The Impact of Anthropogenic Activities on Sediment Quality of Kolo Creek, Rivers State, Nigeria

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Abstract
The characteristics of the sediment of Kolo Creek at Okarki in Rivers State, Nigeria were determined. Six sampling stations were studied; Five (Stn1 to Stn 5) within the creek in areas with considerable operation of illegal bunkering of petroleum products, while Stn 6 was a Control. The concentrations of total petroleum hydrocarbons (TPH) ranged from a mean of 5.0 (±1.4) at Stn 6 to mg/kg 1049 (±799) mg/kg at Stn 4. There was a significant difference in mean TPH between stations ($p<0.001$), and Stns 4, 2 and 5 had significantly higher values than Stn 6 (Control). Apart from the Control, the mean values in other stations are above the DPR target value of 50mg/kg but lower than the intervention value of 5000mg/kg. The lowest mean values of all heavy metals determined were recorded at Stn 6 (Pb 1.14±1.13 mg/kg, Cu 0.83 ±0.03 mg/kg, Cd 0.02 ± 0.01 mg/kg, Zn 4.03 ±2.36 mg/kg). The highest mean values were observed at Stn 2 for Pb (8.82 ± 2.08 mg/kg) and Zn (23.14 ± 5.02 mg/kg,), Stn 1 for Cd (0.50 ± 0.12 mg/kg,) and Stn 5 for Cu (5.71 ± 0.42,). There was no significant spatial difference in concentrations of lead, but significant difference were observed for Zn, Cu and Cd. In conclusion, anthropogenic activities in Kolo Creek, Rivers State have resulted to contamination of sediments with hydrocarbons and heavy metals in relation to controls. Although guideline limits were not breached in most cases, this could lead to ecological damage and needs to be stopped.

Keywords: *Kolo Creek; Rives State; Heavy metal; Petroleum Hydrocarbon; Sediment*

Introduction

Contamination of waters by oil related operations, which is the, most obvious industrial activity in the Niger Delta, is a chronic problem which has drawn a considerable attention in the area. Rapid increase human in population urbanization with poor waste management practices have increased the potential of environmental degradation and ecological damage.

Kolo Creek, a fresh water non-tidal creek flows through a region of Niger Delta from its origin at Okarki in Rivers State through to Otuoke in Bayelsa State that has been urbanised and industrialized due to the quest for crude oil and natural gas, a natural resource that is in abundance in this area. As a result of these activities, Kolo creek receives loads of human and industrial effluents which may be detrimental to the quality of the creek. There is a high concentration of industrial activities in the Bayelsa end of the creek with oil field facilities such as flow stations, oil and gas manifolds, and network of pipelines Thus several studies have been conducted to assess the effects of these activities on the physicochemical and biological characteristics. These include. Survey of heavy metals in sediments (Inengite *et*

al.,2010), water quality evaluation (Eremasi *et al*., 2015), Level and impact of hydrocarbon in sediment characteristics of Imiringi oil and gas field facilities (Seiyaboh & Jackson, 2017), bioavailability Of heavy metals in epipelagic sediments and tissues of African Catfish (*Clarias gariepinus*) (Elijah *et al*., 2016), heavy metal Concentration in water, sediment and tissues of *Eichhornia crassipes* from Kolo Creek, Niger Delta (Ogamba *et al*., 2017), ecological and potential health effects of hydrocarbon and heavy metal concentrations (Ezekwe *et a.l*, 2018).

Relatively few studies have been conducted at the Rivers State end of the Kolo Creek. Alfred-Ockiya (1996): studied the ichthyofauna of the creek. In recent times, there has been a preponderance of illegal oil bunkering activities on the Rivers State axis of the Kolo creek which has led to uncontrolled discharge of petroleum products into it. In this paper, we present the effects of the anthropogenic activities in the area on the quality of the sediment of Kolo creek, Okarki, Rivers State, Nigeria.

