Lithological Characterisation and Suitability of the Sub-Soils and Bedrocks Around Lapite Municipal Dumpsite as Liner Materials at Akinyele Area of Ibadan, Southwestern Nigeria

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Abstract

Dumpsites are land areas assigned for solid waste deposition and accumulation that are liable to contaminate the sub-surface environment and underground water, hence; the underlying soils and bedrocks in such areas should be impervious to leachates plume. In this regard, the present study applied a total of forty-one vertical electrical soundings (VES) geophysical resistivity method to characterize the lithology of the subsurface soils and bedrocks around the Lapite dumpsite at Akinyele area of Ibadan. The aim is to assess the worth of the underlying natural materials as suitable liners for the dumpsite and the vulnerability of the area to leachate contamination.

From the results, the dominant VES curve across the study area are the 3-layer H and the 4 – layer KH types characterised by more conductive middle sub-soil layer. The overburden thickness varied widely between 1.5 to 42.3 m, which is considered thick enough as liner materials for the dumpsite. The bedrock resistivities were 10 – 12,962 Ωm Ωm and there are more permeable fractured and weathered bedrocks than the fresh basement. From the lithologic characterisation, 52% of the saprolite layers are predominantly clayey and compacted lateritic clays that are classified as good materials for dumpsite liners. However, the dominant permeable bedrocks of about 76% occurrence are major concern that can substantially permit percolation of leachate and contaminated water into the underground environment despite the favourable overburden thickness and fairly good saprolite lithology. These geo-electric results are not suitable for further extension of the dumpsite. There may be the need to evacuate the dumps or provide suitable liners either by modifying the sub-soils or by providing artificial liners for the area in order to safeguard the safety of the underground water for human.

Keywords: Dumpsites, leachate, liner, saprolite, bedrock

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1. Introduction

Solid wastes are waste products generated from human and animal activities discarded as useless or unwanted solid materials. It may also consist of by-products from processing lines including materials that may be required by law to be disposed of (Okecha, 2000). Solid waste is a global environmental problem in all (Hussein and Mona, 2018). The management of these solid wastes is quite challenging and constitute major environmental problem. The world generates 2.01 billion tonnes of municipal solid waste annually and about 33% of this colossal amount is not well managed in environmentally safe manner (World bank, 2018; UNEP, 2019) and are either dumped on land or incinerated in most developing countries including Nigeria. Solid waste products are sourced from our way of life and are posing an increasing problem mainly because of the quantity involved and its consequent effects on the pollution of water, air and land. Solid waste management is the process of collection, separation, transportation, and disposal of solid wastes such that they are moderately safe for humans, plants, animals, and the environment, while putting into consideration public health and aesthetic quality (Olanibi and Emmanuel, 2022). The increasing rate of population growth, improving standards of living, industrial growth and increasing commercial activities are major factors behind the increase in the quantity of waste produced around the world (El-Fadel et al., 1997). In developing countries of the world like Nigeria, municipal solid waste threatens the safety of both the environment and social qualities (Costi et al., 2004).

Landfills and dumpsites are considered the most common methods for solid waste disposal. Dumpsite is a widespread land meant for deposition of waste and unwanted materials from household, institutions, industry or environment and it is usually open or covered with soil layer with or without liner. Liners are low permeable barriers placed beneath landfills in other to create a barrier between the waste and the environment and to drain leachate to collection points and treatment plants (Igboama et al., 2022). Liners also prevent downward migration of leachate plumes from the overlying waste dumps to the underlying underground environment. The absence of liner most times lead to pollution and contamination of the environment and the hydrological ecosystem. Different kinds of industrial, household, and sometimes hazardous wastes are usually found mixed together in the same landfill or dumpsite (Scott et al, 2005). Careless dumping of waste and poor refuse management could therefore be disastrous (Adeyemi and Oyediran 2005). A solid waste disposal site should be placed far from human settlements and airports by a certain distance which is referred to as buffer zone (a neutral zonal area between the dump and settlements). A minimum of 5-kilometer buffer zone is deemed safe for large cities, while lower buffer zones is acceptable for smaller cities and villages as a safety measure (Sharifi et al., 2009).

Ibadan which is one of the largest cities in Africa generates well over 7600 tonnes of waste daily due to rapid urbanization and population explosion. The quantity of solid waste has increased rapidly and it has become more diverse in composition due to introduction of new products and consumption goods. The present study applies electrical resistivity geophysical method to characterised the lithology of the subsurface soils and bedrocks of the Lapite dumpsite, which is located along Akinyele-Ojoo expressway in Ibadan with the aim of investigating its worth as liners and the likelihood of leachate infiltration into the underground water.

2. Materials and Methods

2.1 Geophysical Techniques

The electrical resistivity technique adopted was the vertical electrical sounding (VES) which was used to characterise the various lithological units of subsurface soils and bedrocks around the dumpsites. For this present study, the Schlumberger configuration was used. In schlumberger, the distance L between the current electrodes (AB) is varied and the distance l between the potential electrodes (MN) are kept constant for a while over a set of AB separation. For these configurations, the apparent resistivity (ρa) which is a measure of the effects of all the layers between the maximum depth of penetration and the surface is calculated as follows.

$$\rho a = \pi (L2 /2l) R$$

where, R is the measured resistance (in voltage/current) and a, L and l are as defined above. The electrode separations, L and l determines the depth of investigation. The electrode (AB) spacing is then increased and the corresponding apparent resistivity 'ρa' value is measured.

