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Research Article

# TEMPORAL CHANGES IN CHEMICAL AND HEAVY METAL CHARACTERISTICS OF CRUDE OIL POLLUTED TOP SOILS OF IZOMBE, SOUTHEASTERN, NIGERIA

**[1]Ihem, E.E, [1]Aririguzo, B.N, [2]Ogueri, C, [2]Anyanwu, C.N, [1]Agim, L.C, [2]Nwaka, D, [2]Chinnah, U.K, [3]Madu, H.C, [4]Nwaka, S.U, [3]Agorua, U.N, [5]Nwokeke, B.C, [6]Ihezie, C.I, [7*]Ndukwu. R. I, [1]Chukwu, E.D, [1]Osisi, A and [8]Chikaire, J.U**

[1]Department of Soil Science Technology, Federal University of Technology, Owerri, Imo State
[2]Department of Fisheries and Aquaculture, Federal University of Technology, Owerri, Imo State
[3]Department of Fisheries Technology, Imo State, Polytechnic, Omuma, Imo State
[4]Department of Fisheries Technology, Federal Polytechnic, Nekede, Owerri; Imo State
[5]Department of Food Science and Technology, University of Agriculture and Environmental Sciences, Umuagwo, Owerri, Imo State
[6]National Root Crops Research Institute, Umudike, Abia State
[7]Department of Geoinformatics and Surveying University of Nigeria, Enugu Campus, Enugu State
[8]Department of Agricultural Extension, Federal University of Technology, Owerri, Imo State, Nigeria

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## ABSTRACT

Crude oil pollution is a significant environmental issue in Izombe, Imo State, Nigeria, and an oil-producing region experiencing frequent oil spillage in the area. Izombe lies in the northeast of Niger Delta and covers about 59 $km^2$ in Njaba River. The study was aimed at investigating the physico-chemical and heavy metal characteristics of top soils (0-15 cm) depth of Izombe oil spill fields, 2024. A free survey technique was adopted in the field sampling of seven (7) stations (5 polluted and 2 control) in the months of April and June, 2024. Standard laboratory procedures were followed to determine some physical, chemical and heavy metal concentrations of the study area. Results showed that crude oil pollution increased the Electrical Conductivity (EC) by 148% and 290% in April and June respectively; calcium by 209% and 171%; potassium by 208% and 156%; magnesium by 211% and 170% in April and June respectively. Crude oil pollution increased zinc (Zn) by 150% and 142% in April and June respectively; copper (Cu) by 28% and 20%, lead (Pb) by 815 and 89% in April and June respectively. The study showed that crude oil pollution affected most of the basic soil properties significantly and increased with time. Consequently, heavy metal values from the results were found to be below the critical limits, and as such may not pose a serious threat to the terrestrial and aquatic environment. However, standard procedures should be adopted in the oil producing activities to prevent soil and water against contamination beyond permissible limits.

**Keywords:** Oil spillage, Heavy metals, Permissible limits, Crude oil, Izombe.

## INTRODUCTION

Petroleum industries in Nigeria have eventually created economic boom and remains the backbone of the Nigerian economy contributing over 90% of its revenue and about 45% of its GDP (Akinlo, 2012; Ekeghe, 2022). Izombe, Imo State being one of the nine major states in southern states in Nigeria produce crude oil in very large quantities (Ejechi, 2022). Available data showed that over 9,500 cases of oil spillage occurred in Nigeria from 2011 to 2021 with an estimate of about 450,000 barrels of oil released into the environment (Akinpelu, 2021). The release of large quantity of crude oil in the environment in form of spillage significantly result to substantial level of soil pollution,

