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INVESTIGATION OF LEACHATE PLUMES AND GROUNDWATER POLLUTION USING GEOPHYSICAL METHODS IN THE FEDERAL CAPITAL TERRITORY (FCT) ABUJA, NIGERIA

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Abstract

The aim of this study is to use electrical resistivity i.e (VES and Wenner profiling),and Physico-chemical in groundwater pollution at a closed or an open dumpsite located in part of Federal Capital Territory (FCT)Abuja, Nigeria. These methods have been useful in the determination of the geological structures, layers and depths of the aquifer. Three major subsurface layers were delineated these include the topsoil, weathered and fresh basement. A total of 10 VES were modeled in the areas. The results revealed that H-type curve was predominately in these location with one A-type curve in Zuba dumpsite .A low resistivity value <100 Ωm was observed all through the weathered basement which is the aquiferious zone within the study area. The resistivity of these zones varies 15.3Ωm to 96.2Ωm while the thickness of these zone varies from 4.5m to 14.3m. depth of these zone 6.5m to 15.8m The 2D Wenner profiling reveals the lateral and vertical variation of the subsurface strata with the resistivity of high conductive zone value ranging from 1.6Ωm to 55Ωm i.e (< 100Ωm)with depth < 10m. Physio-chemical analysis was useful in correlating. Water sample analysis which includes surface water and borehole within the study this reveals that most of the water sample has high EC, TDS and the presences of heavy metals like Pb which is a above WHO standard for groundwater, which could be as result of possible migration and infiltration of leachate plumes resulting to groundwater the contamination.

KEYWORD: Vertical Electrical Sounding (VES), Groundwater, Sample, Dumpsite, Leachate, Contamination.

1.0Introduction

Groundwater resources are important natural resources that sustain life on earth. In the last one century, the enormous expansion of industrial and agricultural activities has led to an increased environmental pressure on groundwater systems. Groundwater is very important because it accounts for much of our freshwater and water resources (Adeyemo *et al.,* 2015). In many developing countries such as Nigeria where there is little or no public portable water production schemes, citizens must make personal effort to provide portable water for their domestic and industrial use. However other human activities, such as agricultural and industrial, and open space disposals of both industrial and domestic wastes can expose these invaluable groundwater resources to pollution and contamination (Longe and Balogun, 2010). Notable among such industrial waste that is often release to the ground are hydrocarbon –oil, such as Diesel oil, Petrol and used engine oil (Weave *et al*., 1999). The ease at which such pollutants will get to the groundwater table often depends on the geology of the area and its weathering products. The type of weathering product (comprising the topsoil and weathered layer) in an area determines the rate at which it allows fluid to move through it and this includes pollutants. It is an axiom that fluids transmit fast in the sandy soil than in a clay soil because of the difference in their permeability. Bedrock structures such as fractures and joints have also been identified as possible control factors that determines flow of leachate within the subsurface (Bayode *et al*., 2011).

2.Location

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. It 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. Niger state lies between latitude 8°25' and 11°25'N;longitude 4° 00' and 7°25'E of Niger state lies directly within the northwestern part of the Nigeria Basement complex, which is composed of the three fold lithological units and forms a part of the large Pan- African mobile belt which lies between the West Africa and Congo cratons. The basement complex is in places especially at the north central part intruded by Mesozoic calc-alkaline ring complex rock referred to as Younger Granites, to different them from much foliated, complex and deformed older Granites. The basement complies in parts overlain by Createaceous and younger sediment (Ajibade, 1976).

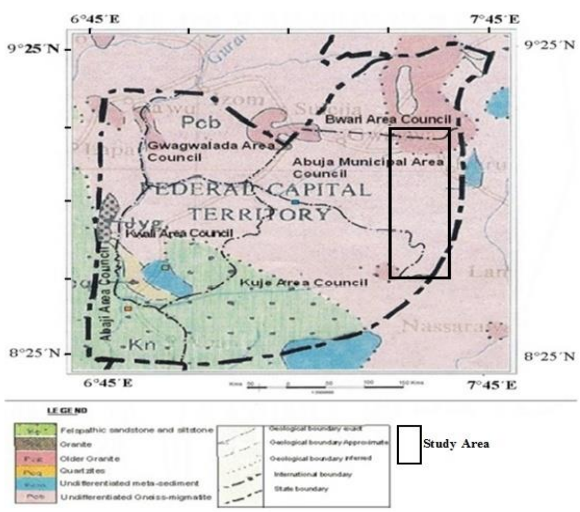


Figure 2. Geology map of Abuja Federal Capital Territory.

3.0 Material and Method

In this geophysical surveys, the data was acquired using terrameter SAS 4000 was used to carry out the survey. identify the dumpsite.