2.1.1 Data Processing and Interpretation

Partial curve matching technique was used for quantitative interpretation of the field data with the help of some auxiliary standard curve charts of Orellana-Mooney, 1966. The apparent resistivities obtained in the field were plotted against half of the current electrode separations (AB/2) to generate VES curves and to obtain the true primary geo-electric parameters including layers' resistivities and thicknesses. After the manual curve matching, field data are input in Winresist software on the computer using the true geo-electric parameters obtained in manual curve matching as models. The final results are iterated to reduce error and the VES graph is more fine-tuned in the process. The final model includes the VES curve and quantitative geo-electric layer parameters including layers' resistivities (ρ) in ohm.m (Ωm) and thicknesses (h) in metre. The layer resistivities are applicable for interpreting the degree of fineness or coarseness of the weathering products and for qualifying the nature of bedrock which could either be fresh, weathered or fractured (Akanbi, 2018).

A total of forty-one (41) VES (or subsurface depth sounding) were conducted in the present study. This included thirty-seven (37) soundings along the border sides of the dumpsite, three (3) control soundings (VES 39-41) conducted at some distances and at different directions away from the dumpsite and one (1) sounding that was directly conducted on the dumpsite as shown in Figure 1. The control VES points were designated as C1, C2 and C3 on the map (Figure 1) and their purpose is to show the natural situation of the subsurface environments around the dumpsite area. These control VES points are correspondingly VES points 39, 40 and 41, and are presented together with other VES points in the lithological interpretation table.

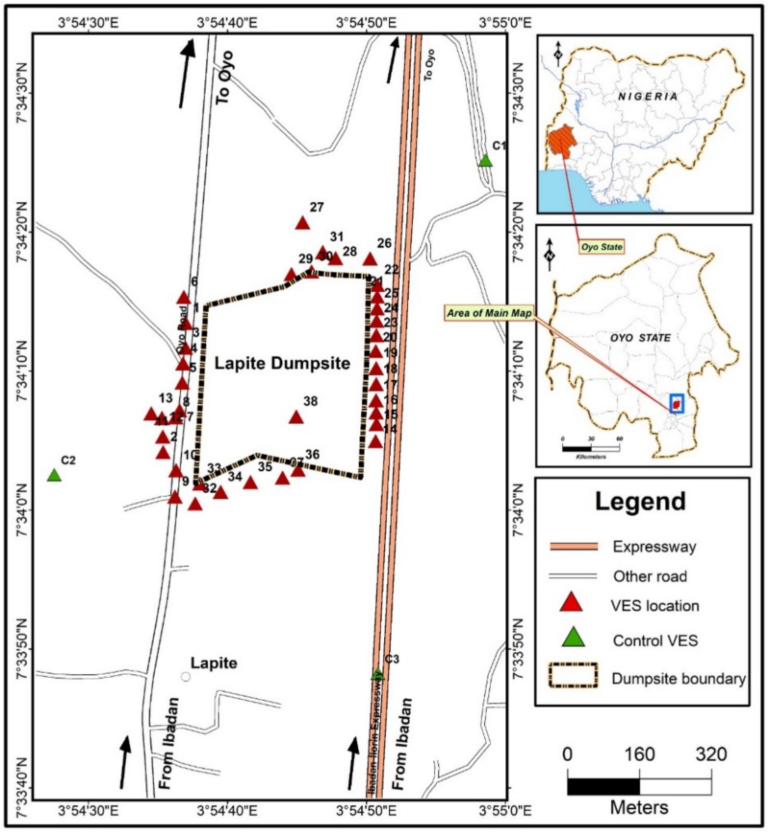


Figure 1: The study area showing the VES points

2.2 *Data evaluation*

2.2.1 *Characterisation of Site Suitability as Dumpsite*

Characterising the suitability of underlying soils and rocks as liner for a dumpsite in the study area entails analysing and quantifying the lithological parameters across Lapite area using the underlisted factors;

i. Thickness of the overburden
ii. Lithology of the overburden
iii. Degree of bedrock intact/freshness

2.2.1.1 Overburden Thickness

The thicker the overburden, the better the soil suitability as dumpsite implying that leachates have longer distance to percolate before coming in contact with fractured or fresh bedrock, which makes underground water and the sub-surface environment less vulnerable to contamination. The thickness of dumpsite liners should not be less than 0.5 m (ASTM, 2018; ISO, 2017; Bouazza and Jefferis, 2017; Rowe, 2012) but thicker overburden is much preferred due to lithological constraints (Harish 2021), as leachates can be transmitted through porous and permeable formations regardless of the thickness. For the present work, the suitability of overburden layer thickness as liners is characterised and presented in Table 1.

Table 1: Classification of suitability of subsoil/overburden thickness

Overburden thickness (m)	Suitability as Dumpsite Liner
< 2.0	Poor
2.0 – 4.9	Fair
5.0 – 15.0	Good
> 15.0	Excellent

2.2.2.2 Lithology of the Overburden and Bedrocks freshness

The lithology of the overburden soils is also of great consideration when selecting desirable areas for siting dumps. Soil lithology is the degree of fineness or coarseness of the individual grains that make up the soil mass. Natural lateritic and clayey soils are the most common compacted soil suitable as liner in sanitary landfills. Ideally, sites should be located in silt and clay soils that restrict leachate and gas movement. A landfill or dumpsite constructed over a permeable formation such as gravel, sand or fractured bedrock can pose a significant threat to groundwater quality. Site suitability as dumpsite is also characterised based on the overburden soil lithology and freshness of bedrock presented in Table 2. The subsoil lithology is interpreted from the resistivities of the saprolite/overburden units based on lithological characterisation of saprolite and bedrock units obtained across Basement Complex area of southwestern Nigeria according to Akanbi (2018).

