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Heavy Metal Contamination Indices for oil spilled Agricultural Soils in three Local Government Areas of River State, Nigeria

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Abstract *This study evaluated the contamination indices of heavy metals in Agricultural soil contaminated with crude oil spills in three local government areas (LGAs) within Rivers State, Nigeria (namely, Eleme, Ahoada and Oyigbo). Soil samples were taken at various depths (0-15cm, 15-30cm and 30-45 cm) from the three LGAs. Concentrations of chromium, copper, iron, nickel and zinc ions were determined using atomic absorption spectrophotometry. Results obtained indicated that mean concentration of chromium ion ranged from 10.53 -24.61mg/kg, copper ion ranged from 1.97-2.73mg/kg, iron ion ranged from 1329.58-1838.32 mg/kg. Nickel ion ranged from 1.07-3.03 mg/kg while mean zinc ion concentrations ranged from 0.38-3.99 mg/kg. The results also revealed that mean concentrations of all the studied heavy metal ions were higher in oil spilled soil samples than those not exposed to spillage, indicating possible increase in soil heavy metal ions concentrations through oil spillage. Also, concentrations of heavy metal ions were found to increase with soil depth and was attributed to natural processes. Calculated contamination factors indicated low to moderate contamination except Cr and Ni for Oyigbo samples whose CF values indicated moderate and considerable contamination. Pollution load index indicated low pollution levels for Ahoada and Oyigbo soil samples while that of Eleme was polluted. The degree of contamination for all the heavy metals revealed low degree of contamination expect for nickel where it showed moderate degree of contamination. The ecological and the potential ecological risks were within the range of low ecological risk pollution for soil samples at the spillage sites in the three Local Government Areas.*

Key Words: *Soil pollution, oil spillage, soil depth, geographical locations*

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1.0 Introduction

Soil is the most valuable component of the farming ecosystem and the sustainable use of agricultural soil on which plants grow is critical for agricultural productivity (Osuocha *et al.,* 2013). Soil pollution is the contamination of the soil by pollutants like heavy metals, pesticides, organic solvents, petroleum products and refuse which limits its use for agricultural production and other human activities (Nnaji and Uzoekwe, 2018). The presence of heavy metals in the soil above recommended limits is of great concern due to their adverse effects on soil physicochemical parameters and absorption of heavy metals by plants may present a health risk for human and animal consumers of plants (Tripathi *et al*., 1990; Wyszkowska and Wyszkowska, 2002; Mansur and Jazuli, 2007). Soil pollution emanating from oil and gas activities limits agricultural production since it negatively impacts soil fertility thereby hampering plant growth. Crude oil pollution occurs when there is man-made or man-aided negative alteration of chemical, physical or biological quality of the environment as a result of the extraction, storage or transportation of petroleum (Ebuehi *et al*., 2005; Guidi *et al*., 2015). Soil and water contamination by crude oil is a sensitive issue, particularly in the Niger-Delta area and the impact of the contamination of the environment by crude oil is known to be disastrous (Olayinka, 2004; Elum *et al*., 2016). The basic activity of an average Nigerian is farming and crude oil spillage has forced farmers in the Niger Delta to abandon their land and seek for scarce alternative means of livelihood (Ani *et al.*, 2015; Adati, 2012). Heavy metals are natural components of crude oil (Akudo, 2016) and their contamination of soil and water is one of the most serious environmental problems across the world due to their toxicity to human, animals, plants and microbes. The investigation of heavy metals in agricultural soil is essential since even slight changes in their concentration above the recommended levels can result in serious environmental contamination and subsequent health problems. The aim of this study was to determine heavy metals (Cr, Ni, Cu, Fe, Zn) in agricultural soil samples collected from oil spillage sites located in Eleme, Ahoada and Oyigbo Local Government Areas (LGAs) of Rivers State, Nigeria at depths of 0-15, 15-30 and 30-45cm. Few studies were found on soil heavy metal contamination in Eleme as a results of oil spill but none for Ahoada and Oyigbo and these studies did not involve the calculation of contamination indices.

