IOSR Journal of Applied Physics (IOSR-JAP)
ISSN: 2278-4861. Volume 2, Issue 5 (Nov. - Dec. 2012), PP 11-20
www.iosrjournals.org

Integrated Geophysical Survey In A Refuse Dumpsite Of Aarada, Ogbomoso, Southwestern Nigeria.

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Abstract:*Surface geophysical survey was conducted around Aarada refuse dumpsite, Ogbomosho, Oyo State, Nigeria to locate leachate plumes migration pathways using the very low frequency electromagnetic and vertical electrical sounding techniques. Eight VLF-EM profiles of length 70 to 150m with 10m interstation spacing and seven Vertical Electrical Soundings with current electrode separation varying from 150 to 200m were established. The analyzed VLF-EM data revealed the presence of conductive pollutants (leachate plumes) at the subsurface while the geoeletric sections generated from the processed VES data showed that the leachate plumes have actually migrated to a depth of 5.4m in the area which confirmed the VLF-EM results.*
Keywords*: Groundwater, Health Hazard, Leachate Plume, Vertical Electrical Sounding, Very Low Frequency Electromagnetic.*

I. Introduction

The quality required of groundwater supply depends on its purpose (Diersing and Nancy, 2009). Groundwater contamination is one of the main concerns of earth scientists and researchers from other related fields of science worldwide. Urban waste materials, mainly domestic garbage, are usually disposed of without the appropriate measures imposing a high risk to the underground water resources. The basic purposes for which water is domestically required include drinking, bathing, cooking and general sanitation such as laundry, flushing of closets and other household chores, whereas for agricultural purposes it is essentially used for irrigation and livestock. Therefore an assured supply of water both qualitatively and quantitatively for these purposes greatly improves the social, economic and agricultural activities of the people. Groundwater pollution results from the elevation in the concentration of its constituent anions and cations (for example, Cu^{2+}, Fe^{2+}, Zn^{2+}, NO_3^-) and also the introduction of bacterial, viral and parasitic micro-organisms. It must be noted that drinking from polluted groundwater by the local community without the necessary treatment in advance causes serious health hazards.

This research work is borne-out of the need to evaluate the groundwater resources at Aarada waste disposal site, Ogbomoso, Oyo state, Nigeria. The hand-dug wells in this area are sunk within a distance of 3 to 25m away from the waste disposal site with depth ranging from 4 to 6m. The study area which was presumed to have existed for over fifteen years covers an area of about 300 to 500 square meters with the refuse content consisting of various kinds of materials like metallic, organic and non-biodegradable materials. Among the available surface geophysical methods, electrical resistivity and electromagnetic methods have been found very suitable due to the conductive nature of most contaminants (Ulrych et al. 1994; Lanz et al. 1994; Atekwana and Sauck 2000; Orlando and Marchesi 2001). Similar methods were applied in the past for landfill characterization and delineation (Stanton and Schrader 2001; Carpenter et al. 1991; Karlik and Kaya 2001; Powers et al. 1999; Porsani et al. 2004; Bernstone et al. 2000) and also in waste disposal site investigation. Adagunodo and Sunmonu (2012) have used Vertical Electrical Sounding technique to estimate the overburden thickness of a Basement complex. Hydro-physicochemical Electromagnetic surveys are particularly useful in such environmental studies as they can delineate waste, conductive fluids and buried metals. Degradation of organic material in field-saturated conditions produces a terrain conductance signature that is enhanced above background conditions. The elevated signature can be used to locate waste, delineate the waste boundaries and provide a rough estimate of depth of wastes.

In this work, the combination of very low frequency electromagnetic and vertical electrical sounding methods was employed to determine the level and extent of contamination at the subsurface around the waste disposal site. This integrated technique has been proved to be highly remarkable for delineating contaminated zones of groundwater.

II. Geology Of The Study Area

Generally, Ogbomoso (Fig. 1) is located in southwestern, Nigeria between latitude 8˚06´70″ and 8˚06´98.7 north and between longitude 4˚14´28.2″E and 4˚14´56.9″ east. The geology of Ogbomoso (Fig. 2) consists of Precambrian rocks that are typical for the basement complex of Nigeria (Rahaman, 1976). The major rock associated with Ogbomoso 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 show considerable similarities to the Achaean Green Stone belts. However, the latter usually contain much larger proportions of mafic and ultra mafic bodies and assemblages of lower metamorphic grade (Ajayi, 1988; Rahaman, 1976). The gneiss complex which underlies the northern and southern part of the Ogbomoso district comprises a considerable broader area of outcrops. Locally, the rock sequence composes of basically weathered quartzite and older granites. The minerals found in this area constitute mostly amphibolites, amphibole schist, meta ultra mafites and meta pelites. Extensive psammitic units with minor meta pelite can also be found. These consist of quartzites and quartz schist. All these assemblages are associated with migmatitic gneisses and are cut by a variety of granitic bodies (Rahaman, 1976).

