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Design/Modification of a Virtual Instrument System for Electrical Resistivity Imaging in Environmental Pollution Studies: A Case Study of Sapele Local Government Area of Delta State, Nigeria

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Abstract

This study was carried out at Elume Grammar School in Elume, Sapele LGA of Delta State, Nigeria with the sole aim of determining hydrocarbon contamination occasioned by petroleum pipeline vandalization near 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 – Schlumberger array with $5m$ minimum electrode spacing was employed. 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, the 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. 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

1. Introduction

The starting point of any geophysical investigation is basic physics. Geophysics will only be effective if a target of interest has a physical contrast with the surrounding ground (Johnson, 2003). The application of the study of principles of physics to the study of geophysics yields a discipline in which several basic concepts of physics can be integrated into a single area of study. The cross-disciplinary field of geophysics makes it possible for many such applications of physics theories to real-world situations (Herman, 2001). In order to develop a technique for geophysical investigations, an instrumentation system capable of acquiring accurate data, analysis and presenting the data is paramount (NGRI, 2009). The study of earth resistivity with virtual instrument system is a recent development. Virtual instrumentation is an interdisciplinary field that merges sensing, hardware and software technologies in order to create flexible and sophisticated instruments for control and monitoring applications (Obrenovie, Starcevic and Jovanov, 2006). The virtual instrument system can be used for so many different purposes, with the attendant advantage of saving money and time. Applications can be for physical, chemical, and biological variables. A humble attempt would be made in this first phase of the research to draw on the electronic resources of modern data acquisition systems and a laptop with usual electrode configurations for electrical resistivity imaging (ERI) at Elume in Sapele Local Government Area, Delta State, Nigeria.

The thrust of the study brings to bear the fundamental principles of instrumentation, rapid data acquisition, signal processing and electrical noise in the earth. The instrument affords the student an opportunity to examine in fine details the way earth modifies a signal probe – which is the essence of geophysics. The Data Acquisition (DAQ) device for the instrument design is the National Instruments (NI) USB data acquisition device with 80 analog channels. It is a state of the art technology instrument designed with minimal hardware, catering for 16-bit accuracy in measurements, with increased reliability and faster data acquisition on the field. LabVIEW SignalExpress virtual panel will be used as graphical user interface and for signal conditioning.

The first phase of this research seeks to achieve the following: design a cost – effective virtual instrument system that can function in a wide range of scientific applications, establish the reliability of geophysical methods in mapping pollution plumes in any geological and hydrogeological terrain, and also help to provide information to both Government and people in the study area about the implications and effects on groundwater and soil contamination.

2. Materials and Method

The VI measurement system is in two parts – hardware and software as shown in Figure 1. The hardware comprises cables, steel electrodes, hammers, DC battery, GPS, measuring tapes, umbrella, NI USB-6255 data acquisition (DAQ) device, Harris oscillator, PC while the software is the LabVIEW SignalExpress used for data acquisition and signal processing.

2.1 Materials

2.1.1 *Hardware*

The signal generator used is the manually controlled Harris Power Signal Generator. There are three types of pulse shape (triangular, square and sine) available and can generate a frequency range of 0.1Hz-2240Hz. The data acquisition is based on a 96 channel 16bits NI USB-6255 analog to digital conversion (ADC). The PC displays the signals on the screen.

2.1.2 *Software*

In a measurement system, the entire architecture cannot interface with the human user without software not to mention the fact that it is almost insignificant with inappropriate software. The software in this design is in two parts – The driver (NI-DAQ_{max}) and the application (LabVIEW SignalExpress). The NI-DAQ_{max} establishes communication between DAQ devices and the PCs. The LabVIEW SignalExpress is an interactive framework for measurement and automation. It is used for acquiring, analyzing, and presenting data from hundreds of acquisition devices and instruments, with no programming required (National Instruments, 2009).

2.2 Method

The 2-dimensional resistivity survey was conducted along three profiles at Elume Grammar School in Elume, Sapele Local Governmentt Area of 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 – Shlumberger array configuration method with minimum electrode spacing of 5m was employed at this site.

This research project used res2Dinv (Loke, 2001) to invert the apparent resistivity data. 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.

3. Results and Discussions

Results of the profiles from the locations are presented in the figures below. Three resistivity or chargeability sections are shown for each profile (measured and calculated apparent pseudo-sections and the inverse model resistivity or chargeability section).