Metal contamination indices are used to assess the degree to which a particular heavy metal pollutes the soil. It entails a comparison of the polluting metal concentration with the concentration of the same metal in an unpolluted soil from the same geographical location.

2.0 Materials and methods

2.1 The Study Areas

Ahoada Local Government Area (LGA) is in the Orashi region of Rivers State, northwest of Port Harcourt City. It consists of two Local Government Areas, Ahoada East and Ahoada West. Ahoada is located on latitude 5º 07'01", 5º 4'26"N and longitude 6º 39'12", 6º 65'01"E. The 2006 census estimated the population of the area to be about 12,848 (NPC, 2006) and their major occupation is farming and fishing. Eleme LGA is located on latitude 5° 04' 60.00" N and longitude 6° 38' 59.99" E with an elevation of 21 m. Eleme is part of the greater Port Harcourt metropolitan area with a population of 190,884 ((NPC, 2006)). The primary occupation of the people is agriculture. Oyigbo LGA (also known as Obigbo) is about 30 km from the Port Harcourt City and is located on latitude 4° 52' 24.59" N and longitude 7° 07' 25.20" E. It has a population of 125,331 (NPC, 2006) whose major occupation is also Agriculture.

2.2 Sampling and sample pre-treatment

The methodology for the sampling was in accordance with Environmental Guidelines and Standards for the Petroleum Industry in Nigeria, EGASPIN (DPR, 2002). The sampling stations (which are indicated in Fig. 1) were five oil spilled sites (A, B, C, D and E) and three control sites (1, 2 and 3, which were 2 km away from the spilled sites). Soil samples were taken from top soil (0.15 cm), sub soil (15-30 cm) and from sub-sub soil (30-45 cm deep). Sample collection was done with a hand-held auger and 200 g of sample was collected from each sampling station. A total of 72 composite soil samples were collected from the 24 sampling sites (15 stations and 9 controls) in each LGA. Extraneous materials (stone and plant materials) were removed from soil samples and they were air-dried. The air-dried samples were grounded into fine powder with acid washed plastic mortar and pestle and passed through a 0.2 mm sieve before being taken for heavy metal analysis.

2.3 Quality assurance

Analytical grade reagents and chemicals were used for this study and all digestion and analyses were done in triplicate. Procedural and reagent blanks were used and a clean laboratory environment was ensured during the analyses and preparation of solutions. In addition, glassware, plastic containers, crucibles, pestle and mortar was washed with liquid soap, rinsed with distilled water and then soaked in 10 % HNO_3 solution for 24 h and dried in an oven at 80 °C for 5 hours.

2.4 Digestion of samples

Standard method (APHA 3111B) was employed. The sieved soil sample (2 g) was weighed with analytical balance into a crucible and digested with 20 ml mixed acids (perchloric acid and concentrated nitric acid in a 1:3 ratio). Anti-bump and 5 ml of deionized water was added and the crucible was heated gently with electro-thermal heater in a fume cupboard to partial dryness. The crucible was then allowed to cool and 10 ml of de-ionized water was added. This was stirred gently with glass rod and filtered through Whatman No. 42 filter paper into a 100 ml volumetric flask and made up to mark with deionized water.

2.5 Instrument parameters for FAAS analysis

The heavy metal concentrations were determined with the FAAS (SpectrAA 100) with the instrument parameters shown in Table 1.

2.5.1 Determination of heavy metal ions

Stock solutions (1000 ppm) of the metals were prepared with the metal salts including ferric nitrate, zinc oxide, potassium dichromate, copper nitrate and nickel nitrate. Working calibration solutions were prepared by serial dilution of the stock solutions of the metals of interest

(Fe, Zn, Cr, Cu and Ni). Five standards with concentrations spanning a specific range were prepared for each metal and absorbances were determined with Flame Atomic Absorption Spectrophotometer (FAAS, model, SpectrAA 100) in triplicate to obtain a good precision. Calibration curves were plotted and the concentration of the metal of interest was determined through extrapolation method.

