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RESEARCH ARTICLE

Assessment of the Leachate Contamination Level of Groundwater Resource at a Dumpsite, In Minna, North Central, Nigeria Using Resistivity Method

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Abstract

This research work focused on the use of direct current resistivity method to analyse data collected from refuse dumpsite at eastern bye pass Minna. The study area lies approximately on longitude 60 36'19.84"E to 6036'23.15"E and latitude 90 38'04.97"N to 9038'08.25"N, with a dimension of 100m x 100m within the basement complex of north central Nigeria. Vertical Electrical Sounding was carried out on the dumpsite with the aim of delineating the leachate contaminant plumes using resistivity method. Nine electrical resistivity profiles were measured on the site. Six transverse profiles was conducted on the dumpsite with thirty six vertical electrical sounding (VES) point, three transverse profiles was also conducted on the control site which is 100 meters away from the dumpsite having nine vertical electrical sounding (VES) point and a dimension of 40m x 40m. The resistivity data obtained was analysed using winresist software. The data obtained from the study area revealed three underlain layer they are the top soil, fractured basement and fresh basement. The dumpsite was typified by A-types and H-types of curve and the control site was typified by H-type of curves. Iso–resistivity maps at various depths were observed, at surface, 3m, 5m,7m and 10m for the dumpsite and the control site. It can therefore be inferred from this study that the depth of contamination is 7 meter and aquifer found within this depth are most likely to be contaminated by leachate and water bearing formation beyond the depth of 7m is safe from contamination. The rate of contamination of the study area is approximately 1.0 meter per year.

Keywords: Contaminant, Dumpsite, Electrical Resistivity, Leachate and Plumes

1. Introduction

As a result of fast growing rural and industrial development, man's activities have led to increasing volume of solid waste worldwide despite the current level of global technological advancement and industrialization. Dumpsite serves as the ultimate recipient of solid waste. Industrial development and uncontrolled increase of rural-urban migration have also resulted in an increased production rate of different types of wastes ranging from municipal to industrial, which have adverse effects on human health through groundwater quality (Ramakrishnaiah et al., 2009, and Omolayo et al., 2014). The challenge is worsened by the fact that there are inadequately trained waste disposal personnel and equipment, poor waste collection, sorting and disposal methods, and location of this disposal site without regards to the local geology and hydrogeology of the area (Jatau and Ajodo, 2006).

Groundwater contamination from landfills often results from leaking leachate water that has percolated through waste and accumulated various ions in solution (Capenter et al., 2012). The leachates become part of the groundwater flow system immediately they reach the water table. The extent of pollution is greater in high rainfall area than less humid and arid areas (Al-Yaqout et al.,2003).

This situation is not any way different in Minna, where numerous dumpsites are distributed at almost every area within the metropolis. The locations of these dumpsite such as that of the study area causes environmental pollution which may eventually lead to environmental hazards if nothing is done about it. These wastes discarded into landfills and dumpsite undergoes decay, oxidation, and corrosion which result to the releasing of metal ions causing potential risk to the soil, groundwater and community health (Soupios et al., 2007).

The dump site used for this research was chosen because of the uniqueness of the kind of wastes deposited there. Apart from domestic waste dumped in this area, there is also a considerable large amount of clinical waste present on the site this is as a result of a pharmaceutical company (Dana pharmaceutical) few kilometres from the dump site. Although the area is sparely populated, there is a likely hood of future settling of people in the area since the dump site is not a legal site and the land belongs to Nigeria Union of Teachers (N.U.T) who intends commencement of housing project in the area. The major sources of water in the community are wells and bore hole.

As a result of the imminent impact of solid waste on the environment, it is of necessity to carry out research of this magnitude to investigate the potential for the contamination of soil and groundwater around the dumpsite. Electrical resistivity method was used to carry out this research because the method is the most used method in hydrogeological studies as relevant data can be provided on lithologies and subsurface water resources without the large cost of an extensive programme of drilling (Kearey, 2002). It is also a useful tool for investigation of the subsurface of an area as it can provide information on the spatial variation in lithology, subsurface integrity with respect to the evaluation of the protective capacity of the area and the direction of groundwater flow and hence, direction of the contaminant plume. (Aweto and Mamah 2014)

2. Geology and Location of the Study Area

The study area lies within the basement complex rocks in the north-western Nigeria basement bounded by longitude 60 36'19.84"E and 6036'23.15"E and latitude 90 38'04.97"N and 9038'08.25"N, it occupy the central portion of the Nigerian basement complex. The basement complex is one of the three major litho-petrological components that make up the geology of Nigeria (Figure 1). The Nigerian basement complex forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg Shield (Black, 1980 as cited by Obaje, 2009). The Minna area comprises of meta-sedimentary and meta-igneous rocks which have undergone polyphase deformation and metamorphism (Amadi et al., 2011). Total area covered for the study is 100m x100m north-eastern part of Minna along eastern bye pass after Serikin Power road Maitunbi off Kaduna express road Minna Niger state. This dumpsite (Figure 2) is large and it's among the known dumpsite in the state although is not an official dumpsite used by Niger State.

