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# Environmental Assessment of Hydrocarbon Impacted Site at Ajeokpori Oil Spill Site Using Electrical Resistivity Tomography Technique.

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***Abstract- This study investigates the environmental assessment of Ajeokpori of an oily-impacted site using electrical resistivity tomography. A fusion of field-based measurements with advanced geochemical method was used to delineate the precise depth and boundaries of the affected zones. This study characterizes crude oil-impacted sites using Electrical Resistivity Tomography (ERT) at depths of 1.0, 3.0, 6.0, 9.0, and 12.0 meters. An inverse resistivity model was employed to analysed contamination zones based on resistivity values. The colour gradient in the resistivity profile ranged from dark blue and green (low resistivity) to brown, orange, and red (high resistivity), indicating variations in subsurface material properties. Low-resistivity zones, extending from 1.0m to approximately 10.5m depth, suggested the presence of clay or water-saturated materials. Analysis along a 150.0m survey line in the NE-SW direction revealed three contamination plumes. The first and third plumes extended laterally between 0m–100.0m and 155.0m–162.0m, with depths from 0m to 6.0m. The second plume, spanning 106.0m–144.0m laterally, extended beyond the maximum investigation depth of the Res2Dinv model. The depth of oil contamination was from 4m that sometimes varies from different location and the plume direction that predominantly spread beyond the maximum investigation depth of 11 .8m for both Res2Dinv and earth imager model. The Earth Imager model corroborated these findings, showing scattered low-resistivity zones, likely representing localized high-moisture or clayey deposits within higher-resistivity surrounding material. These results provide critical insights for contamination assessment and remediation planning.***

***Index Terms- Electrical Resistivity Tomography, ERT, oil contamination, Ajeokpori, contamination plumes, resistivity model, geophysical methods, environmental assessment, remediation planning, subsurface contamination, hydrocarbon pollution***

## I. INTRODUCTION

Hydrocarbon contamination causes disruption of migratory pathways, degradation of important animal habitats, and the integrity of human existences has been threaten due to oil spill notably, eating contaminated food (Kuppusamy et al., 2019). In 2020 and 2022, Nigerian Oil Spill Detection and Response Agency (NOSDRA) documented 822 combined oil spills amounted to 28,003 barrels of oil spewed into the environment. In 2023, the rupture of underground Trans-Niger Pipeline owned by a multinational company crosses through Eleme, Okulu River and Oke-Olebo stream polluted the environment (Aljazeera, 2023). The spill polluted residential areas, upending livelihoods in fishing and farming thereby affecting communities of the Eleme local government area including Ogale, Aleto, Agbonchia, Onne, Okpaki, and Alesa people caused by the facility of the multinational. The polluted farmland and water surfaces blighted by oil sheens spread for approximately 10 kilometres reaching creeks near Port Harcourt contributed to dead fish mired in sticky crude and the disappearance of micro and macro habitat (Adebayo, 2023).

## II. CHARACTERIZING THE SUBSURFACE DISTRIBUTION OF CRUDE OIL

Characterizing the subsurface distribution of crude oil after a spill in a coastal environment is challenging due to variations in the soil and fluid properties. Crude oil spillage has been recognized as a major source of subsurface contamination in most oil-producing countries (Essaid et al., 2015; Ite et al., 2018). Oftentimes, corrosion, equipment failure, and deliberate acts of vandalism are the three most common causes, with the latter being responsible for the vast majority of crude oil spills (Adeniran et al., 2023). The adverse effect of crude oil on the environment makes it a global issue that has drawn the attention of researchers, policymakers, governments, and non-governmental organizations due to the recorded numbers of crude oil spills across the world (Ukaogo et al., 2020). The detrimental impacts of crude oil spills manifest across various domains, encompassing food security, health concerns, environmental degradation, and economic depreciation (Ogundipe et al., 2020). These challenges have spurred the scientific community to devise remediation solutions that enhance the likelihood of successful restoration, thereby enabling the reclamation of highly contaminated land for both environmental and economic development (Ivshina et al., 2015). However, environmental scientists face the challenge of understanding the migration and distribution patterns of crude oil contamination in the shallow subsurface, a crucial precursor to the formulation of effective cleanup strategies (Brusseau, 2019). The effective remediation and management of sites affected by crude oil contamination requires an in-depth understanding of contaminant distribution and migration pathways (Kuppusamy et al., 2016). Developing practical strategies to address crude oil spills entails a comprehensive subsurface characterization and understanding of the interactions between in-situ soil components and crude oil contaminants (Essaid et al., 2015).

