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Effects Of Crude Oil Spillages On Agricultural Soil In Upenekang Village, Ibeno Lga Of Akwa Ibom State, Nigeria

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***Abstract*—A field study was conducted with the focus to assess heavy metal concentrations on crude oil contaminated soil in Upenekang village in Ibeno Local Government Area of Akwa Ibom State, Nigeria. Crude oil spillage has been identified to be a regular occurrence in this area as a result of crude oil exploration and exploitation. This study has been carried out to find out the effect of crude oil spill on soil and the environmental impact it has on the inhabitants of this area. Soil samples obtained from the crude oil polluted soil at varying distances of 10, 20, 30, 40, 50, 60, 70 and 80 metres and a sample of unpolluted soil (control) at the study area were digested and analysed for zinc, lead, copper, chromium, iron and manganese using standard methods. These toxic heavy metals were observed to be significantly present in high concentrations in the soil samples obtained from the oil spill farm when compared to the World Health Organization's maximum permissible limit. The heavy metal concentrations of zinc, copper, iron and manganese observed in the control sample were 3.0, 1.481, 1.68 and 0.19 milligram per kilogram respectively and all lower than those obtained from the soil samples at the spill site while lead and chromium were not detected. A one-way ANOVA showed that there is significant influence of distance away from spill on the level of heavy metals in the soil samples obtained from the study area.**

Keywords—Oil spill, heavy metals, Soil, WHO, ANOVA.

INTRODUCTION

Soil exists in many forms and its definitions vary according to application. The soil scientists identified it as the unconsolidated mineral material on the immediate surface of the earth that has been subjected to and influenced by genetic and environmental factors. On the other hand, the Engineer defines soil as the mass of unconsolidated mantle of weathered rock and loose material lying above the solid rock [3]. The definition of soil according to [21] has it as unconsolidated earth material composing the superficial geologic strata consisting of clay, silt, sand and gravel size particles as classified by the U.S soil conservation science. Soil according to [9] is the layer of minerals and organic matter, in thickness from centimetres to a metre, on the land surface. Its components are rock, mineral and organic matter, water and air. Soils differ in the ratio of these components and hence mechanical properties are largely determined by particle size and strongly influence the behaviour of polluting agents like hydrocarbons. The type of soil, its characteristics and behaviour towards different pollutants contribute to its future preservation and composition. Soil porosity and permeability determine the ease of flow of water through it. Oil spill contamination of the top soil has rendered the soil unsuitable for plant growth by increasing the toxic contents of the soil [14]. Soil chemical fertility which include the macro nutrients (such as nitrogen, phosphorus and potassium), trace element (manganese, zinc, copper, iron, molybdenum, boron, chloride, and cobalt), cation exchange capacity, electrical conductivity and soil pH are affected by crude oil soil contamination as a result of toxic heavy metals present [13].

Oil hamper proper soil aeration as oil film on the soil surface acts as a physical barrier between air and the soil. Oil pollution affects the physicochemical properties of the soil such as temperature, structure, nutrient status and pH. The general region in which water is held in the soil is called the aeration zone and the water present in it is called vadose water. At lower depths, adequate amounts of water will fill voids to produce a zone of saturation, the upper level of which is the water table. Water in the zone of saturation is called groundwater. The surface tension of water is drawn slightly above the water table to a region known as the capillary fringe [8].

Crude oil contaminants will carve out their pathway by leaching into the soil, come in contact with the ground water from the water table and subsequently discharge its content into the canals, lakes, rivers and then to the sea. Soil is not just a simple environment, lots of chemical, physical, biological and geological factors constantly interact to vary its composition. The fate and integrity of soil, sediments and waters in these spill areas continue to degrade due to contaminants accumulated from crude oil, petrochemicals and petroleum related products. From the environmental point of view, the parameters to characterize the soil and sediment will depend on organic contaminants and the metals, especially the heavy metal content and their species in the soil [10].

MATERIALS AND METHODS

The study area

Ibeno clan consists of twenty-three villages; it stretches for about forty kilometres from Ikot-Abasi in the West to the mouth of Cross River in the East. It is bordered by Oron and Eket in the North East and by Eket Central and Oniong Eket in the North West, as well as by the Atlantic Ocean in the South. It lies between the latitudes 8.00" and 8.15" East of the Greenwich Meridian. It is located in the transitional zone between the swamp forest and the rainforest region. Ibeno is divided into two sub areas by the Qua Iboe River. The area across the river is made up of six villages. Most of the villages are further separated from one another by small creeks and marshlands. The area lies about ten metres above sea-level and houses occasional creeks and sand banks. The original thick mangrove swamp is giving way in some places to scanty bushes due to the effect of pollution [6].

