Integrated Geophysical Characterization of Subsurface conditions around Ilesha Dumpsite: Case of Southwestern Nigeria

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ABSTRACT

The possible existence of latent subsurface structures as conduit for leachate and contaminant potential of pollution plumes from waste disposal/dump site along Ilesha-Ife express road, 1.5 km from Iwara junction, Ilesha was investigated. The depth to bedrock, distribution and orientation of fractures, probable zones of leachate concentrations, if any, and rate of transport of the contaminants from the dumpsite within the subsurface were investigated using a total of fifty-five(55) Vertical electrical sounding points along ten(10) profiles within the vicinity of the site and one(1) profile (control) outside the area at about 300m from the dumpsite, four(4) 2-D Wenner Electrical resistivity and four(4) profiles of Very low frequency EM method of geophysical investigations. The area shows a wide distribution of conductive zones which are mostly depicted in up – dip incline pattern and occur as pockets of conductive bodies as observed from Karous Filtering Pseudosection.. The top layer has a resistive cover material of 34-950Ωm and varies in thickness. The second layer is a low resistive zone of 10-130Ωm and indicate a zone of fluid/ leachate activities. The weathered layer is thicker in areas with fractures in the bedrock. The third layer is a more resistive layer >200Ωm which is the basement rock that underlies the study area. The 2-D electrical imaging result reveals a low resistivity signature in the eastern parts of the site and relatively higher resistivity in the western parts which indicate presence of leachate/fluid activities in the eastern part. The cross-sectional map of the site revealed that the concentration of the contaminants was restricted to a particular zone and the leachate flows towards the Eastern direction of the dump site area and there are presences of near surface linear structures that may act as conduit for leachate emanating from the dumpsite.

Key words: Dumpsite, Leachate, Geoelectric section, conductivity, bedrock

1 INTRODUCTION

Waste disposal is highly essential in man's daily activities and also are potentially sources of pollution to the environment, over the decades there had been increasing concern of environmental pollution over the public health of the populace. Poor management of solid wastes materials leads to potentially disastrous environmental and health hazards. Among health hazards that have resulted from the lack of an effective disposal system are periodic epidemics and communicable diseases. Ground water pollution in and around a waste disposer site occurs due solely to the contaminants potential of leachate (i.e. fluids residing beneath the dumping site) from the wastes. These leachates are solution or suspensions of stabilize, essentially organic or inorganic complexes of biodegradation of components of solid wastes flowing out from the refuse dumps, saturated with rainwater flowing through them. (De Rooy, C., 1986;). A dumpsite should be chosen so as to ensure minimal environmental impact in the surrounding areas. The dumpsite (located in Ilesa express way, Nigeria) was sited on the basement complex rocks. The rocks of the area are structurally stable, though a system of joints and fractures exist in the area. These joints and fractures could serve as migration channels for leachates (pollution plumes) to establish contact with the environment Olayinka, A. I., Abimbola, A. F., Isibor, R. A. and Rafiu, A. R. 1999. However, non-invasive geophysical techniques (Electromagnetic and DC Resistivity methods) were applied to study the area. Conductivity geophysical techniques can be used to map out areas where conductive materials are concentrated while the resistivity geophysical techniques have the potential of not only mapping the dumpsites, but can also reveal potential pollution plumes and their direction of migration and therefore provide a basis for remediation if the environment is under threat.

Geological Setting

The geology of ilesa on co-ordinates 7°37'46"N 4°45'25"E consists of Precambrian rocks that are typical for the basement Complex of Nigeria (Rahaman, 1976). The major rock associated with Ilesa area form part of the Proterozoic schist belts of Nigeria, which are predominantly, developed in the western half of the country. In terms of structural features, lithology and mineralization, the schist belts of Nigeria show considerable similarities to the Achaean Green Stone Belts. However, the latter usually contain much larger proportions of mafic and ultramafic bodies and assemblages of lower metamorphic grade (Rahaman, 1976) Rocks in this area are structurally divided into two main segments by two major fracture zones often called the Iwaraja faults in the eastern part and the Ifewara faults in the western part (Jones H.A. and Hockey R.D., 1964). The rocks of the Ilesa district may be broadly grouped into gneiss-migmatite complex, mafic-ultramafic suite (or amphibolites complex), meta-sedimentary assemblages and intrusive suite of granitic rocks.

Study Location

The Ilesa dumpsite is located at the outskirt of the town. It is located along Ilesa-Ife express road. Villages such as iwara, ifetepe, etc exist few hundred metres away from the site. The site is on high elevation and situated on basement complex. There is a river channel a few metres away from the dumpsite that cut across the main road to the other side of the road to the villages .The dumpsite covers an area of 200 by 250 meters.

