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EFFECT OF DRILLING WASTE ON SOIL QUALITY IN AN OIL PRODUCING COMMUNITY OF THE NIGER DELTA REGION OF NIGERIA

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ABSTRACT
The disposal of drilling waste on agricultural land may adversely affect soil quality but few studies to date have addressed the problem. The central goal of this study is to determine the extent to which soil quality parameters of Opukushin community, in the heart of the Niger Delta region, were affected by drilling waste dumped by oil companies in the area. Soil samples were collected at the depth of 0-15cm from two impacted (sites A and B) and control (site C) sites. The physic-chemical properties of these samples including the concentration of some trace metals were analyzed using different statistics. Results obtained showed that there was spatial inequality of variance in means of these indicators ($p<0.05$) The variability of pH decreased with increasing concentration of PAHs. Several parameters correlated with one another. Clay correlated positively with sand density (0.95) and K (0.09) silt correlated positively with pore size (0.95) and lead (0.85) while pH correlated positively with PO_4^{-3} (0.96) and NO_3^- (0.91). The concentration levels of PAHs and chromium of the impacted soils were considerably high. In conclusion it was observed that drilling waste greatly contaminated the soils of agricultural land of the studied community, a situation which calls for urgent intervention of federal authorities to checkmate indiscriminate dumping of such waste by oil companies operating in the area.

KEYWORDS: contamination, drilling waste, Niger Delta, oil companies, Opukushin, soil quality.

INTRODUCTION

In the past four decades, the Niger Delta Region of Nigeria has been experiencing a lot of environmental problems resulting from oil exploration and exploitation (Nkwocha and Duru, 2010; Okpara, 2004). Environmental mediums such as air, water and agricultural soils have suffered considerable degradation, a situation which has attracted a broad spectrum of research interests. Consequently, different studies have been carried out to investigate the effect of flaring Associated Gas (AG) on the built environment (Nkwocha and Pat-Mbano, 2010; Olukoya, 2008), oil spillage on vegetation (Daniel-Kalio and Braide, 2008; Emerole, 2008) and on food crops (Akwuiwu et al 2002, Obili and Ogunyemi, 2002). There were also studies on the effect of oil pollution on human health (Omoweh, 2002), on biodiversity (Ekwezor, 2003), on community conflicts (Kemedi, 2003; Akpobibibo, 2001) and on rural water supply (Nkwocha, 2009). Most of these researches presented results and findings of high scientific and political interests. On the contrary, few researches have been carried political interests. On the contrary, few researches have been carried out to investigate the effects of drilling waste on soil of agricultural lands which constitute the fulcrum of rural existence in this region. Drilling waste consists of drilling fluid and diverse chemicals used in drilling operations in order to achieve specific results at a given site (Idodo-Ume and Ogbeibu, 2010). A close observation on these few researches showed polarized results. While earlier studies, mostly financed by Multi-National Oil Companies (MNOCs) operating in the area, surprisingly contended that drilling waste has limited or no effect on soil quality and the environment (Udo and Fayemi, 1975; Odu 1982; Sada, 1988), recent findings showed that these wastes contain available minerals which help plants to grow (Duru, 2009; Osuji et al, 2005; Uffot et al 2003). In all these studies, analysis on the characterization of the physical and chemical properties of the impacted soil, and even their level of toxicity was perfunctory and hasty. It was based on this lacuna that most MNOCs chose to dispose of their drilling waste on agricultural lands despite serious recommendations to pre-treat these wastes before disposal as contained in the Environmental Impact Statements (EISs) and Environmental Management Plans (EMPs) on all the drilling sites. The goal of this study was to determine the extent which drilling waste affected the soil quality in one of the oil producing communities in the region. This will help to increase the level of mechanistic understanding of this growing problem in the area.

