GLOBAL JOURNAL OF GEOLOGICAL SCIENCES VOL. 3, NO. 1, 2005: 25-33

ENGINEERING GEOLOGICAL EVALUATION OF A PROPOSED LANDFILL SITE AT ABA-KULODI, NEAR IBADAN, SOUTHWESTERN NIGERIA.

G. O. ADEYEMI and I. A. OYEDIRAN

(Received 4 July 2003; Revision accepted 25 March, 2004)

ABSTRACT

Evaluation of a location at Aba-Kulodi adjacent to kilometre 8 along the Ibadan / Ile-Ife expressway, Southwestern Nigeria was carried out to determine its suitability or otherwise as a landfill site.

Two Vertical Electrical Soundings (VES) 30.00m apart were executed to obtain subsurface information on depth to bedrock and possibly the water table. Disturbed and undisturbed soil samples were collected from each of the two trial pits established at vertical interval of 0.50m up to a depth of 3.00m. The disturbed samples were subjected to grain size distribution and consistency limits tests while consolidation and permeability tests were carried out on undisturbed samples.

The VES results revealed 3 geo-electric layers with depths to bedrock of between 14.30m and 17.60m at VES 1 and VES 2 respectively. The depths to water table measured from an existing nearby well were 8.10m and 7.00m during the dry and rainy seasons respectively, suggesting that the water table lies within the second geo-electric layer. The soil samples taken from the depth of 3.00m in the two pits are generally well-graded non-plastic sandy clayey silt, a possible indication of no compressibility. The coefficients of permeability obtained for samples from pits 1 and 2 ranges from 1.85×10^{-4}mm/s to 3.91×10^{-6}mm/s and 1.91×10^{-4}mm/s to 2.91×10^{-6}mm/s respectively. The coefficient of permeability obtained for samples taken from the 3.00m depth in the two pits are significantly higher than the minimum value of 10^{-6}mm/s recommended for soil that should form the base of landfills. The coefficient of volume compressibility at the sampling pits 1 and 2 range from 1.83 to 7.69×10^{-3} m^2/KN but generally increases with applied pressure (31.2 - 498.9 KN/m^2) and decrease with depth (0.5 to 3.0m). Statistical treatment of the values of the coefficient of compressibility of soil samples from the depth of 3.00m in the two test pits shows no significant variation, an indication that there is no likelihood of differential settlement if the site is used for disposal of solid wastes. If in-situ compaction and lining are done, the location can be used as a landfill site.

KEY WORDS: Landfill, Plasticity, Compressibility, Permeability, Compaction.

INTRODUCTION

The most effective and simplest way of dealing with waste is to ensure that it does not arise. However where it does arise it is important to ensure that it is managed responsibly with proper regard to the environment. This calls for proper environmental management, which Uchegbu (1998) defined as the process of putting together those items of natural environment where man exists so that man's activities do not have adverse effect on the environment.

Rapid technological changes, increased population growth and high concentration of people in urban centres are compounding the problems of maintaining the environment at a healthy level due to enormous waste generated. No other issue has perhaps dominated the environmental scene in most developing countries as that of management of solid waste. Sittig (1979) attributed this to the increased awareness of the consequences of environmental change to future generations by indiscriminate dumping of refuse.

In 1970, the World Health Organisation (WHO) expert committee defined solid waste as useless unwanted or discarded materials that arise from man's activities and is no free floating. Ajagbe (2000) defined waste as any unavoidable material resulting from domestic activity or industrial operation for which there is no economic demand and which must be disposed of, while solid wastes are all wastes arising from human and animal activities, that are normally solid and that are discarded as useless or unwanted. Solid waste products arise from our way of life and are posing an ever-increasing problem mainly because of the quantity involved and its consequent effects on the pollution of water, air and land. Careless dumping of waste and poor refuse management could therefore be disastrous.

According to Tchobanoglous et al (1977) (Fig. 1), the exploitation of raw materials stage is the beginning of solid waste generation. Thereafter solid wastes are generated at every step in the process as raw materials are converted to goods for consumption.

It is thus obvious that the site for disposal of waste must be selected scientifically. Ogunsanwo and Mands (1999), did indicate that the site which are constructed on foundations of soils and rocks are sites specially (scientifically) prepared for the repository of waste such that the wastes themselves or their products (leachates or radiation) do not pollute the environment. Thus the main purpose is to prevent pollution of the environment by waste and their products. As shown by Cheremisinoff and Morresi (1977) (Fig. 2), the final step in the solid waste management system is disposal, which could be by Open dumps, Landfill, Incineration, Onsite disposal, Hog feeding, and Composting. Of these, according to D.O.E (1995), the most economical and most commonly practiced disposal method is LANDFILL. This method encourages in order of priority;

1. Prevention or reduction of waste
2. Recovery and Re-use
3. Disposal.

Landfills also called Tips (UK), Coups (Scotland), Sanitary Landfill (USA) and Dumps (Worldwide) means waste disposal sites. They are defined by Tchobanoglous et al (1993) as waste disposal sites, which are also physical facilities, used for disposal of residual waste in the surface soils of the earth. According to the Federal Ministry of Housing and Environment (1983) it is an engineered method in which solid waste are disposed of by spreading them in their layers, compacted to the smallest practical volume and covering them with earth daily or more frequently in a manner that will minimize environmental pollution. Gettinby et al (1996) described the practice of land filling as involving refuse being deposited in a suitable void i.e. one which permits control of the movement of mobile pollutants.

Ibadan according to the National Population Commission (1991) census figures has a population of 1,991,367 with an enormous amount of waste at an estimate of 0.46 kg/person [Uchegbu (1998)] generated on a daily basis as a result of domestic,

G. O. ADEYEMI, Department of Geology, University of Ibadan, Ibadan, Nigeria
I. A. OYDIRAN, Department of Geology, University of Ibadan, Ibadan, Nigeria.