The rocks of the Ogbomoso district may be broadly grouped into gneiss-migmatite complex, mafic-ultra mafic suite (or amphibolite complex), meta sedimentary assemblages and intrusive suite of granitic rocks. A variety of minor rock types are also related to these units. The gneiss-migmatite complex comprises migmatic and granitic, calcareous and granulitic rocks. The mafic-ultramafic suite is composed mainly of amphibolites, amphibole schist and minor meta ultramafites, made up of anthophillite-tremolite-chlorite and talc schist. The meta sedimentary assemblages, chiefly meta pelites and psammitic units are found as quartzites and quartz schist. The intrusive suite consists essentially of Pan African (c.600Ma) Granitic units. The minor rocks include garnet-quartz-chlorite bodies, biotites-garnet rock, syenitic bodies, and dolerites (Rahaman, 1976: Folami, 1992).

It overlies the western upland region of the Nigeria highland plateaux with average altitude between 1000m and 1500m above mean sea level (Akinloye, et al. 2002). The drainage type is intrinsically dendrites. Locally, Ogbomoso area experiences tropical rainfall which dominates most of southwestern part of Nigeria and the area has two distinct seasons, the wet season usually between March and October, and the dry season which falls between November and February every year. The annual rainfall for the study area is 1247mm, but the amount varies from 1016mm to 1524mm, and is almost entirely concentrated in the wet season. The study area falls within the guinea savannah belt of Nigeria but human activities such as exploitation are gradually changing the vegetation to that of Sudan savannah. Aarada dumpsite is located in Ogbomoso South Local Government Area of Ogbomoso township (Fig. 3).

