Investigation of Leachate Plume and Groundwater Pollution using Geophysical and Physio-chemical Methods in an Open Dumpsite at Idugosa, Federal Capital Territory (FCT), Abuja, Nigeria

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Abstract

A geophysical study has been carried out using the electrical resistivity method, Very Low-Frequency Electromagnetic (VLF-EM) and physiochemical analysis to investigate the effects of groundwater contamination in the vicinity of an open dumpsite at Idugosa. A Vertical Electrical sounding was carried out at 100 m away from the dumpsite and the results revealed an H-type curve with 3- layers, with a low resistivity value of 90.0 Ωm, thickness of 9.8 m and depth of 11.3 m at the weathered basement. The control VES revealed 5 –layers of HK-type curve. The resistivity of the weathered and fractured basement ranged from 241.8 Ωm to 2908.4 Ωm with a thickness range of 3.5 m to 13.6 m and a depth range of 5.6 m to 19.1 m. Results of the horizontal profiling using Wenner profiling revealed a low resistivity value of 1.6 Ωm to 3.8 Ωm at a depth of 15 m to 30 m, concentrated at stations 20 to 100. The bottom of the western part showed that the leachate plume had infiltrated and contaminated the groundwater in the zone. The VLF-EM with the three profiles revealed high current density values on the Karous-Hjelt filter plot at distances of 20 m to 38 m for profile 1, 25 m to 50 m and 75 m to 95 m for profile 2, revealing the presence of contaminants which is mainly from decayed organic matter from waste bodies and heavy metals from the dumpsite. Profile 3 which is further away from profile 1 revealed that the contamination is reduced as we move further away from the dumpsite at about 10 m to 20 m, 50 m to 60 m and 90 m respectively. The physio-chemical analysis results showed a pH range of 6.73 – 7.17 which is within the World Health Organization (WHO) standard (6.5 - 8.5). The Electrical Conductivity (EC) value of the Idugosa dumpsite was found to be 804.9 μS/cm, which is above the WHO standard for EC values, which should not exceed 400 μS/cm. This high value can be attributed to the infiltration of the leachate plume from the dumpsite. The EC for Idugosa control which is 188.0 μS/cm is within the WHO limit for groundwater, thus its safe for consumption.

Keywords: Electrical conductivity (EC); Groundwater; Leachate; Dumpsite; Vertical Electrical Sounding (VES); Very Low-Frequency Electromagnetic (VLF-EM).

I. INTRODUCTION

Domestic, commercial, and industrial activities all produce solid waste. Open dumps, wasteland farm contamination, ponds, contamination in rocks, and deep underground injection are only a few of the different ways that solid waste can be disposed of [1]. The use of landfill systems as a means of waste disposal is frequently outside of what is generally advised [2-3]. Due to the creation of leachate and its movement through waste, landfills are sources of groundwater and soil pollution [4]. After some time, a dumpsite experiences biological, chemical, and hydrological processes that cause the waste to weather and, as a result, become a source of pollution [5]. In the FCT, open dump has been the standard procedure.

In a recent study conducted by [6] on geophysical, geotechnical and water quality investigations of Gosa dumpsite in Abuja, Nigeria to unravel the feasibility of upgrading it to a modern sanitary landfill, inversion results of VES-DC data revealed 3-4 geoelectric layers with the soils classified as well graded clayey-sand to silty-sand with permeability between $5.1 \times 10^{-7}\ m/s$ and $1.1 \times 10^{-6}\ m/s$, which makes the groundwater prone to leachate pollution. The physio-chemical parameters of the water were generally below the WHO-recommended value. It could be inferred that only the northern part of the area possesses the required geophysical and geotechnical characteristics for upgrading to a sanitary landfill. The high concentration of radioactive elements in the water revealed that the present dumping activities have negatively impacted the groundwater quality

This study is aimed at investigating leachate plume and groundwater pollution within an Open dumpsite at Idugosa, Federal Capital Territory (FCT) Abuja, Nigeria using geophysical and physio-chemical Methods.

