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(Research Article)

Evaluation of hydrocarbon accumulation and some chemical properties of soil sediment from crude oil polluted mangrove ecosystem in Okrika

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Abstract

Composite soil sediments samples collected from three polluted sites in Okrika local Government Area of Rivers State. Old Isakka (01), Imonitanbie (1M) and Agiahi Ama (AA) were investigated to examine the effects of crude oil pollution on chemical properties of soil sediments from mangrove ecosystems. The soil sediments were collected at a distance of 0, 20, 40 meters and a control sample taken from distance of 140 meters away from the polluted sites near the river with a spade from each of the locations. A total of twelve soil sediments samples were collected from the three locations. The samples were analyzed for: Total hydrocarbon contents (THC), Total Nitrogen (TN), Available Phosphorus (P), soluble potassium (K), Total organic carbon (TOC) and soil pH. Results of the study showed significant ($P<0.05$) difference in % TOC in polluted soil sediments in all the distances and locations over the control samples. Percentage TOC increases in a decreasing order in the studied locations as: AA>1M>01. Available P in polluted soil sediments were significantly ($P<0.05$) lower than the control soil sediments. Available P in soil sediments increases with distance away from the polluted site with control samples having the highest values in all the locations. The value of P were below the critical limits of 8.15mg/kg. Total nitrogen was significantly higher in polluted sediments over control. There were significant variations in the content of soluble K in both the distance and locations in the studied area. The values of K were not consistent with crude oil pollution but above the critical limit. The order of significant of soluble K were 01>1M>AA. Significant ($P<0.05$) difference was observed in THC between the crude oil polluted sediment and the control samples in all the distances and locations. Pollution of the soil sediment with crude oil impacted negatively on some soil sediments properties as there was a decrease in available P content, reduction of the soil sediment pH to strongly acidic (4.00±10c to 4.30±0.1a) in all the locations and an increase in TOC , TN and THC of the mangrove sediments. THC of the soil sediments in the three locations decreases in the order of 01>1M>AA. The THC of the studied sites exceeded the alert and intervention limit of 200 and 20000mg/kg for less sensitive soils and 100 and 1000mg/kg for sensitive soils.

Keywords: Mangrove soil sediments; Crude oil; THC; Soil chemical properties; Okrika

1. Introduction

Mangrove forests cover an area of approximately 160,000 km^2 all over the world, in which the largest forest areas are found in Malaysia, India, Bangladesh, Brazil, Venezuela, Nigeria and Senegal (Giri and Muhlhausen, 2008; Alongi, 2009). The soils in mangrove forest are characterized by the combination of various physical, chemical and biological factors, which may vary considerably among different forest sites (Sherman *et al.,* 1998; Otero and Macias, 2002; Ferreira *et al.*, 2007). The accumulation and degradation of toxic compounds and the mobilization and availability of trace elements also significantly influence the zonation of mangroves (Machado *et al.*, 2002, 2004 and Ke et al., 2002).

Studieshave shown that mangroves have the ability to absorb up to four times more carbon dioxide by area than upland terrestrial forests (Donato *et al.*, 2011). The pollution of mangrove soil and plant by crude oil and petroleum products

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have become a serious problem that represents a global concern due to their potential consequences on ecosystem and human health (Onwurah *et al.,*2007).

Petroleum Hydrocarbon pollution represents an important environmental issue due to their toxic and carcinogenic effect(Sayara *et al*.,2011) as they pose serious ecological and health problems. The amount of hazard imposed on the natural environment depends on the surface of the area polluted by the petroleum products, their chemical composition and the depth at which pollutants occur (Wolicka *et al*., 2009).

It has been widely reported that crude oil exploration, refining and other allied industrial activities in Niger Delta area of Nigeria have led to contamination of most of its creeks, swamps and rivers (Zabbey, 2004). The contamination of the habitats constitutes public health and socioeconomic hazard (Smith and Dragun, 1984). Soil which are contaminated by hydrocarbons have extensively damage the local ecosystem since accumulation of pollutants in animals and plants tissues may cause death or mutation (Alvarez *et al*., 1991).

Crude oil pollution/ contamination affects some soil chemical properties as well as presence of heavy metals. Jia *et al.,* (2009) stated that crude oil pollution reduced soil pH. This is also true for some other chemical properties of soil sediments like TOC content. Crude oil pollution led to a decrease in Available P concentration in the soil (Wang *et al.,* 2009; 2010; Eneje *et al.,* 2012). A study on the Mangrove wetlands showed that the concentration of available P decreased with increasing time of oil exploration and production (Wang *et al.,* 2010).