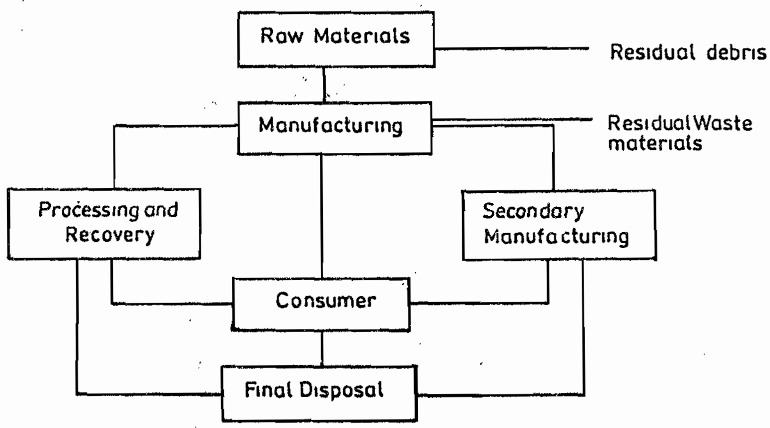


Fig.1. Material Flow and generation of solid waste
[Tchobanoglous et al, 1977]

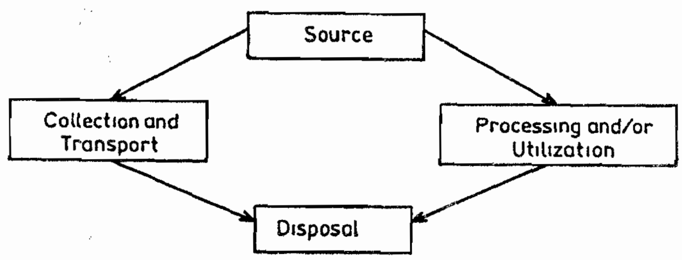


Fig. 2. Solid Waste Management System
[Cheremisinoff and Morresi, 1977]

agricultural and industrial activities. The bulk of the wastes generated include leaves, paper, food waste, tins, glass, plastics, metals, rags e.t.c.

With due consideration of the implication of the hazard posed by improper disposal of waste on human being and animals in Ibadan, engineering geological evaluation of a location adjacent to km 8 Ibadan-Ile-Ife expressway was carried out. The investigation was meant to:

- Provide data and information necessary to design an acceptable landfill.
- Establish baseline conditions for the site with the determination of permeability coefficients of the soil in the area so as not to contaminate groundwater.
- Provide sufficient information for the engineering design and construction of the site by determining geotechnical properties such as grain size distribution, consistency limits, consolidation and compressibility characteristics.
- Enable an assessment of the impact of the development on groundwater with the use of geophysical investigation (Electrical Resistivity method) to determine the depth to bedrock.

PHYSIOGRAPHY OF THE STUDY AREA

The study area is located at Aba-Kulodi, adjacent to km 8 on the outskirt of Ibadan along the Ibadan-Ile-Ife Expressway southwestern Nigeria. The area lies between longitudes 4^0 00 and 4^0 02' East of the Greenwich meridian and latitudes 7^0 23 and 7^0 24' North of the equator. The area is easily accessible due to the availability of effective road network. The Ibadan/Ile-Ife Expressway on one hand and the presence of footpaths and untarred feeder roads on the other links the study area. (Fig. 3). The choice of the study area was based on the fact that it is fairly remote from the habitable area, major highway and river. It is also flat–lying. There is however no immediate plan by anybody to use it as a landfill site.

The physiography or relief of the area is the result of the geomorphologic processes that have shaped the rocks of the area. The area has an undulating rolling topography with a height of between 241-245m above mean sea level, (SF Consultants 1979). The study area has a well-developed drainage system with River Omi and River Ihan serving as the major rivers. The direction of river flow is north of the study area and is fairly controlled by the undulating rocks (Fig. 3). SF Consultants (1979) indicated that the study area is located in the intertropical convergence zone on the west-east boundary of Nigeria. This zone is defined as an area influenced by two different major wind directions intersecting each other. Most of the year the main wind movement is directed from the southwest, which carries warm and humid air from the sea. The opposed winds carrying hot and very dry air, blow from the northeast and predominating in weather conditions in November, December and January, decreasing again in February; this determines the changes between the dry season and the rainy season. During the dry season the number of rainy days (days with a rainfall of 0.25mm or more) amounts to only 1 or 2 days per month while during the rainy season, the number ranges between 7 and 16 days per month. But even during the dry season, occasional showers of high intensity do occur and can produce as much as 50mm at a time while we can have a high of 166mm during the rainy season.

GEOLOGY

The study area is underlain by the Basement Complex rocks of Nigeria (Wilson, 1922, Jones and Hockey, 1964.) The Basement

