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ORIGINAL RESEARCH

Assessment of some selected heavy metals and their pollution indices in an oil spill contaminated soil in the Niger Delta: a case of Rumuolukwu community

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ABSTRACT
This study assessed heavy metals (Ni, Pb, Cr and V) in oil spill contaminated soils in Rumuolukwu community, Eneka, Obio/Akpor Local Government Area, Rivers State, Niger Delta region of Nigeria. Ex-situ analysis was carried out for 6 months i.e. 3 months wet and dry seasons each. The samples were collected at different depth using soil auger. The samples were processed and analyzed using flame atomic absorption spectrophotometer. Results ranged from 0.16 – 3.02 mg/kg Ni, 0.20 – 8.14 mg/kg Pb, 0.18 – 7.88 mg/kg Cr and 0.01 – 0.20 mg/kg V for oil spill contaminated soil. The concentration of heavy metals (Ni, Pb, Cr and V) was higher than the control samples, but below Department of Petroleum Resource Nigeria Limit. Ecological risk factor showed that the contamination level is low at various depth, however instance of moderately and considerable contamination were observed at 45 – 60 cm and 15 – 30 cm depth for Pb during the wet season. Also, contamination factor showed moderate contamination. Although in few instances Pb and Ni contamination factor was very high. Heavy metal mean distribution was in the order: Pb>Cr>Ni>V. A decreasing degree of contamination was observed during the dry season.

KEY WORDS: *Contamination factor, Ecological risk factor, Environmental pollution, heavy metals, Oil spill*

Introduction

Nigeria is a major producer and exporter of crude oil and as such a member nation of organization of petroleum exporting countries. Globally, Nigeria is the 12th and 7th largest producers and exporter of crude oil (Ohimain, 2013a). The Nigeria crude oil resource is found in the Niger Delta. Like natural gas and oil equivalent of tar sand, Nigeria crude oil resources is about 35 – 36.22 billion barrel (Sambo, 2008; Ohimain, 2013b - d). Of these, Nigeria daily production is about 2.2 – 2.7 million barrels of crude oil per day (Ohimain, 2013b; Sambo, 2008).

Crude oil production in Nigeria often fluctuates due to the activities of militia, sabotage, illegal bunkering and pipeline vandalism. During these activities, oil could spill into nearby environment (i.e. water and soil). Oil is also spilled during oil spill exploration, drilling, pipeline and oil transportation, refining, sales and distribution, illegal bunkering and sabotage. During transportation via pipeline oil could spill via rupture resulting from corrosion and vandalism of pipes. According to Adelana *et al*. (2011) corrosion of pipelines and tankers, sabotage and oil production operations accounts for 50%, 36% and 6.5% oil spill incidence in Nigeria. Generally oil spill incidence and causes have been widely reported by Iniaghe *et al*. (2013), Nwilo and Badejo (2005). The quantity of oil spill between 1976 to 1996 have been reported by Kadafa (2012a,b), Nwilo and Badejo (2005), 2006 – 2010 (Borok *et al*., 2013)

The quest for crude oil and the network of underground pipelines which has criss-crossed the area for the transportation of petroleum products occasionally results in the adverse effect of oil spillage and its associated consequences which include loss of fertile land, contamination of underground waters, bioaccumulation of contaminants in plants, organisms, humans and its redistribution across the human food chain. The impacts of oil spill are severe. For instance, Oil spills could cause fire and lead to loss of wildlife, vegetation, loss of fertile soil, pollution of air and drinking water, degradation of farmland and damage to aquatic ecosystems (Ogbeibu and Iyobosa 2013), loss of lives, farmland and other infrastructural resources (Ambe *et al*., 2015).

Generally, oil spills is a big threat to the environment in producing region (Kadafa, 2012a, b). This is because it can lead to accumulation toxic substances such as heavy metals into the environment. For instance, soil contamination by heavy metals leads to a negative impact to human health as well as the ecosystem especially soil. This is because soil acts as a major reservoir and sinks for urban micro pollutants and its quantity and holding capacity for organic pollutants (Wild and Jones, 1995).