Objectives

Objectives of this research are:

i. To determine the overburden thickness/depth to bedrock
ii. To delineate subsurface contaminated zone, if any
iii. Establishment of structural control/direction within subsurface profile
iv. To reveal potential pollution plumes and their direction of migration.

Material and methods

Vertical Electrical Sounding (VES), constant separation technique (CST) and Very Low Frequency Electromagnetic (VLF-EM) methods were used to carry out geophysical investigation of the study area. These are electrical resistivity and electromagnetic methods respectively. The electrical techniques require the measurement of potential differences in the ground between suitably implanted electrodes (Keller, G.V. and Frischknecht, F.C. 1966). The electromagnetic technique detects subsurface conductivity anomalies remotely; they do not need contact with the ground. Is an inductive technique which relies on Very Low Frequency horizontal EM signals from remote military transmitters as an electrical source. Localized conductors, such as water-filled fractures, cause angular disturbances in this signal (Barker, R.D., 1981). A total of fifty five (55) Vertical Electrical Soundings were carried out round the waste dumpsite. The Schlumberger electrode configuration was used with half electrode spacing AB/2 varying from 1 to 150m and station spacing is 50m was adopted. The ABEM Resistivity meter was used for resistance measurements. Field data were plotted on bi-logarithmic graph and a preliminary interpretation was carried out using partial curve matching involving two-layer master curves and the appropriate auxiliary charts. This procedure is known as quantitative interpretation. The layered model thus obtained served as input for an inversion algorithm using the software called RESIST (Zordy 1989). The conductivity survey using WADI ABEM instrument was carried out beginning from North to South and from east to West Respectively. 10m spacing was adopted for each profile with minimum of 200m in the N-S direction and Maximum of about 380m in the E-W directions. The operating frequency for the EM survey was 15.8 Hz with station distance and other conductivity parameters such as Raw Real, Filtered Real, Raw imaginary, Filtered Imaginary were downloaded immediately after the field work for analysis.

2 Results and Discussion

VLF- EM The interpretation of VLF profile is mere qualitative and this involves visual inspection of the profile for points where the maximum peak of the Filtered Real coincides with the point of inflection of raw real as such points are usually suggestive of presence of conductive (weak) zones. Several of such points were identified on the profiles; furthermore, the presence of multiple peak Positive filtered real anomalies (as observed on the profiles) is suggestive of inhomogeneity of near surface material.

The plots of filtered real are presented as profiles (Figures 2a-d) while their corresponding Karous-Hiljet (K-H) pseudo sections are shown in Figures 2a(iii)-d(iii) respectively. The interpretation of these profiles and pseudo sections were basically qualitative or semi quantitative.

Figure (2a-d) shows the corresponding K-H pseudo section of the profile. The pseudo section is a measure of conductivity of the subsurface as a function of depth. The conductivity is shown as colour codes with conductivity increasing from left to right (that is, from negative to positive). Different features of varying degree of conductivity trending in different directions were delineated on the section.

EM Traverse 1 shows about 3-regions of high conductivities, that is, regions in which high peak are observed at 20m, 50m, 100m and at about 200m respectively. Fig. 2a(i-iii). These points indicate possible presence conductive fluid within soil/rock pores, joints and fractures.

EM Traverse 2- has about 20 point stations with maximum distance of 200m along which measurements are taken in the N-S direction (Fig. 2b). The EM shows maximum peak at about 100m indicating presence of conductive medium, that is, conductive fluids may be located along faults and fractures. Other points on the profile show low to very low conductivity peak hence constitute region of relatively high resistivity or low conductive zones.
EM Traverse 3 is about 400m in length and measurement was taken in the E-W direction. This part of Ilesa waste dumpsite has series of high conductivity peak such Station points include 50m, 110m, 170, 230, 300m and 380m. Hjelt Karous Pseudosection indicates series of pocket of high conductivities. Other areas of high resistivity are also delineated.
This invariably has physiographical and hydrogeological implications since the western part indicate points of depression towards the minor drainage located at about 100m from the waste dumpsite.
EM Profile 4 is also about 400m long the measurement was also taken in the E-W direction. The Karous filter indicates high conductivities at about 130m, 240m and 350m respectively, along the profile. Some structures were seen dipping in the west direction Figure (4d). These also corroborate the VES profile 4 where low resistivity was recorded in some areas.

