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Geo-electrical investigation of underground water contamination by solid waste: Case study of Solous III Dumpsite, Igando, Lagos, Nigeria

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ABSTRACT

This research examines the effects of solid waste on the quality of underground water in Solous III dumpsite, Igando, Alimosho Local Government area of Lagos, Nigeria. The study was born out of the unregulated manner in which common dumpsites are operated and the way in which both domestic and industrial wastes are deposited in the streets, river courses, buried or burnt and discarded in refuse heaps. Solid wastes commonly generated in Lagos includes papers and cartons, food remnants, glass and bottles, plastic and polythene, tin and metals, ashes and dust, textile and rags, aluminum and other minerals. The geo-electrical methods used in the survey are Vertical Electrical Sounding and Very Low Frequency techniques. Measurements of eleven vertical electrical soundings (VES) were conducted using the Schlumberger configuration and eighteen profiles using the very low frequency (VLF) method. The resistivity method was carried out with a view to characterize different subsurface geological units and to provide the engineering or environmental geophysical characterization of the study area. The VES data were subjected to an iteration software (WIN RESIST) which showed that the area is composed of top soil, clay, sandy clay and sand. The Very Low Frequency data was also subjected to iteration software (SURFER 8) which gave the imaging of the lateral variation in resistivity. Based on the interpretation of the two methods, interested layer under the geo-electric section is VES1-11 which signifies a probable aquifer's zone with resistivity range between 206.2 Ωm and 406.6 Ωm, and thickness from 3.0 m to 13.0 m. The graph of the very low frequency method also shows that areas close to the dumpsite and areas of about 300m away from the dumpsite had been greatly contaminated. [Profiles 1 to 18]

Keywords: Geophysical characterization, dumpsite, horizontal profiling, leachates, vertical electrical sounding.

INTRODUCTION

Waste is anything that is of no use to the disposer. It can also be defined as any material obtained from an activity, which has no immediate economic demand and which must be disposed off. Wastes can be classified into three: solid, liquid and gaseous. Solid wastes are residual from homes, businesses or institutions and are referred to as trash, garbage, rubbish, refuse, discards and throwaways that are of no relevance to the disposer. For example, broken bricks, broken glass and bottles, cans, plastics, paper, battery casings, plantain skin, and nylon[1]. Liquid wastes are those dissolved in water resulting from industrial processes known as effluent, domestic liquid, acid waste and waste oil from workshops. Gaseous wastes are substances like air (neither solid nor liquid) that move freely to fill any available space. Examples are wastes resulting from gas flaring, particulate dust and waste gases from cement factories, stone crushing excavation activities, lime dust, asbestos dust, acid fumes and cigarette fumes. Solid waste can also imply unwanted materials or substances that are left or discarded after use, included are by-products of process materials that may be required by law to be disposed of [2]. Solid wastes can be grouped on the basis of source, environmental risks, utility and physical properties. On the basis of source which is commonly used, solid wastes are classified as: municipal, industrial, agricultural, mining and mineral wastes, construction and demolition, healthcare, radioactive (or nuclear), human and animal wastes. These solid wastes can as well contaminate ground water (Meadows 1995). Most of the urban solid wastes, irrespective of their classification, are degradable; this aids the rate of leachate formation and migration. The non-biodegradable wastes however, can last for many years without any sign of decomposition. Therefore, there is possibility of leachate generation, plume extension and migration at the base of urban landfill owing to the composition of discarded materials and frequent surface water ingression from urban precipitation. Leachate is a liquid associated mainly with open dumps. Leachate is produced when rainwater percolates through wastes that are dumped in a disposal site. This leachate forms at the base of the dump, is usually composed of inorganic ions and organic constituents that were present in the original waste and organic products resulting from microbial activity. Trace elements such as lead, iron, copper, zinc, and manganese are also found in leachates.

Dumps also contaminate water as organic matter enters the water by surface runoff, which carries leachates from disposal sites. These leachates consist largely of solids, microbial organisms and in some situations chemicals; shallow wells are more dangerously polluted [3]. This paper examines the possible effects of solid waste on underground water using electrical resistivity method, a geophysical technique and most preferred method in groundwater prospecting while the vertical electrical sounding (VES) is a geo-electrical method of measuring vertical alterations of electrical resistivity. The method has been recognized to be more suitable for hydrogeological survey of sedimentary basin [4]. The electrical resistivity technique involves the measurement of the apparent resistivity of soils and rock as a function of depth or position.

The vertical sounding method was chosen for this study because the instrument is simple, field logistics are easy and straight forward while the analysis of data is less tedious and economical [5]. It also has ability to distinguish between saturated and unsaturated layers. The Schlumberger array was employed because it has a greater penetrating power than the Wenner array. In resistivity method, Wenner configuration discriminates between resistivities of different geo-electric lateral layers while the Schlumberger configuration is used for the depth sounding [6]. Geo-electric method is regularly used in determination of depth, thickness and boundary of an aquifer [7- 9] in determination of groundwater potential [10], exploration of geo-thermal reservoirs [11] and estimation of hydraulic conductivity of aquifer [12 ,13]

MATERIALS AND METHODS

Lagos State is basically a sedimentary area located within the western part of Nigeria, a zone of coastal creek and lagoon [14]. The subsurface geology reveals two basic` lithology: clay and sand deposits. These deposits may be inter-bedded in places with sandy clay or clayed sand and occasionally with vegetable remains and peat. The water bearing strata of Lagos State consist of sand, gravel or mixtures from fine through medium to coarse sand gravel [15]. Basically, there are four major aquifer units that are being tapped for the purpose of water supply in Lagos state. The first aquifer extends from the ground level to a depth of 12m below the ground layers of clay and sand. This shallow aquifer is of minor importance for large water supply purposes since it is prone to contaminations. The second aquifer is encountered between 20m and 100m below sea level and it can be found around Igando axis. The third aquifer is encountered in the central part of Lagos at the depth ranging between 130-160m below the sea level. The fourth aquifer is located at approximately 450 m below sea level. It is separated from the third aquifer by a rather thick layer of shale of the Ewekoro formation. Only few boreholes tap water from this aquifer [16, 17]. The hydrogeology of the study area falls within the first and second aquifer described here.