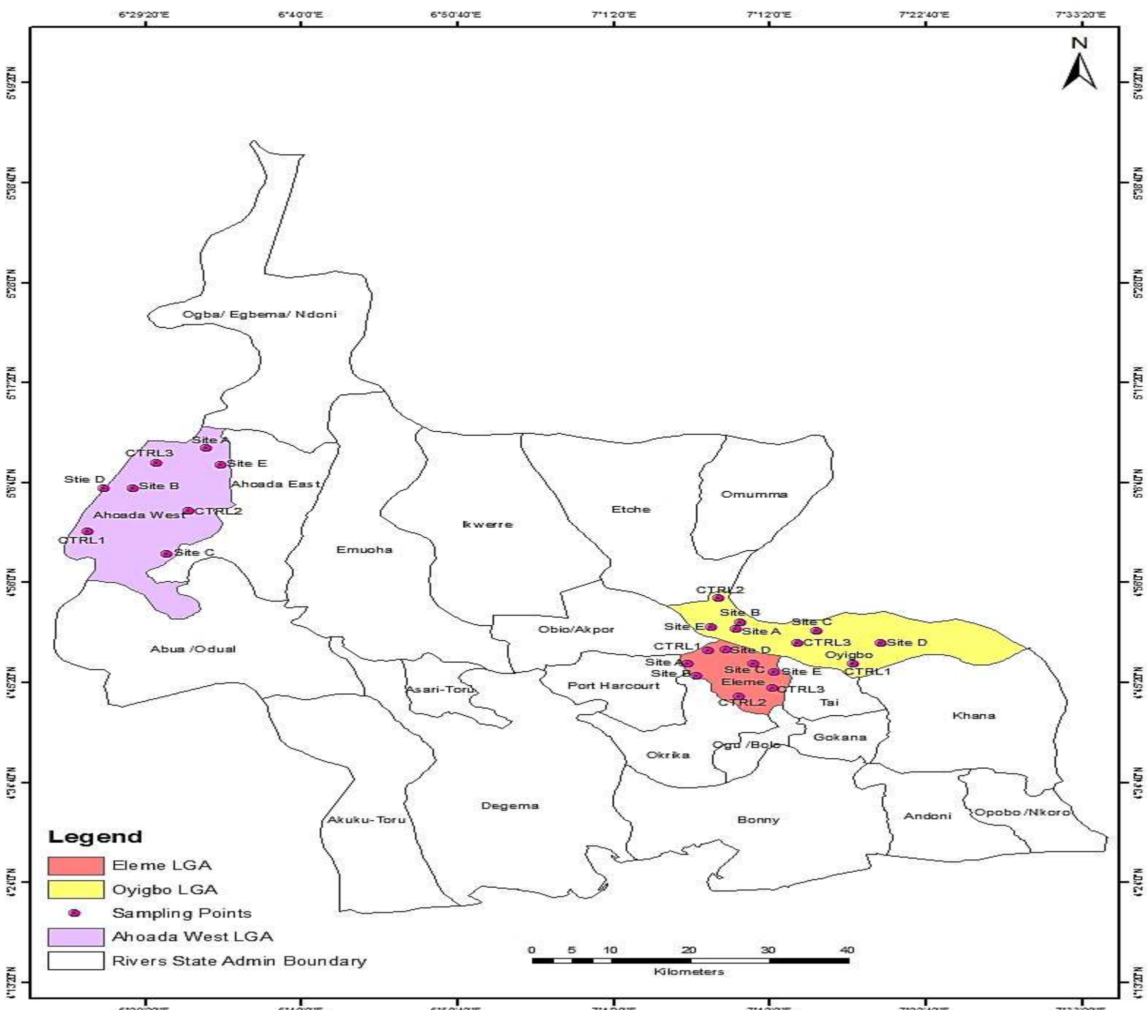

Fig. 1. Map of Rivers State showing the sampling points in the three L.G.A.