Material and Methods

Study Sites

The study area is located at Kolo creek in Ahoada West Local Government Area of Rivers State, Nigeria. Its coordinate lie within latitude 5◦58´28"N and longitude 6◦26´5"E in the Niger Delta of Nigeria. It is a section of the Lower Orashi River in South-Western part of River State. The floating vegetation in the study area is dominated by *Eichhornia crassipes*, *Azolla* sp, and *Nymphea* sp. Patches of fallow areas can be seen during the dry season with emerging vegetation such as *Nymphea* and *Pasplam* sp.

Five sampling stations associated with various degrees of illegal oil bunkering activities were located within Kolo Creek, while a Control station (with relatively low anthropogenic activity) was located upstream of the confluence between the Orashi River and Kolo Creek (Fig. 1). The sampling stations and their coordinates are as follows: Stn 1 (4°58'59"N 6°25'54"E,. Stn 2 (4°58'53"N 6°25'57"E): Stn 3 (4°58'45"N 6°25'54"E): Stn 4 (4°58'27"N 6°26'3"E):. Stn 5 (4°58'13"N 6°26'8"E), Stn 6-Control (4°59'3"N 6°25'50"E).

Sample Collection and Analysis

Monthly sampling was undertaken from December 2017 to May 2018, covering wet and dry season months. The sediment samples were air-dried and the Bouyoucos hydrometer method (Bouyoucos, 1951; Day, 1953). Was used for the particle size analysis, nitrate and phosphate were determined using a UV spectrometer, and total organic matter (TOM) was determined using the Walkley and Black method (Walkley, and Black, 1934; Black, 1965). For total petroleum hydrocarbon (TPH) pentane was used for extraction; the extracts were processed and analyzed by gas chromatography (API, 1994). Using Agilent 5890 GC with FID. Sediment samples for heavy metal analyses were digested in 1:2 nitric acid and hydrochloric acid and analyzed for Cu, Pb, Cd, Zn using GBC Avanta 6600 AAS.

Data Analysis

Analysis of Variance (ANOVA) was used to test for significant between stations, while t-tests were performed to test for differences between seasons. Where ANOVA gave significant differences, Tukey tests were performed to deduce pair-wise differences between stations at $p \leq 0.05$. All data were log (x+1) transformed except particle size (which were arcsine transformed). These analyses were computed using MINITAB and Microsoft Excel.

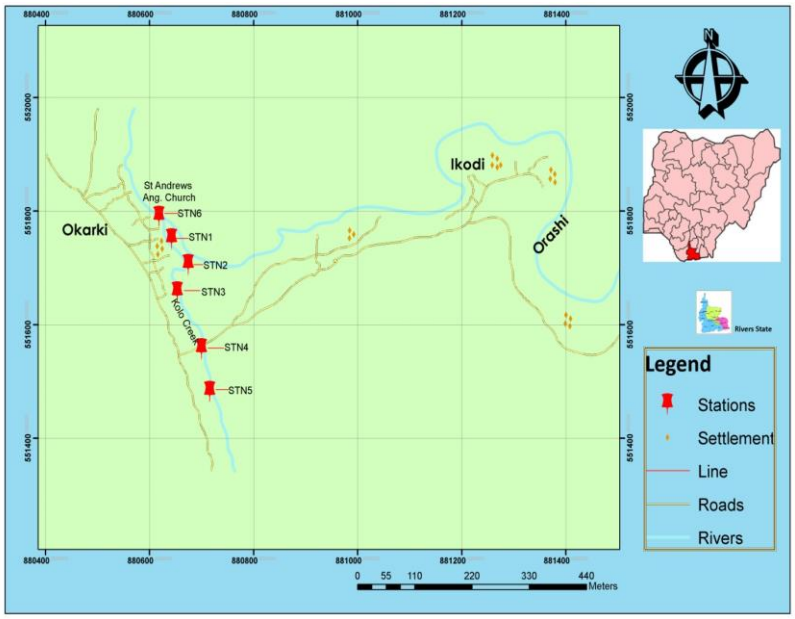

Fig 1: Map of the Study Area Showing Sampled Stations along Kolo Creek.