Several heavy metals are associated with crude oil including lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn) (Fatoba *et al*., 2015), nickel (Ni), vanadium (V), chromium (Cr). Similarly, the heavy metals most frequently detected in oil spill are in the order; Pb>Ni>V>Zn>Cd and majority causes health related effects (Mustafa *et al*., 2015). Diseases/ pathological conditions related to heavy metal contaminants have been recently reviewed by Izah *et al*. (2016). Osuji *et al*. (2006) also reported that Ni and V are major heavy metal contaminants in crude oil. Pb and Cr is associated with piping system (Inengite *et al*., 2010). These elements are found naturally in soils and rocks at different concentrations. They are also components of ground, surface waters and sediments (Hutton and Symon, 1986), water (Izah *et al*., 2016), fisheries (Izah and Angaye, 2016).

These heavy metals are both industrially and biologically important and as such occur naturally in soils as natural components except for cases where wherein their presence is being accelerated by human activities which lead to excessive concentrations in the environment which result in the negative health impact of some metal ions in humans, animals and plants (Odukoya and Abimbola, 2010).Hence this study aimed at assessing the heavy metal concentration in crude oil contaminated soil and assessing their pollution risk in the environment using contaminant factor ecological risk factors.

Materials and Methods

Study area description

Rumuolukwu community is a developing area witnessing urban sprawl of expansion of the Port Harcourt metropolis. Hitherto, a subsistent farming community in the Niger Delta seriously undergoing urbanization. Rumuolukwu community is within Eneka and it is located in Obio/Akpor Local Government Area of Rivers State. Rumuolukwu community lies within Lat. N 04º89' and Long. E 007º03' (Figure 1).Two sampling stations were established within this community. The oil contaminated plot was located adjacent to the point source of oil spill, along the SPDC right of way and the control plot was 50m from the affected plot. The control plot was an existing farmland with no history of pollution

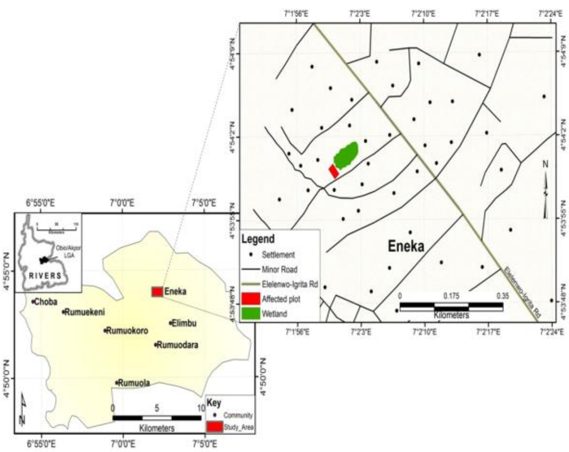

Figure 1: Site map of Eneka community showing the oil contaminated plot at Rumuolukwu, Obio/Akpor LGA, Rivers State

Sampling

Sampling covers a period of six months between August 2013 and January 2014 covering 3 month wet season

(August – October) and 3 months dry season (October – January of the following year i.e. 2014). Prior to sample collection, a petroleum or oil sheen test as recommended by the Minnesota Pollution Control Agency (MPCA, 2008) was carried out to ascertain that the site under study was actually saturated or contaminated with crude oil. This test was carried out by placing a small quantity of the oil contaminated soil in a glass jar. Then after water was added to break apart and completely submerge the soil particles in water. The glass jar with the water and soil sample was shaken. Positive results were indicated by presence of droplets of oil or rainbow sheen in the soil.

Soil samples were collected at various depth viz; 0 – 15cm, 15-30cm, 30 -45cm and 45 – 60cm at contaminated and control soil. Also composite soils were collected at 0-15cm and 15 – 30cm. The soil samples were collected using a hand auger. The samples were collected and stored in aluminum foil packs and labeled accordingly. The samples were stored in ice coolers packed with ice chips before being transported to the laboratory for sample preparation and analysis.

Sample Preparation

Soil samples collected were air dried in a clean, well-ventilated laboratory under ambient temperature. The dried samples were homogenized by grinding, and filtered by passing through a 2 mm mesh size sieve to remove debris and gravels larger than 2 mm in diameter. The samples were sub-sampled into polythene vials and labeled accordingly prior to analysis. Large and small portions of the pulverized soil were transferred into reaction vessels using a sterile stainless steel spoon spatula for heavy metal determinations.