METHODOLOGY

Study Area

This study was carried out at Opukushi, a rural oil producing community in Delta State of Nigeria. It lies on the low undulating terrain of the Niger Delta within Latitude 05^0 31'N and longitude $05^0$44'E in Warri South-West Local Government Area of the State. With an area of 1184 square kilometers, a good climate, vast and fertile agricultural land, the local population turned to land for their existence. These people are basically subsistence farmers who subsidize their diet by fishing and hunting. Characterized by periods of high rainfalls (March to October) and dry seasons (November to February), these farmers practice crop rotation and depend on rain-fed agriculture to produce different crops such as cassava, yam, maize, plantain, melon, banana and various vegetables which form their major staples. In addition, this community is blessed with oil reserves, which have been exploited for the past three decades by the MNOCs; especially Shell and Chevron. Presently, more oil wells have been opened up with the result that oil exploitation occupies a major position in the community's landscape. The activities relating to oil have led to the doubling of population of Opukushi. The land on which the rural population stakes her life is gradually rendered derelict due to indiscriminate dumping of drilling waste produced from more than 8 drilling sites in the area. There is limited evidence to suggest that drilling waste has limited or broad effects on local soil quality.

Data Collection

The research was designed to observe, gather, analyze and interpret data obtained from soil samples collected from the area. In this study, a completely random design was adopted due to the undulating nature of the terrain. Three independent soil samples were collected from three different sites designated Site A, Site B and Site C. Site A was a freshly impacted site, Site B was where the drilling waste was deposited after a six-month period, while Site C was the control site located at 500 meters from site B. The latter is located at 80 meters from Site A. The collection of soil samples was facilitated with the use of hand auger, at a depth of 0-15cm at around 10am in mid August 2010. Each sampling point was defined by laying out a 30-meter diameter sampling ring and the three equally-spaced cores were collected within the ring. All sample location coordinates were established using global position system procedure for future references. The collected samples were bagged, numbered, sealed and stored in ice blocks (4^0C) before being transported to the UNIDO Regional Laboratory Centre Owerri for analysis. Soil quality has been associated with its productivity, capacity to sustain biological diversity, environmental quality as well as plant and animal health (Monteiro 2005, Sarkar 1998). Based on this premise, soil quality parameters analyzed include sand, silt, clay, pore size, bulk density, pH, infiltration rate, total organic carbon (TOC), polycyclic aromatic hydrocarbons (PAHs), sodium (Na), potassium (K), sulphates (SO_4^{-2}) nitrates and some heavy metals associated with oil drilling and pollution (Barium (Br), Lead (Pb), Ascenic (As,) and Cromium (Cr) using B.S. 1377 (1975) guidelines.

Statistical Analysis

To assess the effect of drilling waste on soil quality, descriptive statistics were explored through analysis of mean, standard error, range etc. The mean values were used to represent concentration levels of each parameter category. The Pearson's two-tailed correlation coefficient was used to test for correlation of the soil data set. The odd-ratios for the data obtained on soil quality parameters above the standards were calculated using logistic regression models. The statistical significance was assessed at the 95% level. The statistical analysis was done using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Results obtained from laboratory analysis showed wide variations in some physical and chemical parameters of the soil samples from the impacted and control sites. For example, pore size of these samples varied between 26.20 and 38.90 (mean 33.20-1.8), and bulk density between 2.40–3.12 (mean 2.76-0.80g/l). In the same vein, wide variations were obtained on the values of heavy metals such as lead varying between 19.00 and 50.18mg/kg (mean 30.01-4.17 mg/kg), chromium between 15.20 and 35.25mg/kg (mean 26.00-2.73mg/kg), barium between 63.15 and 140.10mg/kg (mean 98.50 -9.23mg/kg), and PAHs between 0.00 to 290.12mg/kg (125.8-38.79mg) as indicated in Table 1. Slight variations were recorded in clay with range between 10.20% and 13.20% (11.84-0.40), silt 70.00% – 78.40% (73.70- 1.22), sand density 0.25g/l – 0.68g/l (0.44-0.05), Na 0.84mg - 1.42mg/kg (1.10-0.10); K 0.60mg-1.60mg/kg (1.04- 0.24) and pH between 5.00 and 5.80 (5.30-0.11). Spatial variations were equally observed on these parameters. For textual classification, clay composition was highest at sampling Site B (13.1%) while the least value was recorded at sampling Site A (10.30%); silt composition was highest at the freshly impacted site A (78.20%) while the least was obtained at Site B.