Results and Discussion

The concentrations of total petroleum hydrocarbons (TPH) ranged from a mean of 5.0 (±1.4) at Stn 6 to mg/kg 1049 (±799) mg/kg at Stn 4 (Fig. 2). There was a significant difference in mean TPH between stations ($p<0.001$ Table 1). Tukey tests showed there were no significant differences between Stns 1, 2, 3, 4 and 5. However, Stns 4, 2 and 5 had significantly higher values than Stn 6 Control). Obviously the illegal bunkering activities are responsible for the elevated values of TPH it the other stations when compared with the Control. Apart from the Control, the mean values in other stations are above the DPR target value of 50 mg/kg but lower than the intervention value of 5000 mg/kg (DPR 2002). The TPH values observed in this study are also higher than 0.08 to 2.4 recorded by Seiyaboh *et al.* (2017) in Kolo Creek bordering Imiringi Bayelsa State. However, similar values of total hydrocarbon content in the range of 19.11 – 1125.9 mg/kg (wet season) and (17.80 – 1118.5 mg/kg (dry season) were reported by Gijo *et al.* (2017) from sediments of the Nun River estuary in the vicinity of makeshift oil refineries.

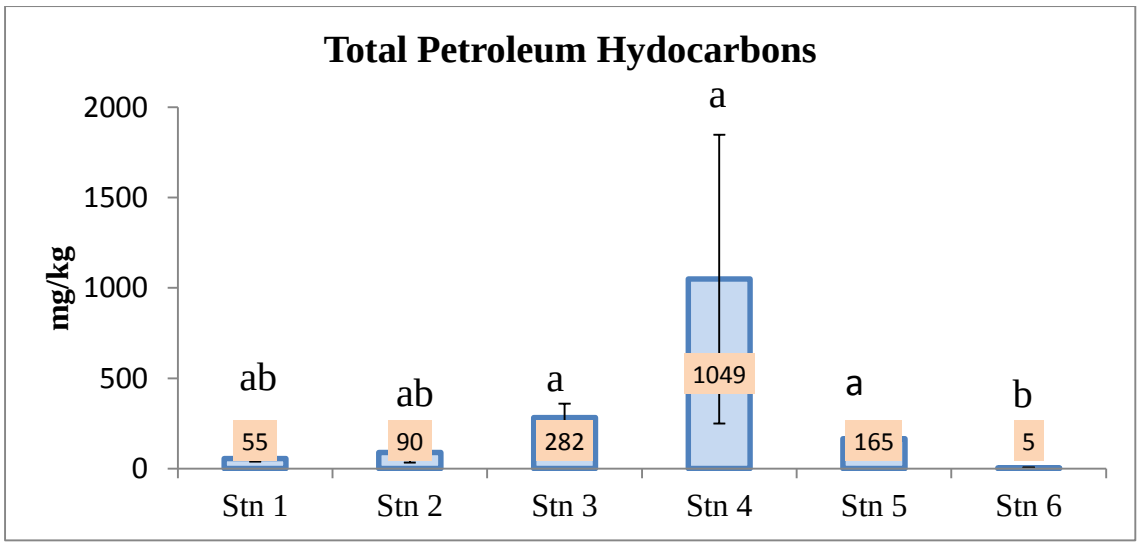

Fig 2: Mean (± SE) Concentrations of Total Hydrocarbons in the Sediment of Kolo Creek. Stations with different alphabets are significantly different (Tukey test, $p<0.05$).