Crude oil pollution also affects the total organic carbon content (TOC). Wang *et al.,* (2009) reported that increase in crude oil contamination increased the TOC content of soil. Organic carbon in the soil is generally derived from biota such as peat formation with time, plant fine roots turnover, microbial biomass and others which contribute their carbon to the soil. Crude oil also has carbon as one of the main components and as such on breakdown contribute some of the carbon to the soil (Wang *et al.,* 2009). The study is aimed at evaluating the effect of crude oil pollution on some chemical properties of soil sediment in mangrove ecosystem.

2. Material and methods

2.1. Study area

The study area is Isakka community in Okrika Local Government Area of Rivers State. Soil sediment samples were collected from three different locations. Location one is Old Isakka at latitude 4°44'38.738"N and Longitude 6°59'6.004"E, Location two is Imonitanbie with latitude 4°44'7.390"N and longitude 6°59'18.403"E and Location three is Agiahi Ama with latitude 4°44'16.606"N and longitude 6°59'41.575"E.

The study areasare basically mangrove ecosystem with mean daily temperature of 18°C, wind velocity at 5km/hour and relative humidity of 95%. Okrika is surrounded by rivers including Bonny river. Rainfall varies between 3500mm to 4000mm per annum, peaks between June and September with an average elevation of 452 meters.

2.2. Soil and plant sample collection.

Composite soil samples were collected from three different locations (old Isakka, Imonitanbie and Agiahi Ama). A total of three soil sediment samples and one control was randomly collected from each location at a distance of 0m, 20m and 40m away from the water body with a spade at a depth of 0-20cm from the polluted sites while the control sediment samples was taken at 140m away from the polluted site near the river at the same depth.

It was very difficult to get a place to collect the control samples because the entire community (locations) where the study was carried were completely polluted with crude oil because of the activities of oil bunkers but the distance of 140 meters away was chosen for control samples in all the locations as the activities were less. The samples were homogenized, air dried sieved in a 2mm mesh sieve and bagged in a polythene bag.A total of twelve sediment samples were taken to the laboratory for analysis.The samples were sieved in a 2mm mesh sieve, placed in a well labelled polythene bag ready for analysis.

2.3. Laboratory analysis of soil sediment and plant samples

The soil pH wasdetermined using a ratio of 1:2.5 in KCL, reading was taken with the electrode pH meter as described by (Tel and Hargarty, 1984). Total Organic Carbon was determined by the dichromate wet oxidation method of Walkey-Black as described by Nelson and Sommers (1982).

Nitrogen was determined through the kjedahl method (Bremner and Mulvancy, 1982).

Phosphorus was determined using the Bray-2 method (Page *et al*., 1982). P. Exchangeable Calcium and Magnesium was determined using titration method (Mbah, 2004).

Potassium was extracted with NH4OAC at pH of 7.0 and determined by Flame photometer (Jackson, 1962).

Total hydrocarbon content (THC) was estimated using the method of Odu et al., (1985). Ten (10g) of soil sample was shaken with 10ml of carbon-tetrachloride. The hydrocarbon was extracted and determined by the absorbance of the extract at 420nm spectrophotometer. Standard curve of the absorbance of different known concentrations of equal amount of crude oil in the extractant was first drawn after taking reading from the spectrometer.