*Corresponding Author: NDUKWU, R.I, Department of Agricultural Extension, Federal University of Technology, Owerri, Imo State, Nigeria Email: raphael.ndukwu@unn.edu.ng

deforestation, toxic discharges into available water sources, biodiversity loss, as well as recurring and extensive oil spills (Owugah, 2006; Chijioke *et al*., 2018; Akinpelu, 2021). Chijioke *et al*. (2018) in a review opined that farmers have been compelled to evacuate their farmlands and properties due to increasing soil sterility caused by the depletion of soil microbes and diminishing crop yields. It is obvious that crude oil contains metals and their mobility depends on the concentration and soil properties. Similar studies on crude oil polluted areas indicated that oil spillage ruined the subsistence economic activities of the affected areas, drinking water sources lost, agricultural and fishing operations hampered and the ecology of the region deteriorated. According to Moneke *et al*. (2022), air in the affected areas is also polluted by oil spillage. Impact of oil spillage on coastal and aquatic environments can be both short and long term (Kujawinski *et al*., 2020; Al-Hamadani *et al*., 2022). It also affects generally the ecosystem, soil properties and food production (Wokocha *et al*., 2011), seed germination and vegetation cover hampered (Gulshen and Datsi, 2012).

Soil health, soil and water toxicity increased with high heavy metal concentration (Ihem *et al*., 2015). Research works have been carried out on the effects of oil spillage without much emphasis on time variations. Therefore, this research finding was aimed at determining the physico-chemical, and heavy metal characteristics of the crude oil polluted surface soils with time in the study sites.

## MATERIALS AND METHODS

### Site Description

Izombe lies in the Northeast of Niger Delta. It covers about 59 km$^2$in Njaba River basin, Imo State. It comprises of Izombe and Ossu oil fields (Figure 1). The experiment was conducted at seven (7) oil and gas exploration sites in Izombe, Imo State, Nigeria as shown in Table. 1 in April and June, 2024.

A free survey technique was adopted in the choice of sampling sites. Surface soil samples were collected at a depth of 0 – 15cm in each of the seven sites (five polluted and two unpolluted as control). Samples collected in each of these sites were Pseudo-replicated and the means were then used for statistical analysis. Soil auger (2 auger bores) was used to collect the soil samples, homogenized to form a composite sample. The samples were collected in foil packs and nylon bags, properly labelled and preserved for analysis in line with the world standard methods.

**Table 1.** Sampling location sites of Izombe oil fields.

| S. No | Sampling sites | Longitude | Latitude |
|---|---|---|---|
| 1. | Flare Area (200m away) | 05°37'08.6"N | 006°49'02.1"E |
| 2. | Process Area | 05°37'04.6"N | 006°48'59.3"E |
| 3. | Generator Area | 05°37'03.4"N | 006°49'00.4"E |
| 4. | Compressor Area | 05°37'03.9"N | 006°49'02.8"E |
| 5. | Accommodation Area | 05°37'06.6"N | 006°49'07.6"E |
| 6. | Community Control Point (1) | 05°38'32.7"N | 006°50'57.4"E |
| 7. | Community Control Point (2) | 05°38'36.1"N | 006°50'56.7"E |

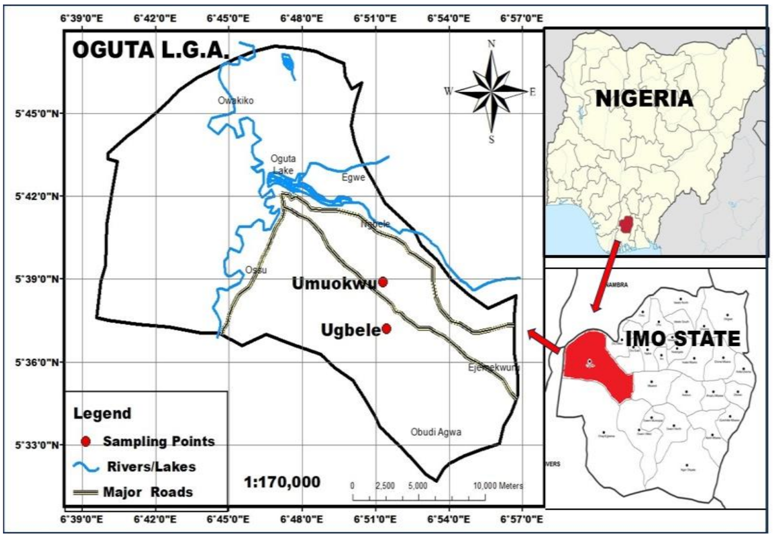


**Figure 1.** Map showing Sampling points.

Legend: SS = Soil Sample Points , AQ = Air Quality Points, HDW = Hand Dug Well Points, SW = Surface Water Points