Upon spillage, crude oil contaminants migrate vertically as a result of gravity and laterally, mainly due to advection and dispersion processes (Yoon et al., 2009). The inherent complexity of these process stems from variations in saturation, porosity, and hydraulic conductivity. During migration, a portion of the crude oil remains trapped within pores as disconnected ganglia, while others may be trapped above horizons characterized by low permeabilities (Kang et al., 2018). Additionally, the immiscible phase and the residual phase are present due to the multiphase features of crude oil (Engelmann et al., 2019). Studies on the multiphase behavior of crude oil in the subsurface, its distribution, and evolution in porous media have shed light on these mechanisms (Liu, 2005; Engelmann et al., 2019). Over time once the free product is removed, crude oil trapped between pore grains (the residual phase) may migrate downstream under the influence of the hydraulic gradient, emerging as an additional pollution source (Leharne, 2019). Additionally, dissolved particles suspended in pore water may migrate with the flow, further contributing to contaminant redistribution (Simmons et al., 2002). These complexities make the distribution of crude oil contaminants non-uniform, as they can potentially traverse the vadose and saturated zones as discrete accumulations, posing challenges in terms of characterization and monitoring (Adepelumi et al., 2006).

### 2.1. Environmental and Hydrogeological Applications

Your paper must use a page size corresponding to A4 which is 210mm wide and 297mm long. The margins are set as follows: top= 15 mm, bottom= 15 mm, right=17.5 mm, left = 20 mm. Your paper must be in two column format with a space of 1.93 characters between columns.

2.1.1. Several environmental Studies on the resistivity profiles revealed potential contamination zones, as contaminants can increase the conductivity of groundwater, especially in areas with industrial or agricultural activity. Low-resistivity anomalies could indicate leachate plumes or seepage from 12 waste deposits. In groundwater exploration, resistivity surveys are often used to locate aquifers and determine their extent. High-resistivity zones can sometimes represent impermeable layers (like consolidated rock), which could act as boundaries for aquifers or affect groundwater flow. size 9. Email address must be centered, italic, font size 9. Recommended font sizes are shown in Table 1. No more than 3 levels of headings should be used. Level 1 heading must be left-justified, bold, regular font size 14 and numbered using Arabic numerals. Level 2 headings must be left-justified, bold, regular font size 12 and numbered as sub-heading (i.e 1.1). Level 3 heading must be left-justified, bold, italic font size 10 and numbered as sub-sub heading (i.e 1.1.1) and the first letter of each word capitalized.

2.1.2. Composting

Composting is a biological treatment of contaminated matrix environment in aerobic condition. Matrix phase is a term in soil science that refers to an environment comprising of solids, water and air-filled void spaces between solid particles. Composting also called "bio pile method" has recorded success in the sustainable recycling of organic wastes It is an aerobic process consisting of aerating sludge mixed with organic matter such as animal manure, wood chips and saw dust to a contaminated matrix. The reason for organic matter addition is to encourage the development of microbes for the breaking down of complex contaminants favourable temperature, moisture and nutrient level conditions (Jorgensen *et al.*, 2000). This method of remediation is the preferred method of treatment for municipal sludge because the process produces a marketable end-product that can be used as a soil conditioner and organic fertilizer.

2.1.3. Methods

2.1.3.1 Survey Design

This study was carried out for two months from 14th June through 9th July, 2023 using 2D and 3D electrical resistivity tomography (ERT) survey plan. The 2D and 3D ERT surveys was necessary to quantify the area and volume of contamination within the area at 1.0, 3.0, 6.0, and 9.0m depth overlaid on google map with a resistivity cut-off for oil contamination at ≤600 Ohm.m. The survey method selected was the Wenner 2-D array configuration. The rational for Wenner 2-D array was because of the depth, lateral lines and plume migration pathway were considered using Table 3.1. The geometry of each survey line along with their associated lengths and geographic reference coordinates. To ensure a good coverage of the study area. The data sheet sample utilized for this survey was to ensure an accurate interpretation, using a 3D resistivity interpretation model which 22 gives the most accurate and reliable results (Loke, 2000) was carried out using the acquired 2D apparent resistivity data.