Soil heavy metal analysis

The analysis was carried out using ASTM method D 3974 – 99.About 5 g of sieved sample was weighed into a 250 ml beaker and an empty beaker was stood in the analysis set up to represent the reagent/glass ware blank. 100 ml of distilled water was added, followed by 1.0 ml of concentrated HNO_3 (sp. gr 1.42) and 10 ml of concentrated HCl (sp. gr 1.19).The beakers were covered with ribbed watch glasses and heated at 95°C on a hot plate. The beakers were removed from the hotplate when the remaining solution was about 10 to 15 ml, and then allowed to cool to room temperature after which each solution was filtered and quantitatively transferred into a 50 ml volumetric flask while diluting to volume with distilled water. A reagent blank was also prepared and analyzed.

Calculation:

The heavy metal concentrations were calculated as percent dry weight samples as follows:

$$C = \frac{(Q-S)\ V}{U}$$

Where: Q = concentration of the element in the digested solution, mg/l

S = concentration of the trace element found in the reagent/glass ware blank, mg/l

V = volume of sample extract, ml

U = dry weight of the sample, g, and

C = trace element per kilogram of dry sample, mg

The instrument settings and conditions were in line with manufacturer's specifications. A prepared working solution of 1 mg/l of each element was introduced after every three samples run to monitor instrument deviation, if any, and to serve as a quality check procedure. The Flame atomic absorption spectrophotometer (FAAS) (GBC Avanta PM type) was calibrated with prepared working solutions from stock solutions (1,000 mg/l AccuStandards Inc, USA) for each of the respective heavy metals analyzed viz: V, Ni, Cr, Pb. Soil extracts were aspirated into the flame atomizer via the capillary tube attached to the nebulizer unit of the FAAS (air-acetylene flame was applicable, at flow rates of 2 l/min for the fuel and 10 l/min for the oxidant for Pb, Ni and Cr, and nitrous oxide-acetylene flame with fuel flow rate of 6 l/min and oxidant flow rate of 10 l/min was used for V analyzes). The wavelengths for Ni, Pb, Cr and V analysis were 232.0, 217.0, 357.9 and 318.3 nm respectively. Triplicate analysis of each sample was carried out and the mean concentration was reported. The results of the analysis were expressed as mean and standard deviation.

Assessment of the pollution indices

Data obtained for soil samples collected from the control plot were compared against those from the contaminated plot so as to have an idea of the levels of contamination of the oil contaminated soil. The baseline data obtained for the control soil represent the maximum amount of that element in a naturally undisturbed environment beyond which the environment is considered polluted with the test element (Puyate, 2007). Mean concentration of these metals in the oil contaminated soil depicts that they are not of a natural, undisturbed geology of the area when relatively compared to the control soil. Based on the data, pollution indices model calculations that have been employed to assess the impact of anthropogenic inputs, and how they alter the concentration and distribution of toxic heavy metals across soil depths were assessed. The pollution indices (i) Contamination factor (C^i_f), (ii) Ecological risk factor (E^i_r).

The contamination factor was calculated based on the method previously described by Hakanson (1980) in assessing toxic substance in a lake or sub-basin where $C^i_f = C^i_{0-1}/C^i_n$ where C^i_{0-1} is the mean content of the substance, and C^i_n is the pre-industrial reference level. The degree for expressing the contamination factor is described as: $C^i_f < 1$ for low contamination factor; $1 \leq C^i_f < 3$ for moderate contamination factors; $3 \leq C^i_f < 6$ for considerable contamination factors and $C^i_f \geq 6$ for very high contamination factor.

Ecological risk factors (E^i_r) were calculated based on quantitative method suggested by Hakanson (1980). Thus, $E_r^i = T_r^i \cdot C^i_f$ where T_r^i is the toxic response factor for a given substance (i.e. heavy metal), and C^i_f is the contamination factor. Based on findings, risk factor of $E_r^i < 40$, $40 \leq E_r^i < 80$, $80 \leq E_r^i < 160$, $160 \leq E_r^i < 320$ and $E_r^i \geq 320$ indicates low, moderate, considerable, high and very high ecological risk respectively. However, information about Ni and V toxic response factors (T_r^i) is scarce in literature; hence their ecological risk factor was not calculated (Gong *et al*., 2008).

