DETECTION OF LEACHATE PLUMES MIGRATION USING VERTICAL ELECTRICAL SOUNDING METHOD AND PHYSICOCHEMICAL ANALYSIS AT KPANGUNGUN, MINNA, NIGER STATE, NIGERIA

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Abstract
The aim of this study is to use electrical resistivity method and heavy metal determination as indicators for groundwater pollution at a waste dump site to map leachate plumes and determine the extent of groundwater contamination at Public Dump Site in Kpagungun, Minna. Twenty VES points with an electrode spacing's of AB/2 80 m were occupied along three traverses. Surface data were acquired with an ABEM SAS 4000 terrameter set. Data were processed by conventional curve matching and computer iteration methods using Win Resist Software. VES data were plotted as pseudo sections to provide information on resistivity distribution and geo-electric sections were generated from VES interpretations which revealed second and third layers to be mainly clayey sand and lateritic soils of low resistivity values which varied with distance; an indication of leachate migration. The interpretation of electrical resistivity models revealed regions of very low resistivity (14.8 -25.3 Ωm) to be from an average depth of 4.5 m to an average depth of 17.8 m for profile A; and to a maximum depth of 11.3 m for profile B. These regions of very low resistivity could be contamination zones of the subsurface beneath the profiles resulting from leachate seeping into the soil and or groundwater from the waste dump. The result of the heavy metal determination reveal that concentration of heavy metals (water sample collected from hand dug well and soil sample collected at the waste dump site) was more than that of profile C (water sample collected from hand dug well away from the waste dump site). In terms of WHO, 2011 guideline for drinking water quality, Lead, Chromium and Cadmium are above the guideline values in both water samples.

Keywords: Contaminant; Groundwater; Refuse; Sample; Vertical Electrical Sounding

Introduction

There is an ever-increasing demand for fresh water resources to meet the requirements for industrial, agricultural and domestic needs. The over exploitation of groundwater resources and its contamination have put a stress on the available groundwater resources in the country at large and Minna in particular. However, pollution of groundwater resources can occur directly from municipal waste water, industrial discharges, agricultural waste, urban runoff, landfills or waste dump. There is the possibility that the groundwater within the premises of the refuse dump site could have been polluted. Therefore there is need to carry out a geo-electric investigation of the area around the Kpagungun waste dump site; delineate the lithological sequence, identify the aquifer units and use the resistivity values to assess the groundwater quality; evaluate the quality of the groundwater by carrying out chemical analysis of sampled hand dug wells and soil samples; and use it to assess the degree and extent of impact of the waste dump site on the quality of the groundwater in the study area.

Geophysical surveys are useful in the study of most subsurface geologic problems. Such surveys have found enormous applications in hydrogeological studies. Electrical resistivity method of geophysical technique happens to be the most preferred methods in groundwater contamination studies and hydrogeologic investigations by Mazak et al. (1987) and Carpenter et al. (1990). However, Electrical resistivity surveys have been found very useful for mapping the resistivity structure of the complex subsurface geology (Singh et al., 1985) and the integrated use of hydrochemical and geophysical methods is often recommended (Matlas
et al., 1994), (Kayabali et al., 1998), (Olayinka, and Olayiwola) and (Badmus et al., 2001).

Geology of the Study Area

Minna is located between longitude 6.25^{0}E and 6.45^{0}E and latitude 9.24^{0}N and 9.48^{0}N, it occupy the central portion of the Nigerian basement complex. The Minna area comprises of metasedimentary and meta-igneous rocks which have undergone polyphase deformation and metamorphism. 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 suitesat 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. Granitic rocks dominate the rock types in the area and vary in texture andcomposition.