A. Study Area

The Federal Capital Territory, Abuja is situated in the central parts of Nigeria, between latitudes 8° 25' and 9 °25' north and longitude 6° 47' and 7 °40' east. The location study area, Idugosa lies between 9° 03'N and 7° 34' E with an elevation of 403.1 m and 9° 03'N and 7° 33' E with an elevation of 394.1 m.

Abuja is bounded in the north by Kaduna state, in the west by Niger state, in the east by Nasarawa state and Kogi state in the south-west. The basement complex especially at the north-central part is intruded by Mesozoic calc-alkaline ring complex rock referred to as younger granites, to differentiate them from much foliated, complex and deformed older granites. The basement complies in parts overlain by cretaceous and younger sediment [7]. Fig. 1, shows the geology map of FCT while Fig. 2 shows the location map of the study area.
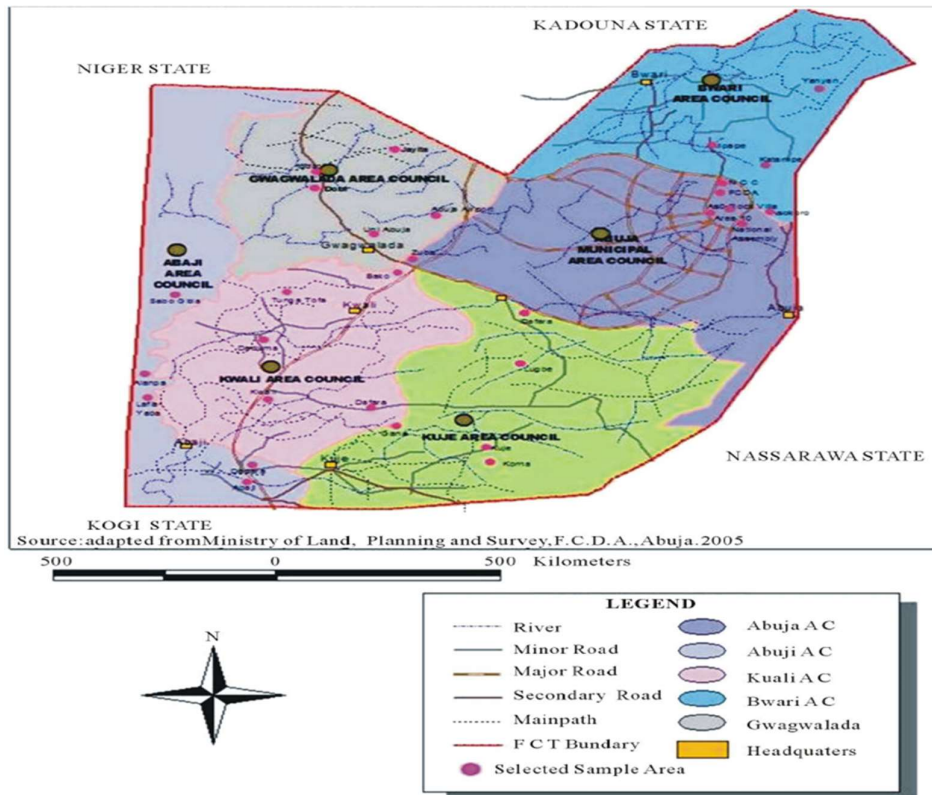

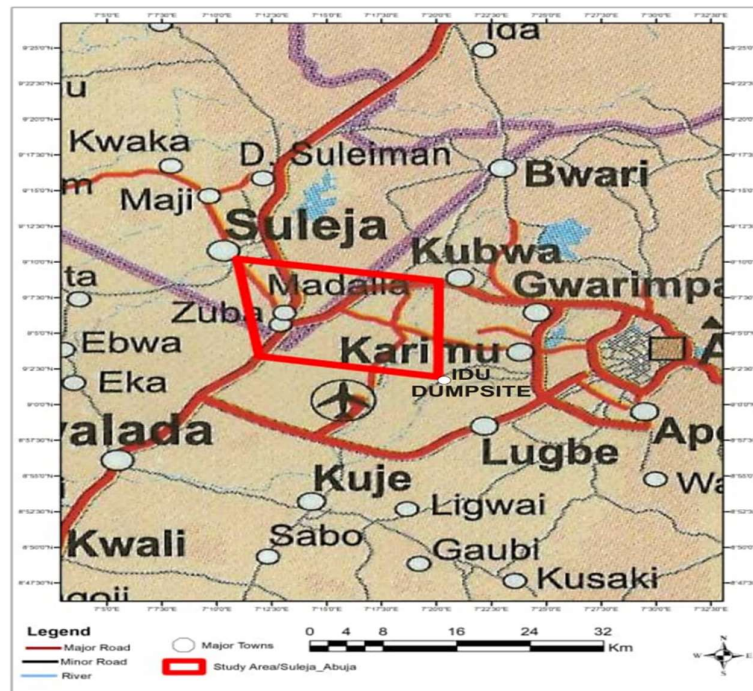Fig. 1 Geology map of Abuja Federal Capital Territory [8]

