effective management of our coastal ecosystem.

Keywords: *Sediment, Tidal Flood Plain, Pollution and Physiochemical parameters*

Introduction: The tidal flood plain sediment serves as water sink for a number of nutrients due to industrial wastes, water effluents, inorganic leachates from refuse dumpsites, fertilizers, runoffs among others.(Chmeilewska and Medved, 2001), and are well known for their sensitive indicators between natural and anthropogenic variables. Tidal flood plains are areas where sediments from river runoff, or inflow from tides deposit mud or sand. They are usually sandwiched between marine, freshwater and land environments and are found in areas where there are low slopes and regular flooding occurs (Mackinnon, Verkuil and Muway, 2012; Nyong, *et al*.,2023; Miththapal, 2013). There are global concerns over the rate at which water bodies and tidal flood plains are being polluted. High population growth, mostly in the developing countries, has given rise to increased human activities which in turn results to indiscriminate dumping of refuse and waste disposal among others in water bodies thereby making it difficult to have access to clean and uncontaminated water (Duru and Nwanekwu 2012). Surface water appear to be the most threatened by human activities of all the natural water bodies. Water may be available in adequate quantities but may not be of good quality thereby limiting what we can do with the available water. Naturally, ecosystems such as tidal flood plains and water bodies will be in harmony with each other and their qualities but any significant alterations to quality of any usually disrupts the ecosystem.

Water and its environments require adequate and proper conservation in other to continue in sustaining life. Since the advent of the discovery and exploration of crude oil in Nigeria, so many wastes have been introduced into our environment, mostly the water environment. These wastes comprise of various heavy metals and other nutrients. According to Tam and Wong (2000) and Li, Wu, Chu, Zhang, Cai and Fang (2007) environmental contamination arising from rapid urbanization and industrialization has become a serious concern worldwide. The contamination is very significant especially in sediments of the estuarine and coastal areas through adsorption onto suspended matter and subsequent sedimentation. Sediments are composite materials, which consist of inorganic components, mineral, particulate and organic matter in various stages of decomposition. They are well known for their sensitive indicators between natural and anthropogenic variables Nyong, *et al*.,2023; Devanesan, Suresh, Selvapandiya, Senthilkumar and Ravisankar 2017). Pollutants in sediments can be released back to water strata by the process of resuspension. This gets the chemical compound or pollutant trapped in the sediment to be reabsorbed (Lick, 2009).

Tidal flood plains experience complicated problems such as pollution and encroachment that have almost suffocated valuable lifelines of the surroundings. This is majorly due to anthropogenic activities, chiefly among them being the activities of the oil exploration and producing companies. Some works have been done on the tidal flood plains and related issues. For example, Isotuk, Etesim, Nsi and Ukpong.(2023) worked on bottom sediment, surface water and oyster in Eastern Obollo while Yawo and Akpan (2021) worked on sediment from Utiebe river also in Eastern Obollo. Ubong, Ekwere and Ikpe. (2020) on their part worked on *Tympanotomos fucatus* and sediment from Iko river. Eni, Arikpo and Oko. (2021) worked on heavy metals and total hydrocarbon concentration in Qua Ibo river estuary while Nyong, *et al*.,2023) Udofia, Uba, Inyang-Eni, Ubiebi,Ntino and Etok (2022) did their work on microbial abundance, diversity and physicochemistry of Iko river estuary in Akwa Ibom State. Another is a work on textual and heavy minerals characterization of costal sediments in Ibeno and Eastern Obolo Local Government Areas of Akwa Ibom State by Nyong, *et al*.,2023; Bassey, Ite, Asuwaiko and Emmanuela (2019). However, none was done on all five locations as in this work. Hence, the importance and usefulness of the current work.

Study Area: This study was carried out in Akwa Ibom State, Nigeria. Akwa Ibom State lies between Latitudes 4º32’ to 5º33’N and Longitudes 7º25’ to 8º25’E with a landmass of 8412sq km and population of 3,920,208 (NPC, 2006). Its 129 km coastline happens to be the longest in the country and is a very rich source of wide varieties of fishes and sea foods (Wikipedia).Rainfall in Akwa Ibom is usually heavy ranging between 2000mm and 3000mm annually. The rainfall pattern is bimodal, starting in March and ending in November. There is also, a short period of less moisture in August which is traditionally referred to as August break. The temperature ranges between 26º and 28º C throughout the year with slight variations. It has the vegetation of the tropical rainforest (AKSG, 2023) The state is largely made up of peasant farmers, fishermen and traders with some civil servants and entrepreneurs. The hospitality industry thrives well in Akwa Ibom as there are quite some tourism centres that attract tourists to the State. (AKSG, 2023).

