IMPACT ANALYSIS OF SOIL CONDITION POLLUTED WITH OIL SPILLAGE IN OTU–JEREMI, DELTA STATE, NIGERIA

Ohwoghere–Asuma, O. and Aweto, K. E.
Department of Geology, Delta State University, Abraka, Nigeria. *Corresponding author. E-mail: ohwonero@yahoo.com.

Accepted 28th September, 2016

The implication of oil spillage is the degradation of land and water. Consequently, soil becomes infertile for farming and water un-potable for drinking. We investigated the impact of oil spillage on soil collected from depth of 150 cm. Soil affected and that not affected by crude oil spill from same geographical location were sampled and analyzed. Texturally, the soil is classified as fine, medium and coarse sandy and sandy loam. The sand fraction increased by 0.2% (86.174 to 86.414); silt by 53.5% (3.852 – 5.91) and clay decreased by 22.6% (9.916-7.672) when contaminated with petroleum. Physiochemical properties of $pH_{(H20)}$, $pH_{(kcl)}$, organic matter, organic carbon and nitrogen, exchangeable bases (Na^+, K^+, Mg^+ and Ca^{3+}), exchangeable acidity ($Al^{3+,}$ and H^+), effective cation exchangeable capacity, phosphorus, heavy metals ($Pb^{3+,}$ $Fe^{2+,}$ Ni^+, V^+, $Cd^{3+,}$ Cr^{3+} and Cu^{3+}) were analyzed in the laboratory by standard methods and compared. The $pH_{(H20)}$ of the unaffected soil increased by 5.17% (5.85 to.5.00); $pH_{(kcl)}$ by 4.25% (4.7 to 4.50); organic matter by 264.92%; organic carbon by 356.7% and organic nitrogen by 311.19% when contaminated with petroleum. Exchangeable bases increased in values (Na^+ by 80.94%, K^+ by 126%, and Ca^{3+} by 11.75%) except Mg, whose value decreased by 65%; ECEC by 35%; P by 67.1%; exchangeable acidity by 7.83%. Heavy metals were also released into the soil upon contamination with petroleum; Pb^{2+} increased by 46% (1.4 to 2.044); Fe^{2+} by 25.96% (512.788 to 646.1); Ni^+ by 19.11% (100.416 to 119.6); V^+ by 80.26% (3.86 to 6.658), Cd^{3+} by 55% (2.772 to 4.324) and Cr^{3+} by 47.98% (2.528 to 3.741). There was significant positive correlation between heavy metals and $pH_{kcl,}$ organic matter, carbon and nitrogen.

Key words: Otu-Jeremi, heavy metals, exchangeable bases and acidity, Western Niger Delta, crude oil spillage.

INTRODUCTION

Otu-Jeremi hosts oil exploration and exploitation companies, consequently many oil and gas wells are sited there. Most gas wells in the area supply gas to the Utorogun Gas Plant which in turn supplies gas to Ughelli Delta IV Power and Lagos Egbin Power for generation of electricity and to Agbara-Ota's industrial estate in Ogun State, Western Nigeria. The concentration of these oil related industries has made Otu-Jeremi one of the economic nerves of Nigeria like other Niger Delta regions. In spite of being endowed with natural resources, the town lacks basic infrastructural facilities like public water, road, health and other developmental facilities that are not proportionate to the millions of dollars that have been derived from the resources abounding in the region, a characteristic common to all oil producing communities in the region and peculiar to Nigeria alone as far as exploitation of oil and gas is concerned and consequently, the cause of the unrest associated with the Niger Delta.

Prior to the discovery of oil and gas as the mainstay of Nigeria economic, the people of Otu-Jeremi were engaged in subsistence farming. They planted food crops like cassava, yam, plantain, and cash crops like rubbers and palm trees and also engaged in fishing.

The community of Otu-Jeremi has over 48 production wells producing oil and gas as recorded in 2004, and the numbers may have increased since then. Aghalino (2000), Robert (1997), Ohwoghere Asuma et al. (2005) and Ozumba et al. (1990)

attributed the activities of oil and gas related industries to be responsible for land degradation in areas characterized by oil/gas exploration and exploitation. The production of oil and gas from land has contributed immensely to poverty as a result of the degradation of the land meant for agricultural purpose. IFPRI (2008) has reported that land degradation has a significant correlation with poverty. Poverty arises when there is decline in the fertility status of the soil and subsequently low agricultural yield as a result of land degradation occasioned by crude oil spillage.