The Qua Iboe River and the Atlantic Ocean constitute natural waterways which is the most important traffic route in the area. Many paddle canoes, engine boats and ships. The mouth of the Qua Iboe River is about 100 meters wide and its estuary is about 39 kilometres wide at its entrance. The physical conditions of Ibeno significantly influence the economic activities of the people; the activities of the oil companies have also influenced the economic life of the people. The principal occupation of the people is agriculture, such as farming and fishing.

Climate of the area

The climate of the study area is humid tropical type. The climatic conditions of the area are influenced by the rain-bearing south westerly wind from the Atlantic Ocean and by the dry North East Trade Winds from the Sahara desert [4]. The area is therefore characterised by two main seasons; the wet or rainy season (April - October) and the dry season (November - March). The mean annual rainfall is 2,472 mm distributed throughout the year. The rainfall pattern is bimodal with two peak periods in July and October, and 2 - 3 weeks of moisture stress period in August, popularly known as "August break". Temperatures are high and change only slightly during the year. The mean annual maximum temperature is about 29°C while the mean annual minimum is about 21°C. Temperature is lower in the raining months than in the dry months. Relative humidity is high especially in the wet season than in the dry season; usually with no month less than 60 percent.

Geology of the area

The area lies entirely on the coastal plain sands of South Eastern Nigeria where sediments are supplied by the Cross River, the Qua Iboe River, Imo River and the Gulf of Guinea. The underlying parent materials consist of coastal plain sands [5]. The area generally has an undulating topography which breaks at river and stream valleys. The soils are derived from sand deposits and shales, sandy parent materials which are highly weathered and are dominated by low activity clay [20]. The clay contents of the soil increase down the profiles while sand fraction decreases and the soils are generally very susceptible to accelerated erosion. The soil mapping unit as classified by [21] shows that the soils belong mainly to the ultisols order [5].

Vegetation and land use

The vegetation of the area falls within the tropical rainforest belt where Akwa Ibom State belongs.

Field studies

Soil sampling

Soil samples were obtained from one of the crude oil spilled farms in the study area at distances 10, 20, 30, 40, 50, 60, 70 and 80m for analyses to ascertain the effects of crude oil spill on soil nutrients and heavy metal contents and to ascertain the effect of distance on the heavy metal concentrations in the soil. The soil sample obtained outside the site of the oil spilled farm served as the control sample. Each soil sample obtained was properly packaged and labelled in a brown envelope and sent to the laboratory for analysis.

Preparation of samples for analysis

Soil samples were air dried to remove the residual moisture and then oven dried for 3 h at 60°C. The dried samples were ground using agate mortar and pestle and sieved. The sieved samples were obtained and stored in an air tight container for analysis [19].

Laboratory analysis

3g of each sample was weighed with electronic weighing balance into a 250ml beaker. 10ml of hydrochloric acid was measured using measuring cylinder into the beaker containing the samples and kept for 2-3 minutes. Then 30ml of Nitric Acid was measured also and was added into the beaker of the sample. The beaker was then heated on a hot plate for about 10 – 15 minutes at a temperature between 65°C to 70°C to digest in the fume cupboard and the beaker was removed from the hot plate and kept to cool [1]. After cooling, the digested sample was filtered into another beaker using funnel with filter paper, distilled water was added into the filtrate and made up to 100ml and was ready for instrumental analysis. The digested solutions were analyzed for the presence of zinc, lead, copper, chromium, iron and manganese using atomic absorption spectrophotometer (Unicam 939 AAS) with different lamps in position [1].

Statistical Analysis

Results were subjected to analysis of variance (ANOVA) with the least significant difference and significant means compared at 0.05 level of probability level as described by [16].

RESULTS AND DISCUSSION

The characterization of the soil samples obtained from the crude oil spill farm at different distances is presented in table 1.

Table 1: Characterization of Soil samples Obtained from the Study area at different distances.

Samples	Distances (m)	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	Fe mg/kg	Mn mg/kg
S_1	10	52.98	19.20	52.01	13.82	12.55	2.63	6.36	0.99	14.61	13.81
S_2	20	54.61	19.41	47.10	13.54	16.31	1.81	4.83	0.80	8.03	4.03
S_3	30	30.96	11.08	50.56	12.44	13.16	0.93	2.93	2.4	4.75	3.62
S_4	40	47.82	10.86	38.40	13.86	16.25	1.17	3.01	1.82	3.80	2.36
S_5	50	38.08	10.56	47.60	14.32	17.77	0.75	2.51	0.93	4.27	1.90
S_6	60	35.84	18.32	53.10	12.96	11.43	0.92	2.90	1.99	4.53	2.81
S_7	70	42.41	12.43	41.73	10.76	9.17	1.56	3.21	0.77	3.85	0.93
S_8	80	31.63	14.10	48.00	11.28	18.14	0.85	2.34	1.14	3.80	1.73
S_9	Control	75.83	392.00	196	205	3.00	ND	1.481	ND	1.68	0.19
W.H.O MAXIMUM STANDARD		-	-	-	-	3.0	0.01	1.0	2.0	0.3	0.05

