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COAST
JOURNAL OF THE SCHOOL OF SCIENCE
Volume 6, Issue 2. November, 2024 ISSN: 2714-3716
Coast, J. Sch. Sci. 6 (2): 1069 - 1079

GEO-ELECTRICAL EVALUATION OF LEACHATE INFILTRATION INTO THE AQUIFER OF THE AGIRIFON DUMPSITE, ILUTITUN SOUTHWEST NIGERIA

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https://doi.org/10.61281/coastjss.v6i2.7

Abstract
The effect of leachate infiltration from the Agirifon dumpsite to the aquifer system of Ilutitun was investigated using the Electrical Resistivity methods. The investigation was aimed at determining the geoeletric geometry of leachate plume at the subsurface of the dumpsite. Six traverses were established to cover the entire study area, Dipole-Dipole electrode configuration was employed using electrode separation of 5m and 10 m. The expansion factor n was varied from 1-5meters and 1-10meters respectively. The 2-D resistivity structures delineated virtually a single type of subsurface formation (Coastal Plain Sands) which can be divided into three zones; the topsoil or upper zone made up of sandy clay/clayey sand/sand, the intermediate zone made up of clayey sand/sand and the lower zone majorly made up of sand. The three zones generally transit into one another. The 2-D Resistivity imaging revealed a radial migration of leachate in the range 7.2Ωm in the NW/SW direction of the study area from the topsoil to a depth of 30 m beneath the dumpsite facility. The leachates were observed to have infiltrated through the porous and permeable layers into the subsurface aquifers, subsequently contaminating the underlying groundwater resource. It could therefore be concluded that the leachates produced from the dumpsite has gradually infiltrated into the subsurface (shallow and deep) aquifers in the study area.
Key Words: *Dumpsite, Leachate, infiltration, Aquifers, 2-D resistivity Imaging*

Introduction

Generation of waste is an indispensable characteristic of life and living. A variety of wastes, ranging from large quantities of relatively innocuous municipal refuse to much smaller quantities of potentially lethal radioactive wastes are deposited on land (as dump) or in landfills or waters Dauda and Osita (2003). The generated wastes are usually disposed off discriminately in developed countries and indiscriminately in the developing countries of the world into the environment. The environment receives all kinds and amount of waste. (Marshall and Farahbakhsh,2013)

The recognition of the connection between human activities and pollution and the need to protect human health, recreation and fisheries production led to the early development of water quality regulations and monitoring methods (Hen, 1985; Jenkins *et al.,* 1996; USEPA, 2007).

No landfill is sufficiently tight that groundwater contamination by leachate is totally avoided. Rainwater infiltrating into sanitary landfills dissolve materials from the disposed refuse and runs off as leachate both vertically into the groundwater system and horizontally to adjoining surface water. Hence, the spate of leachate contamination is increased in the humid regions where the moisture available exceeds the ability of the waste pile to absorb water (Adeoti *et al* 2011).

In the area of study, the open dump system of refuse disposal is what has been in use from time immemorial, the effect of which cannot be underplayed on the geological and groundwater system of the area. The increase in the population of the area has been gradual over the years, which has led to the continual increase in the waste disposed on the dumpsites.

Description of Study Area

The dumpsite under study (Figure 1) is located in Ilutitun, Southern part of Ondo State Southwestern Nigeria, within the eastern flank of the Dahomey Basin. The study area is located within latitudes 6^0 31' 21.31" N to 6^0 31' 34.68" N and longitudes 4^0 38' 5.87" E to 4^0 38' 19.32" E. The study area is underlain by the Dahomey Basin of the Nigerian Geology. The portion where the study area is located is characterized by Coastal Plain Sands that are generally moderately sorted and poorly cemented. The Coastal Plain Sands is overlain by lateritic overburden or recent Alluvial deposits and underlain by the Eocene Ilaro Formation. The Coastal Plain Sands constitute the major shallow hydrogeologic unit in the area (Omosuyi, 2010). The geologic and hence the aquifer settings of the study area, makes the infiltration of leachate a possibility. The aquifers are generally shallower than 200 m and can be classified into three types (Longe *et al.*, 1987). The first is the water table aquifer that is prone to pollution because of its unconfined state. The second and third aquifers are confined (Omosuyi, 2010).

