INVESTIGATION OF CONTAMINATION PLUMES AT MECHANIC ROAD, BOSSO WASTE DISPOSAL SITE USING GEOPHYSICAL AND GEOCHEMICAL APPROACH

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Abstract
Geophysical survey involving electrical resistivity method, soil sampling analysis and hydrochemical was conducted around Mechanic road dump site in Bosso, Minna, Niger State, Nigeria with the aim to assess the degree and extent of impact of the waste dump site on the quality of the groundwater in the study area. Thirty Vertical Electrical Sounding survey were carried out in Mechanic road, Bosso, Bosso local government area of Niger state. The schlumberger array with a maximum electrode spread of 80 m was employed in all the points. Results from the sounding data indicates that the area is generally underlain by three to four geoelectric sections which include top soil, Sandy clay, weathered basement, and Fresh basement. Based on the result obtained the fractured and the weathered basement makes the aquiferous zone within the study area. The resistivities of these zones vary from 12.7 to 475.2 Ωm, while the thickness varies from a value of 0.9 to 7.8 m. Depth to this zone varies from 0.9 to 8.6 m. The result of water analysedin this area is found to be contaminated by Lead, Chromium and Cadmium with level of contamination exceeds WHO regulated guidelines. The results of soil analysed also indicated that the soils collected in this survey were contaminated by Cd, Ni, Pb, Zn and Cr.

Keyword: Cadmium, Contamination, Geophysical leachate, Waste disposal, Winrest

Introduction

Solid wastes are generated by domestic, commercial and industrial activities. Various methods of disposing solid wastes include open dumps, wasteland – farms containment ponds, containment in rocks and deep underground injection (Ismail & Hashim, 2006). The practice of landfill systems as a method for waste disposal in many developing countries is usually far from standard recommendations (Mull, 2005; Adewole, 2005). Landfills are sources of groundwater and soil pollution due to the production of leachate and its migration through refuse (Christensen et al., 1993). After some years, a dumpsite undergoes biologically, chemically, and hydrologically-mediated changes resulting in a weathering process of the refuse and, consequently, become a source of pollutants (Al Sabahi et al., 2009). Open dump has been in practice in Niger state. Disposed solid wastes get decomposed and degraded forming open dump gas and leachate. Leachate is formed by both intrinsic solid wastes moisture and water infiltration into the dump site; its generation and composition depends on factors such as climatic factors, open dump operation practice and waste nature (Manon et al., 2011). Leachate presence from dump sites leads to contamination of groundwater in the vicinity of the dumpsite as it percolates into the ground and traverses with groundwater. The migration might involve simple advection which is the movement of contaminants in porous media along with flowing groundwater at the seepage velocity. It might also involve diffusion which is a molecular mass transport process in which solutes move from areas of higher concentration to areas of lower concentration. The use of electrical method in groundwater and landfill is unique (Adabanija & Ajabi, 2014; Ehirim & Ofor, 2011; Fasuwon et al., 2011; Popoola & Fakunle, 2011; Iyoha et al., 2013). The aim of this study is to determine the extents of groundwater pollution for future groundwater exploitation in and around Mechanic road, Bosso, Minaa, Niger state, Nigeria.

Geology of the Study Area

Minna is situated in the central part of Nigeria basement complex, surrounded by rugged terrain f granitic rocks. Minna is located between longitudes 6.42^0E and 6.75^0 E and latitude 9.42^0 N and 9 8^0 N. Minna area comprises of metasedimentary and meta-igneous rocks which have undergone polyphase deformation and metamorphism (Alab1, 2011). These rocks have been intruded by granitic rocks of Pan-African age. Five lithostratigraphic units have been recognized in Minna area (Figure 1). The schist which occur as a flat laying narrow southwest-northeast belt at the central part of Minna with small quartzite ridge parallel to it, the gneiss occur as a small suites at the northern and southern part of the area forming a contact with the granite. Feldspathic rich pegmatite is bounded to the east, with average width of 65meters and 100 meters long, the pegmatite host tourmaline (Alabi, 2011). Granitic rocks dominate the rock types in the area and vary in texture and composition.

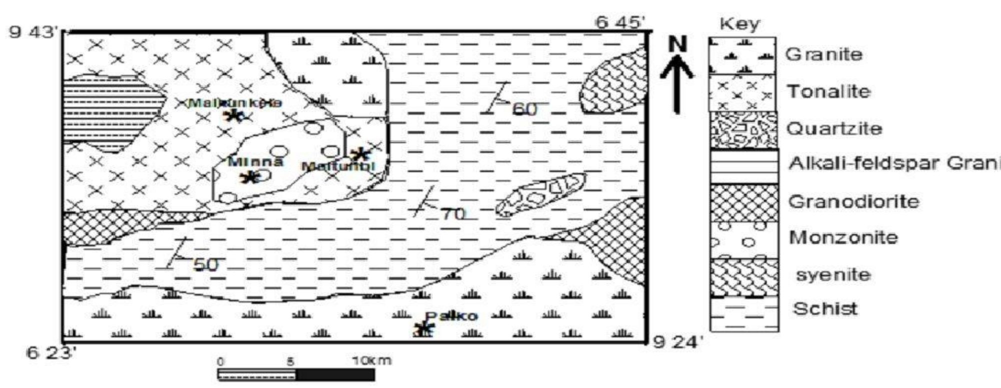

Figure 1: Geqologicaql map of Minna Area (modified after Alabi, 2011)