The instrument used in the research work is the OHMEGA Terrameter and ABEM WADI VLF. A total of eighteen profiles using the ABEM WADI VLF and a total of eleven vertical electrical soundings were carried out in the study area. The traverse separation was 3 m. The eleven traverses are represented as VES1-11. An average spread of 200m (AB) was covered.

RESULTS AND DISCUSSION

An iteration software (WIN RESIST) is used to analyze the curves of VES1-11. The smooth curves taken through the set of data points were interpreted quantitatively by the method of partial curve matching. Layer resistivity and thickness were obtained from VES1 to VES11 diagram. The VLF data were subjected to SURFER 8 software which gave the imaging of the sub-surface showing the area that has been contaminated by leachates.

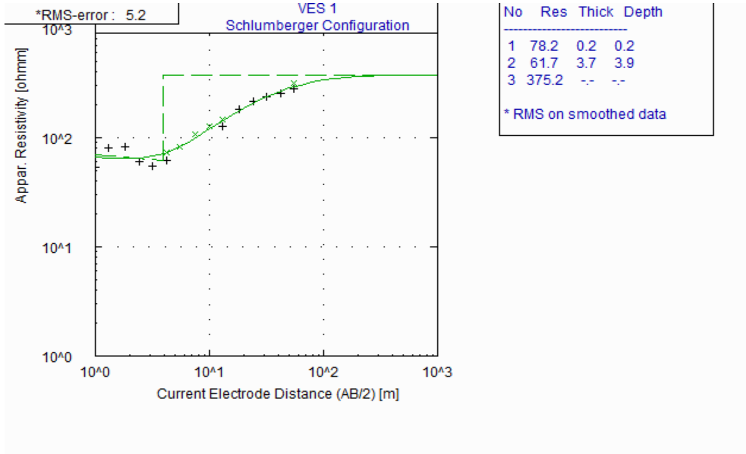
TABLE 1: Vertical Electrical Sounding Method Data

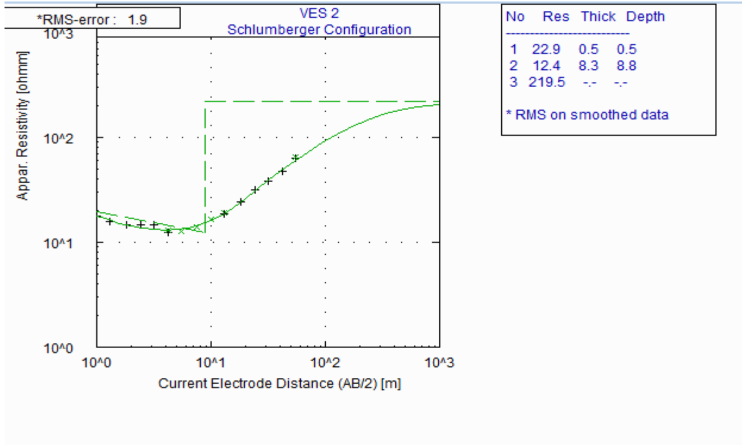
S/N	AB/2 (m)	VES 1 ρ(Ωm)	VES 2 ρ(Ωm)	VES 3 ρ(Ωm)	VES 4 ρ(Ωm)	VES 5 ρ(Ωm)	VES 6 ρ(Ωm)	VES 7 ρ(Ωm)	VES 8 ρ(Ωm)	VES 9 ρ(Ωm)	VES 10 ρ(Ωm)	VES 11 ρ(Ωm)
1	1	54.14	17.98	37.63	95.83	153.7	118.33	7.09	36.51	20.71	16.21	73.92
2	1.3	80.98	15.72	36.17	136.67	190.38	110.89	7.52	35.45	13.35	16.03	72.45
3	1.8	81.63	14.7	35.91	166.57	240.23	109.14	8.31	26.28	8.99	13.91	69.39
4	2.4	60.39	14.53	35.38	196.72	259.3	118.32	9.31	18.38	6.94	12.8	66.16
5	3.2	55.06	14.58	35.52	206.21	258.91	127.86	9.44	11.56	6.74	10.92	71.32
6	4.2	61.36	12.43	35.17	196.4	276.26	139.73	10.29	8.58	5.81	9.76	73.14
7	5.5	72.98	12.89	26.77	180.65	243.02	161.23	7.1	8.45	8.67	11	77.19
8	7.5	82.62	12.64	26.81	177.69	269.58	176.31	8.49	6.28	6.74	7.57	69.66
9	10	106.32	13.86	25.54	162.99	266.01	193.54	9.5	5.79	5.5	4.6	68.27
10	13	127.33	16.55	25.46	167.04	267.36	227.56	10.86	5.59	5.25	9.4	60.61
11	13	146.87	19.14	26.49	150.86	258.21	278.18	13.87	5.59	4.9	11	67.86
12	18	127.33	18.79	25.16	169.46	240.33	237.27	11.51	6.01	6.07	11.3	63.59
13	13	180.12	24.25	27.08	157.86	274.75	300.7	10.03	7.1	4.75	14.5	74.22
14	24	213.64	31.72	29.06	150.69	322.16	363.04	8.88	8.27	5.65	18.52	78.01
15	32	238.99	38.48	35.46	150.93	356.61	404.07	8.93	9.38	7.25	25.51	109.17
16	42	254.05	47.04	45.6	140.83	359.43	356.11	10.13	12.43	13.52	37.61	125.37
17	55	279.99	62.69	63.45	144.05	366.75		14.22	18.69	11.86		163.12
18	55	313.41	64.95	65.8	144.87	369.79		13.54	37.02	5.89		