Problem Definition

The main environmental problem of waste dump sites is its potential risk of groundwater pollution and subsequent influence on surface water quality. Location of landfills inside aquiferous units, migration or infiltration of contaminants from waste disposal sites can also be a source of pollution to adjoining aquiferous units, thereby affecting local wells and drilled holes used for public water (Matias *et al.,* 1994). Groundwater pollution happens mostly due to percolation of fluvial water and the infiltration of the contaminants through the soil. The total pollutant load to the environment is dependent on the quantity and quality of the water that percolates through the disposal site and reaches the groundwater (Bengtsson *et al.* 1994). The overall implication of this is the hydrochemical facie of groundwater changes in response to its flow path history, that is, underground water quality is dependent on pollution status of its environment (Olabaniyi and Owoyemi, 2006).

The application of several geophysical methods has provided an important tool for the cost-effective mapping of the Landfill geometric characteristics and evaluation and characterization of contaminants generated by urban residues (domestic and/or industrial). Among the available geophysical methods, electrical and electromagnetic methods have been found remarkably suitable for such environmental studies, due to their usefulness in mapping subsurface electrical resistivity structure and the conductive nature of most contaminants (Ulrych *et al.,* 1994; Lanz *et al.,* 1994; Sauck, 2000; Atekwana *et al.,* 2000; Orlando and Marchesi, 2001).

In this study, the 2-D Electrical Resistance Tomography method is used to map the groundwater regime and possible leachate pathway and infiltration into the aquifer matrix in some parts of Ilutitun, Southwestern, Nigeria. Geophysical methods have found useful application in environmental investigation and subsurface sequence mapping. Landfill/dumpsite-related geophysical surveys are frequently reported in the literature

Omosuyi *et al.,* (2007), conducted an electrical resistivity survey of the Okitipupa Coastal Plain Sands for delineating the boundaries, depth range of the shallow aquifer units and assess their vulnerability to near-surface contaminants.

Adeoti et al., (2011) used constant spacing traversing (CST) technique using the Wenner array to delineate the possible Leachate infiltration into the aquifer matrix of an active waste dump site and also to probe the geological setting of the Ile-Epo dump site, Lagos Nigeria.

Impact assessment of solid waste on groundwater conducted on Arada dumpsite by Olafisoye et al., (2013) used a combination of electrical resistivity method and hydro physicochemical analysis, utilizing a total of seven (7) VES stations and nine (9) hand dug well. The results show a low second layer resistivity of between 10 Ωm and 27 Ωm across the study area, high coliform counts and high concentration TDS, NO_3-, Cl^-, in some of the water samples.

Figure 1: Agirifon Dumpsite at Ilutitun (is an active dumpsite in residential area)