Table 1: Descriptive statistics of the physical and chemical parameters of soil samples

Parameters	Range	Minimum	Maximum	Mean	
	Statistic	Statistic	Statistic	Statistic	Std. Error
Clay %	3.00	10.20	13.20	11.8444	.39655
Silt %	8.40	70.00	78.40	73.7000	1.21735
Sand %	5.90	11.10	17.00	14.4556	.82397
Bulk Density g/L	.72	2.40	3.12	2.7689	.08926
Clay Density g/L	1.96	.24	2.20	.8878	.29881
Silt Density g/L	1.53	.43	1.96	1.4422	.24668
Sand Density g/L	.43	.25	.68	.4478	.05847
PoreSize %	12.70	26.20	38.90	33.2000	1.79490
pH	.80	5.00	5.80	5.3000	.10672
TOC %	1.60	3.30	4.90	3.8800	.20469
Na mg/kg	.58	.84	1.42	1.1056	.06327
K mg/kg	.154	.06	1.60	1.0378	.24043
Pb mg/kg	31.18	19.00	50.18	30.0111	4.16715
Cr mg/kg	20.05	15.20	35.25	25.9500	2.72798
Ba mg/kg	76.95	63.15	140.10	98.4767	9.23120
PAHs mg/kg	290.12	.00	290.12	125.8467	38.79711
Sulphate mg/kg	11.73	14.45	26.18	18.7644	1.55056
Phosphate mg/kg	8.95	9.45	18.40	12.8411	1.25213
Nitrates mg/kg	11.00	11.10	22.10	15.2278	1.53899

On the other hand, pore size was highest at Site A (38.50%) while the least was at site B (26.20%). Sand and sand density values were highest at Site B with 17.0% and 0.67g/l and appeared least at Site A with 11.10% and 0.25g/l respectively as shown in Table 2.

TABLE 2: Result for Physical Parameters

S/N	PARAMETERS	SITE A (0-15cm)					SITE B (0-15cm)					SITE C (0-15cm)				
		1ST	2ND	3RD	(x)	S.D	1ST	2ND	3RD	(x)	S.D	1ST	2ND	3RD	(x)	S.D
1	Clay (%)	10.5	10.4	10.2	10.3	0.12	13.0	13.2	13.0	13.1	0.09	12.1	12.2	12.0	12.1	0.08
2	Silt (%)	78.4	78.2	78.4	78.2	0.16	70.0	70.2	70.1	70.1	0.08	72.5	72.5	73.0	72.7	0.24
3	Sand (%)	11.1	11.4	11.4	11.1	0.05	17.0	16.6	16.9	21.3	0.08	15.4	15.3	15.0	15.3	0.08
4	Bulk density (g/l))	2.5	2.4	2.5	2.47	0.05	3.12	3.10	3.00	3.1	0.05	2.7	2.8	2.8	2.8	0.05
5	Clay density (g/l)	0.26	0.25	0.24	0.25	0.01	2.02	2.02	2.20	2.08	0.08	0.33	0.34	0.33	0.33	0.005
6	Silt density (g/l)	1.96	1.85	1.94	1.92	0.05	0.43	0.46	0.48	0.46	0.02	1.96	1.95	1.95	1.95	0.005
7	Sand density (g/l)	0.28	0.25	0.26	0.26	0.01	0.67	0.68	0.64	0.66	0.02	0.42	0.40	0.40	0.42	0.01
8	Infiltration rate	High	High	High	-	-	High	High	High	-	-	High	High	High	-	-
9	Plasticity/stickness	NP/NS	NP/NS	NP/NS	-	-	NP/NS	NP/NS	NP/NS	-	-	NP/NS	NP/NS	NP/NS	-	-
10	Pore size (%)	38.6	38.0	38.9	38.5	0.37	26.4	26.5	26.2	26.4	0.12	34.9	34.5	34.8	34.7	0.17

