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APPLICATION OF GEO-ELECTRICAL IMAGING TO DETERMINE SIGNATURES OF BURIED WASTE

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ABSTRACT
Electrical resistivity and induce polarization data were collected to generate 2D subsurface resistivity and chargeability models to delineate signatures of buried waste which includes domestic waste, oil sludge and metal scraps at Kurmin Mashi Kaduna metropolis, North Western, Nigeria. Four profiles (A, B, C & D) each of length 100m with a separation of 10 m were investigated with the help of ABEM SAS1000 Terrameter using the Wenner-alpha electrode array configuration with minimum electrode spacing of 3.00 m. Results from the resistivity model reveals high resistivity values (> 998 ohm-m) which corresponds to the position of the buried sludge and a low resistivity values ranging from 33.5 - 88 ohm-m indicating the geo-electric signatures of the buried metal scraps. Both the resistivity and IP models could not resolve the position of the buried domestic waste but the IP models revealed chargeability values of 84 msec and 54 msec corresponding to the positions of the buried oil sludge and metal scraps respectively. The results of this research show that integrated technique applied at the same location allows a more precise description of the subsurface and thus reduced the degree of ambiguity and improvement in the interpretation of anomaly greatly.

Keywords: Electrical resistivity, Induce polarization, Chargeability, Wenner alpha array, Buried waste

INTRODUCTION

Over the recent years, advances in electronics in data gathering and processing software has widen experience in data interpretation in the discovery of illegal buried waste, through the use of geophysical surveys. The low cost of obtaining the geophysical data and their non-invasive characteristics have promoted a great increase in their use in the field (Marchetti, 2000). Electrical resistivity technique uses parameters like potential difference and induced current to measure electrical resistivity distribution of the subsurface layers that can be used to determine depth and thickness of, for example, buried waste confined in geologic layers. Geo-electrical surveys are commonly used in Hydrological, mining and geotechnical investigations. More recently, it has been used for environmental surveys (Loke, 1999).Many geophysical techniques can be used in the investigation of buried waste (Emerson et al, 1992) but the choice of the methodology to be used will depend on the physical characteristics of the materials and the depth of the target. For example, Magneto metric method is used frequently for environmental exploration of the subsoil and has been an effective method for the survey and detection of buried ferromagnetic objects (Sheinker et al, 2009). Since waste is often segregated in landfills (green waste, construction waste, household waste, e.t.c), magnetic surveys often show only the footprint of areas that contain substantial amount of metal, but resistivity techniques unlike magnetic provide substantially more information because they are capable of detecting non-metallic waste. (Dahlin, 1996). These benefits of the resistivity methods have made it an extremely valuable tool in our environmental work in general and in this study particularly. Resistivity data has serious ambiguities in distinguishing between equally electrically conducting targets like electrolytic, metallic-ion contamination plumes from saline clay (Dahlin, 2000). One of the more recent developments in the instrumentation for electrical imaging surveys has been the addition of Induced Polarization (IP) capability in the multi-electrode resistivity meter system (Loke, 2004). IP application has been in the area of exploration of metalliferous mineral deposits, clay location for hydrogeological survey and recently in mapping electrochemical reaction for pollutants in the ground. Details of IP theory can be found in many fine textbooks, such as by Keller and Frischknecht (1966), Summer (1976), Telford et al. (1990) and Zhdanov and Keller (1994). In simple terms, the IP response reflects the degree to which the subsurface is able to store electrical charge, analogous to a capacitor (Sumner, 1976). This polarization occurs at the interface between [1] metal and a fluid (identified as electrode polarization IP effect), and [2] a non-metal (e.g. silica or clay minerals) and a fluid (traditionally called membrane polarization). Thus, time-domain IP data is generally integrated in pollution studies for the reason that it has the potential through its electrical chargeability to distinguish between these targets. With the introduction of automated data acquiring equipment and fast computer interpretation software, Tomography techniques are now employed in the field. Tomography is an imaging technique which generates a cross-sectional picture (tomogram) of an object by utilizing the objects response to non-invasive, non-destructive energy of an external The present research investigates the electrical and chargeability signatures of three types of waste (domestic waste, sludge and metal scraps) employing 2D geo-electrical method. The geo-electrical data were collected manually and processed with the RES2DINV code.