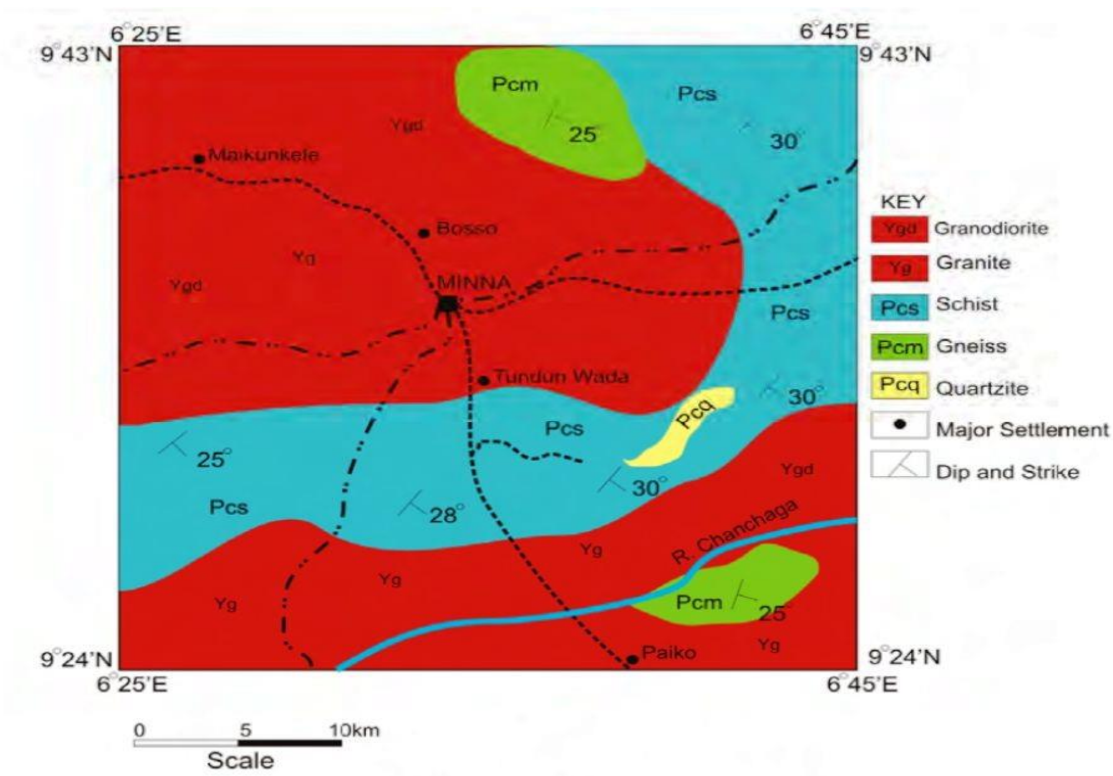

Figure 1: Geology of Minna (after Alabi 2011)

Materials and Methods

The resistivity data acquisition used in this survey was the SAS 4000 ABEM. A minimum of sixteen Schlumberger Vertical Electrical Soundings (VES) with maximum current electrode spacing of 80.0 m were conducted directly inside the dumpsite. Four VES point conducted 200.0 m away from the dumpsite at a location free from temporary dump site served as the control.

Sclumberger array configuration is adopted for this study. A set of nine soil samples were collected around refuse dump from surface and away from refuse disposal siteto a depth of 30 cm and four water sample from existing hand dug wells around the site were collected. Six soil samples inside the dump and three samples at distance of about 200 m away from the dump site and one water sample away from the dump site to serve as control. The cations concentrations were determined using Atomic Absorption Spectrophotometer (AAS). The temperature in (^{O}C) and electrical conductivity (µS/cm) of all groundwater samples were measured and recorded using a Jenway 4010 Conductivity meter. An Oyster Series pH meter calibrated using a buffer 7 solution was used to measure the pH of all groundwater samples. All these physical parameters were determined at time of sampling on the field.

These samples were analysed at laboratory. These heavy metals were analysed for the water samples and soil samples include: Cadmium, Lead, Iron, Calcium, Magnesium, Nickel, Copper, Manganese, Cobalt and Zinc.