Source: Field Survey; 2010

TABLE 3: Result for Chemical Parameters

S/N	PARAMETERS	SITE A (0-15cm)					SITE B (0-15cm)					SITE C (0-15cm)				
		1ST	2ND	3RD	$(\bar{X})$	S.D	1ST	2ND	3RD	$(\bar{X})$	S.D	1ST	2ND	3RD	(x)	S.D
1	pH	5.20	5.00	5.10	5.10	0.08	5.10	5.20	5.00	5.10	0.08	5.80	5.80	5.40	5.70	0.19
2	TOC %	4.90	4.50	4.60	4.7	0.17	3.80	3.41	3.30	3.50	0.21	3.41	3.50	3.50	3.47	0.04
3	Na(meqK)	0.94	0.84	0.92	0.9	0.04	1.21	1.18	1.30	1.23	0.05	1.06	1.08	1.42	1.19	0.17
4	K(meqK)	0.06	0.08	0.10	0.08	0.02	1.60	1.54	1.42	1.52	0.07	1.42	1.52	1.60	1.51	0.07
5	Pb(mg/kg)	42.80	45.12	50.18	46.03	3.08	28.54	22.12	23.40	24.69	2.77	19.64	19.30	19.0	19.31	0.26
6	Cr(mg/kg)	30.32	31.40	35.25	32.3	2.12	28.32	30.2	32.1	30.21	1.54	15.46	15.20	15.30	15.32	0.11
7	Ba(mg/kg)	116.25	120.11	140.1	125.49	10.45	98.56	106.4	110.4	105.12	4.92	68.14	63.15	63.18	64.82	2.35
8	As(mg/kg)	BDL	BDL	BDL	-	-	BDL	BDL	BDL	-	-	BDL	BDL	BDL	-	-
9	$PAH_{(s)}$ (mg/kg)	113.59	100.08	120.25	111.31	8.39	258.58	250.00	290.12	266.23	17.25	0.00	0.00	0.00	0.00	0.00
10	SO_4^{2-} (mg/kg)	15.00	14.45	16.14	15.20	0.70	16.45	16.00	16.26	16.24	0.18	24.40	24.00	26.18	24.86	0.95
11	PO_4^{3-} (mg/kg)	10.12	9.45	11.18	10.25	0.71	11.18	10.15	10.21	10.51	0.47	18.18	18.40	16.70	17.76	0.75
12	NO_3^- (mg/kg)	12.20	12.32	11.10	11.87	0.55	13.21	13.20	11.18	12.53	0.95	20.42	21.32	22.10	21.28	0.69

Source: Field Survey; 2010

TABLE 4: Test of Homogeneity of variance in means (spatial)

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	57	1435.83	25.19	1908.827
Column 2	57	114	2	0.678571

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*Fcrit*
Between Groups	15326.62	1	15326.62	16.05297	0.000111	3.925834
Within Groups	106932.3	112	954.7527			
Total	122258.9	113				

Results on heavy metals showed maximum mean values of Pb and Cr at Site A (46.03mg/kg and 30.21mg/kg respectively), while minimum values were recorded at Site C. Also, the highest mean concentration values for Br was highest at Site A (125.49 mg/kg) and PAHs at Site B (22.6mg/kg) while the least values were recorded at Site C for the three parameters. An opposite trend was observed for the values obtained on sulphates, nitrates and phosphates where the maximum mean concentration values were recorded at Site C; with 24.86mg/kg, 17.76mg/kg and21.28mg/kg respectively while the least values were obtained at Site A with 15.20mg/kg, 10.25mg/kg and 11.87mg/kg respectively as indicated in Table 3.

These results show that there was spatial inequality of variance in means of these parameters investigated. The test of homogeneity of variance in means of the physical and chemical parameters revealed significant spatial inequality ($F_{(16.05)} > F_{crit(3.93)}$ at $p < 0.05$ as shown in Table 4.

The variability of pH decreases with increasing concentration of PAHs. Several parameters correlated significantly with one another. For example, at p<0.05, clay correlated positively with sand (0.75), bulk density (0.96), Na (0.76) and at p <0.01 correlated with sand (0.95), K (0.92) and sand (0.95). Silt correlated with pore size (0.90), TOC (0.91) and Pb (0.85). Equally, pH correlated with Ba (0.86), SO_4^{-2} (0.89), and PO_4^{3-} (0.96). Na correlated with K (0.83). Negative correlations were also recorded between clay and silt, pore size, TOC and Pb as clearly indicated in Appendix I.