2.1.4. Geometry of ERT Survey Lines along Reference Coordinates

| ERT Line No. | Length of Line (m) | Orientation of Line | Line Start Coordinates (mE) | | Line End Coordinates (mN) | | Zone |
|---|---|---|---|---|---|---|---|
| Line 1 | 150 | NE-SW | 294242.00 | 531939.00 | 294393.00 | 531965.00 | 32N |
| Line 2 | 150 | NE-SW | 294564.00 | 531791.00 | 294445.00 | 531698.00 | 32N |
| Line 3 | 150 | NW-SE | 294358.00 | 531964.00 | 294290.00 | 532098.00 | 32N |
| Line 4 | 150 | NW-SE | 294472.00 | 531689.00 | 294389.00 | 531566.00 | 32N |
| Line 5 | 150 | NW-SE | 294438.00 | 531992.00 | 294491.00 | 531848.00 | 32N |
| Line 6 | 150 | NW-SE | 294379.00 | 531972.00 | 294413.00 | 531834.00 | 32N |
| Line 7 | 150 | NW-SE | 294422.00 | 531808.00 | 294443.00 | 531668.00 | 32N |
| Line 8 | 150 | NE-SW | 294325.00 | 531957.00 | 294355.00 | 531810.00 | 32N |
| Line 9 | 150 | NW-SE | 294495.00 | 531996.00 | 294356.00 | 531948.00 | 32N |
| Line 10 | 150 | NE-SW | 294252.00 | 532129.00 | 294392.00 | 532055.00 | 32N |
| Line 11 | 150 | NW-SE | 294427.00 | 532034.00 | 294298.00 | 531970.00 | 32N |
| Line 12 | 150 | NW-SE | 294325.00 | 531957.00 | 294355.00 | 531810.00 | 32N |
| Line 13 | 150 | NE-SW | 294387.00 | 531657.00 | 294348.00 | 531801.00 | 32N |
| Line 14 | 150 | NW-SE | 294351.00 | 531834.00 | 294466.00 | 531855.00 | 32N |

2.1.6. Electrical Resistivity Tomography (ERT) Procedures

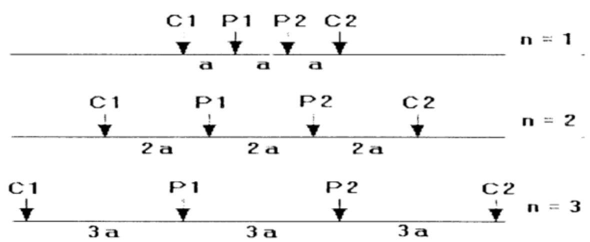
In order to investigate the impact of oil on a soil environment, Tetrameter calibration prior to assessment was done and a base map of the Ajeokpori oil impacted site using GPS for planning survey line paths and trajectories for georeferencing various points along the ERT lines. Tetrameter, metal electrodes, reels of cables, Data recording sheet, ERT working principle, Data Processing.

2.1.7 Data Sheets

Data sheets were prepared for the survey for easy entering of data acquired from the survey. The data sheets consist of the survey configuration method, measurement to be acquired, spacing of the current electrodes, spacing of the potential electrodes, geometric factors associated with each spacing and Resistance measurement in Ohms

2.1.8 . Electrical Resistivity Tomography (ERT) working Principle

The basic principle behind the collection of data in electrical resistivity field measurement is the measurement of an electric potential (V) due to the dissipation of electric current which travels in a radial fashion from its point of origin within an infinite homogenous half-space. The electric potential V = V (x, y, z) changes with respect to three coordinates to become a 3D function of the given current. The 2D and 3D geological model on descriptive earth systems was used to compute the theoretical electric potential with the governing equations V (x, y, z) (Schwarzbach et al., 2005). This was ascertained with the fundamental physical law on resistivity surveys that governs the flow of current in the ground (Kearey et al., 2002). The Wenner field configuration array was utilized as the choice resistivity method for this study due to the depth of contamination. In using the Wenner array configuration, two current electrodes (Cl and C2) were placed outwards and hammered into the ground to transmit current, while two potential electrodes (P1 and P2) were placed inwardly to measures the potential difference across the current electrodes.