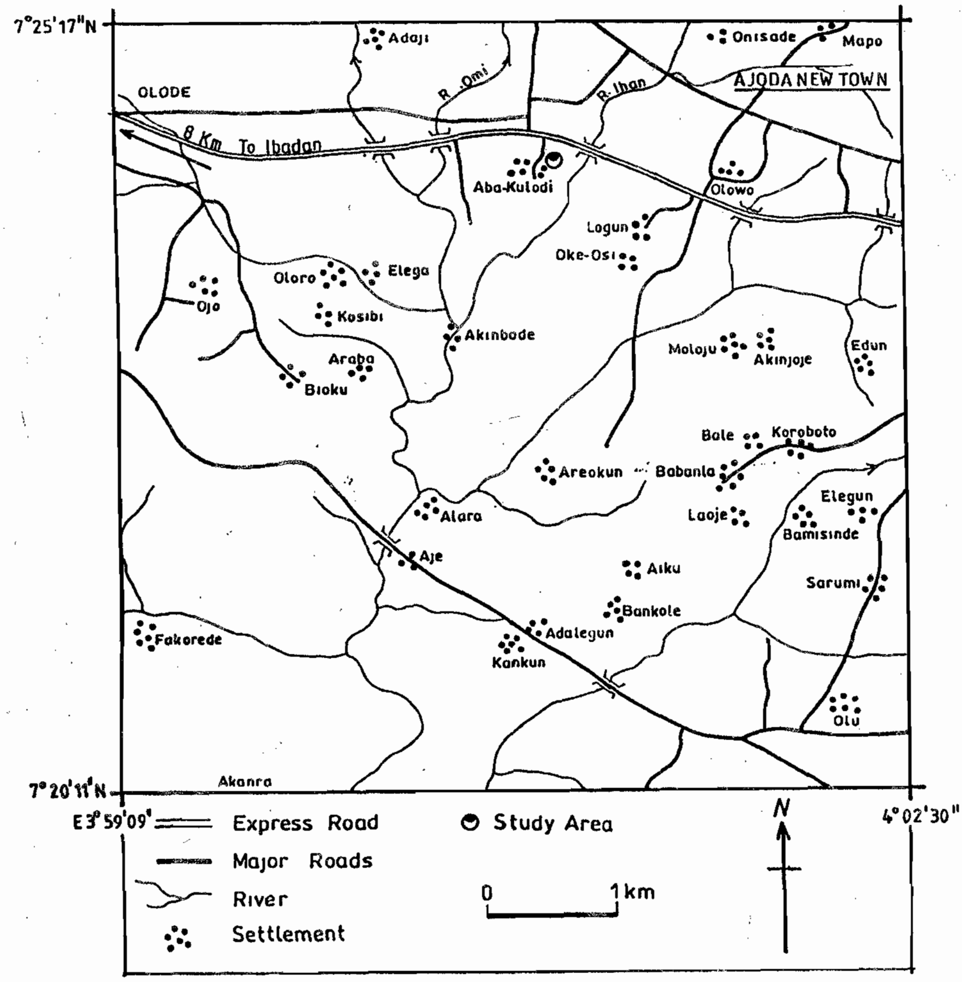


Fig. 3. Map of Study Area Showing Drainage and Road Network
[SF Consultants 1979]

Complex rocks of Nigeria consist of crystalline igneous and metamorphic rocks. Though the assemblages have been variedly classified, they may be broadly subdivided into the ancient gneiss-migmatite complex, the schist belts and the Pan-African (ca. 0.6 Ga) intrusive series or the Older Granites plus minor rocks. Radiometric ages obtained from the ancient migmatite gneisses, are notably between ca. 2.8 and 2.0 Ga (Rahaman, 1988). Older dates (≥3.0 Ga) have more recently been derived from some (Dada et al., 1998). The schist belts occur prominently within the western half of the country though a few have more recently been highlighted in the central and southern parts (Elueze, 2000). The major outcrop in the study area is undifferentiated Schist which includes some Gneiss. Other rock types found around the area include Granite gneiss, Quartzite and Quartz Schist and Gneiss, which occur with undifferentiated Migmatites (Fig. 4). Presence of only one well in the study area made it impossible to determine the groundwater flow direction. But the static water level in the well varies from 7.00 to 8.10m during the year (dry season and rainy season, respectively)

METHODOLOGY

The research work involved both *Geophysical* and *Geotechnical* methods of investigation. Geophysical Investigation includes non-destructive techniques of investigating the dynamic characteristics of soils and rocks, (Jongmans et al, 1990). Geophysical methods encompass a wide range of surface and down hole measuring techniques, which provide means of investigating surface geologic and hydro geologic conditions, (Benson, 1993). They are particularly useful as they allow for a

Table 1. Grain Size Distribution (Percentage Particle Size)

Pit	Sample Depth (m)	% Clay	% Silt	% Sand	% Gravel	D_{10} (mm)	D_{25} (mm)	D_{60} (mm)
BORA 1	0.5	23.69	59.45	17.86	-	-	0.0028	0.066
	1.0	23.81	56.38	19.81	-	-	0.0028	0.066
	1.5	23.90	56.29	19.81	-	0.013	0.062	0.120
	2.0	2.65	41.99	55.36	-	0.028	0.065	0.280
	2.5	1.37	28.45	70.28	-	0.046	0.075	0.350
	3.0	0.61	20.76	78.63	-	0.070	0.170	0.440
BORA 2	0.5	44.59	39.82	15.59	-	-	-	0.060
	1.0	44.63	38.64	16.73	-	-	-	0.062
	1.5	-	73.02	26.98	-	0.018	0.060	0.070
	2.0	-	44.98	55.02	-	0.012	0.065	0.280
	2.5	1.86	36.26	61.88	-	0.028	0.065	0.290
	3.0	1.17	25.62	73.21	-	0.029	0.075	0.410