There is strong evidence that significant difference exist between the mean of soil quality indicators in the soil samples impacted with drilling waste and those not impacted with the waste. The results obtained on the impacted soils at sites A and B showed that the physical and chemical properties of these soils such as bulk density, texture, etc which govern the development of the root system of plants (Khitoliya 2004) were greatly affected by drilling waste. For example, the high bulk density recorded at site B and to a smaller extent at the newly impacted site A decreases water infiltration rate and therefore affects plant root penetration (Lekwa et al 2004; Ekundayo and Fagbemi, 1996). The high concentrations of phosphates, sulphates and nitrates including potassium and other minerals at these impacted sites may be available to plants, but at high pH values, some of them may combine to form insoluble compounds which reduce nutrients solubility thereby causing their unavailability to plants (Coscione *et al*, 2009). It is also evident that drilling waste increased the concentration of heavy metals in the soils thereby increasing the toxicity of these soils which retards plant growth (Mckelvey *et al*, 2007; Hart *et al* 2005), and invariably contaminate the food chain of the local population (Duru, 2009). As the organic matter contents of these impacted soils were low, by reason of the low concentrations of total organic carbon, it suggests low chelating activities of drilling products including phosphates (Osuji and Onojake 2004). Despite the same range of soil pH values recorded at the three sites, it was observed that the rate decrease in concentrations of the trace metals were still high at Site B than at Site A. This could be attributed to the age of the exposed contents of drilling waste which might have given room to interactions of natural processes at the impacted sites as these results are consistent with other research findings (NRC, 2007; Russom 2002).

All these changes in soil parameters of the two impacted sites suggest that they have been polluted by drilling waste as most of the values obtained exceeded established national standards. The most astonishing fact is that the MNOCs continue the practice of disposing of their drilling waste on the agricultural lands of Opukushi and other host communities despite the observed dangers to local soils and environment. These companies are much more concerned about the gains that accrue to them through oil extraction than preoccupying themselves with the damages done to the environment. Consequently, the continued pollution of agricultural soils of Opukushi and other host communities has led to the feelings of neglect, bitterness, anger, frustration and sometimes protest about the economy of oil which has shaped and reshaped the local economics (Akali, 2007). At present, the relationship between Opukushi community and the MNOCs is undermined by loss of trust and hostility, to the extent of an increasing resort to extra-legal means of settling disagreements such as subversion, violence and disruptions of oil extraction activities (Ikelegbe, 2004). All these actualities and observations go a long way to buttress the arguments that the problems of the Niger Delta Region, its underdevelopment, unjust treatment, repression and violence result from the non-challance attitude and neglect on the part of the MNOCs in their host communities in the area (Ugbomeh and Alubi, 2011). The onus still lies on the federal authorities on the strict enforcement of the provisions of laws on petroleum extraction and most especially on operational guidelines stipulated in the various EISs and EMPs prepared before the commencement of oil extraction at various sites. It is also pertinent to inform local farmers at Opukushi on the dangers of working on land contaminated with drilling waste. They should not be allowed to work bare-footed in these areas and should be subjected to periodic medical checkups in order to detect short-term and long-term effects of direct exposure to these lands. If the oil companies operating at Opukushi and its environs should pre-treat its drilling wastes before disposal, these observed effects on local soil quality will be reduced to the barest minimum.

REFERENCES

Akali K N (2007) The state identity and new forms of conflict in the Niger Delta. "Paper presented for the 4th Congress of the Association of African Histman: society, state and identity in African History". *Jointly organized by the Dept of History, Addis-Ababa University and Forum for Social Sciences Addis-Ababa 22th -25th May.*

Akpobibibo O P (2001) Sustainable development as a strategy for conflict resolution: The case of the Niger-Delta.http://www-org/featuresniger.delta.html (No5/2001).

Akwiwu C D, Nwajiuba C U and Nnadi F N (2002) Oil pollution and agro-forestry practices of farmers in Imo State: Implication for household livelihood. Paper presented at 36th Annual Conference of the Agricultural

Society of Nigeria held at the Federal University of Technology Owerri. October 20 -24.