Fig. 2 Location map of the study area

II. MATERIALS AND METHODS

In this geophysical survey, the data was acquired using Terrameter SAS 4000 for the Electrical resistivity method while Abem Wadi for (VL-EM) was used to carry out the survey. Electrical prospecting makes use of a variety of principles each based on some electrical properties or characteristics of the material within the earth [9-10].

A. Vertical Electrical Sounding (VES)

The Schlumberger soundings were carried out with a current electrode spacing (AB/2) ranging from 1- 200 m maximum depending on the dumpsite. The distance used for potential electrode spacing (MN/2) ranged from 0.5 m to 10 m. At each of the VES stations electrodes were placed in a straight line and the inter-electrode spreads were gradually increased about a fixed centre.

B. Wenner Profiling

For 2D imaging, the Wenner array method was conducted along a profile in each of the 10 locations in the field. The technique was achieved by sending a direct current into the ground through a pair of current electrodes, while the voltage drop was measured through another set of potential electrodes. For each profile, a constant electrode spacing of 1a, 2a, 3a, 4a, and 5a each for both current and potential electrodes was used consecutively depending on the nature of the location. For an electrode spacing of 1a, the spacing distance of current and potential electrodes are equal and are shifted successive readings along the spread of a 150 minimum and maximum of 200 m. The same procedure was repeated for each of the electrode spacing of 2a, 3a, 4a and 5a, separately, where 'a' is the electrode spacing and equal to 10 m.

C. Physio-chemical analysis

Groundwater samples were collected from hand-dug untreated wells, surface water and boreholes around the location of the dumpsites at a distance of 10 m from the dumpsites. The physio-chemical parameter that was tested to ascertain groundwater pollution includes Electrical Conductivity (EC), Total dissolved solids (TDS), Turbidity Nitrate, Lead, Iron, Magnesium, Copper, and Cadmium. The cation concentrations were determined using an Atomic Absorption Spectrophotometer (AAS).

D. Very Low Frequency Electromagnetic (VLF- EM) Abem Wadi

Very low frequency (VLF-EM) electromagnetic geophysical method involves the use of electromagnetic frequencies in the range of 3-30 kHz to investigate subsurface features. In this method, an electromagnetic transmitter is used to generate a VLF signal, which is then transmitted into the ground. The signal is affected by the subsurface geology, such as the electrical conductivity of the different rock layers and the presence of subsurface structures. The VLF-EM method was used at different locations in the study area.

III. RESULTS AND DISCUSSION

Fig. 3 depicts the Vertical Electrical soundings (VES) carried out at 200 m away from the dumpsite. The results

revealed of 3-layer with an H-type curve ($\rho_1 > \rho_2 < \rho_3$) with resistivity of the topsoil 336.5 Ωm, with thickness and depth of 1.5 m. The 2-layer which is weathered has a low resistivity value of 90.9 Ωm with a thickness of 9.8 m and depth of 11.3 m respectively the 3-layer is the basement with a high resistivity value of 5811.0 Ωm, with an infinite thickness and depth.

