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Geoelectric study of major landfills in the Lagos Metropolitan Area, Southwestern Nigeria

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Geoelectric study of Abule Egba, Igando and Olushosun landfills within Lagos municipality has been undertaken to determine their hydrogeologic implications. The field technique involved vertical electrical soundings utilizing Schlumberger electrode array. At Abule Egba, landfill materials are defined by resistivity varying between 1.6 Ω-m at decomposed stage and 144 Ω-m within fresh dump. The Igando landfill is defined by resistivity varying between 2.5 Ω-m at decomposed stage and 26.1 Ω-m at fresh dump. Olushosun landfill is defined by resistivity varying between 2.4 Ω-m at decomposed stage and 51.5 Ω-m at fresh dump. Interpretation of sounding curves showed that Abule Egba is underlain by fairly thick column of clayey sand indicating an unconfined aquifer. Igando landfill is underlain by thick clay column indicating a confined aquifer. The northern flank of Olushosun landfill is overlain by thin refuse dump (4.4 m) while thick refuse dump (22.9 m) overlies the central area. The hydrogeologic system at Abule Egba is vulnerable to contamination. The impermeable geoelectric characteristics of materials underlying Igando landfill offer the hydrogeologic system some form of protection. At Olushosun landfill, materials of impermeable geoelectric characteristics in the northern flank offer hydrogeologic protection while fairly permeable materials in the south offer limited hydrogeologic protection.

Key words: Geoelectric, landfill, resistivity, contamination, hydrogeologic system, aquifer.

INTRODUCTION

Land filling remains the most important technology for municipal solid waste management (Petruzzelli et al., 2007). However, groundwater contamination remains a major concern in the operation of landfills. This is due to the pollution effects of landfill leachates and its potential health risks (Lee and Jones-Lee, 1993a, b; Christensen et al., 2001; Stollenwerk and Colman, 2003; Longe and Enekwechi, 2007). Landfill is the cheapest way of disposing municipal solid wastes, but all efforts to get rid of waste also pollute the environment to some extent. For instance, landfills may pose serious threat to the quality of the environment if incorrectly secured and improperly operated while the threat to surface and ground waters could be deleterious (Longe and Balogun, 2010).

Many landfills in Nigeria have not been designed to protect the environment from pollution. As rain washes through dumped waste, some of the solids are dissolved while liquids are mixed. The water can become acidic and act on the waste in containers thus producing leachate. Leachate formation therefore is the main environmental impact during land-filling operation. The greatest contamination threat to groundwater therefore comes from the leachate generated from the fill materials

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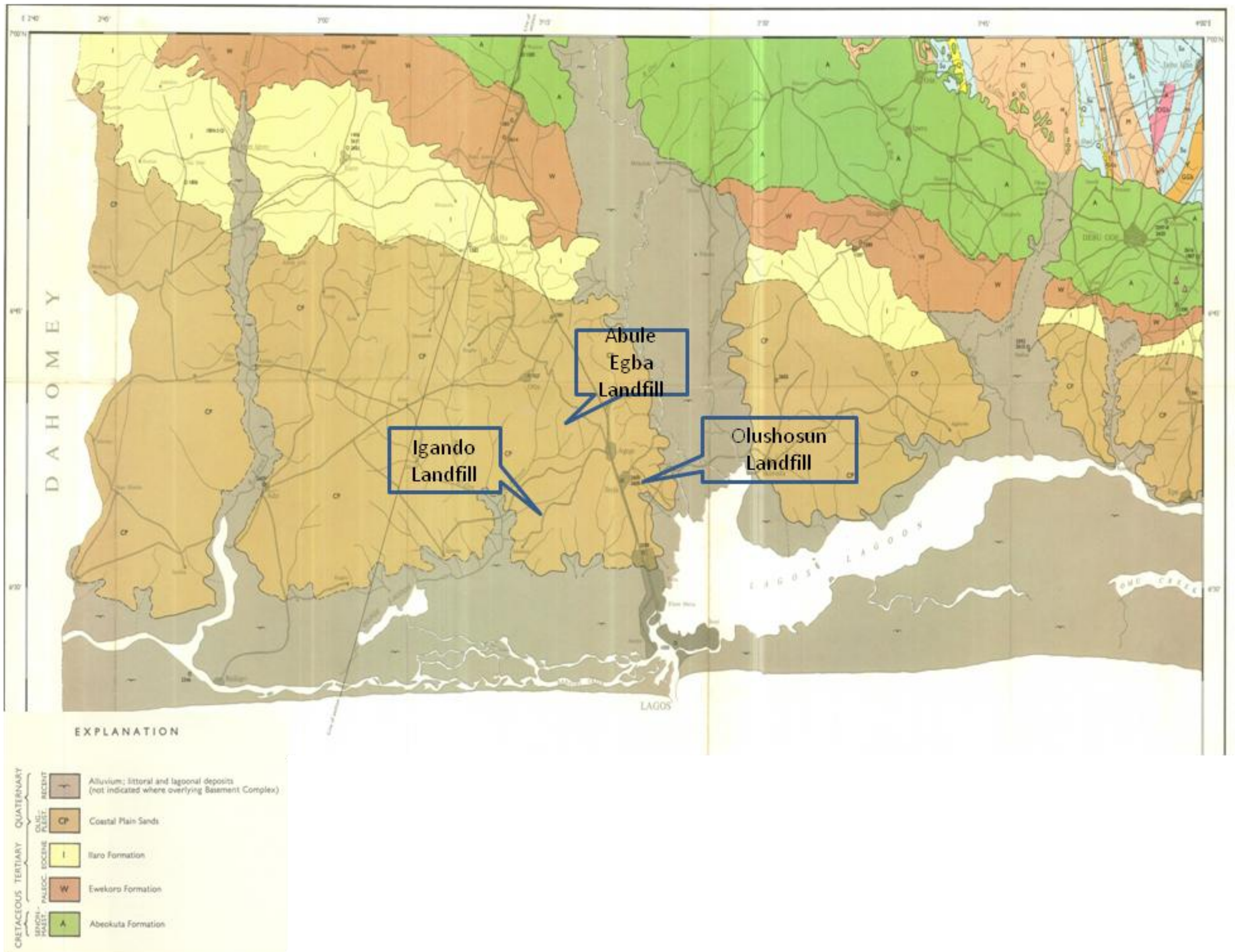


Figure 1. Geological map of Lagos showing location of the three major landfills of study.

which most often contain toxic substances especially when wastes of industrial origin are landfilled (Longe and Enekwechi, 2007; Ogundiran and Afolabi, 2008; Longe and Balogun, 2009). Composition of leachates is variable depending on type, origin and composition of the wastes, the structure, management and the age of the landfill (Ehrig, 1989; Eckenfelder, 2000).