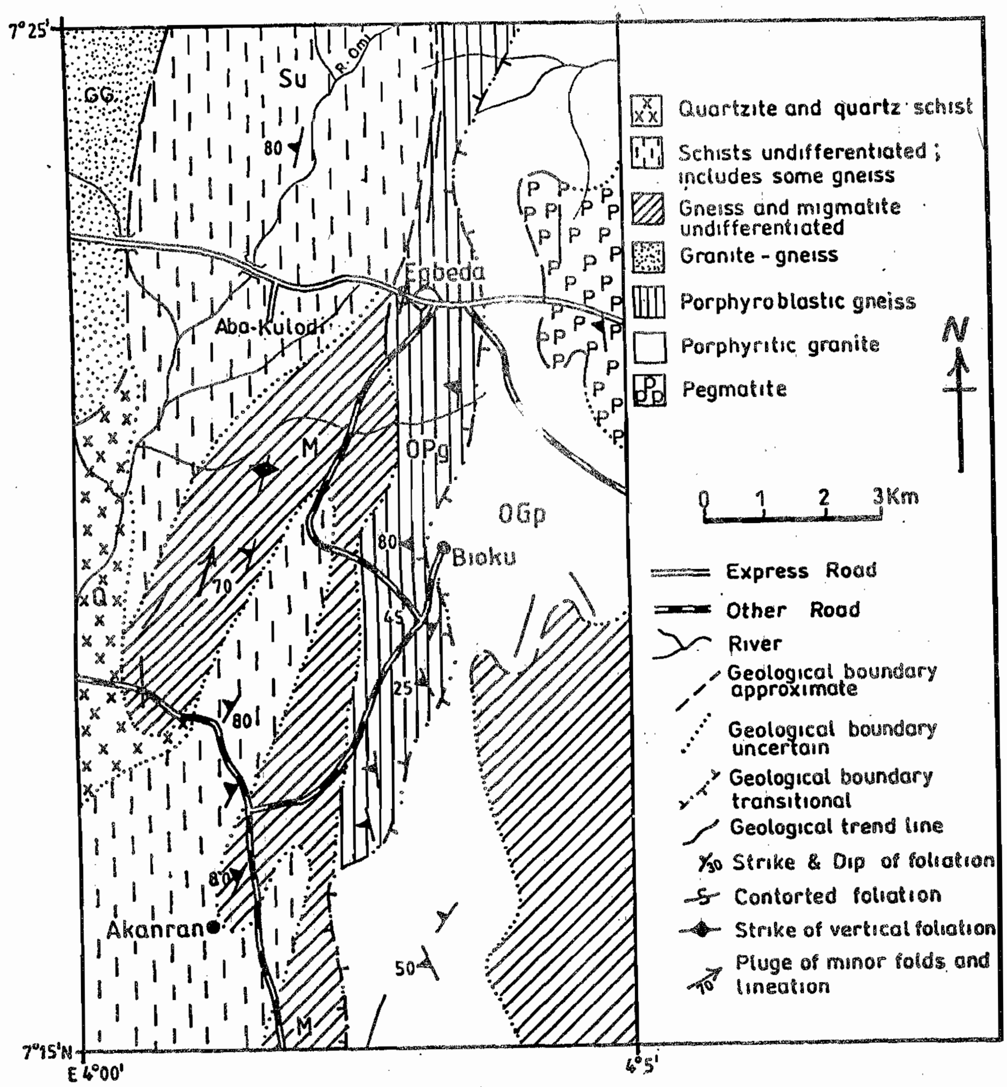


Fig: 4.Geological Map of the Study Area
[Adapted after Jones and Hockey 1964]

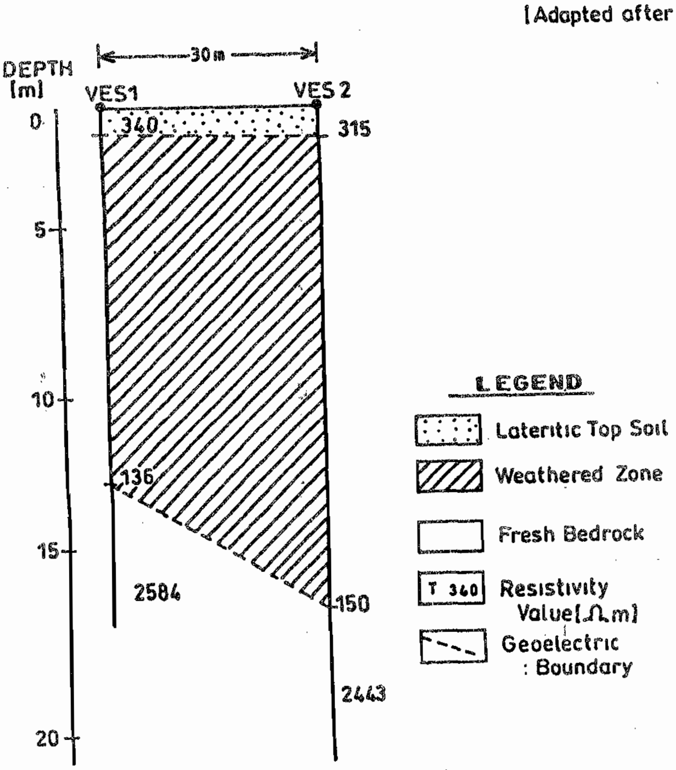
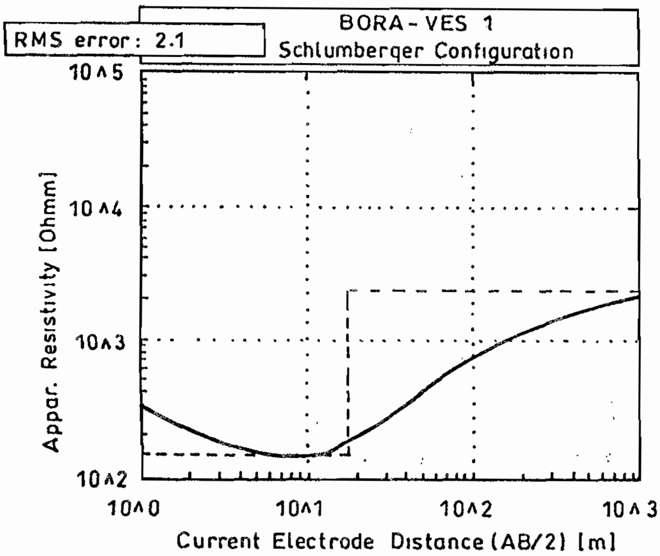


