Spatial Distribution of Residual Petroleum Hydrocarbons in an Oil Spill Site Located at Isoko South LGA, Delta State, Nigeria

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The study was done to evaluate the residual total hydrocarbon content (THC) concentration in an oil spill site within Delta State, Nigeria. To achieve this study's objective, soil samples were collected from two sites (contaminated site and control site) within Delta state. The soil samples were collected from the contaminated site (between Oleh and Idheze communities of Delta State) about nine months after the oil spill and the clean-up by the oil company. The THC concentration of all the soil samples collected were analyzed in accordance with standard ASTM recommended procedures. Results obtained from the laboratory tests showed that the THC concentrations were higher in the already cleaned up oil spill site, when compared with the results obtained from the control site. This indicates a significant residual THC concentration in the already cleanup oil spill site. Lower THC concentrations were generally observed at the soil surface (0-10 cm) when compared with higher THC concentrations obtained at higher soil depth (30 cm and 70 cm). Concentration of residual THC at the soil surface (samples collected from the contaminated site) ranged between 1201 to 10046 mg/kg with a mean value of 5858.83 mg/kg; while the concentration of residual THC at subsurface soil (40 cm depth) ranged between 1016 to 11675 mg/kg with a mean value of 6374.50 mg/kg. These results show the relevance the oil companies to practice remediation follow-up in oil spill sites, in order to prevent remediation failure; leading to accumulation of residual hydrocarbon in the environment.

Keywords: Contamination, Delta State, Oil spill, Soil, Total hydrocarbon content

INTRODUCTION

Crude oil exploration and exploitation in Nigeria, which dated back to the 1950’s in the Oloibiri oilfield, located presently in Bayelsa State, Southern Nigeria has taken a new dimension, with more focus on Northern and central Nigeria. According to data obtained from the Organization of the Petroleum Exporting Countries (OPEC) official website, Nigeria oil and gas sector accounts for about 10% gross domestic product (GDP), and petroleum exports revenue accounts for about 86% of Nigeria total exports revenue (OPEC, 2020). Presently in Africa, Nigeria is the leading crude oil producer (about 2.4 million barrels per day), with its oil reserves standing at about 37 billion barrels (Akpodjje and Uguru, 2019; OPEC, 2020). Due to the increasing oil exploration activities, crude oil spill has become a common occurrence in the Nigeria Delta oil hub of Nigeria. Most of the oil exploring companies operating in Nigeria attributes about 85% of oil spill incidence to sabotage of their facilities, as well as illegal crude oil refining activities by the locals (SPDC, 2020). The largest crude oil spill in Nigeria history occurred at the SPDC Forcados Terminal tank farm in 1978, and spilled about 580,000 barrels of crude oil into the environment (Usman, 2017). According the International Tanker Owners Pollution Federation (ITOPF) statistics, a total volume of 1,000 tonnes of crude oil was spilled to the environment in 2019, which was a lowest annual spillage volume recorded globally in the last five decades.

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According to Scott (2003), contamination of soil by crude oil (oil spill) can occur through extraction, accidents, spillages, consumption, illegal refining processes, and indiscriminate disposal of petroleum waste products (Akporokodge et al., 2019). According to Chinedu and Chukwuemeka (2018) more than 12,000 crude oil spill incidences have occurred in the oil-rich Niger Delta region of Nigeria, between 1976 and 2014. These amount to about 3.1 million barrels of oil been spilled into the oil-rich ecosystems. High concentrations of petroleum hydrocarbons or any other pollutant in the soil or water bodies may result to the death of plants’ species, change in their normal development, reduced their functional ability; and mortality in birds and fishes that lives within the ecosystem (Samarasekara, 1994). The presence of THC and other heavy metals in the soil continue to receive increasing attention, in order to understand their nature as well as their toxicological relevance within the ecosystems and human health (Wang and Qin, 2007). According to Devkota and Schmidt (2000), THC and heavy metals are harmful to the ecological system because they tend to bioaccumulate in soils and plants with time; thereby, negatively influencing plants’ physiological activities (photosynthesis, nutrient absorption, etc.), causing reductions in their growth performance and yield in the process. Likewise, Das and Chandran (2010) reported that hydrocarbon pollutants in the soil can caused disruptions of natural equilibrium between the plants and animals and their ecosystems. Hydrocarbon contamination of the ecosystems has drawn public concerns because many hydrocarbons contaminants are highly toxic, neurotoxic, mutagenic, and carcinogenic (Cerniglia and Sutherland, 2001). Bello and Anobeme (2015), observed significant increment in the petroleum hydrocarbons concentration of soil samples polluted with petroleum oil, when compared with results obtained from unpolluted soil samples.

The toxicity of crude oil depends on the oil composition and characteristics, climatic condition, exposure routes and regimen, and its bioavailability (Lin and Tjeerdema, 2008; Saadoun, 2015). After each oil spill, the affected oil company usually carried out environmental clean-up (remediation) practices. But there is tendency of remediation failure, which may result from the complex nature of the environmental conditions. According to Abioye (2011), soil environment has very complicated nature and remediation materials added to it tends to be affected by its physicochemical and biological features. Therefore, remediating petroleum contaminated soils with degrading microorganisms may leads to bio-augmentation failure at times (Gentry et al., 2004). According to Thieman and Palladino (2009), bio-augmentation is not always an effective remediation method of remediating contaminated soil, because at times laboratory strains of microorganisms rarely grow and biodegrade xenobiotics, when compared with indigenous microbes.