2.6 Method validation

This involved the use of certified reference soil material and spiking experiment (Csuros and Csuros, 2002). The reference material (RM) which was obtained from an independent source was used. Metal concentration in the RM was measured and used to validate the analytical system. Accuracy was expressed in the percentage recovery and contained the true value, acceptance range and reported value.The spiking experiment was done by adding 2 ppm of an analyte of interest (Cr) to the sample before preparation to measure the performance of the analytical system including chemical interference from the sample matrix. The sample was thoroughly mixed with 1.99 ml of the 2 ppm standard solution before digestion. Percentage recovery was calculated after digestion and FAAS analysis.

2.7 Statistical analysis

Statistical analysis was done using the SPSS (version 22.0) for Windows software package. Mean concentrations and standard deviations were calculated for each heavy metal. The results were subjected to analysis of variance (ANOVA) and means were compared using Duncan Multiple Range Test

Table 1: Optimal Instrumental parameters for FAAS determination of metals

Parameters	Metals				
	Fe	**Zn**	**Cr**	**Cu**	**Ni**
Time of measurement(sec)	4.0	4.0	4.0	4.0	4.0
Wavelength (nm)	248.3	213.9	357.9	324.8	232.0
Spectra width slit (nm)	0.5	0.5	0.5	0.5	0.5
Flame	**Air – acetylene**				
Acetylene flow rate (L/min)	0.9	0.9	0.9	0.9	0.9
Background correction	On	On	on	On	on

.3.0 Results and Discussion

3.1 Metal concentrations

Mean concentrations of heavy metals in some soils in Eleme are recorded in Table 2. The availability of trace metal ions in soil are controlled by physical and chemical interactions. These interactions are affected by several factors including pH, redox potential, temperature, carbon dioxide level, type and concentration of available ligands and chelating agents as well as type and concentration of metal ions (Navarro-Pedreño *et al.*, 2018). A significant variation ($P<0.05$) in the mean concentrations of heavy metal ion was found across depths and sites in both spillage and control sites. This may be due to blockages of the exchange sites by hydrocarbon residues (Gersper *et al.,* 1974). The mean concentrations of heavy metals obtained from the top soils in the spillage sites were; 10.53±3.44, 1.97±0.71, 1525.26±428.87, 2.18±0.15 and 2.92±0.63 mg/kg for Cr, Cu, Fe, Ni and Zn ions respectively. At the control sites, the mean concentrations of top soil samples were; 2.78±0.71, 0.55±0.21, 734.37±223.67, 0.88±0.53 and 0.93±0.26 mg/kg respectively. At estimated depth of 15-30 cm, the mean concentrations of Cr, Cu, Fe, Ni and Zn ions were 17.07±6.13 mg/kg, 2.12±0.83 mg/kg, 1702.95±405.61 mg/kg, 2.58±0.31 mg/kg and 3.45±1.46 mg/kg respectively. At the control sites, mean concentrations were 6.17±2.80, 0.78±0.43, 875.30±120.10, 0.93±0.19 and 0.96±0.18 mg/kg respectively. At estimated depth of 30-45 cm depth, mean concentrations were 19.30±6.67, 2.16±1.04, 1838.32±397.72, 3.03±1.10 and 3.99±1.64 mg/kg at the spillage sites. The control sites recorded 8.11±3.78, 1.16±0.41, 1022.67±244.43, 1.11±0.23 and 1.17±0.91 mg/kg for Cr, Cu, Fe, Ni and Zn respectively.