The negative impact of oil exploration and exploitation activities in Niger Delta is reflected in the form of land degradation. Degradation of land in oil producing areas is majorly caused by the spill of crude oil from wellheads and pipe lines. In Nigeria, spillage is often due to the lack of maintenance of obsolete oil facilities; sabotage and vandals who destroy pipelines in order to claim compensation from the operators; delays in the detection of spillage due to slow response from the operators to outbreak of spillage.

Over thousands of oil wells and trunk flowlines that span over 47,000km are domiciled in the Niger Delta region. Consequently, the communities in the Niger Delta are liable to contamination arising from oil spillage and gas flaring. According to the annual report of the Department of Petroleum Resources in 1997, over 6000 spills have been recorded in Nigeria's forty years of petroleum exploration and exploitation. Between 1976 and 1996, 240 million barrels of crude oil were spilled from 647 incidents; of these, 54 million was recovered, while the remaining 186 million barrels were invariably lost to the environment. The amount of oil lost during these periods is alarming. The reason may be attributable to the slow instead of fast response to salvage the situation by the operators. The volume spilled that could not been recovered finds itself into land, groundwater as well as surface water as pollutants. The implication is degradation of land and water leading to soil infertility and un-portable drinking water.

The operational activities of most oil company span from exploration, through drilling to the construction of pipelines for the transportation of crude oil. Environment impact assessments of such projects on the hosts' environment are often carried out prior to the commencement of construction and drilling. However, the outcome of such impact studies is never made public. The need for independent study on areas where oil and gas exploration and exploitation is being carried has already been emphasized by Oduvwuedechies et al. (2000); according to them such independent studies on the impact of oil spillage are often rare. Consequently, the paper is aimed at complementing the shortfall of independent study on the impact of oil spillage on soils and to ascertain the degree of soil degradation in Otu-Jeremi.

MATERIALS AND METHODS

The study area is characterized by low lying topographic, with elevation of 5 m above the mean sea level. It is located at Ughelli South Local Government Area of Delta State, South-south region of Nigeria (Figure 1). The climate is humid and typical tropical region with two seasons: wet and dry seasons. The wet season usually spans from April to October and dry, from November to March. The mean annual rainfall is usually above 3000 mm; means temperature ranges from 27-35°C; it has colder and warmer temperatures associated with wet and dry season respectively. Like other communities in the delta, the study area usually experiences rainfall throughout the year, with over 80% of the rainfall concentrated in July to September, making the soil to be water logged.

Geologically, the soil of Otu-Jeremi is derived from the coastal plain sand, deltaic plain and Sombreiro and meander belt (Reyment, 1965; Short and Stauble, 1965). The soil types include uppermost organic and humus soil, clay, silt and sand; all are depositional products derived from terrigenous and detrital sediments by flowing rivers. The area is mantled by the upper Benin, median Agbada and basal Akata Formations. The detail lithologic description of the stratigraphy of the Niger Delta are contained in Reyment (1965) and Short stauble

