Evaluation of Deviation of Some Soil Contamination Indicators Due to Oil Spillage in Akinima, Rivers State

Nwankwo, I L
Department of Geology, Faculty of Physical Science &Information Technology
College of Natural and Applied Sciences, University of Port Harcourt
East – West Road, Choba, Rivers State, Nigeria

Ekeocha, N E
Department of Geology, Faculty of Physical Science & Information Technology
College of Natural and Applied Sciences, University of Port Harcourt
East – West Road, Choba, Rivers State, Nigeria
Email: nnamdi.ekeocha@uniport.edu.ng

Ikoro, D O
Department of Geosciences, Federal University of Technology
Owerri, Imo State, Nigeria

***Abstract-* This study evaluates changes in the acceptable concentrations of some analyzed soil parameters due to oil spillage in Akinima, Rivers State, Nigeria. Twenty contaminated soil samples were collected from a spill site and four control soil samples from uncontaminated area within the community. The samples were analyzed in the laboratory for total petroleum hydrocarbon (TPH), heavy metals and hydrogen ion concentrations. The results of the heavy metals analysis on samples from the contaminated site were compared to the Department of Petroleum Resources (DPR) Target Value and the control value from uncontaminated sites and it was found showed that Zinc (with Target value of 140 mg/kg) ranged from 4.392 to 235.985 mg/kg with a mean value of 51.49615 mg/kg, Cadmium (Target value of 0.8 mg/kg) ranged from 5.2 to 9.35 mg/kg with a mean value of 7.031mg/kg, Chromium (Target value of 100 mg/kg) ranged from 1.02 to 13 mg/kg with a mean value of 7.6635mg/kg and Lead (Target value of 85 mg/kg) ranged from 12.97 to 109.2 mg/kg with a mean value of 7.6635mg/kg while the heavy metals analyzed from the control soil samples ranged in values from <0.001 to 0.05 mg/kg for Zinc, <0.001 mg/kg for Cadmium, <0.001 mg/kg for Chromium, and Lead ranged from below detectable limit (bdl) to <0.001 mg/kg. For the contaminated soil, the TPH (Target value of 85 mg/kg) ranged from 330.427 to 4365.667mg/kg and pH ranged from 4.8 to 6.97 respectively, while the control samples had TPH below detectable limits while pH values were 6.82-6.99. The heavy metals and TPH values from the contaminated soil were higher than the control values from the uncontaminated soil. The TPH values from the contaminated soil also exceeded the Target value while the mean pH value was within the acidic range. The parameters analyzed could be toxic when found above certain levels in soil and could be transported to groundwater even at greater depth and wider area into streams and other water bodies. It is recommended that plans such as oil spill contingency plan should be adopted effectively to minimize the magnitude of spillage and its effect and soil samples should be extensively analyzed to select an appropriate remediation measure.**

***IndexTerms*—Oil Spillage, Heavy Metals, Total Petroleum Hydrocarbon, Hydrogen Ion Concentration, Contamination**

I. INTRODUCTION

One of the impacts of crude oil spillage on soil properties is indicated by increased levels of petroleum hydrocarbon, acidic pH values, and increased concentration of heavy metals such as lead, zinc, cadmium, chromium (Meindinyo and Agbalagba, 2012; Ogboi, 2012;, Wegwu et. al., 2011; Madukosiri and Dressman, 2010; Ogbeibu, 2011; UNEP, 2011; etc). Deviation of these indicators in soil from their provisional or guideline values can result to adverse environmental and health problems and can also limit the use of the impacted soil. And if the soil does not undergo immediate or prompt remediation, the contaminants contained can be deposited into groundwater and other water bodies causing more damage.

Investigation of heavy metals is very essential since slight changes in their concentration above the acceptable levels, whether due to natural or anthropogenic factors, can result in serious environmental and subsequent health problems (Yahaya et.al, 2009). A number of them are essential at low concentration but become deleterious at high concentrations (Hudgson, 1954; Stanislav, 2004). Ogbeigbu (2011) stated that these metals are toxic in relatively high concentrations and nonbio-degradable but easily assimilated and bio-accumulated in the protoplasm of aquatic organisms e.g. Minamata Bay (Japan) mercury poisoning, Zamfara lead poisoning in Nigeria, etc.