Electrical prospecting makes use of a variety of principles each based on some electrical properties or characteristics of the material within the earth (Olorunfemi et.al 1995 and singh et.al 2002)

3.1 Vertical Electrical Sounding :

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

3.2 Wenner Profiling.

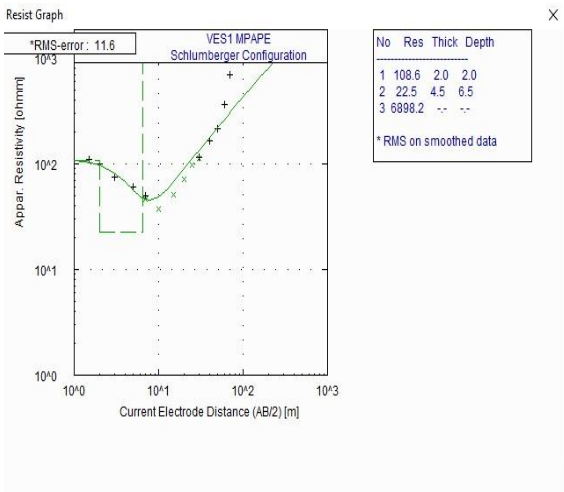
For 2D imaging, the wenner array method was conducted along a profile in each of the 10 location in the field, the technique was achieved by sending a direct current into the ground through a pair of current electrodes, while the voltage drop was measured through another set of potential electrode. For each profile, a constant electrode spacing of 1a, 2a, 3a, 4a, 5a and 6a each for both current and potential electrode were used consecutively depending on 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 200m. The same procedure was repeated for each of the electrode spacing of 2a,3a,4a, 5a,and 6a separately, where represent ‘a’ is the electrode spacing and equal to 10m.

3.3 Physio-chemical analysis

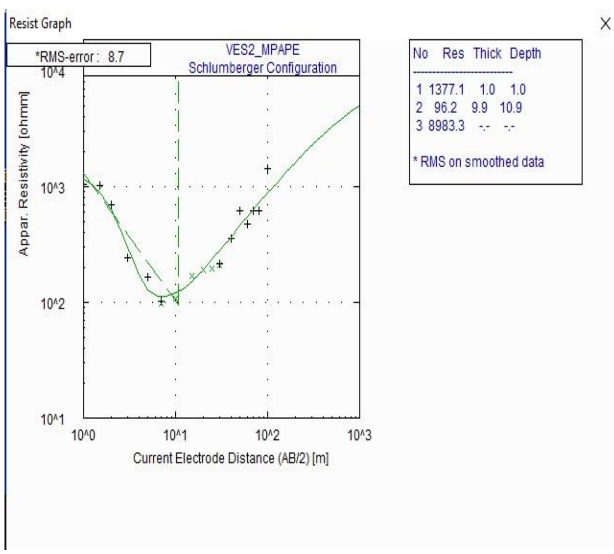
Groundwater samples were collected from hand dug untreated wells, surface water and borehole around the location of the dumpsites at a distance of 10m from the dumpsites. The physio-chemical parameter that was test to ascertain groundwater pollution include Electrical Conductivity (EC) Total Dissolve Solid (TDS), Turbidity Nitrate , Lead, Iron , Magnesium, Copper, Cadamium . The cations conceration were determined using Atomic Absorption Spectrophotometer (AAS). The results are presented under results and discussion.

4.1 Results and discussion:(Vertical Electrical Sounding)

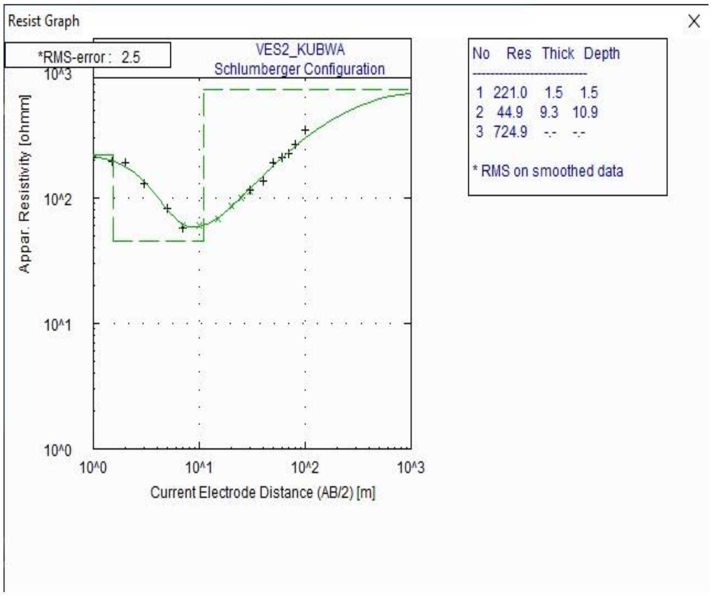
VES 1 MPAPE: this was carried out within the dumpsite this consist of 3-layer with H-type curve($\rho_1 > \rho_2 < \rho_3$) with resistivity of the topsoil 108.6Ωm, with thickness and depth of 2.0m . The 2-layer which is the weathered has a low resistivity value of 22.5 Ωm with thickness of 4.5m and depth of 6.5m respectively the 3-layer is the basement with high resistivity value of 6898.2 Ωm, with infinite thickness and depth.