THEORY OF 2-DIMENSIONAL GEO-ELECRICAL TECHNIQUE

A 2-D imaging survey is usually carried out with a computer controlled resistivity meter system connected to a multi-electrode cable system, (but in this study particularly, no multi-electrode system was used as data were collected manually). The control software automatically selects the appropriate four electrodes for each measurement to give a 2D coverage of the subsurface. Figure 1.1 shows the sequence of measurements for the Wenner electrode array which was adapted for this research. In the figure, the spacing between adjacent electrodes is “a”. For the first measurement, electrodes number 1, 2, 3 and 4 are used. Notice that electrode 1 is used as the first current electrode C1, electrode 2 as the first potential electrode P1, electrode 3 as the second potential electrode P2 and electrode 4 as the second current electrode C2. For the second measurement, electrodes number 2, 3, 4 and 5 are used for C1, P1, P2 and C2 respectively. This is repeated down the line of electrodes until electrodes 31, 32, 33 and 34 are used for the last measurement with "1a" spacing. 34 electrodes were used for this work, thus, there are 31 (34 - 3) possible measurements with "1a" spacing for the Wenner array adapted. After completing the sequence of measurements with "1a" spacing, the next sequence of measurements with "2a" electrode spacing is made. Electrodes 1, 3, 5 and 7 are used for the first measurement. The electrodes are chosen so that the spacing between adjacent electrodes is "2a". For the second measurement, electrodes 2, 4, 6 and 8 are used. This process is repeated down the line until electrodes 28, 30, 32 and 34 are used for the last measurement with spacing "2a". With "2a" spacing there are 28 (34 - 2x3) possible measurements. The same process is repeated for measurements with "3a", "4a", "5a" and "6a" spacing. To get the best results, the measurements in a field survey should be carried out in a systematic manner so that, as far as possible, all the possible measurements are made. This will affect the quality of the interpretation model obtained from the inversion of the apparent resistivity measurements (Dahlin and Loke 1998). Note that as the electrode spacing increases, the number of measurements decreases. The number of measurements that can be obtained for each electrode spacing, for a given number of electrodes along the survey line, depends on the type of array used. The Wenner array gives the smallest number of possible measurements compared to the other common arrays that are used in 2-D surveys (Loke, 2004).

LOCATION AND GEOLOGIC DESCRIPTION OF THE STUDY AREA

The survey area is located at Kurmin Mashi, in Kaduna metropolis, north western Nigeria with coordinates $10^{0}32'27.50^{0}N$ and $7^{0}25'08.52^{0}E$ (Fig 2). The study area lies within the Guinea Savannah belt, with two distinct seasons. The dry season normally begins in October/November to March/April, while the wet season occurs between April/May to October/November. Average annual rainfall for Kaduna is 1270mm (Eduvie, 2003) and rainfall usually reaches a peak in August. Temperatures vary between less than $50^{0}C$ in December/January and $20^{0}C$ in March/April. Geologically, the survey area lies entirely within the Basement Complex of Northern Nigeria. The rocks consist of series of granites, gneisses, migmatite, low-grade schist, quartzite and amphibolites that have been grouped by the British authors as 'Basement Complex' of the Precambrian age (Olugboye, 1975). Groundwater occurs under water table conditions in the clay sand/sand aquifer and under semi-confined to confined conditions in the weathered /fractured zone (Hazell, 1992).

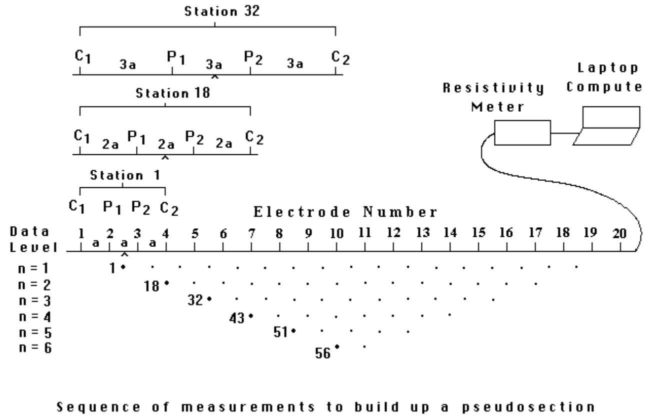

Figure. 1: The arrangement of electrodes for a 2-D electrical survey and the sequence of Measurements used to build up a pseudosection (Loke, 2004).