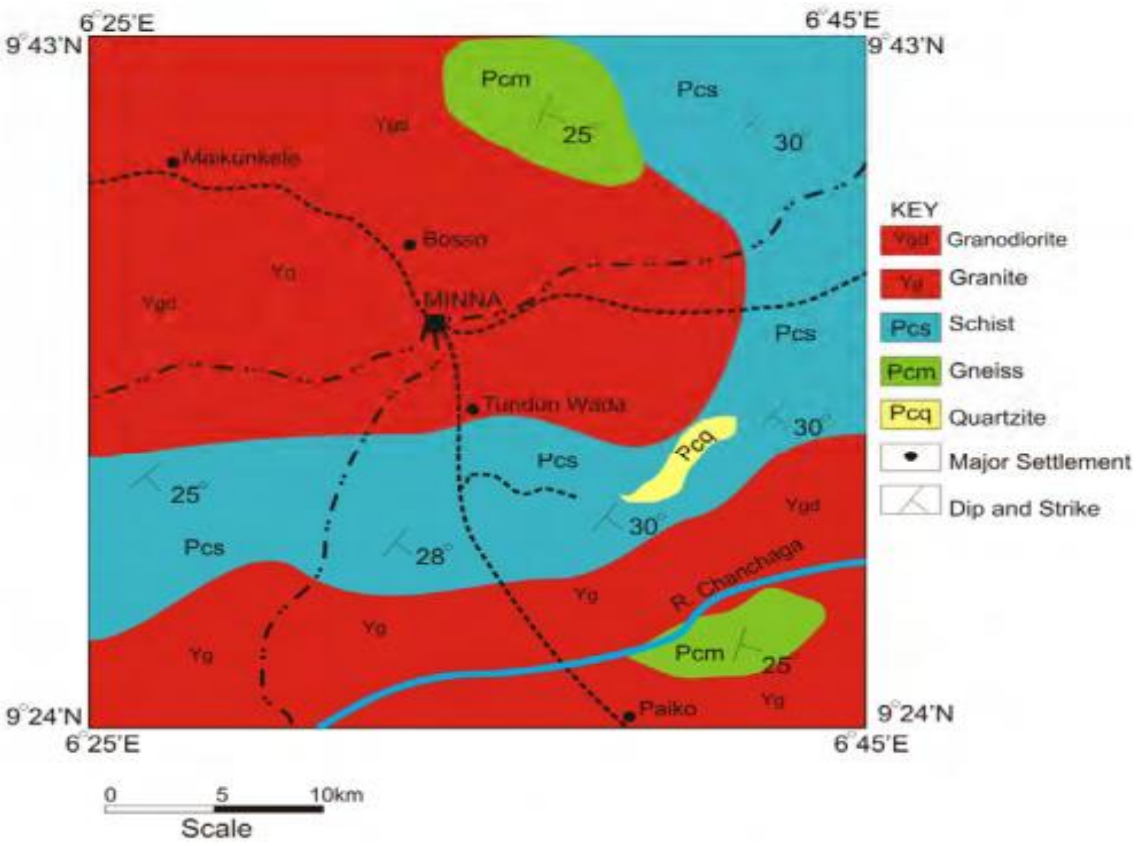

Fig 1. Geological Map of the Study area (Adapted from Amadi et al, 2011).

Fig 2.The Dumpsite – The Study Area.

3. Methodology

2D electrical resistivity was carried out within one of the popular dump site in Minna using Terameter. The area of study under investigation was first inspected and gridded into profiles. The length of the profile is 100 x100m. six profiles were taken on the dump site with distance of 20 meters apart. A control site situated 100m away from the dumpsite was measured and gridded with a profile length of 40mx 40m having three profiles and an interspacing between each profile of 20m. Since the aim and objective of this study is to assess leachate contamination of ground water the most suitable electrical method to be adopted would be vertical electrical sounding (VES) Schlumberger method this is because it is most suitable in revealing variations in apparent resistivity with depths.

Vertical Electrical Sounding (VES) was carried out on the gridded profile which has thirty-six (36) VES points marked with pegs using Schlumberger method of electrode configuration spread. The control site is also gridded with nine (9) VES points marked with pegs. Schlumberger configuration is also used to measure its apparent resistivity with depth.

4. Field Procedure

Schlumberger array was used for VES survey by keeping the potential electrodes fixed at one location while the current electrodes are expanded about a centre point. Only when the current electrodes become relatively distant does the potential electrode spacing need to be expanded in order to have measurable potential. The potential electrodes are moved only when the signal become too weak to be measured.

By using schlumberger array method, features with electrical properties different from those of the surrounding material may be located and characterized in terms of electrical resistivity, geometry and depth of burial. The electrical resistivity data are collected using a terrameter (computer-controlled measurement systems connected to multi-electrode arrays). The data acquisition process is totally controlled by the computer software which checks that all the electrodes are connected and properly grounded before measurement starts. After adequate grounding is achieved the software scans through the measurement protocol selected.

5. Data Collection

The dimension of the area of study was measured to be 100m by 100m and was gridded with an interspacing of 20m (i.e. between each VES point is 20 m) with six profiles and a control site of 40m by 40m gridded with an interspacing of 20m with three profiles represented by Figure 3a and Figure 3brespectively. Vertical electric sounding were required at thirty-six stations along the six profile on the dumpsite and nine points on the control site which was taken azimuthally north-east direction for all the profiles. At each point, the maximum current electrode spacing was 100 m.

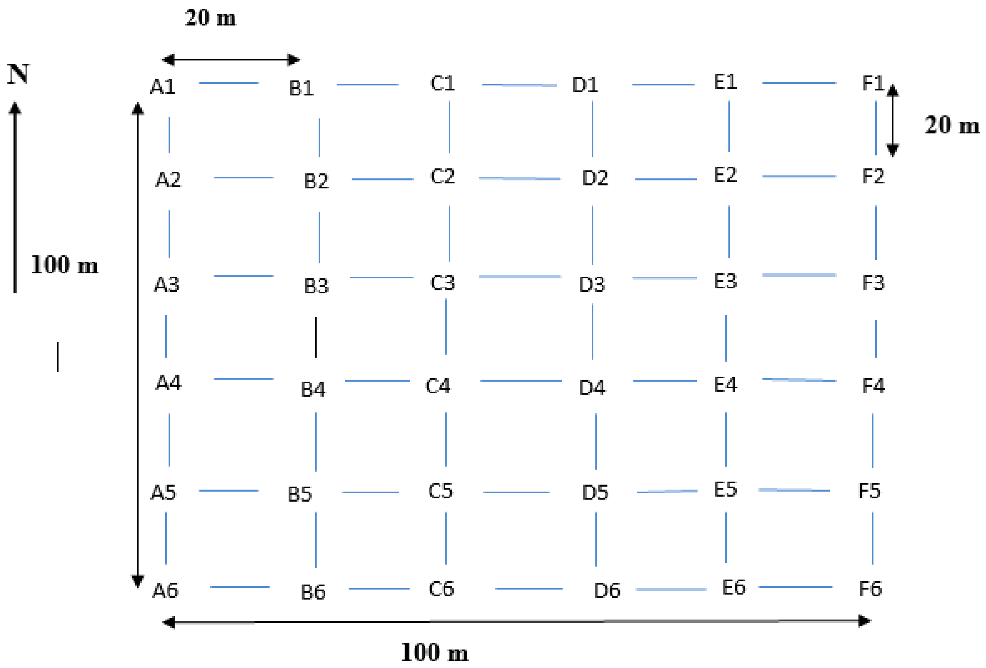

Fig 3a. Layout of the field procedure on the dumpsite.

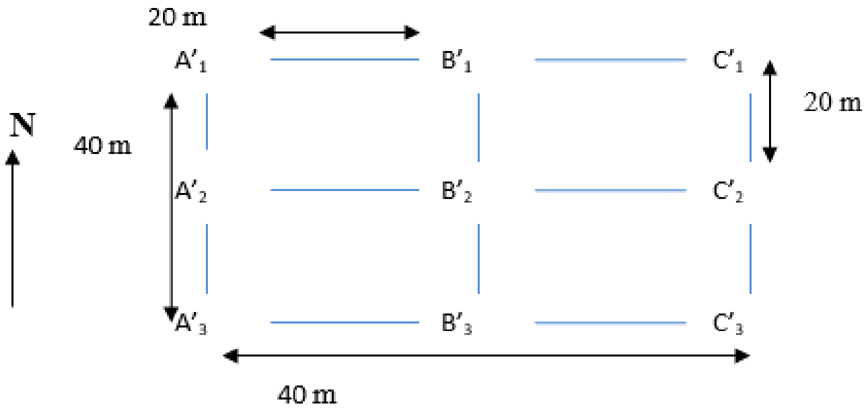

Fig 3b. Layout of the field procedure on the control site.