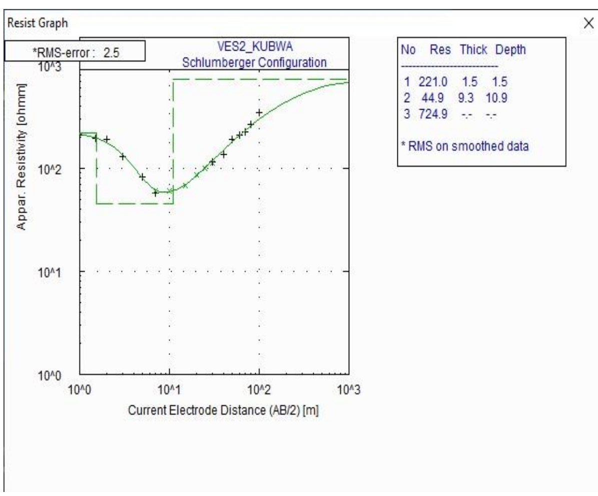
VES 2 MPAPE Control : was carried out in an undisturbed area away of about 200m away from the dumpsite also show a H-type curve with the resistivity values ranging from 1377.1 Ωm at the topsoil, 96.2 Ωm at the weathered and 8983.3 at the basement. The thickness ranging from 1.0m 9.9 m and the depth ranging from 1.0m – 10.9m respectively.



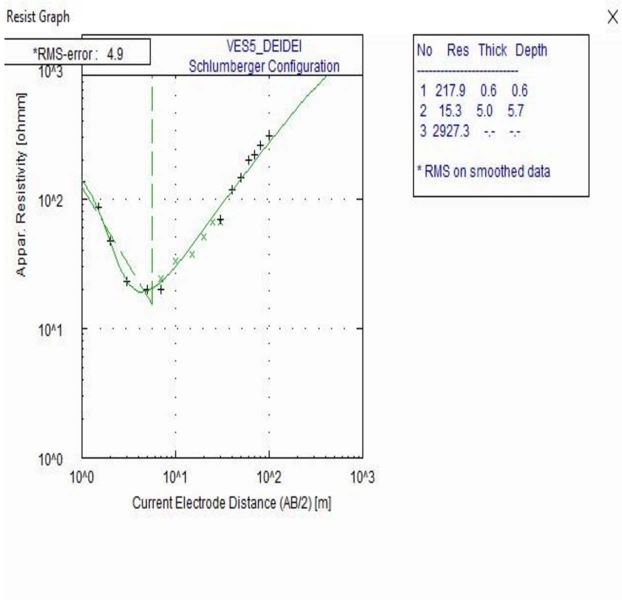
VES 3 KUBWA: this was carried out 10m clo[se to the dumpsite ,3 –layers was observed from the computer iteration. H-type curve was observed, the resistivity of the layers ranging from 221.0 Ωm , 44.9 Ωm , 724.9 Ωm , thickness1.5 m and depth of 9.3m - 10.9m respectively.



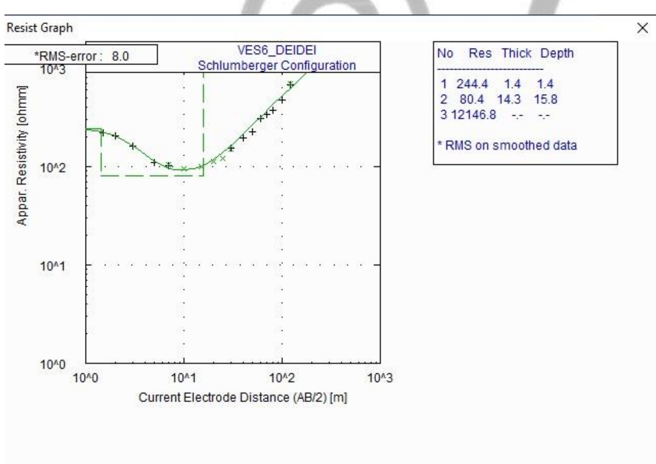
VES 4 KUBWA control: was carried out in an undisturbed area of about 200m away from the dumpsite also show a H-type curve with the resistivity values ranging from 441.5 Ωm at the topsoil, 57.5 Ωm at the weathered and 823.7 at the basement. The thickness ranging from 0.4m and the depth ranging from 10.9 – 11.3m respectively.



