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MAPPING THE RESISTIVITY VARIATIONS IN THE SUBSURFACE SURROUNDING AT KIPKENYO DUMPSITE, ELDORET TOWN, KENYA

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Abstract: A geophysical investigation of groundwater contamination within the solid waste disposal site was carried out at Kipkenyo dumpsite which is typically non controlled solid waste disposal site. Total of twenty six (26) VES survey points were conducted at measurements of between 20 to 30 meters between the (VES) points. The schlumberger array was used to collect data, Earth Imager 1D software were used in analyzing data obtained. The purpose of the research was to determine whether the presence of the landfill compromises the quality of groundwater within a vicinity of the dumpsite. Profile 6 and 7 in the southeast direction showing low resistivities indicating possible dissolution of heavy metals, from depths of 1.96 to 4.32 m, 29.65 to 47.75, 3.75 m to 9.00m and 17.45 m to 47.75 m respectively, High a resistivities at the eastern wing of the study area demonstrates uncontaminated compared to northwest, west and southwest which have low values of resistivities resulting to high level of contamination, this could be attributed to varying hydraulic conductivity depending on the composition of the solid waste in the landfill, compaction and soil contaminant interaction**.** The region 80 m from dumpsite to the northwest, west and southwest show low resistivities across the profiles' depths Profiles 5 and 8 were used as control points done at about 100 meters from the dumpsite and presents resistivities' ranges of 141.7 Ohm-m to 2616.2 Ohm-m suggesting its uncontaminated zone. The contamination runs to a depth of 47.75 m.

Key words: Vertical Electrical sounding, groundwater, leachate, contamination, resistivities

1. Introduction

Municipal solid waste (MSW) consists of refuse from homes, harmful solid waste from manufacturing, business and organizational firms such as hospitals, marketplaces, yard dissipate, along with avenue sweeping (Ogwueleka, 2009). Percolation of leachates from the waste dumps into the soil and groundwater of the environment may impact the standard of the groundwater negatively which can consequently have adverse effects on humans' health (Ramakrishnaiah et al., 2009).Quality drinking water is essential for life but the occurrence of physico-chemical parameters above the permissible standards make it unsafe for drinking (Onwughara et al., 2013). Drinking water affects the health of human beings due to the presence of various dissolved chemical constituents in it (Kumar et al., 2015). Groundwater is a major and important source of water for domestic use in both urban and rural settings and is believed to be among the purest forms of water available in nature (Kumar et al., 2015). Groundwater provides water to the rural dwellers in most parts of the world, especially in Africa and its origin is from rain water which infiltrates into the aquifers via the different soils and rock layers (Onwughara et al., 2013). In urban Africa explosive population growth rates is seen to translate into generation of noxious toxic chemicals. (Ogwueleka, 2009) Regardless of this kind of situation in Africa there is lack of infrastructural endowments to face challenges associated with huge amounts of solid waste and as a result, heaps of solid wastes are common in the urban centers. Electrical resistivity method is one of the most favorable geophysical methods for dumpsite investigation because it delineates contaminated zones of groundwater effectively because of conductive nature of most contaminants (Atekwana et al., 2000; Karlik and Kaya, 2001). The electrical imaging technique that's environmental friendly, measures low resistivity in polluted groundwater and soil is beneficial in mapping contamination plumes generated from solid waste dumps. Electrical resistivity method is fast, cost-effective and a non-destructive geophysical technique for mapping the shallow subsurface anomaly (Kumar, 2012). Electrical resistivity of soil depends on various factors including soil type, water content and pore fluid property (George et al., 2015).

2. Materials and Methods

2.1. Study Area

Study area is located in kapseret constituency which is one of the sub counties in Uasin-Gishu County. Kipkenyo dumpsite is located at outskirts of Eldoret city. Approximately 1.9 km from Eldoret town via Nandi road .The geographical co-ordinates are 0^0 52`18.50``N, $35^0$ 23`85.57` E, $0^0$ 52`16.69`` N, 35^0 23`92.83` E, 0^0 52`28.52`` N, $35^0$ 23`83`.25 E, $0^0$ 52`33.70`` N, 35^0 23`76.61` E and 0° 52' 29.69" N 35° 23' 76.71" E Elevation is 2100 meters. Vertical electrical sounding method was applied.