gure 3: Wenner Array Configuration utilized for this study

Figure 1: Wenner Array Configuration Utilized for this Study

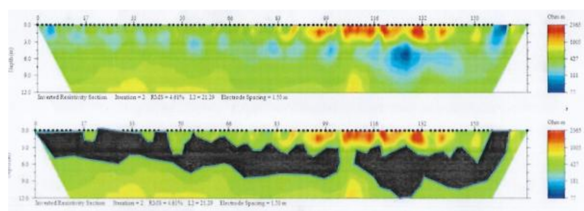
2.1.9 Resistivity Inverse Model

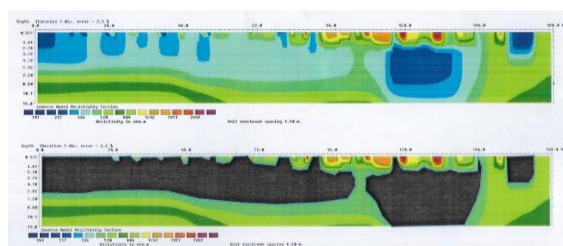
In order to generate the synthetic data for the 2D resistivity inverse model, various datasets measured from the terametre were employed based on the equation for calculating apparent resistivity expressed as $\rho a = G \Delta VI$ 3.1
where; $\rho a$ = apparent resistivity
G = geometric factor depending on the electrode array configuration
$\Delta V$ = potential difference between the electrodes, and
I = injected current

## III. RESULTS AND DISCUSSION

### 3.1.1. Assessment of various Depth of Contamination

Characterizing crude oil impacted sites using electrical resistivity tomography (ERT) at different depth of 1.0, 3.0, 6.0, 9.0, and 12.0 m of contamination using inverse resistivity model with resistivity values (in ohm-m). The colour profile indicates resistivity represented by a colour gradient ranging from dark blue and green (low resistivity) to brown, orange and red (high resistivity). The colour scale and depth indicators suggest different resistivity layers at various depths. The depth of 1.0m to about 10.5 meters, with deeper depths typically indicate less resistive materials such as clay or water-saturated zones along the survey line. Figure 4.1. shows the trends in the north east to south west (NE-SW) direction with a line length of 150.0m. The three plumes were observed with lateral spread of contamination between 0 m to 100. 0m, 106. 0m to 144. 0m and 155. 0m to 162. 0m. The first and the third plume depth were observed from 0m to 6. 0m while the second plume from 0m extending pass the maximum investigation depth for Res2Dinv model presented in Figure 4.1. Similar plume trend was observed for earth imager model with notable low-resistivity in blue that are scattered along the profile. These may represent localized areas with high moisture content or clayey deposits within the generally higher-resistivity surrounding material.





## IV. CONCLUSION

The assessment of oil contaminated site using electrical resistivity tomography (ERT) was investigated. The environmental site characterization was employed using 2D and 3D electrical resistivity tomography to assess the depth and extent of hydrocarbon contamination in an oil-contaminated site of Ajeokpori, Ogale community, Eleme L.G.A, Rivers State.

1. The depth of contamination of Ajeokpori, oil impacted sites were within 1.0 to 10.5 meters, with deeper depths of 12.0 m indicating less resistive materials such as clay or water-saturated zones along the survey line.
2. The presence of oil contamination suggests low-resistivity zones which migrate laterally towards NW-SE and NE-SW to contaminate groundwater flow. By mapping the extent of the low-resistivity zones (141–520 Ω·m), an approximate contaminated area was determined.
3. The plume transport was in the NW-SE direction of the area at depth of 1.0m with lateral spread extending beyond the maximum investigation depth of 11.8m.
4. The 3D model from 2D geological map using ERT imaged indicated hydrocarbon contaminant plume to a maximum depth of l2.0m which adversely pollute groundwater flow in the area.

Hence, groundwater available for domestic use has been polluted by hydrocarbon leakage from an abandoned well head within the experimental site.

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