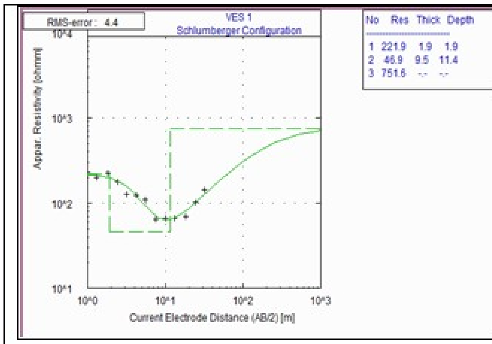
Table 2: Subsoil and bedrock suitability as dumpsite liner based on the lithology

Resistivity range (Saprolite) (Ωm)	**Lithology of saprolite**	**Suitability as Dumpsite Liner**
(Adapted from Akanbi, 2018)		
>400	Compacted clay/ hardpan	Excellent
< 50	Predominantly clay	Good
50 - 120	Sand and clay mixture	Fair
> 150	Predominantly sand to gravel	Poor
Resistivity range (Bedrock) (Ωm)	**Bedrock status**	
>1800	Fresh	Good/suitable
601 - 1800	Weakly/slightly weathered	Fair
<600	Fractured	Poor/Unsuitable

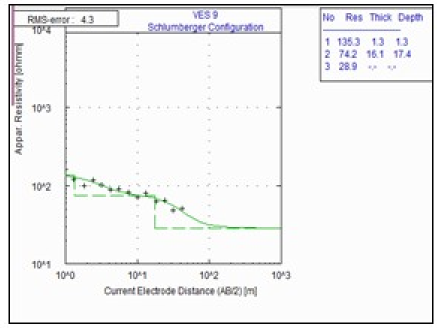
3. Results

3.1 Geoelectric Curves Characteristics

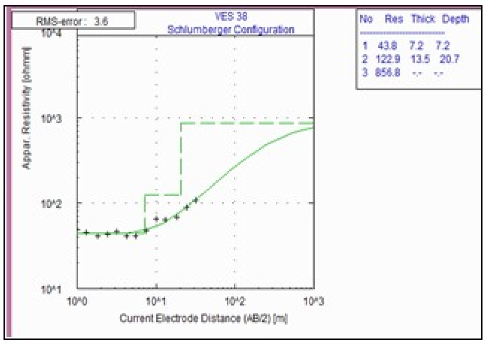
From the generated electrical resistivity soundings curves, nine (9) different VES curve types were obtained from the study area. These included four (4) three-layer each of H, A, K and Q types, three (3) four-layer HK, KH and HA- types, and two (2) five-layer HKH and HAK- types. The H-type is the dominant curve type obtained in the area with twenty-three (23) occurrences (or 58.5% frequency of occurrence). The H-type curve is a typical subsurface environment with a lower resistivity saprolite (middle layer) that is succeeded by or terminates on more resistive (i.e. less conductive) last or infinite layer. The KH type which is the next abundant has seven occurrences (17%), followed by HK with four soundings (9.7%) while others have just one (1) occurrence each. The samples of various typical VES curves types obtained in the area are presented in Figures 2a-g while the frequency distribution chart is presented in Figure 3.



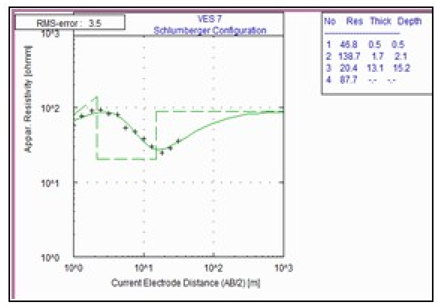
3-layer H-type curve at VES-1



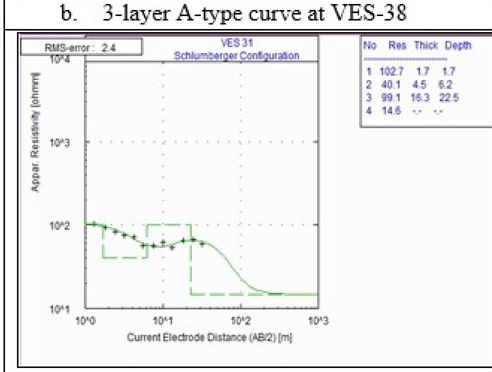
a. 3-layer Q-type curve at VES- 9



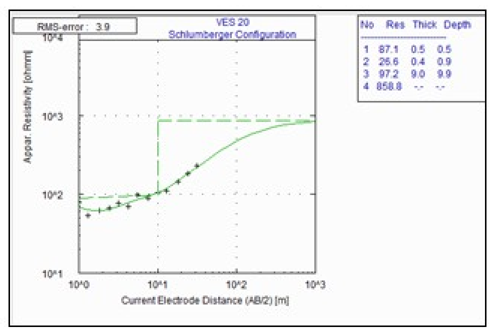
b. 3-layer A-type curve at VES-38



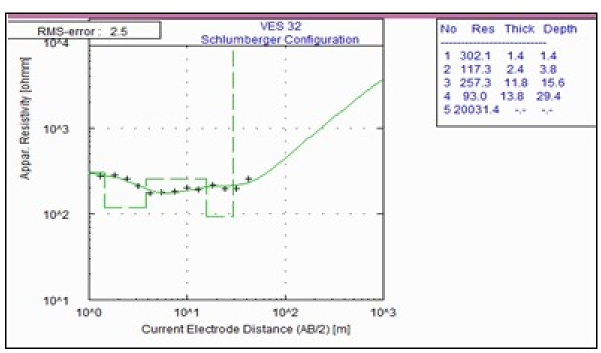
c. 4-layer KH-type curve at VES-7



d. 4-layer HK-type curve at VES31



e. 4-layer HA-type curve



f. 5-layer HKH type curve at VES32

Figure 2: Typical examples of VES curve types obtained across Lapite dumpsite area