Figure 1: Map of Nigeria showing the location of Ogbomosho

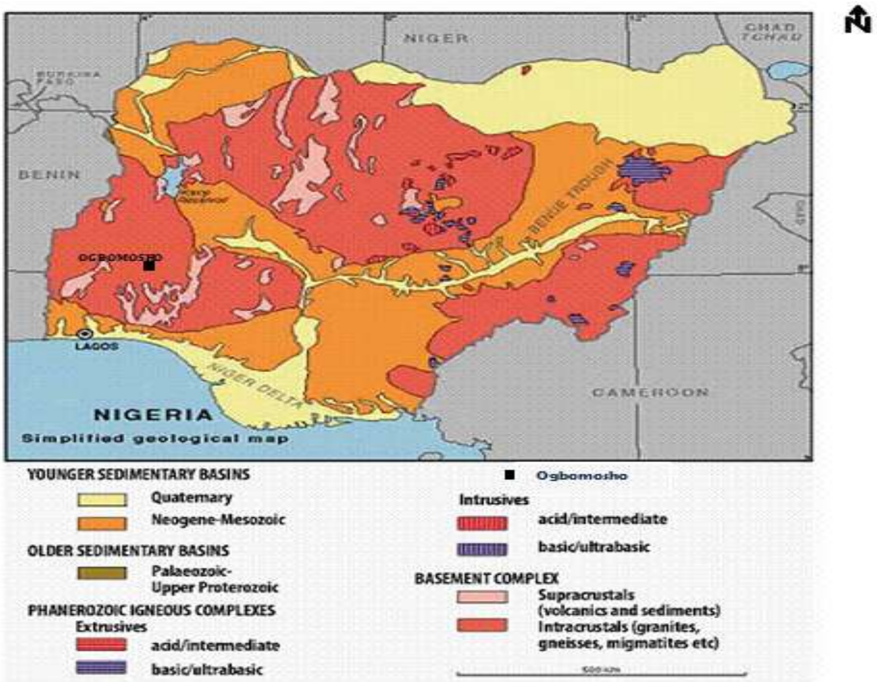

Figure 2: Geological map of Nigeria showing the location of Ogbomosho

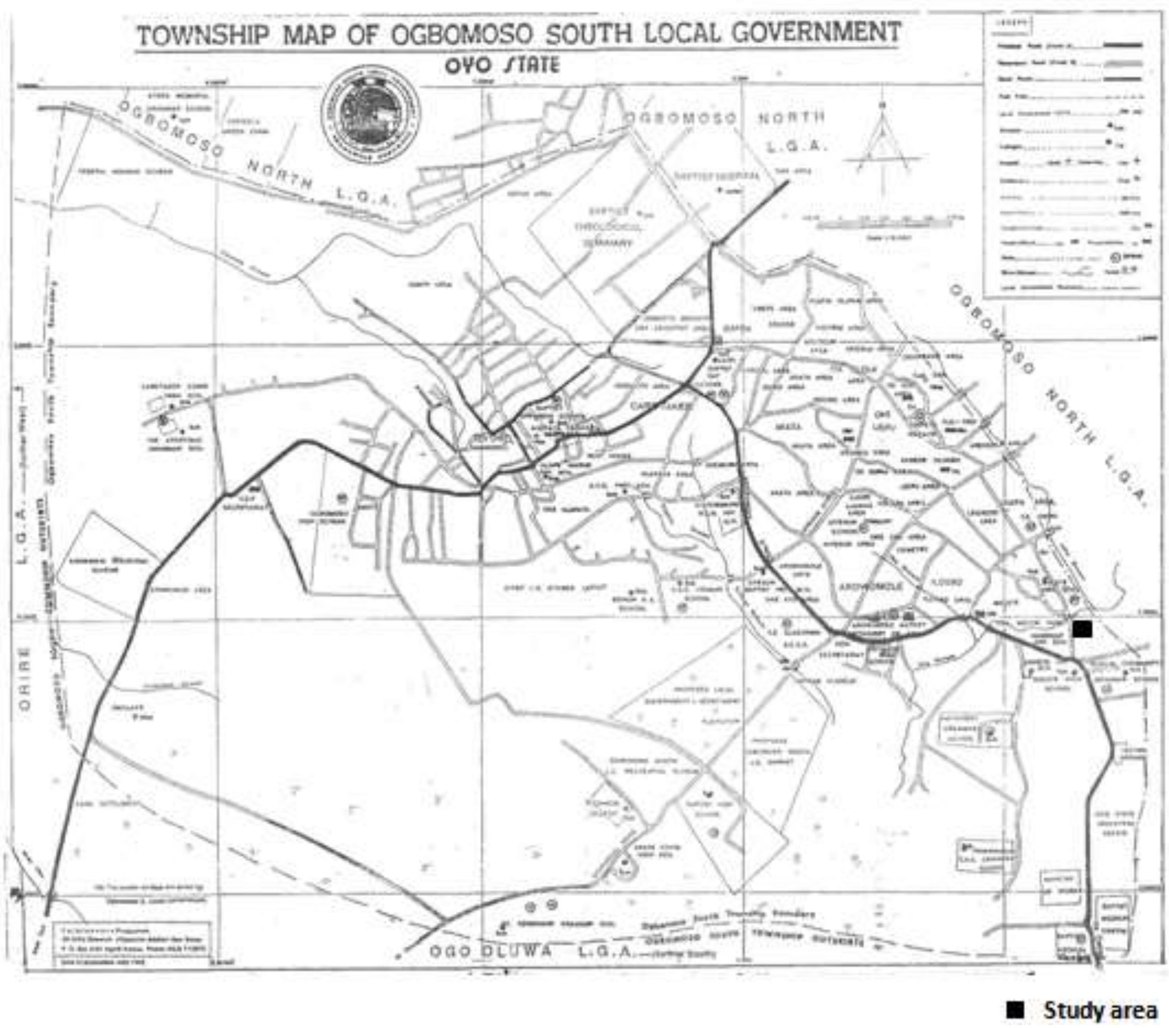

Figure 3: Map of Ogbomoso showing the location of the study area

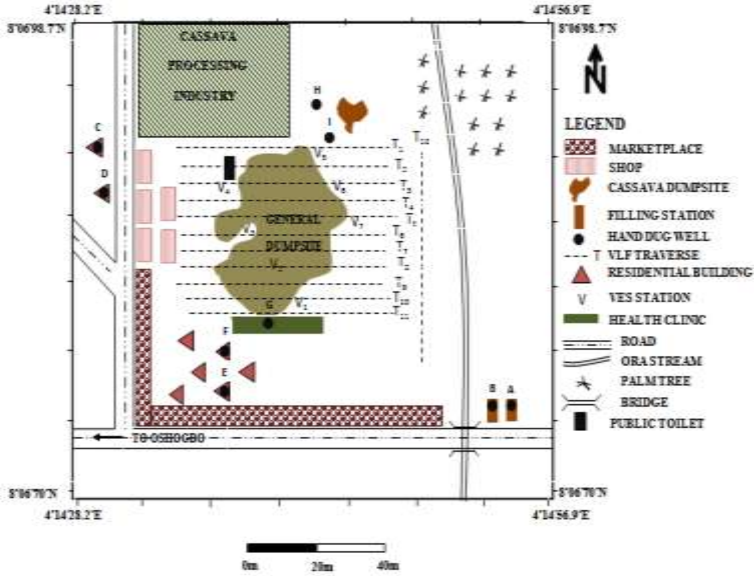

Figure 4: Base map of the study area

III. Materials And Methods

3.1 VLF-EM Measurements

Very Low Frequency electromagnetic (VLF-EM) geophysical prospecting method is a passive geophysical method which uses radiation from military navigation radio transmitters operating in the very low frequency band (15–30 kHz) as the primary EM field to generate signals for various applications (Babu et al., 2007). In this research work, VLF-EM method was employed to map the contaminant zones using the Abem Wadi VLF-EM equipment with an in-built digital display unit and powered by 12V battery type. For the VLF-EM measurements, radio signal station with frequency value of 22.4 kHz was employed to generate the primary electromagnetic field around the contamination plumes in order to induce the detected secondary field and measured as a fraction of the primary field by the VLF-meter. In total, eight profiles were occupied with measurement station intervals of 10m with lengths ranging from 50m to 120m for convenience of space limitation. Each profile runs perpendicular to the general north–south geologic strike in the study area (Fig. 4).