However, soils from Izombe are derived from coastal plain sands and are dominated by ultisols and inceptisols (Onweremadu and Peter, 2016). The study sites belong to the lowland area of Nigeria, with a humid tropical climate having a mean annual temperature range of 26 - 31°C and annual rainfall ranges between 1500mm to 2500mm which runs from March to December with its peak in July, through October/November to March with a dry dust and cold intervals, locally termed as Harmattan. The vegetation of the area is tropical rainforest zone mostly dominated by grasses like *Sida acuta, Panicum maximum, Pennisetum purperum, Cromolina odorata, Centrosima purpesence* among others.

**Laboratory analytical methods**

Soil pH: Soil pH was determined electrometrically with a Horiba Multi-parameter water checker (U-50 series) in a solution ratio of 1:2.5 according to Bremner, (1996). Electrical Conductivity (us/cm) :(EC) was determined in a ratio of 1:2 soil-to-water ratio by APHA 2510B electrometric method using a calibrated Horiba Multi-parameter water checker as described by Hendershot *et al* (1993). Total Organic Carbon (%) :(TOC) was determined using the titrimetric dichromate oxidation method (Walkley-Black's method) as described by Nelson and Sommers, (1982). Exchangeable Cations ($Na^+$, $K^+$, $Ca^{2+}$ and $Mg^{2+}$) mg/kg: The level of cations was determined in the soil samples using standard procedure with an Atomic Absorption Spectrophotometer (Shimadzu AA-6650) and (ASTM D1971/4691) as described by Sparks (1996). Total Hydrocarbon Content (mg/kg) ASTM D3921 was employed for the determination of the THC. Solutions of total hydrocarbon content was further examined by infra-red spectroscopy. Exchangeable Anions ($SO_4^{2-}$, $NO_3^-$& $PO_4^{3-}$): This was analyzed using international standard methods (APHA 4500- $NO_3^-$, E for Nitrate, APHA 4500-P.C for phosphate). Heavy metals (mg/kg): Heavy metal concentration in the studied soils were measured using standard procedure with an Atomic Absorption Spectrophotometer (Shimadzu AA-6650) and a standard method (ASTM D1971/4691) as descrined by Beckhof *et al* (2006). Hydrocarbon Utilizing Bacteria, cfu/g: Bacteria in the soil capable of utilizing hydrocarbon as their sole source of carbon and energy were determined using APHA 9215C (Spread plate) test Methods.

## RESULTS AND DISCUSSION

The results of the Physico-chemical properties of the top soils samples in Izombe oil spill fields, 2024 is presented in Table 2. The mean value of the soil pH in April was 5.85 and 5.84 in June. T-test analysis showed that there were no significant differences in the soil pH from the seven sampling oil spill fields. However, the pH value is rated moderately acidic according to the ratings of Babalola *et al*. (1998). Soils of the study area are from coastal plains (ultisols), highly weathered as a result of rainfall. The electrical Conductivity showed a mean value of 182.2 (us/cm) in April and 177.4 (us/cm) in June, indicating an increase by 148% in April and 290% in June influenced by oil spillage. High EC value in the soil is an indication of salinity (EC >4 ds/m) problems, which may impede crop growth and yield as well as microbial activities (Abu-Hassanein *et al*., 1996; Choo *et al*., 2022; Comma *et al*., 2011; Moral *et al*., 2008). The mean value for Total Organic Carbon (TOC) in April was 0.60% and 0.2% in June, showing an increase of 63% in April and only 4% in June. It was generally observed that TOC relatively were higher in April than in June. possible, there could be cases of more spillage occurring in the month of April than in June resulting to more accumulation of hydrocarbon in the affected fields where immobilization of these substances occurred. This finding agrees with that of Ihem *et al.* (2015).