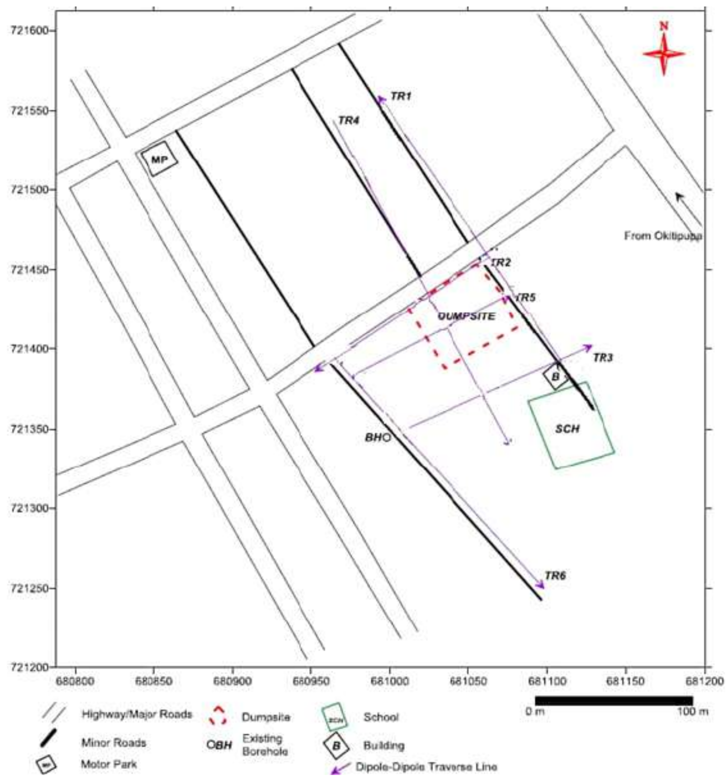

Figure 2: Data Acquisition Map of the Study Area showing traverses and the dumpsite

Materials and Methods

The electrical resistivity geophysical method was employed for the data acquisition. Six traverses were established across the study area (Figure 2) which runs in the NW-SE, SE-NW, NE-SW and SW-NE directions. The necessary materials used in carrying out this study include GPS, Electrodes Cables reels, Hammers, Resistivity meter (Terrameter), etc.

The resistivity meter used is the Ohmega Resistivity Meter which has a DC (battery) power source, sends current through the ground through two current electrodes and measures the potential difference across them through two other potential electrodes, these electrodes are connected to the resistivity meter.

The dipole-dipole electrode configuration was used to acquire data along the six traverses.

The interpretation techniques employed for the interpretation of the data obtained was Qualitative. Qualitative interpretation involves the visual inspection of profiles, maps and pseudosections for anomaly signatures that are diagnostic of a particular target. 2-D Dipole-Dipole resistivity pseudosections, generated geoelectric sections and maps were interpreted qualitatively.

Results

The results of the data obtained from the field are presented in the form of Pseudo sections. The Dipole-Dipole pseudo sections and the 2-D resistivity structures are shown as figures below. The 2-D resistivity structures show the subsurface images inverted from the field data and its calculated theoretical data pseudo section revealing both lateral and vertical variations in ground apparent resistivity values of the subsurface. Apparent resistivity varies from as low as 9Ωm on some part of this study area and as high as 11660Ωm in some other part. The 5m electrode separation 2-D resistivity structure reveals the upper 15m of the subsurface, while the 10m electrode separation 2-D resistivity structure reveals the upper 30 m of the subsurface. The 2-D resistivity structures delineated virtually a single type of subsurface formation (Coastal Plain Sands) which can be divided into three zones; the topsoil or upper zone made up of sandy clay/clayey sand/sand (in blue to reddish-brown colour bands), the intermediate zone made up of clayey sand/sand (in bluish-green to yellowish colour bands) and the lower zone majorly made up of sand (in reddish/purple colour bands). The three zones generally transits into one another.

Discussion

Traverse (Profile) 1

The 2-D resistivity structures beneath traverse 1 (Figs. 3-4) shows the degree of inhomo- geneity of the subsurface and the result of anthropogenic activities. The datafor this traverse was obtained using two electrode separations of 5 and 10 m. The 5 m electrode separation 2-D resistivity structure reveals the upper 15 m of the subsurface (Fig. 3) while the 10 m electrode separation 2-D resistivity structure reveals the upper 30 m of the subsurface (Fig. 4). A low resistivity portion between distances of 40 - 115 m (Fig. 3) along traverse 1 was observed. The resistivity structure shows a gradual increase in the thickness of the low resistivity zone from 0 m beneath distance 40 m to greater than 15 m beneath distances 90-115 m. The resistivity values of these low resistivity portions is less than 200 ohm-m. The low resistivity zone was also observed beneath distances 40 – 180 m on the 2-D resistivity structure for 10 m electrode separation (Fig. 4) reaching a depth of about 25 m, beneath distances 90 - 110 m. It has a basin-like shape with surface patches of high resistivity zones between distances 90-100 m and 140-150 m. A very low resistivity portion (in bluish colour) of less than 94 ohm-m is observed between distances 80 – 120 m (Fig. 4) typical of leachate concentration in this zone between the depths of 5 - 16 m. The other greenish portions are also typical of leachate pollution within the vicinity of the dumpsite. The reddish to purple colour bands (Figs. 3-4) within the three identified zones are typical of unpolluted clayey sands and sand formations.

