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Investigating Groundwater and Sub – Soil Pollution Using Electrical Resistivity Imaging (ERI): A Case Study of Sapele Athletic Club, Sapele Local Government Area of Delta State, Nigeria

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ABSTRACT
This study was undertaken at Sapele Athletic Golf Club, Sapele Local Government Area of Delta State, Nigeria with the aim of determining hydrocarbon pollution occasioned by vandalization of petroleum pipeline crossing the area and eventual leakage of oil onto the Benin River and the surroundings of the study area. The National Instrument (NI) USB – 6255 data acquisition device was used for the electrical resistivity imaging (ERI) of the study area. The Wenner array configuration with minimum electrode spacing of $5m$ was utilized at the site. Res2Dinv software was used for the processing and iteration of the $2-D$ resistivity data acquired. The results of the geoelectric investigation revealed five geoelectric layers namely, lateritic topsoil, sandy clay soil, fine coarse sand, medium coarse sand and coarse sand. The generated profiles of the acquired data helped map hydrocarbon contamination which was delineated as an area of anomalously high interpreted resistivities. This high resistivity can be attributed to the presence of hydrocarbon within the subsurface which is an indication that shallow aquifer in the study area may have been polluted as a result of intrusion from the Benin River which is about $100\ m$ East of survey site. From physical examination of the river, it can be seen that it is polluted and as such there is a high possibility that the aquifer is contaminated. It is therefore recommended that chemical analysis of borehole water and soil samples from the survey environment should be carried out to ascertain the nature of the pollutant and the level of contamination if any.
Keywords: Electrical Resistivity Imaging (ERI), Virtual Instrumentation (VI), Hydrocarbon contamination

INTRODUCTION

Pollution is the release of substances (such as chemicals or microorganisms) into subsurface groundwater or into lakes, streams, rivers, estuaries and oceans to the point where the substances interfere with beneficial use of the water or with the natural functioning of ecosystems. These pollutants can be pathogenic microorganisms, putrescible organic waste, plant nutrients, toxic chemicals, sediments, heat, petroleum (oil) and radioactive substances.

Commercial oil exploration which began in Nigeria in 1958 has subjected the oil producing communities to environmental degradation leading to depletion of resources on which the livelihood of the people depends (Tse and Nwankwo, 2013). Also, these oil exploration activities have for the most part contaminated/polluted both the aquifer and surface water in the study area due to spillages arising from petroleum pipeline vandalism. Water contained in underground geologic formations called aquifers is a source of drinking water for many people.

Environmental challenges which affect the groundwater system are of various types. Such challenges could be contamination occasioned by hydrocarbon spill from pipelines, leachate from dumpsite, industrial waste, etc. Groundwater contamination as a result of hydrocarbon spill from pipelines is a common phenomenon in some areas with pipeline crossing. Hydrocarbon spill from pipeline could be caused by several factors which include blowouts resulting from overpressure, equipment failure, operators' errors, corrosion, vandalization, pigging operations, etc (Akinrinade, Oladapo & Onwah, 2016).

When spills occur, the groundwater or aquifer systems as well as the soil in such environment remain at risk of contamination. One of the negative environmental consequences of oil exploration and exploitation in Nigeria that degrades the environment and its resources is oil spillage (Tse A.C. and Nwankwo A.C., 2013).

Geophysical methods have been found to be useful to the study of polluted areas. These methods are dependent on the contrasts in several physical properties that typically make up the different constituents of the affected zone (Uchegbulam and Ayolabi, 2014). However, hydrocarbons have much higher resistivity than water. This circumstance makes the ERI suitable for hydrocarbon contamination delineation. In this research, the 2 – D Electrical Resistivity Imaging (ERI) was employed to delineate hydrocarbon pollution in the study area.

Two-dimensional resistivity measurements provide a two-dimensional vertical picture of the sounding media. The 2-dimensional electrical imaging method increases electrode separation as well as makes measurements at multiple locations along the horizontal axis and provides data for two dimensional interpretation of subsurface (Allen, 2004). According to Cardimona, 2011, 2-dimensional images of the subsurface apparent resistivity variation are called pseudo-sections and data plotted in cross-section is a simplistic representation of actual complex current flow paths.

The behavior of electrical resistivity of contaminants with respect to the survey area is dependent on so many factors, including lithology, moisture and solubility of the contaminants in the groundwater.

The Study Area

Sapele lies along the Benin River just below the confluence of the Ethiope and Jamieson rivers, $98\,miles\ (158km)$ from the Escravos Bar and entrance to the Bight of Benin.