Material and Methods

The Schlumberger Configuration was used by applying current to the ground through two electrodes (A and B) and then measuring the resultant potential difference (V) between the potentials M and N. The centre point of the electrode array remains fixed but the spacing's of the electrodes was increased so as to obtain the information about the stratification of the ground. The schlumberger data are often taken in overlapping segment because at each step of AB spacing, the signals of the resistivity meter become weaker. Therefore, MN spacing was enlarged and two values for the same AB/2 were measured, one for the long MN spacing's. The schlumberger configuration was employed not only because it is faster and less likely to be influenced by lateral model and it requires a fewer number of field personnel as the only the current electrode A and B requires changes. A total of thirty VES points were engaged, twenty four of these were acquired around the refuse dump and six at an area free from refuse. Electrode spacing's AB/2 of 80 m wasused along the transverse. Data were acquired using surface geophysical equipment SAS 4000 terrameter set. Apparent resistivity values were determined by taking the product of the resistance as measured by the terrameter and the geometrical factor a parameter which is dependent on the potential and the current electrode spacing's. The data obtained was later subjected to computer assisted iterative interpretation using Winrest software. This programme was used to perform quantitative analysis and interpretation of the field curves. The starting model and its corresponding resistivity are transformed, refined or modified by the programme to obtain a best fit relation to thefield data. The method of iteration was performed untilfitting error between field data and synthetic model curve becomes least and constant. Thus, the software yields the number, thickness and resistivity of the various layers.

Hydro-chemical Analysis

To carry out a comprehensive pollution assessment of the study area, hydro-chemical analysis of water samples collected from three hand dug wells around the dump site were carried out. The sampling wells were designated Well A, Well B and Well C and other Well 200 m away from refuse dump to serve as control. The physico-chemical parameters that are indicative of groundwater pollution such as Total dissolved Solid, Chloride, Nitrate, Sulphate, Lead, Iron, Calcium, Magnesium and Sodium were analyzed. Thecationsconcentrations were determined using Atomic Absorption Spectrophotometer (AAS). The results of the hydrochemical analysis of the groundwater samples from the study area are presented under results and discussion.

Soil Chemical Analysis

Chemical analysis was done on the soil samples collected close to and away from the dump site. The preliminary assessment of the extent of pollution with respect toexchangeable metals were carried out, using X-ray fluorescence. Soil samples from ninesampling points were obtained and analyzed for theirelemental concentrations. The sample points were designated as MR1 to MR6 with each sampling point separated by 10 m and MRC1 to MRC3 to serve as the control points and was at a distance of 200 m away from MR6. The results of the chemical analysis are tabulated and presented under results and discussion.

Results and Discussion

Tables 1 to 6 show the VES results from Mechanic road refuse site for both dry and wet seasons as well as control site.

Table 1: General VES results from Profile A during dry season at the Mechanic Road refuse dump

VES NO	Number of resistivities of layers(Ωm)				Thickness of layers(m)				Depth to bottom layers(m)			
	ρ_1	ρ_2	ρ_3	ρ_4	t_1	t_2	t_3	t_4	d_1	d_2	d_3	d_4
1	26.5	12.6	6339.9		1.2	1.6	--		1.2	2.8	--	
2	29.3	17.4	6261.7		0.9	2.4	--		0.9	3.3	–	
3	6.0	15.1	5098.2		1.8	1.7			1.8	3.5	--	
4	27.7	17.1	5464.3		0.9	2.5	--		0.9	3.4	--	
5	25.3	18.3	5463.8		1.0	2.6	--		1.0	3.6	--	
6	24.1	18.2	5656.7		1.0	2.5	--		1.0	3.6	--	
7	25.7	19.4	5532.4		1.1	2.7	--		1.1	3.8	--	
8	28.4	18.1	5403.4		1.0	2.7	--		1.0	3.6	--	

The VES curves in this profile are characterised to be a three layer model. All VES curves for this profile are type H curves with configuration $\rho_1 > \rho_2 < \rho_3 = H$. The resistivity values for the first layer range between 24.1 Ωm and 29.3 Ωm, while the corresponding thickness range between 0.9m to 1.8 m and the corresponding depth also range between 0.9 m to 1.8 m. The lowest resistivity is at VES6 and the highest at VES2. The resistivity values for the second layer range between 12.6 Ωm and 19.4 Ωm. The lowest resistivity is at VES7 and the highest is at VES1. The third layer resistivity range between 5098.2 Ωmand6339.9 Ωm. All the VES have cumulative depth that range between 2.8m and 3.8 m. All the VES in this profile could be contaminated because they are characterised with low resistivity ranging between 12.6 Ωm and 29.3 Ωm. The third layer with high resistivity ranging between 5098.2Ωmand6339.9 Ωm indicated fresh basement (Ehirim & Ofor, 2011) which is very shallow and therefore the underground water might be contaminated.