Traverse (Profile) 2

The 2-D resistivity structures beneath traverse 2 (Figs. 5-6) shows the degree of inhomogeneity of the subsurface and the result of anthropogenic activities. The data for this traverse was also obtained using two electrode separations of 5 and 10 m. The 5 m electrode separation 2-D resistivity structure reveals the upper 15 m of the subsurface, while the 10 m electrode separation 2-D resistivity structure reveals the upper 30 m of the subsurface (Fig. 6). A low resistivity portion is identified between distances of 0 - 60 m along traverse 2 within the topsoil and the intermediate zone to a depth of about 10 m. The leachate is observed to be likely concentrated in the intermediate zone (due to the bluish colouration of the zone and the very low resistivity of such zone) than at the upper zone. The resistivity structure shows a gradual decrease in the thickness of the low resistivity zone from 0 m distance to the end of the profile at 80 m. The resistivity values of these low resistivity portions is less than 80 ohm-m. The low resistivity zone was also observed throughout the profile on the 2-D resistivity structure for 10 m electrode separation (Fig. 6) reaching a depth of about

10 m. The high resistivity lower zone has an undulating surface but almost relatively flat surface. The 2-D resistivity structure for the 5 m electrode separation shows surface patches of high resistivity zones between distances 50-80 m but not visible on the 2-D resistivity structure for the 10 m electrode separation (Fig. 6). The very low resistivity portion (in bluish colour) showing high concentration of leachate in this zone is rarely deeper than 5 m. The other greenish portions are also typical of leachate pollution within the vicinity of the dumpsite. The reddish to purple colour bands *(Figs. 5-6)* within the three identified zones are typical of unpolluted clayey sands and sand formations.