Results and Discussion

Table 1 presents heavy metal properties of oil spill contaminated soil and control between August 2013 – January 2014 in Rumuolukwu community, Niger Delta region of Nigeria. While Table 2 presents seasonal variation of heavy metal properties of oil spill contaminated Top (0-15cm) and Bottom Soils (15-30cm) soil and control between August 2013 – January 2014 in Rumuolukwu community, Niger Delta region of Nigeria. The heavy metals were typically higher at 0-15cm depth followed by 15 – 30cm. Furthermore fluctuation exits between 30 – 45cm and 45 – 60 depth in both contaminated soil and control for most of the heavy metals (Table 1).

Nickel (Ni)

Based on seasonal variation, for Ni in the rainy season it ranged from 0.57 to 3.02 and 0.09 to 0.96mg/kg with mean values of (1.64 ± 0.75) and (0.53 ± 0.29) mg/kg in the oil contaminated and control plots respectively. Observed Ni values for the dry season ranged between 0.16 to 1.54 and 0.10 to 0.48 mg/kg with mean values of (0.62 ± 0.33) and (0.28 ± 0.11) mg/kg in the oil contaminated and control soils respectively. The Ni concentration for both contaminated soil and control is within the DPR recommended limit of 35 mg/kg. However, higher concentration in contaminated soil suggests pollution. There was a sharper decline in Ni concentrations of 15 – 30cm depth compared to 0 – 15cm depth. Ni concentrations had sharpest drop during the month of November (Table 1). This may be due to rainfall flowed by flooding and soil erosion which may have characterized the preceding rainy month of October. The trend and findings of this study is similar to the work of Benka-Coker and Ekundayo (1995) where oil spill led to the significant build-up of heavy metals in the contaminated soil.

Lead (Pb)

Rainy season Pb values ranged from 0.20 to 8.14 and <0.002 to 2.75 mg/kg with mean values of (2.75 ± 1.98) and (0.47 ± 0.81) mg/kg for oil contaminated and control soils respectively. Dry season Pb values ranged from0.78 to 2.75 mg/kg and below detection limit (<0.002) mg/kg with mean values of (1.52 ± 0.54) and <0.002 mg/kg in the oil contaminated and control soils respectively (Table 1). However, the observed Pb values were below the DPR target value of 85 mg/kg for a standard soil. Higher lead concentration was observed in October. This could have resulted from the intense rainfall and flooding of the oil contaminated plot which may have led to the redistribution of contaminants within the oil contaminated plot (Figure 2).

Rainy season Pb concentrations in the oil contaminated soil recorded maximum values of 3.90 and 5.37 mg/kg in the top and bottom soils respectively, while the maximum Pb concentration of control soil was 2.75 and 0.09 mg/kg in the top and bottom soils respectively. In the dry season, oil contaminated soil depicted maximum Pb concentrations of 2.75 and 2.66 mg/kg in the top and bottom soils respectively, but the control soil recorded no values (<0.002) as they were below detection limit of the AAS (Table 2). The relatively higher concentrations of Pb in the oil contaminated soil may be an indication of oil spillage and the Pb heavy metals that are found in association with the spilled petroleum oil. The increase in Pb at some bottom soils may have resulted from vertical delineation, due to soil structure. These findings were consistent with the work of Inengite *et al*.(2010) who had reported that oil contaminated soils were relatively more spiked with Pb as compared to the control soils.

Figure 2: A water logged areas during the peak rainy periods on the oil contaminated plot, October 2013.

Chromium (Cr)

Cr concentrations during the rainy season ranged from 0.18 to 6.12 and <0.001 to 4.15 mg/kg with mean values of (2.67 ± 2.07) and (0.96 ± 1.36) mg/kg in the oil contaminated and control soils respectively. Dry season values ranged from 2.42 to 7.88 and 0.72 to 3.36 mg/kg with mean values of (4.52 ± 1.71) and (2.02 ± 0.90) mg/kg for the oil contaminated and control soils respectively (Table 1). Observed Cr values were below the DPR target value of 100 mg/kg for a standard soil.