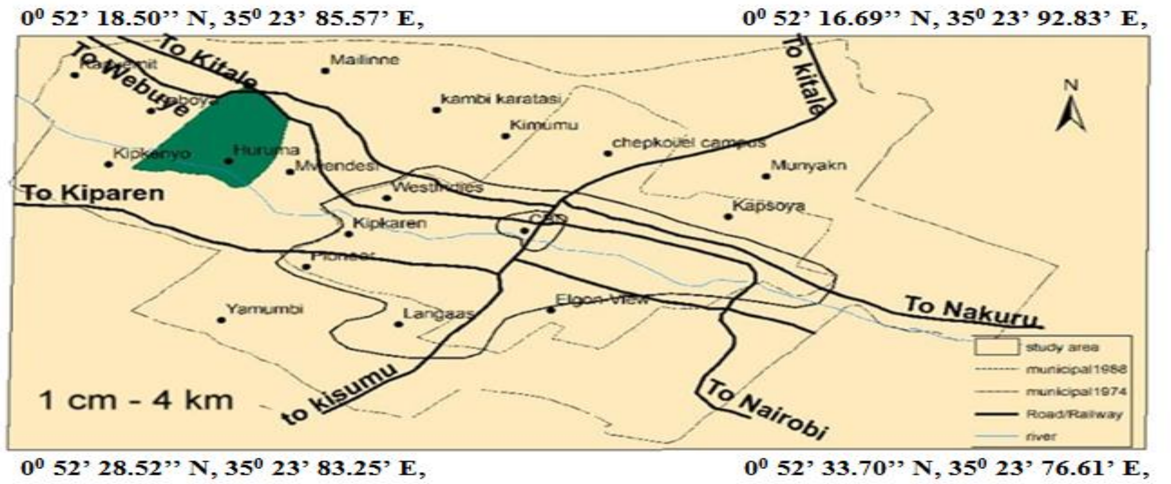


Fig. 1: Map of a study area

2.2. Vertical Electrical Sounding Method

Procedure

Abem SAS 1000 Terrameter resistivity meter equipment was used in collecting data in the field. The Schlumberger array was used in the study area; the four electrodes were positioned symmetrically along a straight line for current electrodes (A1 and A2) on the outside and the potential electrodes (B1 and B2) inner electrodes place in between A1 and A2. The Terrameter was powered by DC source. To change the depth range of penetration, the current electrodes were displaced outwards while the potential electrodes remained fixed. Terrameter was used to measure and record the resistance of the subsurface. The acquired data was plotted on a log-log graph sheet and the resultant curve was quantitatively interpreted. The process was repeated severally for the subsequent VES points and voltage (v) and current (I) value taken from measurements. The resistivity (ρ) of the subsurface was calculated using ohm law. The apparent resistivity ρa for the half-Schlumberger configuration is calculated with the formula shown below.

$$:\rho a = 2K\frac{\Delta V}{\Delta I} \qquad \textbf{(1)}$$

Where ρa= apparent resistivity on Ohm m (Ωm)

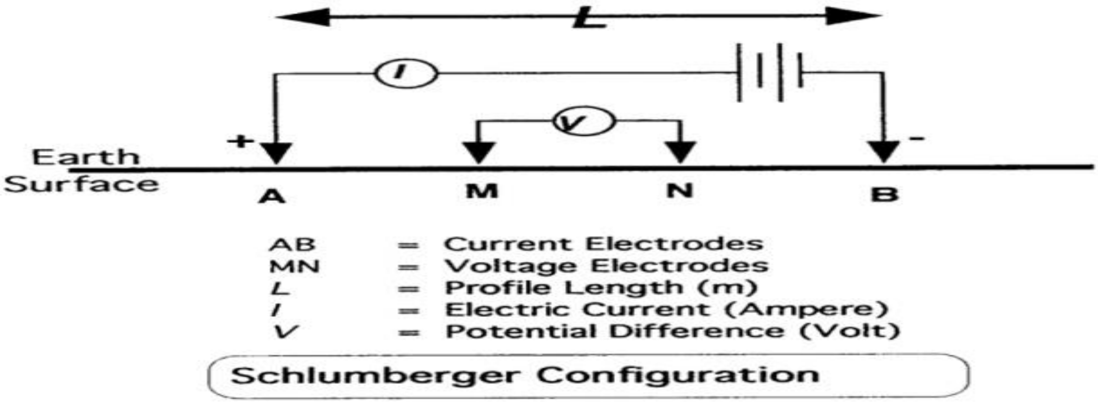


Fig2. Schematic electrode configuration for Schlumberger array (Okwueze & Ezeanyim1985; Zohdy 1988).