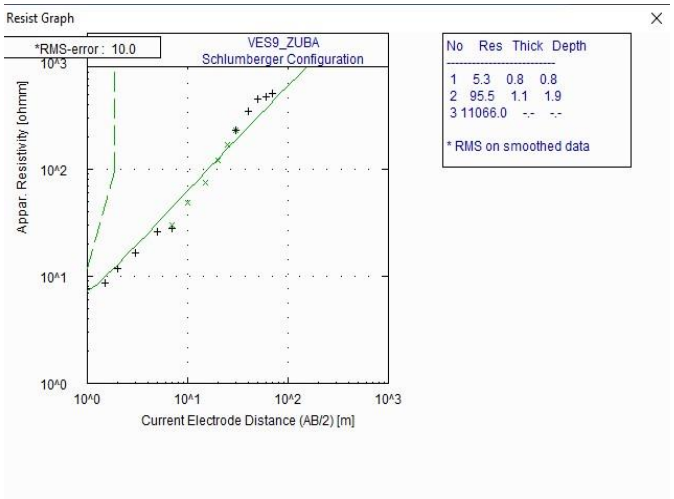
VES5 Dei-Dei: this was carried out within the dumpsite, this consist of 3-layer with H-type curve($\rho_1 > \rho_2 < \rho_3$) with resistivity of the topsoil 217.9Ωm, with thickness and depth of 0.6m .The 2-layer which is the weathered has a low resistivity value of 15.3 Ωm with thickness of 5.0m and depth of 5.7m respectively the 3-layer is the basement with high resistivity value of 2927.3 Ωm, with infinite thickness and depth



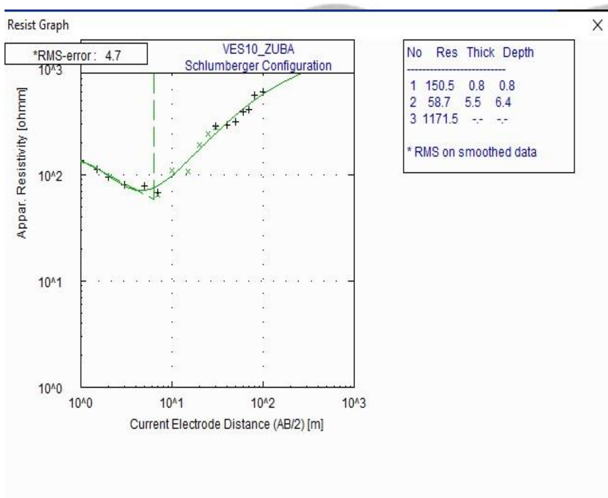
VES 6 Dei – Dei: this survey was carried out in an undisturbed away of about 500m away from the dumpsite. 3-layer was observed with H-type curve($\rho_1 > \rho_2 < \rho_3$) with resistivity of the topsoil 244.4Ωm, with thickness and depth of 1.4m. The 2-layer which is the weathered has a low resistivity value of 80.4 Ωm with thickness of 14.3m and depth of 15.8m respectively the 3-layer is the basement with high resistivity value of 12146.8 Ωm, with infinite thickness and depth.



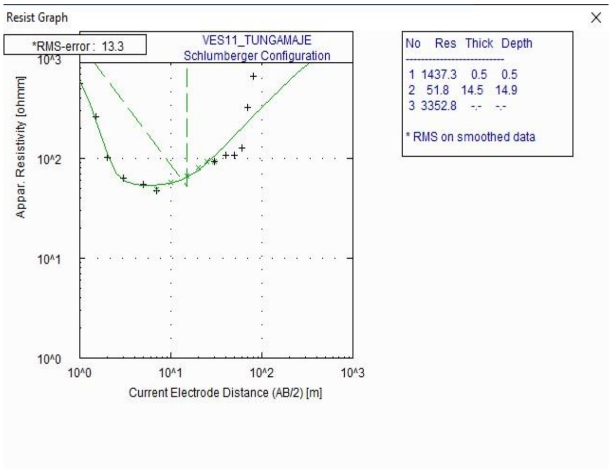
VES 7 Zuba: this consist of 3-layer with A-type curve with the resistivity range of 5.3Ωm. 95.5 Ωm. and 11066.0 Ωm. thickness of 0.8m and 1.1m and depth of 0.8 and 1.9m respectively this suggested that leachate plume migration from (Jegede et al ., 2012)