Table 2. Mean concentrations of heavy metal ions in soils from Eleme LGA

Heavy metal ion	Depth (cm)	Oilspillage Sites		Control sites	
		Range (mg/kg)	Mean (mg/kg)	Range (mg/kg)	Mean (mg/kg)
Cr	0-15	6.50-16.50	10.53±3.44	1.50-4.00	2.78±0.71
	15-30	13.00-29.00	17.07±6.13	2.00-9.00	6.17±2.80
	30-45	15.00-32.50	19.30±6.67	3.00-13.00	8.11±3.78
Cu	0-15	1.25-3.20	1.97±0.71	0.20-0.95	0.55±0.21
	15-30	0.90-3.30	2.12±0.83	0.30-1.55	0.78±0.43
	30-45	0.50-3.65	2.16±0.64	0.70-1.70	1.16±0.41
Fe	0-15	1008.45-1964.97	1525.26±428.87	566.79-1031.81	734.37±223.67
	15-30	1017.60-2205.86	1702.95±405.61	789.67-1035.31	875.30±120.10
	30-45	1130.80-2304.02	1838.32±397.72	829.19-1346.58	1022.67±244.43
Ni	0-15	1.00-4.15	2.18±0.15	0.55-2.00	0.88±0.53
	15-30	1.25-4.35	2.58±0.31	0.70-1.20	0.93±0.19
	30-45	1.60-5.25	3.03±1.10	0.80-1.50	1.11±0.23
Zn	0-15	1.00-4.85	2.92±0.63	0.15-2.00	0.93±0.26
	15-30	1.25-4.95	3.45±1.46	0.20-2.05	0.96±0.18
	30-45	1.75-6.00	3.99±1.20	0.35-2.50	1.17±0.91

****Mean ± SD of three replicates**

The overall mean concentrations of heavy metal ions were; Cr (11.90±7.43 mg/kg), Cu (1.61±0.95 mg/kg), Fe (1384.57±534.84 mg/kg), Zn (2.54±1.80mg/kg) and Ni (1.98±1.32 mg/kg). Mean concentrations of chromium ion at spillage and control sites were all above the Department of Petroleum Resources (DPR) recommended value of 0.5 mg/kg for total chromium (EGASPIN, 2002) but they were below the Canadian agricultural soil quality guideline value of 64 mg/kg (CCME, 2007). Mean concentrations of Cu^{2+} were all below DPR and CCME recommended values of 35 and 63 mg/kg respectively. Concentrations of Ni^{2+} at all sites were above the DPR limit of 0.8 mg/kg but below the CCME (2007) limit of 50 mg/kg while concentration of Zn^{2+} were also below the DPR and CCME recommendation of 50-300 and 200 mg/kg respectively.

In Table 3. Mean concentrations of heavy metals ions in oil contaminated soil samples from some sampling stations in Ahoada local government area are presented. The results are presented as mean of three replicate analysis.

Table 3. Mean concentrations of heavy metal ions in soils from Ahoada LGA

Heavy metal ion	Depth (cm)	Oil Spill Sites		Control sites	
		Range (mg/kg)	**Mean (mg/kg)**	**Range (mg/kg)**	**Mean (mg/kg)**
Cr	0-15	8.95-36.00	19.95±10.25	2.00-14.05	6.67±1.55
	15-30	14.35-36.00	22.52±8.13	4.45-18.50	13.64±4.85
	30-45	15.00-39.05	24.61±8.83	6.50-20.55	15.30±6.60
Cu	0-15	0.84-3.50	2.16±0.79	0.55-1.05	0.81±0.20
	15-30	0.90-3.50	2.42±0.81	1.15-1.60	1.33±0.19
	30-45	1.35-3.80	2.73±0.82	1.25-1.90	1.49±0.29
Fe	0-15	834.01-464.06	1403.85±577.43	734.45-439.56	1067.14±306.72
	15-30	907.67-544.15	1479.69±576.47	827.00-1533.30	1247.55±321.97
	30-45	933.47-695.91	1536.80±623.57	1031.90-1716.75	1431.62±308.74
Ni	0-15	0.45-1.75	1.08±0.41	0.34-0.70	0.52±0.15
	15-30	1.15-1.95	1.53±0.27	0.60-0.95	0.73±0.12
	30-45	1.10-2.05	1.69±0.31	0.65-1.05	0.84±0.15
Zn	0-15	0.20-0.55	0.38±0.14	0.10-0.55	0.33±0.07
	15-30	0.25-0.85	0.55±0.21	0.15-1.00	0.49±0.13
	30-45	0.45-0.95	0.70±0.17	0.20-1.05	0.58±0.16

Means ± SD of three replicates

It is evident from the results presented in Table 3 that mean concentrations of chromium ion at various depths (0-15, 13-30 and 30-45 cm) were 19.95±10.25, 22.52±8.13 and 24.61±8.83 mg/kg respectively. However, at the control sites, mean concentrations were 6.67±1.55 mg/kg, 13.64±4.85 mg/kg and 15.30±6.60 mg/kg respectively.