In the Lagos area (Figures 1 and 2), the cheap mode of disposal of huge refuse matters being generated domestically and industrially has over the years, been reducing the potential sources of utilizable water for the growing population (Asiwaju-Bello and Akande, 2001). Information on sub-surface geology and aquifer characteristics below the metropolis indicate a complex lithology of alternating sand and clay deposits with three aquifer horizons (Longe et al., 1987). The water table aquifer (average thickness of 8 m) which is mostly exploited (Longe et al., 1987) is exposed to the danger of pollution by leachate effluent from indiscriminately sited refuse dump grounds (Asiwaju-Bello and Akande, 2001).

Location description

The Lagos metropolitan area is situated within latitudes N06° 23' and N06° 40' and longitudes E03° 13' and E03° 27'. There are 3 major landfills sites serving the Lagos metropolitan area. They are Abule Egba, Igando and Olushosun (which is the largest and still remains very active) (Figure 2).

Abule Egba landfill (Figures 3 and 4) is situated on the NNW flank of Lagos along the Lagos – Abeokuta highway. The site occupies a land of about 10.2 ha in the Western part of Lagos in the Alimosho Local Government and receives waste from the densely populated area. The residual life span is approximately 8 years. The Abule Egba landfill has been inactive since 2008. Four Vertical Electrical Sounding (VES) points were occupied within the refuse dump area while one VES point was occupied along Balogun Crescent as control. VES 1 and VES 2 data were acquired within the old refuse dump where landfill activities commenced in 1992. VES 3 data were

Figure 2. Satellite image of Lagos Mainland showing the location of three major landfills.

Figure 3. Satellite image showing the location of Abule Egba Landfill.

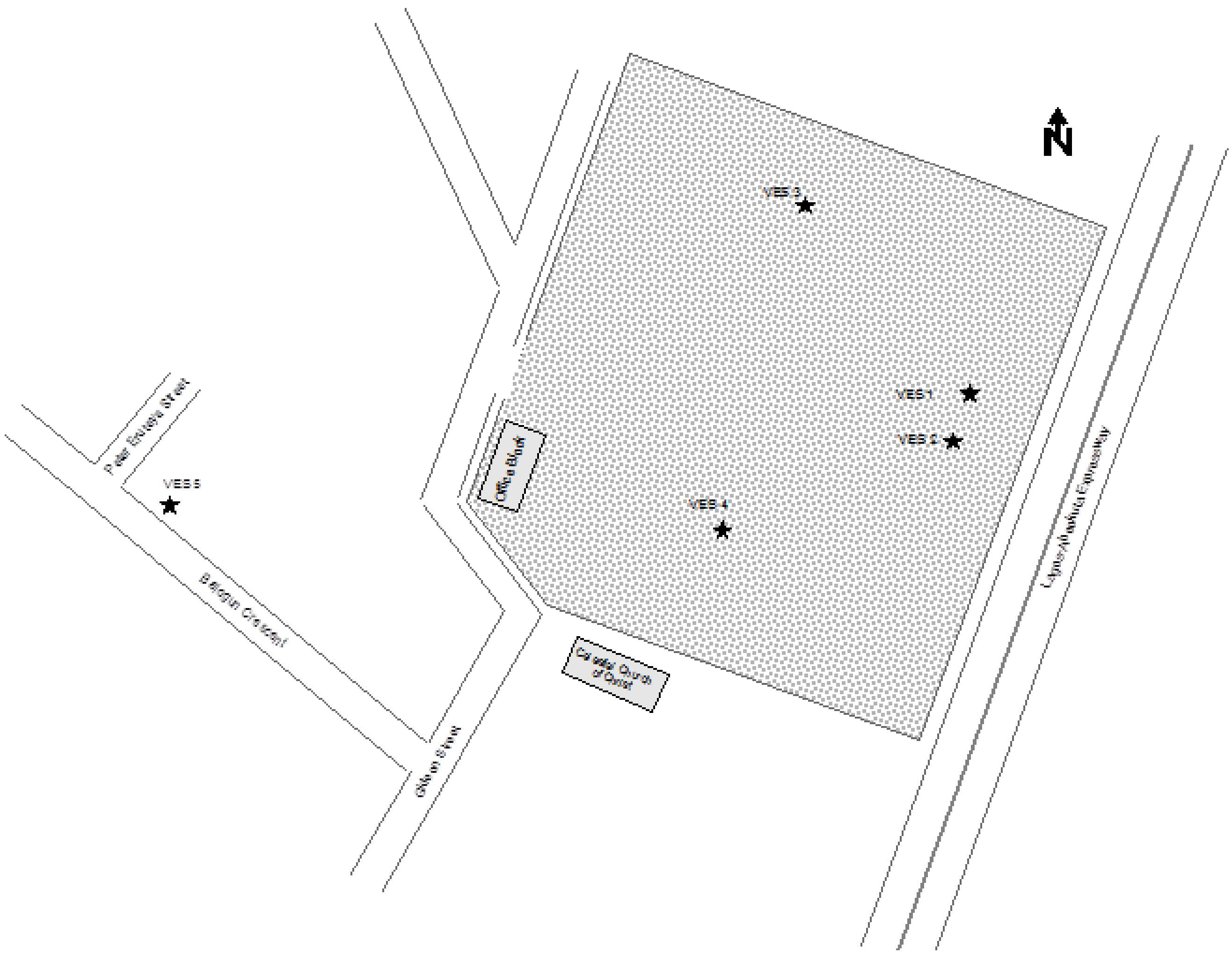


Figure 4. Layout map of Abule Egba landfill showing data points.

acquired in area of fairly recent refuse dump (2006 to 2007 phase). VES 4 data were acquired within area of long abandoned dump.

Igando landfill is situated along Lagos State University – Iba Road on 7.8 ha of land (Figures 5 and 6) with average life span of 5 years. The landfill has not been active since 5th October 2006. Four VES points were occupied (Figure 6). VES 1 was located in the central area of the landfill. VES 2 was located on the western limit of the landfill. The data were acquired on cut segment of the burrow pit. VES 3 was located on area of recent dump with fairly unconsolidated refuse. VES 4 was located close to the Lagos State University/Ojoo – Idimu roadway and served as control to enable the understanding of hydrogeologic setting in the Igando area.