A study by Ogbeibu (2011) revealed that heavy metals, especially Cd, Ni, V and Pb which have very strong positive correlation with THC and Total Hydrocarbon Content are better indicators of oil spill in any environment. Therefore emphasis was laid on these parameters in both sediment and water

Ekweozor *et. al.* (1987) studied the effect of chronic oil pollution in the Central Bonny estuary. The study reported reduced faunal density and diversity in sediments contaminated by oil from oil spill incidents. In extreme cases of pollution, there is complete absence of fauna from the affected site.

Soil can become acidified by anthropogenic processes such as oil spillage, and crude oil contains organic acids that can lower the pH of the soil. The loss of basic ions responsible for raising soil pH results in a reduced buffering capacity of the soil due to oil spillage (Osuji et. al., 2010). Odu et. al., (1985) stated that acidic pH values are not favourable for nutrient supply in agricultural soil. And the output of horticultural crop produce is significantly lower in oil and gas polluted farms than in non-polluted farms (Ojimba and Iyagba, 2012). Wegwu et. al. (2011) stated that acidic pH values are noticed in oil impacted sites.

Anthropogenic processes such as crude oil spillage are possibly one of the major factors responsible for the introduction of organic contaminants into the environment because most organic contaminants do not occur naturally in rocks and ore minerals (Birke, 2003). Increased level of total organic carbon/matter is usually noticed in affected soil (Wegwu et al., 2011). TPH exceeding 50mg/kg (which is the DPR Target value for TPH stated in the Environmental Guideline and Standard for Petroleum Industry in Nigeria (DPR, 2002)) in soil indicates that the soil is contaminated. United Nations Environmental Programme (UNEP, 2011) carried out an intensive and extensive investigation of the status of remediated sites belonging to Shell Petroleum Development Company in Ogoni land. The total petroleum hydrocarbon values for the investigated soil samples ranged from $157 mgkg^{-1}$ to $139{,}000 mgkg^{-1}$. These values are far above DPR target value. Existence of petroleum hydrocarbons above acceptable level in components of the ecosystem can induce negative health and environmental related problems.

Madukosiri and Dressman (2010) carried out a study on some biochemical parameters in *Gallus domesticus*, and heavy metal content of oil polluted areas of Yenagoa, Bayelsa State, Nigeria. Soil samples collected from Yenagoa (oil polluted) and Amassoma (non-oil polluted) areas of Bayelsa State were analyzed for heavy metal contents and hydrocarbon levels. The results showed that the hydrocarbon and heavy metal contents from contaminated soil were above WHO recommended levels.

It is very important to have an understanding of changes of measured soil parameters caused by oil spillage and an increased level of these parameters above recommendation shows deviation from soil sustainability. Adverse environmental and health conditions occur due to an increased level of this contamination indicators in soil. This study evaluates precisely some contamination indicators in oil spill contaminated soil with a view to maintaining ecological balance.

II. THE STUDY AREA

The study area is a spill site in Akinima (Fig.1), an oil and gas producing community in Ahoada West Local Government Area of Rivers State, Nigeria. It is located between latitudes 5.106097N and 5.106343N and longitudes 6.477516E and 6.480799E. The study area is a pipeline (facility right of way) located in Oshie Oil field, with numerous pipelines and flow lines found above the ground. The study area has a natural fresh water pond with fish, fresh water snails, and edible worms (grub).

The occupations of the people in the community are farming (cassava, plantain, and banana) and fishing. The area supports dense and lush vegetation with palm trees being dominant. The river in the study area is the Orashi River.

The study area is located in the southern lowlands in humid tropical zones and experiences a well distributed annual rainfall. The wet season is relatively long, lasting for about seven to eight months between the months of March and October. There is usually a short break around August, otherwise termed the "August break". The dry season begins in late November and extends to February or early March, a period of approximately three months. Evapo-transpiration is estimated at over 1000 mm annually (Ekundayo, 2006). Temperature is generally high, with average monthly maximum and minimum temperatures varying from 28^oC – 33^oC and 21^oC - 23^oC respectively.