The value of the resistance that was obtained in the field was multiplied with their respective Geometric factor (k), whose calculation is given in equation (2).

$$K=\frac{\left[\left(\frac{AB}{2}\right)^2-\left(\frac{MN}{2}\right)^2\right]}{(2\,MN)}\ X\ \pi \qquad \textbf{(2)}$$

The geometric factor (K) was calculated using a formula above, AB is the distance (m) between the two current electrodes and MN is the distance between the potential electrodes. The geometric factor, K, was first calculated for all the electrode spacing using the formula in which a total of twenty six (26) vertical electrical sounding was done on the field. Geometric factor was multiplied with the resistance values to obtain the apparent resistivity values. Then the apparent resistivity, ρa, values were plotted against the electrode spacing (AB/2) on a log-log scale to obtain the VES sounding curves profiles using an appropriate computer software Earthmager 1D in drawing profiles and ip2win software's in drawing pseudo and resistivity crossections with maximum 50m was carried. The VES(1) that was carried at the centre of the landfill shows a low resistivities this is as a results that a leachate are concentrated more at the surface of the earth.

Having a current source electrode planted on the surface of a homogenous medium of uniform resistivity, ρ with the return current electrode at a great distance from the source; there is a radial flow of currents away from the source electrode. This ensures that current distribution is uniform over hemispherical surface centered on the electrode **(fig 3).**

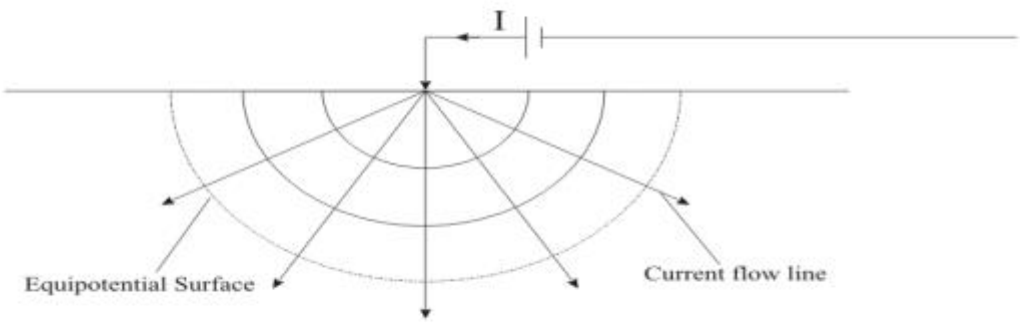


Fig 3: Current flow from a single surface electrode

At a distance from the source electrode, the hemispherical shell has the total surface area of a hemisphere = 3πr^2 square units **(**$volume = \frac{2}{3}\pi r^3$**)**

So that the current density 'j' which is a ratio of current 'I' to the surface area, is given by

$$j=\frac{I}{A}=\frac{I}{2\pi r^2} \qquad \textbf{(3)}$$

Ohm's law in the case of a linear isotropic medium states that, field strength E,

$$E=pj \qquad \textbf{(4)}$$

substituting equ (3) in to equ (4) so that the field strength E, becomes

$$E=\frac{\rho I}{2\pi r^2} \qquad \textbf{(5)}$$

The field strength is associated with current density by

$$E = \frac{dv}{dr} \quad (6)$$

Since ȷ is the negative partial derivative of field potential E, V divided by resistivity 'ρ', the potentialgradient, $\frac{\partial v}{\partial r}$associated with current density, ȷ is given as

$$\frac{\partial V}{\partial r} = -pj = -\frac{p1}{2\pi r^2} \quad (7)$$

Integrating dv/dr with respect to r gives the potential Vr at distance r from the current source and these becomes

$$\int \frac{\partial V}{\partial r} = -\int \rho j = -\int \frac{\rho}{2\pi r^2} \quad (8)$$

$$Vr = \int dv = -\int \frac{\rho 1}{2\pi r^2} \partial r \quad (9)$$

The electric potential **Vr** at any point **P**, distance **r** from a point electrode emitting an electric Current **I,** in an infinite homogenous and isotropic medium of resistivity, ρ is given by:

$$V_r = \frac{p1}{2\pi r} \quad (10)$$

$$p = \frac{v}{I} 2\pi r \quad (11)$$

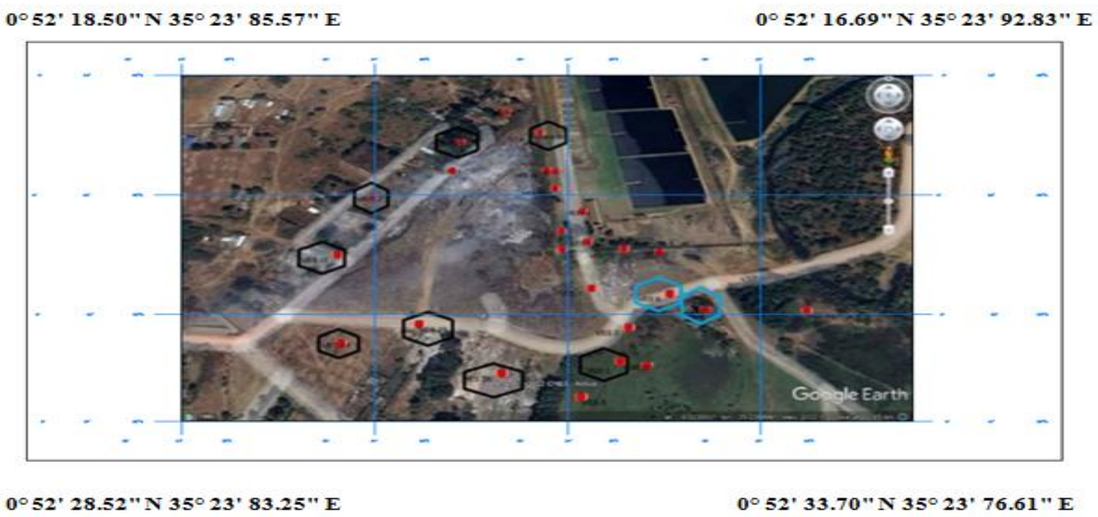
For a semi-finite medium, this is the simplest earth model with both current and potential point-electrodes placed at the earth's surface.

$$p = \frac{\Delta V}{I} . G = R . G \quad (12)$$

Where **R** is the measured resistance and **G** is the Geometric Constant which is a function of the electrode configuration employed during the survey. (Anthony et al, 2006)

2.3 Data Acquisition

A total of twenty (26) VES measurements were conducted with a maximum electrode spacing (AB/2) 50 m. The VES points (1–26) were located at 10 m 20m and 30m from landfill at interval,1.6 m,2.0m,2.5m,3.2m,4m,5m,6.3m,8m,10m,13m,16m,20m,25m,32m,40m and 50m. Profiles VES 5 and VES 8 were used as control points done at about 100 meters from the dumpsite their resistivities' rangers from 141.7 Ohm-m to 2616.2 Ohm-m. The location of each sounding station was recorded in Universal Traverse Mercator (UTM) coordinates with the aid of a GERMIN 12 channel personal navigator Global Positioning System (GPS) unit. The survey was carried out during the rainy season to allow good contact resistance of the electrodes in the ground for high conductivity of the subsurface.



Fg4: Map of the study area showing distribution of vertical electrical sounding methods points'

2.4 Data processing and analysis

Data processing was achieved using Schlumberger array which formed first phase, second phase involve digitally use of ABEM SAS 1000 Terrameter in handling data. The instructions were keyed into the equipments, the current electrodes were inserted into the ground and readings were taken in Ohms. The four collinear electrodes were inserted into the ground following Schlumberger array configuration in which current electrodes (A and B) and potential electrodes (M and N) in collecting a raw data from the study area. Terrameter has two terminals (C- and C+).Data analysis was achieved by using AGI Earth Imager ID inversion automated computer program which is an inversion modeling software program was used to interpret one-dimensional electrical resistivity data and reveal a layered model of subsurface geology. Earth Imager 1D was used to process vertical electrical sounding (ves) data collected with Schlumberger arrays. Computer program that interprets one-dimensional (1D) electrical resistivity sounding data and produces a layered resistivity model that reveals subsurface geology Earth Imager 1D processes vertical electrical sounding (ves) data collected with Schlumberger arrays, The forward modeling calculation is based on a 2D finite element method. Both smooth model inversion and damped least squares inversion methods were implemented in Earth Imager 1D. The qualitative approach, the shape of the field curve in each point was observed to get an idea of the number of layers and resistivity layers. Isopparent electrical resistivity maps and geoelectrical were then generated employing sufer9.