6. Results and Discussion

6.1 Results

The analysis of leachate contamination over a dump site in Eastern bypass, Minna, Niger state was successfully investigated. Six (6) profiles were taken in this study with the total number of forty five (45) VES points. For the purpose of this paper, three profiles (C, D and F) will be taking into consideration because the profiles show the extent of the leachate in the subsurface.

The summary of the analysis on VES points along profile C shows that the profile is underline by three basic layers; these are the topsoil, the fractured basement and the fresh basement (Table 1). The resistivity value for the first layer of this profile ranges from 13.4 - 447.9 ohms-meter which is the topsoil and it percolates into the subsurface with a relative thickness of 0.7 to 6.6 meters. And the analysis on VES points along profile D (Table 2) reveals that the profile is also underline by three basic layers, these are the topsoil, the fractured basement and the fresh basement. The resistivity values for the first, second and the third layer of this profile ranges from 31.7 - 333.6 ohms-meter with relative thickness of 0.6 – 6.8 meters, 99.4 - 725.5 ohm-m with relative thickness of 3.4 – 9.0 meters and 1036.8 - 25164.6 ohm-m with infinite relative thickness respectively.

The analysis on VES points along profile F (Table 3) shows that the profile is underline by three basic layers, these are the topsoil, the fractured basement and the fresh basement. The resistivity value for this profile ranges from 23.1 to 316.9 ohms-meter for the first layer which is the topsoil which percolates into the subsurface with a relative thickness of 0.4 to 9.0 meters. The second layer has a resistivity value which ranges from 35.4 to 709.9 ohm-m which is fractured basement made of granite, with a thickness range of 2.3 to 5.7 meters. The third layer has resistivity value ranging from 1948.0 to 10169.1 ohm-m which is fresh basement and has infinite thickness.

Table 1. Summary of VES Analysis along Profile C (Dumpsite).

VES POINT	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (M)	CURVE TYPE
C1	1	32.8	1.0	0.0	
	2	332.4	2.6	1.0	$\rho_1 < \rho_2 < \rho_3$
	3	7439.8	∞	3.6	A
C2	1	13.4	1.9	0.0	$\rho_1 < \rho_2 < \rho_3$
	2	177.6	2.7	1.9	A
	3	1103.0	∞	4.6	
C3	1	13.5	1.9	0.0	
	2	177.7	2.7	1.9	$\rho_1 < \rho_2 < \rho_3$
	3	1109.4	∞	4.6	A
C4	1	118.0	1.5	0.0	$\rho_1 < \rho_2 < \rho_3$ A
	2	339.5	3.5	5	
	3	1232.3	∞	8.5	
C5	1	60.6	6.6	0.0	
	2	280.9	3.6	6.6	$\rho_1 < \rho_2 < \rho_3$
	3	2358.8	∞	10.2	A
C6	1	447.9	0.7	0.0	
	2	373.4	19.2	0.7	$\rho_1 > \rho_2 < \rho_3$
	3	3110.3	∞	19.9	H

Table 2. Summary of VES Analysis along Profile D (Dumpsite).

VES POINT	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (M)	CURVE TYPE
D1	1	31.7	6.8	0.0	
	2	1732.1	6.3	6.8	$\rho_1 < \rho_2 < \rho_3$
	3	25164.6	∞	13.1	A
D2	1	43.6	2.1	0.0	
	2	129.8	5.8	2.1	$\rho_1 < \rho_2 < \rho_3$
	3	1036.8	∞	7.9	A
D3	1	1458.2	0.6	0.0	
	2	99.4	5.4	0.6	$\rho_1 > \rho_2 < \rho_3$
	3	1503.9	∞	6.0	H
D4	1	277.9	0.9	0.0	
	2	344.6	9.0	0.9	$\rho_1 < \rho_2 < \rho_3$
	3	5666.2	∞	9.9	A
D5	1	139.9	2.1	0.0	
	2	478.5	3.4	2.1	$\rho_1 < \rho_2 < \rho_3$
	3	2376.8	∞	5.5	A
D6	1	333.6	4.0	0.0	
	2	725.5	8.2	4.0	$\rho_1 < \rho_2 < \rho_3$
	3	1532.5	∞	12.2	A

Table 3. Summary of VES Analysis along Profile D (Dumpsite).

VES POINT	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (M)	CURVE TYPE
F1	1	23.7	1.6	0.0	
	2	709.9	2.3	1.6	$\rho_1 < \rho_2 < \rho_3$
	3	6394.4	∞	3.9	A
F2	1	23.1	4.6	0.0	$\rho_1 < \rho_2 < \rho_3$
	2	847.0	5.7	4.6	A
	3	6781.8	∞	10.3	

VES POINT	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (M)	CURVE TYPE
F3	1	93.3	9.0	0.0	$\rho_1 < \rho_2 < \rho_3$ A
	2	244.4	5.1	9.0	
	3	3378.1	∞	14.1	
F4	1	71.0	2.2	0.0	$\rho_1 < \rho_2 < \rho_3$ A
	2	507.6	4.9	2.2	
	3	1948.0	∞	7.1	
F5	1	316.9	0.4	0.0	$\rho_1 > \rho_2 < \rho_3$ H
	2	35.4	3.7	0.4	
	3	8879.6	∞	4.1	
F6	1	66.5	6.6	0.0	$\rho_1 < \rho_2 < \rho_3$ A
	2	458.7	4.0	6.6	
	3	10162.1	∞	10.6	