Mean concentrations of copper ions at the spillage sites were 2.16±0.79, 2.42±0.81 and 2.73±0.82 mg/kg 0-15, 15-30 and 30-45 cm soil depths respectively. At the control sites, mean Cu^{2+} concentrations were 0.81±0.20, 1.33±0.19 and 1.49±0.29 mg/kg respectfully. Iron had the highest concentrations among all the studied heavy metals at all sites and depths. Mean concentrations of iron ion at the spillage site were 1403.85±577.43, 1479.69±576.47 and 1536.80±623.57 mg/kg at the 0-15, 15-30 and 30-45 cm depths respectively but at the control sites, the mean concentrations were 1067.14±306.72, 1247.55±321.97 and 1431.62±308.74 mg/kg respectively.

Nickel ions in the spillage sites had mean concentrations of 1.08±0.41, 1.53±0.27 and 1.69±0.31 mg/kg at depths of 0-15, 15-30 and 30-45 cm respectively at the control stations, the mean concentrations were 0.52±0.15, 0.73±0.12 and 0.84±0.15 mg/kg respectively. Zinc at the spillage sites had mean concentrations of 0.38±0.14, 0.55±0.21 and 0.70±0.17 mg/kg at 0-15, 15-30 and 30-45 cm depths respectively. However, mean concentrations recorded at the control stations were 0.33±0.17, 0.49±0.33 and 0.58±0.36 mg/kg respectively.

Mean concentrations of heavy metal ions in soil samples from various locations in Oyigbo LGA are shown in Table 4. The results obtained revealed that chromium ion had mean concentrations of 5.83±4.85, 12.99±2.20 and 15.31±2.50 mg/kg at depths of 0-15, 15-30 and 30-45 cm respectively. At the control stations, the mean concentrations were 2.78±1.59, 3.36±0.26 and 5.51±0.76 mg/kg respectfully.

Table 4. Mean concentrations of heavy metal ions in soils from Oyigbo

Metals	Depth (cm)	Oil spill Sites`		Control Sites	
		Range	Mean	Range	Mean
Cr (mg/kg)	**0-15**	**0.95-13.00**	**5.83±4.85**	**1.50-5.50**	**2.78±1.59**
	15-30	3.50-35.50	12.99±2.20	3.00-3.60	3.36±0.25
	30-45	4.50-38.50	15.31±2.50	4.50-6.55	5.51±0.76
Cu (mg/kg)	0-15	0.50-2.50	1.22±0.53	0.800-2.00	1.23±0.37
	15-30	1.00-1.85	1.37±0.33	1.10-1.60	1.32±0.22
	30-45	1.10-2.20	1.70±0.41	1.25-2.40	1.79±0.42
Fe (mg/kg)	0-15	540.78-2017.18	1327.58±581.57	1343.80-3223.55	2412.46±836.56
	15-30	808.00-2126.98	1472.49±536.13	1418.9-3245.61	2539.83±849.86
	30-45	1150.15-2422.36	1667.05±577.96	1523.58-3275.95	2615.57±824.94
Ni (mg/kg)	0-15	0.50-1.65	1.07±0.45	0.15-0.31	0.22±0.07
	15-30	0.60-1.95	1.30±0.53	0.20-0.60	0.34±0.16
	30-45	0.70-1.95	1.39±0.49	0.30-0.60	0.39±0.12
Zn (mg/kg)	0-15	0.15-1.10	0.63±0.37	0.60-1.65	1.11±0.41
	15-30	0.25-1.45	0.81±0.45	0.60-1.75	1.28±0.39
	30-45	0.28-1.65	1.04±0.52	0.95-1.95	1.43±0.37

****Mean ±SD of three replicates**

At the spillage sites, mean copper concentrations at depths of 0.15, 15-30 and 30-45 cm were 1.22±0.53, 1.37±0.33 and 1.70±0.41 mg/kg respectively while mean concentrations at control sites were 1.23±0.37, 1.32±0.22 and 1.79±0.42 mg/kg respectively. However, concentrations of chromium ion were above the Department of Petroleum Resources (DPR) recommended value of 0.5 mg/kg for total chromium (EGASPIN, 2002).