Results and Discussion

Table 1 to 3 show the VES results from profile A, profile B and the control site at the Kpagungun refuse dump.

Table 1: General VES results from Profile A during dry season at the Kpagungun Refuse dump

VES NO	Number of ressitivities of layers(Ωm)					Thickness of layers(m)					Depth to bottom layers(m)				
	ρ1	ρ2	ρ3	ρ4	ρ5	t1	t2	t3	t4	t5	d1	d2	d3	d4	d5
1	26.1	20.9	154.0	4241.5		1.0	1.0	2.5	--		1.0	2.1	4.5	--	
2	28.5	101.4	309.0	5296.3		2.0	5.2	4.9	--		2.0	7.2	12.1	--	
3	28.2	14.8	280.4	13956.2		0.9	1.3	3.4	--		0.9	2.2	5.6	--	
4	28.3	15.1	379.9	13735.7		1.0	1.3	3.6	--		1.0	2.2	5.8	--	
5	25.2	25.3	336.3	5695.7		0.8	0.7	14.7	--		0.8	1.5	16.1	--	
6	24.4	20.4	352.2	5347.6		0.7	0.7	14.8	--		0.7	1.4	16.2	--	
7	22.7	240.2	217.0	3968.9		1.4	9.7	6.7			1.4	11.1	17.8	--	
8	22.2	229.2	199.9	4132.4		1.4	9.6	6.6	--		1.4	11.0	17.6	--	

The VES curves in this profile also have been delineated to be a four layer model. VES curves 1, 4 and 6 are HA type curves with configuration $\rho1 > \rho_2 < \rho_3$ = H and $\rho_1 < \rho_2 < \rho_3$ = A which equal $\rho_1 > \rho_2 < \rho_3 < \rho_4$ = HA curve, VES curves2,3 and 5 are AA type curves with configuration $\rho1 < \rho_2 < \rho_3$ = A and $\rho_1 < \rho_2 < \rho_3$ = A which equal $\rho_1 < \rho_2 < \rho_3 < \rho_4$ = AA and VES curves 7 and 8 are KH type curves with configuration $\rho1 < \rho_2 > \rho_3$ = K and $\rho_1 > \rho_2 < \rho_3$ = H which equal $\rho_1 > \rho_2 < \rho_3 < \rho_4$ = KH. The resistivity values for the first layer range between 22.2 Ωm and 28.5Ωm, while the corresponding thickness range between 0.7m to 2.0 m and the corresponding depth also range between 0.7 m to 2.0 m. The lowest resistivity is at VES8 and the highest at VES2. The resistivity values for the second layer range between 14.8 Ωm and 240.2 Ωm, while the corresponding thickness range between 0.7 m to 9.7 m and the corresponding depth also range between 1.5 m to 11.1m. The lowest resistivity is at VES3 and the highest at VES7. The third layer resistivity values range between 154.0 Ωm and 379.9 Ωm. The corresponding thickness and depths for the third layer range between 2.5 m and 14.8 m and 5.6 m and 17.8 m respectively. The lowest resistivity is at VES1 and the highest at VES4 The resistivity values for the fourth layer range between 3968.9 Ωm and 13956.2 Ωm. All the VES have cumulative depth that range between 5.6m and 17.8m. The resistivity values for the first layer range between 22.2 Ωm and 28.5 Ωm correspond to leachate (Abdullahi et al., 2010, Omolayo and Fatoba, 2014) and the resistivity values for the second for some of the VES point show resistivity values that implies sandy soil (permeable), therefore the plume noticed on the surface will percolate in to the groundwater.