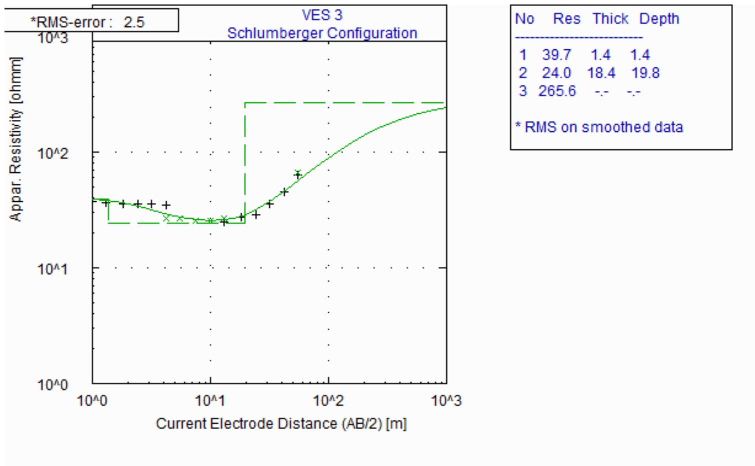
TABLE 2: Interpreted Resistivity Result for Vertical Electrical Sounding

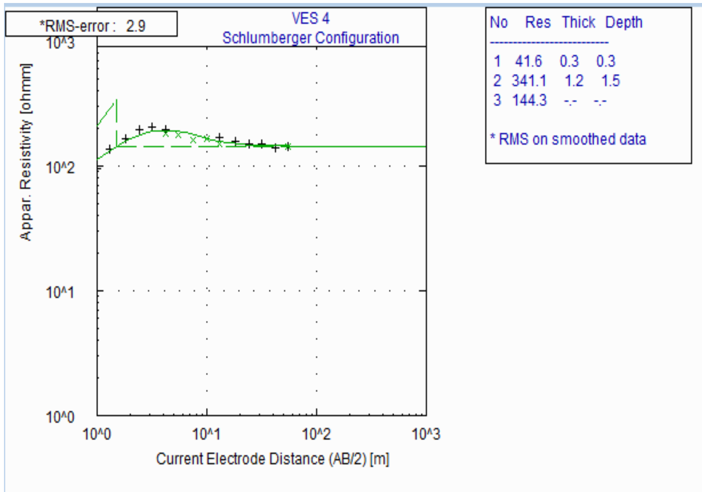
VES NO	NO OF LAYERS	RESISTIVITY (OHMS –M)	LAYER THICKNESS (M)	TOTAL THICKNESS (M)	REFLECTION COEFFICIENT	INTERPRETATION
1	1	78.2	0.2	3.9	0.718	Fractured Basement
	2	61.7	3.7			
2	1	22.9	0.5	8.8	0.893	Fractured Basement
	2	12.4	8.3			
3	1	39.7	1.4	19.8	0.834	Fractured Basement
	2	24	18.4			
4	1	41.6	0.3	1.5	-0.405	Fractured Basement
	2	341.1	1.2			
5	1	51.4	0.2	0.7	-0.369	Fractured Basement
	2	333.2	0.5			
6	1	116.6	0.8	2.1	0.662	Fractured Basement
	2	85.6	1.3			
7	1	6.4	0.6	4	0.044	Fractured Basement
	2	9.8	3.4			
8	1	42.3	1	13.9	0.916	Fractured Basement (medium yield)
	2	5	12.9			
	3	783				
9	1	35.2	0.5	23.9	0.787	Fractured Basement
	2	5.8	23.4			
10	1	16.7	1.7	5.1	0.977	Fresh Basement
	2	3.2	3.4			
11	1	110.9	0.2	17.1	0.713	Fractured Basement