Fig. 4 illustrates the VES carried out in an undisturbed area about 500 m away from the dumpsite to serve as a control. This shows 5-layers of HK -type curve with resistivity values ranging from 2100.1 Ωm with thickness and depth of 0.6 m for the first layer, 730.6 Ωm with thickness of 1.7m and depth of 2.3 m at the second layer, 2908.4 Ωm with thickness of 3.3m and depth of 5.6m at the third layer, 241.8 Ωm with thickness of 13.6m and depth of 19.1m at the fourth layer and 5413.2 Ωm with infinite thickness and depth for the fifth layer.
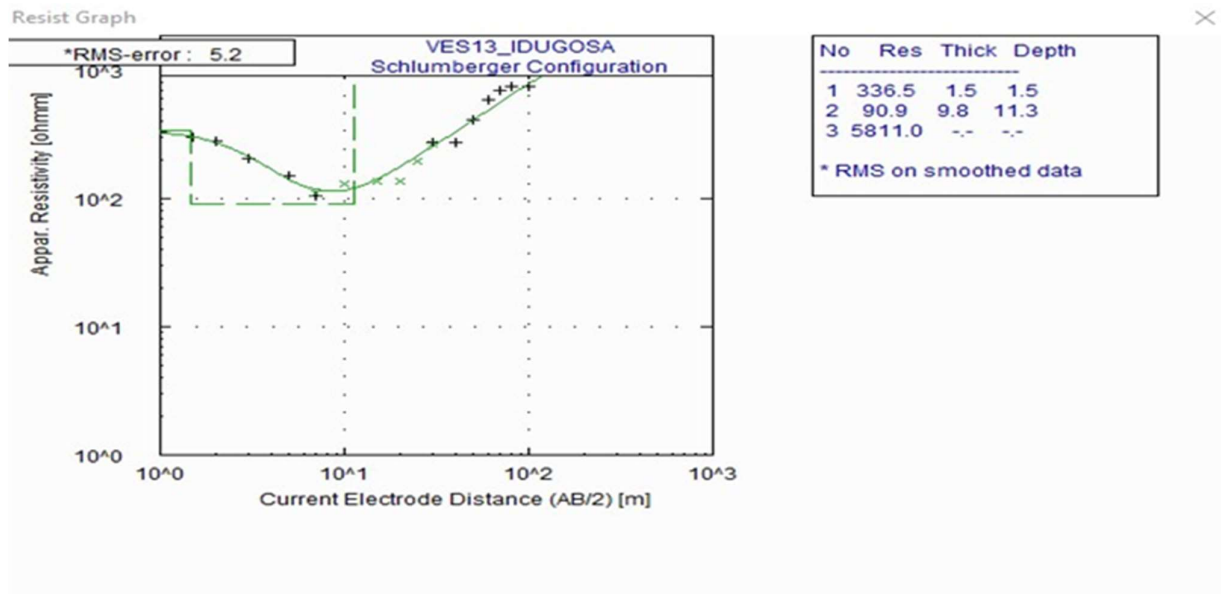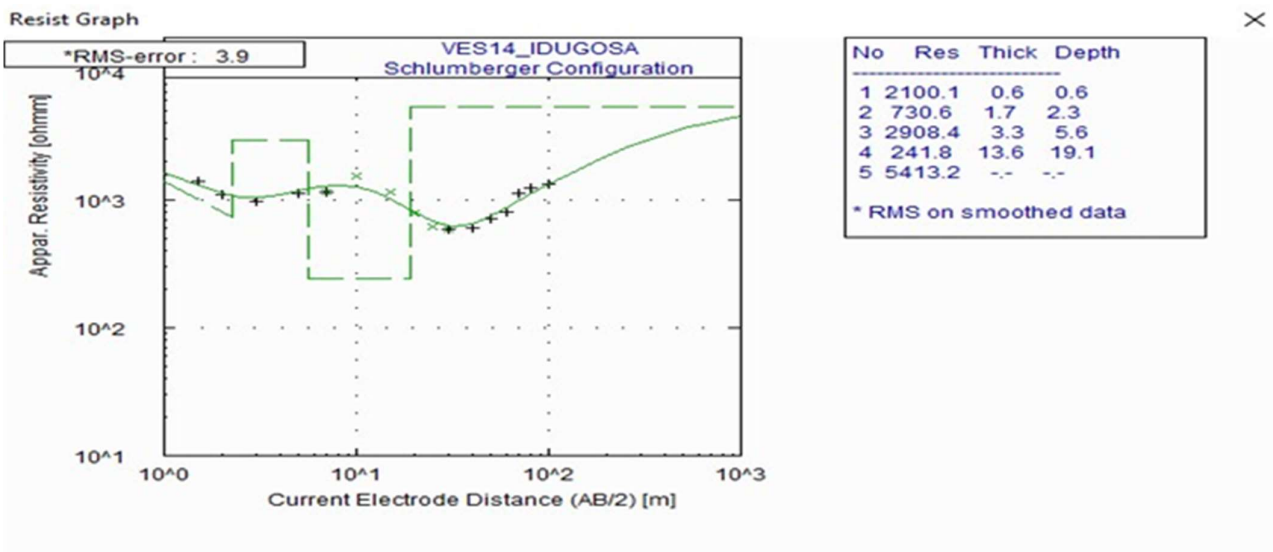