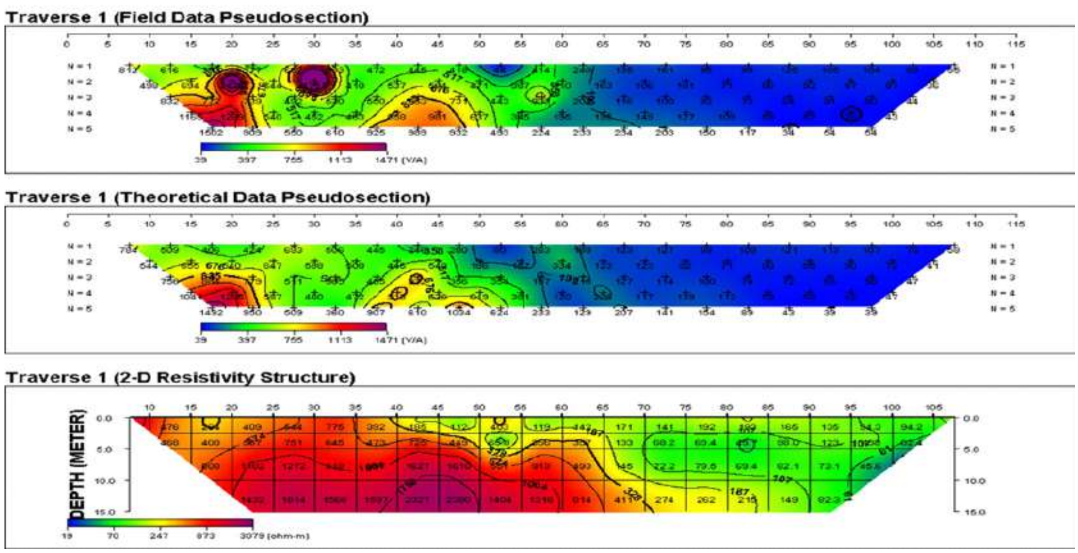

Figure 3: A typical 2-D Modeling of Dipole-Dipole data. Data obtained along Traverse 1 at Electrode Separation of 5m showing the field and theoretical data modeled to produce the 2-D Resistivity Structure under the traverse showing variation in resistivity in the subsurface, with blue colour representing least resistivity and red colour showing highest resistivity zone

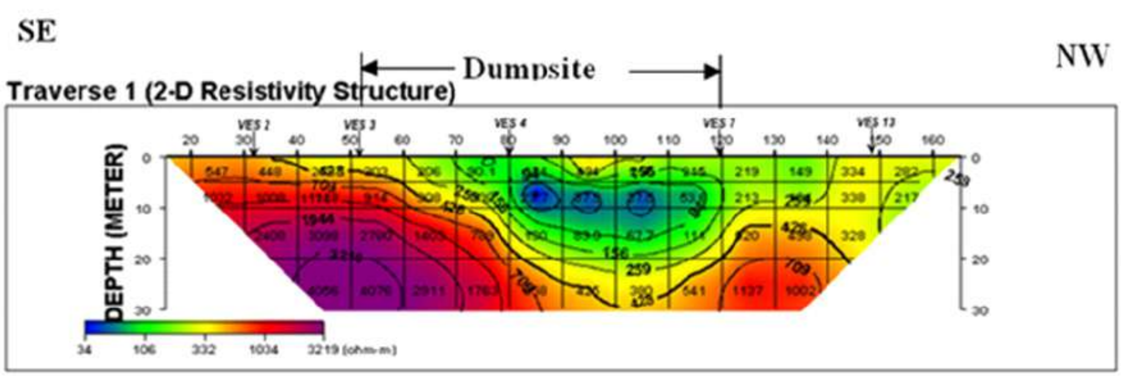

Figure 4: 2-D Resistivity Structure obtained along Traverse 1 at Electrode Separation of 10m showing the location of the dumpsite.

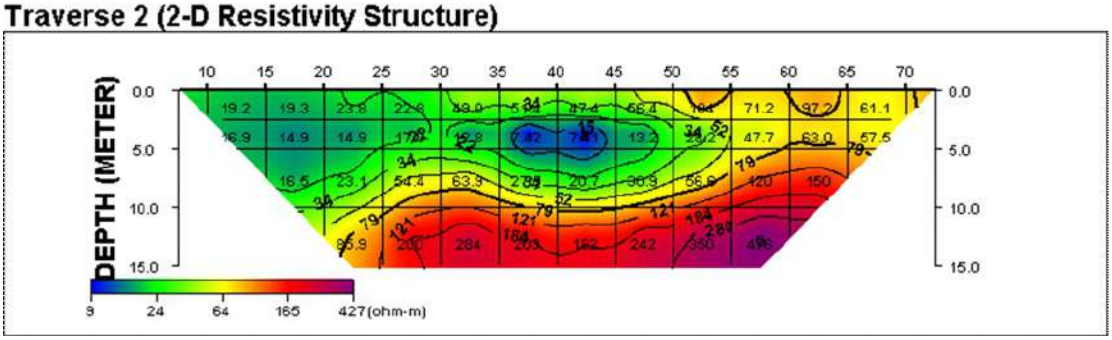

Figure 5: 2-D Resistivity Structure obtained along Traverse 2 at Electrode Separation of 5m