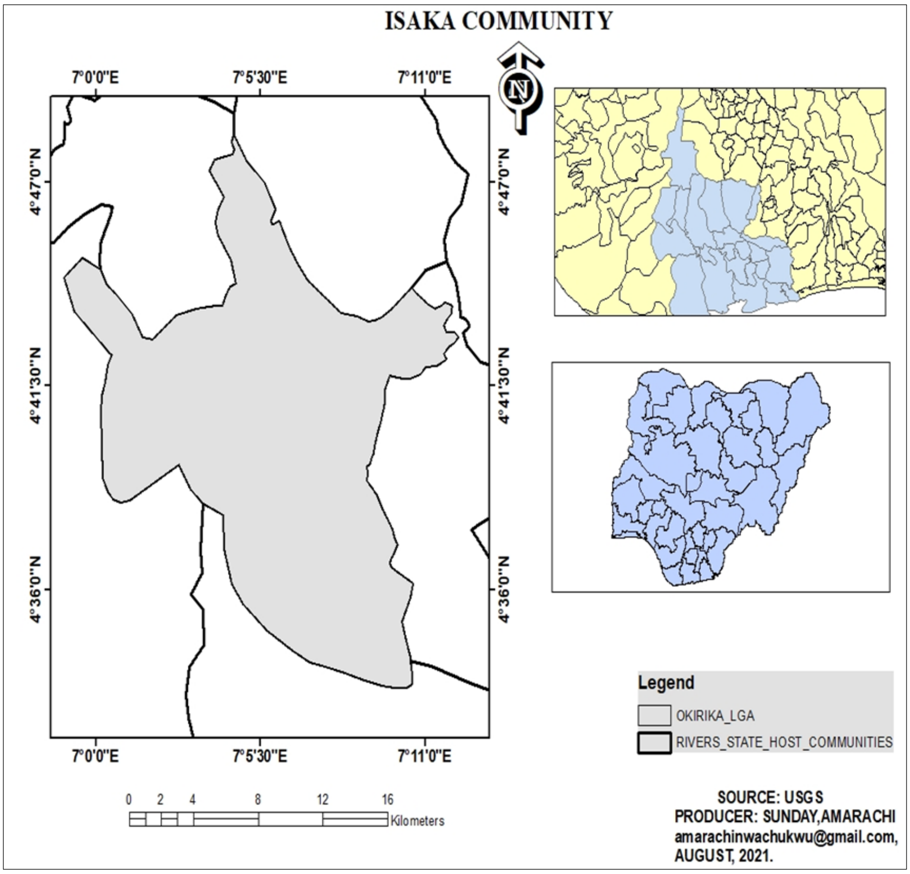

Figure 1 Map of the Studied Sites

3. Results and discussion

3.1. SOIL pH

Results of the study on the chemical properties of crude oil polluted sediment is as presented in Table 1 below: the pH of the soil sediments ranged from 4.00 ± 0.10^{c} to 4.10 ± 0.20^{bc} in location 01,4.00 ± 0.20^{c} to 4.20 ± 0.20^{ab} for location 1M and 4.00**±**017^{c} to 4.30 ± 0.10^{a} for location AA. There is no significant (P> 0.05) differencein soil pH between the different distances in location **01**and the control, though at a distance of 20 meters from the sea, the pH of the soil sediment was slightly higher than the other distances but not significant.

The observed pH range (4.00 ± 0.10^{c} to 4.30 ± 0.10^{a}) in all the locations from the study showed that the crude oil pollution impacted negatively on the soil sediments as the soils were highly acidic and could lead to toxicity of the soil. This agrees with the findings of Jia et al., (2009) and Wang et al., (2010) who reported that crude oil pollution reduces soil pH. The pH values in location OI at distances 0, 20 and 40m were 4.00 ± 0.10^{c}, 4.00 ± 0.17^{c} and 4.10 ± 0.20^{bc}.

These values varied insignificantly with the control (140m) 4.00±0.10[c], the trend was similar to other locations studied.Thisvaluedeviated from the findings of Jia *et al.,* 2009; Wang *et al.,* 2010). However, the general pH value ranges from 4.00±0.10[c] to 4.30±0.10[a] showing that the soil sediments for the locations studied were acidic. A pH range of 6.0 to 7.5 was reported to be necessary for proper functioning and growth of most plants (Bobbink et al., 2002). Therefore, the studied area may not be suitable for crops that are sensitive to acid conditions.

Table 1 Effects of Crude Oil Pollution on Some Chemical Properties of Soils from Three Different Locations