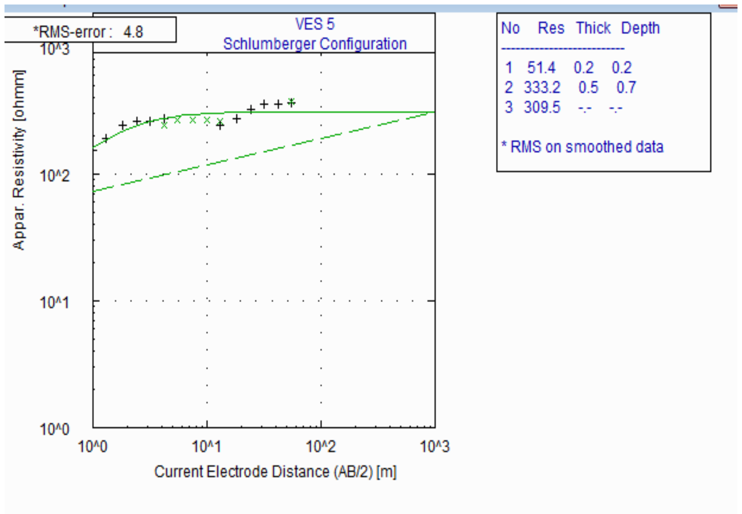
GRAPHS OF VERTICAL ELECTRICAL SOUNDING DATA

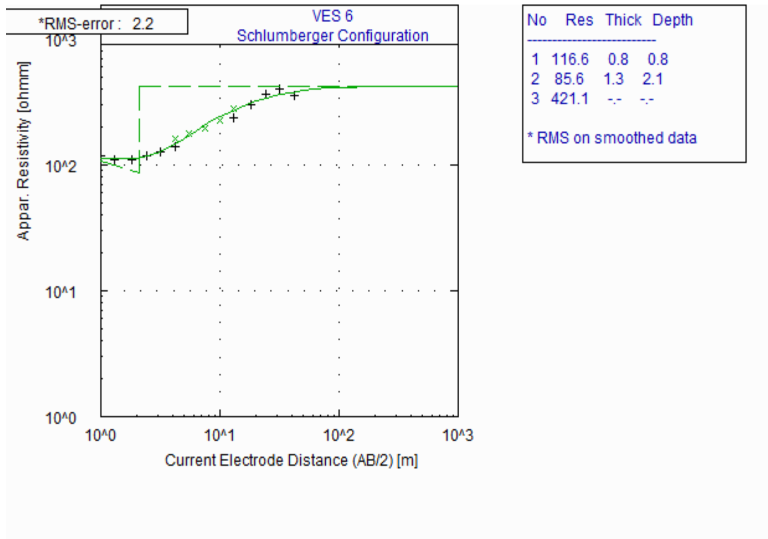









*RMS-error : 4.8
VES 5
Schlumberger Configuration
No Res Thick Depth
1 51.4 0.2 0.2
2 333.2 0.5 0.7
3 309.5 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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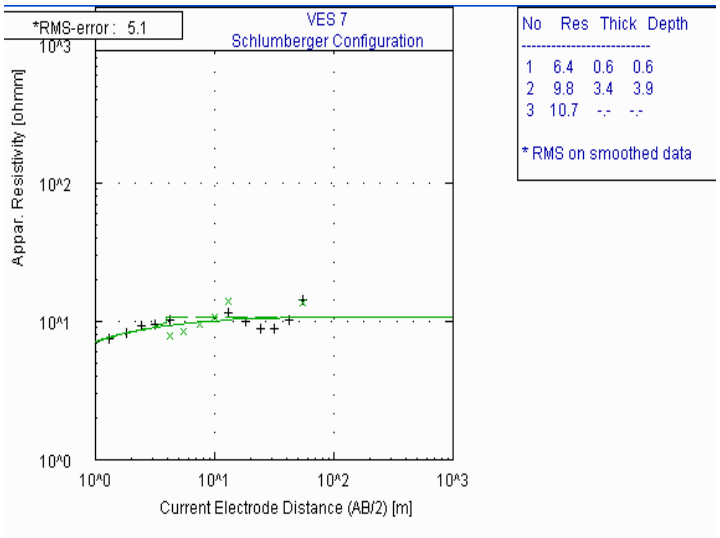
VES 6
Schlumberger Configuration
No Res Thick Depth
1 116.6 0.8 0.8
2 85.6 1.3 2.1
3 421.1 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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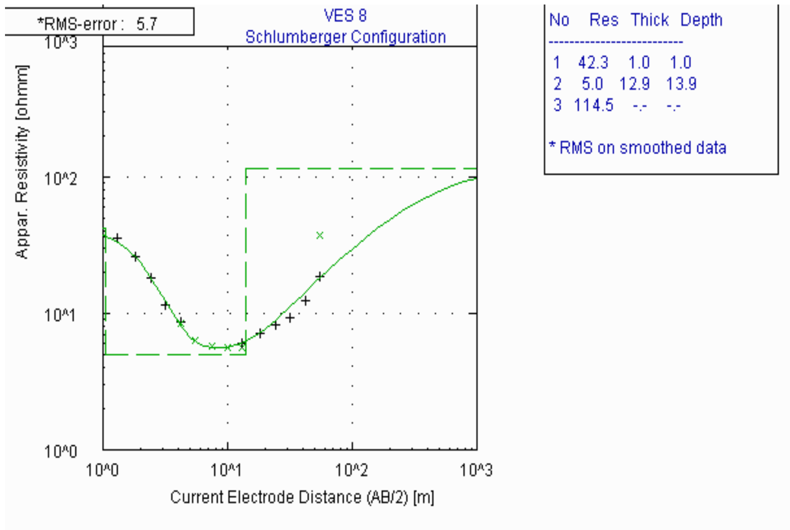
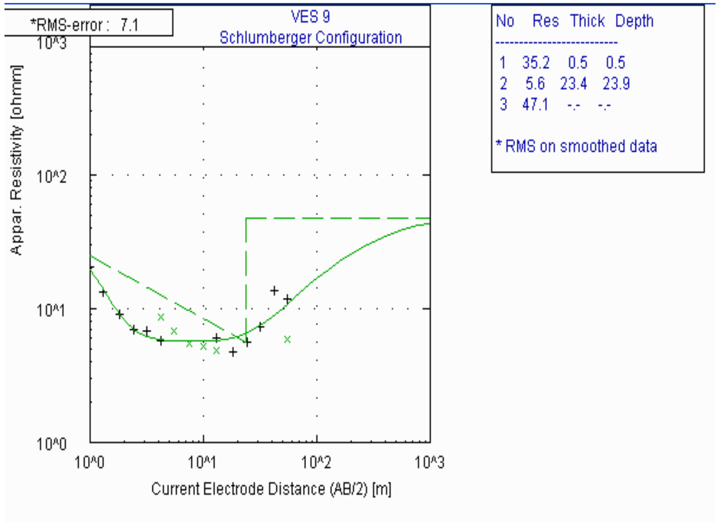
VES 7
Schlumberger Configuration
No Res Thick Depth
1 6.4 0.6 0.6
2 9.8 3.4 3.9
3 10.7 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


*RMS-error : 5.7
VES 8
Schlumberger Configuration
No Res Thick Depth
1 42.3 1.0 1.0
2 5.0 12.9 13.9
3 114.5 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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VES 9
Schlumberger Configuration
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2 5.6 23.4 23.9
3 47.1 -.- -.-
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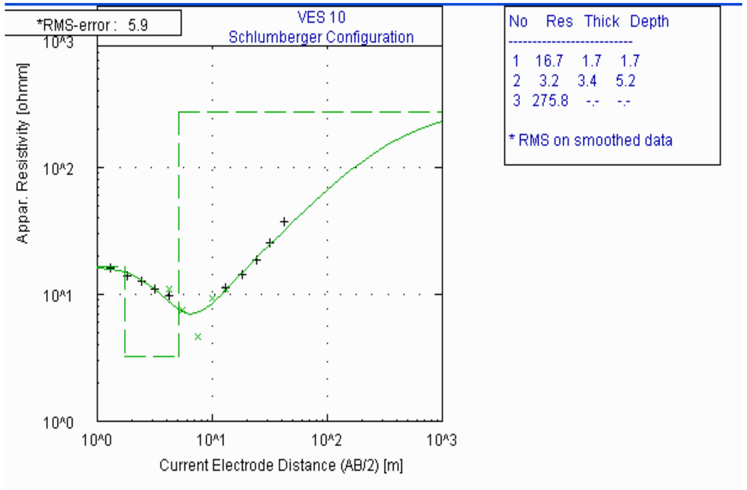
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