**Table 2.** Characteristics of surface soil samples in Izombe oil spill field 2024.

| | Sampling Sites (0-15cm) Depth | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | APRIL, 2024 | | | | | | | | JUNE, 2024 | | | | | | | | | |
| Soil parameters | SL1 | SL2 | SL3 | SL4 | SL5 | Mean | SL6 | SL7 | Mean | SL1 | SL2 | SL3 | SL4 | SL5 | Mean | SL6 | SL7 | Mean |
| pH | 5.87 | 5.63 | 5.84 | 5.90 | 5.79 | 5.81 | 5.98 | 5.95 | 5.97 | 5.92 | 5.88 | 5.86 | 5.79 | 5.82 | 5.85 | 5.73 | 5.94 | 5.84 |
| Electrical conductivity µs/cm | 53.0 | 145 | 72.0 | 269 | 372 | 182.2 | 65.0 | 82.0 | 5.97 | 42.0 | 138 | 64.0 | 286 | 357 | 177.4 | 51.0 | 40.0 | 45.5 |
| Total Org. Carbon (%) | 0.078 | 0.314 | 0.629 | 0.94 | 1.06 | 0.60 | 1.10 | 1.10 | 73.5 | 0.314 | 0.197 | 0.393 | 0.943 | 0.708 | 0.53 | 0.943 | 0.157 | 0.55 |
| Total hydrocarbon (mg/kg) | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | 0.98 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Av. phosphorus (mg/kg) | <0.095 | 0.724 | 1.65 | 2.73 | 3.84 | 1,81 | 2.11 | 3.72 | 2.92 | <0.095 | <0.095 | 3.80 | 6.08 | 5.12 | 3.04 | 0.623 | 1.95 | 1.23 |
| Total Nitrogen (mg/kg) | 0.032 | 0.046 | 0.68 | 0.087 | 0.098 | 0.066 | 0.84 | 0.099 | 0.092 | 0.047 | 0.039 | 0.052 | 0.089 | 0.073 | 0.06 | 0.189 | 0.037 | 0.063 |
| Calcium | 3.06 | 10.0 | 4.66 | 25.9 | 30.2 | 14.7 | 4.17 | 5.39 | 4.78 | 2.99 | 9.84 | 4.45 | 25.6 | 30.0 | 14.5 | 4.68 | 6.17 | 5.38 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mg/kg) | | | | | | 6 | | | | | | | | | 8 | | 5 | |
| Sodium, (mg/kg) | 17.6 | 57.8 | 26.8 | 149 | 174 | 85.04 | 24.0 | 31.0 | 27.5 | 17.2 | 56.6 | 25.6 | 148 | 172.83 | 83.88 | 25.7 | 33.2 | 29.45 |
| Potassium, mg/kg | 1.39 | 4.57 | 2.10 | 11.8 | 13.7 | 6.71 | 1.90 | 2.45 | 2.18 | 1.36 | 4.48 | 2.02 | 11.6 | 13.6 | 6.61 | 2.24 | 2.92 | 2.58 |
| Magnesium, mg/kg | 7.04 | 23.1 | 10.7 | 59.6 | 69.3 | 33.95 | 9.60 | 12.2 | 10.90 | 6.88 | 22.6 | 10.3 | 58.8 | 68.8 | 8.33 | 10.8 | 14.0 | 12.4 |