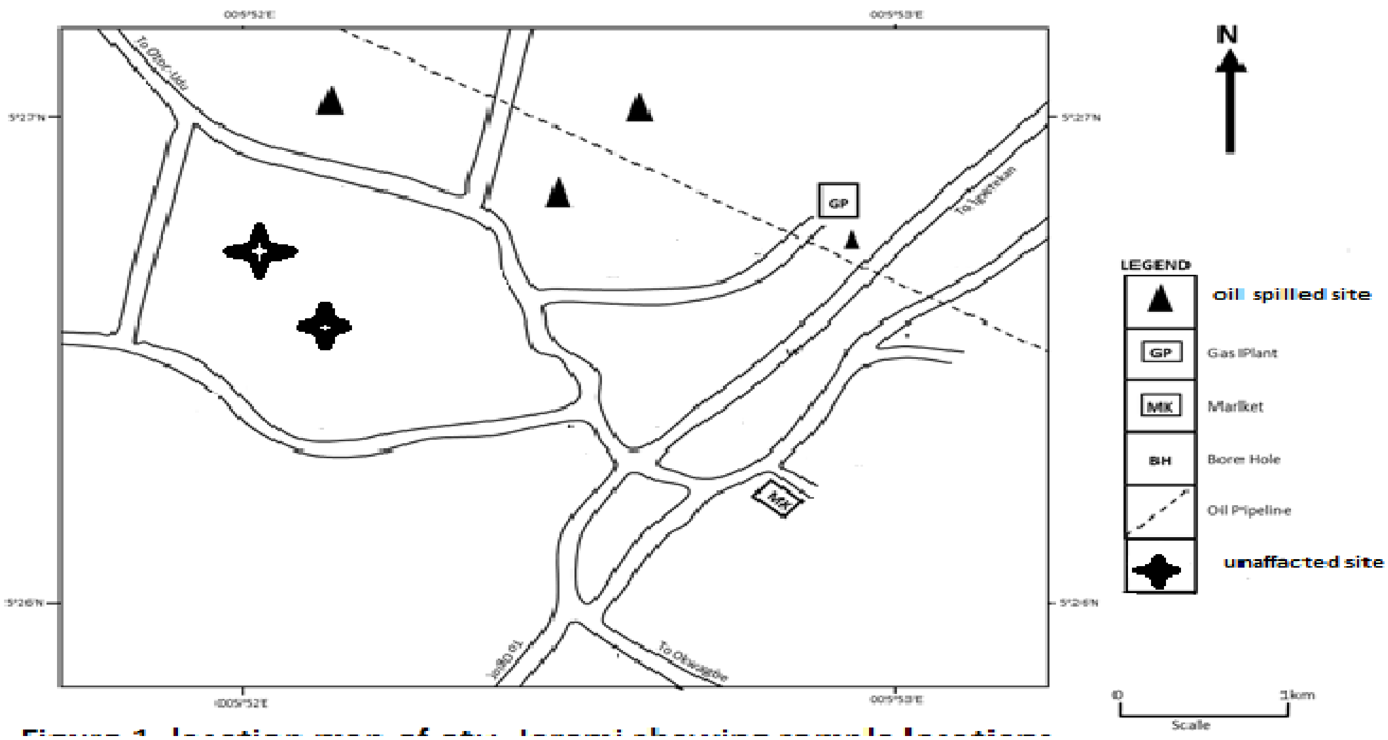

Figure 1. location map of Out-jeremi showing sample locations.

(1965) among others.

Sample collection

Soil profile pits were dug to depth of 150 cm into the soil in February 2006, a year preceding the 2005 oil spillage from Shell oil pipeline; one was dug in site not affected by the spillage, which served as control and the other in the site affected by spillage. Soil samples were taken from specific interval ranging from 0-150 cm. A total of 10 samples were collected from 2 locations, bagged, labeled and subsequently taken to the laboratory for heavy metals, physical and chemical analysis.

Laboratory analysis

Heavy metals were extracted from a solution of ammonium acetate, with pH of 4.8 and soil/solution in the ratio of 1:5. Sample was placed in an Erlenmeyer flask with 50 ml of extracted solution of ammonium and acetic acid. Mechanical agitation was done for 30 min and subsequently filtered in a dry flask with acetic acidic. Total concentrations (in mg/kg) of $Pb^{2+,}$ Fe^{2+}, Ni^{+} and V^{+},Cd^{3+}, Cr^{3+}, Cu^{3+} were determined by atomic absorption spectrophotometer Varian AAA 200 after calibrating with standard prepared in the acetate ammonium solution.

pH of the active acidity (pH_{H2o}) and reserve acidity (pH_{Kcl}) of the soil samples were determined by mixing a solution of 0.1