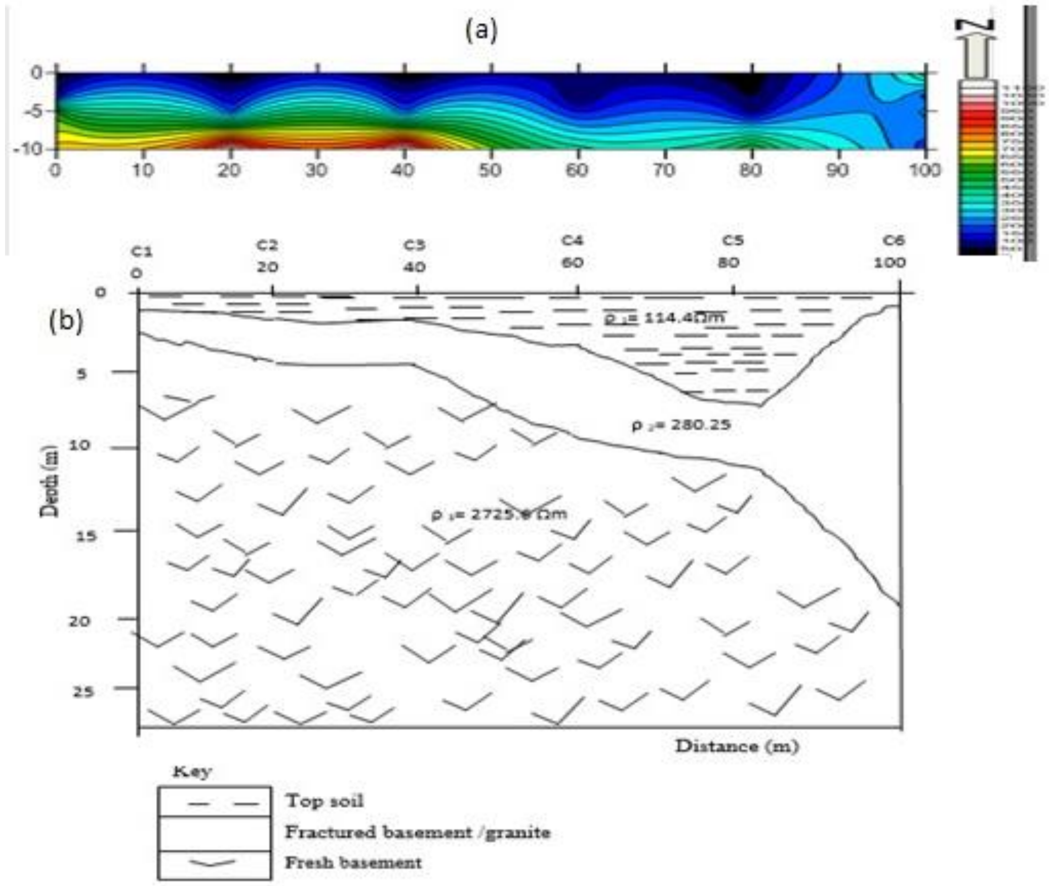

Fig. 4 (a) Subsurface geoelectric section along profile C, (b) Subsurface geologic section along profile C.

6.2 Discussion

The analysis made from the above (Tables 1- 3) makes it easier to draw a number of deductions regarding the thickness of the leachate plume and zone of water saturation (aquifer). By correlating the two, we can deduce if the aquifer is affected by leachate which is among the objectives of this research. The deductions and correlations shall be made from Iso–resistivity maps at some depths of interest, geologic sections with their range in resistivity value and geo-electric sections. The delineation of the water tables that are likely affected by leachate shall be based on the thickness of the leachate plumes, geologic sections in succession and maximum weathering depth from the surface.

The geo-electric section and the subsurface geo-electric section of profile C (Figure 4a and 4b) shows that the profile is underlain by three layers. The first is the topsoil with average resistivity of 114.4 ohm-meter and a maximum depth of 6.6 meter. It has the best water bearing formation on this profile at C5. The second layer has an average resistivity value of 280.25 ohm-meter which is the fractured basement. The best water bearing formation in this layer is C6 having a resistivity of 373.4 with a depth of 19.9 meter. The third layer is the fresh basement with an average resistivity of 2725.6 ohm-meter.

The geo-electric section and the subsurface geo-electric section of profile D (Figure 5a and 5b) reveals that the profile is also underlain by three layers. The first is the topsoil with average resistivity of 380.8 ohm-

the best water bearing formation on this layer is at VES F3 having a resistivity of 93.3 and at the depth of 9.0 meter. The second layer has an average resistivity value of 357.55 ohm-meter which is the fractured basement. Its best water bearing formation is at F3 having a resistivity of 244.4 having a depth of 14.1

meter and a maximum depth of 6.8 meter. The second layer has an average resistivity value of 580.9 ohm-meter which is the fractured basement, the best water bearing formation for this profile is at D4 at the depth of 9.9 meter. The third layer is the fresh basement with an average resistivity of 6213.5 ohm-meter. The geo-electric section and the subsurface geo-electric section of profile F (Figure 6a and 6b) shows that the profile is underlain by three layers. The first is the topsoil with average resistivity of 109.4 ohm-meter and a maximum depth of 9.0 meter,

meter. The third layer is the fresh basement with an average resistivity of 6256.81 ohm-meter. The extent at which the leachate has gone into the subsurface is more pronounced in this profile and this indicate that this region is prone to groundwater contamination.