Subsequent to field survey measurements, VLF-EM data were subjected to data processing and evaluation as the basis for interpretation. These procedures transform the raw field data into a simplified form that is directly related to the physical property of the subsurface geological structure. Thus measured raw real and imaginary components were subjected to Karous-Hjelt (Karous & Hjelt, 1983) filtering operations to suppress noise and enhance signal.

3.2VES Measurements

The VES was carried out using Schlumberger electrical array (Zohdy et al., 1974). The Campus Tiger resistivity meter was employed for resistance measurements. A total of seven electrical soundings were established (Fig. 4), with maximum half current electrode spacing (*AB/2*) of 65m. The field data was interpreted by applying partial curve matching technique (Koefoed, 1979) with the help of master curves (Orellana and Mooney, 1966) and sets of auxiliary charts (Zohdy, 1965; Keller and Frischnecht, 1966). From the preliminary interpretation, initial estimates of the resistivity and thickness of the various geoelectric layers at each VES locations were determined. These geoelectric parameters were then employed as starting models for the computer-aided iteration using Resist software (Vander Velpen, 1988). The partial curve matching technique carried out on the seven VES revealed a 3 layered model with H type curve (resistive-conductive-resistive).

IV. Result And Discussion

The Karous-Hjelt current density data plots were employed for the VLF-EM data interpretation to detect the leachate flow and to map its spatial distribution as shown from Fig. 5 to Fig. 11. The current density value on the Karous-Hjelt filter plot in Fig. 5 is high at a distance of 13 to 19m, revealing the presence of dissolved salts from decayed organic matter from the waste body. The VLF-EM profile 2, also carried out at the northern side of the waste disposal site area revealed high conductivity value on the apparent current density cross-section of the 2-D Karous-Hjelt filter image at a distance of 44 to 50m as a result of the infiltration of leachate which is made up mainly dissolved salts from the refuse dumping site in the research area. Similar geologic trend was also observed in Fig. 7 at a distance of 41 to 49m in which the Karous-Hjelt modeled plot depicted high conductivity value indicative of leachate contamination from the waste disposal site. The apparent current density cross section of the Karous-Hjelt filter model in Fig. 8 detected high conductive zones at distance 6 to 7m due to the presence of contamination plume from the decomposition of organic matter in the study area, and also at distance 41 to 46m. From a distance of 19 to 25m in Fig. 9, leachate contamination was observed revealing high current density zone on the Karous-Hjelt modeled section. High conductivity value was depicted on the apparent current density cross section of the Karous-Hjelt modeled filter plot on VLF-EM profile 6, reflecting the presence of contamination plumes between distance 52 and 65m, and from distance 88 to 112m in the research area. In the same vein, contaminated zone was detected at the subsurface in Fig. 11, at distance 50 to 65m. Finally, intrusion of leachate plumes was also depicted at distance 38 to 42m and also between 65 and 71m distance on the apparent current density cross section of the Karous-Hjelt model plot in Fig.12.