N potassium chloride with distilled water and soil in the proportion of 1:2:5 using Beckman zeromatic pH meter after equilibrating according to the procedure of Peech (1965). The method of Mathieu and Pieltain (2003) that utilizes oxidation of organic carbon by potassium dichromate ($k_2Cr_2o_7$) in acid medium was used for the detection of organic carbon. Organic nitrogen was determined by the method of Kjeldahl (Bremna, 1965); nitrogenous organic matter is mineralized by 98% hot concentrated suphate acid (H_2So_4). The carbon and hydrogen were reduced to dioxide, carbon and water. Nitrogen was converted to ammonium by H_2So_4. Exchangeable bases were determined by the method recommended by Jackson (1958), and exchangeable acidity was determined by titrimetric method using potassium chloride as the solution (McLean, 1965). Soil cation exchange capacity was determined by the ammonium acetate in congruent with Jackson (1958). Available phosphorous was determined based on the method prescribed by Bray and Kurtz (1945).

Statistical analysis

Simple statistical tool of correlation in the SPSS 10 was utilized to ascertain if simple relationship exists between heavy metals and some selected parameters and, subsequently it was presented in the form of correlation matrices table.

RESULTS AND DISCUSSION

The soils from the flat lying topography of Otu-jeremi town are characterized by particles whose shapes vary from angular to sub-angular block. The colour varies from dark grey through dark brown to yellowish brown. Texturally, the soil is classified as fine, medium and coarse sandy, sandy loam and loam. The sand fractions varied from 82.92 to 94.12%, a characteristic common to unconsolidated coastal plain sand, deltaic plain and Sombreiro and meander belt (Akamigbo and Asedu, 1986). The values of silts and clays are very low. The low value as suggested by Akamigbo (1984) and Sanchez (1976) indicates soils which have experienced some degree of leaching, erosion and the nature of the parent materials. This should be expected considering the heavy and almost all season rainfall that are common to the regions of the Niger Delta.

The sand fraction in the soil increased from 86.176% among the unaffected soil to 86.414% in the affected soil. The observed increment is occasioned by soil contaminated with crude oil. This extent of spillage is recognized by 0.2% increase in the value of sand in the affected soil (Tables 1 & 2). The increase tends to create a negative impact on growth of plants as the voids are blocked by oil, which is responsible for air displacement from soil (Chinda and Braide, 2000). The silt content of the soil also increased from 3.852% in the unaffected soil to 5.91% in the contaminated soil, representing 53.5% increment. However, the value of clay in the unaffected soil was lowered by the presence of oil from 9.916 to 7.672% in the affected soil, representing 22.6% drop in clay content. The perceived decline in clay content has an adverse effect on the water retentive capacity of the soil. The explanation is that available fine soil particles were replaced by larger particles of silts and sand fraction upon contamination.

The detailed results of the soil analysis for both unaffected and affected soils are displayed in Tables 3 and 4. The chemical properties of the soil reflect low presence of soil nutrients required for agricultural purpose. This may have been caused by leaching and probably due to oil exploitation over time. The pH of soil matrix

Table 1. Physical properties of Soils not contaminated with crude oil.

Parameter	Minimum	Maximum	Mean	Sd
Sand %	82.92	94.12	86.18	4.7398633
Silts%	1.70	6.76	3.852	1.7262955
Clay	4.18	12.96	9.916	3.6352585

Table 2. Summary of the physical properties of soil affected with crude oil contamination.

Parameter	Minimum	Maximum	Mean	S d
Sand %	79.97	95.15	86.414	5.3337739
Silts%	2.85	10.39	5.91	2.5576786
Clay %	2.00	10.88	7.672	3.5772078

Table 3. Summary of chemical properties of soils not contaminated with crude oil.