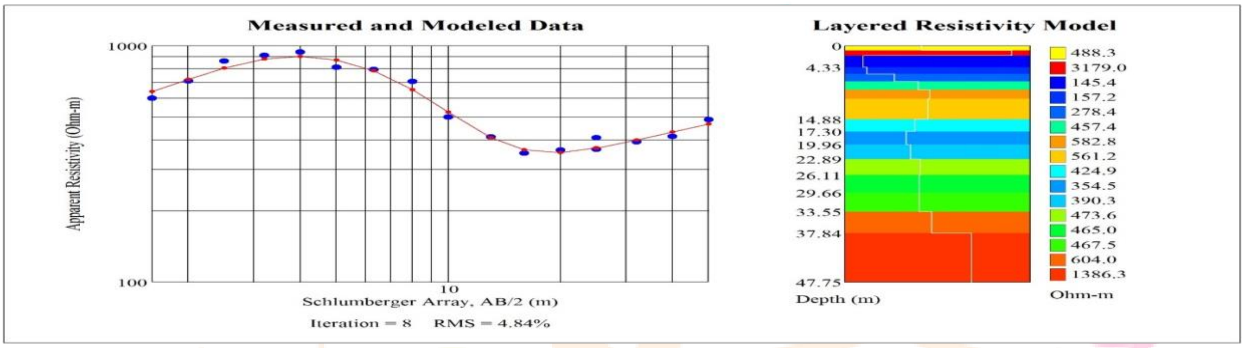


Fig5.1 A Typical KH- type of a curve representing profile 1 in the survey area

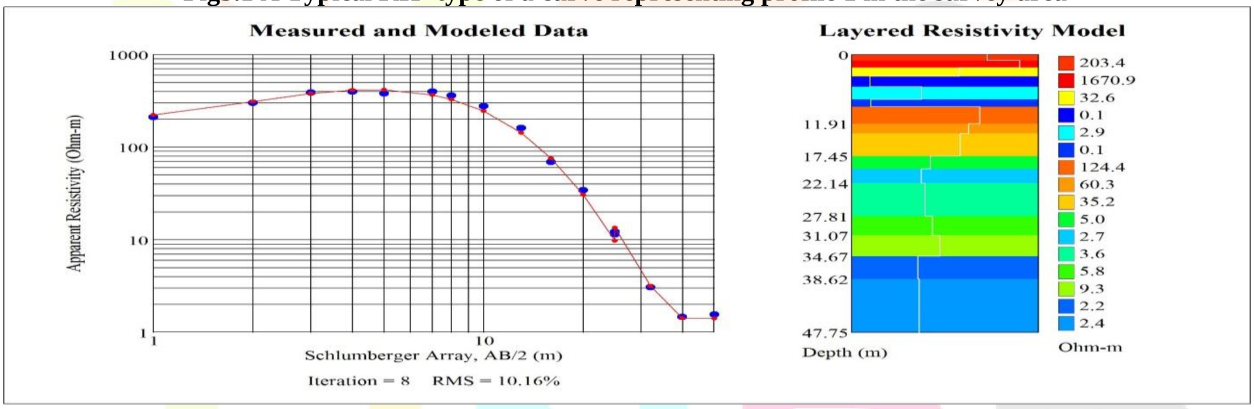


Fig5.2 A Typical K-type of a curve representing profile 7 in the survey area

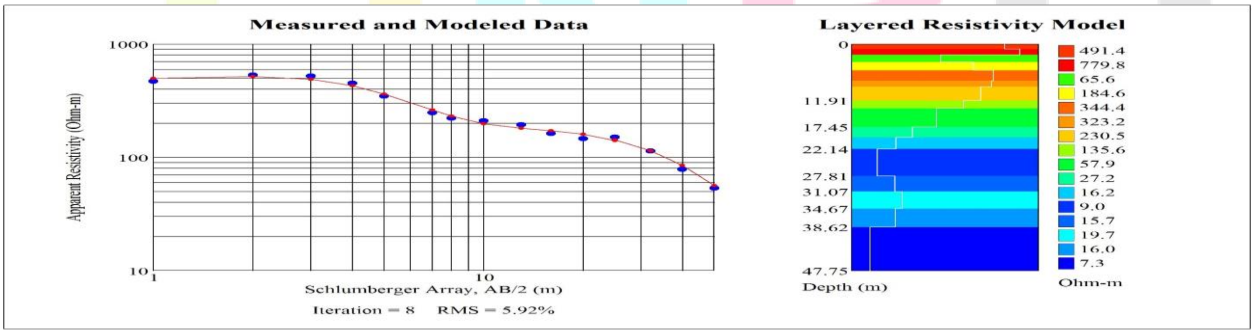


Fig5.3A Typical Q-type of a curve representing profile 11 in the survey area

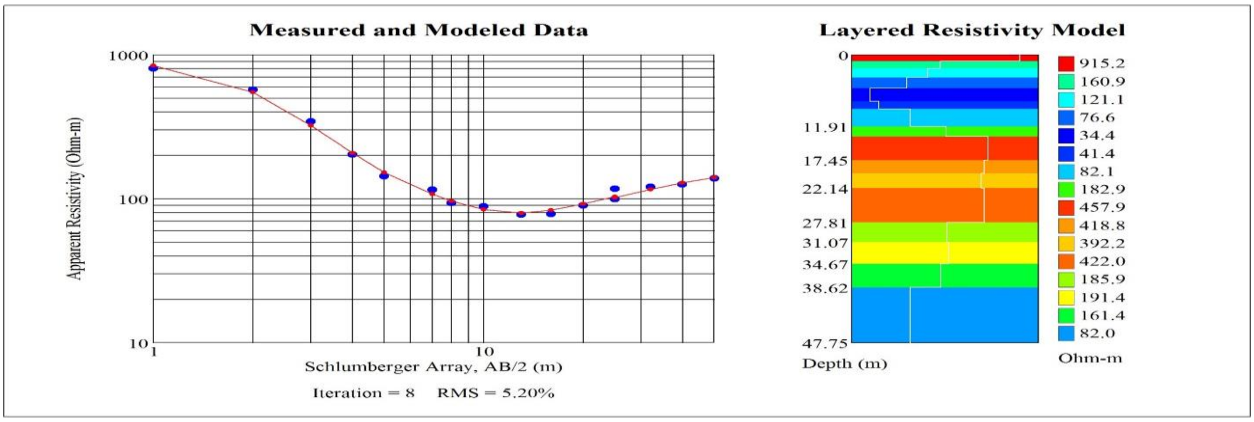


Fig5.4 A Typical H-type of a curve representing profile 13 in the survey area

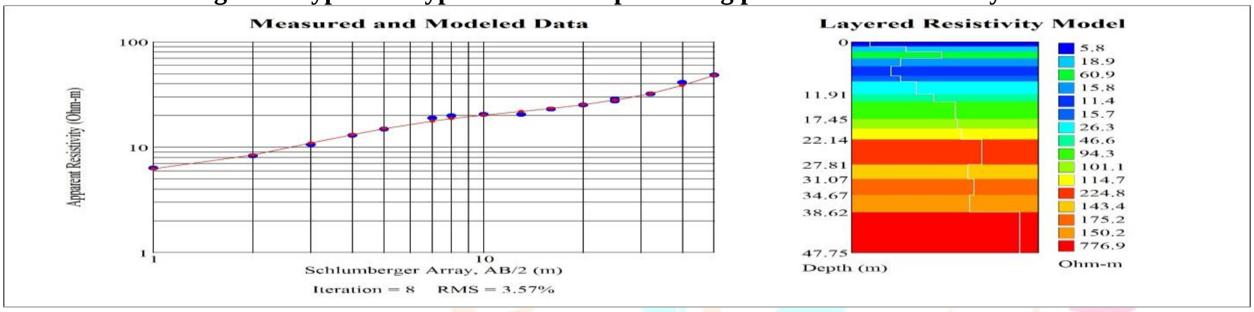


Fig5.5A Typical A-type of a curve representing profile 19 in the survey area

5 .CHAPTER FIVE: DISCUSSION

The profiles showed low resistivity zones of (0.1–0.5 **Ω**-m) for AB/2 of 1–1.6 m for ves 1, ves 5, ves10 and ves 15. This can be attributed to contamination of the top-most soil as a result of accumulation of leachate plume. The geoelectric curves generated were as follows KH (ℓ1 < ℓ2 > ℓ3 < ℓ4), K(ℓ1< ℓ2 > ℓ3), Q (ℓ1 > ℓ2 > ℓ3),H(ℓ1 > ℓ2< ℓ3) and A(ℓ1< ℓ2 <ℓ3) .Types of curves in decreasing order Q- Type (30.77%) figure (5.3), KH-Type (30.77%) figure (5.1), H-Type-26.92% figure (5.4) K-Type (7.69%)figure (5.2) and A-type 3.85% figure (5.5) According to Omosuyi et al. (2021), H and KH type VES curves represent the unconfined weathered, confined weathered and fractured aquifers. Hence, majority of the curves types are containing H or K types indicating good groundwater accumulation and storage. Interpretation of Vertical Electrical Sounding using Earth Imager 1D, Profiles of ves 4-8 cross sections for VES points with low resistivity zone (0.18-2.6Ωm) for AB/2 spacing of (1-20m), The black color at cross-section can be as a result of uneven distribution of leachate to the earth surface. This could be as a result of the age at which those solid wastes were deposited at a dumpsite and types of the rocks porosity. The water bearing layers as shown by yellow, pink, grey and green colors these layers have high apparent resistivities demonstrating that at the shallow aquifers the level of contamination is very high. The low resistivities end <80 Ωm could be attributed to contamination of the groundwater due to leachate invasion (Abdullahiet al, 2010) **.