Olushosun landfill (Figures 7 and 8) is situated in the northern part of Lagos within Ikeja Local Government and receives approximately 40% of the total waste deposits from Lagos. The size is 42.7 ha and a residual life span of 20 years. It is the largest in Africa, and one of the largest in the world. The landfill has been active since Friday 19th Novermber 1992. The site was initially a burrow pit where laterite was obtained for construction of roads around Lagos. The landfill was designed to receive 7,365.000 tonnes of solid waste during its operational lifespan of 10 years. This figure represents a yearly average tipping volume of 736,500 tonnes (Longe and Enekwechi, 2007). Operational design of waste to cover ratio of 9:1 was chosen for the ten years duration (Lavalin, 1992) Five VES points were occupied (Figure 8) within the landfill. VES 1 was located on active refuse dump area in the middle of the landfill. VES 2 is located on the fairly consolidated refuse column on the northern flank of the landfill. VES 3 was located on the area which was free of refuse dump at time of investigation on the northern flank. VES 4 was located within leachate drain area north of the landfill. VES 5 was located in the deep burrow pit south of the landfill.

Figure 5. Satellite image showing the location of Igando Landfill (landfill east of motorway is under reference).

Local Geology/Geomorphology

Lagos metropolis is located within the Western Nigeria Coastal Zone, a zone of coastal creeks and lagoons (Pugh, 1954; Longe et al., 1987) developed by barrier beaches associated with sand deposition (Hill and Webb, 1958). Adegoke et al. (1980) recognized five geomorphologic sub-units in the coastal landscape. These are the abandoned beach ridge complex, coastal creeks and lagoons, swamp flats, forested river floodplain and active barrier beach complex.

Lagos is underlain by the Dahomey Basin (Figure 1) with lithologic constituents that are mainly sands, clays and limestones (Jones and Hockey, 1964; Longe et al., 1987; Nwankwoala, 2011). The basement complex which forms the basement rocks in the basin is overlain in succession by the Cretaceous Abeokuta Formation which is sandy with inter-bedded shales and limestone formation. Following it is the Tertiary Ewekoro Formation comprising of limestone, clays and shales and the Ilaro Formation consisting of clays and shales followed by the poorly sorted Coastal Plain Sands and Recent Alluvial Deposits. The latter which consists of lithoral and lagoonal sediments of the coastal belt is characterized by Mangrove (saltwater) and freshwater swamps where aquifers, are readily recharged by copious rainfall thus making them vulnerable to leachate contamination in areas proximal to landfills. The lithological disposition of the aquifers gives rise to artesian and sub-artesian conditions in places. In the Lagos metropolitan area, the Coastal Plain Sands are the major aquifers generally exploited by low and medium income earners for water supply.

MATERIALS AND METHODS

Electrical resistivity method commonly used for hydrogeological, mining, geotechnical investigations, and environmental surveys (Koefoed, 1979; Loke, 1999) was adopted for the study. Subsurface electrical resistivity is related to buried materials and various geological and hydrogeological parameters such as the mineral and fluid content, porosity and water saturation (Stanton and Schrader, 2001).

The current electrode separation (AB) was varied from a minimum of 2.0 m to a maximum ranging from 80 to 450 m at the VES locations. PASI model 16-GL resistivity meter complete with

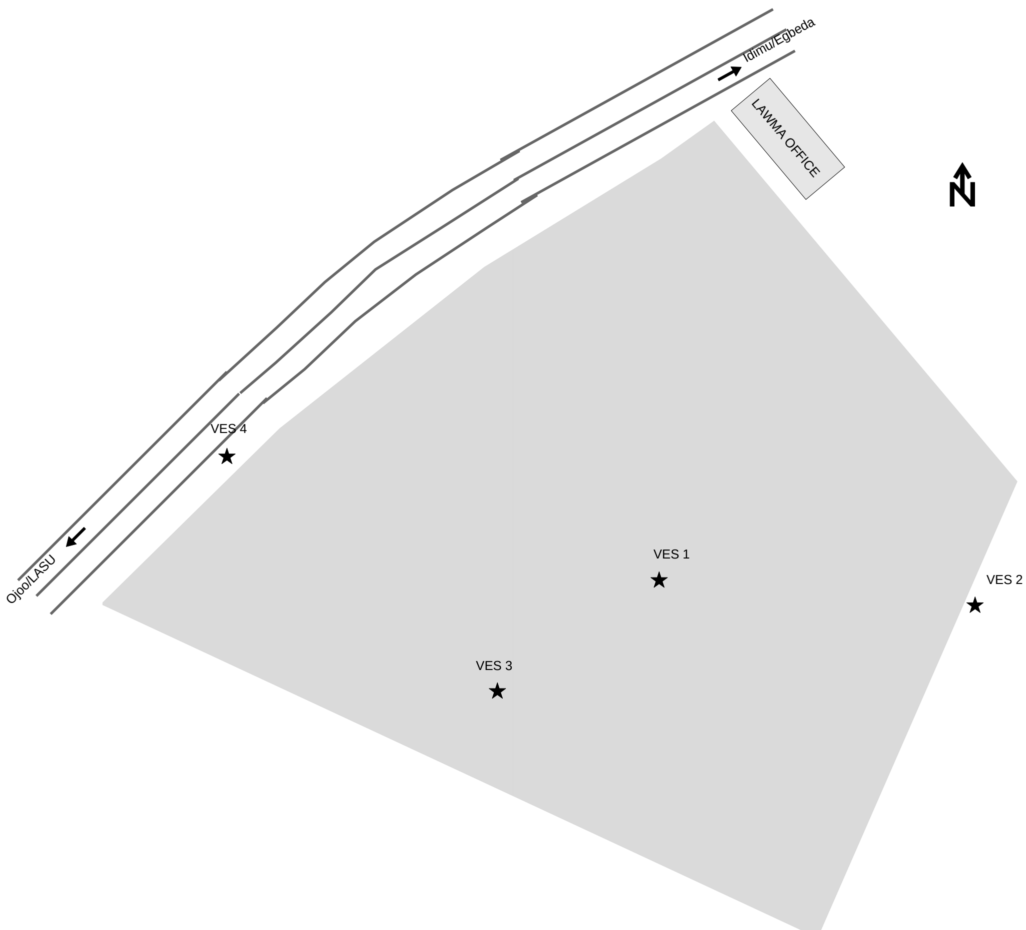


Figure 6. Layout map of Igando Landfill showing data points.