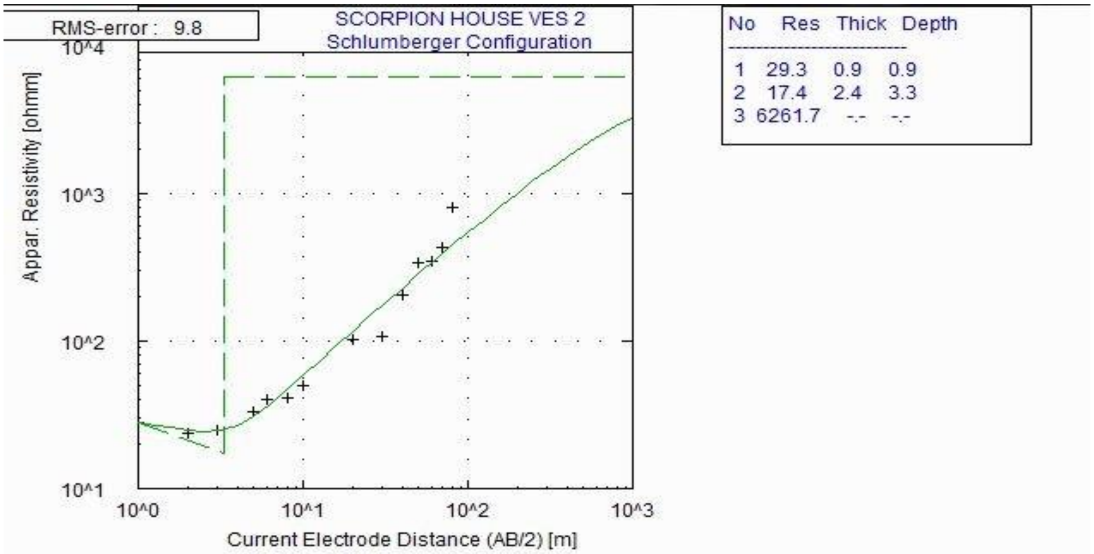

Figure 2: Typical VES curve along profile A during the dry season

Table 2: General VES results from Profile B during dry season at the Mechanic Road refuse dump

VES NO	Number of ressitivities of layers(Ωm)			Thickness of layers(m)			Depth to bottom layers(m)		
	ρ_1	ρ_2	ρ_3	t_1	t_2	t_3	d_1	d_2	d_3
1	31.7	253.1	1037.1	0.8	5.5	--	0.8	6.3	--
2	30.8	230.3	1638.9	0.8	5.8	--	0.8	6.6	–
3	31.6	255.5	1379.6	0.9	4.7		0.9	5.5	--
4	30.5	231.2	1640.2	0.8	5.6	--	0.8	6.4	--
5	30.4	251.1	2376.4	0.7	5.9	--	0.7	6.6	--
6	29.1	264.7	4407.3	0.7	6.8	--	0.7	7.5	--
7	28.9	235.9	1823.8	0.7	6.0	--	0.7	6.7	--
8	28.1	246.9	3517.7	0.6	7.8	--	0.7	8.5	--

The VES curves in this profile are characterised to be a three layer model. All the VES curves for this profile are A type curves with configuration $\rho_1 < \rho_2 < \rho_3$ =A. The resistivity values for the first layer range between 28.1 Ωm and 31.7 Ωm, while, the corresponding thickness range between 0.6m to 0.9m and the corresponding depth also range between 0.7 m to 0.9 m. The lowest resistivity is at VES8 and the highest at VES1. The resistivity values for the second layer range between 230.3 Ωm and 264.7 Ωm. The lowest resistivity is at VES4 and the highest is at VES6. The third layer resistivity values range between 1037.1 Ωm and 4407.3 Ωm. All the VES have cumulative depth that range between 5.5m and 8.5 m. The second layer resistivity value is corresponding to sand/gravel (Fasuwon et al., 2011) which is porous as a result of this; the leachate noticed at top layer will percolate in to the groundwater thereby contaminate it.