Location	Distance	Ph	% TOC	% N	Avail P (mg/kg)	K (mg/kg)
OI	A	4.00± 0.10[c]	5.13± 0.02[h]	0.11± 0.02[a]	1.67± 0.005[c]	18.85± 0.18[e]
	B	4.00±0.17[c]	5.19± 0.08[h]	0.08± 0.002[c]	1.05± 0.078[f]	61.8± 0.61[a]
	C	4.10± 0.20[bc]	4.95± 0.05[i]	0.06± 0.003[e]	0.94± 0.04[g]	
	D	4.00± 0.10[c]	5.01± 0.05[i]	0.08± 0.04[b]	2.75± 0.21[b]	
IM	A	4.10± 0.02[bc]	6.03± 0.04[e]	0.05± 0.001[g]	0.40± 0.01[h]	7.05± 0.06[j]
	B	4.20± 0.20[ab]	6.99± 0.17[a]	0.06± 0.003[e]	0.91± 0.008[g]	50.00± 0.46[b]
	C	4.00± 0.20[c]	6.63± 0.04[c]	0.07± 0.002[d]	1.52± 0.01[d]	14.70± 0.15
	D	4.10± 0.20[bc]	6.33± 0.04[d]	0.05± 0.007[f]	3.11± 0.009[a]	
AA	A	4.00± 0.17[c]	6.87± 0.02[b]	0.03± 0.004[h]	0.18± 0.002[i]	9.75+ 0.06[h]
	B	4.10±0.10[bc]	5.36± 0.04[g]	0.07± 0.001[d]	0.91± 0.006[g]	10.85± 0.04[g]
	C	4.30± 0.10[a]	5.13± 0.036[h]	0.07± 0.001[d]	1.20± 0.001[e]	9.05± 0.05[i]
	D	4.20± 0.10[ab]	5.95± 0.06[f]	0.06± 0.007[f]		
LSD (0.05)		0.102	0.07178	0.00395	0.1009	0.371

THC = Total hydrocarbon, TOC = Total Organic Carbon, Avail = Available; a,b,c…means values with the same letters are not significantly different (P< 0.05); A, B, C, D are different distances O, 20, 40 and Control where samples were taken respectively; OI, IM and AA represent the different locations from where samples were taken; Significant (p < 0.05) difference were observed as we moved from location **OI** to **AA**, and between the distances and control in locations **1M** and **AA.**

3.2. Percentage total organic carbon

The percent Total organic carbon (TOC) increases from 4.95±0.05[i] to 5.19±0.08[h] in location 01, 6.03±0.04[e] to 6.99±0.17[a] in location 1M and 5.13±0.036[h] to 6.87±0.02[b] in location AA.Statistical analysis of the results revealed a significant (P<0.05) difference in percent total organic carbon between the polluted soil sediments along the distance 0, 20, 40m (5.13±0.02[b], 5.19±0.08[h], 4.95±0.05[i]) in location **01**and the control 140m (5.01±0.05[i]). Similar trend was observed in the other locations (IM and AA).

There was a significant (P<0.05) reduction in % TOC between the sediment samples collected from distances 0, 20, 40m and the control (140m); this implies that % total organic carbon decreases with distance away from the polluted sediments. Significant difference was also observed between the different locations studied with maximum levels of TOC occurring at IM (6.99±0.17[a]).

The above result therefore showed that crude oil pollution increased the percent total carbon content of the soil sediments. This result is in line with the study of Wang et al., (2009) who noted that crude oil contamination increased the total organic carbon content of the soil. The finding also agrees with the work of Chukwumati et al., (2019) who reported a higher percentage of organic carbon in crude oil contaminated soil over control. Percentage total organic carbon was observed to be highest in location 1M (6.03±0.04[e], 6.99±0.17[a], 6.63±0.04[c] and 6.33±0.04[d]) for 0, 20, 40- and 140-meters distances respectively, followed by location AA and 01.

3.3. Percentage total nitrogen

Percentage total Nitrogen from the studied areas ranges from 0.06±0.003[e] to 0.11±0.02[a] in location 01, 0.05±0.001[g] to 0.07±0.002[d] in location 1M and 0.03±0.0004[h] to 0.07±0.001[d] in location AA. Generally, location 01 at “0” distance (0.11±0.02[a]) has the highest percentage of nitrogen content while location AA “0” had the lowest (0.03±0.0004[h]). The result revealed that percentage nitrogen significantly (P<0.05) increased in all the distances in polluted sites over the control and between the locations.

The increase in % nitrogen in crude oil polluted sediments over control samples affirm with the report of Ayolagha et al., (2006), Chukwumati and Abam, (2021). The observed increase could be due to the mineralization activities of micro-organisms during breakdown of crude oil components. This agrees with the report of Amadi et al., (1993). Increase in % nitrogen in the studied locations were in the order of 01>1M>AA.

The low % nitrogen observed in locations 1M and AA could be attributed to the high organic carbon recorded in these locations which may bring about a high C:N ratio. An increase in C:N ratio could be as a result of the activities of hydrocarbon oxidizers that break down petroleum molecules by adding oxygen to them which are used leaving behind biomass and carbon dioxide.