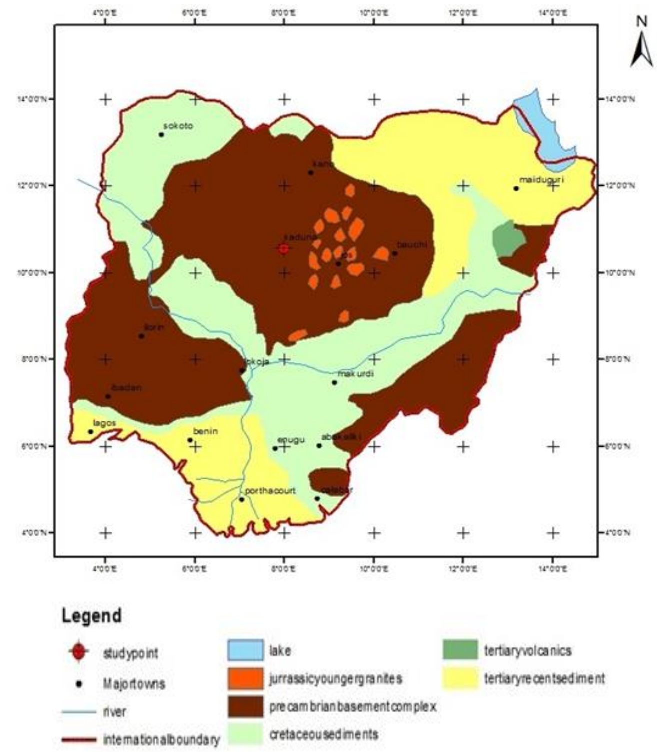

Figure 2 Geologic map of Nigeria and location of study area

A

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B

C

Figure 3. Waste types. (a) Domestic waste, (b) Oil sludge and (c) Metal scrap

FIELD PROCEDURE

Four profiles designated as profiles; A, B, C, and D each of length 100 m with a separation of 10 m from each other were examined. Profiles A, B and C each contains a hole dug 1m deep with a diameter of about 0.4 m while profile D contains no hole and its kept as a control profile. The hole in profile A was dug 5 m from the starting point of the profile and was filled with domestic waste to about 0.6 m. Profile B's hole was filled with oil sludge at a profile distance of 50 m on the profile while C was filled with metal scraps to about 0.6 m depth at a profile distance of 100 m. (Fig 3) Electrical resistivity and induce polarization data collected used to generate 2D subsurface resistivity distribution and chargeability. The electrical resistivity tomography and IP data were collected using the ABEM SAS1000 Terrameter manually using the Wenner alpha electrode array configuration. The measurement starts from the east end of each profile to the west with minimum electrode spacing of 3.0 m, using electrodes 1, 2, 3 and 4 initially. Each electrode was then shifted a distance of 3.0 m (one unit electrode spacing) after taking the measurements at that data point, the active electrode position becomes 2, 3, 4 and 5. This procedure was continued to the end of the profile line with electrode positions for the last measurement being 90, 93, 96 and 99.The electrode spacing was then increased by 3.0 m for the measurements of the next data level, such that the active electrode positions were 1, 2, 4 and 5. The procedure was then repeated by shifting each of the electrodes a distance of 3.0 m (one-unit electrode spacing) and maintaining the electrode spacing for the data level. This procedure was followed until 9 data levels were observed with 72 data points for each of the profiles A, B, C and D. The operator set the Terrameter for the next electrode and the method is repeated up to the last electrode, adhering to the Wenner array electrode configuration. The equipment was then moved to the next profile until all the four profiles were investigated.