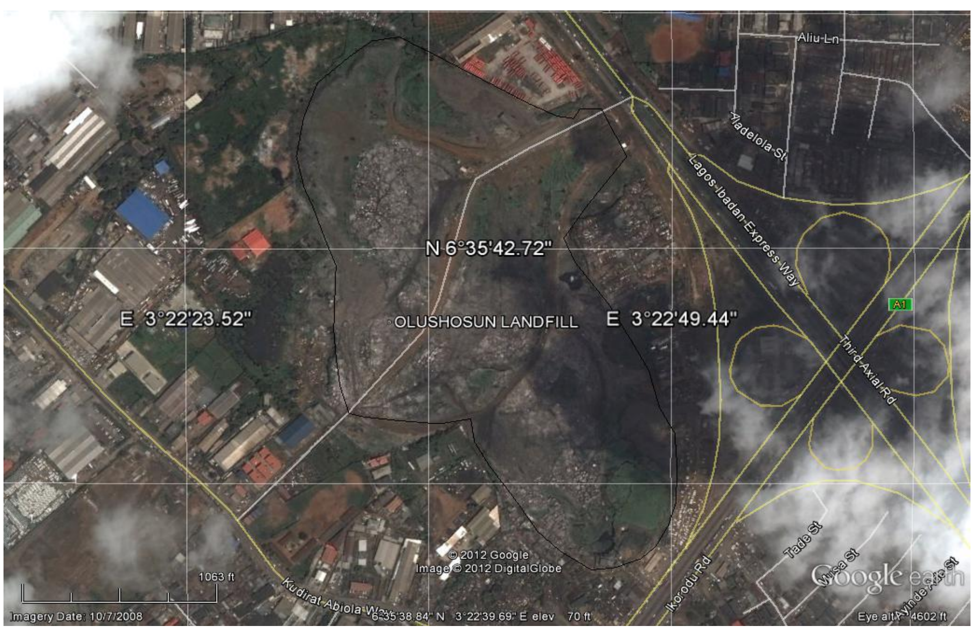


Figure 7. Satellite image showing the location of Olushosun Landfill.

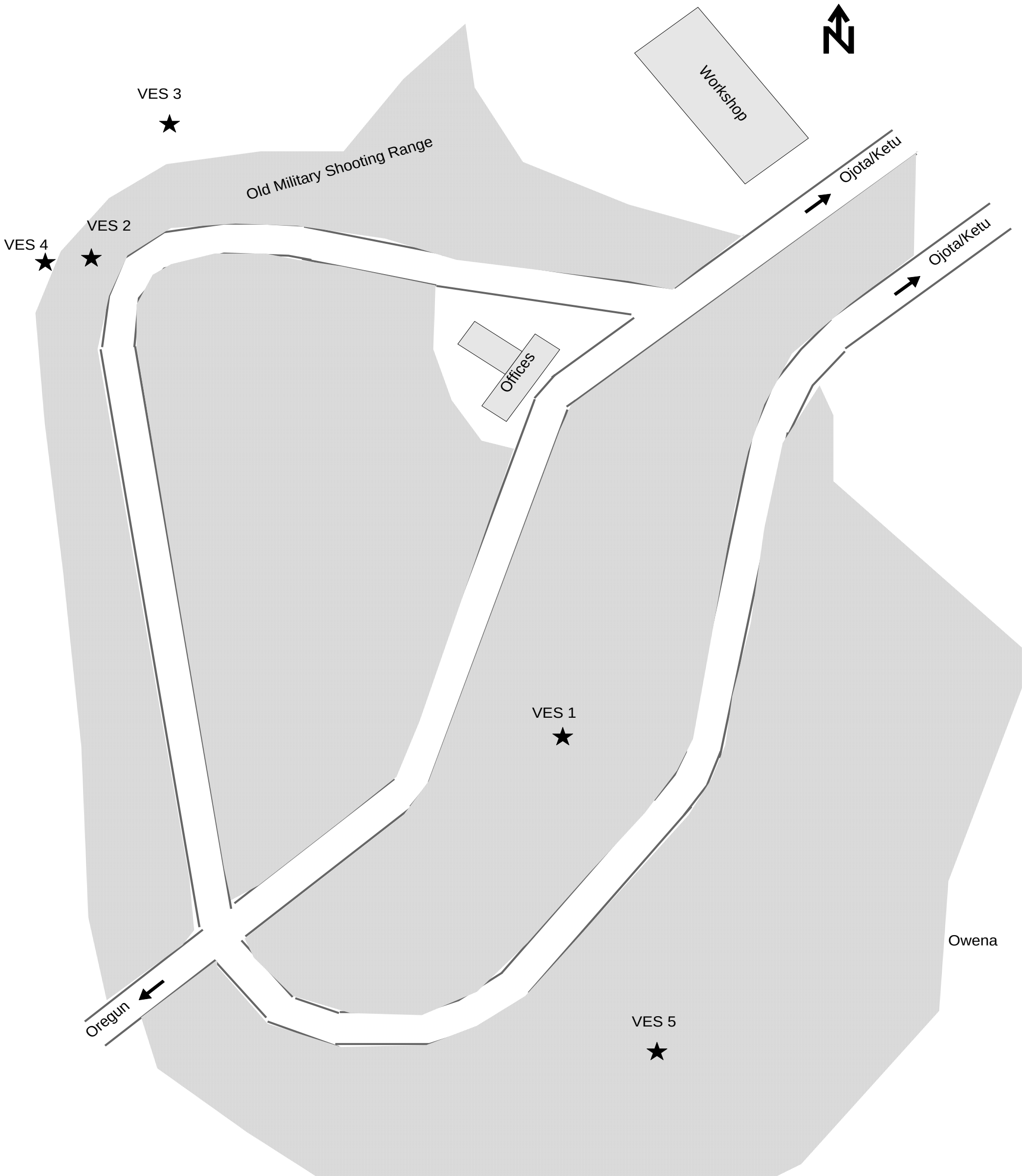


Figure 8. Layout map of Olushosun Landfill showing data points.

peripherals, (www.pasigeophysics.com) were used for field data acquisition in form of apparent resistivity measurements.