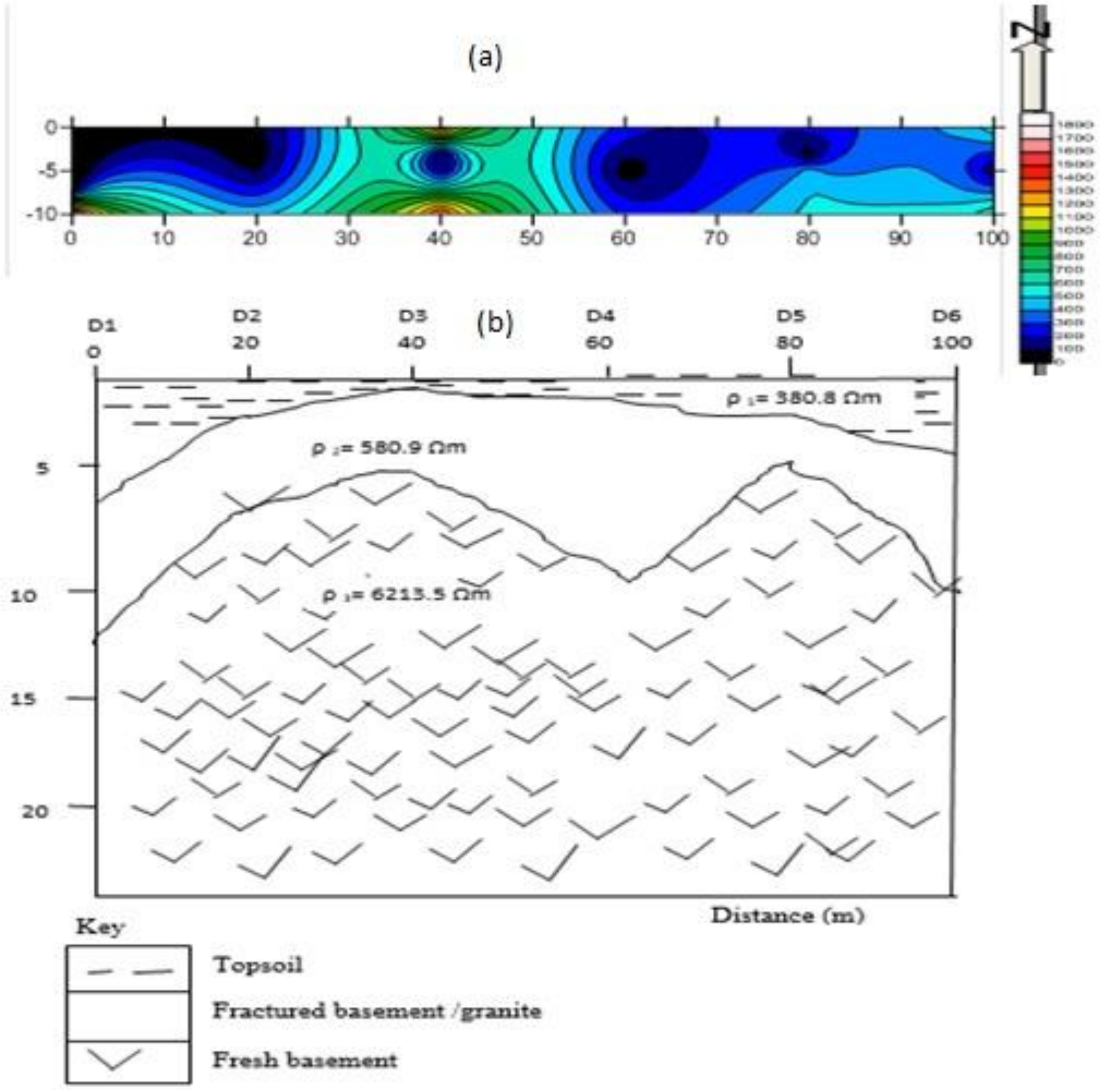

Fig. 5 (a) Subsurface geoelectric section along profile D, (b) Subsurface geologic section along profile D

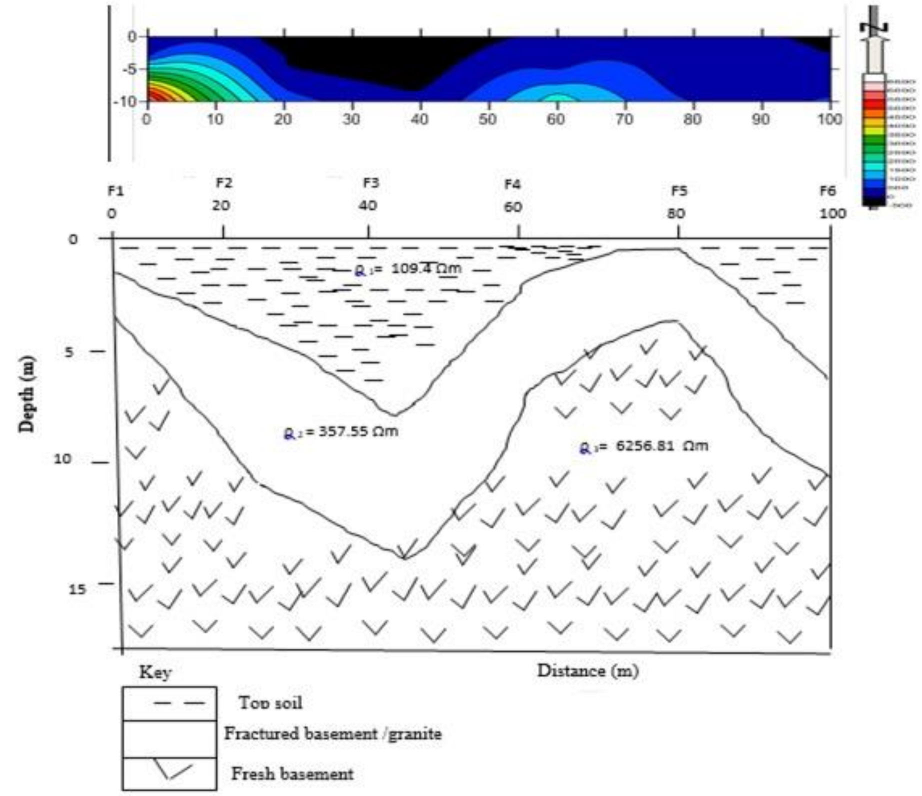

Fig. 6 (a) Subsurface geoelectric section along profile F, (b) Subsurface geologic section along profile F

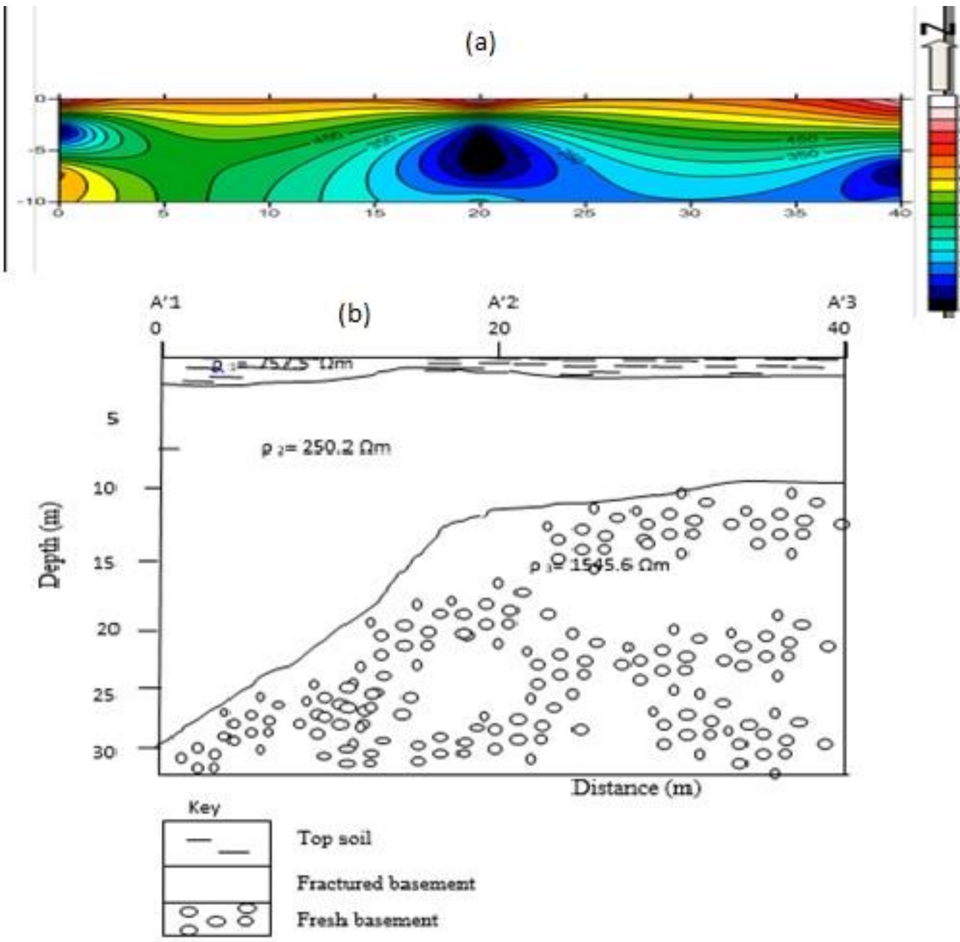

Fig. 7 (a) subsurface geoelectric section along profile A', (b) subsurface geologic section along profile A'