Apart from bio-augmentation (bio-remediation), there are other remediation techniques approved for the cleaning up of oil spill contaminated sites; these include the chemical and thermal techniques. Air sparging technique which is another remediation technology, injects air through a contaminated aquifer. The injected air traverses horizontally and vertically in channels through the soil column, creating an underground stripper that removes contaminants by volatilization (EPA, 2001; Abioye, 2011). All these remediation techniques have their limitations and adverse effects on the soil physical and bio-chemical properties. Therefore, more feasible natural remediation techniques should be developed to provide more environmentally friendly and cost-effective cleanup of sites impacted by crude oil spills (Alkorta and Garbisu, 2001; Akporokodge et al., 2019).

The objective of this study is to determine the residual total hydrocarbon contents (THC) concentration in the soil samples collected from an already cleaned up oil spill site, in Isoko South Local Government Area of Delta State, Nigeria. Results obtained from this study will be helpful in planning further evaluation, and possible re-remediation of all crude oil spills sites within the Niger Delta region of Nigeria.

MATERIALS AND METHODS

Description of the Study area

This study was conducted between two communities (Oleh and Idheze) located at Isoko South Local Government Area of Delta State, Nigeria (Figure 1). The area falls within the tropical rain forest, with two major climatic seasons (rainy and dry season); having average atmospheric temperature of 25°C and average relative humidity of about 85%. The rainy season starts from April and ends around October, but a short break between July and August. Major economic activities of the area are peasant farming and petty trading.

Soil samples collection and preparation

Soil samples used for this study were collected from two sites; contaminated site and control site (reference point). The contaminated site was affected by massive crude oil spill during early 2019, which the oil company blamed on saboteurs. Cleanup of the site was done by the oil company few weeks later, remove (and possible degrade) the crude oil spilled on the area. A grid technique was used to demarcate an area of 1 km × 1 km within the oil spill site (contaminated site), from where soil samples will be collected at various spatial locations. The reference point was located about 10 km from the oil spill high index point, to evaluate the residue THC in the soil after the cleaning up by the oil company. The control site was grassland without oil spill record for the past 10 years; and has the similar geographical features as the contaminated site.
All the soil samples used for this study were collected at three different soil depths (10 cm, 40 cm and 70 cm) using a calibrated soil auger. The samples were collected at the beginning of the rainy season (March, 2020). Spatial coordinate points of all the locations from where the samples were taken were captured and registered by employing a hand-held global positioning system (GPS) receiver. All the spatial points from where the soil samples were collected are presented in Table 1. At each spatial point and soil depth, three soil samples were collected for THC evaluation. After each sample collection, the auger was washed and dried with a cloth to remove all remnants of the old soil sample from it. All soil samples collected were stored individually in amber glass bottles, coded and transported immediately to the laboratory for chemical analysis.

Table 1: spatial location of points of soil samples collection

<table>
<thead>
<tr>
<th>Point of collection</th>
<th>Point coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6°13.17 N 5°28.67 E</td>
</tr>
<tr>
<td>2</td>
<td>6°13.02 N 5°28.61 E</td>
</tr>
<tr>
<td>3</td>
<td>6°13.69 N 5°28.16 E</td>
</tr>
<tr>
<td>4</td>
<td>6°13.86 N 5°27.93 E</td>
</tr>
<tr>
<td>5</td>
<td>6°13.33 N 5°28.63 E</td>
</tr>
<tr>
<td>6</td>
<td>6°12.31 N 5°27.07 E</td>
</tr>
<tr>
<td>7 (Reference point)</td>
<td>6°92.04 N 6°01.22 E</td>
</tr>
</tbody>
</table>

Determination of total Hydrocarbon Content (THC)

Total Hydrocarbon Content of all the soil samples collected from the two study sites was tested by using Soxhlet Extraction Method recommended by ASTM D 9071B – 7 (APHA, 1995). All the soil samples were air-dried under ambient laboratory temperature for two weeks, and sieved with a 2 mm stainless steel sieve; to remove stones, roots and other debris. Then 10 g of the sieved dry soil sample was mixed thoroughly 10 g of Na₂SO₄, was added with 90 ml of n-hexane, and was poured into an extraction thimble. The extraction thimble with the content was arranged into a soxhlet apparatus and heated over a hot plate for 4 h. The soil THC test was carried out under ambient laboratory temperature (26±4°C).

Statistical Analysis

All data gotten from this study were analyzed using geostatistical methods; while the means were separated using The Duncan’s New Multiple Range (DNMR) Test (p ≤0.05). In addition, the summary of the readings was plotted with Microsoft Excel 2015.