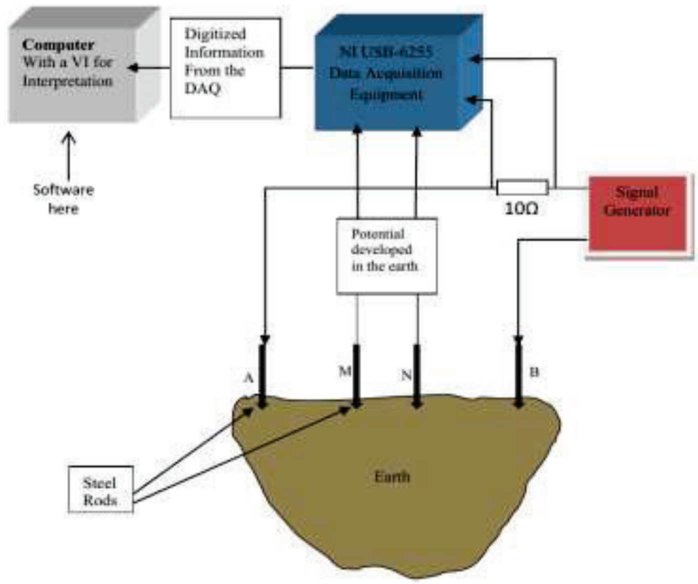

Figure 1. A typical PC-based DAQ system for earth resistivity survey

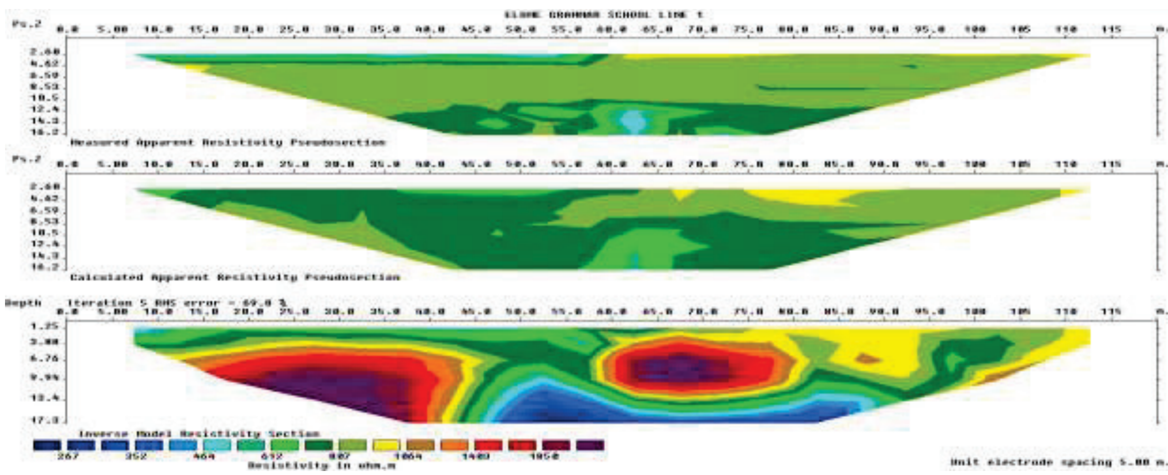

Figure 2. Elume

The inverted resistivity model (Figure 2) shows variation of resistivity values ranging from about $267 - 1850\,\Omega m$, revealing varying degree of conductivity associated with fluid types and lithology.

Also, the two – dimensional section revealed an anomalously high resistivity ($2000 - 4299\Omega m$) structure within a varying lateral and vertical location across the traverse.

At a lateral distance of $15m - 40m$, possible hydrocarbon pollution was noticed at a depth of $7m - 17.3m$ while at a lateral distance of $60m - 78m$, the depth of pollution vary from $3.88m - 10m$ beneath the surface. This may be a clear evidence of possible groundwater pollution by the hydrocarbon since the water table lies within $4 - 5m$ within the study area.

The inverse model resistivity section (Figure 3) obtained along traverse 2 shows that the subsurface is composed of varying degree of resistivity as can be seen from the resistivity values from about $295 - 4299\,\Omega m$, revealing varying degree of conductivity associated with lithology and fluid types.

Also, the two – dimensional section revealed an anomalously high resistivity ($2000 - 4299$) structure within a varying lateral and vertical location across the traverse.

At a lateral distance of $36m - 70m$, possible hydrocarbon pollution was also noticed at a depth of $9.94 - 17.3m$ while the depth of possible low pollution vary from $13.4m - 17.3m$ at a lateral distance of $80 - 86m$.