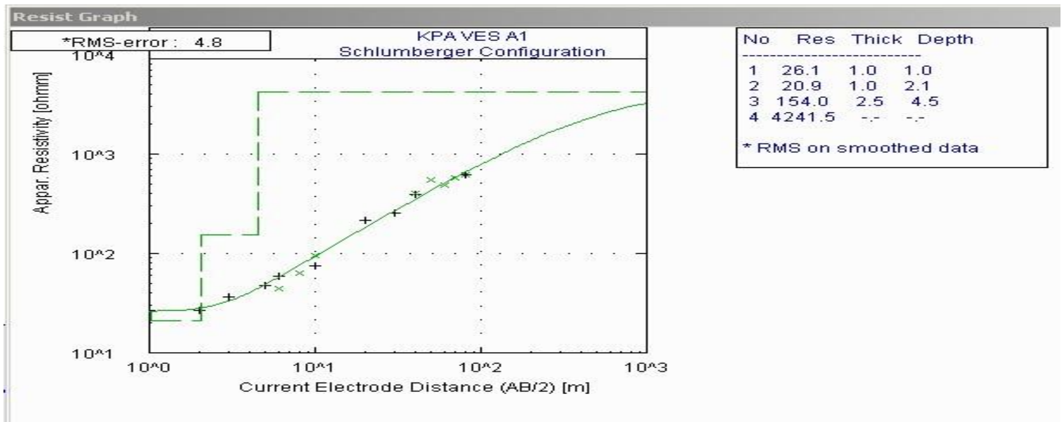

Figure 2: Typical VES curve along Profile A at Kpagungun Refuse dump

Table.2: General VES results from Profile B during dry season at the Kpagungun Refuse dump

	ρ1	ρ2	ρ3	ρ4	ρ5	t1	t2	t3	t4	t5	d1	d2	d3	d4	d5
1	26.7	22.9	2983.0			1.1	1.2	--			1.1	2.3	--		
2	32.6	35.8	3192.8			2.2	1.9	--			2.2	4.1	–		
3	26.9	15.1	13304.8			1.1	1.4	--			1.1	2.54	--		
4	26.5	16.7	12947.8			1.7	9.6	6.6	--		1.7	11.3	17.9	--	
5	22.8	29.8	379.1	5774.1		0.8	0.7	15.3	--		0.8	1.4	16.8	--	
6	25.3	19.8	1669.7			1.7	9.5	6.5	--		1.7	11.6	17.7	--	
7	25.3	20.5	881.3			0.9	0.9	--			0.9	1.8	--		
8	26.7	16.8	306.9	1262.3		0.6	0.7	5.7			0.6	1.4	7.0	--	

The VES curves in this profile are characterised to be a three and four layer model. VES curves 1, 3, 4, 6 and 7 for this profile are H type curves with configuration $\rho 1 > \rho_2 < \rho_3 = H$ and VES curve 2 is an A type with configuration $\rho_1 < \rho_2 < \rho_3 = A$, VES curve 5 is an AA with configuration $\rho 1 < \rho_2 < \rho_3 < \rho_{4=}$ AA and VES8 is HA with configuration $\rho 1 > \rho_2 < \rho_3 = H$ and $\rho_1 < \rho_2 < \rho_3 = A$ which equal $\rho_1 > \rho_2 < \rho_3 < \rho_4 = HA$. The resistivity values for the first layer range between 22.8 Ωm and 32.6 Ωm, while the corresponding thickness range between 0.6m to 2.2 m and the corresponding depth also range between 0.6 m to 2.2 m. The lowest resistivity is at VES3 and the highest at VES1. The resistivity values for the second layer range between 15.1 Ωm and 35.8 Ωm, while the corresponding thickness range between 0.7 m to 9.6 m and the corresponding depth also range between 1.3m to 11.6m. The lowest resistivity is at VES3 and the highest at VES2. The third layer resistivity values range between 306.9 Ωm and 3192.8 Ωm, while the corresponding thickness range between 0.7 m to 9.6 m and the corresponding depth also range between 7.0 m to 17.9 m. The lowest resistivity is at VES8 and the highest at VES3. All the VES have cumulative depth that range between 7.0 m to 17.9 m. The resistivity values

for the first layer range between 22.8 Ωm and 32.6 Ωm correspond to leachate (Bayode et al., 2011, Oladunjoye et al., 2011, Jegede et al., 2011).and the resistivity values for the second for some of the VES point show resistivity values that implies sandy soil (permeable), therefore the plume noticed on the surface will percolate in to the groundwater.

