The present study evaluated the impact of crude oil exploration on soil quality and crops grown in Kpean Community in Khana Local Government Area of Rivers State. Soil samples were collected at a depth of 0-50cm³ using plastic auger while tuber crops and vegetables were harvested from the same spot as the soils. Findings from this study showed an increase in soil temperature, moisture, electrical conductivity and organic matter content of crude oil impacted soil compared to control (P<0.05). Soil pH ranged from acidic in the crude oil impacted soil to slightly acidic in the control while soil anions levels were significantly decreased compared to control (P<0.05). Soil enzyme activities of crude oil impacted soils decreased significantly. Crops grown on impacted soils accumulated significant heavy metals compared to control (P<0.05) and a decrease in proximate composition of vegetables and crops were obtained in test samples compared to control (P<0.05). The results of this study indicates that crude oil pollution of agricultural farmlands in Kpean Community is yet to be remedied even after 20 years following oil spillage and the soil still remain unsuitable for crop production. Hence, proper remediation of the studied area is paramount in order to reduce metal accumulation and subsequent exposure of the populace to metal poisoning via food chain.

**Keywords:** Crude oil, exploration, soil quality, crops.

**INTRODUCTION**

Soil pollution due to oil exploration in Niger Delta, Nigeria has created consciousness on pollution status of the environment. Soil is the most valuable component of the farming ecosystem and environmental sustainability largely depends on proper soil management (Osuocha et al., 2013b). Sustainable use of agricultural soil on which plants depend is absolutely necessary for agricultural productivity. Osuocha et al., (2016) reported that soil represents a dynamic system in which continuous interaction takes place between soil minerals, organic matter and organisms that influence physicochemical and biological properties of terrestrial systems. Plants as essential components of the ecosystem and agrosystems represent the first component of the terrestrial food chain due to their capacity of toxic metal accumulation when they grow on soils polluted with such metals (Osuocha et al., 2015). Contamination of foods by heavy metals has become an inevitable challenge. Soil pollution due to oil spillage is contributing to the presence of harmful element such as cadmium, lead and mercury in food crop produce. The entry into food chain by these metals may lead to increased susceptibility and exposure of the populace to metal poisoning.

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This study aims at evaluating the impact of over 20 years of oil spillage on soil quality and its effect on selected crops and vegetables grown in these areas.

MATERIALS AND METHODS

Study area
This study was carried out with samples (soils, tuber crops and vegetables) obtained from Kpean community of Khana Local Government Area of Rivers State. The rural settlers are mainly peasant farmers with most farm produce as cassava, vegetables, yam and cocoyam. While oil exploration and production were the major industrial activities in Kpean Community of Rivers State, Nigeria (Fig. 1).

Sample collection
Soil samples and commonly cultivated vegetables and tuber crops were collected and harvested from farmlands in Kpean Community in Khana Local Government Area of Rivers State, Nigeria. Soil samples were collected from the four cardinal points- North, East, West, South and the epi centre while the control samples were collected and harvested from an areas devoid of oil exploration. Samples of soils were collected with plastic auger 100m away from the epi centre in each of the four cardinal points at a depth of 0-50cm and packaged in bags for laboratory analysis. Samples of the following tuber and vegetable cultivars were harvested from the same spots where the soil samples were collected: Cassava (*Manihot spp*), Cocoyam (*Colocasia esculenta*), Yam (*Diascoria rotundata*), Water leaf (*Talinum triangulare*) and Fluted pumpkin (*Taliferia occidentalis*).
Method of Analysis

Soil temperature was determined at the site of soil samples collection using mercury in glass thermometer (APHA, 1998). The soil pH was determined by the method of Bates (1954) using air dried soil samples. Soil moisture and chloride content was determined by the method of APHA, (1998). Soil sulphate and phosphate content was determined according to the method described by James et al., (2000) who posited that high electrical conductivity may occur as a result of contamination from anthropogenic sources, such as application of chemicals, industrial wastes, poor irrigation and excessive use of fertilizer which affect seed germination, plant growth and soil water balance. Electrical conductivity values between 0.2 - 1.2 dSm⁻¹ are generally accepted for plant growth. This implies that crude oil impacted soils studied have high electrical conductivity values above the recommended values.