FIELD RESULT AND DISCUSSION

The 2D electrical resistivity and chargeability images of the earths subsurface along the profiles obtained in the study area are presented in figure 3 to 7. A total number of four profiles were taken for this work. The four profiles were taken along the east-west direction. The inversion result for each profile as shown in figures 4 to 7 depicting the images of the geo-electric sections obtained from the processed data. The results show two images for each profile. The upper image is a plot of the resistivity model which is obtained after a definite number of iterations of the inversion program and the lower image is the corresponding chargeability model. The resistivity and chargeability models shows variations in the geologic properties of the subsurface, which is in relation to the measured resistivity/IP with scales shown at the lower end of the plot, the side bar shows the depth below the subsurface with a mean depth of about 12.0 m and the lateral distance is shown above the section.

INTERPRETATION OF PROFILE A

Figure (4a.) shows the resistivity model of profile A. The resistivity model reveals a top layer with moderate resistivity values ranging from 215- 656 Ωm trending down along the profile within the depth of about 2 m. Some pockets of high resistivity regions lie within the same layer with high resistivity values ranging from 114 -3505 Ωm cutting down intermittently to a depth of about 6 m. These high resistivity values could be inferred to represent laterite. Underlying the top layer at profile distance of 28-57m from the depth of 4.5 m down to 15 m and at profile distance 84 - 126 m within the depth range 4.5-15m with resistivity values ranging from 70 - 215 Ωm are suspected clay zones. The domestic waste buried at a distance of 5 m on the profile could not be identified and delineated due to edge effect (insufficient of data coverage).Figure (4b.) shows the chargeability model with indistinguishable, uniformly homogenous layer with a completely spread chargeability value of 0.0375 Msec. No qualitative interpretation could be deduced from this model as it contains mostly negative values which are indicative of noisy data. This is expected as a result of using steel potential electrode in hard resistive ground (Abdullahi, 2009)