**The low resistivity value is due to high levels of contamination at the subsurface of the earth due to presence of leachates from ves 10-17.The movements of leachates are unevenly distributed this is as a results of presence of wetland at the southern part which accelerates percolation of leachates. Apparent resistivity from ves 10-17 varies from lowest 0.3Ωm to highest 49147.02Ωm highest apparent resistivity indicates there is high level of contamination on the top soil. Movements of leachates have not reached at the shallow aquifer making water at shallow aquifer safe for human consumption. The black color at the top level indicates that there is high level of contamination due to accumulation of leachates from VES (18-26) the apparent resistivity values ranges from lowest 2.51 Ωm -2055.50 Ωm. Profile 1-9 is divided into three sections composed of 4, 3 and 6 layers with highest values of resistivities of 488.3 Ωm, 536.5 Ωm and 469Ωm, indicating low level of contamination at the subsurface to a depth 4.33m. Contamination is also low on Ves 4, Ves 5, Ves 6, Ves7, Ves 8 and Ves9 based on high values of resistivities. Contamination increases at depth of 19.96m to 38.4m Ves 5, resistivity values on Ves 6 and Ves 7 at 22.14 Ωm to 47.75 Ωm indicates level of contamination is very high. Profile 10-17 contains geoelectric layers are K, Q and QH. It is divided into three sections; there are low level of contamination on VES 10, 13, 14, and Ves 17 resistivities ranging from 915.2-635.4. Low levels of contamination occurs on Ves 12, VES 15 and Ves 16 based on high values of resistivities ranging 133.3 Ωm 203.7, Ωm at a depth of 17.45m the level of contamination increases. The geophysical method used in this research was helpful that it clearly shows the movements of leachate from the landfill outwardly. The leachates are more concentrated at the landfill compared to its outskirts. The resistivities at the landfill was too low (0.1–0.5 **Ω**-m) due to presence of high concentration of ionic contents.