3 Vertical Electrical Sounding

This entails the use of current flow via the movement of ions in groundwater. In environmental surveys, electrolytic conduction is probably the more common mechanism. Electrical resistivity of weathered layer are controlled by the degree of water saturation (Odusanya and Amadi 1990). Resistivity of rocks is greatly dependent on the degree of fracturing and percentage of fracture filled with ground water. In all 11 profiles of VES were carried out with VES stations surrounding the four coners of the dumpsite with the view to decipher the site subsurface geometry and condtions. VES stations are 30m apart(station interval) and N-S side has 3 profiles each and are 20m apart from one another. The E-W side has 2 profiles each and consitiute the longest part of the site .The remaining one profile consitiute the control for the site and is located at about 150m from the site across the road.
PROFILE 1:- This profile [VES 1-5], as shown by geoelectric section, is on higher elevation. The top soil resistivity values range from 72Ωm-381Ωm. it has one of the thinnest top layers with the highest value of 1.4m. Overburden thickness from occurs from 5.0m to 9.0m with resistivity values range from 34Ωm to 94Ωm. the resistivity values indicate presence of saturated clay/sandy clay. These resistivity values show no trace or rather negligible level of contamination.
PROFILE 4: Includes {VES 16-21}; The top soil resistivity ranges from 34Ωm to 440Ωm with maximum thickness of about 1.5m. The overburden layer is thicker at the centre and the resistivity values range from 19Ωm to 133Ωm. Most of the resistivity here falls within clay. The 3rd layer which is the basement rock has resistivity range between 703Ωm and 1574Ωm. the geoelectric section shows that most part of the profile is fresh basement rock with few fractures/joints. VES 21 has lowest value of 703Ωm indicating possible fracture but there may be possibility of insipient cumulative effect of the above overburden layer with resistive value of 19Ωm which inadvertently leads to lower resistivity in the basement rock.

PROFILE 5 : This consists of VES 26-35. This profile also showcased thin Top soil layer (0.5m-3.3m) with resistivity range between 104Ωm-338Ωm. It is note worthy that the resistivity curve is H-type which is typical of a basement complex. The overburden thickness varies from 6.5m to 40m. The highest thickness obtainable here is at VES point 31, about 200m from the East of the site. The overburden resistivity range occurs between 33Ωm-86Ωm. this value indicate possible presence of Lateritic Clay with high fluid saturation.

PROFILE 6 :-This consists of {VES 35-40}. The top soil has thickness range from 1.4m - 4.3m with resistivity range occurring between 57Ωm - 172Ωm. the overburden layer has thickness down to about 45m with resistivity signature ranging from 35Ωm to 167Ωm indicating presence of fluid saturated clay. The basement rock occurs at depth greater than 30m and most of the resistivity values are greater than 1100Ωm.

4 2-D Electrical Tomography

Pseudo-sections shown by figure (5) is the results of the inversion of the 2D-resistivity data obtained in the area. It is the interpreted pseudosection of the 2-D profile running from E-W over a distance of 200m few meters away from the dumpsite. The Pseudosection shows three pronounced layers of different resistivities. The top layer which is about 3m shows resistivities range between 49 and 197 Ωm. This represents the resistivity of the top soils which is thinner in some parts of the dumpsite. The areas with thin top soil coincide with the ones in figures (3) where conductivities are seen to be high. The imaging Pseudosection reveals the existence of shallow water level at the northern part of the site. This part is close to the small drainage running from east to west and located about 100m from the dumpsite. The middle layer is represented by very low resistivity values (12-25Ωm). The low resistivity area is interpreted as area of low to medium leachates activities. From the cross-sections the thickness of the layer can be estimated to be up to ten meters. The bottom layer seen on the interpreted 2-D section represents the basement rock of the dumpsite. This layer is represented by higher resistivity values (greater than 500Ωm). The average depth to fresh rock ranges between 21m to depth.

5 Conclusion

Detailed geological, electrical and conductivity survey was carried out so as to unravel the implication of Ilesa waste dumpsite on the surface and ground water within its vicinity. The electromagnetic data also corroborate the electrical resistivity data in that, conductivity anomalies are very prominent and exist at high frequency in the Northern part compared to any other part of the site. Hence confirm the presence of high conductivity zones/fractures and joints under and within the vicinity of the Ilesa waste dumpsite. These fractures and joints are believed to be filled with conductive fluid such as water.Resistivity Data within the overburden layer indicates certain level of leachate contamination from the surface waste dump. This is reflected in the resistivity value of 15Ωm, 12Ωm, 12Ωm at VES 9, 13 and 14 respectively. While other resistivity value in the overburden layer is between 22Ωm and 100Ωm, these probably indicate the presence of lateritic clay/clayey sand. The presence of fractured basement as indicated by VLF data and electrical resistivity values may act as a transmitting medium for leachate that may subsequently emanate from waste dump on the surface.The 2-D imaging Pseudosection indicate possible occurrence of leachate activities between VES 8 and 10. It also confirm shallow occurrence of groundwater level which invariably implies the possibility of leachate entering into the ground water level within short human and geological time. The middle layer is represented by very low resistivity values (12-25Ωm). The low resistivity area is interpreted as area of low to medium leachates activities. The result of the electrical resistivity survey reveals three(3) and four(4) geoelectric layers with 84.9% and 15.1% respectively

6 Recommendation

Since the Ilesa waste dump site was not properly investigated before usage, detailed geotechnical and geochemical analysis must be carried out to unravel the other necessary parameters for the characterization of the subsurface within and around Ilesa waste dumpsite. These parameters to be determined include permeability, compressibility factors, bearing capacity, clay mineral types, consolidation factor, porosity, geochemical analysis such as determination of presence and concentration of heavy mineral. Geophysical and geotechnical investigation must be carried out on any other proposed waste dumpsite before usage so as to allow easy access to the site for detailed investigation and to reduce geophysical noise.