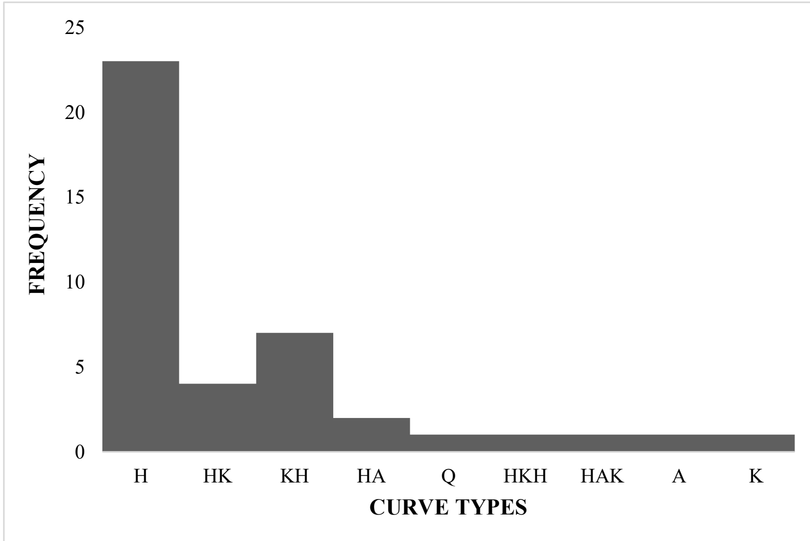


Figure 3: Frequency of occurrences of curve types

4. Discussion

4.1 Lithologic characterisation

The curve type, geo-electric parameters and layer by layer lithologic interpretation based on resistivities values is presented in Table 3. The layer interpretations were made based on the range of resistivity for lithological characterization and groundwater prospect of saprolite and bedrock after Akanbi, 2018. Based on range of resistivity values, the saprolite layers were described as predominantly clayey, compacted clay/ hardpan, sand and clay mixture and predominantly sandy to gravelly. The bedrock description was also described as fresh, weak/slightly weathered and fractured bedrock.

VES points 1-13 on the western side of the dumpsite (Figure 1) consist of three 3-layer H-curves, eight 4-layer curves and one 5- layer curve. The topsoil thickness ranged from 0.5m – 2m depth. The saprolite at VES stations 1-6 shows very low resistivity values ranging between of 19.6 Ωm - 46.9Ωm indicating the presence of infiltrated leachate while VES points 7-13 have relatively higher values of 68.5 Ωm – 889 Ωm. Leachate plumes normally have low resistivity values because of high ion concentration (Rosqvist et al. 2003). Extremely low resistivity values were recorded at VES 3, VES 6 and VES13 at depths below 12.9 m, 39.2 m and 8.7 m respectively. Other low resistivity ranges were observed at VES stations 4, 5, 9 and 12 within the range of 19.6 Ωm - 41.3 Ωm. These low values may be attributed to leachate infiltration (Bayode et al 2011) that expressed that very low resistivity values could be an indication of leachate saturation.

The thickness of the topsoil ranges from 0.5 to 1.4 m in VES points 14 - 25 carried out at the eastern side of the dumpsite. The resistivities of the middle-layer also known as the saprolite are very low ranging between 10.1 Ωm. and 56 Ωm, except VES15 with higher resistivity value of 149.1 Ωm. The low resistive zones are an indication of leachate infiltration from the dumpsite. The thickness of the saprolite lies between 1.5 m – 26.8m and most of the saprolite layers within the depth of 0.5 m - 0.9 m exhibit very low resistivity values within the range of 10.0 to 41.6 Ωm. Previous works place the resistivities of leachate infiltrates from dumpsite to be between 3 – 55 Ωm (Bayode et al 2011; Ojo, 2020). Another key observation is the relatively thin topsoil unit of less than 1 m thickness along most survey stations at the eastern side of the dump. However, the resistivities of the succeeding layer to the saprolite i.e. the last layers are higher than those of the saprolite and are found between the range of 149 – 8832.6 Ωm. These higher resistivity values of the bedrocks indicate zone of low conductivity; and consequentially of low porosity. Locations with last layers resistivities above 600 Ωm which are mostly slightly weathered to impervious fresh bedrocks.

The geo-electric curves of six VES points, VES 26 - 31 conducted at the northern side of the dumpsite (Fig. 1) consist of three 4- layer and three 3-layer curves. The thickness of the topsoil ranges between 0.5 and 2.2m.

Based on the resistivity values of the middle layer that ranged between 36.6 and 54.4 Ωm, the saprolite is largely clayey while points 26 and 27 have higher values of 302.1Ωm and 137.5Ωm respectively. The areas are underlain by bedrock with resistivity values ranging from low values of 14.6 Ωm at VES 31 to as high as 5096.4 Ωm in VES29. Most of the saprolite layers below 1.3 m depth have low resistivity values between 29.8 and 40.1 Ωm. The predominantly clayey nature of the saprolite is favourable for dumpsite purpose since it implies lower infiltration rate for leachate into underground water formations. However, there may be leachate infiltration in locations (VES27, VES28 and VES31) underlain by fractured and weathered bedrocks.