6. Conclusion and Recommendations

Based on the findings the low values of resistivities at the sub-surface demonstrate that the leachate have concentrated more at the shallow aquifer and moving uniformly to the interior of the earth. The eastern part of the study area is safe from underground water contamination based on high values of resistivities that was obtain in exception of profiles 6 and 7**.** The presences of the landfill at that location have not yet compromised the quality of the water at shallow aquifer. This research has demonstrated that the leachate that was generated by the landfill accelerated by high precipitation have not found its way to the shallow aquifer. The vertical electrical sounding (VES) method was chosen for this study over other geophysical methods because the target anomaly would most likely to respond to electrical conductivity since the migrating leachate are more conductive to the surrounding area. The results from pseudo and resistivity cross-section indicate that contamination of groundwater and soils does not exceed 47.75m which is within shallow aquifer in the study area. Solid waste at the site must be evacuated to prevent the contaminant plumes from finding its way to deeper aquifer thus compromising the quality of underground water. Sanitary landfill should be constructed to ensure all leachate generated at a landfill are confined in one area. Boreholes should be drilled above 50m underground to reach deeper aquifers which water is uncontaminated by leachates plumes. Boreholes should be drilled at the eastern part which is uncontaminated by movements of contaminant plumes.

Declaration of competing interest

There are no conflicts of interests with regards to this manuscript.

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