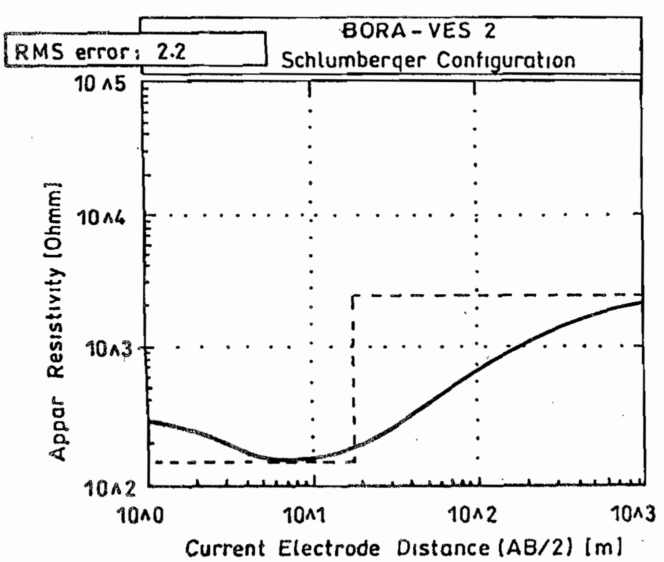
Fig 5 Geoelectric Cross Section

wide ground coverage in a short while. Geophysical investigation involving Vertical Electrical Sounding was carried out with the use of ABEM Terrameter model SAS 300 with relevant accessories using the Schlumberger electrode configuration described by Parasnis (1986) and Zohdy et al (1974). Two Vertical Electrical Sounding (VES) points 30m apart were established to obtain subsurface information on depth to bedrock. The investigation involved passing of electrical current into the ground via a pair of steel electrodes (current electrodes) and measurement of the resulting potential drops (pd) across electrode symmetrically displaced linearly about a fixed point. The distance between the two current electrodes was increased and the potential electrodes were practically kept fixed and the separation only increased when the measured potential drop became too small for accurate determination. Analysis of the resulting graph of apparent resistivity against current half-electrode separation yields a layered earth model composed of individual layers of specified thickness and resistivity. The quantitative analysis and interpretation of VES data was carried out by partial curve matching (Orellana and Mooney, 1966) and computer assisted iteration (Ghosh, 1971 and Zohdy et al, 1974). Geotechnical methods involve collection of soil samples (disturbed and undisturbed) at varying depths in a trial pit which according to Tomlinson (1963) is the cheapest method of exploration to shallow depth which enables a clear picture to be obtained of the stratification of soils and the presence of any lenses or pockets of weaker material.



No	Res	Thick	Depth
1	340.0	0.8	0.8
2	136.0	13.5	14.3
3	2584.0	-.-	-.-

Fig.6. Electrical Resistivity Curve [VES 1]



No	Res	Thick	Depth
1	314.9	0.9	0.9
2	149.7	16.7	17.6
3	2442.5	-.-	-.-

Fig. 7. Electrical Resistivity Curve [VES 2]

For the purpose of this work geotechnical sampling involved the establishment of two trial pits 30m apart. Samples of soil both disturbed and undisturbed were obtained from the pits up to a depth of 3m at 0.5 m vertical interval. The disturbed samples collected in polythene bags were obtained using a digger and shovel. The undisturbed sample were obtained using core cutters (100mm x 150mm) with a marshal rammer ramming it into place. The core cutter was sealed on both edges immediately with candle wax melted on the field to prevent loss of moisture. The disturbed samples were subjected to classification tests such as grain size distribution and consistency limits while consolidation and permeability tests were carried out on undisturbed samples.

RESULTS AND DISCUSSION

Geophysical Investigation

The study area as revealed by geophysical sounding data is composed of 3 layers (Fig. 5). The topsoil with layer resistivity of between 340Ωm and 315Ωm and thickness of 0.8m and 0.9m below VES 1 and VES 2 respectively consists of a clayey sandy soil. This is underlain by highly weathered rock with resistivity and thickness ranging between 136Ωm and 150Ωm and 13.5m and 16.7m beneath VES 1 and VES 2 respectively. Although the depth to water table could not be located exactly from the VES data, information obtained from an existing well located 30m away from VES 1 has a total depth of 9.05m and produces throughout the year. The depths to water table in the well were found to be 8.10m and 7.00m during the dry and the rainy seasons respectively shows that it lies within the weathered layer. It can thus be inferred that the water table cannot be less than 5.0m in the study area. The weathered rock is underlain by fresh (unfractured) rock of apparent resistivity greater than 2000Ωm at both sounding points. According to Clayton and Huie (1973) the base of a landfill should not be less than 6m above the lowermost aquifer. The absence of fractures in the underlying rock would also prevent pollution of ground water. With these results the area under investigation is suitable for the location of a landfill site. (Fig. 6 and 7 show the Electrical Resistivity curves)

Geotechnical Investigation

1. ***Grain Size Distribution***

Table 2 shows that soil samples in the first trial pit (BORA 1) at 0.5m, 1.0m and 1.5m and at 0.5m, 1.0m and 1.5m in the second trial pit (BORA 1) have amount of fines greater than 50 %. The amounts of fines at greater depths are less than 50%. Daniel (1993b) recommends amount of fines not less than 20% for land fill seals. The soils are thus good for the base of a landfill. (Fig. 8 and 9 show the Grading curves)

2. ***Consistency Limits***

The Plasticity index is the measure of the affinity, which a soil has for water. Casagrande (1932) did indicate that the higher the value, the poorer would be the soil as an engineering soil. Materials with low plasticity do not compress appreciably under load nor do they shrink extensively when dried so that once they have acquired a firm consistency near plastic limit they are quite stable. Table 3 indicates that soil samples obtained from the 2.0m, 2.5m and 3.0m depths in BORA 1,

Table 2:. Grain Size Distribution (Amount of Fines and Uniformity Coefficient)

Pit	Sample Depth (m)	Amount of fines (%)	Particle Coarse than 63 μm (%)	Uniformity Coefficients D_{60}/D_{10}
BORA 1	0.5	83.14	17.86	-
	1.0	80.19	19.81	-
	1.5	80.19	19.81	9.23
	2.0	44.64	55.36	10.00
	2.5	29.72	70.28	7.61
	3.0	21.37	78.63	6.29
BORA 2	0.5	84.41	15.59	-
	1.0	83.27	16.73	-
	1.5	73.02	26.98	3.89
	2.0	44.98	55.02	23.33
	2.5	38.12	61.88	10.86
	3.0	26.79	73.21	14.14

Table 3: Result of Consistency Limit Test

PIT	DEPTH (m)	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX %
BORA 1	0.5	56.50	26.18	30.32
	1.0	59.00	25.15	33.85
	1.5	54.40	32.91	21.49
	2.0	30.98	NON-PLASTIC	NON-PLASTIC
	2.5	31.00	"	"
	3.0	32.00	"	"
BORA 2	0.5	69.00	32.47	36.53
	1.0	55.96	26.24	29.72
	1.5	37.50	26.28	11.22
	2.0	51.35	27.59	23.76
	2.5	33.20	NON-PLASTIC	NON-PLASTIC
	3.0	30.10	"	"

2.5m and 3.0m depths in BORA 2 have low plasticity hence they are good engineering soils and can be used for the base of a landfill. Daniel (1993b) recommends low plasticity index of between 7 and 10 for landfill seals. Soil samples taken from depths of 3.0m are thus suitable as a result of their non-plastic nature.