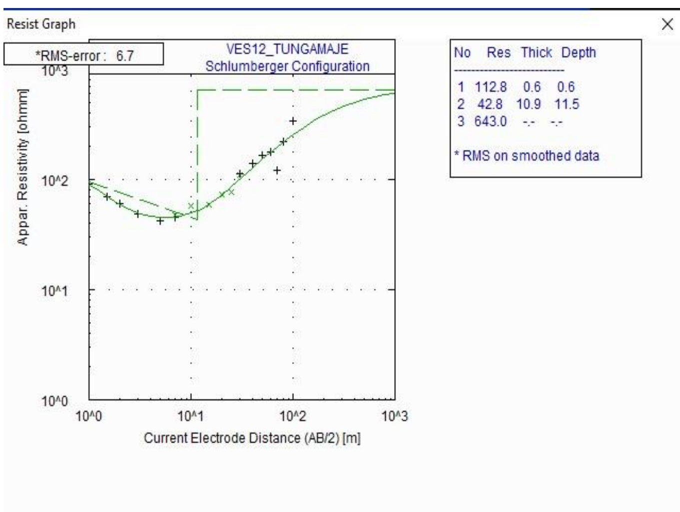
VES 8 Zuba control : this was survey was done in an undisturbed area of about 500m away from the dumpsite, this consist of 3-layer with H-type curve($\rho_1 > \rho_2 < \rho_3$) with resistivity of the topsoil 150.5Ωm, with thickness and depth of 0.8m .The 2-layer which is the weathered has a resistivity value of 58.7 Ωm lower than the first layer with thickness of 5.5m and depth of 6.4m respectively the 3-layer is the basement with high resistivity value of 1171.5 Ωm, with infinite thickness and depth.



VES 9 Tungamaje: In this survey 3-layers was observed from the curve with the resistivity value of the first layer 112.8 Ωm thickness and depth of 0.6m . the second layer has a resistivity value of 42.8 Ωm thickness of 10.9m depth of 11.5m .lastly the third layer has resistivity value of 643.0 Ωm.



VES 10 Tungamaje Control: 3-layers was also observed with the resistivity value of the first layer 1437.3Ωm thickness and depth of 0.5m . the second layer has a resistivity value of 51.8 Ωm thickness of 14.5m depth of 14.9m .lastly the third layer has resistivity value of 3352.8 Ωm.



4.2:Results and Discussion (Wenner Profiling)

Sheet 1(Mpape): The survey covered a total of 160m. This was acquired in the NE-SW direction. Apparent resistivity measured in ohm-meter (Ωm) was plotted against depth in meter (m). The blue and green color spread through the study area trending down at the western path of the study area, with low resistivity value of 9.0 Ωm to 88.0 Ωm and depth of 0.1m to 30m from the top to the basement, at station 20 to 120 which is a clear indication of the presence of contamination in those stations. From station 130 to 160 the orange and red color was observed on the surface trending down toward the eastern path of the dumpsite at station 100 with a resistivity value of 228.0 Ωm to3998.0 Ωm at 0.1m -30m . Which is an indication that those areas are free from leachate contamination as shown in fig(4.1) below