Moisture content is defined as the direct capacity of the soil to hold water (Singh et al., 2004). Results from this study revealed that moisture content of crude oil impacted soil were significantly higher than the control soil (P<0.05). This may be due to the oil pollution or due to predisposition of the area under study. This findings are in consonance with the reports of Li et al., (2005) and Wyskowka et al.,(2000) who reported change in soil moisture properties due to oil contamination and that high moisture content can have drastic effect on the organic matter compositions through indirect reduction of soil ventilation. Results of the present study also showed significant reduction in the levels of anions (chloride, phosphate and sulphate, calcium carbonate and carbon content).This may be due to the variations in level of the exchangeable ions. Organic carbon of the impacted soil increased significantly compared to control (P<0.05). These observed increase may be attributed to the metabolic processes following oil spill that facilitate agronomical addition of organic carbon from petroleum hydrocarbon. (Osuji and Onojake, 2006). This observation is also in line with report of Lee et al., (2002) on crude oil polluted soil.

Soil enzymes are the direct mediators for biological catabolism and as such could be easily applied in assessment of soil quality. The oxidoreductase enzymes assayed in this study (dehydrogenase, alkaline phosphatase and hydrogen peroxidase) indicate a decrease in activity in the impacted soil compared to control soil, which could be attributed to the impact of oil pollution. The decrease in activities of soil enzymes is similar to the results reported by Zhang et al., (2005); Wyzskowska and kucharisk (2000) and Malachowska-Jutz et al.,(1997.) who reported decrease in enzyme activity of soils contaminated with crude oil. In soil polluted by petroleum spill, Zhang et al.,(2005) reported undesirable reduction in the activities of these enzymes which indicate low activities of microorganism in the polluted soil.

RESULTS AND DISCUSSION

Results of the physiochemical properties of soil samples from different sites in Kpean community affected by crude oil spillage are presented in Table 1. Soil temperature plays a vital role in many biological processes that occurs in soils. Temperature of impacted soils ranging from 26.60 to 27.28 were relatively higher compared to control 25.50 (P<0.05). These Variations in soil temperature as observed in different location of the impacted soil may be due to biochemical reactions following oil pollution. This finding is in line with a similar observation made by Akubugwo et al., (2010) who reported increase in soil temperature in refined oil spillage soil in Isiukwato Local Government Area of Abia State, Nigeria. Naranjo et al., (2004) also reported that change in soil temperature will have impact on plant growth, biomass and activities of microorganism.

Soil pH is considered a master variable that affect virtually all soil properties: chemical, physical and biological (Singh et al., 2004, Akubugwo et al., 2007; Osuocha et al., 2015). The pH of crude oil impacted soils ranging from 5.92 to 6.65 were significantly (P<0.05) lower compared to control 7.12 (Table 1). This observed reduction in pH could be attributed to the impact of crude oil spillage. This finding is in line with similar reports of Osuji and Adesiyian (2005) who posited low acidic pH in crude oil contaminated soils.

Electrical conductivity is defined as the measure of the amount of dissolved salt in a given soil (Singh et al.,2004). High electrical conductivity indicates more soluble salts in the soil. The electrical conductivity of crude oil impacted soils were significantly higher compared to control (P<0.05). The electrical conductivity values obtained were higher than the recommended ideal soil electrical conductivity value(0.2-1.2mScm⁻¹) accepted for optimum plants growth. This finding agreed with similar result of Arias et al., (2005) who posited that high electrical conductivity may occur as a result of contamination from anthropogenic sources, such as application of chemicals, industrial wastes, poor irrigation and excessive use of fertilizer which affect seed germination, plant growth and soil water balance. Electrical conductivity values between 0.2 - 1.2 dSm⁻¹ are generally accepted for plant growth. This implies that crude oil impacted soils studied have high electrical conductivity values above the recommended values.