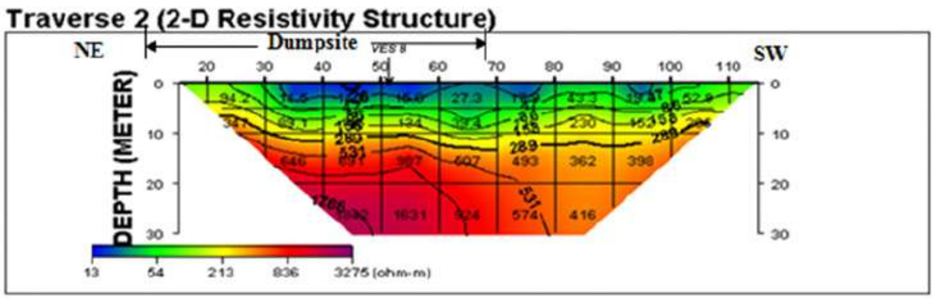

Figure 6: 2-D Resistivity Structure obtained along Traverse 2 at Electrode Separation of 10m showing the location of the dumpsite

Traverse (Profile) 3

The 2-D resistivity structures beneath traverse 3 (Figs. 7-8) shows the degree of inhomo- geneity of the subsurface and the result of anthropogenic activities. The data for this traverse was also obtained using two electrode separations of 5 and 10 m. The 5 m electrode separation 2-D resistivity structure reveals the upper 15 m of the subsurface (Fig. 7) while the 10 m electrode separation 2-D resistivity structure reveals the upper 30 m of the subsurface (Fig. 8). A very low resistivity portion is identified between distances of 0 - 45 m (Fig. 7) along traverse 3 within the topsoil and the intermediate zone to a depth of about 10 m (bluish colouration) with resistivity values of less than 140 ohm-m. The leachate is observed to be concentrated in the southwestern portion of the traverse. The low resistivity is continuous on the topsoil to a depth of about 2.5 m but found below it between distances 105-115 m. The feature observed here is typical of structural zone (fault or fracture). Nevertheless, the resistivity increases gradually to the northeastern portion of the traverse at 130-135 m. The information obtained on the 2-D resistivity structure for 10 m electrode separation (Fig. 8) correlates with that obtained for the 5 m but the latter (5 m) shows more inhomogeneity of the near-surface formation than the former (10 m). The high resistivity lower zone has an undulating surface with a feature typical of fault or fracture between distances 90-110 m (Fig. 8). The greenish portions are also typical of leachate pollution within the vicinity of the dumpsite. The yellowish/reddish to purple colour bands (Figs. 7-8) within the three identified zones is typical of unpolluted clayey sands and sand formations.

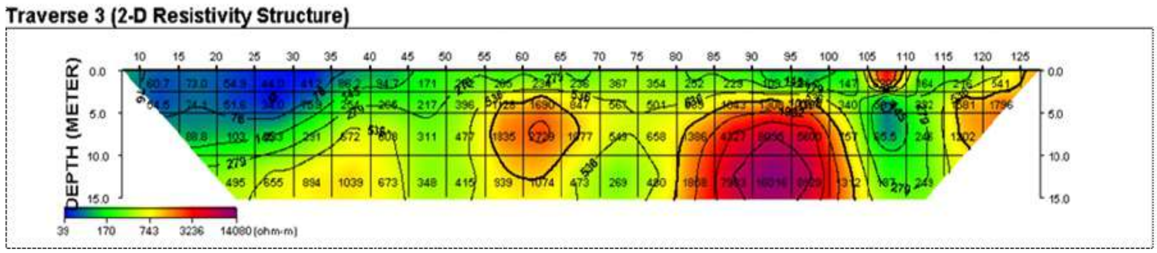

Figure 7: 2-D Resistivity Structure obtained along Traverse 3 at Electrode Separation of 5 m.