Parameters	Minimum	Maximum	Mean	Sd
pH (H_2o)	5.6	6.0	5.8	0.15811388
pH(kcl)	4.6	5.0	4.7	0.20736441
Organic matter %	0.94	3.45	2.158	1.12541992
C O%	0.15	0.64	0.418	0.20079841
N_2	0.05	0.16	0.1126	0.04840248
Na^+ (meq/100 g)	0.38	0.77	0.556	0.15469324
K^+ (meq/100 g)	0.89	1.34	1.114	0.18392933
Ca^{++} (meq/100 g)	0.99	1.82	1.524	0.33768328
Mg^{++} (meq/100 g)	0.3	1.2	0.7104	0.34044207
AL^{3+} (meq/100 g)	0.98	1.7	1.518	0.30792856
H^+ (meq/100 g)	1.57	3.18	2.65	0.69519781
EA	2.55	4.88	4.168	1.07927686
ECEC	5.11	10.01	8.072	0.43562599
Base SAT %	96.0	98	95.09	11.224549
P (mg/kg)	1.02	1.23	1.1432	0.0969082
Pb^+ (mg/kg)	1.04	2	1.4	0.38807216
Fe^{2+} (mg/kg)	57.99	2070	512.788	872.558499
Ni^+ (mg/kg)	20.1	200	100.416	90.4448157
V^+ (mg/kg)	2.36	5.22	3.87	1.28280942
Cd^{3+} (mg/kg)	1.08	4.45	2.772	1.45202273
Cr^{3+} (mg/kg)	1.87	3.1	2.528	0.59776249
Cu^{2+} (mg/kg)	0.98	1.4	1.2234	0.1760

Table 4. Summary of the chemical properties of soil contaminated with crude oil.

Parameters	Minimum	Maximum	Mean	Sd
pH (H_2o)	5.4	6.0	5.5	0.164913
pH(kcl)	4.4	4.8	4.5	0.216281
Organic matter %	4.30	15.79	9.875	5.149922
C O%	0.69	2.92	1.909	0.917147
N_2	0.21	0.66	0.463	0.199418
Na^+ (meq/100 g)	0.75	1.52	1.101	0.306293
K^+ (meq/100 g)	1.92	2.89	2.518	0.397287
Ca^{++} (meq/100 g)	2.13	3.91	3.277	0.726019
Mg^{++} (meq/100 g)	0.27	1.08	0.149	0.306398
AL^{3+} (meq/100 g)	0.72	1.45	1.28	0.225804
H^+ (meq/100 g)	1.30	2.65	2.58	0.821376
E A (meq/100 g)	2.02	4.10	3.86	2.799828
ECEC	7.09	13.50	10.905	0.352901
Base SAT %	84.24	118.3	63.25	13.69395
P (mg/kg)	1.70	2.05	1.909	0.161837
Pb^+ (mg/kg)	1.52	2.92	2.044	0.566585
Fe^{2+} (mg/kg)	73.08	2608.2	646.1	1099.424
Ni^+ (mg/kg)	23.92	238	119.6	107.6293
V^+ (mg/kg)	4.06	8.98	6.656	2.206432
Cd^{3+} (mg/kg)	1.69	6.94	4.324	2.265155
Cr^{3+} (mg/kg)	2.77	4.59	3.741	0.884688
Cu^{2+} (mg/kg)	1.42	2.03	1.7739	0.256102

(pH_{kcl}) for both the unaffected and affected soils is lower than the pH of soil water (pH_{H20}). Consequently, an acidic status is assigned, which is one of the major properties of soils in southern Nigeria due to excessive rainfall leading to removal of basic cations from the soil (James and Wild, 1975). The leached cations are subsequently replaced by the hydrogen ion (H^+) responsible for acidity (Ngobiri et al., 2007). This type of soil, however, is favourable for the availability of potassium in the soil (Cheng, 1997). The above fact has been corroborated by potassium as the second dominant cation after calcium of all the exchangeable bases. Although the soil of the study area is generally acidic, an increase in acidity of the soil is caused by contamination. This is reflected in the reduction of 0.2 and 0.3 in the values of pH_{kcl} and pH_{H2o} of the control site, which represent 4.3 and 5.2% increase in the acidity of the soil.

The organic matter which comprises organic carbon and nitrogen in the unaffected soil has adequate low value (0.94-3.45%). An increase of organic matter (4.30-15.79%) was observed in the contaminated soil: an increase of 264.92% in organic matter; 356.7% in organic carbon, and 311.19% organic nitrogen.