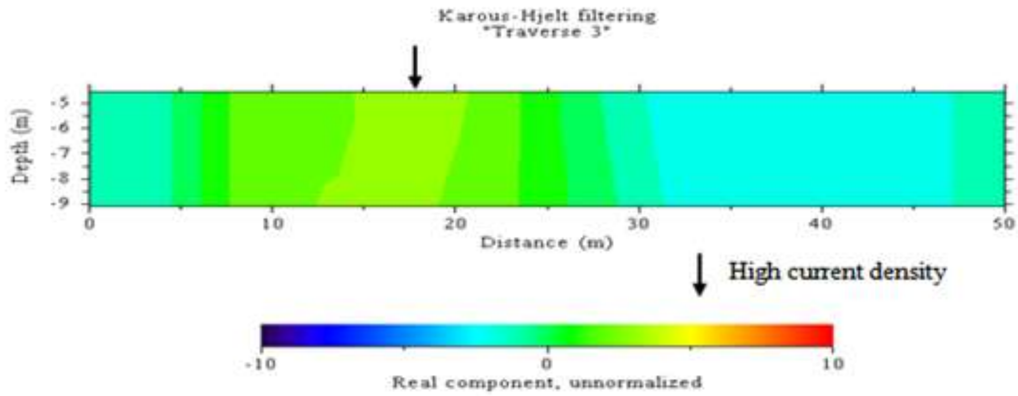

Figure 5: Karous-Hjelt current density plots for VLF-em profile 1

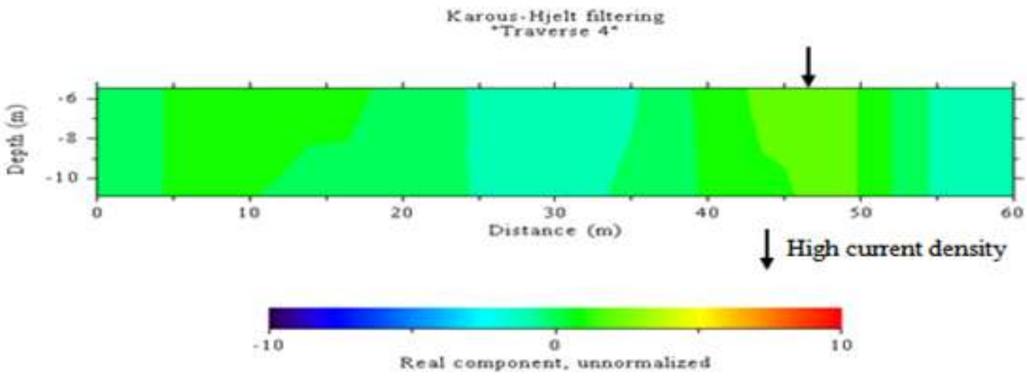

Figure 6: Karous-Hjelt current density plots for VLF-em profile 2

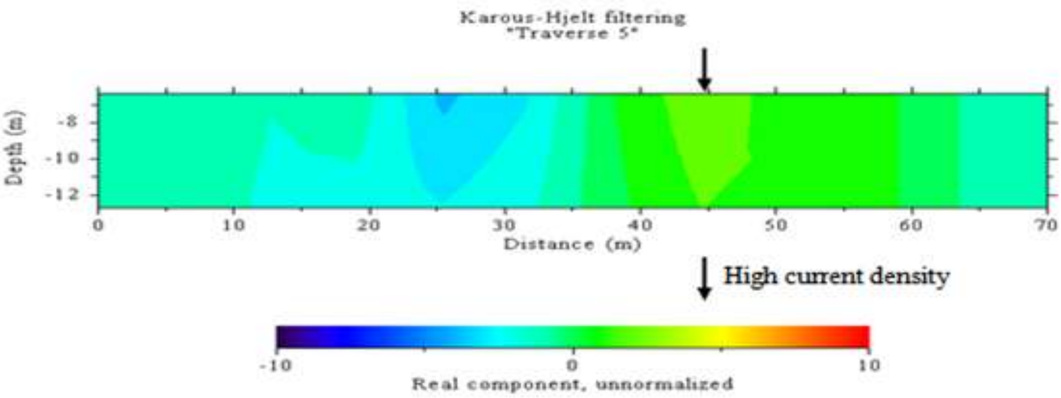

Figure 7: Karous-Hjelt current density plots for VLF-em profile 3

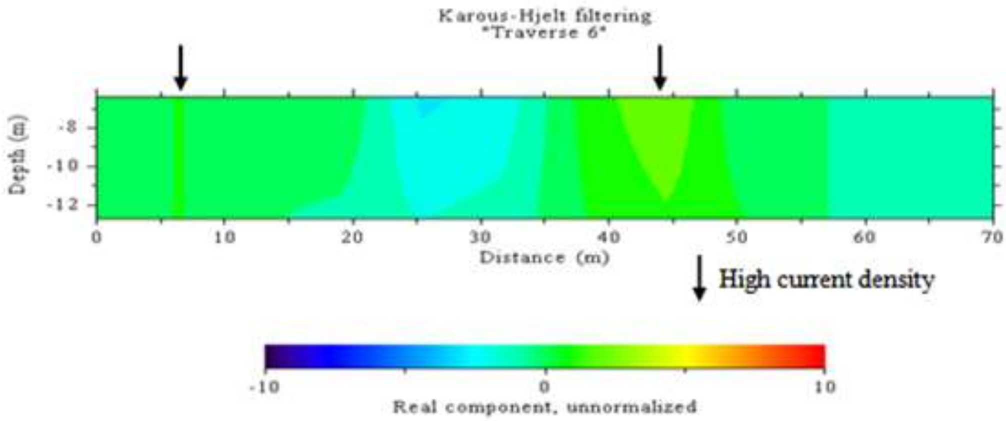

Figure 8: Karous-Hjelt current density plots for VLF-em profile 4

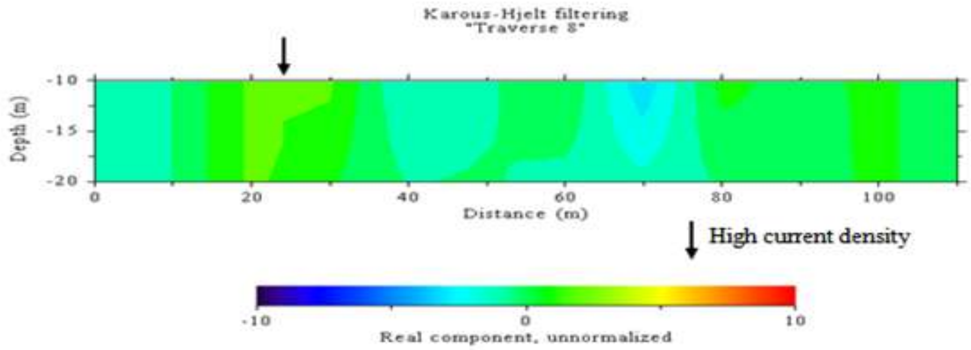

Figure 9: Karous-Hjelt current density plots for VLF-em profile 5

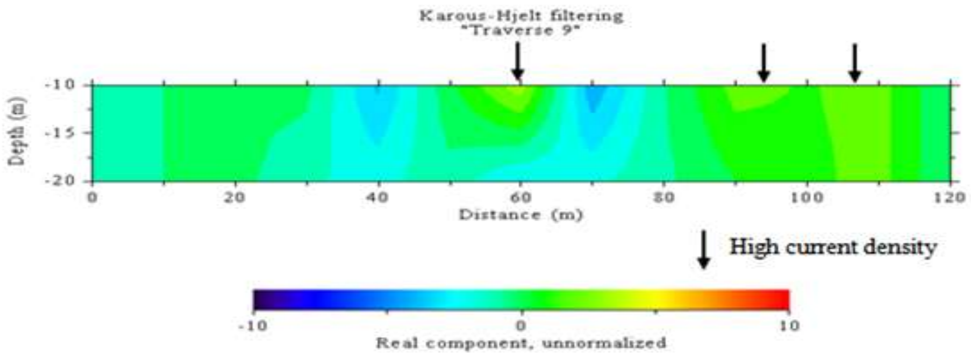

Figure 10: Karous-Hjelt current density plots for VLF-em profile 6

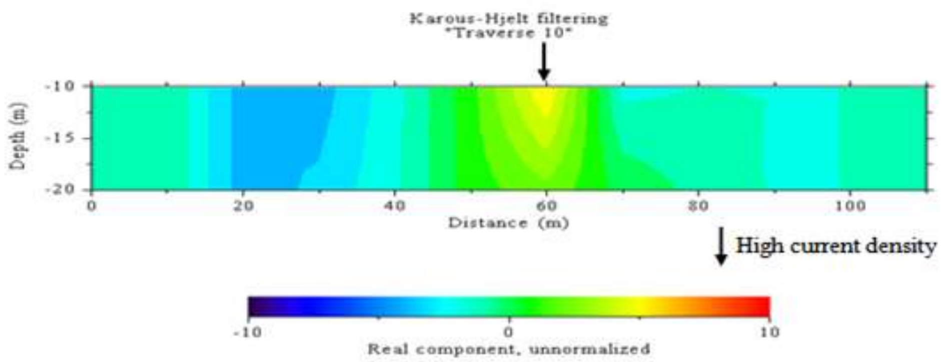

Figure 11: Karous-Hjelt current density plots for VLF-em profile 7

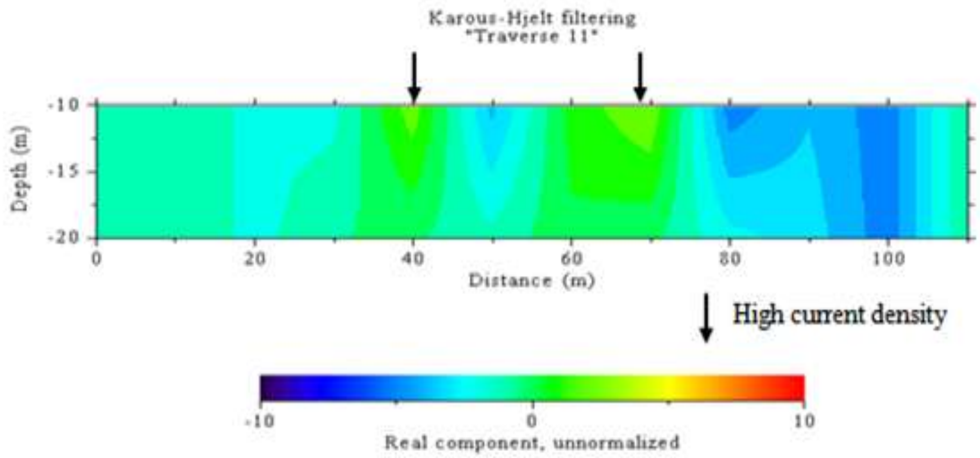

Figure 12: Karous-Hjelt current density plots for VLF-em profile 8

Fig. 13 shows the model curves for VES 1 to VES 7. The results generated from the VES data interpretation (i.e. VES curves) are presented in Fig. 14 and Fig. 15 as geoelectric sections. The partial curve matching technique carried out on the field data revealed a 3 layered model with H type curve ($\rho_1>\rho_2<\rho_3$) for all the soundings. Electrical method primarily reflects variations in ground resistivity (Omosuyi et al., 2007). The electrical resistivity contrasts between lithological sequences (Dodds and Ivic, 1998; Lashkaripour, 2003) in the subsurface are often adequate to enable the delineation of geoelectric layers and identification of aquiferous or non-aquiferous layers (Schwarz, 1988). The VES interpretation reveals three geoelectric layers across the research area: the