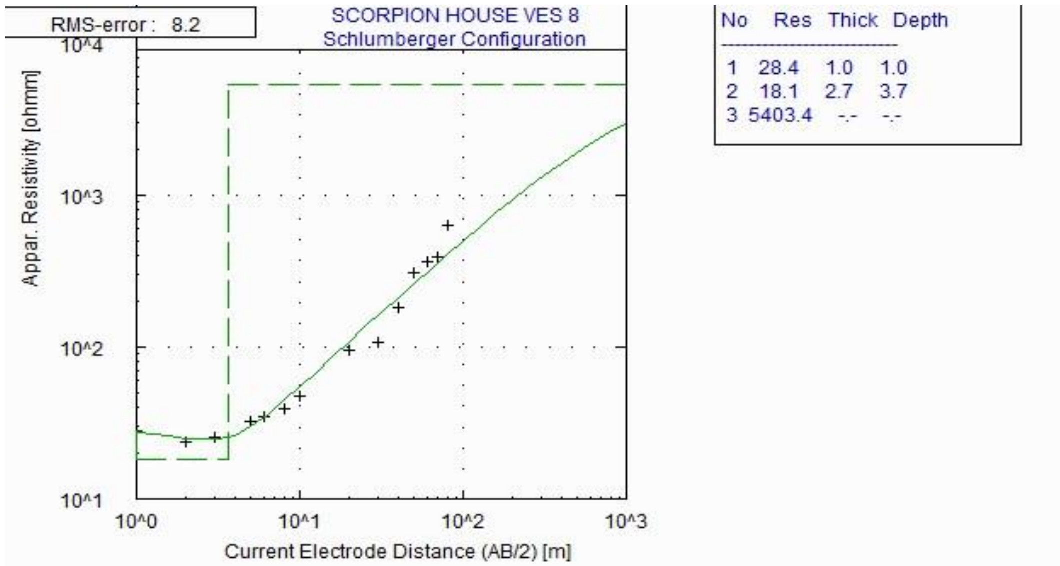

Figure 3: Typical VES curve along profile B during the dry season

Table 3: General VES results from Control site during dry season at the mechanic road refuse dump

VES NO	Number of ressitivities of layers(Ωm)				Thickness of layers(m)				Depth to bottom layers(m)			
	ρ_1	ρ_2	ρ_3	ρ_4	t_1	t_2	t_3	t_4	d_1	d_2	d_3	d_4
1	127.5	164.5	31.0	18022.7	0.7	0.7	2.6	--	0.7	1.5	4.0	--
2	127.7	147.2	28.6	17490.2	0.8	0.7	2.5	--	0.8	1.5	4.0	--
3	137.1	30.1	18577.5		1.9	2.0	--		1.9	4.0	--	
4	123.5	164.9	39.0	17615.6	0.8	0.8	2.9	--	0.8	1.6	4.5	--

The VES curves in this profile also have been delineated to be a three and four layer model.

VES curves 1, 2 and 4 for this profile are HA type curves with configuration $\rho_1 > \rho_2 < \rho_3 < \rho_4$= H and VES curve 3 with configuration $\rho_1 > \rho_2 < \rho_3$ = H curve. The resistivity values for the first layer range between 123.5 Ωm and 137.1 Ωm, while the corresponding thickness range between 0.7 m to 1.9 m and the corresponding depth also range between 0.7 m to 1.9 m. The lowest resistivity is at VES4 and the highest at VES3. The resistivity values for the second layer range between 30.1 Ωm and 164.9 Ωm. The third layer resistivity values range between 28.6 Ωm and 39.8 Ωm. The corresponding thickness and depths for the third layer range between 2.5 m and 2.9 m. The lowest resistivity is at VES2 and the highest at VES4. The resistivity values for the fourth layer range between 17490.2 Ωm and 18577.5 Ωm. All the VES have cumulative depth that range between 4m and 4.5 m. All the VES points in this profile are shallow as seen in the hand dug wells within the vicinity of the refuse dump. The topsoil in this profile correspond to sand and is free of leachate thus the groundwater might not be contaminated and low resistivity observed at the third layer may indicate aquifer zone (Alabi et al., 2010).