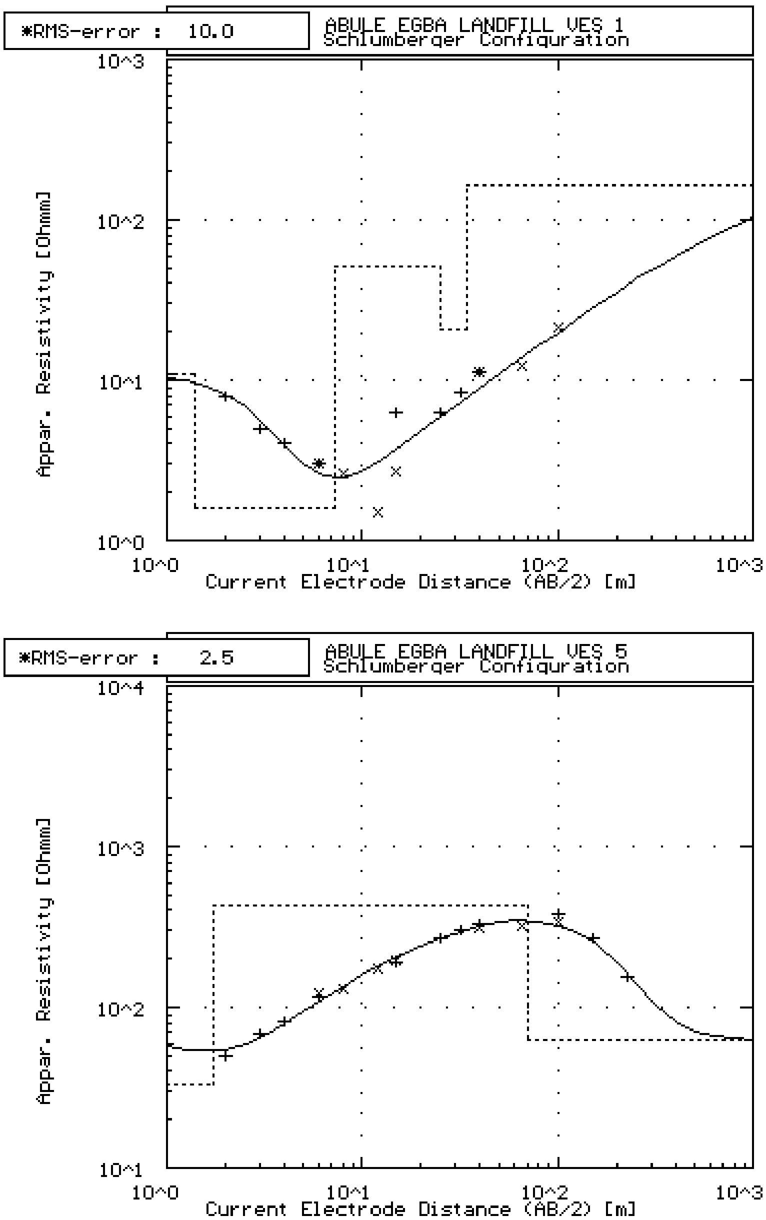
The field data acquired are presented as sounding curves. Qualitative interpretation of the curves involved evaluation of curves for geoelectric characterization of the landfills. Quantitative interpretation of the curves involved partial curve matching using two-layer Schlumberger master curves and the auxiliary curves. Outputs were modelled using computer iterations.

RESULTS

Sounding curve types obtained at Abule Egba are HKH, QH, QQH, KQH and HK (typical curves in Figure 9) while the curve types obtained from Igando are H, K and KH (typical curves in Figure 10). Olushosun landfill is typified by H, HKQ, KH and HKH curve types (typical curves in Figure 11). The interpretation results are presented in Table 1.

DISCUSSION

The results of the geophysical studies conducted on three landfills in Lagos metropolitan area show that the refuse columns are generally characterized by low resistivity values. On the contrary, the superficial soil



No	Res	Thick	Depth
1	10.9	1.4	1.4
2	1.6	5.9	7.3
3	51.5	17.6	24.9
4	20.9	9.7	34.6
5	163.4	-.-	-.-

* RMS on smoothed data

No	Res	Thick	Depth
1	63.5	0.7	0.7
2	33.0	1.1	1.7
3	433.8	68.8	70.6
4	62.0	-.-	-.-

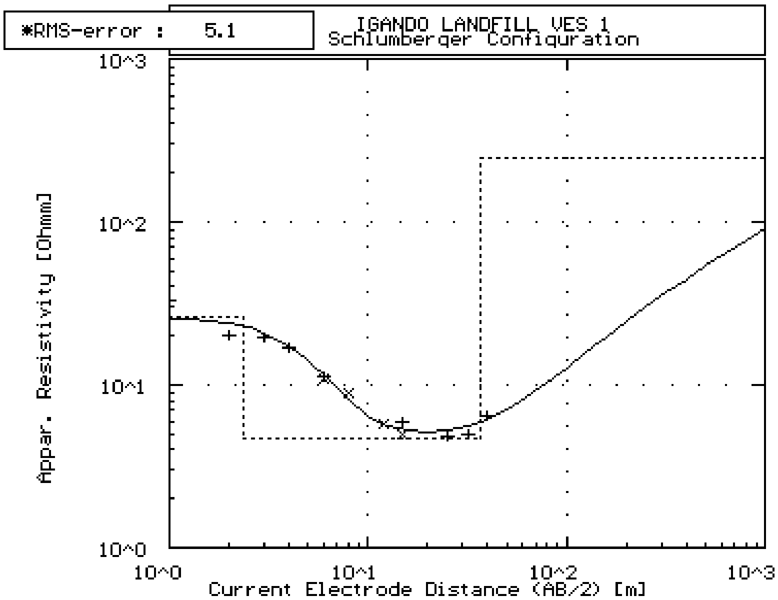
* RMS on smoothed data

Figure 9. Typical Geoelectric Sounding Curves obtained at Abule Egba Landfill.

materials hosting the refuse are characterized by fairly high resistivity values. The contrast in the electrical resistivity characteristics of the dumps and the surrounding host rocks enabled the delineation of the refuse dump column. However, fresh domestic type refuse in the landfills are characterized by high resistivity values.

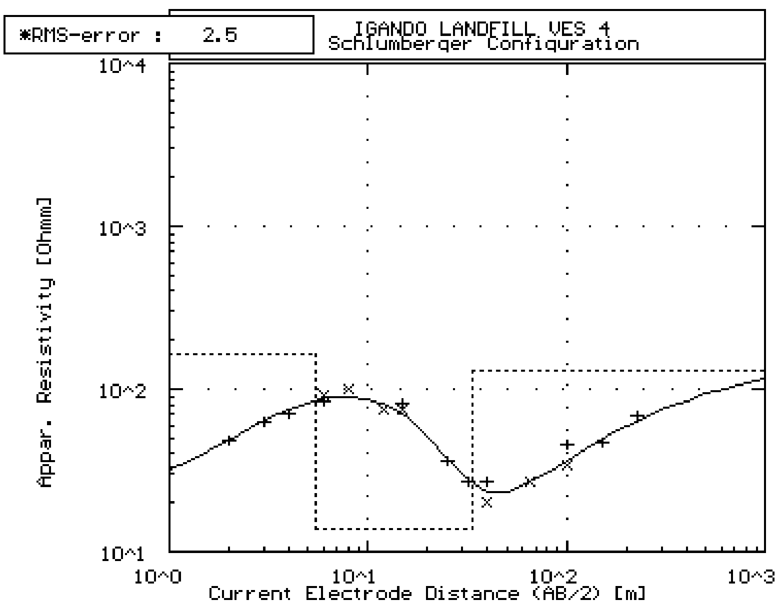
The refuse columns within Abule Egba landfill are defined by low resistivity values at decomposed stage. The decomposed resistivity values vary between 1.6 and 8.5 Ω-m. Within recent dump areas, the resistivity values vary between 14.7 and 144 Ω-m. Hydrogeologic evaluation of VES 5 data which is located within residential area devoid of refuse presented high resistivity upper strata sequence indicative of unconfined aquifer setting. Thus, from hydrogeological point of view Abule Egba landfill is situated in an unsuitable location due to considerable groundwater recharge capability of the resistive upper sequence. Geoelectric section of Figure 12 has also shown that Abule Egba landfill environment is underlain by thick column (70.6 m) of clayey sand and sandy clay.