RESULTS AND DISCUSSION

Total hydrocarbon content distribution in soil

The spatial distribution of total hydrocarbon content (THC) concentration across the contaminated site, and the reference point is shown in Table 2. The results shows the mean values of the three (3) soil samples collected from each registered spatial location, at the various soil depths.
Concentration of residual THC at the soil surface (samples collected from the contaminated site) ranged between 1201 to 10046 mg/kg with a mean value of 5858.83 mg/kg; while the concentration of residual THC at subsurface soil (40 cm depth) ranged between 1016 to 11675 mg/kg with a mean value of 6374.50 mg/kg. The THC concentration was highest at this spatial point 6013.86 N and 5027.93 E, indicating that either remediation failure had occurred or that point received higher oil concentration during the oil spill. According to Abioye et al. (2012) the biodegradation potential of soil microbes in petroleum hydrocarbons polluted soils is highly influenced by the volume and quality of the crude oil spilled, and the petroleum hydrocarbons contamination history of the of the ecosystems.

**Table 2:** Spatial distribution of residual THC on the soil samples

<table>
<thead>
<tr>
<th>Coordinate position</th>
<th>Soil Depth</th>
<th>10 cm</th>
<th>40 cm</th>
<th>70 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>6°13.17 N 5°28.67 E</td>
<td></td>
<td>7844&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10983&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6741&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>6°13.02 N 5°28.61 E</td>
<td></td>
<td>5798&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4862&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7542&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6°13.69 N 5°28.16 E</td>
<td></td>
<td>6251&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6554&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7092&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6°13.86 N 5°27.93 E</td>
<td></td>
<td>10046&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11675&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8738&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>6°13.33 N 5°28.63 E</td>
<td></td>
<td>4013&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3087&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4342&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6°12.31 N 5°27.07 E</td>
<td></td>
<td>1201&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1086&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1101&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Reference point</td>
<td></td>
<td>164&lt;sup&gt;c&lt;/sup&gt;</td>
<td>141&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Mean values of 3 samples tested; Means with the same common letter (superscript) in the same column are not significant different (p ≤0.05)

The variation maps of THC concentration of the soil samples collected from the contaminated site (Figures 2 to 4) show that the THC concentration generally increased as the depth moved downward from the soil surface; indicating that THC contamination is generally higher at the soil subsurface. It was observed in residual THC concentration of the oil spill (but already remediated) area, which ranged from 1201 to 11675 mg/kg. The highest THC concentration was observed at a depth of 40 cm below the soil surface (Figure 3), while the lowest THC concentration was observed at the soil surface (Figure 2). Figure 2 shows that the THC concentration at the soil surface generally decreased from the East to the South western region of the contaminated site. Likewise, Figure 3 shows that at a depth of 40 cm below the soil surface, the THC concentration was highest at the Northern eastern part of the oil spill site and generally declined at it moved southward, with the South Western part recording the lowest THC concentration. Similar results were obtained by Lotfinasabasl et al., (2013), where the mean TPH values of soil samples collected from freshly cleaned up oil spill area, were higher than the global average permissible limit (1000 mg/kg) for soil TPH. Zengler et al. (1999) reported sharp difference between the THC concentrations at the top soil and subsoil in an oil soil area, which they attributed to the biodegradation of hydrocarbon by microbial activities. But on the contrary, Osuji and Adesiyan (2005) reported that THC concentration was higher at the top soil; declined with an increase in soil depth.

The lowest THC concentration recorded at the soil surface could be attributed to the phytoremediation potentials of the plants growing on the contaminated site. Likewise, organic materials present in the soil surface could play a vital role in the bioremediation of the contaminated site. Citing Akpokodje et al., 2019; green plants (mostly grasses) have good potential of remediating petroleum contaminated soil samples. Pollutant attenuation capability possessed by many plants makes them more useful in remediating contaminated areas more than physical and chemical remediation methods (Gerhardt et al., 2009). Microbial deterioration in the plants' roots could be the useful in degrading petroleum hydrocarbons in contaminant soils; because of pollutants most petroleum hydrocarbons are highly hydrophobic in nature (Miya and Firestone, 2001). According to Palmroth et al. (2006), phytoremediation is a remediation method that utilizes plants to remove, contain or detoxify environmental contaminants; and it is quite better other remediation methods because it is not invasive and delivers intact, biologically active soil (Wenzel, 2009).
CONCLUSION

This study treads to evaluate the THC concentration in an already cleaned up oil spill site in Isoko communities of Delta State, Nigeria; to ascertain the residual THC concentration in the cleaned-up soil. Laboratory results showed that THC concentrations in the cleaned-up oil spill site were still significantly higher than the control site, despite the cleaning up and remediation carried out by the oil industry. Concentration of residual THC at the remediated soil surface ranged between 1201 to 10046 mg/kg with a mean value of 5858.83 mg/kg; while the concentration of residual THC at subsurface soil (40 cm depth) ranged between 1016 to 11675 mg/kg with a mean value of 6374.50 mg/kg. The low THC concentration observed at the soil surface could be attributed to the phytoremediation potentials of the plants growing on the contaminated site. This study shows some levels of potential hydrocarbon toxicity in already cleaned up oil spill sites; calling for the need for remediation follow-up in oil spill sites to safeguard the environment.

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Accepted 4 May 2020


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