III. GEOLOGY OF THE STUDY AREA

The study area lies within the Niger Delta region of Nigeria and the geology is typical of the Niger Delta sedimentary Basin.

The geology of the Niger Delta has been described extensively by Allen (1965), Reyment (1965), Short and Stauble (1967), Etu-Efeotor and Akpokodje (1990) and many others.

The three major depositional environments typical of most deltaic environments are observable in the Niger Delta (marine, mixed and continental) and are represented by the Akata, Agbada and Benin Formations (Short and Stauble, 1967). The geologic units of the Niger Delta are summarized in Table 1.

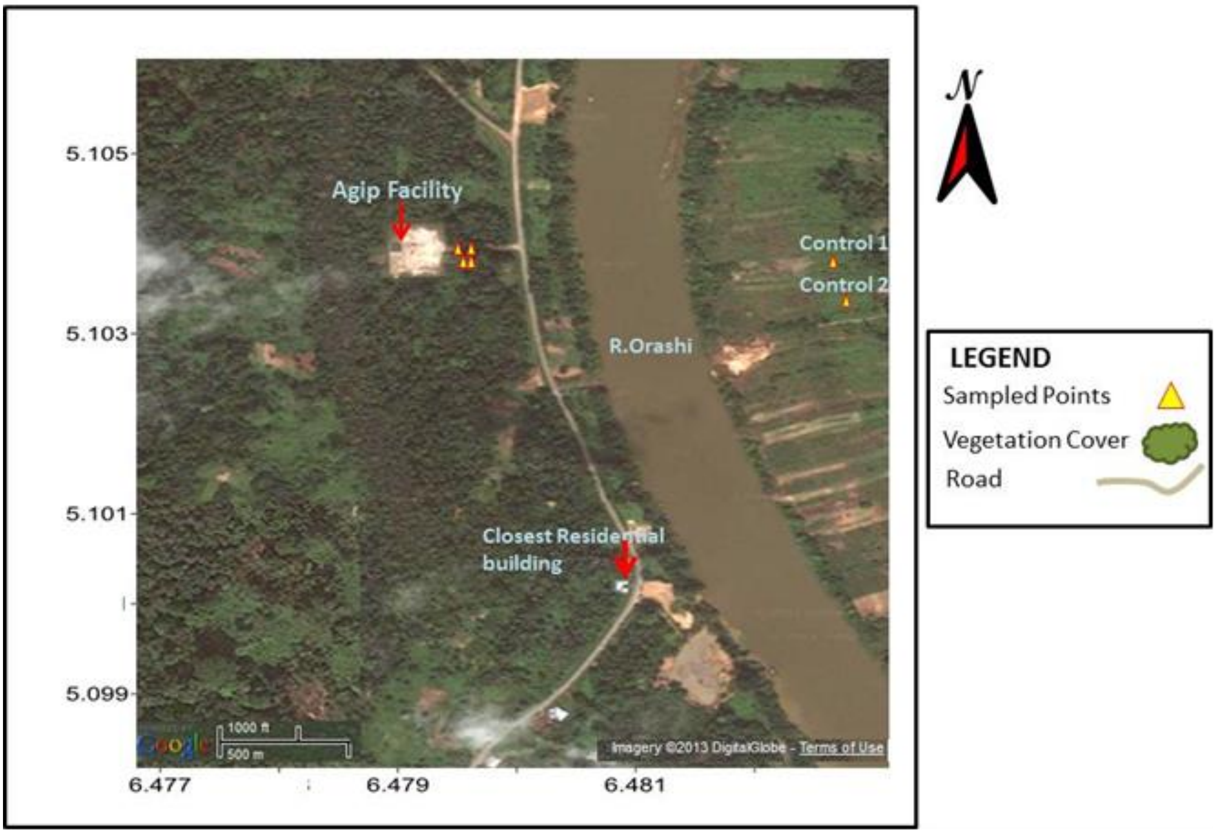

Fig.1: Map of the Study Area Showing Sampled Points (Google, 2013).