*RMS-error : 5.9
VES 10
Schlumberger Configuration
No Res Thick Depth
1 16.7 1.7 1.7
2 3.2 3.4 5.2
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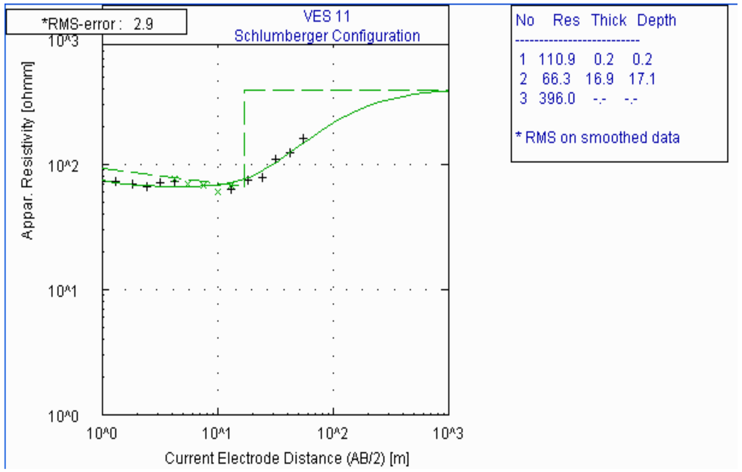
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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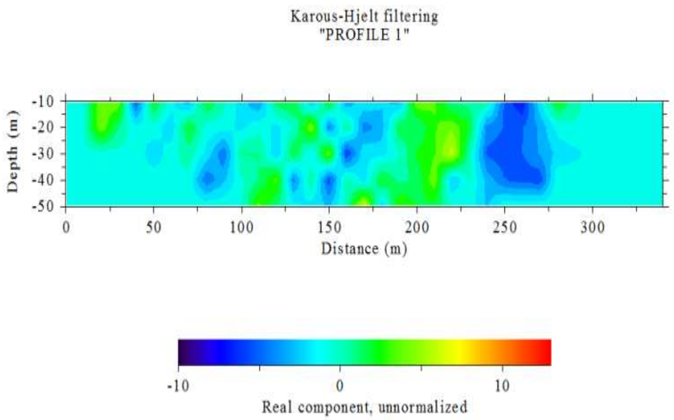
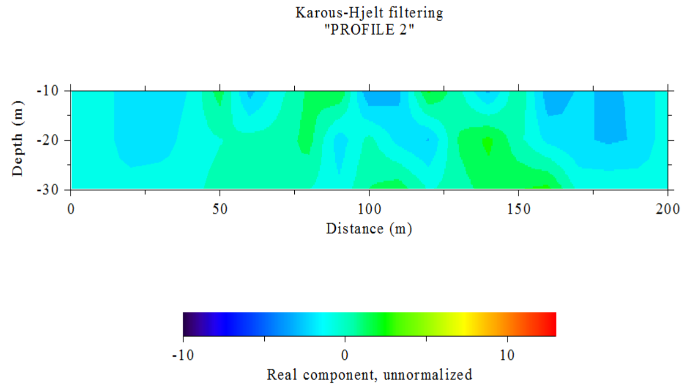
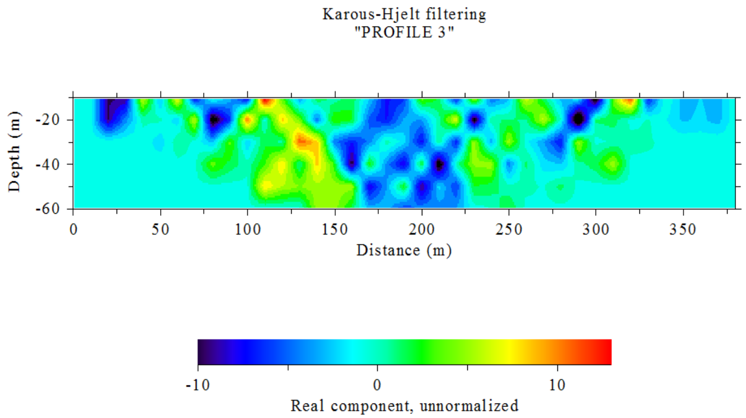
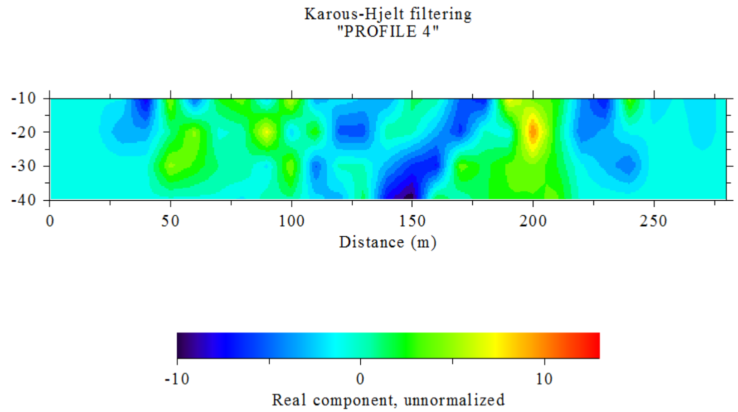
VES 11
Schlumberger Configuration
No Res Thick Depth
1 110.9 0.2 0.2
2 66.3 16.9 17.1
3 396.0 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]

