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Accumulation of hydrocarbons and some heavy metal contents on sediments and plants from crude oil polluted mangrove ecosystem in Okrika, Nigeria

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Abstract

Composite soil sediments samples were randomly collected from three polluted sites in Okrika local Government Area of Rivers State. Old Isakka (01), Imonitanbie (1M) and AgiahiAma (AA). The samples were investigated to examine the effects of crude oil pollution and heavy metals status of soil sediments and plant tissue samples 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. Six samples were taken from each location (four soil sediments and two plant samples) totaling twelve sediments and six plant samples. The samples were analyzed for: Total hydrocarbon contents (THC), and heavy metals (Pb, Cd and Zn) using conventional methods of analysis. Result revealed a significant ($P<0.05$) increase in THC in polluted samples over control in the three locations studied. The concentration of THC in the locations decrease in order of 01>1M>AA, the pollution decreased with increase in distance. The three locations were highly polluted with hydrocarbon thus posing a threat to aquatic organisms and human that consume the sea food. THC exceeded the alert and intervention limit for sensitive and less sensitive soils. Significant ($P<0.05$) difference was observed in Cd concentration in control (D) over the polluted (A, B, C) in all the locations meaning that crude oil may not be responsible for the Cd in the sediments. Cadmium concentration was below the permissible limit for soil. Pb was significantly higher in polluted sediment than control in all the locations. The concentration of Pb decreases in the order of 01>1M>AA. Value of zinc was significantly higher in control than polluted. The order of increase was 01>1M>AA. Both Zinc and Pb were below the permissible limit. There was a significant ($P<0.05$) increase in accumulation of THC, and Pb in plant tissues in polluted than control while the converse was observed in both Zn and Cd in the three locations studied. Generally, Old Isakka (01) has higher amount of pollution in both the sediments and plant tissues than Imonitanbie and Agiahi-Ama.

Keywords: THC; Heavy metals (Pb, Zn, Cd); soil; Plant samples; Isaka communities

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). Research shows 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 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 posed on the

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natural environment depends on the surface of the area contaminated or polluted by the petroleum products, their chemical composition and the depth at which pollutants occur (Wolicka*et al*., 2009).

The accumulation and degradation of toxic compounds (Ke*et al.,* 2002) and the mobilization and availability of trace elements also significantly influence the zonation of mangroves (Machado *et al*., 2002, 2004).

It has been widely reported that crude oil exploration, refining and other allied industrial activities in Niger Delta area have led to contamination of most of its creeks, swamps and rivers (Zabbey, 2004).

Heavy metals are naturally present in the soil, but some geologic and anthropogenic activities increase the concentration of these elements to amounts that are harmful to both plants and animals (Carla, 2002). Some of these activities include petroleum drilling, mining and smelting of metals, burning of fossil fuels, use of fertilizers and pesticides in agriculture, production of batteries and other metal products in industries, sewage sludge, and municipal waste disposal (Shen*et al.*,2002).

Crude oil pollution/ contamination affect some soil chemical properties as well as presence of heavy metals. The general increase of heavy metal content in the soil has been largely caused by crude oil spillage (Anoliefo and Vwioko., 1995).

The most common heavy metals found at contaminated sites in order of abundance are Pb, Cr, As, Zn, Cd, Cu and Hg (USEPA, 1996). These metals are capable of decreasing crop production due to the risk of bioaccumulation and biomagnification in food chain and risk of ground water contamination. Heavy metal can enter food chain as a result of their uptake by edible plants and due to the difficulty in the degradation of the heavy metals, they tend to accumulate at high levels in the plant after their uptake from polluted sites thus posing a potential threat to animal and human health (Udom et al., 2004, Sprynskyy et al., 2007, Arbaoui et al., 2014). These metals become toxic when they are not metabolized by the body and accumulate in the soft tissues (Sobha et al., 2007).

As these metals gain access to food chain, they cause various health challenges such as damage to nervous system, endocrine, circulatory system, skin cancer, malignancy and benign prostatic hyperplasia (Yang et al., 2002, Zokowska and Biziuk, 2008, Zhang et al., 2012). Humans may directly get in contact with heavy metals by consuming contaminated foodstuff, sea animal and drinking of water through inhalation of polluted air as dust fumes, or through occupational exposure at work place (Ming-Ho, 2005).