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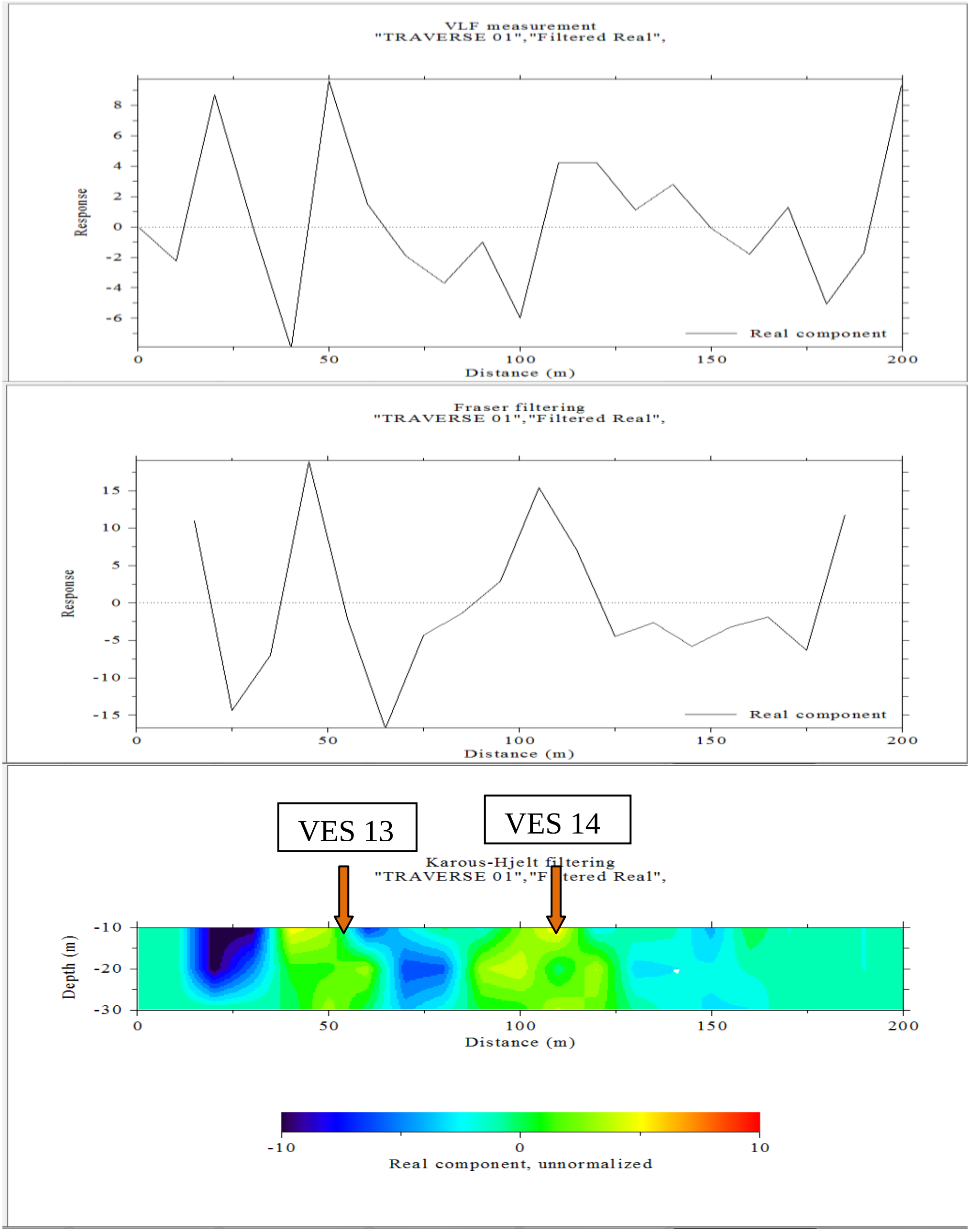

FIGURE 2a (i) Filtered Real profile 1 (ii) Fraser filtering of profile 1 (iii) Karous-Hjelt filtering of profile 1