Calcium is more abundant of all the exchangeable bases of the soils, an indication of soil that must have been heavily weathered. The Ca-Mg ratio in both unaffected and affected soils by crude oil is greater than unity in all the samples. Similar results in support of this have already been obtained by Olade (1987), as well as Abii and Nwosu (2009). There is noticeable variation in the values of calcium in the unaffected soil and that of the affected soils. Calcium varied from 1.524 meq/100 g in the unaffected soil to 3.227 meq/100 g in the affected soil, an increase of 111.75%. Potassium increased from 1.114 meq/100 g in the unaffected soil to 2.518 meq/100 g in the affected soil, an increase of 126%. Apparently sodium varied from 0.556 meq/100 g in the unaffected soil to 1.101meq/100g in the affected soil, an increase of 80.94%. The perceived increment in sodium is in accordance with Odu (1972). Adam (1960) has shown that the recorded increase in sodium is not an index for effective productivity of plants in spite of being one of the essential trace elements needed for plants' growth. Magnesium, on the other hand, dropped upon contamination from 0.710 meq/100 g to 0.149 meq/100 g, a 65% magnesium drop in the unaffected soil.

The exchangeable acidity$^+$ and Al^{3+} (EA) detected are lower than the effective cation exchange capacity (ECEC) values, as a result of high values of base saturation that characterized the soils. The integral effect of exchangeable bases lies in their functions to control the acidity of the soil. In spite of this, the soils in the study area are acidic, a factor attributable to heavy leaching of the exchangeable bases by percolating precipitation. The low value of CEC is quite inadequate for the soils to be considered fertile. The value is lesser than 20 mg/1000 g required for a soil to be regarded as being fertile and sustainable for plants' growth (Green and Hayes, 1978; Ihegiamaizu, 1999). Table 5 shows a comparison of soil properties from Otu–Jeremi with some other oil producing areas in Delta State and a typical normal soil.

The CEC in the unaffected soil was increase

Table 5. Comparison of Otu-Jeremi with soil properties from chosen oil producing areas of Delta State and normal soils.

Parameters	Otu -Jeremi	Afiesere	Kokori	Normal soil
pH	5.6-6.0	5.1	6.7	6.8-8.2
% C	0.15-0.64	4.79	4.3	<500
% N	0.05-0.16	0.419	0.32	1%
P (ppm)	1.02-1.23	2.93	2.45	0.3%
ECEC meg/100 g soil	5.11-10.01	2.67	-	15
Base saturation %	96-98	77.53	-	50

Compiled from Odu et al. (1984), Okpidi et al. (1984), Sobolu et al. (1977) and Viets and Lindsay (1973).

by 2.833 meq/100 g on contamination in the affected soil, which is 35% increase over the value of ECEC in the unaffected soil. The EA in the unaffected soil dropped upon contamination with about 7.38% in the affected soil. The value of phosphorus (P) in the unaffected soil is 1.14 ppm, which is lower than the 12-15 ppm recommended by Odu et al. (1984) as adequate for fertile soil, even after the P has been increased by 67.1% on contamination in the affected soil.

Heavy metals concentrations in the soils are generally low. These values are within the range expected from a normal soil. Also, these concentrations are similar to those found by Viet and Lindsay (1984). Significant variation was recorded in the concentration of heavy metals in unaffected nor contaminated soil (Tables 3 and 4). Consequently, the following increments were recorded when contaminated with crude oil; Pb^{2+} increased by 46% (1.4 to 2.044); Fe^{2+} by 25.96% (512.788); Ni^{+} by 19.11% (100.416-119.6); V^{+} by 80.26% (3.86-6.658); Cd^{3+} by 55% (2.772-4.324) and Cr^{3+} by 47.98% (2.528 to 3.741). These heavy metals are present as organometallic compounds that migrate with hydrocarbon from the source to the reservoirs rocks. They also act as effective catalysts for the formation of hydrocarbon; hence they may have been active in promoting the formation of petroleum from organic remains (Goldschmidt, 1954). The observed increment in heavy metals is adduced to the components of petroleum, which affect the organic carbon, total nitrogen, nitrate, ammonium and exchangeable cation in the soil as demonstrated by Odu (1978). In addition, it may also be adduced to stoppage of the microbial activities of micro-organisms, mineralization and humification of organic matter as a consequent upon the pollution effect of petroleum. The implication of the increase in concentration of heavy metals is that underlying groundwater and surface water susceptible to contamination respectively. If contamination arising from spillage is not cleaned immediately and remediated at the appropriate time, overtime groundwater may be contaminated. The contamination of groundwater may be
facilitated by fluctuation of water lever which is often
close to the surface.