topsoil consisting of sand and decomposed organic matters; the weathered layer which is made up of sandy soil and the bedrock constituting the fractured or fresh basement. The geoelectric sections show subsurface variation in electrical resistivity along the profiles and attempt to correlate the geoelectric sequence across the profiles. In the first layer, the resistivity values ranged from 33.4 to 130.9Ωm with a relative thickness of 1.1 to 1.6m. The second layer has resistivity values varying from 10.4 to 26.8Ωm with relative thickness of 1.3 to 3.8m. However, the low resistivity values depicted in this layer is due to pollution which resulted from the high porosity and permeability characteristics of the sandy soil encouraging the seepages of the leachate plumes to a maximum depth of 5.4m at the subsurface. The region of this layer beneath VES2 conducted on the waste disposal site where there is older wastes deposit depicted low resistivity value of 10.4Ωm. It also reveals an elevation in the resistivity values in the order VES 1, 3, 5, 6, 7 and 4 which revealed that the leachate emanated from the region where there is older deposit of wastes and spreading out in all direction polluting the hand dug wells nearby in the process. This geoelectric layer also served as the first aquifer on the research site from which virtually all the hand dug wells in the area obtained their water. The third layer has resistivity values ranging from 233.6 to 356.7 Ωm which indicated the presence of fractured zones and resistivity values between 1649.9 and 2764.9 Ωm; reflective of fresh basement. The thickness of this geoelectric layer is to an infinite depth.