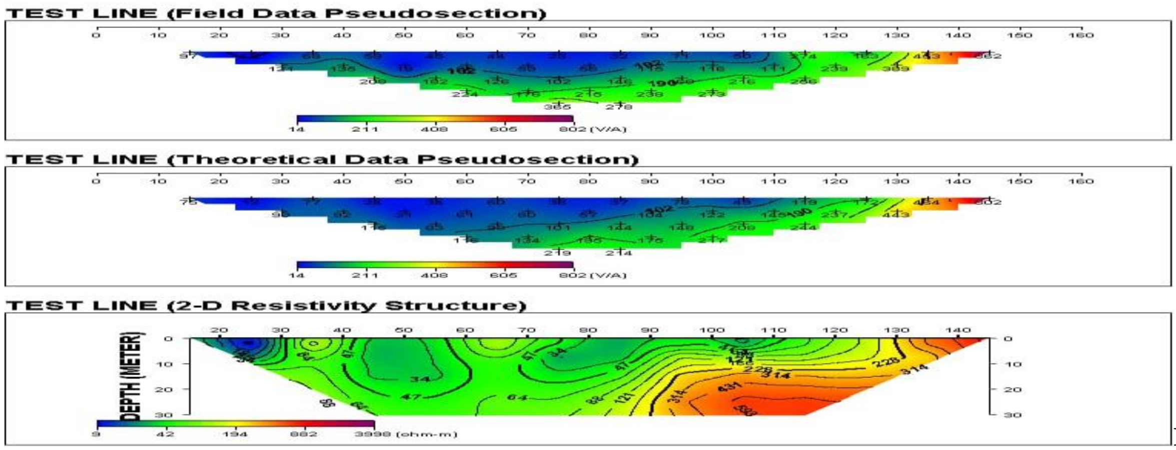


Figure 4.1 2D profiling for Mpape

Tranverse 1(kubwa) covers a total spread of 200m with an electrode spacing of 10m and runs in the (N-S) direction. Three major layers are observed in this 2D resistivity structure. The apparent resistivity, measured in ohm-metre, (Ωm) is plotted against the pseudo-depth in meter (m). The first layer (blue colour) trending in the to northwest direction which is observed at the two edges of the traverse at the western edge with resistivity value ranging from 31.0Ωm to 72.0Ωm and observed between stations 20 to 70, covering a depth of 15m, and eastern edge with resistivity value ranging from 36.0Ωm to 51.0Ωm is observed between stations 90 to 130, covering a depth of about 0 to 5m. This indicates the leachate plume had polluted the surface of this zone. This is due to the relatively low resistivity values as calibrated against the surrounding areas. The second layer (Green) has resistivity value ranging from 101.0 Ωm to 202.0 Ωm,, with a depth of 0.1m at section 70 and 80 towards the east and then trend in the west direction toward station 140 to 200 at and 5m.The third layer (Red/ yellow) has a resistivity value ranging from 285.0Ωm to 589.0Ωm occurring a depth between 15m to 30m and this section reveals clay/sandy clay formation. This area has little or no contamination effect on the groundwater as a higher resistivity value was observed on this area, compared with the resistivity of the first layer.

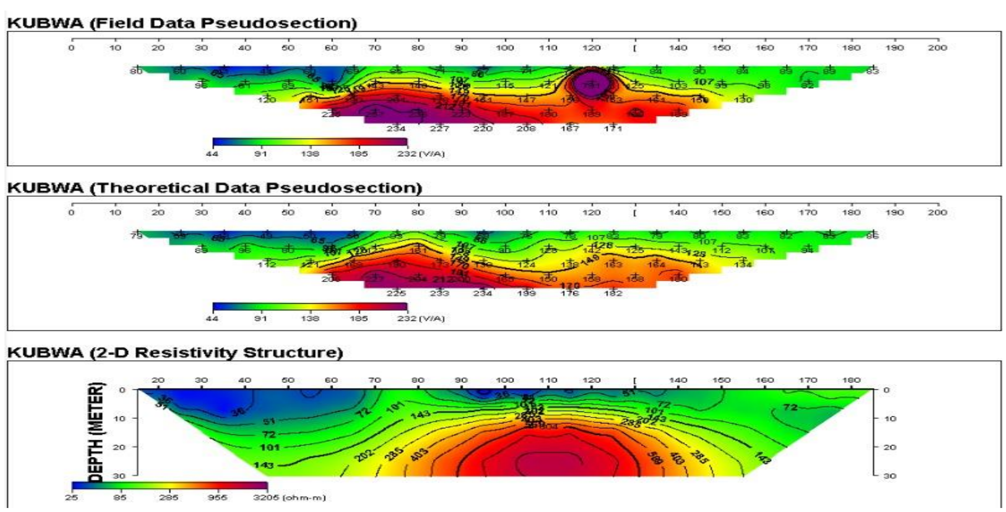


Figure 4.2: 2D profiling for kubwa

Test three (Dei-Dei): The apparent resistivity (Ωm) is plotted against pseudo-depth (m). A low resistivity zone ranging from 45.0Ωm to 53.0Ωm was coded as blue colour. This zone is identified was scattered on the eastern and western direction, close to the surface at depth ranging from 0.0 to 5.5 m this was observed at station 20- 30 and discontinued at 40 to continued partly at 60 and then trended from station 60 to 130 and discontinued again slightly at station at 130 to part of 150 and then proceeded at part of 150 to 200 and the areas where blue color was observed indicates the zone of leachate plume invasion. In this case, some part of topsoil has been contaminated. As a result of the low resistivity observed on the topsoil and weathered layer it showed that leachate have been transported from the surface tin to the weathered layer (Bayode et al., 2011). A high resistivity zone with a range of 122.0 Ωm to169.0 Ωm and coded red colour, this existed at the third layer with depth ranging between 17 to 30 m to the West and East of the section. The migration near the surface is an indication that it is less dense. The lithology is inferred as sand clay. A low resistivity zone of value of 45.0Ωm to 53.0Ωm, and coded as light blue colour, is identified close to the surface this indicates the presence of laterite that probably hindered easy further penetration of the leachate.