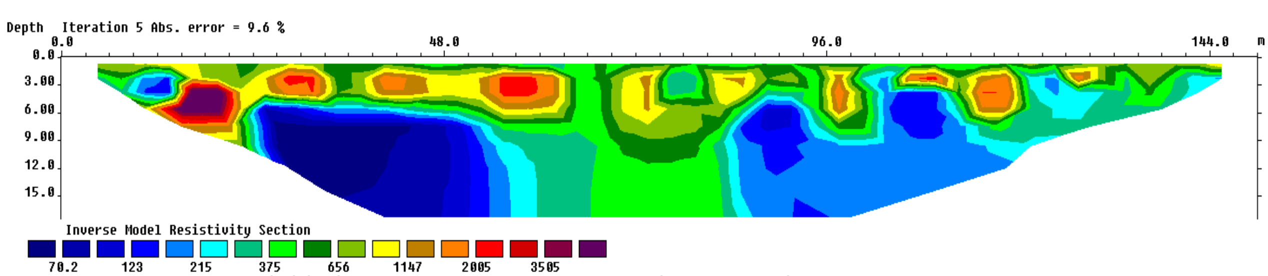

Figure 4a: Result of 2D inversion of the Wenner-alpha array data along profile A

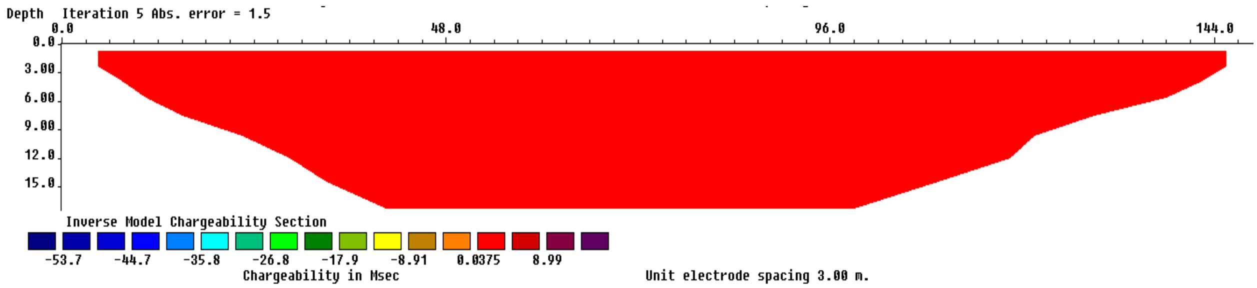

Figure 4b: The corresponding chargeability model along profile A

INTERPRETATION OF PROFILE B

Figure (5a.) Shows the resistivity model of profile B. The resistivity model indicates a top layer with high resistivity values ranging from 515 – 998 Ωm. Extremely high resistive regions could be clearly identified at profile position 30-54 m which corresponds to the position (50 m) of the buried sludge along this profile. It is believed that the buried sludge sips through the soil grains smearing its signatures and spreads both horizontally (up to 30 m) and vertically (8m) along the profile. Underlying the top layer is a fairly low resistivity region with resistivity values ranging from 98.7-137 Ωm from position 30-60 m extending to the depth of 12 m down the profile. This presumably is saturated water trapped in the aquifer. The chargeability model (figure 5b.) reveals clearly the signatures of buried sludge as it migrated from its buried point of 50 m on the profile, concentrating at the point to its buried depth of about 1m. The chargeability model shows a chargeability value of 84.1msec for the buried sludge. There was no chargeability anomaly at profile position 24m which the corresponding resistivity model identified as high resistivity model similar to where the sludge was buried, because chargeability assists in distinguishing IP effects due to predominantly electrolytic controls from effects due to structural (primary clay control) variation better than resistivity measurement (Abdullahi, 2009).