IV. MATERIALS AND METHODS

Twenty soil samples were collected from the study area with a 5" internal diameter hand auger from four points at one meter interval to 5m depth. Four control samples were collected at 1m interval to 2m depth from uncontaminated areas. All necessary precautions (accurate labeling, sample storage in appropriate containers and environment, immediate transportation to the laboratory) were observed during soil sample collection, transportation and storage. The soil samples collected were analyzed for Total Petroleum Hydrocarbon (TPH) using American Society for Testing and Materials method (ASTM D3921, 2003) and gas chromatography. Hydrogen Ion Concentration (pH) was determined using the pH meter and heavy metals (Lead (Pb), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Nickel (Ni), and Vanedium (V)) were analyzed using Atomic Absorption Spectroscopy (Varian Spectra AA 220FS).

Table 1: Geologic Units of the Niger Delta (Etu-Efeotor and Akpokodje, 1990).

GEOLOGIC UNIT	LITHOLOGY	AGE
Alluvium (General)	Gravel, sand, clay, silt	Quaternary
Freshwater back swamp, meander belt	Sand, clay, some silt, gravel	
Mangrove and saltwater/back swamps	Medium – fine sands	
Active/Abandoned beach ridges	Sand, clay, and some silt	
Sombreiro-Warri deltaic ridges	Sand	
Benin Formation (coastal plain sands)	Coarse to medium sand with subordinate silt and clay lenses	Eocene

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Agbada Formation	Mixture of sand, clay and silt	Eocene
Akata Formation	Clay	Paleocene

V. RESULTS AND DISCUSSION

The result of the soil analysis in Table 2 is evaluated using univariate statistical analysis and presented in table 3. The statistical values were compared to the DPR target value. The target value indicates the soil/water quality required for sustainability or expressed in terms of remedial policy, the soil/water quality required for full restoration of the soil's/water's functionality for human, animal and plant life. The target Values therefore indicate the soil quality levels ultimately aimed for.

From Table 3, the mean values for all heavy metals analyzed were below the target values given by DPR in EGASPIN except cadmium that exceeded its target value. The minimum values for the metals were also below the DPR target values with the exception of Cadmium. The maximum value for Zinc, Cadmium and Lead exceeded their target values in some locations at the spill site (Table 2). The control values for zinc ranged from 0.02-<0.001, cadmium is <0.001, chromium < 0.001 and lead ranged from bdl-<0.001. Zinc is an essential element and an integral component of many coenzymes, essential for DNA and RNA synthesis but toxic in higher concentrations but essential for a healthy life in small quantity.

Cadmium is an extremely toxic metal and an environmental hazard. It has no useful role in higher organisms (Horgan, 2010). Chronic cadmium exposures result in kidney damage, bone

Table 2: concentration of heavy metals, TPH and pH of the soil samples in the study area.

SAMPLE ID.	Depth (m)	Zn (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	pH	TPH (mg/kg)
A1	0-1M	84.495	9.30	9.40	109.20	5.10	1024.212
A2	1-2M	54.300	8.45	9.25	91.55	4.80	693.313
A3	2-3M	57.290	6.80	9.60	89.70	5.30	888.303
A4	3-4M	105.135	7.30	8.30	78.70	5.40	624.964
A5	4-5M	33.39	6.65	8.26	69.22	5.41	532.015
B1	0-1M	60.980	9.35	10.40	72.75	6.60	4365.667
B2	1-2M	57.690	7.40	13.00	90.75	5.90	1120.479
B3	2-3M	45.213	6.45	10.90	62.54	5.97	1022.643
B4	3-4M	53.498	5.94	12.23	59.55	5.97	798.203
B5	4-5M	39.022	6.43	9.35	60.39	5.99	777.490
C1	0-1M	23.400	5.25	4.45	19.55	6.20	330.427
C2	1-2M	17.370	6.35	3.30	37.00	6.40	745.593
C3	2-3M	4.975	7.29	1.26	28.52	6.97	397.293
C4	3-4M	4.392	6.34	1.22	30.29	6.41	399.970
C5	4-5M	6.773	5.20	1.02	30.22	6.44	473.209
D1	0-1M	235.985	6.35	10.65	54.90	5.70	1109.26
D2	1-2M	44.225	7.35	10.45	59.75	5.00	1603.570
D3	2-3M	55.29	8.69	8.54	54.34	5.04	1592.252