VES stations 32 - 37 are located at the southern part of the map. The topsoil thickness varied from 0.5 to 2.8m. The saprolite layer has relatively higher values of 112 Ωm – 495 Ωm, compared to those at the northern side. The bedrock resistivity ranged from 576.1 to 6969.4 Ωm. This part of the dumpsite is predominantly underlain by fresh bedrock and it is expected to be the least affected by leachate infiltration due the nature of the bedrocks that are interpreted as fresh bedrocks.

Table 3: Geo – electric Parameters and Lithological Interpretation

VES NO.	Curve Type	Layer Sequence	Layer Thickness (m)	Layer Resistivity (Ωm)	Layer Depth (m)	Probable Lithology	Overburden Thickness (m)
1	H	1	1.9	221.9	1.9	Topsoil	11.4
		2	9.5	46.1	11.4	Predominantly clay	
		3		751.5		Weak/slightly weathered bedrock	
2	H	1	1.1	60.9	1.1	Topsoil	16.0
		2	15.0	46.6	16.0	Predominantly clay	
		3		209.8		Fractured bedrock	
3	K	1	6.2	37.1	6.2	Topsoil	12.9
		2	6.7	53.8	12.9	Sand and clay	
		3		10.0		Fractured bedrock	
4	HK	1	0.5	130.2	0.5	Topsoil	5.2
		2	1.1	40.8	1.5	Predominantly clay	
		3	3.7	77.9	5.2	Sand and clay mixture	
		4		28.0		Fractured bedrock	
5	H	1	4.2	94.1	4.2	Topsoil	16.8
		2	12.6	19.6	16.8	Predominantly clay	
		3		54.7		Fractured bedrock	
6	H	1	0.8	179.2	0.8	Topsoil	24.8
		2	24	25.0	24.8	Predominantly clay	
		3		81.0		Fractured bedrock	
7	KH	1	0.5	46.8	0.5	Topsoil	15.2
		2	1.7	138.7	2.1	Sand and clay mixture	
		3	13.1	20.4	15.2	Predominantly clay	
		4		87.7		Fractured bedrock	
8	H	1	5.4	117.9	5.4	Topsoil	42.3
		2	36.9	45.7	42.3	Predominantly clay	
		3		111.2		Fractured bedrock	
9	Q	1	1.3	135.3	1.3	Topsoil	17.4
		2	16.1	74.2	17.4	Sand and clay mixture	
		3		28.9		Fractured bedrock	
10	H	1	4.4	210	4.4	Topsoil	26.3
		2	22.0	57.0	26.3	Sandy clay	
		3		331.0		Fractured bedrock	
11	H	1	2.7	654.5	2.7	Topsoil	38.9
		2	36.1	177.9	38.9	Predominantly sand to gravelly	
		3		293.3		Fractured bedrock	
12	H	1	5.4	95.6	5.4	Topsoil	14.6
		2	9.2	41.3	14.6	Predominantly clay	
		3		378.9		Fractured Bedrock	
13	H	1	8.7	87.9	8.7	Topsoil	15
		2	6.3	4.4	15.0	Predominantly clay	
		3		570.8		Fractured bedrock	

14	H	1	0.9	144.0	0.9	Topsoil	7.9
		2	7.0	40.1	7.9	Predominantly clay	
		3		399.3		Fractured bedrock	
15	KH	1	0.9	129.4	0.9	Topsoil	6.8
		2	1.9	149.1	2.8	Predominantly sandy to gravelly	
		3	3.9	74.8	6.8	Sand and clay mixture	
		4		1229.5		Weakly/ slightly weathered bedrock	
16	HK	1	0.8	71.2	0.8	Topsoil	22.5
		2	1.5	56.0	2.4	Sandy clay	
		3	20.2	161.1	22.5	Predominantly sand to gravelly	
		4		74.1		Fractured bedrock	
17	H	1	2.0	39.1	2.0	Topsoil	5.1
		2	3.1	48.6	5.1	Predominantly clay	
		3		12962.3		Fresh bedrock	
18	H	1	0.6	78.3	0.6	Topsoil	1.5
		2	0.9	10.1	1.5	Predominantly clay	
		3		4368.1		Fresh bedrock	
19	HK	1	0.6	79.4	0.6	Topsoil	10.1
		2	0.9	10.0	1.5	Predominantly clay	
		3	8.6	362.1	10.1	Predominantly sand to gravelly	
		4		21.6		Fractured Bedrock	
20	HA	1	0.5	87.1	0.5	Topsoil	9.9
		2	0.4	26.6	0.9	Predominantly clay	
		3	9.0	97.2	9.9	Sandy clay	
		4		858.8		Weak/slightly weathered bedrock	
21	H	1	0.6	111.3	0.6	Topsoil	1.7
		2	1.1	12.9	1.7	Predominantly clay	
		3		3655.1		Fresh bedrock	
22	H	1	0.9	57.3	0.9	Sand and clay mixture	2.4
		2	1.5	18.1	2.4	Predominantly clay	
		3		8832.6		Fresh bedrock	
23	HAK	1	0.5	205.4	0.5	Topsoil	16.8
		2	0.9	42.4	1.4	Predominantly clay	
		3	21.4	507.2	8.7	Compacted clay/ hardpan	
		4	8.2	5120.9	16.8	Fresh bedrock lens	
		5		1522.3		Weak/ slightly weathered bedrock	
24	H	1	1.4	58.1	1.4	Topsoil	3.0
		2	1.6	41.6	3.0	Predominantly clay	
		3		507.5		Fractured bedrock	
25	H	1	0.7	99.4	0.7	Topsoil	3.5
		2	2.8	37.4	3.5	Predominantly clay	
		3		174.1		Fractured bedrock	
26	KH	1	0.5	97.8	0.5	Topsoil	4.8
		2	0.8	302.1	1.3	Predominantly sand to gravelly	
		3	3.5	29.8	4.8	Predominantly clay	
		4		1870.5		Fresh basement	
27	KH	1	1.5	47.1	1.5	Topsoil	12.9
		2	4.2	137.5	5.7	Sand and clay mixture	
		3	7.3	22.0	12.9	Predominantly clay	
		4		415.1		Fractured bedrock	
28	H	1	2.2	297.4	2.2	Topsoil	8.5
		2	4.1	54.4	6.3	Sand and clay	
		3		1431.0		Weak/ slightly weathered bedrock	
29	H	1	1.5	193.3	1.5	Topsoil	4.9
		2	3.4	34.6	4.9	Predominantly clay	
		3		5096.4		Fresh bedrock	
30	H	1	1.6	233.5	1.6	Topsoil	12.7
		2	11.2	68.9	12.7	Sand and clay mixture	
		3		6713.3		Fresh bedrock	
31	HK	1	1.7	102.7	1.7	Topsoil	22.5
		2	4.5	40.1	6.2	Predominantly clay	
		3	16.3	99.1	22.5	Sand and clay mixture	
		4		14.6		Fractured bedrock	
32	HKH	1	1.4	303.9	1.4	Topsoil	28.8
		2	2.9	139.9	4.4	Sand and clay mixture	
		3	10.4	243.6	14.7	Predominantly sand to gravelly	
		4	14.1	115.0	28.8	Sand and clay mixture	
		5		2063.4		Fresh bedrock	
33	H	1	2.8	734.6	2.8	Topsoil	19.6