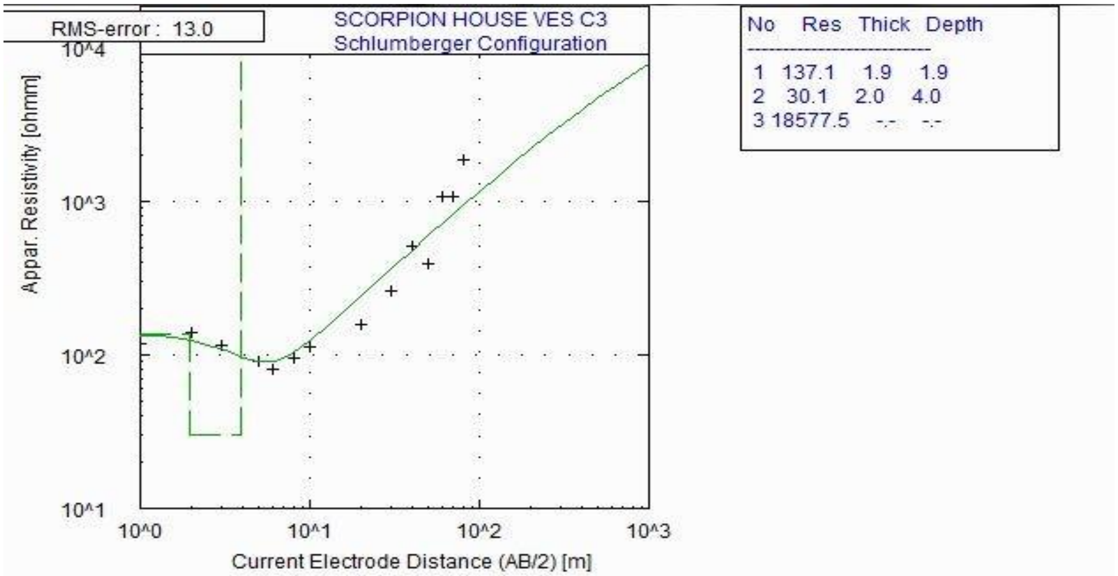

Figure 4: Typical VES curve along profile C during the dry season

Table 4: General VES results from Profile A during wet season at the Mechanic Road refuse dump

VES NO	Number of ressitivities of layers(Ωm)				Thickness of layers(m)				Depth to bottom layers(m)			
	ρ_1	ρ_2	ρ_3	ρ_4	t_1	t_2	t_3	t_4	d_1	d_2	d_3	d_4
1	23.7	12.8	421.6	5883.8	1.3	1.5	6.8	--	1.3	2.9	9.7	--
2	23.3	12.9	382.4	5853.0	1.4	1.6	6.7	--	1.4	2.9	9.7	--
3	23.3	12.8	384.7	5765.9	1.3	1.6	6.8	--	1.3	2.9	9.7	--
4	23.5	12.8	411.4	5782.9	1.3	1.5	9.8	--	1.3	1.5	9.8	--

The VES curves in this profile also have been delineated to be a four layer model. VES curves 1 to 4 for this profile are AH type curves with configuration $\rho 1 < \rho_2 > \rho_3$ = K and $\rho_1 > \rho_2 < \rho_3$ = H which equal $\rho_1 > \rho_2 < \rho_3 > \rho_4$ = HK curve (Adeoti et al., 2012). The resistivity values for the first layer range between 23.3 Ωm and 23.7 Ωm, while the corresponding thickness range between 1.3m to 1.4 m and the corresponding depth also range between 1.3 m to 1.4 m. The lowest resistivity is at VES2 and VES3 and the highest at VES1. The resistivity values for the second layer range between 12.8 Ωm and 12.9 Ωm. The third layer resistivity values range between 382.4Ωmand421.6Ωm. The corresponding thickness and depths for the third layer range between 6.7m and 9.8m. The lowest resistivity is at VES2 and the highest at VES1. The resistivity values for the fourth layer range between 5765.9 Ωm and 5883.8 Ωm. All the VES have cumulative depth that range between 6.7 m and 9.8 m. All the VES points in this profile have low resistivity which indicates leachate (Adabanija and Ajabi, 2014) to the second layer and this could pollute the groundwater within the vicinity of the refuse dump not more than 3 m.

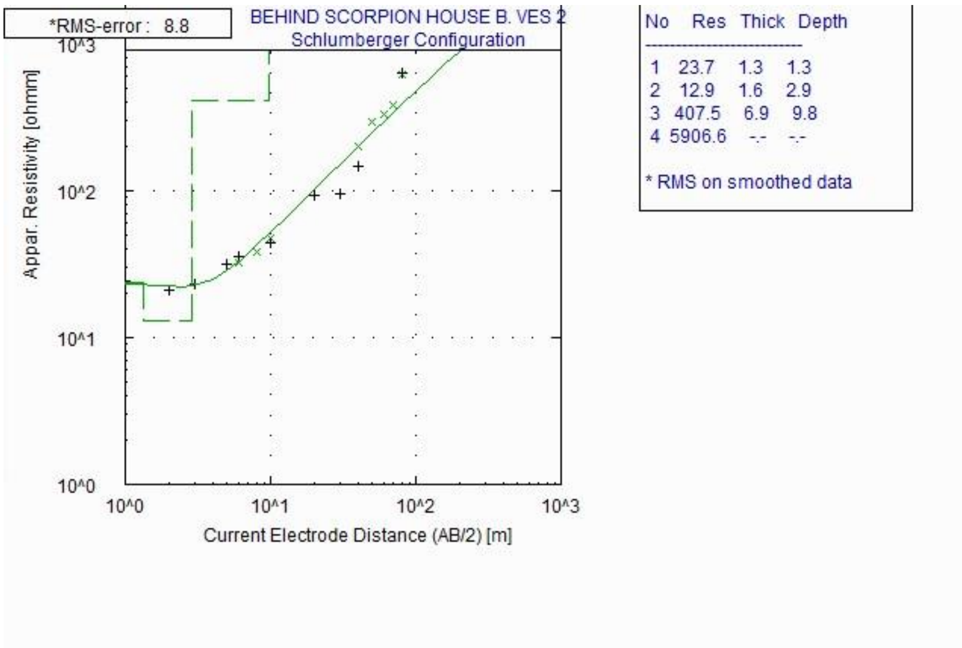

Figure 5: Typical VES curve along profile A during the wet season

Table 5: General VES results from Profile B during wet season at the Mechanic Road refuse dump