The ability of soil to release and retain pollutants such as heavy metals depends on the pH of the soil (pH_{kcl}) as well as its solution (pH_{H20}). Soils are often sinks for contaminants especially the unsaturated zone or vadose zone. Normally unsaturated zone contaminants are subsequently transported downward to contaminate groundwater. The addition of heavy metals to the soil by crude oil prompted the correlation of heavy metals with organic matter and other physiochemical parameters of the soil analyzed. Significant correlation was detected between heavy metals and pH of the soil (pH_{kcl}) and to a lesser extent on the soil solution (pH_{H20}). On one hand, the pH_{kcl} of the soil displayed positive correlation with pb^{2+} (0.71), Fe^{2+} (0.63), Ni^{+} (0.52) and V^{+} (0.60), exhibited no correlation with Cd^{2+} (0.27) and Cu^{2+} (0.17) and a negative correlation with Cr^{3+} (-0.263). On the other hand, the pH_{H20} of the soil is only positively correlated with Cr^{3+} and Cu^{2+}. The significant positive correlation between pH_{kcl} and pH_{H20} and the above heavy metals is attributed to their immobility, and as such are retained by being attached to the surface of the soil layer rich in organic matters.

Furthermore, a positive correlation between organic matter and heavy metals is also observed with an exception of Cr^{3+} (Table 5). The positive correlation recorded is attributable to the close association existing between heavy metals and organic matters; organic carbon and organic nitrogen. This is in accordance with the works of Pilchard et al. (2003), who demonstrated that heavy metals are often attachment to soil surface rich in organic matter in an acidic medium. The positive and inverse correlation obtained in this study shows that pH and organic carbon are not the only factors that affect the mobility of heavy metals in soils.

CONCLUSION

Generally, the soil in the study area is characterized by insufficient nutrients availability, relatively acidic and possessed organic matter that is insufficient to adequate. The acidic nature observed in the study is typical of rainforest soils, an attribute of excessive leaching of exchangeable bases from the topsoil.

The ability of soil to retain water is affected by contamination of crude oil as seen from the reduction of clay constituents which normally hold water. Soil water tends to flow through it more permeably as a result of the increase in the sand fraction of the soil upon contamination with oil spillage. The further downward movement of the crude into the soil may result in the blockage of the soil voids and displacement of air. This may result in the destruction of soil microbial activities and invariably affecting the nutrient status of the soil.

There is significant variation in the chemical properties of unaffected and affected soil respectively by crude oil contamination. The increased variation in the affected soil emanates from the inherent components of hydrocarbon, which were released into the soil on contamination. The recorded increase in the values of essential trace and heavy elements is not related to additional increase in the fertility of the soil because of the inhibition of soil air and microbial activities by crude oil.

Finally, the presence of heavy metals in any soil is promoted by the quantity of organic matter, nitrogen and carbon available in that soil (an acidic medium) as shown by the significant positive correlation between heavy metals and $pH_{(kcl)}$ and $pH_{(H20)}$ and organic matter (carbon and nitrogen).

REFERENCES

Abii, T.A. and Nwosu, P.C. (2009). Effect of oil spillage on the soil of Eleme in River State of the Niger delta area of Nigeria, Research journal of environment science,3(3).Pp.316-320.

Aghalino, S.O. (2000). Petroleum exploration and the agitation for compensation by oil mineral producing communities in Nigeria, J. Environ.Policy Issues, (1);1-11.

Akamigbo, F.O.R. (1984). The accuracy of field texture in a humid tropical environment, Soil Survey and Land Evaluation, (493): 63-70.

Akamigbo, F.O.R. and Asedu, C.L.A. (1986). The influence of toposequence on soil parameter in selected areas of Anambra state, south-south Eastern Nigeria. J.of Soil Science (6); 35-46.

Bray, R.H. and Kurtz, L.T.(1945). Determination of Total organic and available forms of phosphorus in soils. soil science, (59): 39-43.

Bremner, J.M.,(1965). Total Nitrogen, In Black et al., (Eds): Methods of soil analysis, part 11, Samen. Soc. Of Agwu, (9): 1149-1178.