		2	16.7	112.0	19.6	Sand and clay mixture	
		3		576.1		Fractured bedrock	
34	KH	1	0.9	180.8	0.9	Topsoil	8.4
		2	0.5	287.3	1.4	Gravelly	
		3	7.0	67.6	8.4	Sand and clay mixture	
		4		736.9		Weak/slightly weathered bedrock	
35	KH	1	1.0	413.0	1.0	Topsoil	12.7
		2	1.0	495.8	2.0	Compacted clay/ hardpan	
		3	10.8	222.8	12.7	Predominantly sand to gravelly	
		4		841.4		Weak/ slightly weathered bedrock	
36	HA	1	1.1	247.4	1.1	Topsoil	8.5
		2	1.5	130.8	2.6	Sand and clay	
		3	5.9	211.8	8.5	Predominantly sand to gravelly	
		4		1316.2		Weak / slightly weathered bedrock	
37	KH	1	0.5	962.2	0.5	Topsoil	9.8
		2	0.8	4486.3	0.3	Compacted clay/hardpan	
		3	8.5	337.7	7.7	Predominantly sand to gravelly	
		4		5331.0		Fresh bedrock	
38	A	1	7.2	43. 8	7.2	Topsoil	23. 9
		2	13.5	122.9	20.7	Sandy	
		3		856.8		Weak/slighty weathered	
39	H	1	1.3	63.7	1.3	Topsoil	5.7
		2	4.4	31.9	5.7	Predominantly clay	
		3		1359.4		Weak/ slightly weathered bedrock	
40	H	1	1.1	439.5	1.1	Topsoil	37.4
		2	36.3	110.6	37.4	Sand and clay mixture	
		3		362.2		Fractured bedrock	
41	H	1	0.4	2289.7	0.4	Topsoil	
		2	6.7	62.5	7.1	Sand and clayey	
		3		25783.5		Fresh bedrock	

4.2 Lithological description of depth sounding (VES38) on dumpsite

In order to decipher the actual impact of dumps on the subsurface environment, VES 38 was conducted right on the dumpsite (Figure 1). The generated VES curve is a three-layer A- type which is typically an ascending (or increasing) resistivity curve and it is the only A-type VES curve obtained in the present study. The increasing resistivity from the top soil to the bedrock is a good indication signifying reducing conductivity, which means that leachate infiltration is reducing with depth and suggesting the underlying layers are increasing impervious and the leachates are mostly retained or trapped within the topsoil. This is buttressed by the thick topsoil of 7.2 m, which happens to be the thickest topsoil (7.2 m) obtained from the generated geo-electric soundings in the study area. Also, the topsoil resistivity of 43.8 Ωm is similar to the resistivity values of municipal solid wastes (MSW) obtained by other workers (Bayode et al 2011; Ojo 2020) in other dumpsites area of similar environments. The saprolite resistivity which is 122. 9 Ωm is equally higher than most other soundings. This also confirms that leachates are mostly trapped within the topsoil and that the saprolite is not affected as much. In addition, the saprolite which is 13.3 m thick is quite thick enough to reduce infiltration of leachate to the other subsurface layers. The resistivity of the infinite layer is 856.8 Ωm at depth 20.7m.