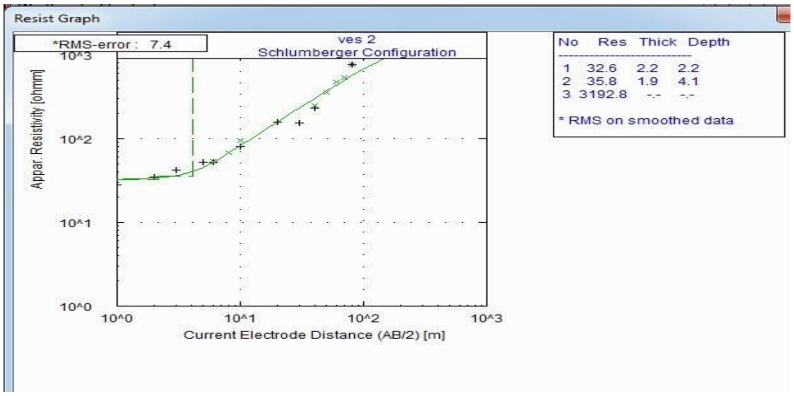

Figure 3: Typical VES curve along Profile B at Kpagungun Refuse dump

Table 3: General VES results from Control site during dry season at the Kpagungun Refuse dump

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VES NO	Number of ressitivities of layers(Ωm)				Thickness of layers(m)				Depth to bottom layers(m)			
	ρ1	ρ2	ρ3	ρ4	t1	t2	t3	t4	d1	d2	d3	d4
1	133.1	77.6	632.4	36530.2	1.1	3.3	2.7	--	1.1	4.3	7.0	--
2	132.9	82.2	127.4	38453.4	1.1	2.3	1.8	--	1.1	3.4	5.2	--
3	132.0	114.8	117.1	34124.6	0.9	2.7	2.1	--	0.9	3.6	5.8	--
4	132.4	112.2	103.0	36724.9	0.9	3.1	5.3	--	0.9	3.1	5.3	--

The VES curves in this profile also have been delineated to be a four layer model. VES curves 1 to 3 for this profile are HA type curves with configuration $\rho1 > \rho_2 < \rho_3$ = H and $\rho_1 < \rho_2 < \rho_3$ = A which equal $\rho_1 > \rho_2 < \rho_3 < \rho_4$ = HA curve and VES curve 4 is a QH curve with configuration $\rho1 > \rho_2 > \rho_3$ = Q and $\rho1 > \rho_2 < \rho_3$ = H which equal $\rho1 > \rho_2 > \rho_3 < \rho_4$ = QH. The resistivity values for the first layer range between 132.0 Ωm and 133.1 Ωm, while the corresponding thickness range between 0.9m to 1.1 m and the corresponding depth also range between 0.9 m to 1.1 m. The lowest resistivity is at VES5 and the highest at VES2. The resistivity values for the second layer range between 77.6 Ωm and 114.8 Ωm, while the corresponding thickness range between 2.3 m to 3.3 m and the corresponding depth also range between 3.1 m to 4.3 m. The lowest resistivity is at VES1 and the highest at VES3. The third layer resistivity values range between 103.0 Ωm and 632.4 Ωm. The corresponding thickness and depths for the third layer range between 2.3 m and 3.3m and 5.2 m and 7.0 m respectively. The lowest resistivity is at VES4 and the highest at VES1. The resistivity values for the fourth layer range between 34124.6Ωm and 38453.4 Ωm. The resistivity values for the first layer range between 132.0 Ωm and 133.1 Ωm implies sandy soil and resistivity values for the second layer range between 77.6Ω m and 114.8 Ωm implies clay soil (impermeable) (Egwebe et al., 2007), thus the groundwater at this site is free from contamination (Adabanija and Alabi, 2014). All the VES have cumulative depth that range between 5.2 m and 7.0 m. All the VES points in this profile are shallow as seen in the hand dug wells within the vicinity of the refuse dump.