**Table 3.** Heavy metal concentrations of surface soil samples in Izombe oil spills fields, 2024.

| | Sampling Sites (0-15cm) Depth | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | APRIL, 2024 | | | | | | | | | JUNE, 2024 | | | | | | | | |
| Elements | SL1 | SL2 | SL3 | SL4 | SL5 | Mean | SL6 | SL7 | Mean | SL1 | SL2 | SL3 | SL4 | SL5 | Mean | SL6 | SL7 | Mean |
| Manganese mg/kg | 0.056 | 0.190 | 0.216 | 0.311 | 0.480 | 0.250 | 0.128 | 0.405 | 0.267 | 0.060 | 0.187 | 0.206 | 0.300 | 0.488 | 0.248 | 0.138 | 0.410 | 0.274 |
| Zinc, mg/kg | 0.073 | 0.162 | 0.216 | 0.436 | 0.336 | 0.245 | 0.080 | 0.116 | 0.098 | 0.070 | 0.170 | 0.214 | 0.428 | 0.340 | 0.244 | 0.078 | 0.124 | 0.101 |
| Copper, mg/kg | 0.150 | 0.227 | 0.144 | 0.220 | 0.208 | 0.190 | 0.152 | 0.146 | 0.149 | 0.148 | 0.226 | 0.140 | 0.215 | 0.206 | 0.187 | 0.158 | 0.153 | 0.156 |
| Vanadium, mg/kg | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Iron, mg/kg | 46.7 | 31.8 | 22.0 | 31.3 | 29.2 | 32.2 | 32.4 | 250 | 28.7 | 47,0 | 31.2 | 21.6 | 30.6 | 31.88 | 32.1 | 25.5 | 25.5 | 28.8 |
| Cadmium, mg/kg | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Lead, mg/kg | 0.240 | 0.166 | 0.111 | 0.313 | 0.146 | 0.215 | 0.082 | 0.166 | 0.119 | 0.211 | 0.154 | 0.114 | 0.405 | 0.168 | 0.210 | 0.082 | 0.140 | 0.111 |

Effects of oil spillage on Total Hydrocarbon Content (THC) in the field sampled were found to be less than 0.01 in both April and June. This value according to EGASPIN (2018) is found to be low, hence below the critical limit, indicating that both plants and animals in terrestrial and aquatic habitats are safe. Available phosphorus (AV. P) in April was 1.81 showing an increase by 61% and 3.04 in June with an increase of 147% due to spillage effect. Low AV. P with crude oil contamination could be linked to microbes in the soils, which utilize petroleum hydrocarbons as a carbon source (Wang *et al*., 2009; Li *et al*., 2020). Generally, it was observed that the mean values for both AV. P and total nitrogen in the studied soils were low according to the ratings of Esu, (1991). Crude oil pollution encourages nutrient elements imbalance in the soils (Ihem *et al*., 2015). Results showed that the exchangeable bases mean values were allwithin the fertility ratings of Esu (1991) and Babalola *et al*. (1998). the highvalues of these cations could be as a result of favourable mineralization and mobilization of these nutrients by microbes (Eneje and Ebomotie, 2011). However, the oil spillage increased the exchangeable cations at various periods under study. Calcium (Ca) was increased by 209% in April and 171% in June, Sodium (Na) increased by 208% in April and 156% in June and Mg increased by 211%in April and 170% in June.

Effects of oil spillage on the studied soils on heavy metal concentration are presented in Table 3. Higher values of heavy metals were recorded in polluted soils in the two months under study compared to the control in 2024. According to Osuji and Onajake (2004), heavy metals in crude oil show significant mobility in polluted soils. oil spillage increased zinc (Zn) by 150% in Apriland142%in June, copper (Cu) by 28% in April and 20% in June, lead (Pb) by 81% in April and 89% in June. However, all the heavy metals observed were below the permissible limits according to EGASPIN limits, Denneman and Robberse, (1990); Ministry of Housing Netherlands, (1994) and WHO, (1996). With this plausible result, it shows that soils of this area are not under threat perhaps for this short period.

## CONCLUSION

This study revealed that the soils were negatively impacted by the oil spillage. Soils were rendered unproductive and less fertile with oil pollution based on the standard fertility ratings. Heavy metal concentrations were observed to be increased with oil pollution compared to the control sites, though the values were below the permissible limit. These results indicate that soils of the studied locations require proper attention hence application of soil amendments and adopting different measures of bioremediation. Precautionary measures should be taken and world standard procedures followed in crude oil processing and handling to prevent extensive and severe spillage into the soil and water environment. The findings revealed that there was no significant change in soil characteristics affected by the time possibly the duration was two short. It is recommended that the effect of spillage based on the duration should be extended.

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## CONFLICT OF INTERESTS

The authors declare no conflict of interest

## ETHICS APPROVAL

Not applicable

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## AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

## DATA AVAILABILITY

Data will be available on request

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