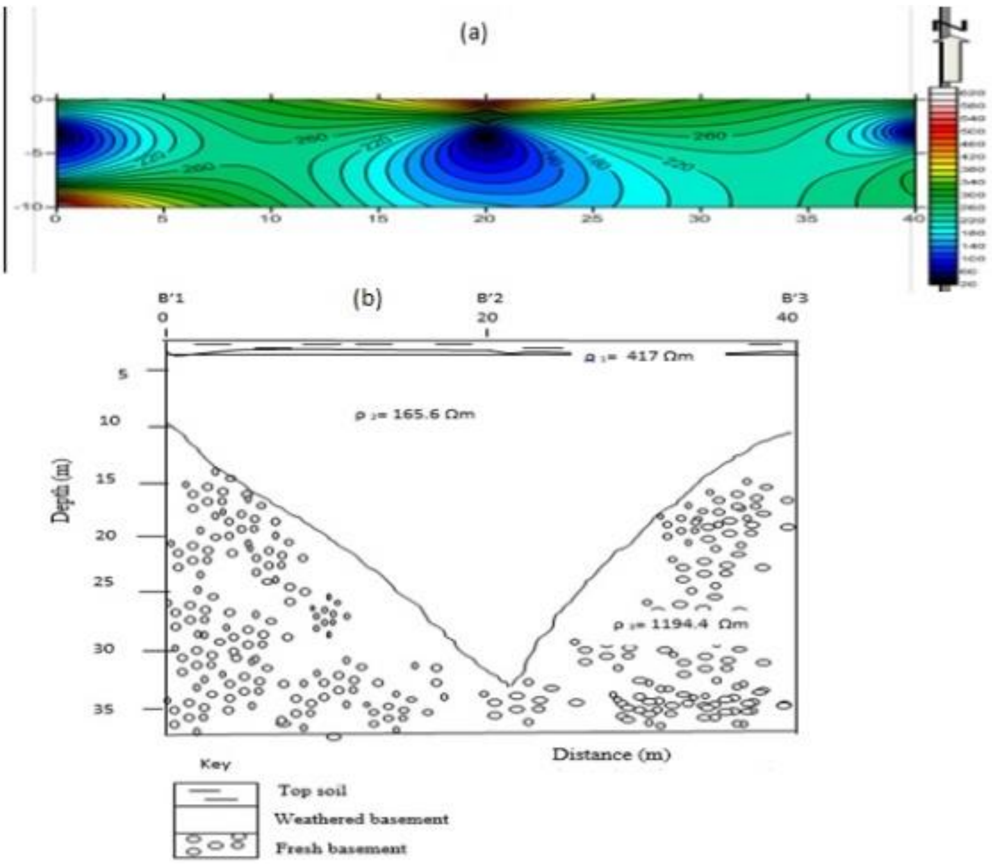

Fig. 8 (a) subsurface geoelectric section along profile B', (b) subsurface geologic section along profile B'

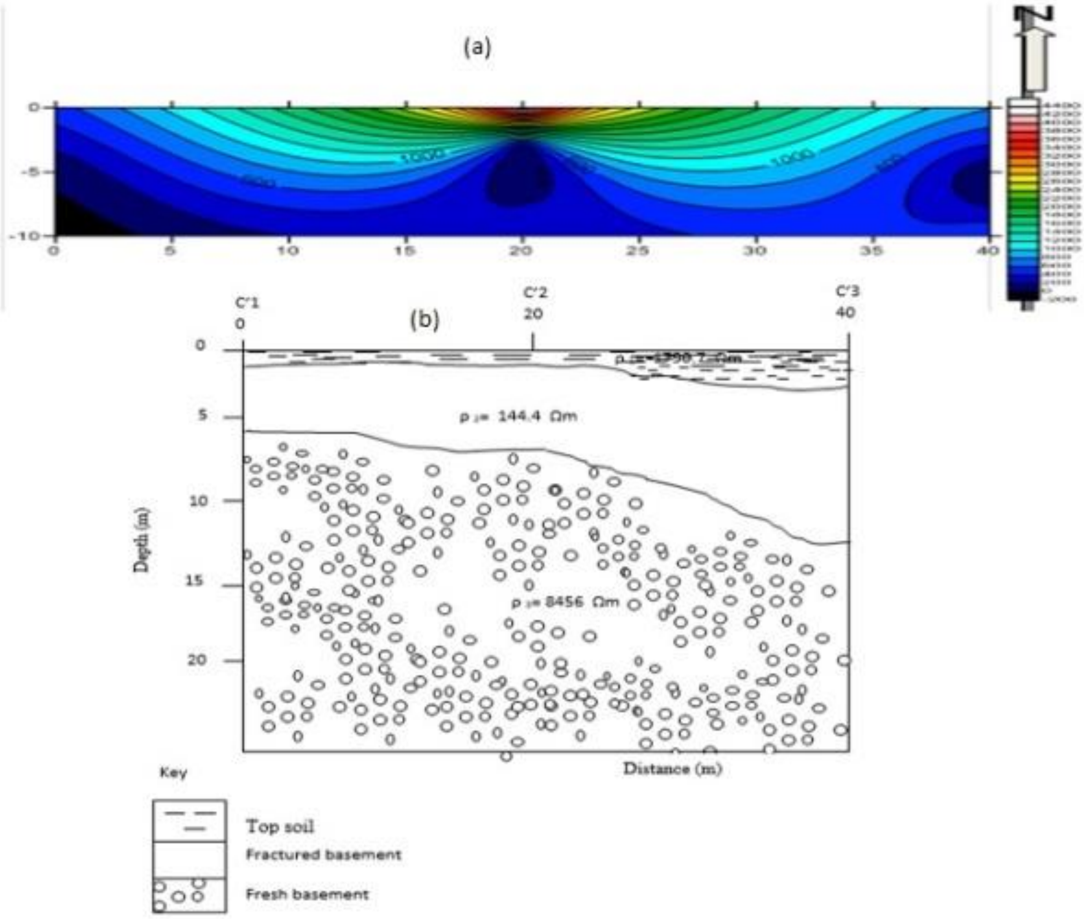

Fig. 9 (a) subsurface geoelectric section along profile C', (b) subsurface geologic section along profile C'

The subsurface geo-electric and geologic section of the control site are presented in the figures 7-9. Figure

7a and 7b shows the geo-electric and geologic section of control site profile A and it reveals that the profile is underlain by three layers; topsoil, fractured basement and fresh basement. The top soil has an average resistivity of 757.5 ohm-meter and a maximum depth of 2.5 meter, the second layer has an average resistivity value of 250.2 ohm-meter with a depth of 30 meters which is the fractured basement, thus it best water bearing formation on this layer and on the profile having a resistivity of 350.7 ohm-meter. The third layer which is the fresh basement has an average resistivity of 1545.6 ohm-meter.