At Igando the refuse is defined by resistivity values varying between 2.5 Ω-m at the decomposed stage and



No	Res	Thick	Depth
1	26.1	2.3	2.3
2	4.7	34.6	36.9
3	247.6	-.-	-.-

* RMS on smoothed data



No	Res	Thick	Depth
1	26.0	0.8	0.8
2	165.6	4.6	5.4
3	13.7	28.3	33.8
4	131.7	-.-	-.-

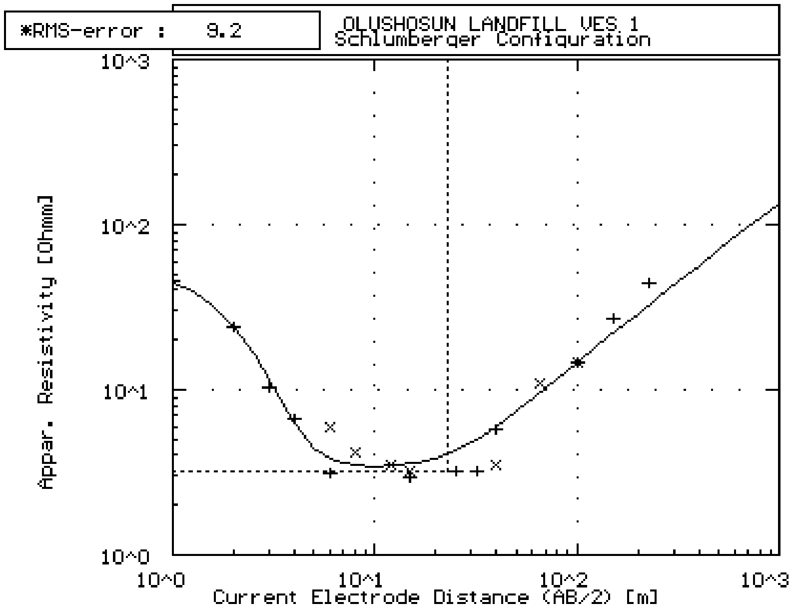
* RMS on smoothed data

Figure 10. Typical Geoelectric Sounding curves obtained at Igando Landfill.

26.1 Ω-m at fairly decomposed/dry stage. The surrounding lithologic units are defined by low resistivity values that are indicative of clay. An average refuse thickness of about 9 m was obtained in the Igando landfill.

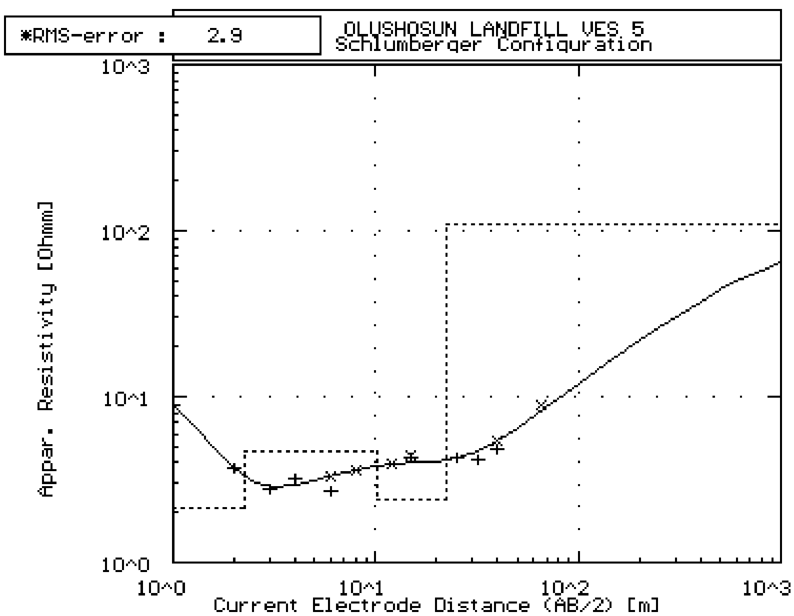
Most of the Igando landfill refuse consist essentially of domestic type trashes with the waste stream consisting of domestic, market, commercial, industrial and institutional origins. The geoelectric section at Igando (Figure 13) shows that the landfill is underlain by thick impermeable laterite/clay column. This geoelectric sequence aptly agrees with the description of Longe and Balogun (2010) where they described the soil stratigraphy of Solous (Igando) landfill to consist of clay intercalated with lateritic clay. This lithology is capable of protecting the underlying confined aquifer from leachate contamination. The aquifer at Igando is confined with limited susceptibility to contamination as already shown by groundwater quality assessment undertaken within the water table zone of the landfill by Longe and Balogun (2010).

The refuse at Olushosun is defined by resistivity values varying between 2.4 Ω-m at decomposed stage and 51.5 Ω-m at fresh dump. The geoelectric section at Olushosun (Figure 14) shows that the northern flank of the landfill is



No	Res	Thick	Depth
1	51.5	1.0	1.0
2	3.2	21.9	22.9
3	1615.9	-.-	-.-

* RMS on smoothed data



No	Res	Thick	Depth
1	15.0	0.5	0.5
2	2.1	1.7	2.3
3	4.7	7.8	10.1
4	2.4	12.0	22.1
5	109.5	-.-	-.-

* RMS on smoothed data

Figure 11. Typical Geoelectric Sounding Curves obtained at Olushosun Landfill.

overlain by relatively thin refuse section (4.4 m) while thick refuse section (22.9 m) overlie the central areas. The Olushosun landfill was excavated to various depth levels thus the underlying soil strata vary in composition from clay/laterite on the northern flank to clay within the deep burrow pit area of the south. The geoelectric outlay as obtained in this study is consistent with the hydrogeological setting of Olushosun earlier described by Longe and Enekwechi (2007). The sub-surface geology of the landfill which is described to be underlain by a water-bearing zone consisting of loose, medium to coarse sand with an average thickness of 10.4 m (Longe and Enekwechi, 2007) poses a threat to aquifers in the environment.