Fig. 3 VES iteration for Idugosa dumpsite.

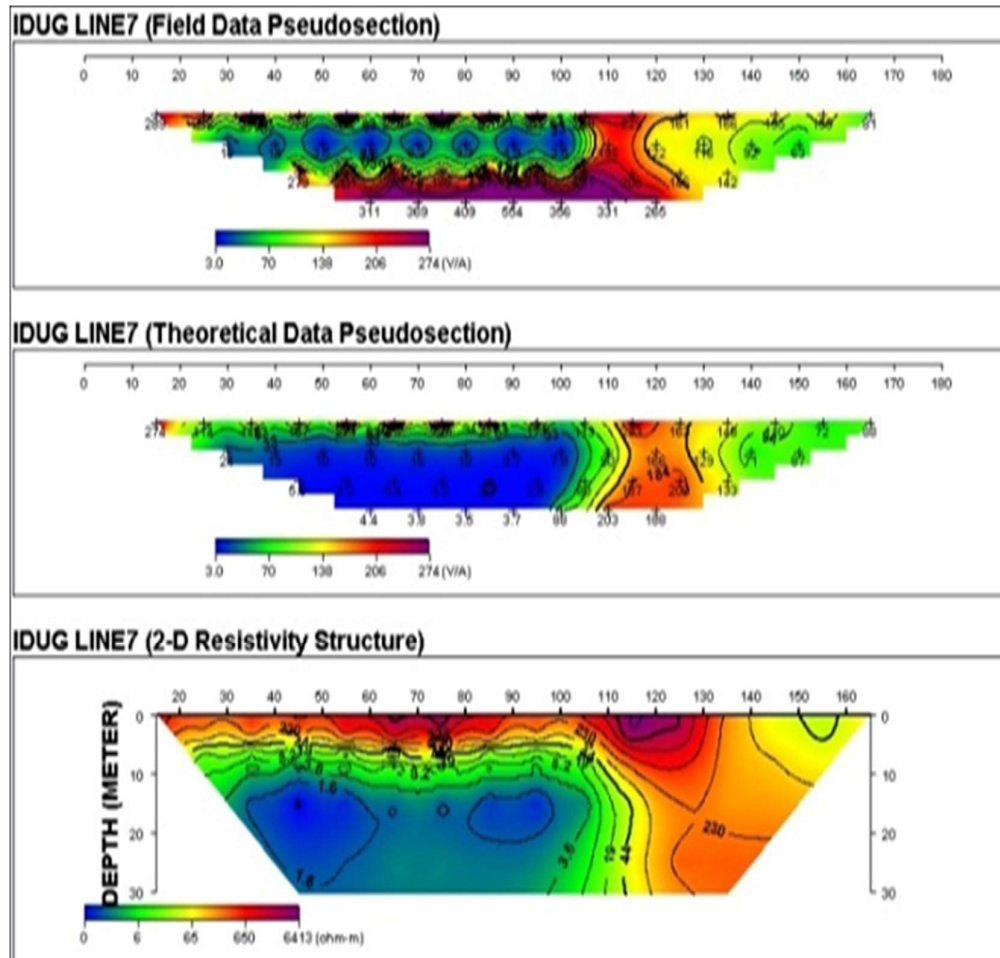Fig. 4 VES iteration for Idugosa Control

Fig. 5 A typical 2D Profiling result.