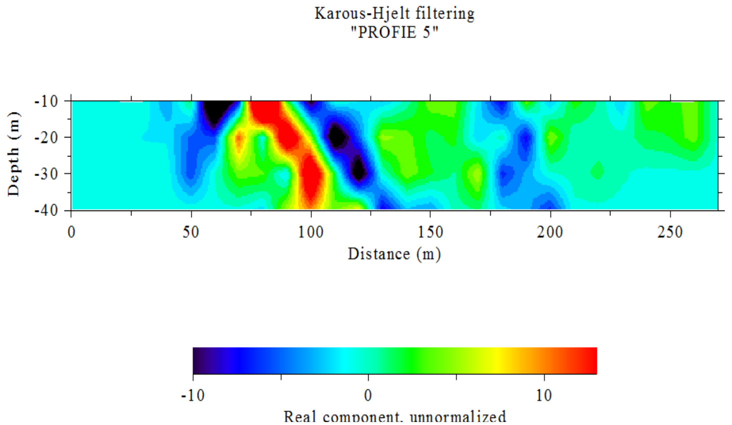
GRAPH OF VERY LOW FREQUENCY DATA







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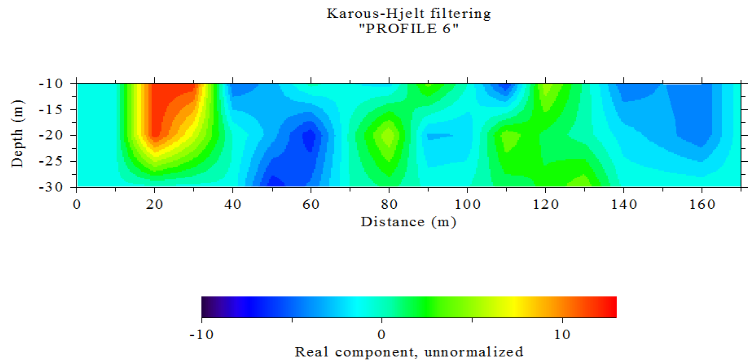
Distance (m)
Real component, unnormalized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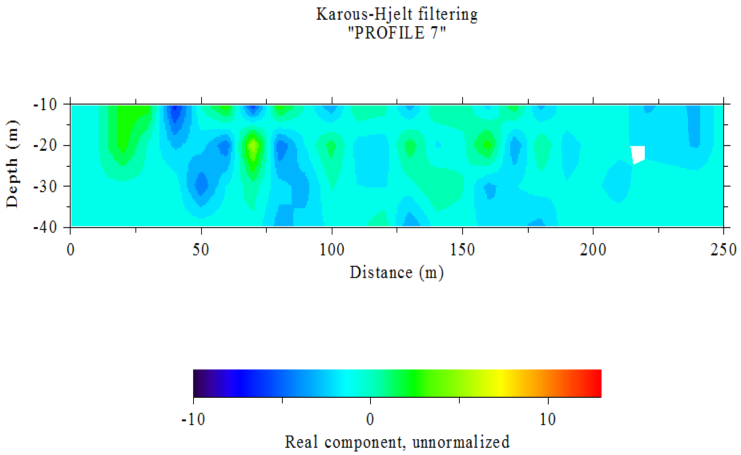
Distance (m)
Real component, unnormalized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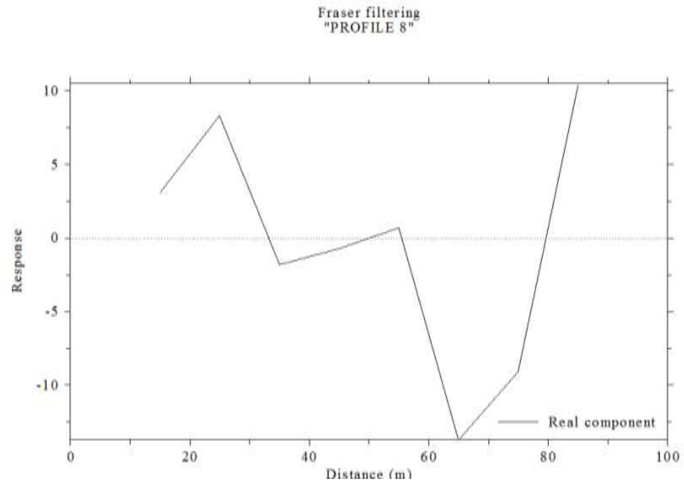
Distance (m)
Real component, unnormalized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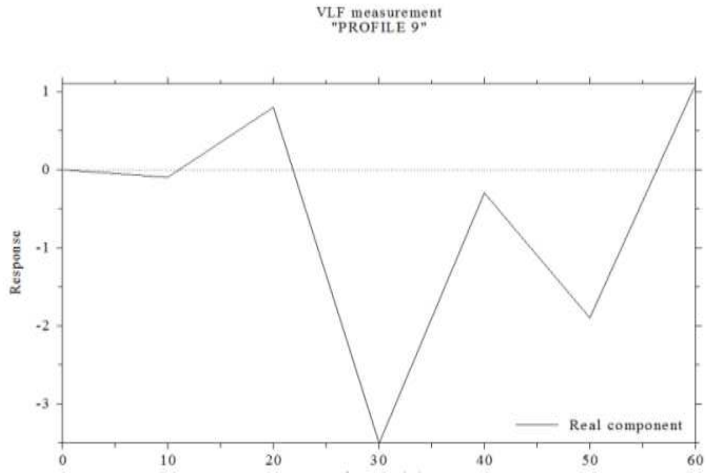
Response
Distance (m)
Real component