Table 1: Summary of One-Way ANOVA for Spatial Differences of sediment Quality Variables measured in Kolo Creek

Parameters	DF	Adj SS	Adj MS	F	P
Total Organic Matter (%)	5,30	0.20	0.04	3.60	0.01
Nitrate (mg/kg)	5,30	0.09	0.02	0.67	0.65
Phosphate (mg/kg)	5,30	0.09	0.02	0.70	0.63
TPH (mg/kg)	5,30	12.70	2.54	7.80	<0.001
Copper (mg/kg)	5,30	1.27	0.25	13.06	<0.001
Lead (mg/kg)	5,30	0.21	0.04	0.29	0.91
Cadmium (mg/kg)	5,30	0.10	0.02	3.84	0.01
Zinc (mg/kg)	5,30	2.75	0.55	9.02	<0.001
Sand (%)	5,30	0.08	0.02	1.01	0.43
Silt (%)	5,30	0.77	0.15	3.48	0.01
Clay (%)	5,30	0.12	0.02	2.43	0.06

TPH= Total Petroleum Hydrocarbons

The lowest mean values of all heavy metals determined were recorded at Stn 6 (Pb 1.14±1.13 mg/kg, Cu 0.83 ±0.03 mg/kg, Cd 0.02 ± 0.01 mg/kg, Zn 4.03 ±2.36 mg/kg) (Fig. 3). The highest mean values were observed at Stn 2 for Pb (8.82 ± 2.08 mg/kg, Fig 3A) and Zn (23.14 ± 5.02 mg/kg, Fig 3D), Stn 1 for Cd (0.50 ± 0.12 mg/kg, Fig 3C) and Stn 5 for Cu (5.71 ± 0.42, Fig 3B). There was no significant spatial difference in mean concentrations of Pb ($p=0.91$), but there were significant differences in Cu ($p<0.001$), Cd ($p=0.01$) and Zn ($p<0.001$), (Table 1). Tukey tests showed that for Cu and Zn, the mean values at Stn 6 were significantly lower than the values at all other stations(Stn 5=Stn 4=Stn 3=Stn2>Stn 6). For Cd, Stn 1> Stn 6=Stn 5=Stn4. This pattern clearly indicates that contamination from discharges from the illegal bunkering and other activities were responsible for the spatial differences in the heavy metals. Nevertheless, the values of Pb were comparable to previously reported values in the Bayelsa segment of Kolo Creek (2.31 to12.3 mg/kg by Inengite *et al*., 2010; 6.00±4.47 mg/kg by Elijah *et al.*, 2016; and 1.757±0.054 by Ogamba *et al*., 2017). The concentrations of Pb observed in this study and the previous study were lower than the DPR target level of 80 mg/l for soil (adapted for sediment) as well as the Canadian sediment quality guideline - interim freshwater sediment quality guideline – ISQG of 30.2 mg/kg (CCME, 2001). The concentrations of Cu, Zn and Cd were also lower than the respective DPR target values 36 mg/kg 140 mg/kg, 0.8 mg/kg. They were also lower than the ISQG of 18.7 mg/kg (Cu), 124 mg/kg (Zn), 0.7 mg/kg (Cd). Ogamba *et al*. (2017) recorded similar values for Cu (0.419±0.011) and Cd (0.147±0.002). However, Elijah *et al.* (2016) reported values of Cd (2.22 ± 2.48) higher regulatory benchmarks as well as this study. Although the values they recoded for Zn (35.19 ± 4.47) were also higher than those observed in this study, they were lower DPR and IOQG limits.