Mean iron concentrations at the spillage sites were 1327.58±581.57, 1472.49±536.13 and 1667.05±577.96 mg/kg at the 0-15, 15-30 and 30-45 cm depths respectively but at the control sites, the mean iron concentrations were 2412.46±836.56, 2539.83±849.86 and 2615.57±824.94 mg/kg respectively. Nickel ion in the spilled sites had mean concentrations of 1.07±0.45, 1.30±0.53 and 1.39±0.49 mg/kg at depths of 0-15, 15-30 and 30-45 cm respectively while at the control sites, mean values of 0.22±0.07, 0.34±0.16 and 0.39±0.12 mg/kg respectively, were recorded at the same depths.

Zinc ions concentrations at the spilled sites had mean values of 0.63±0.37, 0.81±0.45 and 1.04±0.52 mg/kg at 0-15, 15-30 and 30-45 cm depths respectively. Similarly, mean concentrations at the control stations were 1.11±0.41, 1.28±0.39 and 1.43±0.37 mg/kg respectively. All the values for Zn across the sites were below the DPR recommended range of 50-300 mg/kg and CCME agricultural soil guideline value of 200 mg/kg.

3.2 Metal contamination indices

The indices calculated in this study were:

(a) Contamination factor (CF). This is expressed as;

$$CF = \frac{C_{heavy\ metal}}{C_{background}} \quad (1)$$

According to Hakanson (1980), values of CF is a contamination index and the significant of depends on the range obtained for the calculated value of CF. When CF<1, it implies that there is low contamination, 1<CF<3 is consistent with moderate contamination, 3<CF<6 points toward considerable contamination while CF>6 indicates very high contamination.

(b) Pollution load index (PLI). PLI is expressed as (Tomilson *et al.*, 1980);

$$PLI = (CF1 \times CF2 \times CF3 ... \times CFn)^{\frac{1}{n}} \quad (2)$$

where CFn is the CF value of metal, n. When PLI is greater than 1, the soil is said to be polluted. PLI value equal to 1 signifies baseline level of pollution while PLI value less than 1 represents a non polluted areas.

(c) Degree of Contamination (Cdeg) can be expressed according to equation 3 (Hakanson, 1980):

$$Cdeg = \sum_{I=1}^{I=n} CF \quad (3)$$

Cdeg less than 8 indicate a low degree of contamination, Cdeg value greater than 8 but less than 16 signifies moderate contamination, Cdeg value greater than 16 but less than 32 stands for considerate degree of contamination while Cdeg values greater than 32 reflects high degree of contamination.

(d) Ecological Risk Index (Er) is toxicity response factor, which can classify levels of heavy metal toxicity according to ecological risk magnitude (Hakanson, 1980);

$$E_r = T_r \times CF \quad (4)$$

When Er< 40 the risk factor is classified as low ecological risk, E_r values in the range, 40 <Er ≤ 80 indicates moderate ecological risk. The other ranges are, 80 <Er ≤ 160 for considerable ecological risk, 160 <Er ≤ 320 for high ecological risk whereas Er> 320 indicates serious ecological risk

(e) Potential Ecological Risk (PERI). This is calculated as the sum of all risk factors for heavy metals in the soil and is expressed as (Xu *et al.*, 2008);

$$PERI = \sum_{I=1}^{I=n} E_r \quad (5)$$

PERI< 150 = low ecological risk, 150 < PERI < 300 = moderate ecological risk, 300 < PERI < 600 = high potential ecological risk, PERI ≥ 600 = significantly high ecological risk.