Sampling and Sample Collection: Sediments and water samples were collected from five different locations namely; Ibeno, Eket, Esit-Eket, Ikot-Abasi and Eastern Obollo in Akwa Ibom State for physicochemical analysis using systematic sampling method and with the aid of stainless auger and scooper. Water samples were taken in clean sterile tubes with caps in duplicates, using hand gloves. Dissolved oxygen bottles were used to collect samples for dissolved oxygen determination. The samples were put in plastic bags and transferred to soil science laboratory for further analysis (Soil Survey Staff, 2010). Sediment samples were analyzed according to the Association of Official Analytical Chemists (AOAC, 2004). Sediment texture and organic carbon content were determined by Hydrometer method and Walkley Black (Jacob and Clarke, 2002). A factor of 1.72 was multiplied with organic carbon content to determine Sediment Organic Matter (SOM). EDTA Systronics Spectrophotometer-2202 was used to determine the parameters Jenway (model type HANNA 1910) multipurpose tester temperature, pH and conductivity were determined in situ using the HM digital meter-COM-10 and Equip-tronics EQ-614-A, respectively. Turbidity was determined using attenuated radiation method. Chemical oxygen demand was determined according to APHA (2005) method. Taste was determined by the panel method following Ukaga and Onyeka (2002).

Statistical Analysis: ANOVA was used to compare means across the test parameter intervals. Duncan multiple post hoc test was used for the specific significant differences among the sampling intervals. The analysis was computed using IBM SPSS Statistics Version 26.0.

Results and Discussion: Physicochemical Properties of Surface Water: Table 1 shows that all physicochemical properties of surface water exhibited significant differences ($p<0.05$) between the surface water samples from the five sampled locations in the study area. Hydrogen ion (pH) ranges from 4.35 at Esit-Eket to 8.30 at Eket. The pH values showed a significant difference ($p<0.05$) across all sampled locations. Chlorine (Cl) ranges from 11.87 mg/l at Eket to 112.76 mg/l at Eastern Obolo. The chlorine exhibited significant difference ($p<0.05$) across all sampled locations. Potassium (K) ranges from 0.416 mg/l at Ibeno and Ikot-Abasi to 0.607 mg/l at Eket. K also showed a significant difference ($p<0.05$) across all sampled locations. Phosphate (PO_4) ranges from 0.001 mg/l at Ibeno to 2.507 mg/l at Eket. PO_4 showed significant difference ($p<0.05$) in all the sampled locations. Fluorine (F) ranges from 0.001 mg/l at Eket to 0.048 mg/l at Eastern Obolo. The Fluorine values showed a significant difference ($p<0.05$) across all sampled locations.

Table 1: Mean ±SD of Physicochemical Properties of Surface Water

Parameters	SAMPLING LOCATION				
	Ibeno	Eket	Esit -Eket	Ikot- Abasi	Eastern Obolo
pH	$7.45^b \pm 0.071$	$8.30^a \pm 0.283$	$4.35^d \pm 0.071$	$6.95^c \pm 0.071$	$8.15^a \pm 0.071$
Cl (mg/l)	$66.14^c \pm 6.307$	$11.87^e \pm 0.226$	$25.535^d \pm 0.035$	$78.61^b \pm 0.566$	$112.76^a \pm 3.606$
K (mg/l)	$0.416^c \pm 0.021$	$0.607^a \pm 0.006$	$0.581^a \pm 0.00$	$0.43^c \pm 0.028$	$0.479^b \pm 0.001$
PO_4 (mg/l)	$0.001^e \pm 0.00$	$2.507^a \pm 0.135$	$1.152^b \pm 0.07$	$0.225^d \pm 0.034$	$0.54^c \pm 0.00$
F (mg/l)	$0.01^b \pm 0.001$	$0.002^b \pm 0.001$	$0.001^b \pm 0.00$	$0.003^b \pm 0.001$	$0.048^a \pm 0.014$

x ± SD = average mean generated from values across the sampling location, ± standard deviation; post hoc = values with different superscripts (a > b > c > d > e) are significantly different ($p < 0.05$) while values with same superscript are not significantly different ($p > 0.05$).