D4	3-4M	23.24	7.39	6.40	12.97	5.92	1329.254
D5	4-5M	23.26	6.34	5.29	15.29	5.87	557.29
CTRL A1	0-1M	0.02	<0.001	<0.001	BDL	6.82	BDL
CTRL A2	1-2M	<0.001	<0.001	<0.001	BDL	6.90	BDL
CTRL B1	0-1M	0.05	<0.001	<0.001	<0.001	6.97	BDL
CTRL B2	1-2M	<0.001	<0.001	<0.001	BDL	6.99	BDL

BDL: Below Detectable Limit, CTRL - Control Soil Samples, A1- D5: Contaminated Soil Samples

Table 3: Statistical Distribution of Analyzed Parameters

Parameters (mg/kg)	**Mean**	**Minimum**	**Maximum**	**DPR Target Value (mg/kg)**
Zn	51.49615	4.392	235.985	140
Cd	7.031	5.2	9.35	0.8
Cr	7.6635	1.02	13	100
Pb	56.359	12.97	109.2	85
pH	5.8195	4.8	6.97	-
TPH	1019.27045	330.427	4365.667	50

deformities, and cardiovascular problems (Goyer and Clarkson, 2001). Lead (Pb) has no biological role, and is potentially toxic to microorganisms (Sobolev and Begonia, 2008). Although Chromium (Cr) toxicity in the environment is relatively rare, it still presents some risks to human health since chromium can be accumulated on skin, lungs, muscles fat, and it accumulates in liver, dorsal spine, hair, nails and placenta. Cr is traceable to various heath conditions (Reyes-Gutiérrez et al., 2007).

The pH range of the spill - affected soil and control in Table 2 ranged from low value to medium value; this indicates high to medium acidity. The mean, minimum and maximum pH values in Table 3 were within the low pH (high acidity) range. The mean soil pH value is not within the range (6.5-7.5) given by Odu et al. (1985) for favourable nutrient supply in agricultural soil. Addition of lime to the soil can provide some buffering capacity to the soil.

The mean, minimum and maximum TPH values in Table 2 exceed the target value of 50mgkg^{-1} for oil and grease contamination in soil compliance limit for petroleum industries in Nigeria. The control values were below detectable limits and it represents the natural background level for TPH in the study area devoid of crude oil spillage. This is because most organic contaminants do not occur naturally in the lithosphere. And the anthropogenic processes such as crude oil spillage are one of the main factors responsible for the introduction of organic substances into the environment. Most petroleum hydrocarbons are carcinogens and human exposure to them can cause long term effect on the human body. High concentration of petroleum hydrocarbon in the oil impacted soil is capable of creating anoxic conditions in surface and sub-surface soils because the oil film reduces gaseous diffusion and increases the presence of anaerobic organisms which deplete available oxygen [Osuji et.al., 2005; Osuji, 2001). Associated toxicological problems linked with the exposure to high levels of hydrocarbons include blood and kidney problems, disorders of the central nervous system due to loss of myelin, and dermatitis when in contact with the skin (Bhatia, 2006).

Elevated values of these contaminant indicators could pose serious threat to human health and environment. From the review of previous studies, most of the heavy metals analyzed in this study do not have any role to play in the human body and are potentially harmful if found above acceptable concentrations in the environment. This calls for immediate attention because most living organisms depend on the soil for survival and humans also depend on it for agricultural purpose.

VI. CONCLUSION

The maximum value for Zinc, Cadmium and Lead exceeded their target values in some locations at the spill site. The mean, minimum and maximum TPH values in Table 2 exceed the target value of 50mgkg^{-1} for oil and grease contamination in soil compliance limit for petroleum industries in Nigeria. This therefore points to the need for immediate attention as most living organisms and human beings depend on the soil for survival and agricultural purpose.

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