Figure 8a and 8b shows the geo-electric and geologic section of control site profile B. it shows that the profile is underlain by three layers; topsoil with an average resistivity of 417 ohm-meter and a maximum depth of 1.3 meter, fractured basement with average resistivity value of 165.6 ohm-meter and maximum depth of 29.4 meter It also confined it best water bearing formation on this layer and on the profile. The third layer which is the fresh basement has an average resistivity of 1194.4 ohm-meter.Figure 9a and 9b also shows the geo-electric and geologic section of control site profile C and it reveals that the profile is underlain by three layers; topsoil with an average resistivity of 1790.7ohm-meter and a maximum depth of 2.8 meter, fractured basement with an average resistivity value of 144.4 ohm-meter. Its maximum depth is 13.1 meter at C'3 with a resistivity of 238.5 ohm-meter. And the fresh basement with an average resistivity of 8456 ohm-meter. Figure 10 – 12 is the Iso-resistivity contour maps produced by contouring resistivity values obtained from the study area at depths of interest (3m, 5m, 7m and 10m) using Surfer 8 software package. The contour maps (Figure 10 – 12) of all the VES point on the refuse dump site were produced and contour maps for the control site were also taken at the same depths. The purpose of these maps is to correlate the two maps produced and to observe the variation in conductivity of the earth material at different depths to delineate the extent of contamination. Figure 10a and 10b shows the Iso-resistivity contour maps of dumpsite and control site at depth of 3m contoured at interval of 20Ωm and 10Ωm respectively. The resistivity values of the dumpsite ranges from 0 to 460Ωm which are low compared to the resistivity values of the control site which ranges from 200 to 4600Ωm which are very high. This shows that the dumpsite is very conductive at the surface this is because of the presence of leachate and surface water. Figure 11a and 11b shows the Iso-resistivity contour maps of dumpsite and control site at depth of 5 m contoured at 20Ωm and 10Ωm respectively. These maps are produced to examine the extent of contamination at this depth by correlating the two maps. The resistivity values of the dump site ranges from 0 to 360Ωm while that of the control site ranges from 30 to 260Ωm. The resistivity value at the dump site is slightly higher than the control site. It can thus be inferred that the leachate contamination has a minimal effect at this depth this is because of the granitic intrusion at the dump site. However because of the low range, contamination is still visible. Figure 12 a and 12b also shows the Iso-resistivity contour maps of dumpsite and control site at depth of 7m contoured at 20Ωm and 10Ωm respectively. The resistivity values of the dump site ranges from 30 to 250Ωm while that of the control site ranges from 40 to 260Ωm. The resistivity value at the dump site is very similar to that of the control site thus the dump site is less conductive. It can therefore be inferred that the leachate contamination has no effect at this depth.

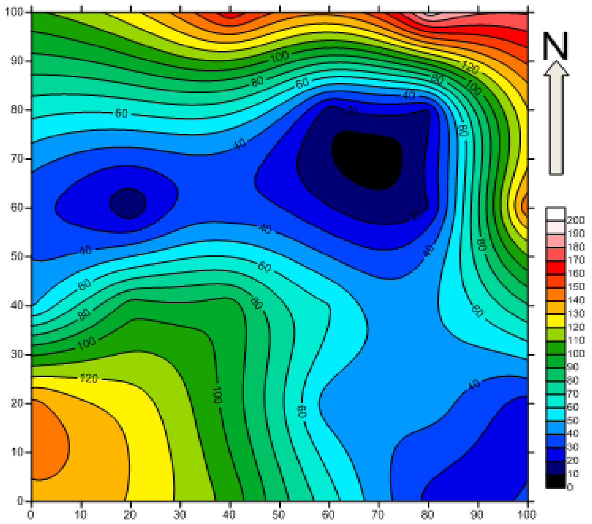

Fig 10a. Dumpsite site iso-resistivity map at depth of 3m

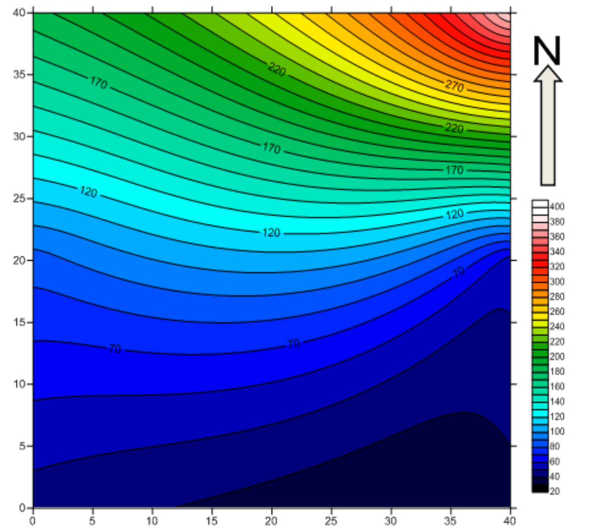

Fig10b. Control site iso-resistivity map at depth of 3m contour interval = 10 Ωm.