Considering the dependence of people living in these communities on sea foods, crops and water which may likely be polluted with crude oil contaminant. The need to examine the effects of crude oil pollution become necessary. The study is therefore aimed at examining the effects of some crude oil pollutants on soil and plants at Isaka communities in Okrika local government area of Rivers State.

2. Material and methods

2.1. Study area

The study area is Isakka community in Okrika Local Government Area of Rivers State. Soil 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 AgiahiAma with latitude 4°44'16.606"N and longitude 6°59'41.575"E. The study area is basically a mangrove ecosystem with mean daily temperature of "18 ^{o}C wind velocity at 5km/hour and relative humidity of 95%. Rainfall amount varies between 3500mm to 4000mm per annum. Rainfall peaks between June and September and Okrika has an average of 9 months of rainfall. Okrika is surrounded by Rivers majorly the Bonny River and the average elevation is 452 meters.

2.2. Soil and plant sample collection

Soil samples were collected from the three different locations with a shovel at a depth of 0-20 cm. A total of three soil samples and one control was collected from each location. The samples were taken at a distance of 0m, 20m and 40m away from the water body. The control was taken 140m away from the polluted site near the river at the same depth.

It was difficult to get a place to collect the control samples because the entire community (locations) where the study was carried out 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.

These samples were randomly collected at various sampling points at the crude oil polluted sites. The collected samples were homogenized in a clean polythene bag and composite samples were drawn from it. From each location, one plant sample was collected from the polluted areas and a control plant taken at the point where the control soil sample were collected. The plant samples collected were washed to remove sand and dirt from root and then air-dried at room temperature.