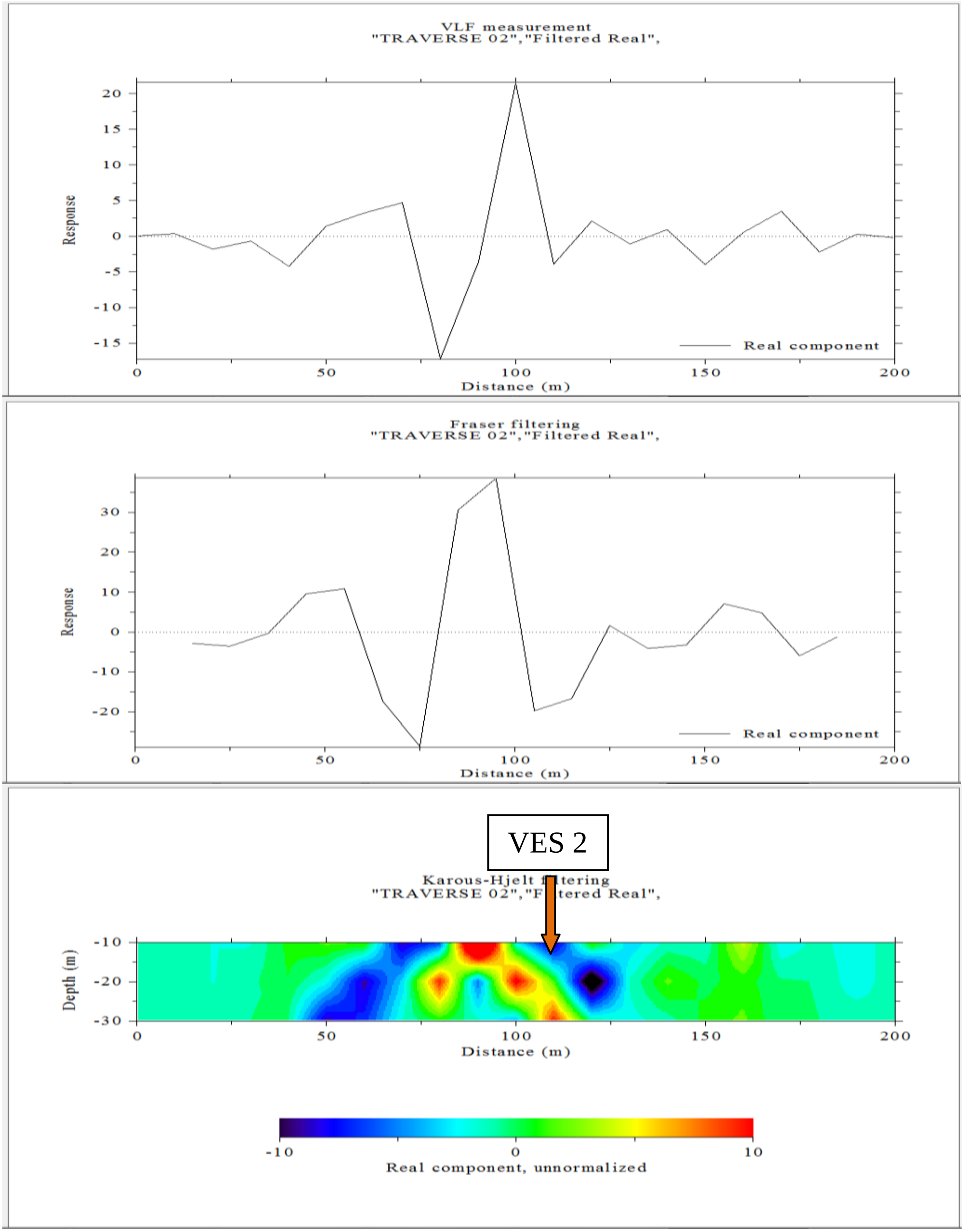

FIGURE 2b (i) Filtered Real profile 2 (ii) Fraser filtering of profile 2 (iii) Karous-Hjelt filtering of profile 2