Studies on the impact of crude oil exploration on soil quality and crops grown in Kpean community in Khana local government area of Rivers State, Nigeria.
Table 1. Physicochemical parameters of crude oil polluted Kpean Community soils studied.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Temperature (°C)</th>
<th>pH</th>
<th>Electrical conductivity (dSm⁻¹)</th>
<th>Moisture (%)</th>
<th>Chloride (gkg⁻¹)</th>
<th>Phosphate (gkg⁻¹)</th>
<th>Sulphate (gkg⁻¹)</th>
<th>Organic carbon (gkg⁻¹)</th>
<th>Calcium carbonate (mgkg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>25.500.00ᵃ</td>
<td>7.120.01ᵃ</td>
<td>37.270.01ᵃ</td>
<td>55.800.01ᵃ</td>
<td>4.990.01ᵃ</td>
<td>20.330.01ᵃ</td>
<td>36.130.01ᵃ</td>
<td>0.040.01ᵃ</td>
<td>14.100.01ᵃ</td>
</tr>
<tr>
<td>Site A</td>
<td>26.270.01ᵇ</td>
<td>5.920.01ᵇ</td>
<td>62.000.01ᵇ</td>
<td>31.720.01ᵇ</td>
<td>2.130.01ᵇ</td>
<td>10.090.01ᵇ</td>
<td>30.120.01ᵇ</td>
<td>0.040.01ᵇ</td>
<td>0.220.01ᵇ</td>
</tr>
<tr>
<td>Site B</td>
<td>26.830.01ᵇ</td>
<td>6.340.01ᶜ</td>
<td>52.330.01ᶜ</td>
<td>42.550.01ᶜ</td>
<td>2.490.01ᶜ</td>
<td>12.190.01ᶜ</td>
<td>17.910.01ᶜ</td>
<td>1.050.01ᶜ</td>
<td>0.040.01ᶜ</td>
</tr>
<tr>
<td>Site C</td>
<td>27.120.01ᶜ</td>
<td>5.710.01ᵇ</td>
<td>25.000.01ᵈ</td>
<td>22.060.01ᵈ</td>
<td>2.480.01ᶜ</td>
<td>8.110.01ᵈ</td>
<td>14.660.01ᵈ</td>
<td>2.600.01ᵇ</td>
<td>0.080.01ᵈ</td>
</tr>
<tr>
<td>Site D</td>
<td>26.600.01ᵇ</td>
<td>5.750.01ᵇ</td>
<td>47.330.01ᵃ</td>
<td>24.300.01ᵈ</td>
<td>2.300.01ᵈ</td>
<td>14.250.01ᵉ</td>
<td>22.200.01ᵉ</td>
<td>2.540.01ᵈ</td>
<td>1.060.01ᵉ</td>
</tr>
<tr>
<td>Site E</td>
<td>27.280.01ᶜ</td>
<td>6.650.01ᵃ</td>
<td>66.000.01ᵃ</td>
<td>51.670.01ᵃ</td>
<td>5.670.01ᵃ</td>
<td>11.770.01ᶠ</td>
<td>31.050.01ᶠ</td>
<td>1.080.01ᶜ</td>
<td>0.250.01ᶠ</td>
</tr>
</tbody>
</table>

Values are the mean of triplicate determination ± standard deviation. Means in the same column having different alphabet are significantly different (P<0.05). Site A = North, Site B = South, Site C = West, Site D = East, Site E = Center.

Table 2. Soil enzyme activities of crude oil polluted Kpean Community

<table>
<thead>
<tr>
<th>Enzymes</th>
<th>Dehydrogenase (mg/g/6h)</th>
<th>Hydrogen (mg/g/3h)</th>
<th>Peroxidase</th>
<th>Alkaline phosphatase (µmol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>21.14±0.01ᵃ</td>
<td>3.17±0.01ᵃ</td>
<td></td>
<td>2.16±0.01ᵃ</td>
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<tr>
<td>Site A</td>
<td>11.16±0.01ᵇ</td>
<td>1.36±0.01ᵇ</td>
<td></td>
<td>1.31±0.01ᵇ</td>
</tr>
<tr>
<td>Site B</td>
<td>8.72±0.01ᶜ</td>
<td>1.24±0.01ᶜ</td>
<td></td>
<td>0.71±0.01ᶜ</td>
</tr>
<tr>
<td>Site C</td>
<td>12.06±0.01ᵈ</td>
<td>0.32±0.01ᵈ</td>
<td></td>
<td>1.91±0.01ᵈ</td>
</tr>
<tr>
<td>Site D</td>
<td>5.27±0.01ᵉ</td>
<td>1.31±0.01ᵉ</td>
<td></td>
<td>0.63±0.01ᵉ</td>
</tr>
<tr>
<td>Site E</td>
<td>4.05±0.01ᶠ</td>
<td>1.02±0.01ᶠ</td>
<td></td>
<td>0.90±0.01ᶠ</td>
</tr>
</tbody>
</table>

Values are the mean of triplicate determination. Means in the same column having different alphabet are significantly different (P<0.05). Site A = North, Site B = South, Site C = West, Site D = East, Site E = Center.