BS1377 (1975) Methods of test for soils for engineering purposes. 2.6.2, Test (6A), Methods for test of chemical properties p.28.

Coscione A R, Abreu C A, Santo G (2009) Chelating agents to solubilize heavy metals from oxisols contaminated by the addition of organic and inorganic residues. *Science Agriculture* 66:103-106.

Daniel-Kalio L A and Braide S A (2008) The Impact of accidental oil spill on cultivated and natural vegetation in wetland area of Niger Delta, Nigeria. *Ambio: A Journal of the Human Environment* p.441-442.

Duru P A (2009) An analytic study of the effect of oil pollution on soil and vegetation of oil producing areas of Imo State. *Unpublished PhD Thesis. Imo State University Owerri p. 245.*

Emerole J (2008) Oil firms must stop gas flaring. *J of Environ and Sc* 3 (2):66-74.

Ekwezor I (2003) Biodioversity and the oil industry in the Niger Delta: A sensitive environment. *Journal of Nigerian Environmental Society* 1 (1):23-28

Ekundayo E O and Fagbemi A A (1996) Land use/Land cover and its association with soils of Oyo State in South West Nigeria. *Int J. of Trop. Agric* 14:21-33.

Hart A D, Oboh C A, and Sokari TG (2005) Concentrations of trace metals in crops harvested in some oil exploiting locations in River State. *Afric Journal of Food and Nutrients Sciences* 5(2):34-39.

Idodo-Ume, G. and Ogbeibu, A.E (2010) Bioaccumulation of heavy metals in cassava tubers and plaintain fruits grown in soils impacted with petroleum and non petroleum activities. *Research J Env Sc* 4:33-41

Ikelegbe A I (2004) Crisis of resistance: Youth militias, crime and violence in the Niger- Delta Region of Nigeria. African Studies Centre Seminar, Leidan,The Netherlands, 5th August.

Kemedi D.V (2003) Community conflicts in the Niger Delta: Petro-weapons or policy failure? Berkeley Workshop on Environmental Politics Working Paper. WP 03-12 Institute of International Studies, University of California, Berkeley.

Khitoliya R K (2004) Environmental pollution, management and control for sustainable development. (1st ed), S. Chand (ed). S. Chand and Co Ltd. New Delhi p. 309

Lekwa G, Ugwu O T, Lekwa M U (2004) Soil description and management practices. Imo State of Nigeria CMD/IITA Project p.106.

Mckelvey W, Charon G R, Jeffery N (2007) A bioaccumulation study of lead, cadmium and mercury in the blood of New York City Adults. *Environ Health Perspect* 115(10): 1435-1441.

Monteiro R T (2005) Soil quality indicators. *Agrociencia Montrerideo*. 9:255-257.

Nkwocha E E (2009) Water supply deficiency and implications for rural development in the Niger Delta Region of Nigeria *Springer Soc Indic Res*, 90:409-418.

Nkwocha E E and Duru P N (2010) Micro-analytic study on the effect of oil pollution on local plant species and food crops. *Advances in Bioresearch*, Vol.1(1):189-198.

Nkwocha E E and Pat-Mbano E C (2010) Effect of gas flaring on buildings in the oil producing rural communities of Rivers State, Nigeria. *African Research Review*, 4(2):90-102.

NRC (National Research Council) (2007) Toxicity testing in the 21st Century: A vision and a strategy. Washington DC: National Academic Press.

Obili O P and Ogunyemi S (2002) The use of maize as an indicator crop and in the reclamation of farm land laden with heavy metals as a result of crude oil pollution. Paper presented at the 36th Annual Conference of the Agricultural Society of Nigeria held at the Federal University of Technology, Owerri. October 20 -24.

Odu C T (1982) Study of environmental and social impact of oil spillage in the Oyakama area. *Snamprogetti S.P.A TETEC/AMB*/59/82 Milan.

Okpara E E (2004) Post-Rio realities of sustainable development in the Niger-Delta Region of Nigeria. N-CoGEP-D Owerri, Ihem Davis Press p. 109.