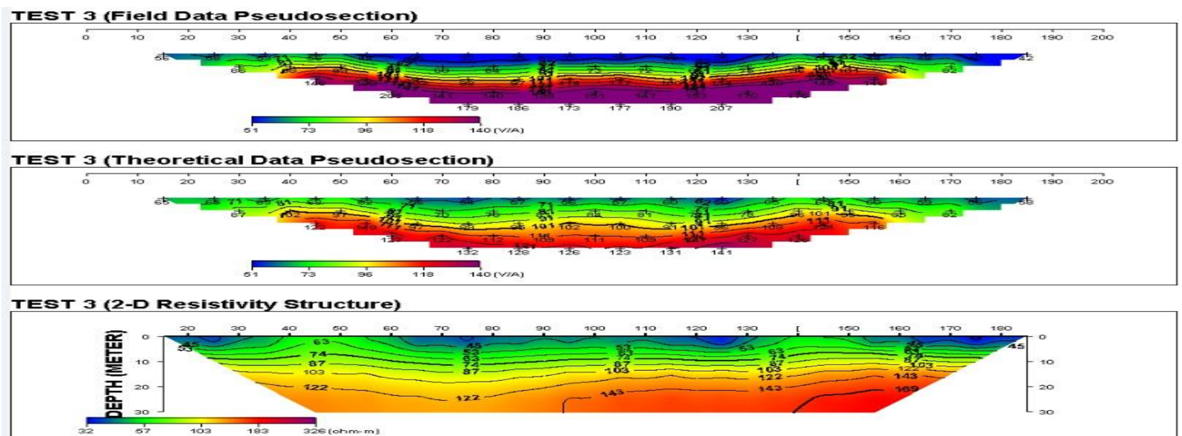


Figure 4.3 2D profiling for Dei-Dei

Zuba : This covered a total spread of 120m with an electrode spacing of 10m.The apparent resistivity, measured in ohm-metre, (Ωm) is plotted against the pseudo-depth in meter (m). A low resistivity zone of < 64 Ωm shown in dark blue colour, occurs along the NW direction of the study area with depth 5m, from the surface, between station 20 to 50. A high resistivity value of 226.0 Ωm to 2756 Ωm at the depth of 15m to 30m was observed at bottom with with red and purple, which indicate at leachate contamination is only evidence at some part of the surface area.

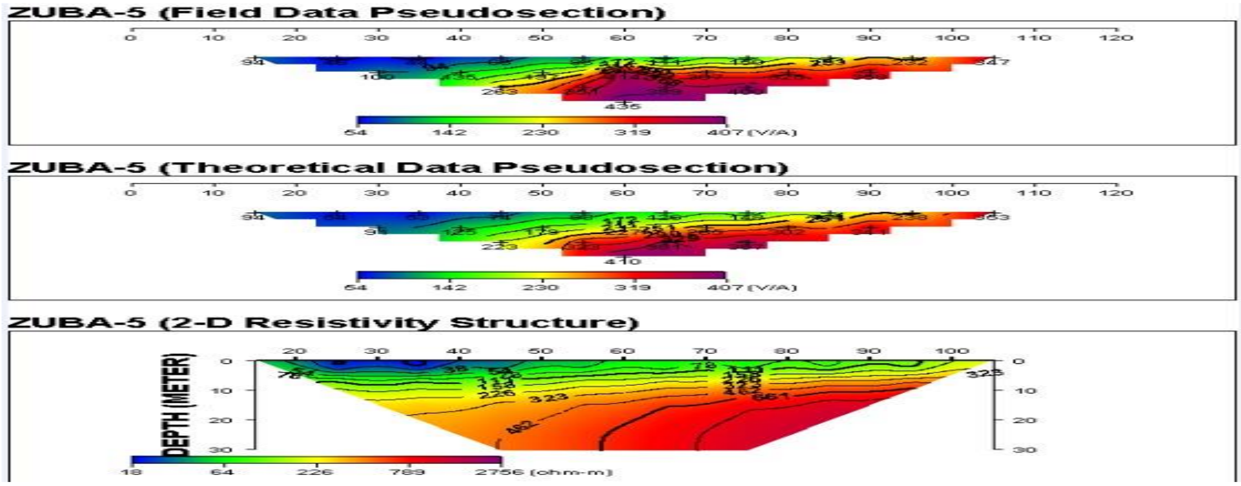


Figure4.4: 2D profiling for Zuba

Tungamaje : the survey covered a total of 130m. Apparent resistivity measured in ohm-metre, (Ωm) was plotted against depth in meter (m). The blue colour was observed from station 70 to 130 which was toward the dumpsite, at low resistivity value of <82 Ωm at the depth of about 10m. at the NW direction at station 10 -30 the color yellow and red was observed moving down to the base with resistivity values 181.0 Ωm to 513.0 Ωm which indicate that a small portion of the area is disturbed at the surface.