Rainy season Cr levels, as observed in the oil contaminated soil were as high as 5.04 and 6.12 mg/kg for the top (0 – 15cm) and bottom (15 – 30cm) soils respectively, while the control soil depicted maximum Cr concentrations of 4.15 and 2.51 mg/kg for the top and bottom soils respectively. Dry season values for oil contaminated soil showed maximum Cr concentrations of 5.62 and 7.88 mg/kg in the top and bottom soils respectively; the control soil however recorded values as high as 3.36 and 1.57 mg/kg for top and bottom soils respectively (Table 2). A higher Cr concentration was observed in the bottom soils of the oil contaminated soil, depicting an increasing vertical delineation for the element, which may have resulted from the soil structure. However, this is contrary to the lower Cr concentrations reported for bottom soils of the control site and may be an indication of the effect of oil spillage.

Highest mean concentration of 5.81 mg/kg Cr was observed in the month of November. This may have resulted from the effect of intense rainfall and flooding of preceding months, while Cr was observed to be the most vertically delineated element. This findings are similar to the observations made from the earlier work by Benka-Coker and Ekundayo (1995) who had reported a significant build up of heavy metals in crude oil contaminated soils collected from the Niger Delta; and the evidence of vertical delineation of oil up to depths of 7.2 m. Further studies by Inengite *et al*. (2010) had similarly shown the relative abundance of Cr in oil contaminated soils.

Vanadium (V)

In the rainy season, V concentrations ranged from 0.030 to 0.201 and <0.01 to 0.064 mg/kg with mean values of (0.109 ± 0.050) and (0.033 ± 0.020) mg/kg in the oil contaminated and control soils respectively. During the dry season, V concentrations ranged from 0.010 to 0.101 and <0.01 to 0.033 mg/kg with mean values of (0.038 ± 0.020) and (0.017 ± 0.010) mg/kg in the oil contaminated and control soils respectively (Table 1).In the rainy season, V concentrations for the oil contaminated soil were as high as 0.20 and 0.19 mg/kg in the top and bottom soils respectively. While the control soil depicted maximum V concentrations of 0.06 mg/kg in both the top and bottom soils respectively. During the dry season, V concentrations were as high as 0.10 and 0.05 mg/kg in the top and bottom soils respectively. The control soil was reportedly as high as 0.03 and 0.02 mg/kg for the top and bottom soils respectively (Table 2). The slightly higher concentrations of V in the oil contaminated soil, when compared to the control soil may be an indication of the oil spillage and the V found in the contaminated soil are association with crude oil (Osuji *et al*., 2005; Mustafa *et al*., 2015). Similarly, higher concentrations of V have been reported oil contaminated soils by Inengite *et al*. (2010).

Heavy metal pollution assessment indices are presented in Table 3. Based on contamination factor assessment, heavy metals depicted a moderate contamination factor in the various depth except for few instances including Ni at 45 – 60cm, Pb at 15 -30cm and 45 – 60cm which has very high contamination factor during the wet season; 15 -30cm which is has considerable contamination factor for Cr and 45 – 60 cm which has low contamination factor for V during the dry season. Typically the contamination factor was highest during the wet season. Higher contamination factor could be due to influence of rainfall leading to flooding and soil erosion.

Table 1: Heavy metal properties of oil spill contaminated soil and control between August 2013 – January 2014 in Rumuolukwu community, Niger Delta region of Nigeria