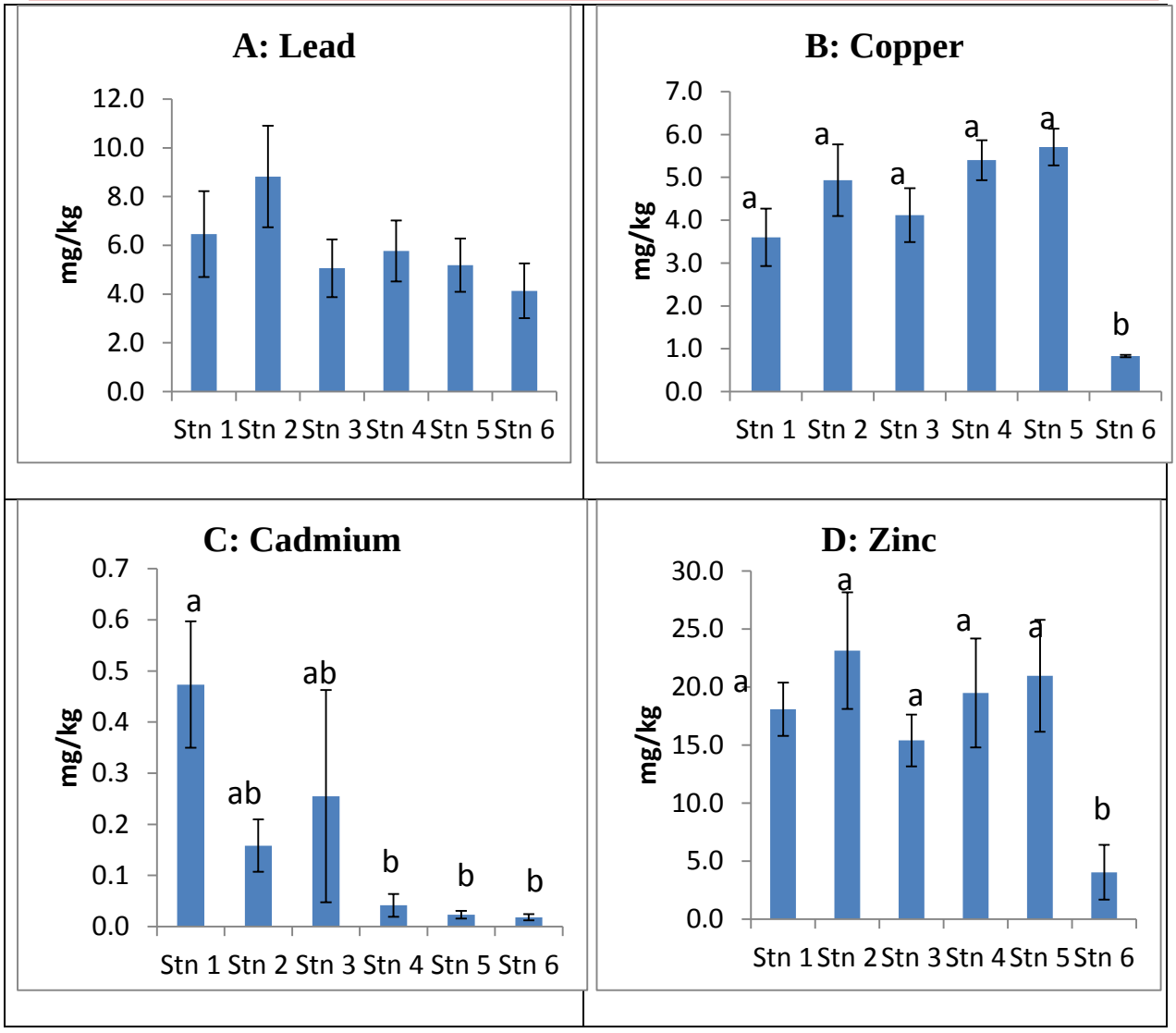

Fig 3: Mean (± SE) Concentrations of Heavy Metals in the Sediment of Kolo Creek. Stations with different alphabets are significantly different (Tukey test, $p<0.05$).

The sediment of the study area was predominantly sandy with mean % sand > % clay > % silt. (Fig. 4). There was no significant difference in the mean proportion of sand ($p=0.43$) or clay ($p=0.06$) between stations (Table 1), but there was significant difference in the mean % silt between stations ($p=0.01$). Tukey tests on silt showed significant differences only between St 1 and St 2 in comparison with St 6. Total Organic Carbon (TOC) ranged from a mean of 1.54 (±0.23) % at St 6 to 3.31 (±0.45) %. There were significant differences in TOC values between stations ($p=0.01$); Tukey tests indicated that the values were significantly lower at Stn 6 when compared with Stn 2 and Stn 5 (Fig. 5A). Similar mean values of phosphate were recorded at Stn 1, Stn 2 and Stn 3 (ca. 0.24 mg/kg), but the highest value of 1.56 (±1.36) mg/kg was recorded at Stn 4 (Fig 5B). There was no significant difference in mean phosphate values between stations ($p=0.63$). Similarly no significant spatial difference was observed in nitrate ($p=0.65$) with the lowest mean value of 0.88 (±0.38) mg/kg at Stn 4 and highest values of 1.20 (± 0.39) mg/kg at Stn 2 (Fig 5C). The TOC, nitrate and phosphate values were generally lower than (for TOC), for nitrate) and (for phosphate) by Seiyaboh *et al.* (2017).