Olukoya S (2008) Climate-Nigeria: Inefficient gas flaring remains unchecked. http://www.ipsnews.net/new (accessed, 15 February, 2010).

Omoweh D (2002) Environmental pollution and culture and health in Nigeria: The sad plight of the Ughelli oil companies. *African Spectrum*, 3 (2):30-36.

Osuji L C, Egbuson E J, Ojinaka C M (2005) Chemical reclamation of crude oil in undated soils from Niger-Delta, Nigeria. *Journal of Chemistry and Ecology* 21(1):1-10.

Russom C L (2002) Mining environment toxicology information: *Web Resource* 173 (1-2):75-88.

Sada O (1988) Environmental Issues and Management in Nigerian development. Lagos: Evans Brothers Limited p. 156

Udo, E J and Fayemi A A (1975) The effect of oil pollution on soil on germination, growth and nutrients uptake of corn. *Journal of Env. Qual* 4:337-344.

Ugbomeh B A and Atubi A O (2011) The role of the oil industry and the Nigerian state in defining the future of the Niger Delta Region of Nigeria. *Africa Research Review* 4(2):103-112.

Uffot O, Uwakwe VC, Akande O, Lekwa G (2003) The effect of oil exploration on the soils of Izombe in Imo State Nigeria. Paper presented at 28th Annual Conference of the soil Society of Nigeria at the National Root Crops Research Institute Umudike, Abia State. 4-7 November.

Appendix I: Correlation matrix of the physical and chemical parameters of soil samples

Parameters	Clay	Silt	Sand	Bulk p	Clay p	Silt p	Sand p	Pore	pH	TOC Size	Na	K	Pb	Cr	Ba	PAHs	SO_4^{2-}	PO_4^{3-}
Silt	0.995**																	
Sand	0.988**	-0.999**																
Bulk p	0.964**	0.953**	0.944**															
Clay p	0.793**	-0.765*	0.748*	0.863**														
Silt p	-0.756*	0.725*	-0.707*	-.839**	-.995**													
Sand p	0.951**	-0.934**	0.922*	0.979**	0.931**	-0.912**												
Pore size	-0.925**	0.908**	-0.896**	-0.954**	-0.962**	0.946**	-0.989**											
pH	0.171	-0.205	0.223	0.009	-0.442	0.491	-0.118	0.205										
TOC	-0.884**	0.908**	-0.916**	-0.764*	-0.500	0.443	-0.730*	0.697*	-0.443									
Na	0.767*	-0.784*	0.784*	0.764*	0.525	-0.471	0.713*	-0.651*	0.152	-0.763*								
K	0.928**	-0.947	0.953**	0.859**	0.531	-0.484	0.791	-0.737*	0.455	-0.944**	0.829**							
Pb	-0.844**	0.856**	-0.859**	-0.711**	-0.359	0.298	-0.647	0.588	-0.610	0.94088	-0.770*	-0.950**						
Cr	-0.277	0.318	-0.336	-0.112	0.358	-0.406	0.012	-0.096	-0.927**	0.543	-0.381	-0.584	0.720*					
Ba	-0.473	0.506	-0.519	-0.314	0.145	-0.196	-0.200	0.122	0.858**	0.676*	-0.530	-0.732	0.843**	0.973**				
PAHs	0.431	-0.390	0.369	0.565	0.891	-0.910**	0.673*	-0.735	-079*	-0.073	0.194	0.093	0.096	0.737*	0.568			
SO_4^{2-}	0.243	-0.297	0.323	0.101	-0.371	0.428	-0.030	0.120	0.890**	-0.566	0.462	0.577	-0.689*	-0.957**	-0.911**	-0.737*		
PO_4^{3-}	0.185	-0.242	0.269	0.034	-0.431	0.485	-0.103	0.184	0.960**	-0.501	0.281	0.511	-0.682	-0.952**	-0.887**	-0.778*	0.969**	
NO_3^-	0.224	-0.266	0.286	0.073	-0.409	0.453	-0.061	0.149	0.917**	-0.519	0.379	0.552	-0.682*	-0.989**	-0.947**	-0.778*	0.974**	-0.955**