Table 3. Soil heavy metals concentrations (mg/kg) of crude oil polluted Kpean Community soil

<table>
<thead>
<tr>
<th>Heavy metals</th>
<th>Lead (mg/kg)</th>
<th>Zinc (mg/kg)</th>
<th>Cadmium (mg/kg)</th>
<th>Nickel (mg/kg)</th>
<th>Chromium (mg/kg)</th>
<th>Manganese (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.038ᵃ</td>
<td>0.059ᵃ</td>
<td>0.014ᵃ</td>
<td>0.046ᵃ</td>
<td>0.027ᵃ</td>
<td>0.029ᵃ</td>
</tr>
<tr>
<td>Site A</td>
<td>1.143±0.01ᵇ</td>
<td>3.74±0.01ᵇ</td>
<td>0.33±0.01ᵇ</td>
<td>2.36±0.01ᵇ</td>
<td>1.29±0.01ᵇ</td>
<td>2.18±0.01ᵇ</td>
</tr>
<tr>
<td>Site B</td>
<td>1.147±0.01ᵇ</td>
<td>1.30±0.01ᶜ</td>
<td>0.16±0.01ᶜ</td>
<td>3.28±0.01ᶜ</td>
<td>4.59±0.01ᶜ</td>
<td>1.58±0.01ᶜ</td>
</tr>
<tr>
<td>Site C</td>
<td>3.28±0.01ᶜ</td>
<td>2.64±0.01ᵈ</td>
<td>3.52±0.01ᵈ</td>
<td>4.64±0.01ᵈ</td>
<td>0.96±0.01ᵈ</td>
<td>2.137±0.01ᵈ</td>
</tr>
<tr>
<td>Site D</td>
<td>2.109±0.01ᵈ</td>
<td>2.38±0.01ᵉ</td>
<td>2.39±0.01ᵉ</td>
<td>1.86±0.01ᵉ</td>
<td>3.45±0.01ᵉ</td>
<td>5.41±0.01ᵉ</td>
</tr>
<tr>
<td>Site E</td>
<td>2.789±0.01ᵉ</td>
<td>1.02±0.01ᶠ</td>
<td>4.25±0.01ᶠ</td>
<td>1.86±0.01ᵉ</td>
<td>2.29±0.01ᶠ</td>
<td>2.29±0.01ᶠ</td>
</tr>
</tbody>
</table>

Values represent mean of triplicate determination ± standard deviation. Means in the same column having different alphabet are statistically significant (P<0.05) when compared. Site A = North, Site B = South, Site C = West, Site D = East, Site E = Center.
Oil pollution generally increases the concentrations of heavy metals (Zhang et al. 2005). Therefore, the concentration of heavy metals (Pb, Zn, Cd, Cr, Ni, and Mn) in polluted soil samples, tubers crops (yam, cocoyam, and cassava) and vegetable crops (fluted pumpkin and water leaf) were higher than those in the unpolluted soils in this study. The increase in heavy metal concentration may be due to hydrocarbon pollution which is in line with the observation of Kakulu et al., (1985) who opined that crude petroleum contributed to a large extent metal pollutions in the Niger Delta area of Nigeria.

Proximate analysis is the most common analysis done for nutritional testing (FAO, 2001). Results show that proximate composition of tuber crops and vegetable crops from polluted soils were significantly lower compared to control (P<0.05). This may be due to the impact of crude oil spill (oil exploration activities) which may have negatively
affected soil conditions required for optimum plant growth and yield. This observation is in consonance with the findings of Adenipekun and Kassim (2006) that spent engine oil pollution negatively affected the proximate and nutritional composition of Celosia argenta plant. Ogbeuchi (2010) observed that spent engine oil pollution had a negative effect on nutrient composition of cowpea (Vigna unguiculata). Results of this study also validates similar reports by Odebanmi et al. (2007) that crude oil negatively affected the proximate composition and nutritional component of Dioscorea rotundata (white yam) and colocasia esculenta (white cocoyam). Thus, these results further validates that, there is observed relationship between the inhibitory effect of oil pollution and plant quality and yield.

CONCLUSION

This study evaluated impact of crude oil exploration on soil quality and food crops grown in Kpean Community of Khana Local Government Area of Rivers state. Results of this study revealed that petroleum oil spillage negatively affected the physical and chemical parameters, enzyme activities and increased the level of heavy metals in soils and food crops. Nutritional composition of tuber crops and vegetables were adversely affected compared to control, indicating the pollution status of the soils where these plant crops are cultivated. Results of this study indicate that crude oil pollution of agricultural farmlands in Kpean Community is yet to be remedied even after 20 years of the spillage. Hence, proper remediation of the studied area is paramount in order to reduce metal accumulation and subsequent exposure of the populace to metal poisoning via food chain.

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