The potassium concentrations of the soil samples from the oil spilled farm at distances 10, 20, 30, 40, 50, 60, 70 and 80m as presented in table 1 were 52.98, 54.61, 30.96, 47.82, 38.08, 35.84, 42.41 and 31.63 mg/kg respectively and lower when compared to 75.83 mg/kg obtained from the control sample. This shows a decrease in the potassium contents of the soil samples obtained from the oil spilled farm indicating soil contamination due to the crude oil spill. The calcium concentrations of the soil samples at these distances were 19.20, 19.41, 11.08, 10.86, 10.56, 18.32, 12.43 and 14.10 mg/kg respectively and lower than 392 mg/kg observed from the control soil sample indicating a decrease in the calcium content of the soil samples from the oil spilled farm. This is an indication that there is a reduction of plant nutrients in the farm indicating soil contamination due to the crude oil spill. Magnesium concentrations were also tested for in the soil samples at distances 10, 20, 30, 40, 50, 60, 70 and 80m and observed to be 52.01, 47.10, 50.56, 38.40, 47.60, 53.10, 41.73 and 48.0 mg/kg respectively and lower when compared to 196 mg/kg observed in the control sample. A similar trend was also observed at these distances for sodium concentrations in the soil samples as 13.82, 13.54, 12.44, 13.86, 14.32, 12.96, 10.76 and 11.28 mg/kg respectively were observed. Crude oil contaminated soil will inhibit, retard plant growth and increase heavy metal presence in the plant [22]. According to [15], crude oil contaminated soil have adversely affected plant growth in the number of species they have so far investigated. The higher the level of soil contamination with crude oil, the worse the detrimental effects of oil on soil nutrient [2]. According to [13] it was reported that soil chemical fertility which include the macro nutrients (such as nitrogen, sodium, phosphorus and potassium), trace element (manganese, zinc, copper, iron, molybdenum, boron, chloride, and cobalt), cation exchange capacity, electrical conductivity and soil pH are affected by crude oil soil contamination as a result of toxic heavy metals present. This is in agreement with this study as the soil nutrients as observed from the experimental results of the soil samples obtained from the crude oil contaminated farm as presented in table 1 were observed to be lower than those obtained from the non-oil contaminated soil. This shows the effect of crude oil spill on agricultural soils. Decrease in soil nutrients for a long period of time due to crude oil spills will lead to soil infertility as reported by [23]. According to [11], it was found that the contamination of soil with petroleum hydrocarbon leads to an increase in the iron, zinc, copper, nickel, manganese, lead and chromium contents of the soil. This is evident in this study as the soil samples obtained from the crude oil spilled farm had high concentrations of these heavy metals tested for when compared to the non-oil contaminated soil (control). According to table 1, the heavy metals tested for in the soil samples were zinc, lead, copper, chromium, iron and manganese. The Zinc concentrations of the soil samples obtained at distances 10, 20, 30, 40, 50, 60, 70 and 80m in the farm were 12.55, 16.31, 13.16, 16.25, 17.77, 11.43, 9.17 and 18.14 mg/kg respectively and higher than 3.0 mg/kg observed in the control sample. According to [18], they reported that the World Health Organization's maximum permissible limit of zinc concentration in agricultural soil is 3.0 mg/kg which is less than the zinc concentrations in soil samples from the crude oil contaminated farm. The lead concentrations in the soil samples at these distances as presented in table 1 were 2.63, 1.81, 0.93, 1.17, 0.75, 0.92, 1.56 and 0.85 mg/kg respectively and higher than the World Health Organization's maximum permissible limit of 0.01mg/kg in agricultural soil as reported by [18] indicating contamination of the soil. The lead concentration in the control soil sample obtained outside the spill site was not detected. Also, the copper concentrations in the soil samples as presented in table 1 at distances 10, 20, 30, 40, 50, 60, 70 and 80m were 6.36, 4.83, 2.93, 3.01, 2.51, 2.90, 3.21 and 2.34 mg/kg respectively and higher than 1.481 mg/kg of the control sample and World Health Organization's maximum permissible limit of 1.0 mg/kg in agricultural soil as reported by [18]. This is as a result of the crude oil spill on the farm which contaminated the soil. The copper concentration of the control soil sample is slightly above the World Health Organization's maximum permissible limit which agrees with the report of [17] that copper is a very common substance that occurs naturally in the environment and spreads through the environment through natural phenomena. Chromium, one of the heavy metals tested for in the soil samples at various distances was detected. At 10, 20, 30, 40, 50, 60, 70 and 80m, its concentrations were observed to be 0.99, 0.80, 2.4, 1.82, 0.93, 1.09, 0.77 and 1.14 mg/kg respectively. These concentrations in the soil samples were within World Health Organization's maximum permissible limit of 2.0 mg/kg in agricultural soil as reported by [18] except the soil sample obtained at 30m which had chromium concentration higher than the World Health Organization's maximum permissible limit. The control soil sample had no detectable chromium concentration. Also, from table 1, iron concentrations at these distances were 14.61, 8.03, 4.75, 3.80, 4.27, 4.53, 3.85 and 3.50 mg/kg respectively thus, higher than 1.68 mg/kg observed from the control sample and World Health Organization's maximum permissible limit of 0.3 mg/kg in agricultural soil as reported by [18]. The control soil sample had its iron concentration slightly higher than the World Health Organization's maximum permissible limit which is in agreement with the report of [12] that iron is known to occur in abundance in the Niger delta region. Manganese concentrations in the soil samples at these distances also followed the same trend with concentrations 13.81, 4.03, 3.62, 2.36, 1.90, 2.81, 0.93 and 1.73 mg/kg higher than 0.19 mg/kg observed in the control sample and World Health Organization's maximum permissible limit of 0.05 mg/kg in agricultural soil as reported by [18]. The presence of high concentrations of zinc, iron, copper, lead, chromium and manganese metals with low soil nutrients as presented in table 1 in the soil samples obtained at the spill farm is an indication of soil contamination arising from crude oil spill on the farm. Soil metal contents as high as revealed in this study for some areas have serious public health implication for the residents of this metropolis, given the catalogue of health effects associated with exposure to metals generally, and toxic heavy metals in particular. In general, heavy metals are systemic toxins with specific neurotoxic, nephrotoxic, fetotoxic and teratogenic effects. Heavy metal toxicity can directly influence behaviour by impairing mental and neurological functions, influencing neurotransmitter production and utilization, and altering numerous metabolic body processes. Systems in which toxic metal elements can induce impairment and dysfunction include the blood, cardiovascular, eliminative pathways (colon, liver, kidneys, skin), endocrine (hormonal), energy production pathways, enzymatic, gastrointestinal, immune, nervous (central and peripheral), reproductive and urinary systems. These toxic impacts of metals are affected through the formation of free radicals (highly reactive oxygen species), a disturbance of the pro and antioxidant balance of the body, both of which can cause cell damage by destruction of proteins, degradation of nucleic acids or lipid peroxidation [17]. It was further reported that toxic heavy metals have been implicated in many health defects arising due to their toxic effects involving several body tissues, organs and systems. Crude oil contaminated soils affects crop yield and toxic heavy metals are ingested by plants as evident in this study.