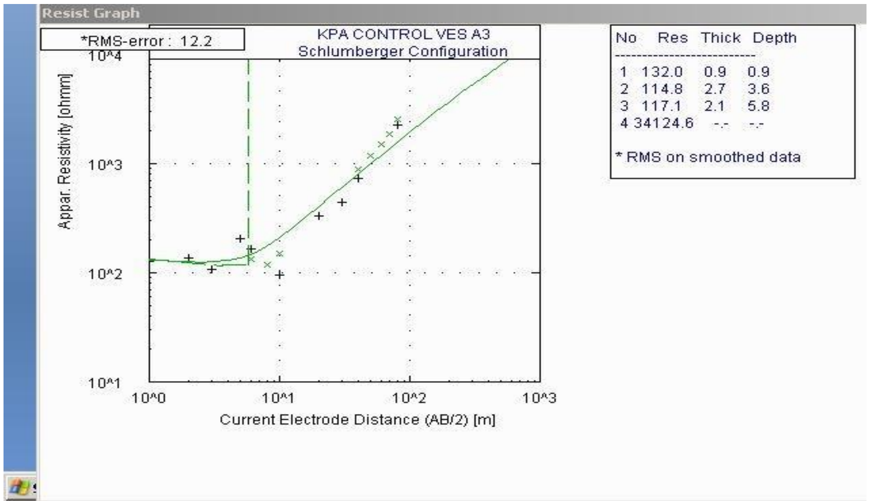

Figure 4: Typical VES curve along Profile C at Kpagungun Refuse dump

Table 4: Physio-Chemical Analysis of Hand Dug Wells in Kpagungun refuse dump

Parameter	Unit	Well A	Well B	Well C	Control Well	WHO
Temp	^{O}C	22.7	27.0	24.0	30.7	40
pH		7.02	7.57	7.14	7.64	6.5-9.2
Conductivity	µS/cm	793	787	793	87	100
Alkalinity	mg/l	1,150	1,440	1,180	169	200
Acidity	mg/l	33	88	83	37	
TDS	mg/l	800	1400	1300	220	500-550
Total Hardness	mg/l	66	66	63	50	500
Zinc	mg/l	0.05913	0.08483	0.07198	0.0005	3.0
Lead	mg/l	0.19231	0.00000	0.38462	0.0000	0.001
Manganese	mg/l	0.22857	0.15714	0.08571	0.0023	0.5
Iron	mg/l	0.06757	0.03378	0.03378	0.0125	0.3
Copper	mg/l	0.00000	0.25000	0.25000	0.0000	2.0
Chromium	mg/l	1.25000	0.41667	0.83333	0.0062	0.05
Nitrogen	mg/l	0.00000	0.00000	0.00000	0.0000	
Cobalt	mg/l	0.02857	0.00000	0.02857	0.0001	
Cadmium	mg/l	0.09697	0.00606	0.00606	0.0012	0.003

The temperature for the groundwater in the study area ranged between 22.7 ^{O}C and 27.0 ^{O}C which is below WHO limits and the control well has a temperature of 30.7 ^{O}C. The Groundwater pH value for Kpagungun well averaged 7.24, while pH value for control well is 7.64. 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 similar to work of Jegede et al., 2011 and Adabanija and Alabi 2014.