The Casagrande soil classification chart (Fig. 10) shows that soil samples in BORA 1 at 0.5m, 1.0m and BORA 2 at 0.5m, 1.0m and 2.0m have high plasticity, while soil in BORA 2 at 1.5m shows medium plasticity. Soil samples in BORA 1 at 2.0m, 2.5m and 3.0m, BORA 2 at 2.5m and 3.0m exhibit no plasticity, a possible indication of no compressibility.

3. Permeability Characteristics

Lambe (1951) in classifying soils based on permeability used a permeability of 10^{-4}mm/s as a borderline between pervious and impervious soils. According to Clayton and Huie (1973) the permeability coefficient for the base of a landfill should not exceed 10^{-6}mm/s. considering the standard set by Clayton and Huie (1973) soil samples from BORA 1 (0.5m, 1.0m and 1.5m) and BORA 2 (0.5m, 1.0m, 1.5m and 2.0m) are suitable for use as base material for a landfill. However soils from the lower layers i.e. BORA 1 (2.0m, 2.5m and 3.0m) and BORA 2 (2.5m and 3.0m) have permeability coefficients in excess of the recommended figures. Since geophysical survey revealed absence of fractures in the rock, fracture controlled (deep seated) ground water will not be polluted by the liquid phase of the wastes.

Statistical (T-test) treatment of the values of the permeability coefficient of soil samples taken from the depth of 3m in the two trial pits indicates an insignificant lateral variation. This implies there would not be any significant lateral movement of ground water and liquid phase of the wastes. T-test is an important statistical analysis often used to determine the nature of difference between two sets of values of a given parameter. When the computed t value is higher than the t in the table at a specified confidence level for a given degree of freedom, the difference is significant, otherwise it is not. In the case of permeability coefficient, the computed t of 0.47 is by far lower than the t in table of 1.81 at 5% confidence level.

Grading Curves

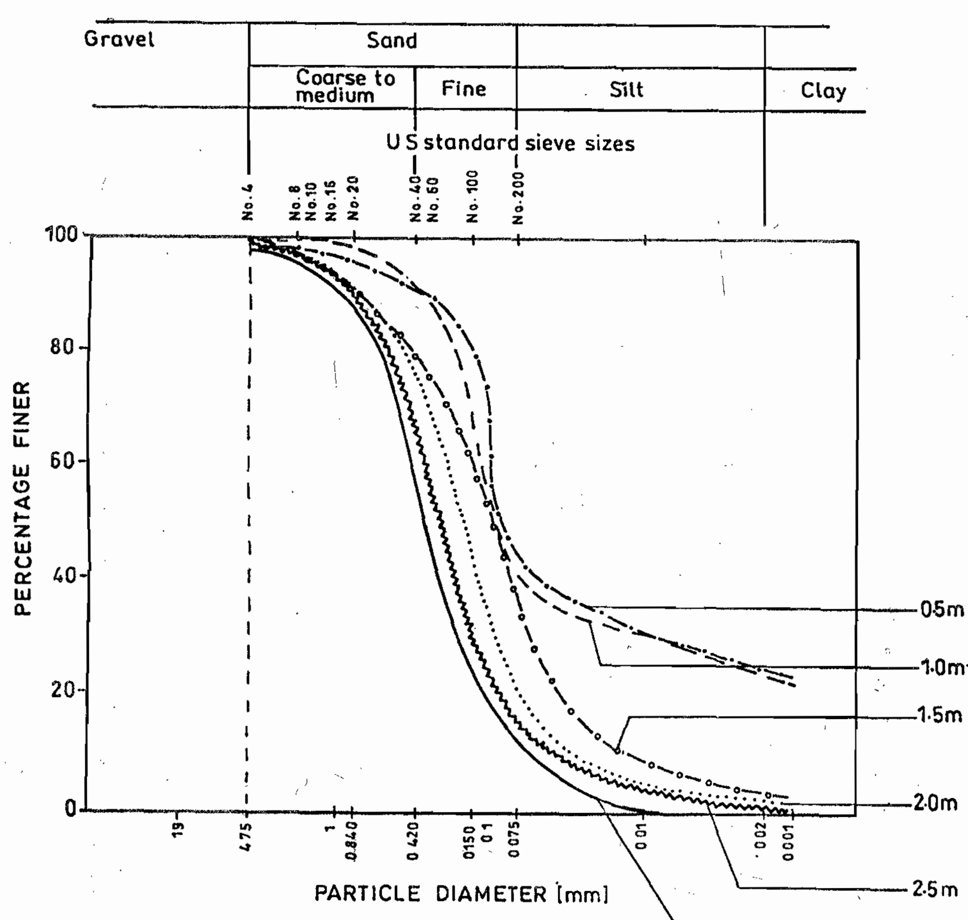


Fig. 8. Grading Curve [BORA 1]