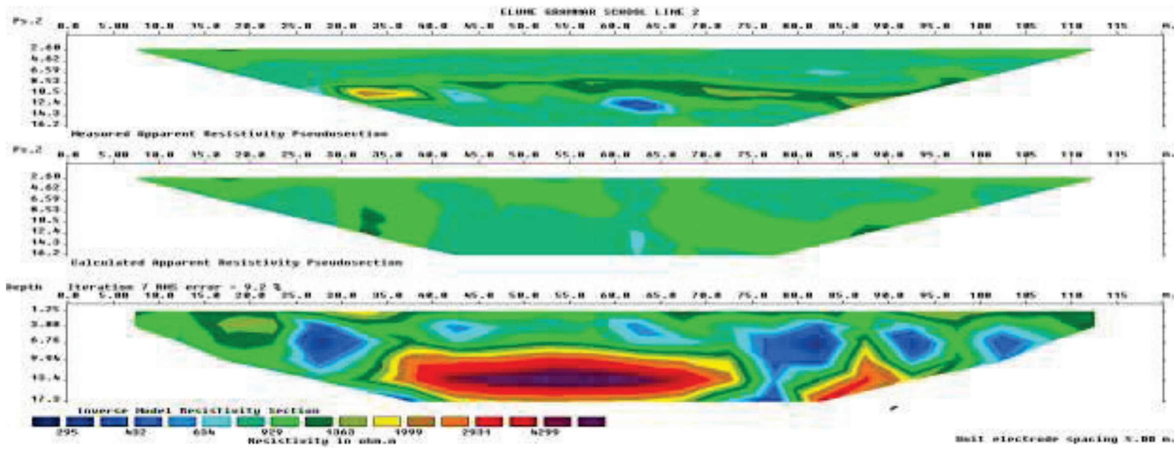

Figure 3. Elume

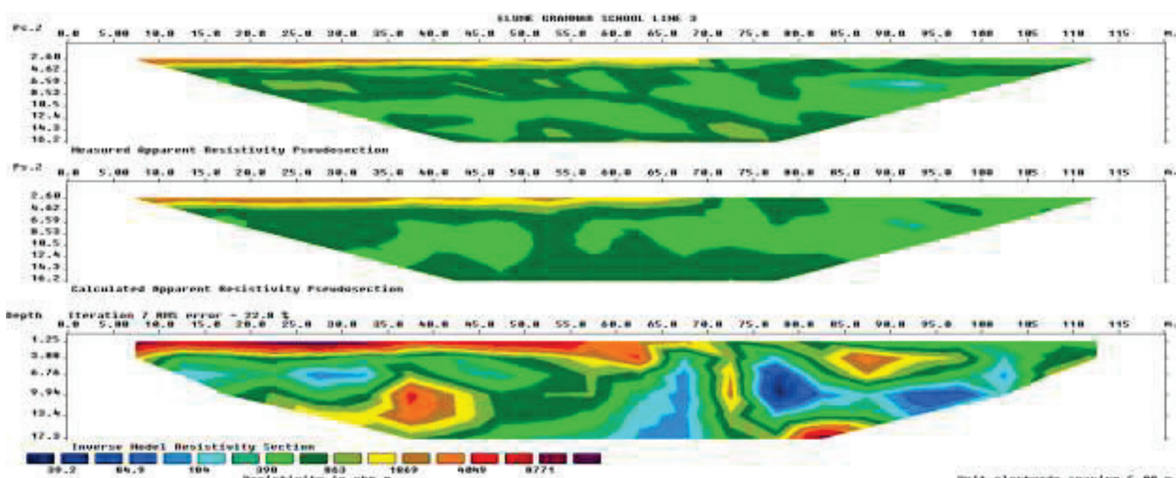

Figure 4. Elume

The inverse model resistivity section (Figure 4) in traverse 3 shows variation in resistivity values ranging from $39.2 - 8771\,\Omega m$, revealing varying degree of conductivity associated with fluid types and lithology.

The two – dimensional section reveals that the high electrical resistivity values at the topsoil between electrode positions $8m - 64m$ could be attributed to possible hydrocarbon pollution reminiscence of the activities of oil bunkers in the study area. Though pockets of high resistivity materials exist at certain locations across the traverse, they may not be unconnected with the presence of high and also low hydrocarbon pollution as earlier mentioned.

4. Conclusion

The results of the electrical resistivity (ERI) at Elume, Sapele, Delta State by using two – dimensional resistivity imaging have enabled us to ascertain possible hydrocarbon pollution of the subsurface at the study area/environment. The results of the geoelectric investigation revealed five geoelectric layers namely, the lateritic topsoil, sandy clay soil, fine coarse sand, medium coarse sand and coarse sand. The two – dimensional electrical resistivity imaging results show the resistivity distribution over a lateral distance of $120m$ from the surface to a depth of about $17.3m$ beneath the surface. Possible hydrocarbon pollution occurred at depths $\geq 17.3m$ with high resistivity reading ranging from $200\Omega m$ and above. The high resistivity formations can be attributed to possible hydrocarbon presence which is an indication of possible underground water pollution in the study area.

5. Recommendation

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

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