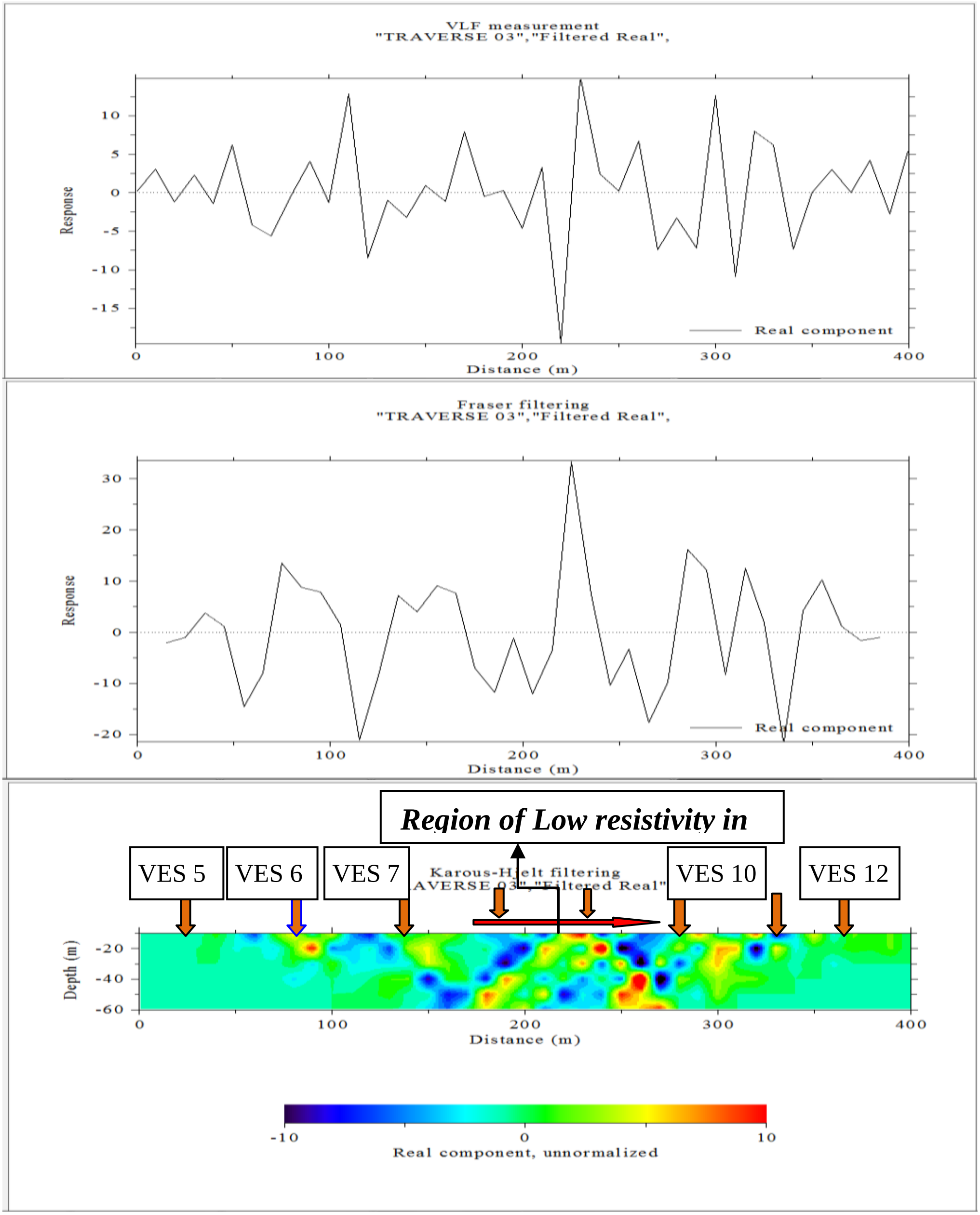

FIGURE 2c (i) Filtered Real profile 3 (ii) Fraser filtering of profile 3 (iii) Karous-Hjelt filtering of profile 3