The 2D profiling data was acquired at the Idugosa Government-approved site in FCT. A total spread of 180 m with an electrode spacing of 10m that runs through the NE-SW direction. The blue colour with a low resistivity value of 1.6 Ωm to 3.8 Ωm was at a depth of 15m to 30m and was concentrated at stations 20 to 100. The green colour was observed at station 20 trending down the bottom at 110. With a low resistivity value of 8.2 Ωm to 44.0 Ωm at a depth of 5m to 30m. the red colour was observed at the topsoil which reveals lateritic soil at the topsoil that trending down to the bottom at the eastern path between station 110 to 130, with a resistivity value of >230 Ωm and at a t depth of 30m. The blue colour observed at the bottom of the western part showed that the leachate plume had infiltrated and contaminated the soil in the zone.

In Fig. 5 the current density value on the Karous-Hjelt filter plot is relatively high at a distance of 20 m to 38 m, revealing the presence of some contaminate from decayed organic matter from the waste body. The VLF-EM profile 2, also carried out along the Northern side of the dumpsite area showed a high conductivity value on the apparent current

density cross-section of the 2-D Karous-Hjelt filter image at a distance of 25 m to 50 m and 75 m to 9 5 m due to infiltration of leachate which is made up of mainly decompose bodies and heavy metals from the dumpsite within the research area. Finally, at profile 3 which is further away from the first profile at about 300 m, results obtained reveal that at 10 m to 20 m, 50 m to 60 and 90 m the contamination is reduced as one moves further away from the dumpsite as shown in Fig. 6.

Physical parameters used for analysis include pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, Nitrate and heavy metals (i.e. Fe, Mn, Cu, Pb and Zn). The study area showed a pH range of 6.73 – 7.17 which is within the WHO standard (6.5 - 8.5). The Electrical conductivity (EC) value of Idugosa dumpsite was found to be 804.9 µS/cm which is above the WHO standard of 400 µS/cm for EC value. This high value is attributed to the dissolved salts and minerals from the dumpsite. Finally, the EC value of 188 µS/cm for Idugosa control was seen to be within the WHO limit for groundwater which is safe for consumption. The other parameters tested such as turbidity, Nitrate, Fe, Mn, Cu, Pb and Zn were all below the WHO limit as depicted in Table I.
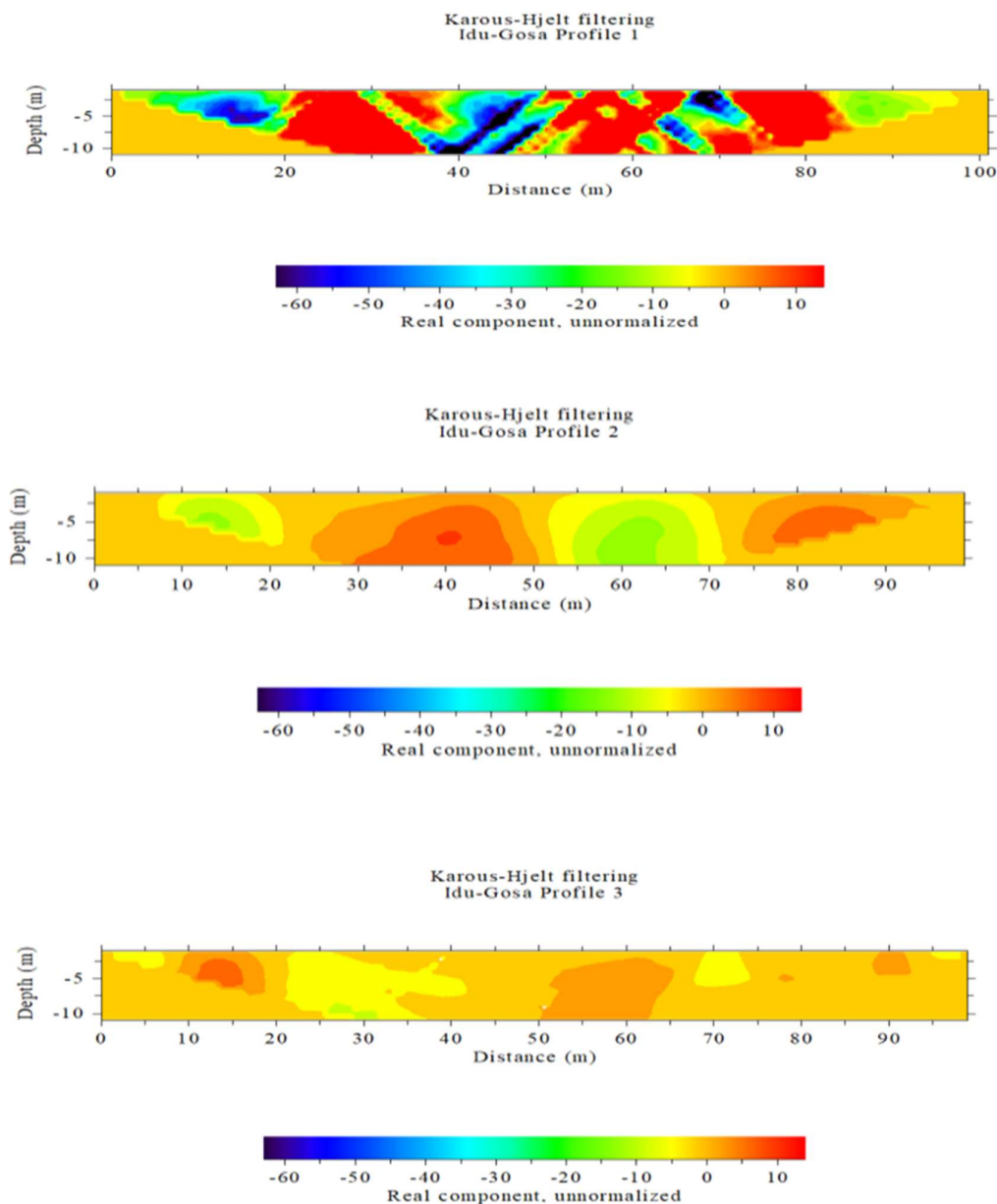
Karous-Hjelt filtering
Idu-Gosa Profile 1