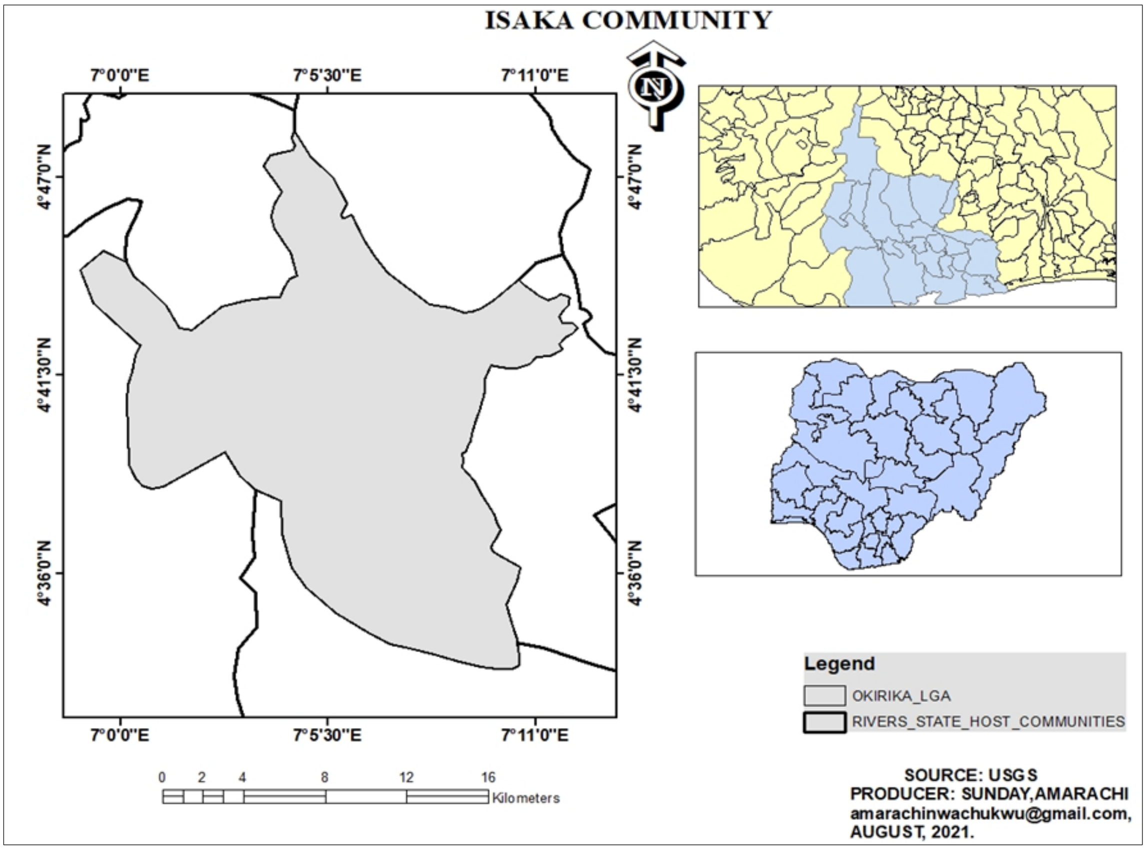

Figure 1 Map Showing the Study Area

The air-dried plant samples were also bagged in clean polythene bags. In total, twelve soil samples and six plant samples were collected across all locations and air-dried. The air-dried samples were passed through a 2mm sieve, carefully poured into well labelled polythene bags and taken to the laboratory for analysis. The soil sediments and plant samples were analyzed for heavy metals (Cadmium, Lead and Zinc) and Total hydrocarbon content (THC).

2.3. Laboratory analysis

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.

Samples for heavy metals (Pb, Zn and Cd) were extracted by wet digestion method of Benton (2001). 0.5g of soil samples were weighed into 50 ml conical flask, 10 mls of nitric acid (HNO_3) was added and heated to dampness in fume cupboard, the samples were removed and allowed to cool to 25 ^oC room temperature before 10mls of perchloric acid ($HCLO_4$) was added to it. The samples were heated again in the fume cupboard until it formed profuse fume. It was then removed from the cupboard, allowed to cool and then made up to 50ml mark with distil water.

The digest was filtered with whatman No 42 filter paper into transparent plastic containers for Atomic Absorption Spectrophotomer (AAS) elemental reading. AAS variance spectra AA 220FS model was used to read the elemental concentration values of the three elements (Pb, Zn and Cd) in soil and plant digests, following Horneck and Hanson method in Benton (2001). The data generated were subjected to statistical analysis.

3. Results and discussion

3.1. Total hydrocarbon and heavy metal content of soil sediments

Table 1 shows the results of heavy metals (Cd, Zn and Pb) and THC contents of the soil sediment samples collected from three different locations (01, IM and AA) at different distances (0, 20, 40) and control (140m) in each location from the study areas are presented in table 1 below.

Results revealed the concentrations of Total Hydrocarbon Content (THC) of the soil sediments in the studied locations varied from 0.01±0.0001[g] to 20.75±0.62[a] × 10^4 mg/kg in all the locations and distances covered.

Results showed significant (P<0.05) difference in THC between the various distances (0, 20, 40M) polluted with crude oil in each location and the control (140M). The significant (P<0.05) increase in THC in polluted samples over control is in line with the observation of (Chukwumati and Abam, 2020, Davetha et al., 2019, Oyedeji et al., 2012 and Ayologha et al 2006) who reported an increase in the content of THC over control in crude oil contamination soil.

Table 1 Heavy metal and Total hydrocarbon content of soil sediments collected from crude oil polluted site from different locations

Location	Distance	THC (mg/kg) x 104	Cd(mg/kg)	Pb (mg/kg)	Zn(mg/kg)
OI	A	20.75± 0.62[a]	0.00±0.00[d]	3.82±0.02[d]	4.11±0.02[ij]
	B	6.19± 0.014[c]	0.00±0.00[d]	5.71±0.03[c]	8.99±0.03[e]
	C	1.59± 0.07[f]	0.00±0.00[d]	33.43±0.11[a]	3.84±0.05[j]
	D	0.04± 0.0006[g]	0.09±0.04[a]	0.00±0.00[g]	81.2±0.63[a]
IM	A	2.89± 0.0006[e]	0.00±0.00[d]	2.14±0.09[e]	4.36±0.05[i]
	B	15.39± 0.012[b]	0.00±0.00[d]	0.00±0.00[g]	24.56±0.04[b]
	C	3.04± 0.002[e]	0.00±0.00[d]	6.47±0.00[b]	5.96±0.08[g]
	D	0.01± 0.0001[g]	0.04±0.004[c]	0.00±0.00[g]	18.83±0.03[c]
AA	A	2.98± 0.0008[e]	0.00±0.00[d]	1.25±0.045[f]	4.68±0.04[h]
	B	1.10± 0.0006[g]	0.00±0.00[d]	2.16±0.02[e]	5.87±0.04[g]
	C	4.45± 0.0099[d]	0.00±0.00[d]	2.11±0.017[e]	6.91±0.04[f]
	D	0.05±0.00009[g]	0.08±0.02[b]	0.00±0.00[g]	15.99±0.12[d]
LSD (0.05)		2983.297	0.00981	0.06695	0.2901

a, b, c....... means values with the same letter are not significantly different (p < 0.05); A, B, C, and D are different distance 0, 20, 40 and Control respectively from where soil samples were taken; OI, IM, and AA are the different locations from where samples were taken.