Conclusion

The results of the geophysical investigation conducted at Abule Egba showed that the lithologic units beneath the dump area have permeable geoelectric characteristics. Thus, the hydrogeologic system at Abule Egba is vulnerable to leachate contamination. The landfill at Abule Egba has the potential to contaminate groundwater.

Table 1. Interpretation results.

Location	VES No.	Depths (m) $d_1/d_2/\ldots\ldots/d_{n-1}$	Resistivity (Ω-m) $\rho_1/\rho_2/\ldots\ldots/\rho_n$
Abule Egba	1.	1.4/7.3/24.9/34.6	10.9/1.6/51.5/20.9/163.4
	2.	1.0/4.3/9.8	58.3/4.4/1.7/120.8
	3.	1.9/4.8/9.5/21.2	60.2/14.7/8.5/5.6/271.9
	4.	0.4/1.8/5.1/17.4	6.4/144.1/5.9/2.0/191.4
	5.	0.7/1.7/70.6	63.5/33.0/433.8/62.0
Igando	1.	2.3/36.9	26.1/4.7/247.6
	2.	0.6/4.9	255/544/152
	3.	1.0/5.7/9.1	3.8/7.7/2.5/249
	4.	0.8/5.4/33.8	26/165.6/13.7/131.7
Olushosun	1.	1.0/22.9	51.5/3.2/1615.9
	2.	0.6/4.4	8.0/2.6/660.7
	3.	0.9/3.7/13.3/25.3	1176/494/6346/874/86
	4.	0.4/2.6/12.4	1.8/56.0/4.7/61.6
	5.	0.5/2.3/10.1/22.1	15.0/2.1/4.7/2.4/109.5

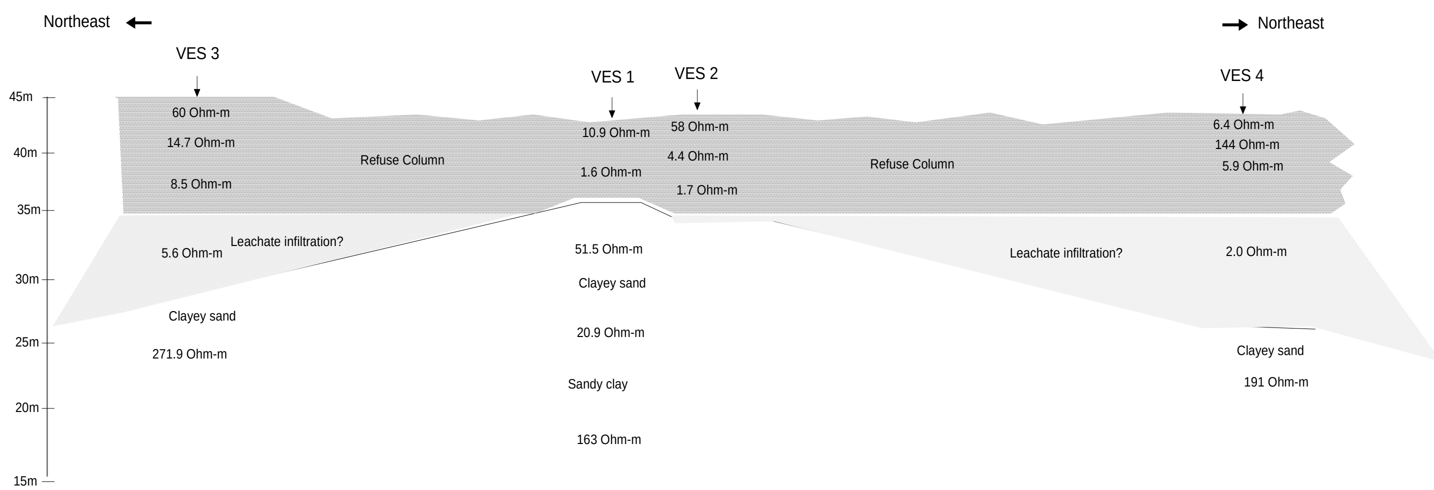


Figure 12. 2-D Geoelectric section along NE-SW section of Abule Egba Landfill.

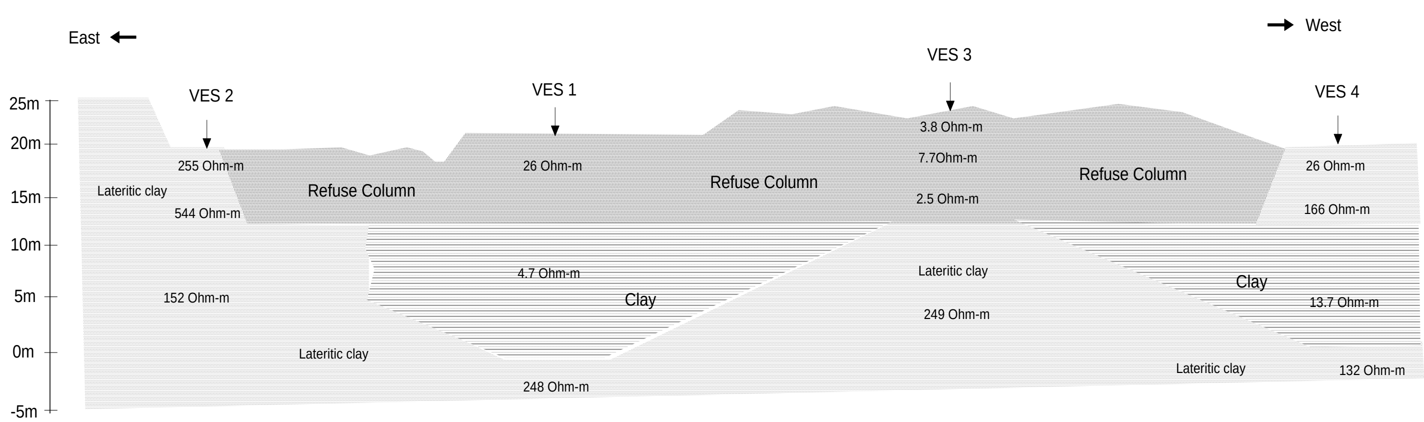


Figure 13. 2-D Geoelectric Section along E-W section of Igando Landfill.