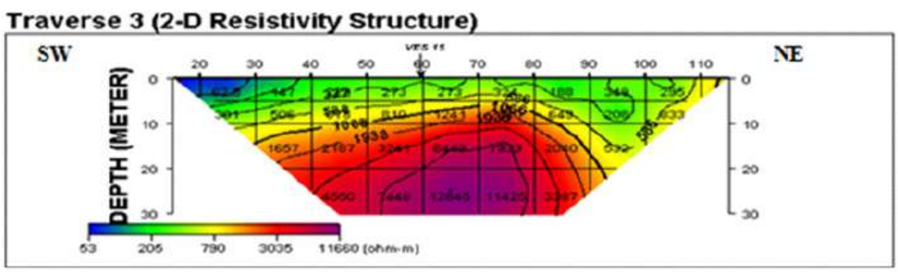

Figure 8: 2-D Resistivity Structure obtained along Traverse 3 at Electrode Separation of 10m.

Traverse (Profile) 4

The 2-D resistivity structure beneath traverse 4 (Fig. 9) reveals the nature of the subsurface along the traverse. The data for this traverse was obtained using 10 m electrode separation and the 2-D resistivity structure reveals the subsurface to a depth of 30 m (Fig. 4.7). The 2-D resistivity structure reveals a low resistivity upper zone with patches of high resistivity portion identified between distances of 0 - 30 m and 135-170 m (Fig. 9). The intermediate and lower zones show high resistivity values greater than 300 ohm-m typical of unpolluted zone (clay/clayey sands and sand formations) except between distances 55-84 m showing a feature typical of structural zone (fault or fracture). The structural zone might have been polluted with leachate from the dumpsite especially the upper zone with very low resistivity zone between 50 and 90 m distances (Fig. 9).

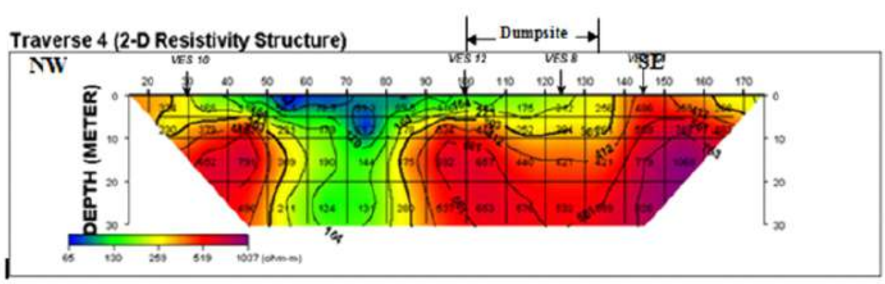

Figure 9: 2-D Resistivity Structure obtained along Traverse 4 at Electrode Separation of 10m.

Traverse (Profile) 5

The 2-D resistivity structure beneath traverse 5 (Fig. 10) reveals the nature of the subsurface along the traverse. The data for this traverse was also obtained using 10 m electrode separation and the 2-D resistivity structure reveals the subsurface to a depth of 30 m (Fig. 10). The 2-D resistivity structure reveals a low resistivity upper zone with high resistivity portion identified at about the center between distances of 40 - 60 m (Fig. 10). The intermediate and lower zones show high resistivity values greater than 200 ohm-m typical of unpolluted zone (clay/clayey sands and sand formations). The southwestern portion shows low resistivity upper zone to a depth of about 12 m between distances 0-40 m as well as the northeastern portion (vicinity of the dumpsite) between distances 60-120 m to a depth of more than 15 m. This shows that the leachates might have infiltrated the vicinity of the dumpsite more than the other areas on this traverse (Fig. 10).