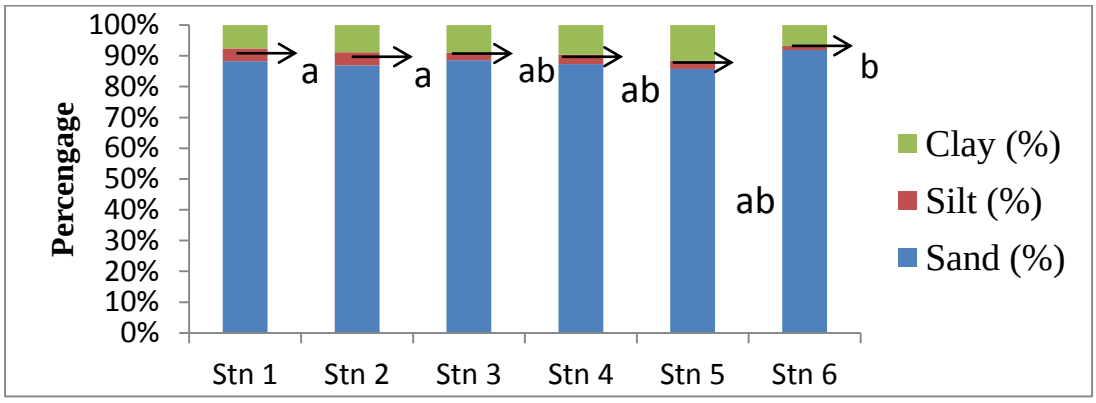

Fig 4: Spatial variation of particle size distribution in Kolo Creek. Stations with different alphabets are significantly different in mean % Silt (Tukey test, $p<0.05$).