VES NO	Number of ressitivities of layers(Ωm)				Thickness of layers(m)				Depth to bottom layers(m)			
	ρ_1	ρ_2	ρ_3	ρ_4	t_1	t_2	t_3	t_4	d_1	d_2	d_3	d_4
1	23.9	13.2	447.7	5965.4	1.3	1.5	6.9	--	1.3	2.9	9.8	--
2	23.7	12.9	407.5	5906.6	1.3	1.6	6.9	--	1.3	2.9	9.8	--
3	24.1	12.7	475.2	6012.1	1.3	1.5	6.9	--	1.3	2.8	9.7	--
4	23.5	12.5	377.8	5772.8	1.3	1.6	6.8	--	1.3	2.9	9.7	--

The VES curves in this profile also have been delineated to be a four layer model. VES curves 1 to 4 for this profile are AH type curves with configuration $\rho1 < \rho_2 > \rho_3$ = K and $\rho_1 > \rho_2 < \rho_3$ = H which equal $\rho_1 > \rho_2 < \rho_3 > \rho_4$ = HK curve. The resistivity values for the first layer range between 23.5 Ωm and 24.1 Ωm, while the corresponding thickness for all the VES points is 1.3 m and the corresponding depth also is 1.3 m.The lowest resistivity is at VES4 and the highest at VES3. The resistivity values for the second layer range between 12.5 Ωm and 13.2 Ωm. The third layer resistivity values range between 377.8 Ωm and475.2 Ωm. The corresponding thickness and depths for the third layer range between 6.8 m and 6.9 m. The lowest resistivity is at VES4 and the highest at VES3. The resistivity values for the fourth layer range between 5772.8 Ωm and 6012.1 Ωm. All the VES have cumulative depth that range between 9.7 m and 9.8 m. All the VES points in this profile have low resistivity which indicates leachate to the second layer and this might pollute (Popoola and Fahunle, 2011) the ground water within the vicinity of the refuse dump up to 3 m.

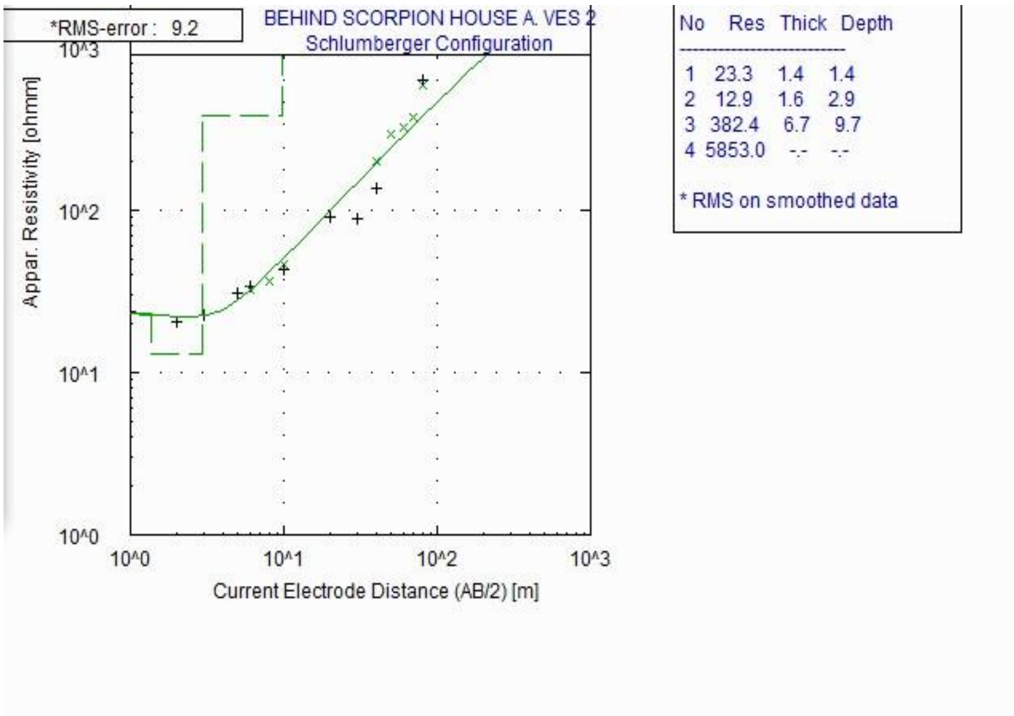

Figure 6: Typical VES curve along profile A during the wet season

Figure 6: Typical VES curve along profile A during the wet season

Table 6: General VES results from Control site during wet season at the Mechanic Road refuse dump