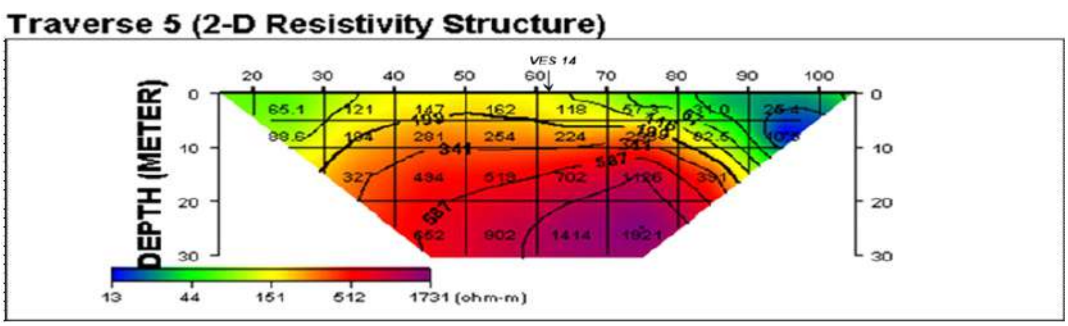

Figure 10: 2-D Resistivity Structure obtained along Traverse 5 at Electrode Separation of 10m

The 2-D resistivity structure beneath traverse 6 (Fig. 11) reveals the geoelectric nature of the subsurface along the traverse. It reveals a low resistivity upper zone throughout the traverse with decrease in thickness and conductivity towards the end of the traverse in the southeast. The low resistivity portion is slightly deeper than 10 m between distances 30-70 m and rarely greater than 10 m in the remaining length of the traverse (Fig. 11). High resistivity (> 250 ohm-m) characterizes most part of the intermediate and lower zones typical of unpolluted zone of clay/clayey sands and sand formations. The northwestern portion (close to the dumpsite) shows the highest concentration of leachates and an intermediate resistivity value characterizes distances 40-50 m and 105-115 m identified as depression and structural zone (fault or fracture) respectively (Fig. 11).

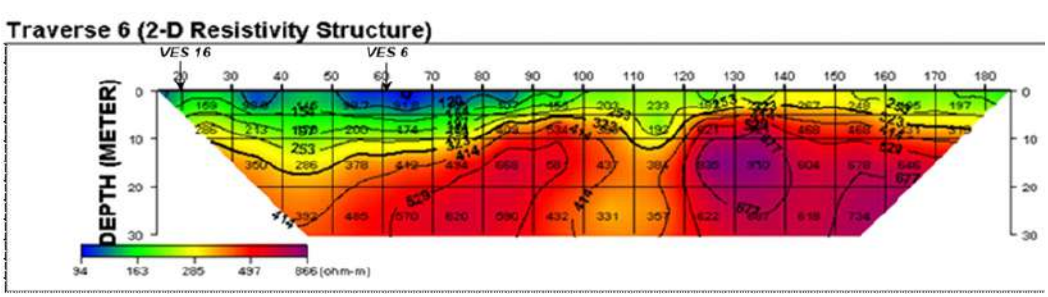

Figure 11: 2-D Resistivity Structure obtained along Traverse 6 at Electrode Separation of 10m

Conclusion

2-D Electrical resistivity investigations were carried out around the Agirifon dumpsite in Ilutitun, Okitipupa Local Government Area, Southwestern, Nigeria to evaluate the groundwater regime and delineate possible leachate infiltration into the aquifer matrix of the study area. The methodology was useful in determining both lateral and vertical variations in electrical resistivity simultaneously along the traverses. Areas affected by the leachate could be identified from the 2D Resistivity Structures.

The results of the electrical resistivity data obtained reveal the existence of conductive zones on the 2-D Resistivity structure obtained on all the traverses within the study area, usually from the upper layers to a depth of about 10 m or more. These zones or layers are classified as leachate contaminated zones or clayey subsurface layers. The leachate are observed to have moved through fractures/porous and permeable layers into subsurface aquifers thereby contaminating them. The high resistivity intermediate/lower zone on the 2-D resistivity structure (reddish-purple colouration) corresponds to the (probably unpolluted) sandy/pebbly sand units.

However, it can be recommended that other array of electrical resistivity methods that gives better vertical resolutions such as schlumberger array should be considered on the low resistivity zones which have been termed leachate infiltrated and concentrated zones on the traverses to determine the vertical extent of the contamination.

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