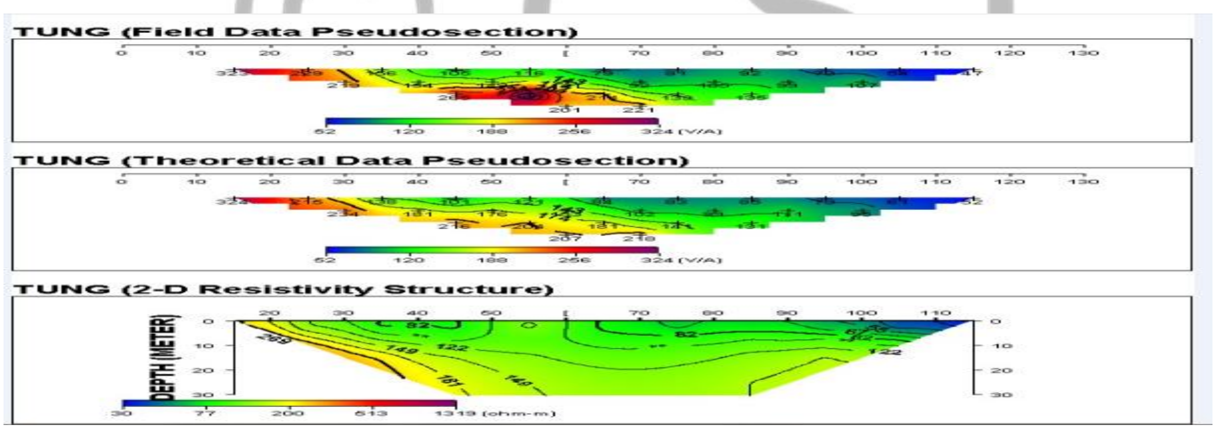


Figure 4.5 : 2D profiling for Tungamaje

Table 1: Physio- Chemical Analysis of Surface Water and Borehole water in the study area.

Parameter	UNIT	MS	MC	DS	DC	KS	KC	WH0 STANDARD
PH	-	6.10	6.07	6.35	6.23	5.93	6.56	6.5 – 8.5
EC	μS/M	284.0	192.9	281.2	251.8	216.6	72.04	400
TDS	Mg/l	139.0	94.46	137.7	123.5	106.2	35.27	500
TURBIDITY	NTU	1.50	0.65	5.90	0.45	0.75	0.16	5

NITRATE	Mg/l	18.7	9.0	13.6	17.5	5.34	11.4	50
Fe	Mg/l	0.15	0.07	0.16	0.20	0.22	0.22	0.3
Mn	Mg/l	0.16	0.12	0.07	0.06	0.07	0.07	0.4
Cu	Mg/l	0.80	0.74	0.85	0.81	0.85	0.92	2
Pb	Mg/l	1.99	1.93	1.90	2.13	2.38	3.02	0.001
Zn	Mg/l	0.09	0.03	0.05	Nil	0.0002	Nil	3
Cd	Mg/l	0.42	0.09	0.08	0.03	0.05	0.02	0.003

Table 2: Physio- Chemical Analysis of Surface Water and Borehole water in the study area.

Parameter	UNIT	TS	TC	ZS	ZC	WH0 STANDARD
PH		7.17	7.29	6.81	6.93	6.5 – 8.5
EC	μS/cm	1170	1295	1752	592.7	400
TDS	Mg/l	577.4	635.1	857.8	290.7	500
TURBIDITY	NTU	1.40	0.60	0.55	0.60	5
NITRATE	Mg/l	57.2	72.4	4.2	NIL	50
Fe	Mg/l	NIL	NIL	NIL	NIL	0.3
Mn	Mg/l	0.25	0.20	0.19	0.21	0.4
Cu	Mg/l	0.69	0.73	0.72	0.68	2
Pb	Mg/l	NIL	NIL	NIL	NIL	0.001
Zn	Mg/l	NIL	NIL	NIL	NIL	3

EC= Electrical Conductivity, TDS= Total Dissolved Salt.

4.3 Results and Discusion

The PH value the water sample (surface and groundwater) ranged from 5.93 – 7.27 respectively. Most of which were within the WHO standard permissible limit expect for KS (Kubwa surface water) which is slightly below 6.5. The electrical conductivity (EC) values ranged from 72.04 to 1295 μS/cm and Total dissolved salt (TDS) values ranged from 35.27 to 857.8 Mg/l. The values of EC and TDS in Table 2 exceeded the required WHO standard permissible limit, except for the TDS of ZC(Zuba Control) which is 290.7 Mg/l which is below 500 Mg/l. the nitrate values in table 2 of TS and TC ranged from 57.2 to 72.4 Mg/l above WHO standard , the concentration of the heavy metals (Fe,Mn, Cu,Pb,Zn and Cd) in values ranges 0.07 to 0.02Mg/l .0.06 to 0.25Mg/l,0.74 to 0.92Mg/l, 1.90 to 3.02mg/l , 0.0002 to 0.09 Mg/l and 0.03 to 0.42 Mg/l. with the Pb exceeding the WHO standard which is 0.001Mg/l.

5 Conclusion

The electrical resistivity method used has been useful in the determination of the geological structures, layers and depths of the aquifer. Three major subsurface layers were delineated these include the topsoil, weathered and fresh basement. A total of 10 VES was modeled in the areas. The results revealed that a H-type curve was predominately in 9VES in the study area and one A-type curve in Zuba. A low resistivity value <100 Ωm was observed in the weathered layer which is the aquefious zone showed a clear indication of the infiltration leachate plume in study area. water sample analysis which includes surface water and borehole within the study this reveals that most of the water sample has high EC, TDS and the presences of heavy metals like Fe, Cd and Pb which exceeded the WHO standard permissible for drinking water, within the study area,could be as result of possible migration and infiltration of leachate plumes resulting to groundwater the pollution.

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