VES NO	Number of ressitivities of layers(Ωm)				Thickness of layers(m)				Depth to bottom layers(m)			
	ρ_1	ρ_2	ρ_3	ρ_4	t_1	t_2	t_3	t_4	d_1	d_2	d_3	d_4
1	127.0	114.0	24.4	14861.0	0.8	0.7	2.9	--	0.8	1.5	4.4	---
2	127.9	112.5	24.9	14987.3	0.9	0.7	2.9	--	0.9	1.5	4.4	--

The VES curves in this profile also have been delineated to be a four layer model. VES curves 1 and 2 for this profile are QH type curves with configuration $\rho 1 > \rho_2 > \rho_3$ = Q and $\rho_1 > \rho_2 < \rho_3$ =H which equal $\rho_1 > \rho_2 > \rho_3 < \rho_4$ = QH curve. The resistivity values for the first layer range between 127.0 Ωm and 127.9 Ωm, while the corresponding thickness range between 0.8 m to 0.9 m and the corresponding depth also range between 0.8m to 0.9 m. The lowest resistivity is at VES1 and the highest at VES2. The resistivity values for the second layer range between 112.5 Ωm and 114.0 Ωm, while the corresponding thickness for both VES points is 0.7 m and the corresponding depth is also 1.5m. The lowest resistivity is at VES and the highest at VES1. The third layer resistivity values range between 24.4 Ωmand24.9 Ωm, while the corresponding thickness for both VES points is 2.9 m and the corresponding depth is also 4.4 m. The lowest resistivity is at VES1 and the highest at VES2. The resistivity values for the fourth layer range between 14861.0 Ωm and 14897.3 Ωm. Both VES have cumulative depth 4.4 m.The groundwater in this area is free from pollutant as the topsoil is made of thin layer while the second layer and the layer are made of clay soil. All the VES points in this profile are shallow as seen in the hand dug wells within the vicinity of the refuse dump.

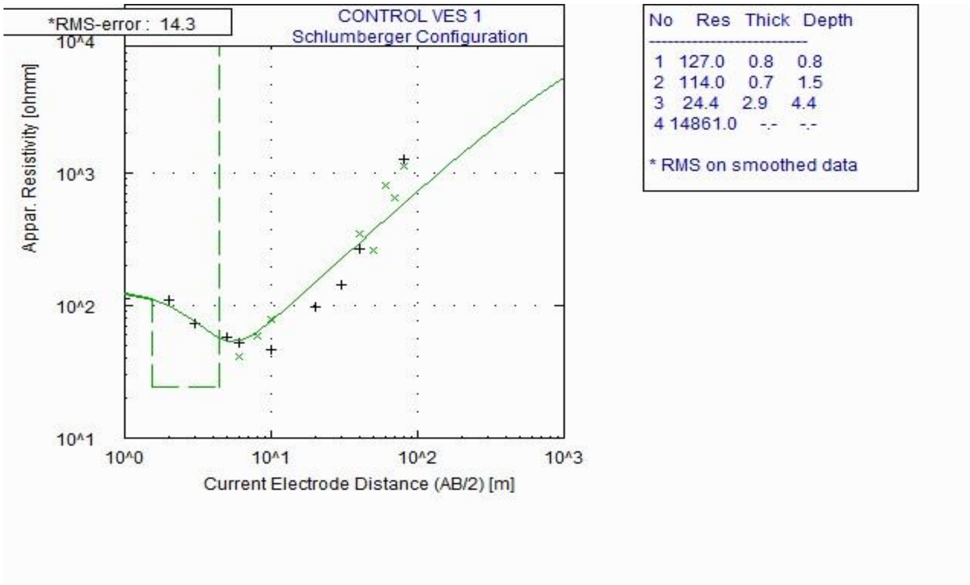

Figure 7: Typical VES curve along profile A during the wet season

The temperature for the groundwater in the study area ranged between 22.1 ^{O}C and 22.7 ^{O}C which is below WHO limits and the control well has a temperature of 28.3 ^{O}C. The Groundwater pH value for Mechanic Road wells averaged 7.53, while pH value for control well is 7.72. The pH values for both wells as well as control well meet the WHO standard. The value of alkalinity for wells A and B are above WHO limits, while the value for Well C is within allowable limits. The Total Dissolve Solid and Total Hardness are lower than WHO allowable limit. Water in this area is found to be contaminated by Lead, Chromium and Cadmium with level of contamination exceeds WHO regulated guidelines, this is similarly to work of Jegede et al., 2011.