Months of the year	Parameter(s)	CPS (0-15)	CPS (15-30)	CPS (30-45)	CPS (45-60)	COMPS (0-15)	COMPS (15-30)	Mean	SD	CCS (0-15)	CCS (15-30)	CCS (30-45)	CCS (45-60)	COMCS (0-15)	COMCS (15-30)	Mean	SD
August 2013	Ni(mg/kg)	3.02	2.85	1.05	1.87	2.00	1.50	2.05	0.76	0.78	0.96	0.51	0.22	0.86	0.67	0.67	0.27
	Cr(mg/kg)	5.04	3.99	3.94	2.23	1.50	2.60	3.22	1.32	4.15	2.51	0.99	2.57	<0.001	<0.001	1.70	1.66
	Pb(mg/kg)	3.07	2.75	1.12	2.62	1.97	3.94	2.58	0.96	2.75	0.06	0.99	0.46	1.04	0.03	0.89	1.01
	V(mg/kg)	0.201	0.192	0.072	0.125	0.138	0.105	0.14	0.05	0.053	0.064	0.032	0.011	0.056	0.038	0.04	0.02
September 2013	Ni(mg/kg)	2.94	2.60	0.90	1.23	1.44	1.30	1.74	0.83	0.40	0.62	0.15	0.09	0.75	0.33	0.39	0.26
	Cr(mg/kg)	0.30	0.39	0.37	0.32	0.24	0.18	0.30	0.08	0.20	0.41	0.11	0.16	0.19	0.22	0.22	0.10
	Pb(mg/kg)	2.11	1.20	0.60	0.58	0.87	0.20	0.93	0.67	0.06	0.09	0.11	<0.002	<0.002	<0.002	0.04	0.05
	V(mg/kg)	0.196	0.185	0.062	0.084	0.098	0.087	0.12	0.06	0.027	0.040	<0.01	<0.01	0.053	0.022	0.02	0.02
October 2013	Ni(mg/kg)	1.21	1.37	0.57	1.17	1.52	0.97	0.51	0.26	NM	NM	NM	NM	NM	NM	NM	NM
	Cr(mg/kg)	4.81	6.12	5.91	3.22	3.54	3.43	5.81	0.73	NM	NM	NM	NM	NM	NM	NM	NM
	Pb(mg/kg)	3.90	3.49	3.80	8.14	3.70	5.37	1.82	0.75	NM	NM	NM	NM	NM	NM	NM	NM
	V(mg/kg)	0.070	0.090	0.030	0.070	0.090	0.060	0.03	0.02	NM	NM	NM	NM	NM	NM	NM	NM
November 2013	Ni(mg/kg)	0.85	0.80	0.41	0.27	0.46	0.27	0.51	0.26	NM	NM	NM	NM	NM	NM	NM	NM
	Cr(mg/kg)	5.62	6.76	6.21	6.18	4.71	5.35	5.81	0.73	NM	NM	NM	NM	NM	NM	NM	NM
	Pb(mg/kg)	1.59	2.66	1.79	1.06	2.75	1.06	1.82	0.75	NM	NM	NM	NM	NM	NM	NM	NM
	V(mg/kg)	0.050	0.050	0.020	0.010	0.030	0.010	0.03	0.02	NM	NM	NM	NM	NM	NM	NM	NM
December 2013	Ni(mg/kg)	0.97	0.77	0.16	0.61	1.54	0.76	0.80	0.45	0.41	0.36	0.27	0.14	0.48	0.35	0.34	0.12
	Cr(mg/kg)	3.63	5.40	5.75	3.97	2.63	7.88	4.88	1.87	3.36	0.96	3.24	3.04	2.09	1.57	2.38	0.99
	Pb(mg/kg)	1.41	1.85	1.54	1.20	1.76	0.87	1.44	0.36	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0	0.0
	V(mg/kg)	0.064	0.051	0.011	0.040	0.101	0.050	0.05	0.03	0.027	0.024	0.018	<0.01	0.033	0.022	0.02	0.01
January 2014	Ni(mg/kg)	0.84	0.52	0.39	0.28	0.81	0.49	0.56	0.23	0.26	0.22	0.18	0.10	0.31	0.25	0.22	0.07
	Cr(mg/kg)	2.87	2.63	2.51	2.42	2.48	4.37	2.88	0.75	2.55	0.72	2.18	2.04	1.37	1.16	1.67	0.70
	Pb(mg/kg)	1.34	1.70	1.42	1.03	1.57	0.78	1.31	0.34	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0	0.0
	V(mg/kg)	0.055	0.030	0.020	0.020	0.050	0.030	0.03	0.02	0.020	0.010	0.010	<0.01	0.020	0.020	0.01	0.01

CPS - Centre of polluted Site, COMPS - Composite of polluted site, CCS - Centre of control site, COMCS - Composite of control site; SD- Standard deviation; NM-Not monitored

Table 2: Seasonal variation of heavy metal properties of oil spill contaminated Top (0-15cm) and Bottom Soils (15-30cm) soil and control between August 2013 – January 2014 in Rumuolukwu community, Niger Delta region of Nigeria