4.3 Lithological characterisation of control VES points

The control VES points namely; VES39, 40 and 41 are all three layer H-type curve and are at a distance of 354 m, 311 m and 438 m respectively away from the dumpsite (Figure 1). These points are essential for characterising the natural lithological situation that has not been influenced by the leachate or dumpsite residues. The corresponding top soil thicknesses are 1.3m. 1.1m and 0.4m with resistivity values of 63.7 Ωm, 439.5 Ωm and 2289.7 Ωm respectively. The saprolite layers have resistivity values of 31.9 Ωm, 110.6 Ωm and 62.5 Ωm with thicknesses of 4.4m, 36.3m, 6.7m respectively. The last layer has resistivity values are 1359.4 Ωm, 62.2 and 25783.5 Ωm respectively. VES 39 and 41 could be inferred to be good representatives of the uncontaminated environment because they are located at the upstream side of the dumpsite. The saprolite of control point C1(VES 39) is predominantly clayey with thickness 5.7m and it is underlain by slightly weathered bedrock (Table 3). The implication of this is that, though; the saprolite will be a good liner material (since it is clayey) for the overlying dumpsite but it is thin and the fact that the bedrock is slightly weathered, leachate can infiltrate into the subsurface environment and will pose a threat to the underground water.

For control point C2 (VES 40), which is located at the southwestern side of the dumpsite (Figure 1) the saprolite is very thick (36.3 m) but sandy in nature with a resistivity of 110.6 Ωm. Sands are porous and permeable formations and are not suitable as liner for the dumps. The sandy formation is underlain by fractured bedrocks, which further complicates the suitability of this location as dumpsite. Leachate can easily penetrate the subsurface environment at this section of the dumpsite. The saprolite thickness of control point C3 (VES 41) at the southeastern part (Figure 1) is much thinner (7 m) compared to C2 and it is also sandy in nature but it is underlain by fresh (nonporous and impermeable) bedrock. This configuration is fair for dumpsite since the bedrock in this area is not fractured. Out of the three control points, C3 or VES point 41 at the southern part of the dumpsite seems fairly better for further expansion of the dumps due to the fresh bedrock which will not permit movement of leachates into the subsurface.

Also, the diverse geo-electric parameters obtained from the lithological characterisation of depth soundings in locations that are unaffected (control VES) by the impacts of MSW dumps shows the heterogeneity of the subsurface environment and the need for caution in extension of the dumpsites in that area.

4.4 Site suitability as liner for the dumpsite

4.4.1 Overburden thickness

From Table 3, the statistic of the overburden thickness variations across Lapite dumpsite is presented in graphical form in Figure 4. This does not include VES points conducted on dumpsite (VES38) and at the control points (i.e. VES39, 40 and 41). The frequency distribution showed that points with poor overburden thickness less than 2 m are just two locations namely VES point 18 and 21 at the eastern side of the site, that is characterised by thin topsoil units and low saprolite (middle layer) resistivities typifying possible leachate infiltration. The thin overburden unit is most likely the reason for this. In the same light, VES points with fair thickness between 2.1 and 4.9 m i.e VES points 22, 24, 25,26 and 29 (Table 3) are also aligned along the eastern end of the dumpsite as well. This clearly pointed that expansion of the dumpsite across the eastern side after the expressway will not be suitable base on overburden thickness. In other directions, the thickness of the overburden is favourable where the overburden exceeds 5 m.

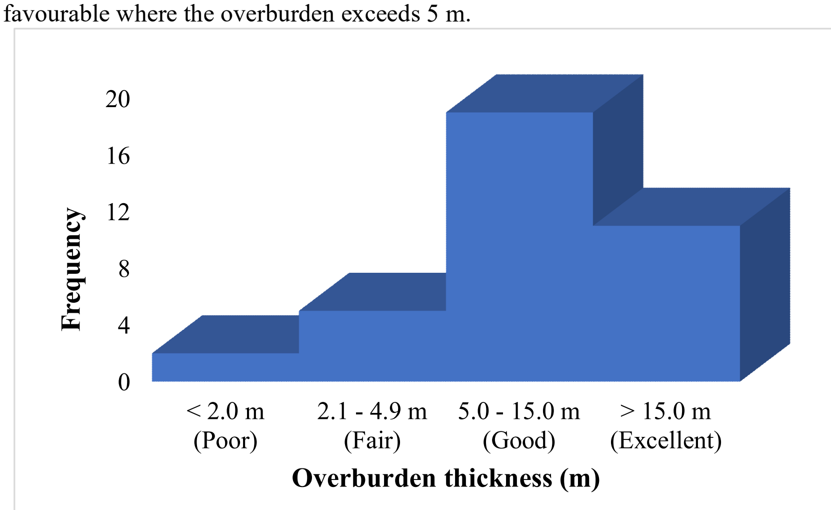


Figure 4: Frequency of suitability classes of subsoil thickness as liner across Lapite dumpsite area

4.4.2 Overburden lithology

The frequency of occurrences of subsurface lithologies across the VES points in Lapite area is presented in Figure 5. Clay and compacted clay are the most suitable lithology as liners for dumpsite. However, compacted clay is more desirable due to its lithification and compact nature, and relatively lower permeability properties compared to other lithologies. For the present lithological characterisation, compacted clay abundance is just 6% while clay adjudged as good liner after compacted clay is the most widespread subsurface soils in the area. Sands and gravel are porous materials and not recommended as liners for dumpsite but in situation where clay intermingled with sand, then the aggregate lithology may be fairly considered as liners provided it is thick enough. Locations with sand and clay mixture occupies 39% in Lapite dumpsite area. Fortunately, most VES

points with clay and sand aggregate are characterised by thick overburden exceeding 5 m.
VES locations with sand or gravel overburden lithology are not recommendable as liner even if the overburden thickness is very thick. These points are on VES points 32, 34, 36 and 37 and the overburden thickness is even shallow in the last three points ranging from 7.7 to 8.4 m (Table 3). These points are found in the southern side of the dumpsite (Figure 1).