Table 7: Physico-Chemical Analysis of Hand Dug Wells in Mechanic Road refuse dump, Minna

Parameter	Unit	Well A	Well B	Well C	Control Well	WHO
Temp	^{o}C	22.1	22.7	22.4	28.3	35-40
pH		7.52	7.52	7.54	7.72	6.5-9.2
Conductivity	µS/cm	740	741	809	92	100
Alkalinity	mg/l	500	380	180	100	200
Acidity	mg/l	38	30	26	42	NA
TDS	mg/l	1000	1119	1476	486	500-550
Total Hardness	mg/l	66	58	64	53	500
Zinc	mg/l	0.085	0.577	0.085	0.003	3.0
Lead	mg/l	0.923	0.769	0.823	0.104	0.001
Manganese	mg/l	0.157	0.229	0.229	0.004	0.5
Iron	mg/l	0.676	0.834	0.534	0.024	0.3
Copper	mg/l	0.250	0.100	0.300	0.000	2.0
Chromium	mg/l	1.250	1.400	0.860	0.000	0.05
Nickel	mg/l	0.036	0.029	0.100	0.000	NA
Cobalt	mg/l	0.010	0.029	0.035	0.000	NA
Cadmium	mg/l	0.0364	0.061	0.064	0.001	0.003

The heavy metals investigated in this study include: Zinc, Lead, Manganese, Iron, Copper, Chromium, Nickel, Cobalt and Cadmium. Based on the results obtained, there was a gradual decrease in the concentration of heavy metals from the centre of the dumpsite to the bottom of the slope. In most cases from locations (1 - 6), there was a significant difference between the concentrations of most metals at the centre of the dumpsite to the bottom of the slope. The variation in different parameters values in this study may be attributed to the fluctuations in waste type and characteristics (Abd El-Salam & Abu-Zuid, 2014).

Researches carried out by Udeme (2001) and Akaeze (2001) for soils along Aba-Ikot Ekpene road in Uyo metropolis (AkwaIbom State, Nigeria) at different sample locations revealed results that are comparable to those obtained in this study.The results indicated that the soils collected in this survey were contaminated by Cd, Ni, Pb, Zn and Cr.

Table 8: Physico-Chemical Analysis of Soil Samples in Mechanic Road refuse dump

Location	pH	Zn (mg/kg)	Pb (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Co (mg/kg)	Cd (mg/kg
MR1	6.56	6.81	38.46	29.29	6.76	50.00	12.50	30.00	8.57	0.93
MR2	6.69	5.52	28.85	21.44	5.07	42.00	10.50	25.00	5.7143	0.74
MR3	6.92	4.88	19.62	16.73	4.38	37.50	8.33	20.00	4.29	0.63
MR4	6.81	4.24	14.64	11.43	3.77	28.50	6.27	15.00	3.53	0.48
MR5	6.66	3.60	9.62	7.86	2.86	18.00	4.16	10.00	2.86	0.33
MR6	6.82	2.96	6.57	4.29	1.69	12.50	2.08	5.00	1.43	0.18
Min	6.52	2.96	6.57	4.29	1.69	12.50	2.08	5.00	1.43	0.18
Max	6.92	6.81	38.46	29.29	6.76	50.00	12.50	30.00	8.57	0.94
Mean	6.74	4.67	19.63	15.17	4.09	31.42	7.32	1.75	4.40	0.55
S.D	0.13	1.3883	12.14	9.24	1.76	14.43	39.11	9.35	2.49	0.49
MRC1	6.18	1.5990	0.00	3.85	1.47	4.00	2.83	0.00	1.43	0.03
MRC2	6.21	1.84	0.00	5.83	1.19	0.70	0.00	0.00	1.43	0.07
MRC3	6.27	1.64	9.62	2.97	0.00	0.00	5.86	0.00	0.00	0.18
Min	6.18	1.60	0.00	2.97	0.00	0.00	0.00	0.00	0.00	0.03
Max	6.27	1.84	9.62	5.83	1.47	4.00	5.86	0.00	1.43	0.18
Mean	6.22	1.69	3.21	4.22	0.89	1.57	2.90	0.00	0.95	0.09
S.D	0.05	0.13	5.55	1.46	0.78	2.14	2.93	0.00	0.828	0.08

MR: Mechanic Road, MRC: Mechanic Road Control

Conclusion

Results from the sounding data indicates that the area is generally underlain by three to four geoelectric sections. Based on theresult obtained the fractured and the weathered basement makes the aquiferous zone within the study area. The resistivities of these zones varies from

12.7 to 475.2 Ωm, while the thickness varies from a value of 0.9 to 7.8 m. The formation do not show good aquifer protective capacity, thereby, they are vulnerable to any near surface pollution. The hyeogeologic features of the site showed that contaminants from the refuse disposal infiltrate through the permeable soil in to the vulnerable aquifers. This implies that the soil and groundwater might have been contaminated to a depth not less than 8.6 m. The result of water analysedin this area is found to be contaminated by Lead, Chromium and Cadmium with level of contamination exceeds WHO regulated guidelines.The results of soil analysed also indicated that the soils collected in this survey were contaminated by Cd, Ni, Pb, Zn and Cr.

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