Results revealed the concentrations of Total Hydrocarbon Content (THC) of the soil sediments in the studied locations varied from 0.01±0.0001[g] to 20.75±0.62[a] × 10^4 mg/kg in all the locations and distances covered.

The THC concentration in the soil sediments decreases with increase in distances. The order of decrease at the different distances were A>B>C>D, while the order of THC concentration in the three locations investigation in decreasing order are 01>IM>AA.

The results therefore showed that the three locations studied in Isaka communities in Okrika local government area of Rivers State, Nigeria were highly polluted thus posing a threat to lives of aquatic organisms such as fish, periwinkle, crab, oyster shells and other sea food including man who may consume these sea food (Ballachey et al., 2003). The THC may also act as sealants preventing oxygen into the water thereby suffocating aquatic organisms (Vajargah et al., 2020).

THC has been known to have considerable effect on soil microbial populations by reducing their growth and leading to eventual death and serve as source of carbon and energy to some heterotrophic bacteria which helps to degrade hydrocarbons (Loser et al., 1998, Nichols *et al.,* 1996).

Results also showed that the total hydrocarbon content in the soil sediments exceeded by far the alert and intervention limit (200 and 2000 mg/kg) and (100 and 1000 mg/kg) set by the EGU general assembly, 2017 for both less sensitive and sensitive soils respectively.

Table 1 above also revealed the effect of crude oil pollution on soil sediments on the concentrations of heavy metals (Cd, Pb and Zn) in the studied locations in all the distances covered. The heavy metal varied from 0.00 ± 0.00^{d} to 0.09 ± 0.04^{a} for Cd, 0.00 ± 0.00^{g} to 33.43 ± 0.11^{a} for Pb and 3.84 ± 0.05^{j} to 81.2 ± 0.63^{a} for Zn.

Result of the study on cadmium indicated significant ($P<0.05$) difference between the control and the polluted sites in all the distances of the locations studied indicating that crude oil may not be responsible for the presence of Cd on the soil sediments. This agrees with the report of (Plant and Thornton, 1983) who inferred that Cd is not a common crude oil heavy metal. The slight increase in Cd concentration in control samples over polluted could be due to human activities (WHO, 2006). The concentrations of Cd were far below the 0.8mg/kg specified by regulatory agency as permissible limit for Cd in soil. In soils where Cd occurs at high levels, it can cause kidney disorders, anemia, anosmia (loss of sense of smell) and also the popular Itai-itai disease was found to be Cd- related (WHO, 2006).

The concentration of lead (Pb) in the studied sites was significantly ($P<0.05$) higher in polluted soil sediments than the control (table 1) with the concentration occurring more in location 01 which may possibly be due to higher pollution with crude oil. This report corroborates with the findings of (Ihedioha et al., 2017) who noted that oil and gas exploration and exploitation have the capability of influencing the distribution and dispersion of heavy metals in the environment.

Lead (Pb) concentration in the three locations sites decreases in order of 01>IM>AA. The values of Pb were below the permissible limit of 85 mg/kg for soils (WHO, 1996, Denneman and Robberse, 1990). Lead has been reported to be major source of concern in the environment especially to aquatic organisms and humans (Pant et al., 2000, WHO, 2006).

In humans, Pb has been known to have carcinogenic effect and have been related to several epidemic effects such as head ache, weight loss, hypertension, miscarriages etc. (Hubbs-Tait*et al.,* 2005).

The content of Zinc varied significantly from the polluted sites (0, 20, 40m) to control (140m) with maximum Zn concentration in control samples (Table 1). The results showed significant ($P<0.05$) decrease in Zn concentration as pollution increases with control sample having the highest concentration in each of the locations. This observation is in contrast to the result of (Chukwuma et al., 2009) who stated an increase in Zn concentration with an increase in crude oil pollution.

Zinc concentration of the polluted soil sediments were below the target level of 50 mg/kg specified by (WHO, 1996). Zinc is known to be one of the essential trace elements in soil, however, large or very small amount of Zn affects some soil properties (Vinodhini and Narayanan, 2009).

High level of Zn especially in drinking water and food is detrimental to human (WHO, 2006).