Physicochemical Properties Of Sediment Samples From The Study Area: Table 2 shows Physicochemical parameters such as pH, P, Ca, Mg, K, Na, EA, ECEC and BS exhibited a significant difference ($p<0.05$) between the sediment samples from the five sampling locations in the study area, while N, OC and OM showed no significant difference ($p>0.05$) between the sediment samples from the five sampling locations in the study area. Result shows that the percentage of Sand, Silt and Clay in the sediment samples varied significantly ($p<0.05$) across all sampling locations. pH ranges from 4.48 at Esit Eket to 7.40 at Ibeno. The pH values showed a significant difference ($p<0.05$) across all sampling locations.

Phosphorus (P) ranges from 15.40 mg/kg at Ibeno to 35.75 mg/kg at Esit Eket. The P values showed a significant difference ($p<0.05$) across all sampling locations. Nitrogen (N) ranges from 0.011 mg/kg at Eket to 0.018 mg/kg at Esit-Eket. Organic Carbon (OC) ranges from 0.041 mg/kg at Esit Eket to 0.44 mg/kg at Esit-Eket. Organic Matter (OC) ranges from 0.159 mg/kg at Esit-Eket to 0.915 mg/kg at Esit-Eket. The N, OC and OM values showed no significant difference ($p>0.05$) across all sampling locations. Calcium (Ca) ranges from 1.45 mg/kg at

Ikot Abasi to 3.555 mg/kg at Ibeno. Magnesium (Mg) ranges from 1.005 mg/kg at Ikot Abasi to 2.69 mg/kg at Ibeno and Eket. Potassium (K) ranges from 0.007 mg/kg at Mobil to 0.073 mg/kg at Esit Eket. Sodium (Na) ranges from 0.004 mg/kg at Eket. to 0.101 mg/kg at Ibeno. Exchangeable Acid (EA) ranges from 0.575 at Eastern Obolo to 1.90 at Eket. Effective cation exchange capacity (ECEC) ranges from 3.06 at Ikot Abasi to 9.26 at Eket. Base saturation (BS) ranges from 60.645 % at Esit Eket to 85.26 % at Eastern Obolo. The Ca, Mg, K, Na, EA, ECEC and BS values showed a significant difference ($p<0.05$) across all sampling locations.

Table 2: Physicochemical Properties of Sediment Samples from the Study Area.

Parameters	Ibeno	Eket	Esit-Eket	Ikot-Abasi	Eastern Obolo
Sand (%)	$90.35^{a} \pm 0.00$	$88.30^{c} \pm 0.00$	$89.35^{b} \pm 0.071$	$90.39^{a} \pm 0.00$	$89.825^{ab} \pm 0.742$
Silt (%)	$0.253^{c} \pm 0.349$	$3.01^{a} \pm 0.014$	$1.80^{b} \pm 0.00$	$0.251^{c} \pm 0.353$	$1.50^{b} \pm 0.707$
Clay (%)	$2.81^{a} \pm 0.00$	$2.81^{a} \pm 0.00$	$3.39^{a} \pm 0.82$	$0.92^{b} \pm 0.707$	$1.92^{ab} \pm 0.707$
pH	$7.40^{a} \pm 0.424$	$4.75^{bc} \pm 0.354$	$4.48^{c} \pm 0.042$	$5.35^{b} \pm 0.354$	$5.10^{bc} \pm 0.00$
P (mg/kg)	$15.40^{c} \pm 0.566$	$23.95^{b} \pm 5.728$	$35.75^{a} \pm 0.212$	$18.00^{bc} \pm 0.141$	$31.745^{a} \pm 0.205$
N (%)	$0.013^{a} \pm 0.00$	$0.018^{a} \pm 0.00$	$0.011^{a} \pm 0.01$	$0.016^{a} \pm 0.004$	$0.017^{a} \pm 0.001$
OC (%)	$0.125^{a} \pm 0.009$	$0.44^{a} \pm 0.58$	$0.041^{a} \pm 0.049$	$0.205^{a} \pm 0.136$	$0.253^{a} \pm 0.072$
OM (%)	$0.286^{a} \pm 0.105$	$0.767^{a} \pm 0.924$	$0.915^{a} \pm 1.025$	$0.159^{a} \pm 0.063$	$0.471^{a} \pm 0.081$
Ca (mg/kg)	$3.555^{a} \pm 0.219$	$3.20^{a} \pm 0.283$	$3.20^{a} \pm 0.283$	$1.45^{b} \pm 0.636$	$2.805^{a} \pm 0.276$
Mg (mg/kg)	$2.69^{a} \pm 0.028$	$2.69^{a} \pm 0.028$	$2.345^{a} \pm 0.516$	$1.005^{b} \pm 0.007$	$2.345^{a} \pm 0.516$
K (mg/kg)	$0.007^{e} \pm 0.001$	$0.045^{b} \pm 0.001$	$0.073^{a} \pm 0.00$	$0.026^{c} \pm 0.001$	$0.016^{d} \pm 0.001$
Na (mg/kg)	$0.101^{a} \pm 0.001$	$0.004^{b} \pm 0.001$	$0.019^{b} \pm 0.023$	$0.037^{b} \pm 0.001$	$0.031^{b} \pm 0.028$
EA	$0.765^{b} \pm 0.078$	$1.90^{a} \pm 0.00$	$1.25^{ab} \pm 0.495$	$0.71^{b} \pm 0.00$	$0.575^{b} \pm 0.601$
ECEC	$7.665^{c} \pm 0.064$	$9.26^{a} \pm 0.00$	$8.675^{b} \pm 0.318$	$3.06^{e} \pm 0.00$	$7.05^{d} \pm 0.00$
BS (%)	$79.94^{b} \pm 1.245$	$62.715^{c} \pm 0.035$	$60.645^{d} \pm 0.474$	$80.92^{b} \pm 0.00$	$85.26^{a} \pm 0.014$