Sampling Site		Rainy Season (August - October 2013)			Dry Season (November 2013 - January 2014)		
		Range	Mean	Standard deviation	Range	Mean	Standard deviation
Ni (mg/kg)							
Oil Contaminated	(0-15cm)	1.21 - 3.02	2.02	0.79	0.46 - 1.54	0.91	0.35
	(15-30cm)	0.97 - 2.85	1.77	0.77	0.27 - 0.80	0.60	0.21
Control	(0-15cm)	0.40 - 0.86	0.70	0.20	0.26 - 0.48	0.37	0.10
	(15-30cm)	0.33 - 0.96	0.65	0.26	0.22 - 0.36	0.30	0.07
Pb (mg/kg)							
Oil Contaminated	(0-15cm)	0.87 - 3.90	2.60	1.16	1.34 - 2.75	1.74	0.52
	(15-30cm)	0.20 - 5.37	2.83	1.88	0.78 - 2.66	1.49	0.72
Control	(0-15cm)	<0.002 - 2.75	0.96	1.28	<0.002 - <0.002	0.0	0.0
	(15-30cm)	<0.002 - 0.09	0.05	0.04	<0.002 - <0.002	0.0	0.0
Cr (mg/kg)							
Oil Contaminated	(0-15cm)	0.24 - 5.04	2.57	2.18	2.48 - 5.62	3.66	1.27
	(15-30cm)	0.18 - 6.12	2.79	2.26	2.63 - 7.88	5.40	1.83
Control	(0-15cm)	<0.001 - 4.15	1.14	2.01	1.37 - 3.36	2.34	0.83
	(15-30cm)	<0.001 - 2.51	0.79	1.16	0.72 - 1.57	1.10	0.36
V (mg/kg)							
Oil Contaminated	(0-15cm)	0.07 - 0.20	0.13	0.06	0.03 - 0.10	0.06	0.02
	(15-30cm)	0.06 - 0.19	0.12	0.06	0.01 - 0.05	0.04	0.02
Control	(0-15cm)	0.03 - 0.06	0.05	0.01	0.02 - 0.03	0.03	0.01
	(15-30cm)	0.02 - 0.06	0.04	0.02	0.01 - 0.02	0.02	0.01

Table 3: Heavy metal pollution indices for the oil contaminated plot

Heavy Metal	Rainy season				Dry season			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm
Contamination factor, C_f^i								
Ni	2.9	2.7	2.5	8.9	2.5	2.0	1.4	3.3
Pb	2.7	56.6	3.3	16.4	1.7	1.5	1.6	1.1
Cr	2.3	3.5	6.2	1.4	1.6	4.9	1.8	1.6
V	2.6	3.0	2.5	1.5	2.0	2.0	1.4	0.02
Ecological risk factor, E^i_r								
Ni	NA	NA	NA	NA	NA	NA	NA	NA
Pb	13.5	283.0	16.5	82.0	8.5	7.5	8.0	5.0
Cr	4.6	7.0	12.4	2.8	3.2	9.8	3.6	3.2
V	NA	NA	NA	NA	NA	NA	NA	NA

NA-Not applicable

The ecological risk factor were low for Pb and Cr apart for few instances including 15 – 30cm depth for Pb lead which risk is considerable and 45 – 60cm depth for Pb with moderate ecological risk factor. In general, the dry season has lower potential ecological risk compared to wet season. Again higher ecological risk factor during the wet season could be due to effects of rainfall and other associated characteristics such as flooding and soil erosion.

Conclusion

Oil spill incidence is caused by several factors including vandalism and rupture of pipeline. Oil spill occurs in nearly all phase crude oil processing from exploration to final use. Crude oil is a mixture of complex substances including heavy metals. This study investigated heavy metal concentration in crude oil contaminated soil and assessing their pollution risk in the environment using contaminant factor ecological risk factor. The study found that heavy metals in oil spill contaminated soil were higher than the control but lower than limit specified by Department of Petroleum Resources Nigeria. The concentration in oil spill environment is higher during the raining/ wet season compared to dry season. Based on pollution indices studied contamination factor is within low to very high depending on the soil depth and type of heavy metals. While the ecological factor is within low to moderate for Pb and with low for Cr. Oil spill contaminated soil elevates soil heavy metals (V, Ni, Pb and Cr) concentration. Based on this, its imperative that concerned stakeholders should routine monitoring and checks on their numerous pipeline right of way to serve as a stop gap measure for repetitive future occurrence.

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