Sapele is situated at $5.89^{\circ}\ North$ latitude, $5.68^{\circ}\ East$ longitude and $33meters$ elevation above the sea level. Figure 1 shows the Benin River and Figure 2 displays a Google map of Sapele, showing the Sapele Athletic Club where the ERI was carried out.

MATERIALS AND METHOD

The instruments used are cables, steel electrodes, hammers, DC battery, GPS, measuring tapes, umbrella, Harris signal generator, and National Instruments (NI) USB-6255 data acquisition (DAQ) device. The 2-dimensional resistivity survey was conducted along three profiles at Athletic Golf club in Sapele Local Government Area Delta State (Figure 2) to determine the Lithological Profile and possibility of contamination of the Site. The First two lines were taken from South to North of the surveyed area while the last profile was taken from East to West of the Surveyed Site. Each of the selected profiles measures 60m in Length. The wenner array configuration method with minimum electrode spacing of 5m was employed at this site.

This research project used res2Dinv (Loke, 2000) for the processing and iteration of the 2-D resistivity data acquired. Res2Dinv is a large and complex program with many user modifiable inversion parameters. The software manually provides a detailed explanation of each parameter and its influence on the inversion process. The process involves converting the data to res2Dinv format that is readable by the software. The software is a computer program which automatically determines a two-dimensional (2-D) resistivity model of the subsurface for the data obtained from electrical imaging surveys. The Dell laptop computer (Pentium 11, 266 MHz processor) was used to invert apparent resistivity data using res2Dinv default inversion parameter settings and this inversion process took less than 90 seconds.

Figure 1. The Benin River

Figure 2. Google map showing Sapele Athletic Club

RESULTS AND DISCUSSIONS

Results of the profiles from the locations are presented in the figures below. A three resistivity or chargeability sections are shown for each profile (measured and calculated apparent pseudo-sections and the inverse model resistivity or chargeability section). In the profiles shown below, two zones are identified: they are the zones of high and low resistivity.

Traverse 1

The inverted resistivity model section (Figure 3) shows variation of resistivity values ranging from about $4.4 - 1501\Omega m$, revealing varying degree of conductivity with respect to lithology and fluid types.