Table 2: One-Way analysis of variance (ANOVA) of influence of distance away from spill on the level of Heavy Metals in Soil samples obtained from the study area

Source of variance	SS	Df	Ms	F
Between groups	47495.75	8	5936.97	2.61
Within groups	183991.23	81	2271.50	
Total	231486.98	89		

Table 2 shows that the calculated F-value of 2.61 was obtained after testing for significance at 0.05 alpha level with 8 and 81 degrees of freedom. The calculated F-value 2.61 was greater than the table F-value 2.10. Hence, the result was significant, signifying that there exists difference in the level of heavy metals in soil samples obtained from the spill site based on different distances (10, 20, 30, 40, 50, 60, 70 and 80m as well as the control group) and this means that there is significant influence of distance away from spill on the level of heavy metals in soil samples obtained from the study area. Due to that fact that the result was significant, it was pertinent to conduct Post-Hoc Test in order to find out the independent groups between which the significant difference lied. From the result of the Post-Hoc Test, it was observed that the significant difference lied only between the control group and every other independent group with the least significant difference 68.62 lying between the control group and 10m distance and the highest significant difference 74.83 lying between the control group and 70m distance.

CONCLUSION

The characterization of the soil samples obtained at distances 10, 20, 30, 40, 50, 60, 70 and 80m at the oil spill farm were observed to be low in plant nutrients investigated for (K, Mg, Ca and Na) and high in toxic heavy metals (Zn, Pb, Cu, Cr, Fe and Mn) also analyzed for when compared with the control sample and World Health Organization's maximum permissible limit. These observations are indicators that the soil samples at the spill farm are contaminated and unsuitable for plant growth as negative health implications may be observed if such plants are consumed. Obviously, animals that graze on these plants are liable to be affected with health problems as a result of the contaminated soil with crude oil. From the analysis of variance, it was observed that there is significant influence of distance away from spill on the level of heavy metals in soil samples obtained from the study area.

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