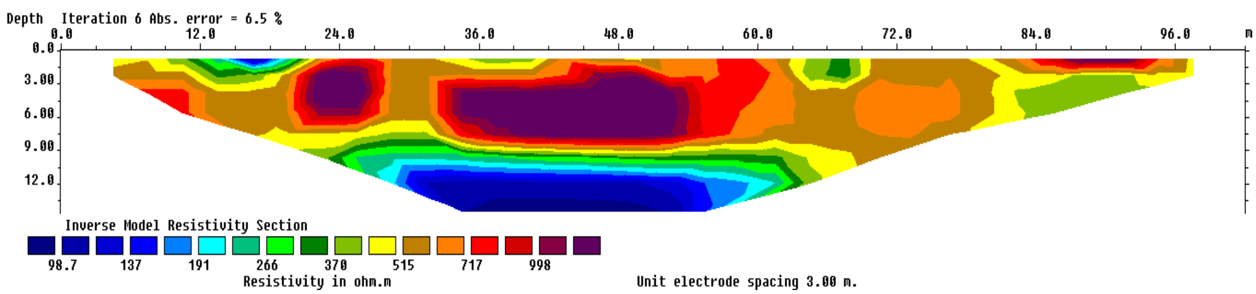

Figure 5a: Result of 2D inversion of the Wenner-alpha array along profile B

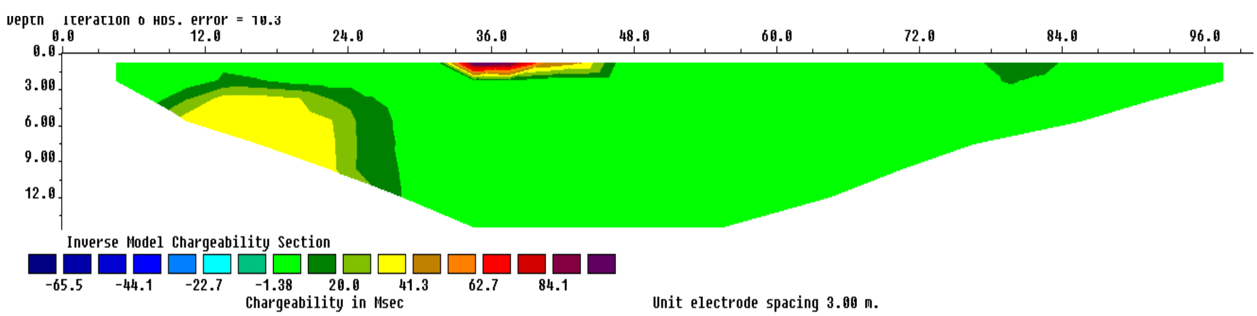

Figure 5b: The corresponding chargeability model along profile B

INTERPRETATION OF PROFILE C

Figure 6a shows the resistivity model of profile C and the corresponding chargeability model (fig. 6b). The resistivity model (fig.6a) reveals high resistivity regions on the profile (0-42m) extending to a depth of 9m with resistivity values of 609-988Ωm. This high resistivity indicates weathered basement. A low resistivity region with resistivity values ranging from 33.5-88 Ωm located at the end of the profile is considered to be the position of the buried metal scraps. The chargeability model (fig.6b) of profile C reveals almost a zone of low chargeability value of -39.5msec running though out the profile with some pockets of intermittently distributed chargeability of 54.5msec at profile positions 12 m, 24 m, 48 m 72 m and 85m. It is difficult to differentiate categorically the signatures of the metal scraps buried on the profile because IP effect will manifest when there is integration of the buried waste (metal scarp) and the host rock.

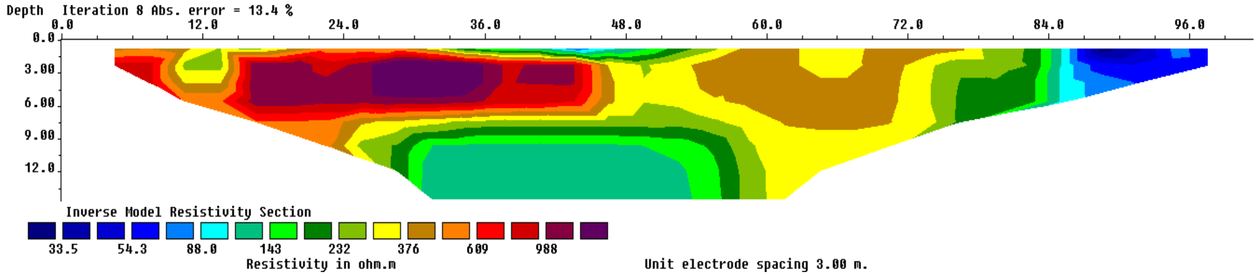

Figure 6a: Result of 2D inversion of the Wenner-alpha array along profile C

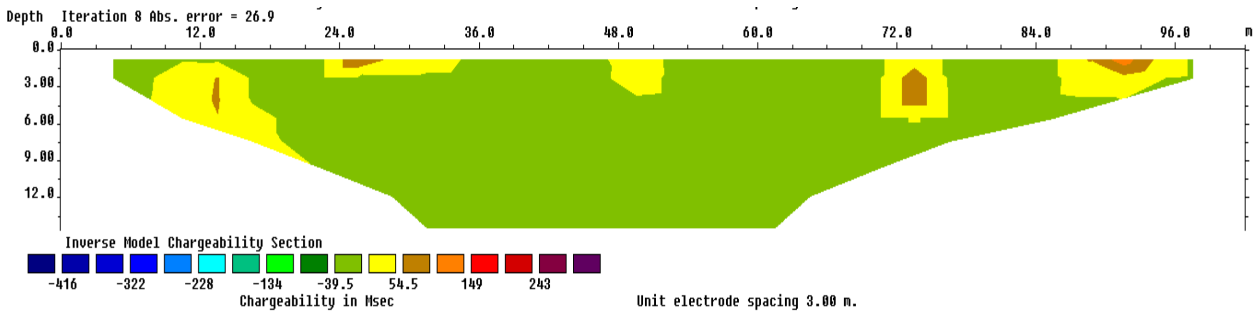

Figure 6b: The corresponding chargeability model along profile C

INTERPRETATION OF PROFILE D

Figure 7 a shows the resistivity model of profile D which is the control profile. The resistivity model (fig.7a) reveals high resistivity zones extending from the 0 m up to 48 m on the profile to a maximum depth of 11 m with resistivity values ranging from 492 Ωm to 821Ωm. This is interpreted as hard laterite. Overlapping this layer at profile position 48 m is a fairly high resistivity layer ranging from 295 Ωm - 636 Ωm running down to a depth of 11m across the profile. This segment on the profile may contain the slightly weathered basement rock. Beneath these two overlapped layers, is a region with low resistivity values ranging between 137 Ωm- 228 Ωm believed to contain saturated ground water trapped in the aquifer. The chargeability model of profile D (fig.7b) reveals a fairly chargeability region with chargeability value of 8.13msec. The negative value is indicative of noisy data as a result of using non-polarizable electrodes on hard rock terrain (Abdullahi, 2009).