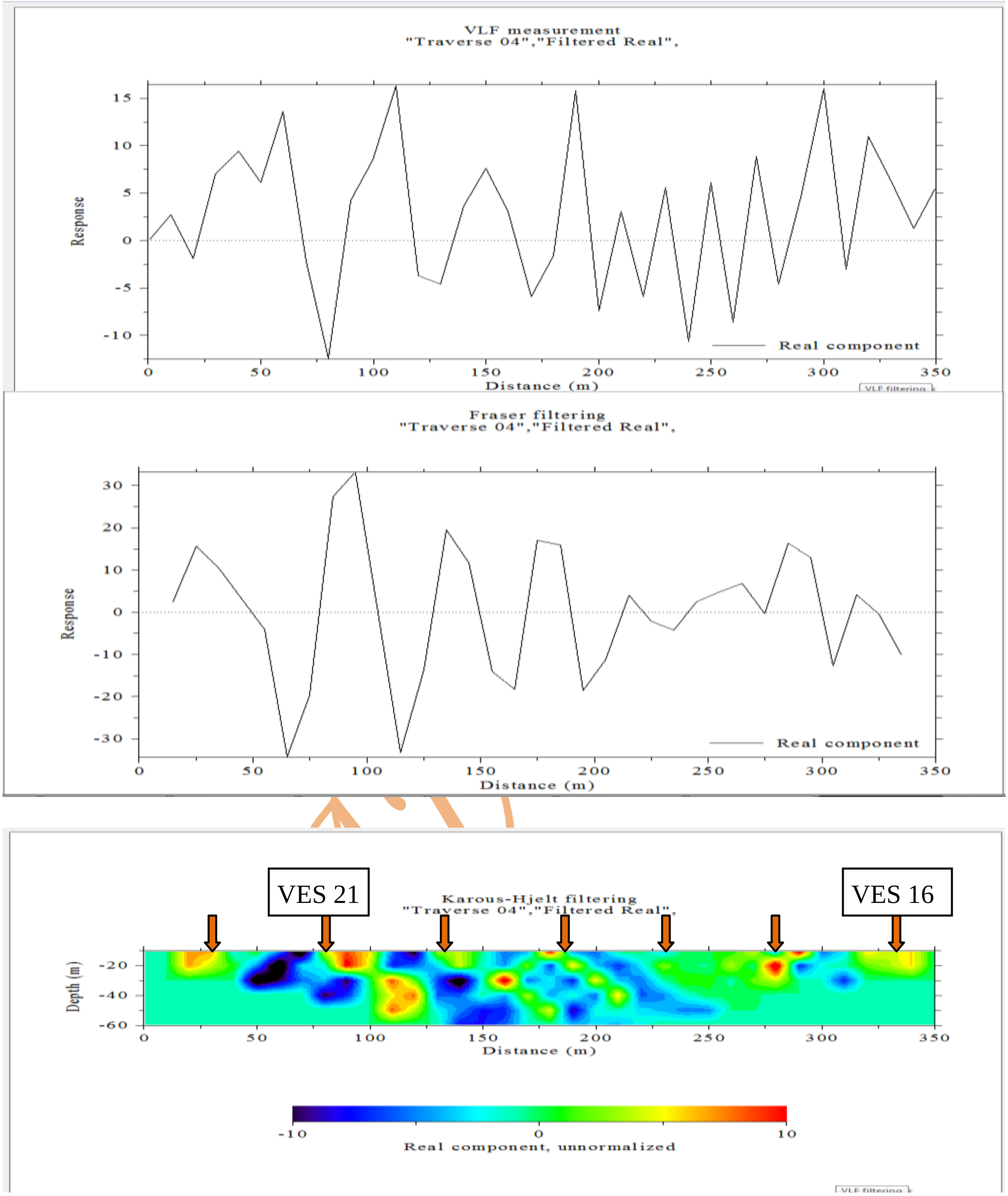

FIGURE 2d (i) Filtered Real profile 4 (ii) Fraser filtering of profile 4 (iii) Karous-Hjelt filtering of profile 4