Karous-Hjelt filtering
Idu-Gosa Profile 2

Karous-Hjelt filtering
Idu-Gosa Profile 3

Fig. 6 A Typical VLF-EM profiling.

Table I. Physio-chemical analysis of Borehole in Idugosa dumpsite, Abuja.

Parameter	Unit	ID1	IDC	WHO Standard
PH		6.73	7.17	6.5 – 8.5
EC	μS/CM	804.9	188.0	400
TDS	Mg/l	394.2	92.23	500
Turbidity	NTU	0.55	0.90	5
Nitrate	Mg/l	7.2	1.7	50
Fe	Mg/l	NIL	NIL	0.3
Mn	Mg/l	0.206	0.194	0.4
Cu	Mg/l	0.9707	0.668	2
Pb	Mg/l	NIL	NIL	0.01
Zn	Mg/l	NIL	NIL	3

IV. CONCLUSION

The VES results obtained were useful in the determination of geological structures, layers and depths of the aquifer. The extent of the leachate migration from the dumpsite-affected areas of about 100 m - 200 m away from the dumpsite. The correlation of the VES and 2D reveals that some parts of the western region were highly infiltrated by the leachate plume migration at a depth of about 15 m to 30 m around the dumpsite. Very Low-Frequency Electromagnetic survey reveals the near-surface fracture. The high conductive zone

was more visible in profiles 1 and 2 and lesser in profile 3 which shows that the migration of leachate plumes was more at regions closer to the dumpsite and less as we move further away from the dumpsite. The physio-chemical analysis of borehole water collected from 50 m away from the dumpsite revealed a high EC value of 804.9 µS/cm which is above the WHO-regulated guidelines for EC value which should not exceed 400 µS/cm. The high value obtained can be attributed to dissolved salts and minerals from the dumpsite.

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