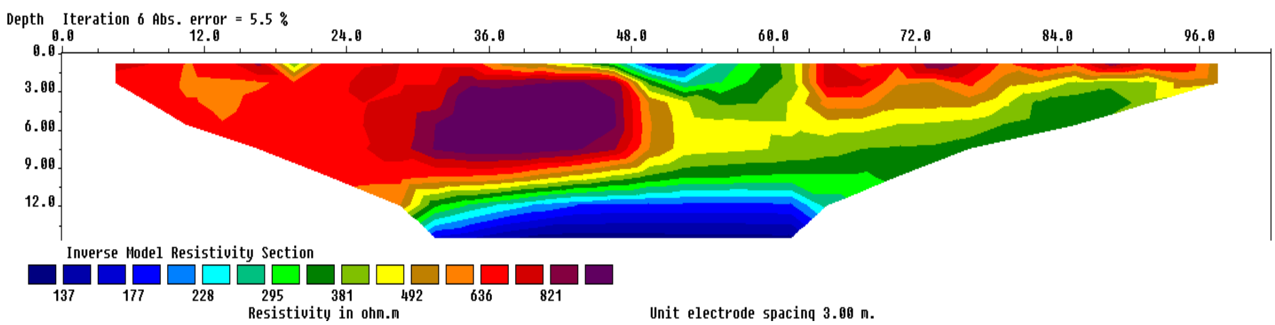

Figure 7a: Result of 2D inversion of the Wenner-alpha array along profile D

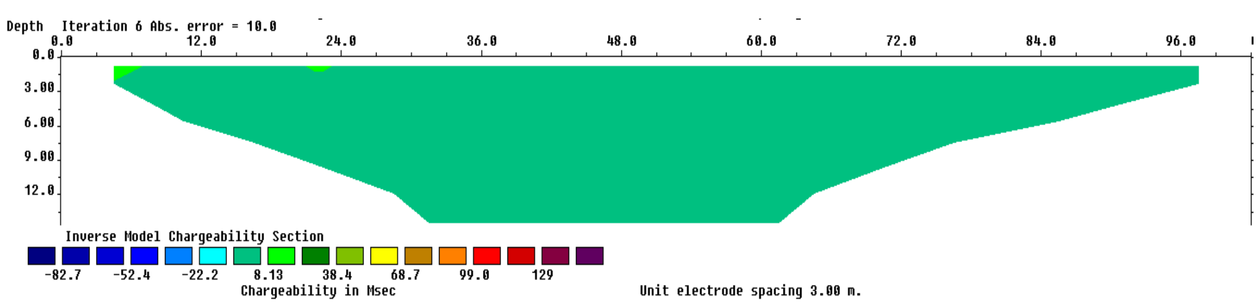

Figure 7b: The corresponding chargeability model along profile D.

CONCLUSION

The result of this research can be used as improve information over buried waste of different composition and as an economic tool in evaluating buried wastes rather than indiscrimate digging over a large area. The results also, reveal that Induced polarization data collected with steel electrodes can identify and delineate buried sludge but could not be applied to fresh domestic and metal scraps. The non-identification of the domestic and metal scraps by the IP data could be attributed to the non-polarization of the wastes at the interface between the heterogeneous waste and host rock. If the buried waste(domestic and metal scraps) were allowed to stay over a period of time before chargeability data is collected, there could be observed IP effect clearly identifying the buried waste since integration between the waste and host rock must have taken place. Identification of the buried waste by both the Resistivity and chargeability models was as a result of rapid integration of the sludge (a fluid) in the host rock resulting from the electrode polarization IP effect.

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