x ± SD = average mean generated from values across the sampling location, ± standard deviation; post hoc = values with different superscripts (a > b > c > d > e) are significantly different ($p < 0.05$) while values with same superscript are not significantly different ($p > 0.05$).

Discussion: The physicochemical properties of water bodies are crucial to aquatic ecosystem and human life at large. Particle size distribution is one of the vital factors determining the extent of sediment contamination with pollutants (Adeyi and Babalola, 2017). Generally, sediment in this study was dominated by sand, followed by clay, and then silt in all the study locations. The sandy nature of the sediment of the study areas makes it highly permeable and might allow pollutants from oil exploration to pass through, thereby had a potential of polluting the surrounding underground water. The high sand fraction in the study could be attributed to the parent material dominant in the area which is coastal plain sand since the texture of soil is highly influenced by the parent material over time (Nyong, and Nweze,, 2012; Abida, Ramaih, Harikrishma and Veena 2009). The result from this study is in tandem with Anju and Banerjee, (2012) who observed similar textural characteristics on coastal plain soil and sediment in Owerri, Southeastern Nigeria. The textural classes ranged from silt loam to silty clay loam.

The pH values indicate the strength of acidity or alkalinity of the water (Nwankwo, Ekeocha and Ikoro. 2015).The result from the study showed that the pH values were relatively similar and were acidic with a range of 3.45 – 7.35. Studies have shown that pH does not only affect the growth of plants indirectly by affecting nutrients availability, but also the presence of toxins and the growth of soil microorganisms (Nyong, and Nweze,, 2012; Dedeke, Owagboriaye, Adebomboi and Ademolu 2015). Therefore, pH range as obtained in this study might have implications on nutrient availability in the polluted soils and could be influenced by the presence of dissolved substances and biochemical developments in the water medium (Bahrami, Moore and Keshavarzi 2019). The average mean of phosphorus across this study showed a significant difference ($p<0.05$) across the study areas ranging from 15.50 – 36.70 (mg/kg) as seen in the tables. This prevailing condition of phosphorus content in this study areas may suggest the utilization/complexation of the nutrients by resident microflora as well as sediment degradation process such as volatilization or leaching (Nwankwo *et al*., 2015). The P values result agrees with a study conducted by Butler *et al*, 2008. However, Nweke and Ukpai, (2016) recorded a higher K of 89.77 mg/kg in Goi Creek in Ogoni land.