4.4.3 Bedrock freshness/intactness
The bedrock resistivities which varied widely from 10 to 12,962 Ωm (Table 1) revealed the heterogeneity of the bedrock across the study area. Those with resistivities of less than 600 Ωm were twenty in number, slightly weathered ones between 600-1800 Ωm were eight while those with >1800 Ωm that interpreted as fresh basement were just nine can be regarded as fresh (Figure 6). The whooping number that terminates on fractured bedrocks which represents 54% of the total VES points are not suitable as liners for dumpsites while just nine bedrocks of 24% of are regarded as being good as liners for dumpsites. This large percentage of fractured bedrock makes about half of the subsurface environment of the area prone to leachate contamination.

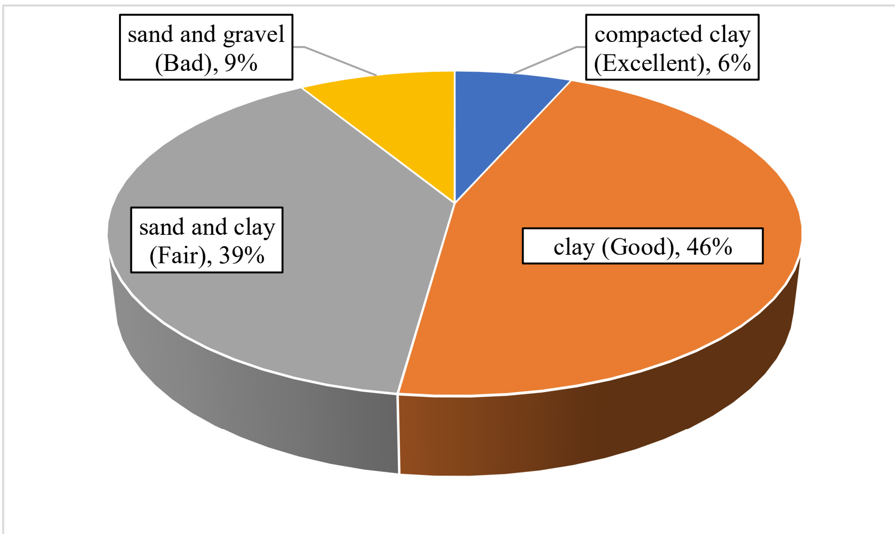


Figure 5: Percentage occurrences of saprolite lithology and relative suitability as liner

Landfill and dumpsite constructed on fractured bedrock can pose a potential risk of contaminant leachate to the surroundings through the fracture zones. Likewise, the remaining 22% of the area underlain by weak to slightly weathered bedrock is also porous and may permit leachate infiltration and are not also suitable as liners for dumpsite. With this bedrock status, the location is not appropriate for further expansion of the dumpsite.

5. Conclusion

Geophysical assessment of the subsurface soils and rocks underlying the Lapite dumpsite along Akinyele-Ojoo expressway has been carried out. The overburden thickness varies greatly spanning from 1.5 m to 42.3 m and the lithology is also diverse but the saprolite (middle layer) units are mostly fine- grained and exhibit good liner property texturally. However, the underlying bedrock status are far from being desirable to be suitable liners as greater percentage (76%) are fractured and weathered bedrocks that can leak leachates and pollution plumes to the underlying underground water.

The diverse heterogeneity of the control VES points in terms of the lithology and the thickness of the overburden unit as swell as abundant fractures of the bedrocks altogether depict the unreliability of this underlying soils and rock units as dumpsite liners. This assessment therefore recommends that there should be no further expansion of the MSW dump particularly towards the eastern and southern borders and the waste dumps be relocated. The alternative is to provide artificial liners and/or modify the natural sub-soils and bedrocks by geotechnical means such as fractures zones infilling and compaction processes to mitigate permeability of leachates. Also, it is mandatory that the impact of the dumpsite on the underground water be investigated to safeguard the health of the human population in adjoining areas.

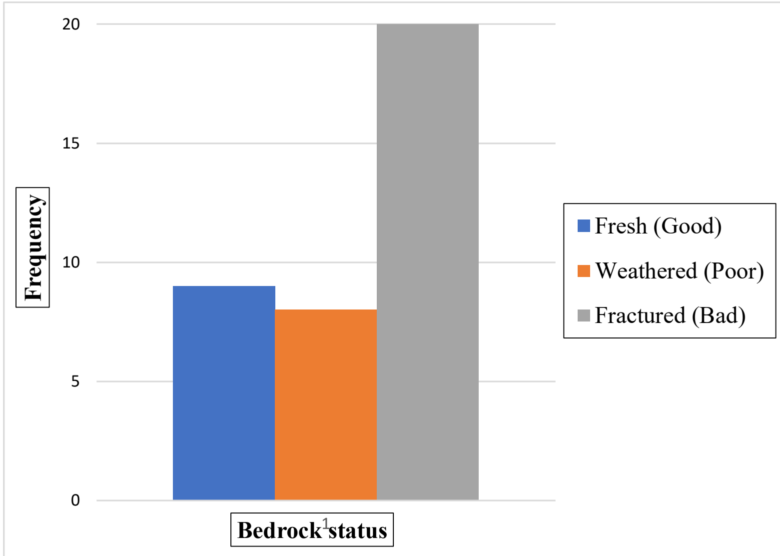


Figure 6: frequency of the suitability of bedrock as liner

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