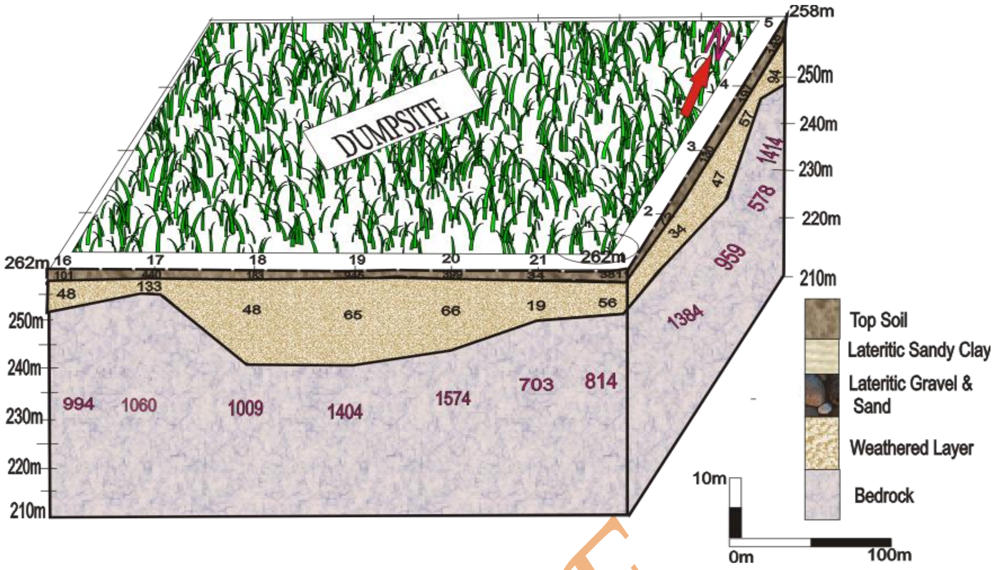

FIGURE 3 : Geo-electric section for profiles 1 and 4 forming 3-D view

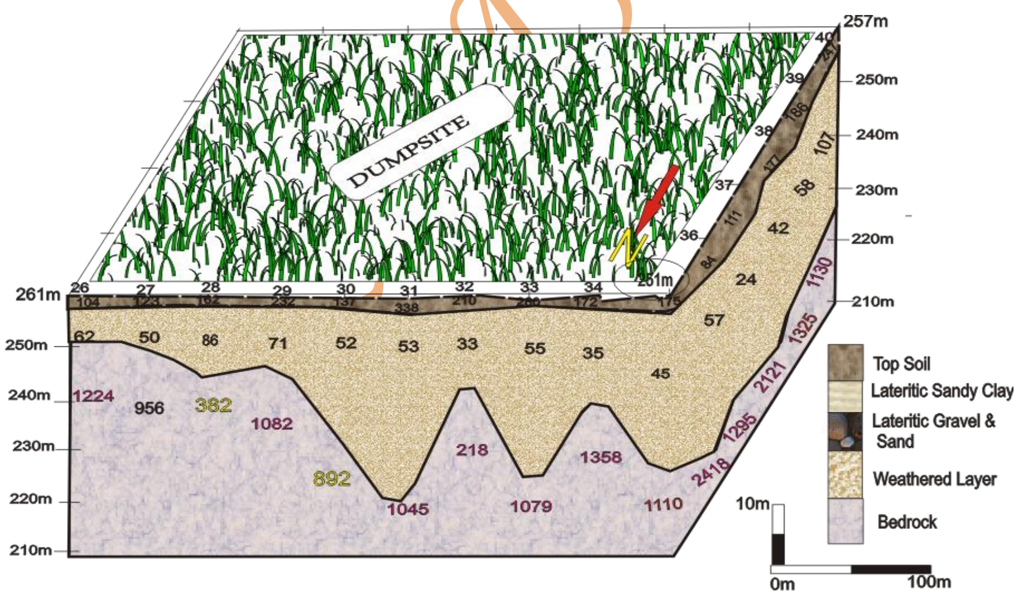

FIGURE 4: showing Geo-electric section for profiles 5 and 6 forming 3-D view

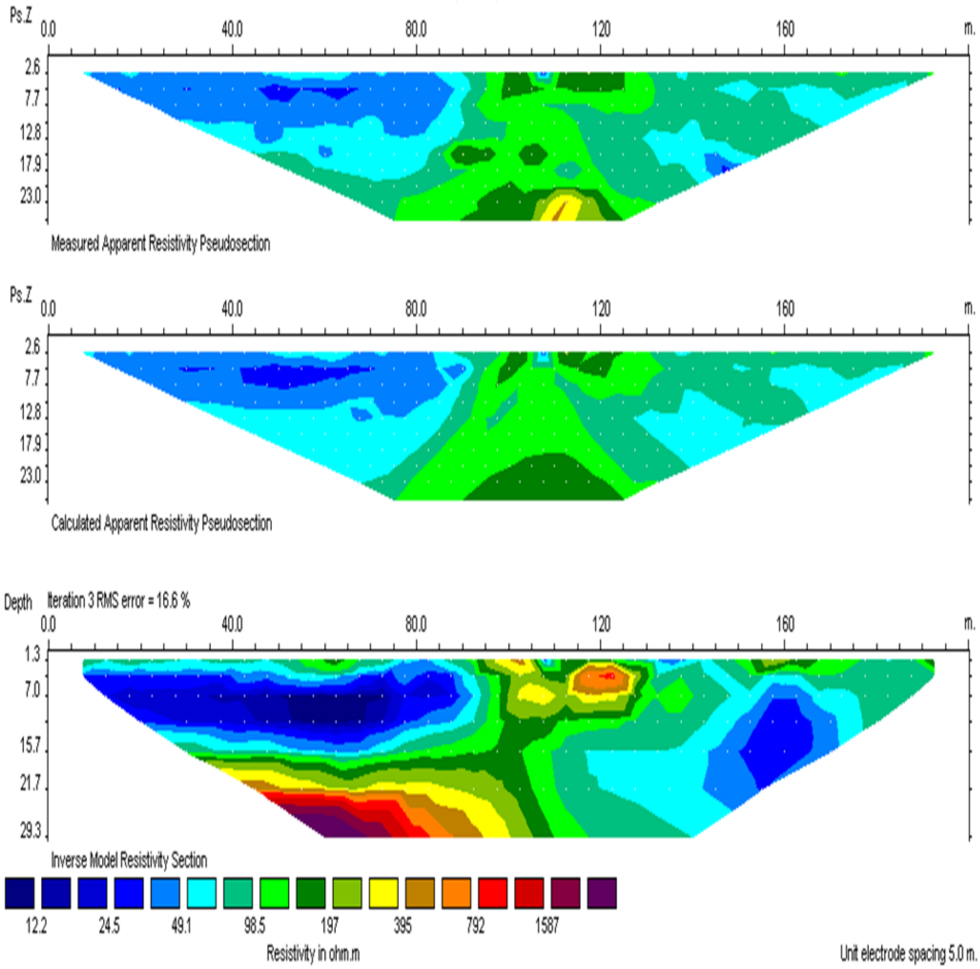

Fig. (5); Showing 2-D resistivity Pseudo section with low resistivity region at the eastern section of the site.