Table 5: Physio-Chemical Analysis of Soil Samples in Kpagungun refuse dump

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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)
KG1	6.81	6.8123	9.61539	18.57140	6.7568	50.00000	125.0000	30.0000	8.5714	0.7369
KG2	6.62	4.8843	9.43271	15.00000	5.3649	37.50000	62.50000	25.0000	5.2857	0.5445
KG3	6.51	4.2417	9.15385	11.42860	4.9716	25.00000	57.30010	20.0000	4.8571	0.3683
KG4	6.41	3.5990	8.72539	7.85714	3.3784	20.00000	41.66670	15.0000	3.5322	0.2312
KG5	6.92	3.2561	8.02583	4.28571	2.8046	16.50000	36.62801	10.0000	2.4286	0.1674
KG6	6.42	2.9563	7.83517	3.21486	1.6892	12.50000	20.83330	6.00000	1.6246	0.0863
Min	6.41	2.9563	7.83517	3.21486	1.6892	12.5000	20.8333	6.0000	1.6246	0.0863
Max	6.92	6.8123	9.61539	18.57140	6.7568	50.00000	125.0000	30.0000	8.5714	0.7369
Mean	6.62	4.2916	8.7981	10.0596	4.1609	26.9166	57.3214	17.6667	4.3833	0.3558
S.D	0.21	1.4172	.7384	6.0625	1.8658	14.2317	36.3645	9.0921	2.4793	0.3334
KGC1	6.18	0.0017	0.0000	0.0072	0.0014	0.0000	1.0057	0.0000	0.0056	0.0004
KGC2	6.25	0.0128	0.0058	0.0156	1.0010	3.5000	2.0000	1.0000	0.0084	0.0003
KGC3	6.30	0.0010	0.0000	0.0018	0.0031	5.0000	4.6667	2.0000	0.0064	0.0011
Min	6.18	0.0010	0.0000	0.0018	0.0010	0.0000	1.0057	0.0000	0.0056	0.0003
Max	6.30	0.0128	0.0058	0.0156	1.0010	5.0000	4.6667	2.0000	0.0084	0.0011
Mean	6.24	0.0052	0. 0019	0.0082	0.3352	2.8333	2.5575	1.0000	0 .0068	.0008
S.D	0.06	0 .0067	0. 0033	0.0.070	0.5767	2.5658	1.8931	1.0000	.0015	0.0004

KG: Kpagungun, KGC: Kpagungun Control

In all the metals analysed, the concentrations are higher at distance 10 m from the centre of each dumpsite and decreases as distance increases to 60 m. The concentrations further decrease at control points of about 200 m away from three sides of the refuse dump. This trend is observed in Awokunmi et al., (2010) and Riziki (2010). This trend showed that the concentration of heavy metals is due to the effect of waste disposal. The pH value for all points at all the sites is less than 7. 0 this implies slightly acidic. Bahaaeldin et al., (2010) found that the average value for pH was 6.7 for municipal landfill leachate indicating the young leachate and waste degradation was at its late stage of acidic phase. The values for the present study also fall within this range. These values imply that the pH of the soil within the study area is acidic and are probably due to the leaching of organic acids from decaying vegetation (Alile et al., 2010).

Conclusion

This study has revealed probable contamination zone beneath the subsurface where the waste dump site is located and this contamination zone is a region of very low resistivity (14.8- 35.8 Ωm) which could result from metals (heavy metals inclusive) entering the soil and ground water from the waste dump site while the heavy metal determination revealed some of the heavy metals that result in such very low resistivity values. The hydrogeologic features of the study areas indicated that contaminants derived from the waste disposal sites infiltrate through the vulnerable sandy aquifer and hence to the groundwater flow. This suggests that the soil and the groundwater system had been contaminated beyond the depth of 17.8 m in the study area. Combining the results of the resistivity survey and the heavy metal determination helped to reveal probable ground water contamination zones and the heavy metals that could result in the contamination.