Calculated contamination factors (CF), pollution load indices (PLI) and degree of contamination (Cdeg) for the studied heavy metal ions are presented in Table 5. CF for the metals in samples from Eleme and Ahoada were between 1 and 3 indicating moderate contamination. CF for Fe, Zn and Cu in Oyigbo soil samples were all above unity indicating low contamination. However, CF for Cr and Ni at the same site indicated moderate and considerable contamination respectively. The PLI for all the spillage sites were above unity indicating that they were all polluted. Akudo (2016) determined the concentrations of Pb, Cu, Cd and Zn in twenty (20) surface soil samples (0- 15 cm depths) from two sites in Odioama Community in the Niger Delta which was impacted by oil spill and concluded that the CF calculated for Cd indicated considerable contamination in all the soil samples while the PLI values for all samples indicated pollution and Cdeg values pointed to very high degree of contamination in all the samples.

Table 5. CF, PLI and Cdeg of metal ions in the soil samples

Locations	CF for the Metals					PLI
	Fe	Zn	Cr	Cu	Ni	
Eleme	1.92	3.38	2.75	2.50	2.67	2.60
Ahoada	1.17	1.17	1.88	2.00	2.07	1.60
Oyigbo	0.59	0.64	2.93	0.99	4.03	1.34
Cdeg	3.68	5.19	7.56	5.49	8.77	

The Cdeg for all the metal ions in the three LGAs were all below 8 which equates to low degrees of contamination with respect to the studied heavy metal ions in the oil spilled sites.

The ecological Risk Indices (Er) and Potential Ecological Risks (PERI) are shown in Table 6. Er for all the metal ions at all the spillage sites in the 3 LGAs were below 40 indicating low ecological risk. Values for PERI also indicated low ecological risk since they were all below the threshold value of 150. Odigi *et al*. (2011) carried out a geochemical evaluation of heavy metal distribution in soils of Port Harcourt in the Niger Delta and concluded that Igeo values of 0.06, 0.02 and 0.00 for Pb, Cd and As indicated low-level contamination while that of Zn (1.14) indicated medium-level contamination. Aigberua *et al*. (2017), assessed the metal pollution indices of an oil spill contaminated soil in Rumuolukwu community, Niger Delta and calculated ecological risk factors of 4.6, 7.0 and 12.4 for Cr at the 0-15, 15-30 and 30-45 cm depths respectively which showed that the contamination level was low at these depths. The average of these Er values was 8 and this was higher than the Er values obtained for soil samples from the three LGAs of this study.

Table 6. Er and PERI of metal ions in the Soil Samples

Locations	Er for the Metals				PERI
	Zn	Cr	Cu	Ni	
Eleme	3.38	5.5	12.5	13.35	34.73
Ahoada	1.17	3.76	10.0	10.35	25.28
Oyigbo	0.64	5.86	4.95	20.15	31.60

4.0 Conclusion

From the result and findings of the present study on heavy metal ions (Cr, Cu, Fe, Ni and Zn), it is found that in Eleme, contamination ranges from low to moderate contamination expect for Zinc where it showed considerable contamination factor. However, zinc contamination does not pose a serious environmental threat. In Ahoada, the result indicated low to moderate contamination for all the studied heavy metal ions Oyigbo is also characterized by low to moderate contamination for all the heavy metal ions expect for nickel ion that had a contamination factor of 4.03, which points toward considerable contamination. Calculated pollution load index indicates that Oyigbo and Ahoada were within the range of low pollution level while that of Eleme were polluted. Low degree of contamination was observed for all the heavy metal ions except nickel ion which had recorded value of 8.77 that translate to moderate degree of contamination. Calculated trend for ecological risk was consistent with the order, Ni > Cu > Cr > Zn > Fe for Eleme and Ahoada but Ni > Cr > Cu > Zn >Fe Oyigbo. Generally, from calculated ecological risk factors, the current risk in the studied area is low.

5.0 References

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