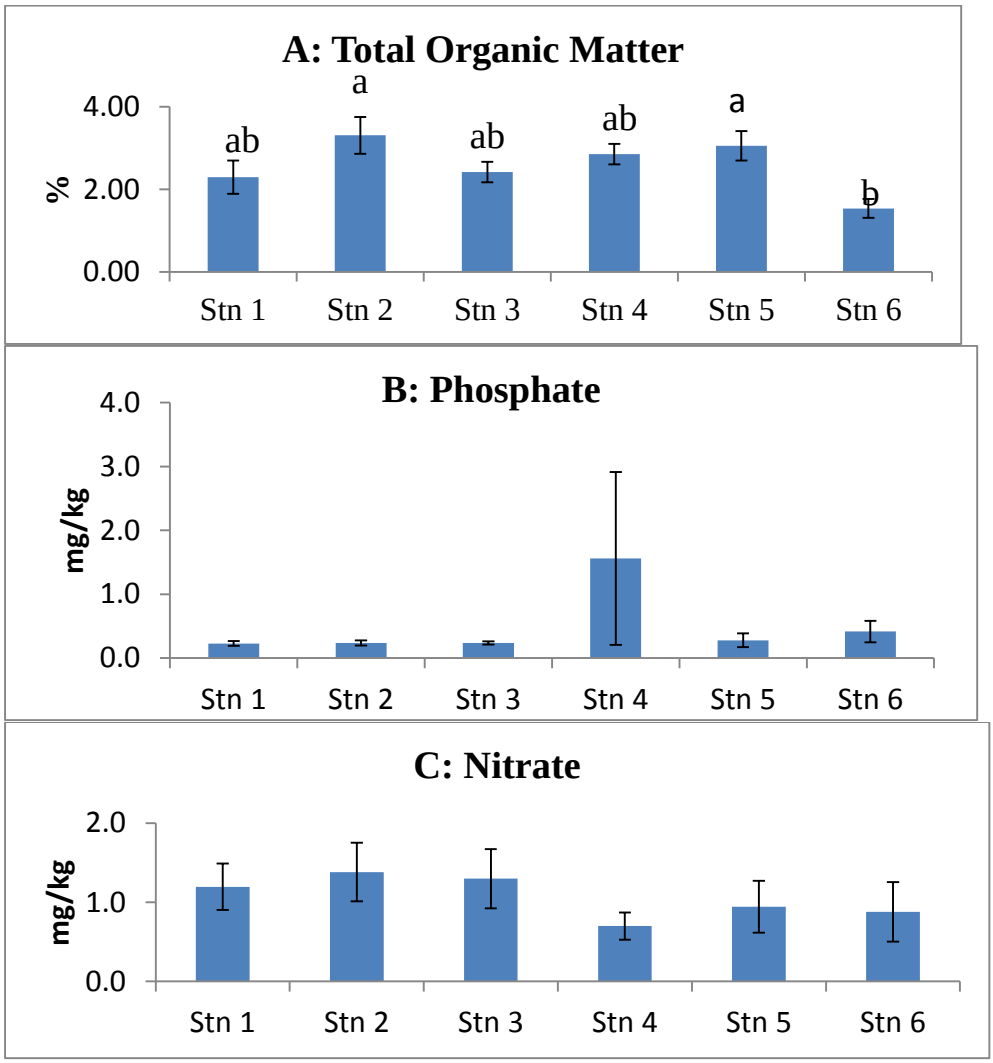

Fig 5: Mean (± SE) Concentrations of Nitrate, Phosphate and Total Organic Matter in the Sediment of Kolo Creek. Stations with different alphabets are significantly different (Tukey test, $p<0.05$).

Table 2 is a presentation of the seasonal variations of the sediment quality variables in Kolo Creek. Apart from % clay (p=0.003) and % silt (p=0.001), no parameter had significant difference between seasons. This must have resulted from the relative abundance of fine particles from run-off during the wet season. It implies that the activities that led to the significant increase in the TPH and heavy metals in Kolo Creek, in comparison with the control were continuous and systemic, rather that seasonal. The sediments were considered to be high in organic carbon as values exceeding 1% are said to have high organic carbon Griggs (1975).

Table 2: Seasonal Variation of Sediment Quality Variables in Kolo Creek

	Dry Season		**Wet Season**			
	Mean	**SE**	**Mean**	**SE**	**t-Value**	**p-Value**
TOM (%)	2.592	0.180	2.553	0.327	0.318	0.753
Nitrate (mg/kg)	1.262	0.165	0.675	0.165	2.215	1.691
Phosphate (mg/kg)	0.292	0.044	0.893	0.678	0.859	0.396
TPH (mg/kg)	331.881	206.6	159.1	48.2	0.150	0.882
Copper (mg/kg)	4.545	0.434	3.206	0.518	1.519	0.138
Lead (mg/kg)	6.520	0.767	4.681	0.929	0.805	0.426
Cadmium (mg/kg)	0.135	0.045	0.215	0.111	0.680	0.501
Zinc (mg/kg)	14.213	1.470	22.127	4.163	-0.993	0.328
Sand (%)	89.2	0.52	82.4	6.3	1.532	0.135
Silt (%)	2.4	0.3	4.3	0.4	3.714	0.001
Clay (%)	9.4	0.4	7.6	0.6	3.228	0.003

TOM= Total Organic Matter; TPH= Total Petroleum Hydrocarbons

Conclusion

Some anthropogenic activities in Kolo Creek at Okarki, Rivers State (mostly illegal bunkering of petroleum products) resulted to contamination of sediments with hydrocarbons and heavy metals in relation to controls. Although guideline limits were not breached in most cases, this could lead to ecological damage and needs to be stopped.

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