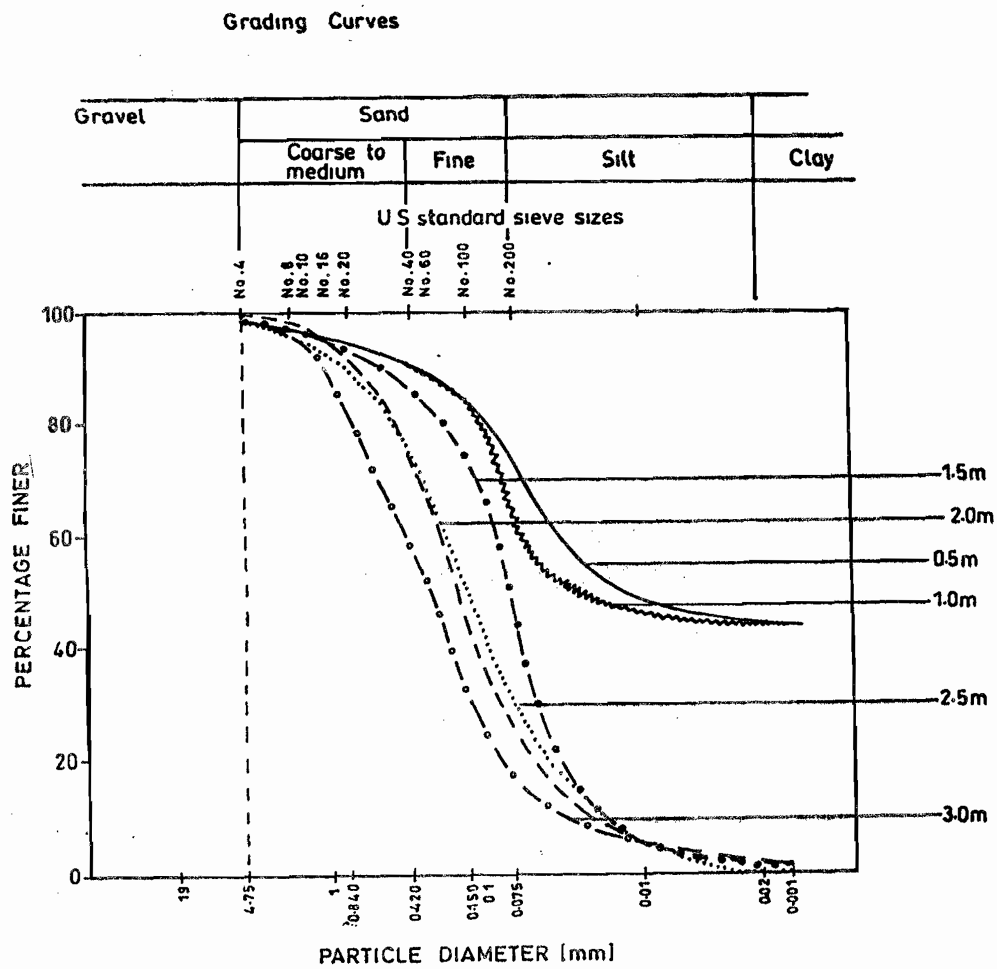


Fig.9. Grading Curve(BORA 2)

Table 4. Result of Permeability Test

PIT	DEPTH (m)	PERMEABILITY COEFFICIENT (mm/s)	PIT	DEPTH (m)	PERMEABILITY COEFFICIENT (mm/s)
BORA 1	0.5	4.44×10^{-6}	BORA 2	0.5	3.99×10^{-6}
	1.0	3.91×10^{-6}		1.0	2.91×10^{-6}
	1.5	6.21×10^{-6}		1.5	3.87×10^{-6}
	2.0	1.30×10^{-4}		2.0	6.23×10^{-6}
	2.5	7.98×10^{-5}		2.5	7.60×10^{-5}
	3.0	1.85×10^{-4}		3.0	1.91×10^{-4}

4. *Consolidation Characteristic*

Table 5 shows the values of coefficients of consolidation and volume compressibility. The coefficient of consolidation helps to estimate the rate of settlement of a structure built on a compressible soil deposit while the coefficient of (volume) compressibility helps to estimate the amount of settlement of the structure on a compressible soil deposit. The coefficient of volume compressibility at the sampling pits BORA 1 and BORA 2 range from 1.83 to 7.69 $\times 10^{-3}$ m^2/KN but generally increases with applied pressure (31.2 - 498.9 KN/m^2) and decrease with depth (0.5 to 3.0m). The computed t value of zero is lower than the t-table value of 1.81 at 5% confidence level. This shows that there is no likelihood of differential settlement if the study area is used for disposal of waste since there is no significant lateral variation in the coefficients of compressibility of the soils that are likely to constitute the base of the landfill. This conclusion is based on the assumption that there will not be differential loading from the solid waste.

CONCLUSION

Vertical Electrical Soundings (VES) and geotechnical Investigations of both disturbed and undisturbed soil samples taken from two trial pits 30m apart in the study area have helped in arriving at the following conclusions;

The depth to bedrock in the study area is between 14.30m and 17.60m. The depths to water table measured from a well 30.00m from a VES point are 8.10m and 7.00m during the dry and the rainy seasons respectively. There will thus be an appreciable vertical difference between the base of the landfill and the uppermost water table. The soil samples at the 3m depths of the two trial pits are generally well graded with no plasticity and are not likely to exhibit any compressibility.

The permeability coefficients of the soil sample taken from the 3.00m depths in the two test pits are significantly higher than the minimum value of 10^{-6}mm/s recommended for soil that should form the base of landfill. However, absence of fractures in underlying rocks will prevent pollution of deep-seated (fracture controlled) ground water. There is no likelihood of