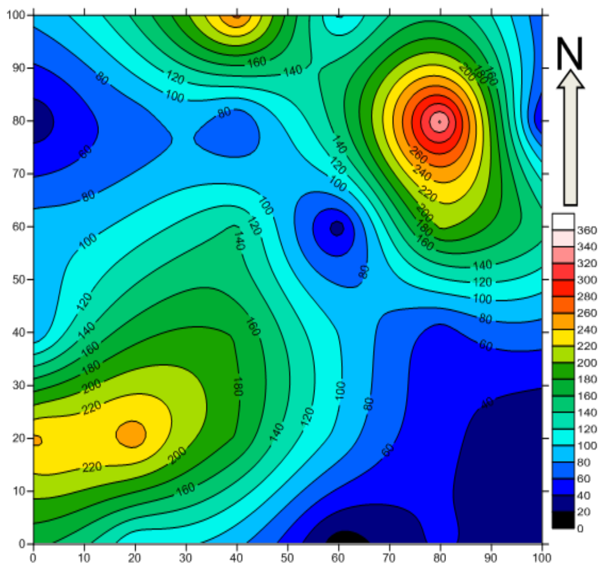

Fig11a. Dumpsite iso-resistivity map at depth of 5m. Contour interval = 20 Ωm

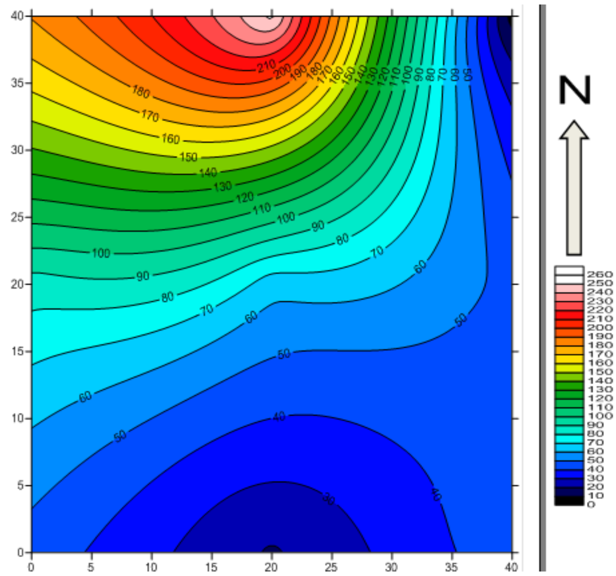

Fig11b. Control siteiso-resistivity map at depth of 5m. Contour interval = 10 Ωm

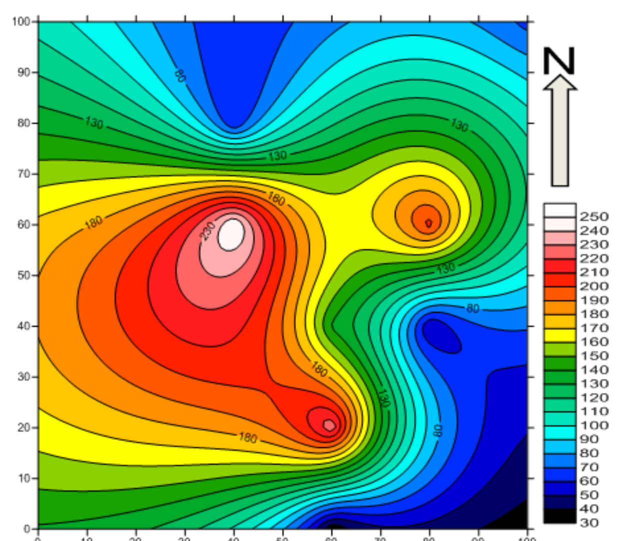

Fig 12a. Dumpsite iso-resistivity map at depth of 7m. Contour interval = 20 Ωm

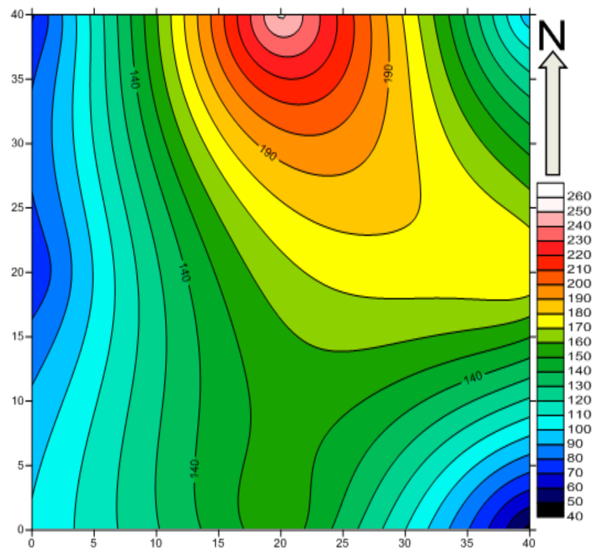

Fig 12b. Conrol iso-resistivity map at depth of 7m. Contour interval = 10 Ωm

7. Conclusion

The analysis of leachate contamination over a dump site in Eastern bypass, Minna, Niger State was successfully investigated. Results suggest leachate contamination in the subsurface which is supported by vertical electrical sounding made on the dump site. Three distinct geologic sections were delineated at the dump site they are; top most layer which consist of the contaminated area, followed by fractured basement which is granitic followed by fresh basement. It can be inferred from this study that the depth of contamination is 7 meter, aquifer found within this depth are most likely to be contaminated by leachate and water bearing formation beyond the depth of 7 m is safe from contamination. The rate of contamination of the study area is approximately 1.0 meter per year.

References

Amadi, A. N., Nwanwulu, C. D., Unuevho, C. I., Okoye, N.O., Okunlolo, I. A., Ako, T. A., & Alkali, Y. B. (2011). Evaluation of the Groundwater Potential in Pompo village, Gidan Kwano, Minna using Vertical Electrical Resistivity Sounding. British Journal of applied Science and Technology, 1(3), 53 - 66

Al-Yaqout, A., & Hamoda, M. (2003). Education of landfill leachate in arid climate: a case study. Environmental. International, 29, 593 – 600

Aweto, K. E & Mamah, L. I (2014). Application of Resistivity Method to Groundwater Protection Studies in Niger Delta. International Journal of Environment Protection. 4(3), 27-35

Black R. (1980). Precambrian of West Africa. (4)3 – 8

Carpenter, P. J., Ding, A., & Cheng, L. (2012). Identifying Groundwater Contamination using Resistivity surveys at a landfill near Maoming, China. Nature Education Knowledge 3(7), 20 - 21

Jatau, B. S., & Ajodo, R. O. (2006). Preliminary Geo-environment evaluation of part of Kaduna North Metropolis, Kaduna, Nigeria. A Paper presented at

Nigeria Association of Hydrogeologists (NAH) 18th Annual National Conference Asaba, 1-2.
Kearey, P, Brooks, M., & Ian, H (2002). An Introduction to Geophyscial Exploration. Third edition Blackwell publishing.
Obaje N.G (2009). Geology and Mineral Resources of Nigeria.Springer Dordrecht Heidelberg London New York pg. 13-19.
Omolayo, D., & Fatoba, J.T. (2014). 2D Electrical Imaging Surveys For Leachate Plume Migration At An Old Dumpsite In Ibadan South Western Nigeria. International Journal. Geophysics, 530, 1 – 6.
Rahaman, M.A., & Ocan O. (1978). Reletionships in Precambrian Migmatite Gneissess of Nigeria. Nigeria Journal mineral geology. 15, 23 – 32.
Soupios, P. Papadopoulo, S. I, Kouli, .M, Georgaki, I, Vallianatos, F &Kokkinous, E. (2006). Environmental Geology 7, 418