3.2. Hydrocarbon and Heavy metal content in plant tissues from crude oil polluted soils.

The results of total hydrocarbon and heavy metal contents of plant tissue samples collected from three different locations (01, 1M and AA) at two different distances (0 and 140 M) is as presented in table 2 below. The three heavy metals (Cd, Pb and Zn) investigated varied from 0.03 ± 0.005^{a} in control to 0.00 ± 0.00^{b} in polluted samples for Cd, 1.90 ± 0.05^{a} in polluted to 0.00 ± 0.00^{d} in control sample for Pb and 57.79 ± 0.03^{a} in control to 3.25 ± 0.05^{f} in polluted for zinc while total hydrocarbon content increases from 142.53 ± 2.95^{a} (mg/kg) $\times10^{2}$ in polluted to 1.15 ± 3.88^{f} (mg/kg) $\times10^{2}$ in control samples in the three locations.

Table 2 Effect of Crude Oil Pollution on Accumulation of Heavy Metals and Hydrocarbon in Plant Tissue

Location	Distance	THC (mg/kg) $\times10^{2}$	Cd(mg/kg)	Pb (mg/kg)	Zn(mg/kg)
OI	A	79.86 ± 0.042^{b}	0.00 ± 0.00^{b}	1.82 ± 0.02^{b}	3.25 ± 0.05^{f}
	D	1.90 ± 0.011^{e}	0.00 ± 0.00^{b}	0.00 ± 0.00^{d}	57.79 ± 0.03^{a}
IM	A	142.53 ± 2.95^{a}	0.00 ± 0.00^{b}	1.90 ± 0.05^{a}	4.17 ± 0.05^{d}

	D	1.15±3.88[f]	0.00±0.00[b]	0.00±0.00[d]	16.91±0.005[b]
AA	A	26.94±3.74[c]	0.00± 0.00[b]	0.91±0.01[c]	3.98±0.08[e]
	D	2.20±1.88[d]	0.03±0.005[a]	0.00±0.00[d]	13.89±0.06[c]
LSD (0.05)		2.8005	0.00371	0.03577	0.04650

THC = Total hydrocarbon Content; [a,b,c]..... Means value with the same letter are not significantly different ($p < 0.05$); A and D are different distances 0 and Control respectively where plant samples were taken; OI, IM and AA represent the three different locations from when plant samples were taken.

The results revealed significant (P<0.05) increase in accumulation of THC and heavy metal (Pb) contents in plant tissues in polluted soil over control in the three locations studied. This tallies with the findings of (Gallego et al., 2001 and Zamoza et al., 2002) who reported that plants growing on polluted soils may contain elevated levels of heavy metals.

This finding is in line with results of (Bunzi et al., 2001) who noted that plants generally have the ability to accumulate heavy metals in their tissues. The plants that are highly affected are those of shallow rooted as heavy metals generally remain in top soil (Yin et al., 2009, Zupani et al., 2009).

However, the concentrations of Cd and Zn in the plant tissues on the three locations were significantly higher in control than polluted samples indicating that pollution of the soil sediments with crude oil may not have been responsible for the heavy metal (Zn and Cd) found in the plant tissues, rather from other sources. The concentration of Zn ions decreases from location 01 to AA in order of 01>1M>AA.

Cadmium concentrations in the plant tissues were below the permissible limit of 0.02 mg/Kg as specified by WHO, 1996, except for the control plant sample in location AA which had Cd concentration of 0.03±0.0.05[a] mg/Kg while the concentration of zinc was far above the 0.6 mg/kgspecified by WHO, 1996. Study carried out by (Ghani, 2010) showed that presence of heavy metals in maize reduced growth and protein content of the plant. Therefore, the possibility of these heavy metals entering human and animal body through food chain where they bio magnify and cause serious health challenge may not be ruled out.

The result for THC showed that, location 01 had higher concentration than the other locations implying that location 01 may have been highly polluted with crude oil than the others. The concentration of THC in plant tissue decreased with increase in distance away from polluted sites.

4. Conclusion

The results from the study revealed that both the soil sediments and plant samples were polluted with hydrocarbon and heavy metals. This pose a great danger to the health of inhabitants of these communities as these pollutants may bioaccumulate, bio magnify and enter into water bodies affecting both humans and organisms through food chain including the underground water.

There is therefore need to examine some sea foods such as fish, crabs, periwinkle etc that are highly consumed in these areas before consumption.

Secondly government should also come out with strong policy that will restrict the operations of illegal drilling and refining of crude oil (oil bunkering) to preserve lives.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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