VLF measurement
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Response
Real component
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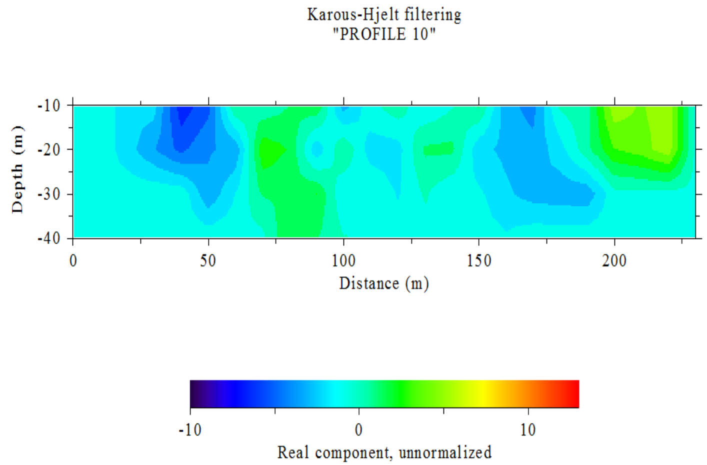
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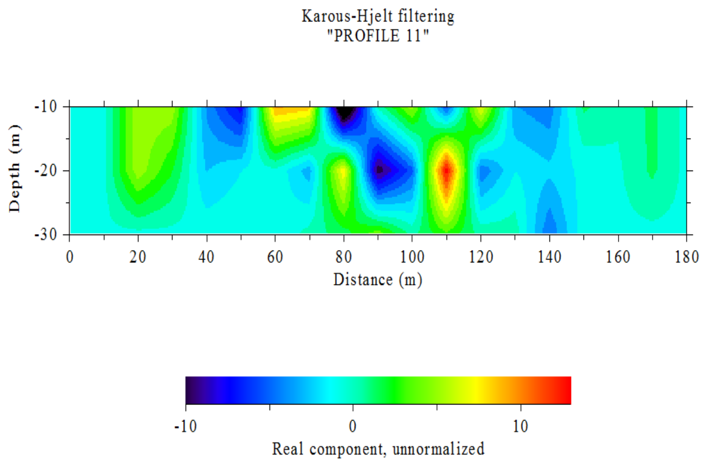
Depth (m)
Distance (m)
Real component, unnormalized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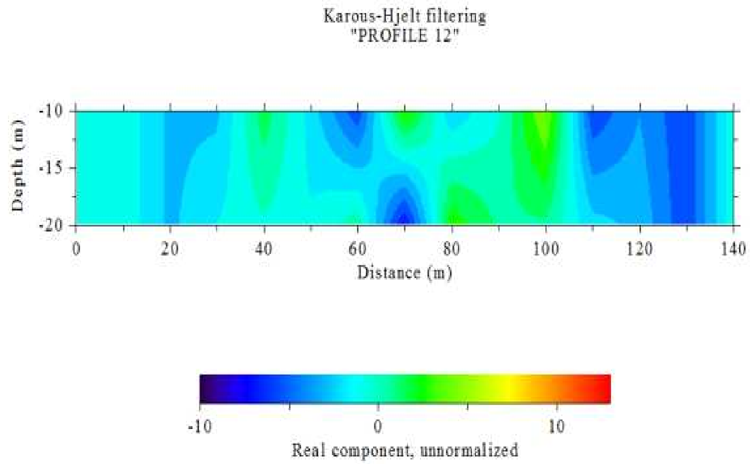
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Distance (m)
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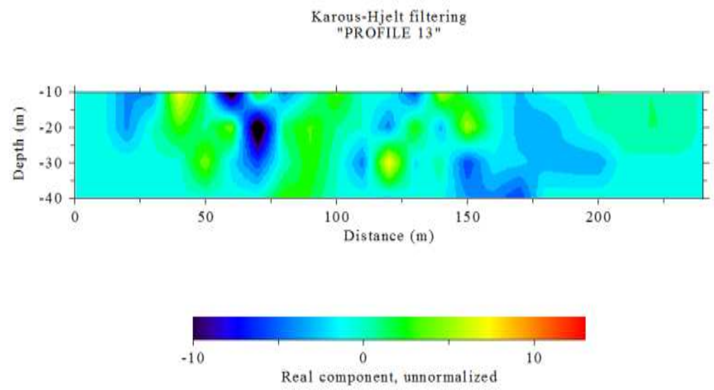
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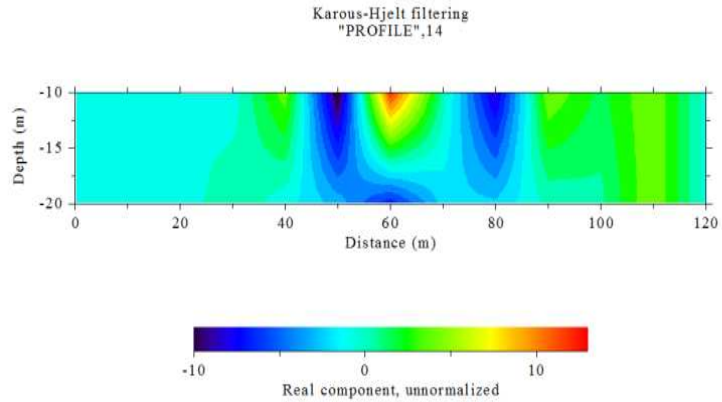
10
Real component, unnormalized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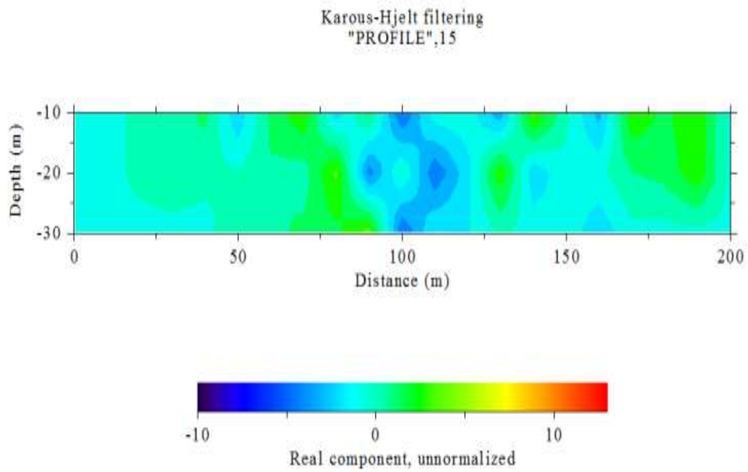
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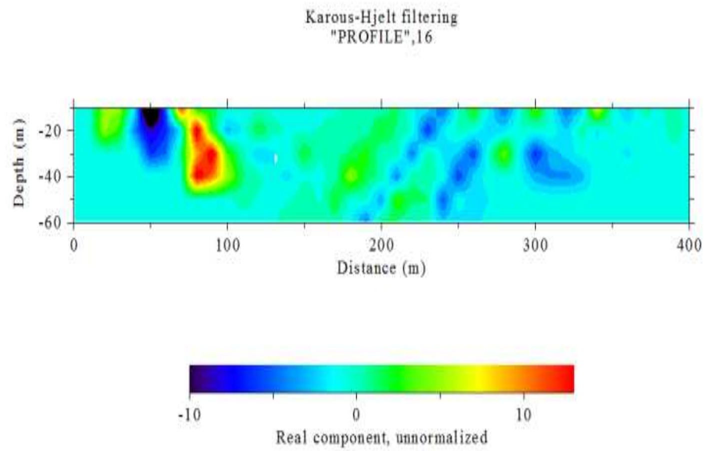
10
Real component, unnormalized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300
400
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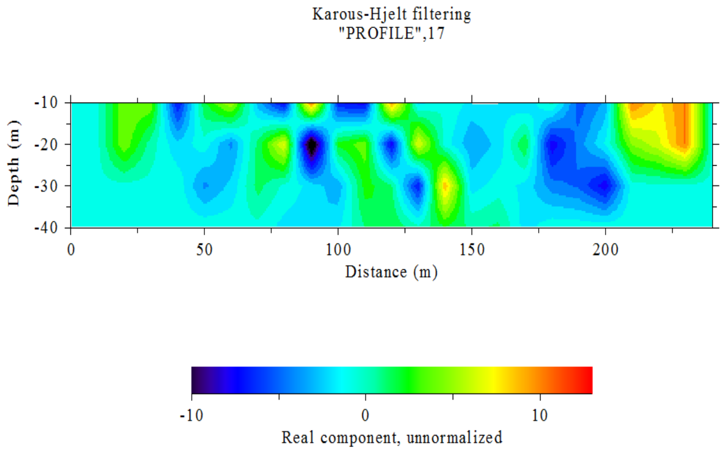
10
Real component, unnormalized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50
100
150
200
Distance (m)
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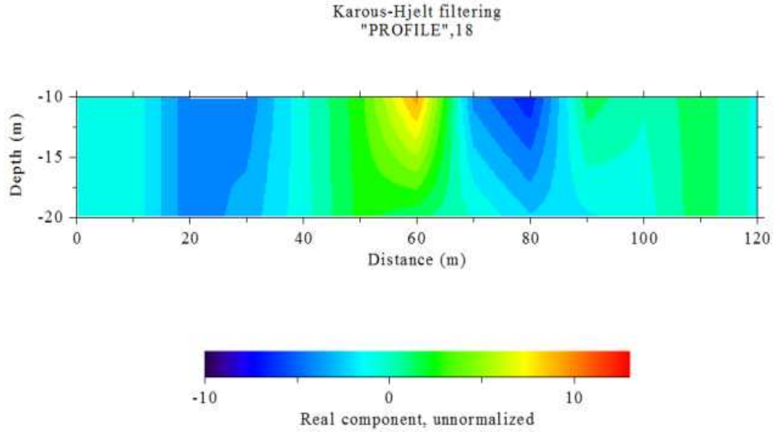
0
10
Real component, unnormalized