Phosphate values recorded in this study were significant and can be attributed to the leaching of fertilizer residues from agricultural farms along the river. The PO_4 in this study was low compared to the study of Okorafor, James and Udoh (2014), who attributed their results to the influence of flooding. Edori, Kieri and Festus (2019) recorded lower values of 0.08 mg/l in water of Silver River in Bayelsa State when compared to this study. Oghenenyoreme and Njoku (2014) obtained higher values of 259.6 mg/l for Chlorine in a selected part of Oji River and its environs, Enugu State. Edori and Nna (2018) recorded similar range values of 18.32 - 123.75 mg/l for Cl in effluents at discharge points into the New Calabar River along Rumuolumeni Axis, Rivers State. As per Fluoride, this study agrees with the findings of Osuji and Nwoye (2017), who obtained a similar concentration of F value of 0.03 mg/l in surface water in the Niger Bayelsa mangrove creek. Otari and Dabiri (2015) also obtained similar values of 0.04 mg/l in surface water samples from Nembe River, while Nnoli, Olomukoro, Odii, Ubrei-Joe, and Ezenwa (2021) recorded a higher F value of 1.86 mg/L in Goi Creek in Ogoni land.

The average mean percentages of nitrogen across the study area were relatively similar and showed no significant difference ($p>0.05$) between the study areas. This prevailing condition of low nitrogen content in this study may suggest that soil degradation process such as volatilization or leaching was higher (Kuppusamy, Thavamani, Venkateswarlu, Lee, Naidu and Megharaj 2017). Organic matter is the most important source of N used by plants (Nazir, Khan, Masab and Rehman 2015). This result is in line with a study by Nyong, and Nweze,, 2012; Nwachukwu *et al*. 2013. Organic carbon (OC) is a measurable component of organic matter (OM). The variability of organic carbon of sediment obtained from the study reflects the intensity of human activities in the study areas (Dudka and Miller, 2019). Exchangeable bases (Ca, Mg, K and Na) content of sediment had significant differences ($p<0.05$) across the study location for these exchangeable bases. Other researchers found different results and opined that there is an increase in exchangeable Ca and Na contents as a result of crude oil and can be attributed to rapid decay and mineralization of organic and mineral materials in the sediment (Onwukeme and Etienajirhevwe, 2020). Orhue and Usi, (2015) recorded a higher Ca, Mg, K and Na of 8.55, 6.17, 2.23 and 3.26 mg/kg respectively in Goi Creek in Ogoni land when compared with this work.

The Exchangeable Acidity (EA) had significant difference ($p<0.05$) across the locations studied. The highest exchangeable acidity value of 2.80 cmol/kg was recorded at Eket while the least exchangeable acidity value of 0.575 cmol/kg was recorded at Eastern Obolo. The Effective cation exchange capacity (ECEC) showed a significant difference ($p<0.05$) across the study area. The highest ECEC value of 10.26 cmol/kg was from the Eket while the least exchangeable acidity value of 3.06 cmol/kg was obtained from Ikot-Abasi. This result confirms the findings of Oseji, Egbai, Okolie and Ese (2018) who recorded an exchangeable acidity of 8.30 cmol/kg. The results of the percentage base saturation (BS) showed a significant difference ($p<0.05$) across the study areas at a range of 70.12 – 90.11%. Generally, the low soil carbon, total nitrogen and organic matter contents indicates poor soil fertility (Osuji and Nwoye, 2017). High base saturation could be attributed to increase in exchangeable bases and organic carbon.

The sediments in this study had more concentration of physicochemical parameters than in corresponding surface water samples. Across the sampling locations, whether within the water column or bottom sediment, the lowest and highest concentrations of the analysed parameters were obtained at Ikot Abasi and Eket, respectively. This was possible due to the significant anthropogenic activities and its proximity to the community, which, combined with run-off from agricultural fields.

Conclusion: The comprehensive assessment of physicochemical parameters in water bodies is critical for understanding environmental health and human well-being. The study investigated the quality status of the coastal environment for the sustainability of same for aquatic organisms and man's survival in particular. The analysis covers various parameters such as particle size distribution, pH, K, Na, Ca, Mg, organic carbon, exchangeable bases.

The pH of the soil is moderately acidic, influencing nutrient availability and pollutant fate. Soil organic carbon and organic matter content are significantly low in the study area, indicating intense anthropogenic activities and slow mineralization. Nitrogen and phosphorus levels vary across study areas with implications for soil fertility. Exchangeable bases content, exchangeable acidity, effective cation exchange capacity, and percentage base saturation are analyzed to understand soil fertility and nutrient availability. These parameters show variations across study areas, influenced by both natural processes and anthropogenic activities.

Recommendation: From the findings of this study, it is recommended that: Stringent measures should be taken to ensure that environmental regulations are complied with by all, especially the oil companies; Monitoring mechanisms should be put in place to checkmate human activities along the coastlines; and Public awareness and advocacy must be regularly carried out in the area of environmental protection and management.

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