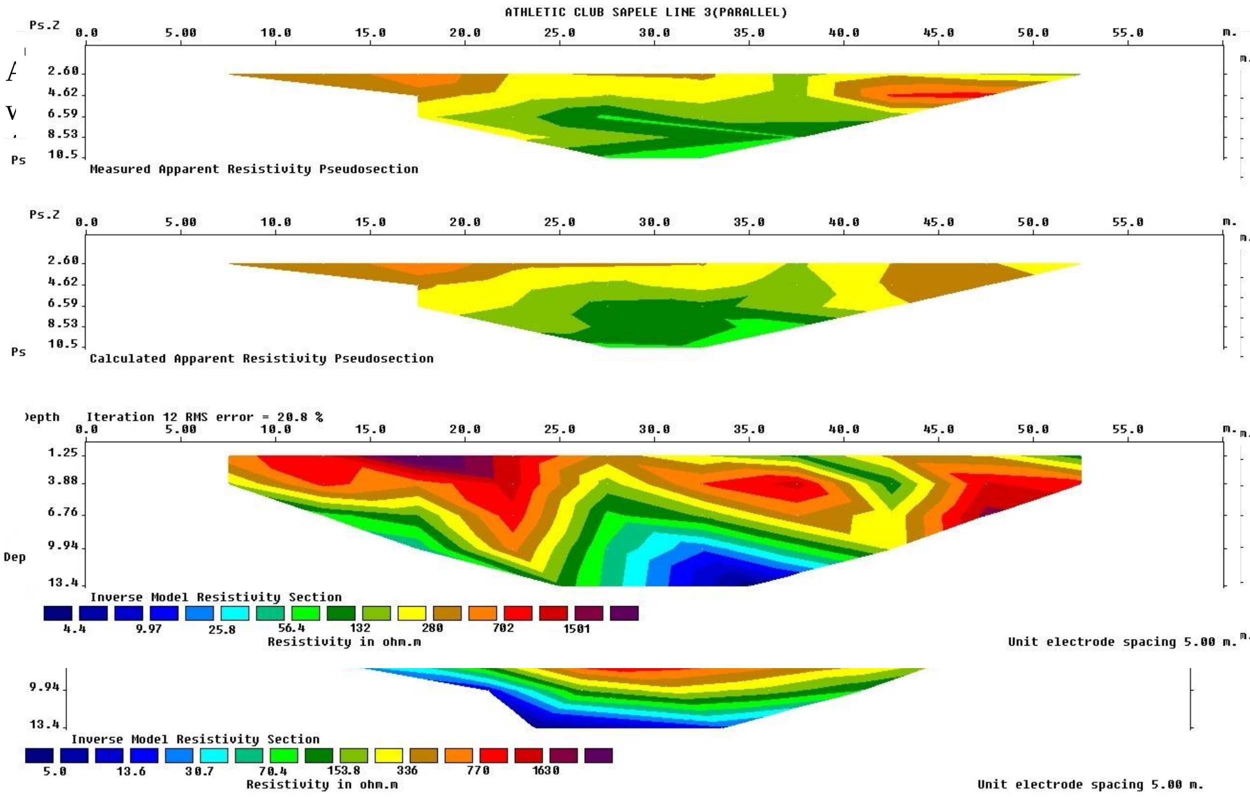

Figure 3. Sapele Atheletic Club (Traverse 1)

Traverse 3

The inverted resistivity model section (Figure 4) shows variation of resistivity values ranging from about $4.4 - 1501\Omega m$, revealing varying degree of conductivity due to fluid types and lithology. The traverse shows an area of anomalously high resistivity ($702 - 1501\Omega m$) structure.

At a lateral distance of $8m - 26m$, possible hydrocarbon pollution was also noticed at a depth of $1.25m - 11m$, while at a lateral distance of $30m - 40m$, the depth of pollution vary from $3.88m - 6.76m$ and also, at a lateral distance of $45m - 53m$, the depth of pollution vary from $3.88m - 9.94m$. There is also a possibility of underground water pollution.

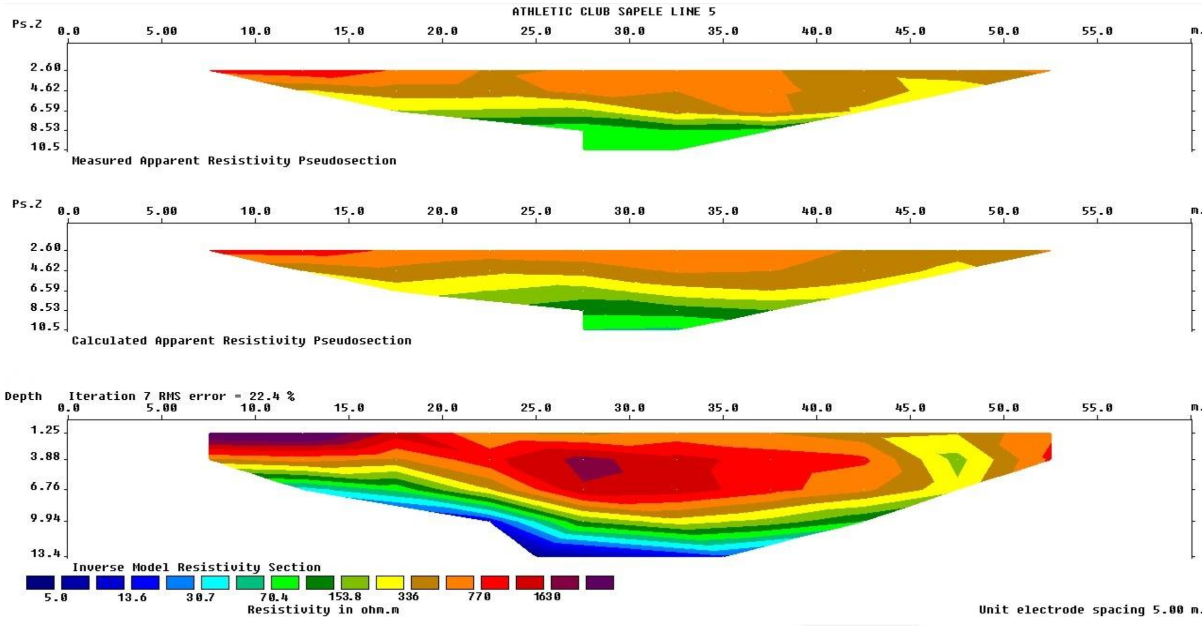

Figure 4. Sapele Atheletic Club (Traverse 2)

Traverse 5

This traverse (Figure 5) shows an area of typical comparative low resistivity. The high resistivity materials are only limited to the surface at the beginning of the profile and this could be a case of hydrocarbon pollution at the surface. This can be seen at a lateral distance of $8m - 43m$ to a depth of $1.25m - 6.76m$.

The relatively low resistivity structures observed were interpreted to be areas with dominant clay materials.