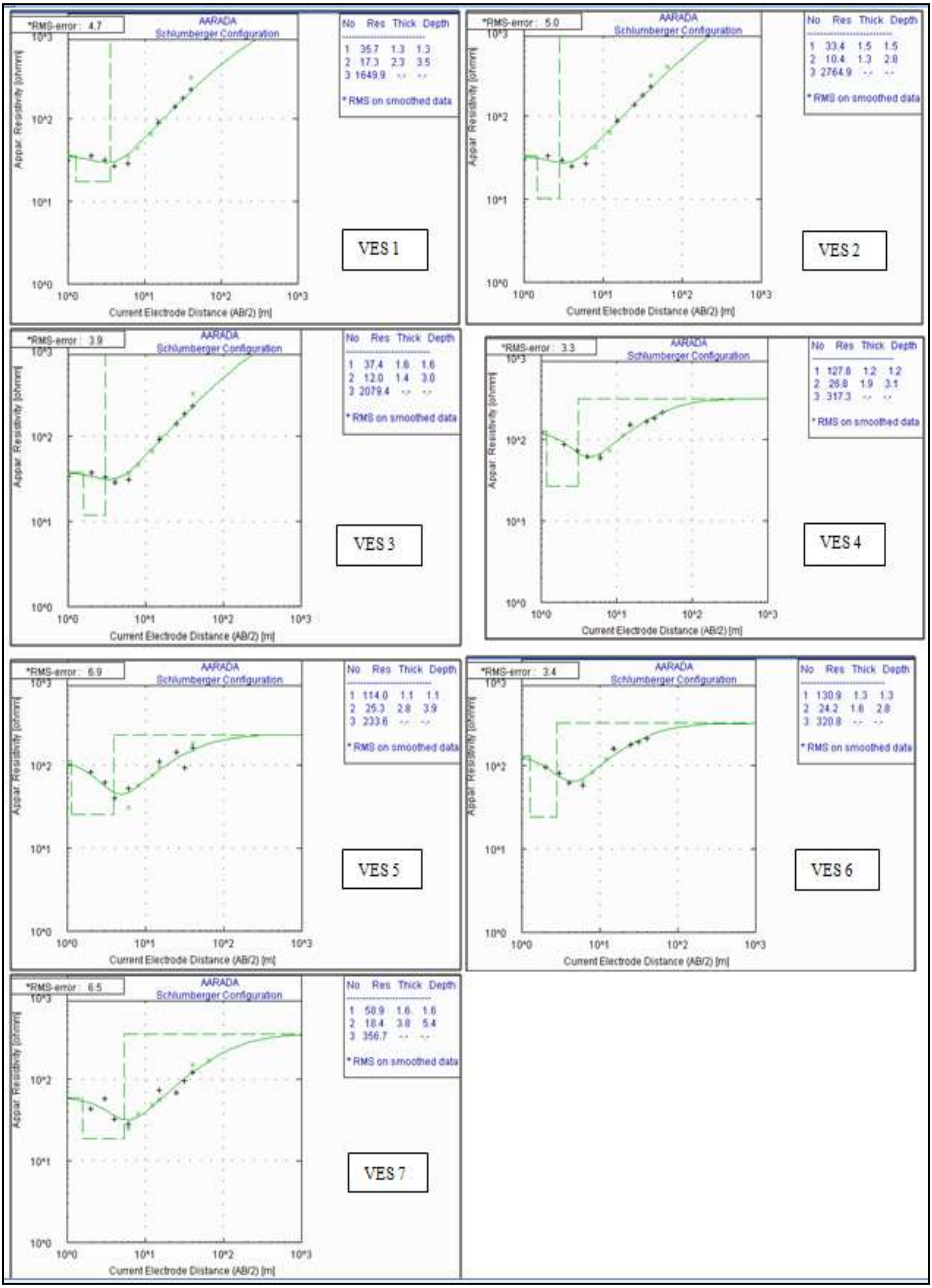

Figure 13: The model curves for VES 1 to VES 7

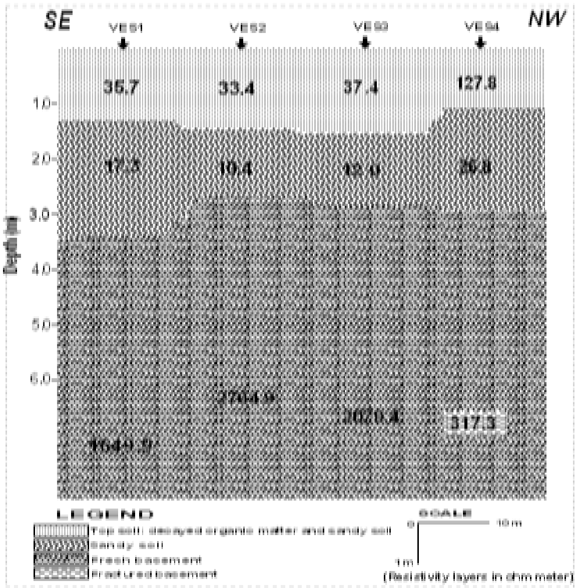

Figure 14: Geoelectric section beneath VES 1, 2, 3 and 4

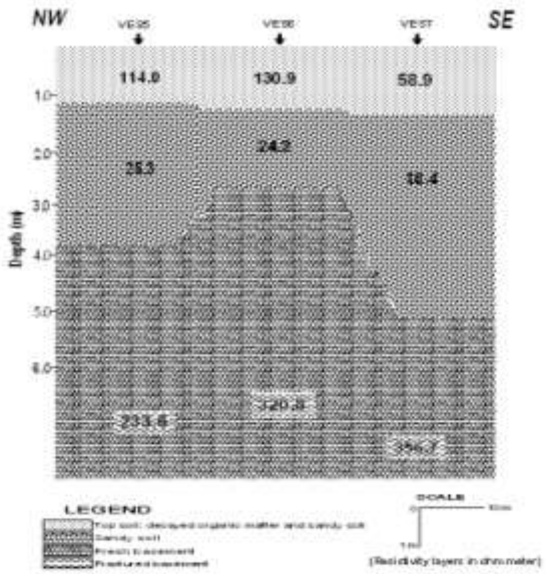

Figure 15: Geoelectric section beneath VES 5, 6 and 7

V. Conclusion And Recommendation

The integration of electrical resistivity (Vertical Electrical Sounding) and electromagnetic (Very Low Frequency Electromagnetic) methods was employed to investigate a dumpsite facility in the research area. Both Vertical Electrical Sounding (VES) and Very Low Frequency Electromagnetic (VLF-EM) techniques were used to locate and determine the spatial distribution of leachates within the area. The VLF-EM data models depict the contamination plumes inside the waste disposal site as conductive anomalies while the geoelectric sections of the VES detected the contaminated zones at the subsurface as resistive anomalies. The analysis of the geoelectric sections generated revealed that the zone with leachate pollution (the second geoeletric layer) has thicknesses ranging from 1.4m to 3.8m and a maximum depth of 5.4m to the basement and the depth of the hand dug wells in the research area varied between 4.1m and 6.5m showing that most of the wells there terminate within the contaminated zone. This observation indicates that the leachate plumes have actually extended to a depth of 5.4m at the subsurface. The infiltration of contamination plumes was due to the high porosity and permeability characteristics of the soil type present in the research area. It is therefore recommended that hydro-physicochemical analysis to determine the concentration of nitrate, heavy metals and coliform counts must be conducted on the hand dug wells in the study area in order to ascertain the quality of available groundwater resources and proffer necessary treatment measures. In addition, the hospital situated less than 4m away from the waste disposal site should be evacuated so that patients seeking health care delivery system in the clinic will not have their health problems compounded due to its close proximity to the refuse dumps. This study also reveals the importance of using an integrated approach of geophysical techniques for acquiring the physical properties of a waste disposal site. The employment of different techniques allows the resolution of possible discrepancies and reveals the most accurate description of a waste disposal site's characteristics.

Acknowledgements

The authors are grateful to God for the success of this research. We are also indebted to the Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso for giving us conducive atmosphere for research. Two out of the authors (Mr. T.A. Adagunodo and Mr. E.R. Olafisoye) are grateful to the Board of Post Graduate School, Ladoke Akintola University of Technology, Ogbomoso, Nigeria for the financial support given at the middle stage of this research.

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