Cheng, B.T. (1997). Soil organic matter as soil nutrient in the soil organic matter, Vienna (1), 21-30.

Chinda, A.C., and S.A Braide, (2000). The impact of oil spills on ecology and economy of Niger delta; proceeding of the workshop on sustainable remediation development technology, held at the institute of pollution studies, river state university of science and tech. Port Harcourt, Pp. 1-10.

Greenland, D.G and Hayes, M.H.B. (1978). The chemistry of soil constituents, 1st (Edn), John Wiley and Son Ltd London.

Ihejiamaizu, E.C., (1999). Socio-economic impact of oil industry activities on the Nigerian environment: the case of Ebocha gas plant and Brass terminal, Int. J.Trop. Environ, (1): 38-51.

James, M.J. and Wild A. (1975). Soils of the West African Savanna. Tech. Com. 55.pp 218-228.

Jackson, M. L. (1958). Soil chemical analysis: An Advanced course, University of Wisconsm, USA.

Mathieu, C. and Pieltain F. (2003). Analyse chrimque des sols: Methods choisies, Tech.& Doc Lavoisier, Paris, p.408.

McLean, E.O. (1965). Aluminum: In black et al, methods of soil analysis, part 11 1st Eds, Amer.Soc of Argon, Monograph, (9); 986-994.

Ngobiri, C.N., Ayuk A.A. and Awunuso, I.I. (2007). Differential degradation of hydrocarbon fraction during bioremediation of crude oil polluted sites in Niger delta area, J.Chem.Soc.Nig., (32)151-164

Odu, C.T. (1972). Microbiology of soil contaminated with petroleum hydrocarbon, J. environ Microboil, (59), 201-208.

Odu, C.T.I.(1978). Fermentation, characteristic and biochemical reactions of organism isolated from oil polluted soils. environment pollution, university of Ibadan, Nigeria,(15); 271-276

Oduwuederhie, I.G., Douglason, O., and N. Felicia Adu, (2006). The effect of oil spillage on crop yield and farm income in delta state Nigeria, J. Central Eur. Agric. (7), 41-48

Ohwoghere Asuma, O., Akpokodje O. and Juwah, H, (2005). Integration of Nigeriasat-1 and Internet Technology in Automatic Detection of oil spillage. International Journal of Science and Tech. Research 2.N. (1& 2), 160-166.

Okpidi, J., (1984). Soil Chemical Analysis, soil Sc. 105.225-248.

Olade, M.A. (1987). Heavy metals pollution and the need for monitoring; illustrated for developing countries in West Africa. In: Lead, Mercury, Cadmium, and Arsenic in the environment, Hutchson, C.T.C and K.M.Mean (Eds), John and Wiley Ltd, New York, 335-341.

Peech,M. (1965). Hydrogen in activity; In C.A. Black(Ed),Amer.Soc.of Argon (9);914-926.

Pilchard, A., Bisson, M., Hulot, C., Lefevre, J.P., Magaud, H., Oberson, G., Morin, A.D. and Pepin, G. (2003). Fiche de donnees toxicologique et environnementales des substances chimques: Plom et ses derives INERIS-DRC-01-25590-ETSC-Ap/Sd N000df257_version2.doc. p.83.

Sanchez, P.A., (1976). Properties and Management of soil of the Tropics, New York, Wiley.

Short, K.C. and Stauble, A.J., (1965). Outline of the geology of the Niger delta. Bull. AAPG (51),761-779.

Sobulo, R.A., Fayemi, A.A. and Agbools, A. (1977). Application of soil and plant analysis to nutrition of tomatoes in S.E Nigeria, Act. Hort. (53). 235-349.

Reyment,R.A. (1965). Aspect of the geology of Nigeria. Ibadan University Press, p.145.

Roberts, H.J. (1997). Oil contaminated soil and some reclamation, J. soil sci. 24. Pp. 231-245.

Viets, F.C and W.L. Lindsay, (1984). Testing soils for Zn,Cu, Mn and Fe. In: soil testing and plant analysis (eds LM. Walsh and J.D Bexton) soil Sci.Soc Am Inc. Madison.