3.4. Available phosphorus

The results for Available P varied significantly at the distance 0, 20 and 40m in each location and between the three location (OI, IM and AA) studied. Available P values ranges from $0.94\underline{+}0.004^{g}$ to $2.75\underline{+}0.21^{b}$ in location 01, 0.40±0.0o1^{h} to 3. 11±0.009^{a} in location 1M and 0.18±0.002^{i} to 1.48±0.004^{d}in location AA.

The result showed that significant (P<0.05) difference existed in available P between the polluted soil sediment and the control. Available P increased as distance away from polluted site increased with the control at different locations having the highest value, showing that crude oil pollution reduced the concentration of available P.

The values were far below the critical limits of nutrients by Bobbink *et al.,* 2002 (8-15 mg/Kg) and this could be due to fixation of phosphorus due to low pH (Agbogidi *et al.,* 2007). Crude oil pollution reduced available P concentration in the soil sediments. The concentration of available Phosphorus in all polluted soils sediments were significantly (P<0.05) lower than that in the control samples. This agrees with the findings of Wang *et al.,* (2009; 2010) and Eneje *et al.,* (2012) but deviates from Liu *et al.,* (2007) whose report shows that available P concentration was not significantly affected by crude oil pollution. More so the values of available phosphorus were significantly (P<0.05) different at the three different locations with location 1M having the highest values followed with location 01 and AA.

There were significant variations in the content of soluble Potassium (K) in both the distances and location in the areas investigated. Soluble K in location 01 was significantly (P<0.05) higher over the other two locations (1M and AA) in the studied area. The order of significant were 01>1M>AA.

The values of soluble K in the studied sites were not consistent with crude oil pollution but is above the critical limit for nutrients as reported by Bobbink et al., (2002).

3.5. Total hydrocarbon content

The result revealed a significant (P<0.05) different between the polluted and the control soil sediments in all the distances and locations investigated, implying that THC impacted negatively to the soil sediments. This result agrees with the findings of (Oyedeji et al., 2012, Ayolagha et al., 2006). Generally, the values of THC ranges from 0.01±0.0001g $\times 10^{4}$ to 20.75±0.62a $\times 10^{4}$ mg/kg.

The result showed that total Hydrocarbon content (mg/kg) in soil sediments of Isakka Communnity of Okrika Local Government Area of Rivers State Nigeria sampled from three locations Old Isakka (01), Imonitanbie (1M) and Agiahi Ama (AA) decreases in the order of 01>1M>AA.

Crude oil pollution of the sites impacted negatively on some of the chemical properties of the soil sediments investigated as there was a decrease in phosphorus content of the soil, a reduction of the pH of soil sediment to strongly acidic level and an increase in carbon content of the sediments and an increase in THC, total nitrogen and total organic carbon content of the soil sediments.

This finding tallies with study of Riser-Roberts, (1998) who reported that Hydrocarbons affected the soil properties such as nutrient availability, texture and organic matter content of the soil.

Studies have also shown that crude oil pollution of soil reduces microbial populations in soil (Chukwumati and Anita, 2022) and also serve as source of carbon and energy to some heterotrophic bacteria thus aiding in degradation of hydrocarbon (Nichols et al., 1996). When total hydrocarbon enters water bodies, it affects negatively aquatic lives like fish, periwinkle, crabs, oysters etc (Ballachey et al., 2003), prevent oxygen penetration into the water thus suffocating aquatic organisms (Vajargah et al., 2020).

Total Hydrocarbon content of the studied soil sediments exceeded the alert and intervention limit of 200 and 2000mg/kg for less sensitive soils, 100 and 1000mg/kg for sensitive soil as established by EGU General Assembly (2017) respectively.

4. Conclusion

The results of study showed that soil sediments of the studied sites (Isakka communities) namely; Old Isakka, Imonitanbie, and Agaiahi-Ama in Okrika local government area of Rivers State, Nigeria were highly polluted with crude oil which negatively impacted some chemical properties of the soil sediments. The danger of this is that the pollutants may enter the water bodies thus affecting negatively the aquatic organisms and human through food chain. The underground water may not also be safe, and the communities depend on them for their livelihood.

Therefore, the State government is required to come up with a policy that will look into illegal oil drilling and refining (oil bunkering) going on in the area to reduce the harm faced by man and the entire ecosystem within these areas.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest in this article.

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