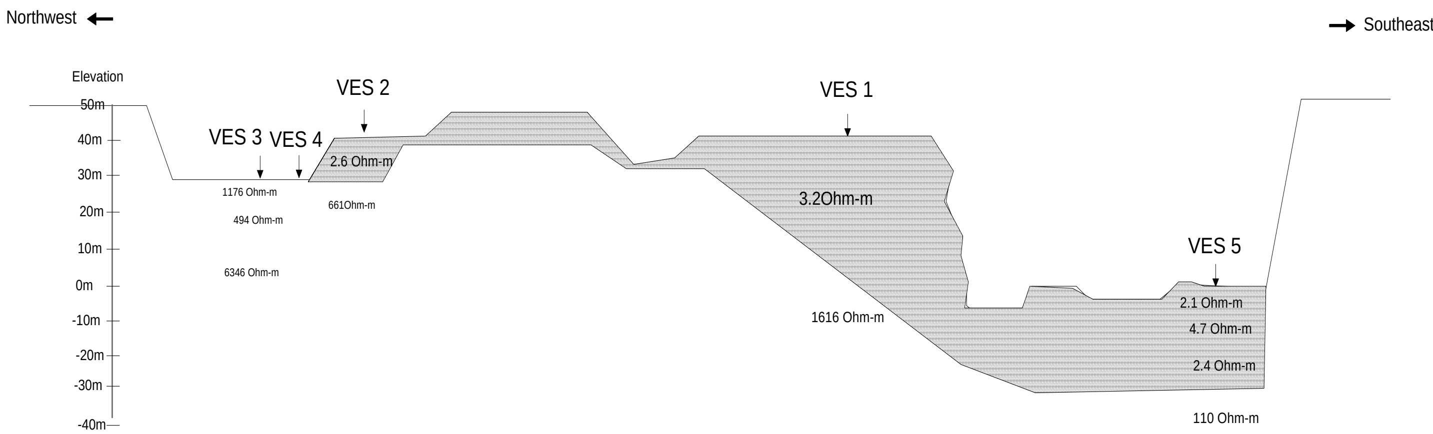


Figure 14. 2-D Geoelectric Section along NW-SE section of Olushosun Landfill.

The Abule Egba landfill is an open dump situated within a high density area with the need to evolve leachate collection system in the dump. Abule Egba landfill is situated in an unsuitable location.

At Igando, the underlying lithologic unit has impermeable geoelectric characteristics thus the hydrogeologic system is presumably protected. The existence of clay/laterite column around Igando landfill provides a means for retardation of leachate movement into the underlying aquifer. The low permeability clay and laterite medium has potential to prevent groundwater contamination at depth.

The Olushosun landfill is underlain by materials of impermeable geoelectric characteristics in the northern flank and fairly permeable geoelectric characteristics in the south around Owena phase. However, the Olushosun landfill which is the largest in the Lagos metropolitan area has no liners and leachate collection system and are therefore likely to cause groundwater contamination especially on the southern flank.

REFERENCES

Adegoke OS, Jeje LK, Durotoye B, Adeleye DR, Ebukanson EE (1980). The Geomorphology and Aspects of Sedimentology of Coastal Region of Western Nigeria. J. Mining Geol. 17:217-223.

Asiwaju-Bello YA, Akande OO (2001). Urban groundwater pollution: Case study of a Disposal site in Lagos metropolis. J. Water Res. 12:22-26.

Christensen TH, Kjeldsen P, Bjerg PL, Jensen DL, Christensen JB, Baun A, Albrechtsen HJ, Heron G (2001). Biogeochemistry of landfill leachate plumes. Appl. Geochem. 16:659-718.

Eckenfelder WW (2000). Industrial Water Pollution Control, 3rd Ed. Mc-Graw-Hill, London, UK.

Ehrig HJ (1989) Leachate treatment overview, in T.H. Christensen et.al. eds. Sanitary landfilling - Process, Technol. Environ. Impact. Acad. Press London, pp. 285-297.

Hill MB, Webb JE (1958). The ecology of Lagos lagoon II. The topography and physical features of the Lagos harbor and Lagos lagoon. Philosophic. Trans. Royal Soc. London 241:307-417.

Jones HA. Hockey RD (1964). Geology of parts of South-Western Nigeria. Bull. Geol. Surv. Nig. No. 31

Koefoed O (1979). Geosounding principles, Resistivity sounding measurements: Elsevier, Amsterdam.

Lavalin (1992). Organizational development and waste management system project. Design and operations report for the Oregun landfill site submitted to the Lagos State Waste Disposal Board.

Lee GF, Jones-Lee A (1993a). Revisions of state of MSW landfill regulations: Issues in groundwater quality. J. Environ. Manag. Rev. 29:32-54.

Lee GF, Jones-Lee A (1993b). Groundwater pollution by municipal landfills: Leachate composition, detection and water quality significance," Proc. Sardinia '93 IV International Landfill Symposium, Sardinia, Italy, 10931103.

Loke MH (1999). Electrical imaging surveys for environmental and engineering studies -- A practical guide to 2-d and 3-d surveys: Austin, Texas, Adv. Geosci. Inc., p. 57.

Longe EO, Balogun MR (2010). Groundwater Quality Assessment near a Municipal Landfill, Lagos, Nigeria. Res. J. Appl. Sci. Eng. Technol. 2(1):39-44.

Longe EO Enekwechi LO (2007). Investigation on potential groundwater impacts and influence of local hydrogeology on natural attenuation of leachate at a municipal landfill. Int. J. Environ. Sci. Technol. 4(1):133-140.

Longe EO, Malomo S, Olorunniwo MA (1987). Hydrogeology of Lagos metropolis. J. Afr. Earth Sci. 6(3):163-174.

Nwankwoala HO (2011). Coastal Aquifers of Nigeria: An Overview of Its Management and Sustainability Considerations. J. Appl. Technol. Environ. Sanit. 1(4):371-380.

Ogundiran OO, Afolabi TA (2008). Assessment of the physicochemical parameters and heavy metals' toxicity of leachates from municipal solid waste open dumpsite. Int. J. Environ. Sci. Technol. 5(2):243-250.

Petruzzelli D, Boghetich G, Petrella M, Dell'Erba A, L'Abbate P, Sanarica S, Miraglia M (2007) Pre-treatment of industrial landfill leachate by Fenton's oxidation. Global NEST J. 9:51-56.

Pugh JC (1954). A Classification of the Nigeria Coastline. J. W. Afr. Sci. 1:3-12.

Stanton GP, Schrader TP (2001). Surface Geophysical Investigation of a Chemical Waste Landfill in Northwestern Arkansas. In Eve L. Kuniansky, editor, 2001, U.S. Geological Survey Karst Interest Group Proceedings, Water-Resources Investigations Report 01-4011:107-115

Stollenwerk KG, Colman JA (2003). Natural remediation potential of arsenic-contaminated ground water, in Welch, A.H., and Stollenwerk, K.G., Eds., Arsenic in groundwater Geochemistry and Occurrence, Boston, Kluwer, pp. 351-379.