References

Abdullahi, N. K., Osazuwa, I. B. & Onugba, A. (2010). Detecting municipal solid waste leachate plumes through electrical resistivity survey and physio-chemical analysis of Ground water samples. Journal of Amereican Science, 6(8).

Alabi, A. A. (2011). Geology and environmental impact assessment and benefit of granitic rock of Minna Area, Northwestern Nigeria. Ethiopian Journal of Environmental Studies and Management, 4(4).

Alile, O. M. & Emekeme, R. E. (2010). Subsurface probe and hydrochemical analysis for the purpose of sitting waste landfill. African Journal of Environmental Science and Technology (AJEST), 4(1).

Awokunmi, E. E., Asaolu, S. S. & Ipinmoroti, K. O. (2010). Effect of leaching on heavy metals concentration of soil in some dumpsites. African Journal of Environmental Science and Technology (AJEST), 4(8).

Badmus. B. S., Odenwande, A. A., & Oyedele, T. (2001). Leachate contamination effect on groundwater exploration. African Journal of Environmental Studies, 2(1), 38 - 41.

Bahaa-eidin, E. A. R., Yusoff, I., Samsudin, A. R., Yaacob, W. Z. W. & Rafek, A. G. M. (2010). Deterioration of groundwater quality in the vicinity of an active open-tipping site in West Malaysia. Hydrogeology.

Bayode, S., Omosuyi, G. O., Mogaji, K. A. & Adebayo, S. T. (2011). Geoelectrical delineation of strucuturally-controlled leachate plume around Otutubiosun dumpsite, Akure, Southwestern Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), 2(6).

Carpenter, P. J., Kaufmanna, R. S. & Price, B. (1990). Use of resistivity soundings to determine landfill structure. Groundwater, 28,569-575.

Egwebe, O., Aigbun, C. O. & Ifedi, S. O. (2007). Geoelectrical evaluation of waste dump sites in Warri and its environs, Delta State, Nigeria. Journal of Applied Sciences and Environment Management (JASEM), 11(2).

Jegede, S. I., Osazuwa, I. B. & Abdullahi, N. K. (2011). Geoenvironmental study of groundwater contamination in a dual aquifer environment using earth resistivity imaging. Journal of American Science, 7(2).

Kayabali, K., Yueksel, F. A. & Yeken, T. (1998). Integrated use of hydrochemistry and resistivity methods in groundwater contamination caused by a recently closed solid waste site. Environmental Geology, 36(3 & 4), 227 - 234.

Matlas, M. S., Marques, B., DeSilva, M., Ferreira, P. & Ramalho, E. (1994). A geophysical and hydrochemical study of aquifer contamination by landfill. Journal of Applied Geophysics, 32, 155-162.

Oladunjoye, M. A., Olayinka, A. I. & Amidu, S. A. (2011). Geoelectrical Imaging at an abandoned waste dump site in Ibadan Southwestrn Nigeria. Journal of Applied Sciences, 11(22).

Olayinka, A. I. & Olayiwola, M. A. (2001). Integrated use of geoelectrical imaging and hydrochemical methods in delineating limits of polluted surface and groundwater at a landfill site in Ibadan area. Southwestern. Nigeria Journal of Mining and Geology, 37(1), 53-68.

Omolayo, D. & Fatoba, J. T. (2014). 2D electrical imaging surveys for leachate plume migration at an old dump site in Ibadan South Western Nigeria: A Case Study. International Journal of Geophysics, Article ID 879530, 6.

Riziki, S. S. (2010). Heavy metal concentrations in soils and leachates of mtoni dumpsite bordering the Indian Ocean in Dares Salaam, Tanzania. Scientific Research and Essays, 5(16).

Singh, S. B., Dhar, R. L. & Gupta, C. P. (1985). Application of deep resistivity soundings for groundwater exploration in Barmer district, Rajastan. Technical report, NGRI-91 Environment – 102 (17).