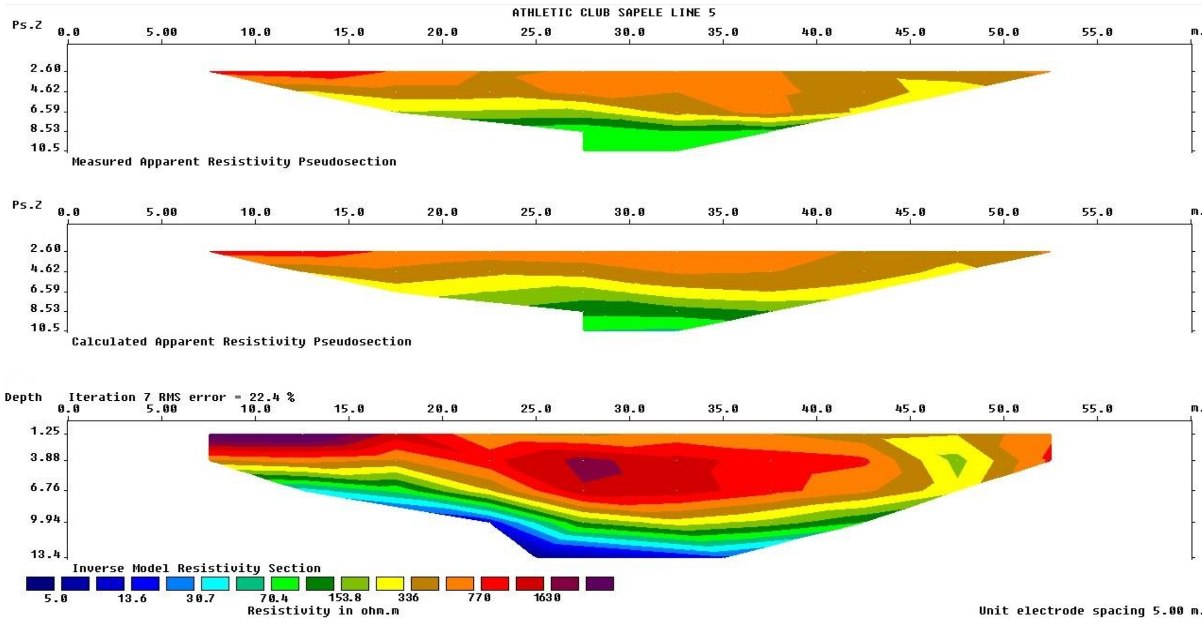

Figure 5. Sapele Atheletic Club (Traverse 3)

CONCLUSION

Three profiles were taken at Athletic Golf club in Sapele Local Govt. Area Delta State to determine the Lithological Profile and possibility of contamination of the Site. The First two lines were taken from South to North of the surveyed area while the last profile was taken from East to West of the Surveyed Site. Each of the selected profiles measures 60m in Length. The wenner array configuration method with minimum electrode spacing of 5m was employed at this site. The data was acquired using Pasi Earth resistivity Meter. The res2Dinv software was employed for the processing and the iteration of the 2-D resistivity data acquired. The results of the Geoelectrical investigation have revealed six geoelectric layers namely the lateritic topsoil, sandy clay soil, fine coarse sand, medium coarse sand and coarse sand. The 2-D electrical resistivity imaging result show the resistivity distribution over a lateral distance of 60m from the surface to a depth of about 13.4m beneath the surface. The inverse resistivity model section of control traverse showed a quite heterogeneous and complex subsurface geological formation. Higher resistivity anomaly with resistivity values greater than 700Ωm which occurred at the topsoil across each of the 3 profiles is suspected to be lateritic soil. This Stretches up to 9m in depth in each of the profiles. The next layers with resistivity ranging from 300Ωm to 650Ωm is suspected to be sandy clayey soil, while the lower layers from 10m to about 11.5 reveals sand bodies of various grain sizes. However a very low resistivity of less than 5Ωm was evident in all the 3 profiles at the average depth of about 12m and below. This very low resistivity is suspected to be aquifer bearing formation. It is also possible that there is an intrusion of the water from the Benin River which is about 100m east of the survey site. From Physical assessment of the river, It is seen that it is polluted hence there is a high possibility the aquifer is contaminated. It is therefore recommended that chemical analysis be carried out to determine the type of pollutant and the level of contamination.

RECOMMENDATION

It is therefore recommended that ERI in other configuration be carried out to confirm the findings of this research. Also, chemical analysis of water samples from Benin River and soil samples from the survey environment to ascertain the nature of the pollutant and the level of contamination if any.

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