Karous-Hjelt filtering
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Depth (m)
-10
-15
-20
0
20
40
60
80
100
120
Distance (m)
-10
0
10
Real component, unnormalized

The graph of the VLF shows the depth to which the leachate had gone into the earth surface and the areas that have being affected underneath. The graph shows how the leachates percolate into the ground. The results from the graphs of the VLF clearly shows that the area have being adversely affected especially those area close to the landfill. The thick and dark areas on the graph show the areas that have being affected by leachates. Areas along profiles 1, 3, 4, 5, 6, 11, 12, 13 and 14 were seriously affected which could be seen from the graphs. Areas along profile 2, 7, 10 and 15 are not affected as much as other areas. Areas at about 400m (profile 12, 13 and 14) from the dumpsite have being affected likewise and at a greater depth. It is clearly seen that water from wells cannot be of any use to the people in the area except if bore holes are dug. Profile 8 and 9 could not give any graph because the distance was small. It is observed that majority of the layers are fractured with a value of reflection coefficient less than 0.8 except VES 10.The overburden thickness of most of the layers have been exceeded, which gives the leachates access to penetrate into the ground. From both methods, it can be clearly seen that the underground water has been seriously contaminated since most of the basements are fractured. Water samples taken from nearby wells also confirm the same result.

CONCLUSION

The study has revealed that many parts of the dumpsite have been considerably contaminated due to migration of leachate which could pose some health risks to the residents. This is evident from the high values of conductivity obtained from the result. The hydro geologic features of the study area showed that contaminants derived from the waste disposal site infiltrate through vulnerable sandy formations and hence to the groundwater flow. From this work, it shows that Very Low Frequency method is a viable alternative to image and detect leachate contaminant plumes because it was found that the method can detect changes in the sub-surface conductivity distributions quickly and relatively accurately. The vertical electronic sounding method was able to show the depth and the resistivity of each layer. The soil stratigraphy of Lagos metropolis or the existing sequence of soil types occurring in the metropolis makes land filling operation very risky especially when one considers the prevalent high water table in the state. The use of impermeable liners made of geo-membranes is recommended at the inception of dumpsites to prevent seeping of contaminants through the subsurface. A sanitary landfill that will be properly engineered and monitored is also recommended and which will be far away from residents to prevent out-break of diseases.

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