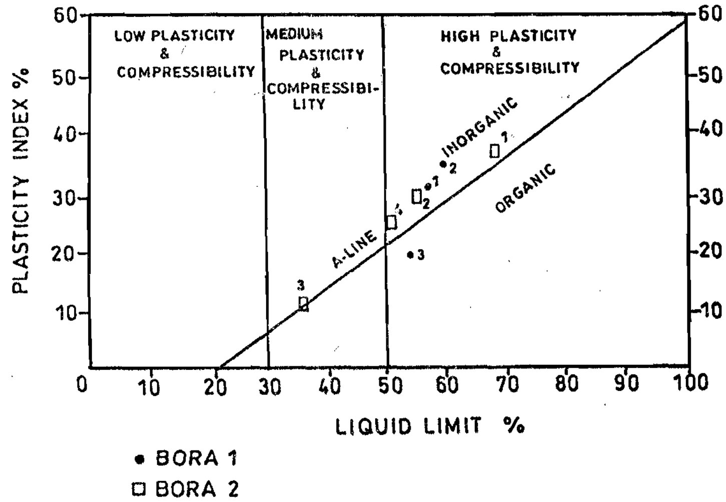


Fig-10-CASAGRANDE'S CHART-CLASSIFICATION OF STUDIED SOILS

Table 5. Result of Consolidation Test

BORA 1				BORA 2			
Sample Depth (m)	Pressure (KN/m^2)	Cv (m^2/min)	Mv (m^2/KN)	Sample Depth (m)	Pressure (KN/m^2)	Cv (m^2/min)	Mv (m^2/KN)
	31.2	2.18×10^{-4}	3.37×10^{-3}		31.2	2.71×10^{-4}	3.70×10^{-3}
	62.4	4.94×10^{-5}	6.12×10^{-3}		62.4	2.63×10^{-5}	6.41×10^{-3}
	124.7	6.54×10^{-4}	5.58×10^{-3}		124.7	2.71×10^{-4}	5.39×10^{-3}
0.5	249.5	1.87×10^{-4}	5.04×10^{-3}	0.5	249.5	8.54×10^{-5}	4.69×10^{-3}
	498.9	6.71×10^{-5}	7.69×10^{-3}		498.9	6.14×10^{-5}	7.22×10^{-3}
	31.2	1.71×10^{-4}	3.98×10^{-3}		31.2	1.87×10^{-4}	3.80×10^{-3}
	62.4	6.04×10^{-5}	6.06×10^{-3}		62.4	1.48×10^{-4}	5.76×10^{-3}
	124.7	1.23×10^{-4}	4.81×10^{-3}		124.7	2.07×10^{-4}	4.64×10^{-3}
1.0	249.5	2.07×10^{-4}	4.02×10^{-3}	1.0	249.5	2.71×10^{-4}	4.13×10^{-3}
	498.9	2.91×10^{-4}	4.71×10^{-3}		498.9	3.93×10^{-4}	5.48×10^{-3}
	31.2	2.71×10^{-4}	3.69×10^{-3}		31.2	2.07×10^{-4}	3.59×10^{-3}
	62.4	3.14×10^{-4}	5.42×10^{-3}		62.4	6.04×10^{-4}	5.44×10^{-3}
	124.7	3.42×10^{-4}	4.20×10^{-3}		124.7	3.74×10^{-4}	4.23×10^{-3}
1.5	249.5	5.04×10^{-5}	3.13×10^{-3}	1.5	249.5	4.91×10^{-4}	3.72×10^{-3}
	498.9	8.93×10^{-5}	2.86×10^{-3}		498.9	3.93×10^{-4}	4.18×10^{-3}
	31.2	2.91×10^{-4}	3.34×10^{-3}		31.2	2.45×10^{-4}	5.29×10^{-3}
	62.4	3.57×10^{-4}	5.09×10^{-3}		62.4	5.10×10^{-5}	7.43×10^{-3}
	124.7	5.61×10^{-4}	3.96×10^{-3}		124.7	1.03×10^{-4}	5.49×10^{-3}
2.0	249.5	1.71×10^{-4}	3.06×10^{-3}	2.0	249.5	1.92×10^{-4}	4.91×10^{-3}
	498.9	8.18×10^{-5}	2.76×10^{-3}		498.9	2.18×10^{-4}	7.69×10^{-3}
	31.2	2.53×10^{-4}	2.74×10^{-3}		31.2	2.62×10^{-4}	3.20×10^{-3}
	62.4	4.36×10^{-4}	4.62×10^{-3}		62.4	4.36×10^{-4}	4.86×10^{-3}
	124.7	4.36×10^{-4}	3.78×10^{-3}		124.7	1.64×10^{-4}	4.38×10^{-3}
2.5	249.5	4.62×10^{-4}	3.29×10^{-3}	2.5	249.5	4.36×10^{-4}	3.80×10^{-3}
	498.9	4.91×10^{-4}	3.63×10^{-3}		498.9	3.74×10^{-4}	4.34×10^{-3}
	31.2	2.81×10^{-4}	2.76×10^{-3}		31.2	2.24×10^{-4}	2.88×10^{-3}
	62.4	2.91×10^{-4}	3.77×10^{-3}		62.4	3.74×10^{-4}	4.00×10^{-3}
	124.7	4.91×10^{-4}	2.87×10^{-3}		124.7	3.14×10^{-4}	2.90×10^{-3}
3.0	249.5	6.54×10^{-4}	2.29×10^{-3}	3.0	249.5	2.31×10^{-4}	2.19×10^{-3}
	498.9	5.24×10^{-4}	2.10×10^{-3}		498.9	3.42×10^{-4}	1.83×10^{-3}

differential settlement if the study area is used for disposal of waste since there is no significant lateral variation in the coefficient of compressibility of the soils that are likely to constitute the base of the landfill.

ACKNOWLEDGEMENTS

The authors wish to express their profound gratitude to all those who contributed in one way or another to make this work a reality. While it is impossible to mention everyone we say thank you to Dr. A.F Abimbola for the use of the Terrameter for the geophysical survey, Mr. Mike Oladunjoye for assisting with the interpretation of the geophysical data, Mr. Yinka Olasupo for helping out with the soil test and Mr. Yemi Oshigbesan for doing the typing and preparing the illustrations. Mr. Tunde Ogunmola and Mr. Ikiriko both of N.N.P.C provided some of the materials used in the study.

REFERENCES

Ajagbe, W. O., 2000. Solid waste Management and pollution control: A pragmatic Approach. Unpbl. B.Sc Project Civil Engr. Dept. Univ. Ibadan. 68p.

Benson, R. C., 1993. Geophysical Techniques for subsurface site characterization. In: D.E Daniel (ed). Geotechnical Practice for waste disposal, Chapman and Hall, London, Pp 311-357.

Casagrande, A., 1932. Research on the Atterberg limits of soils. Public Roads, 8: 121- 136.

Cheremisinoff, P. N. and Morresi, A. C., 1977. Environmental Assessment Impact Statement Handbook. Ann Arbor Science Publ. Inc. 230 Collingwood, Ann Arbor, Michigan 48106 Pp 149-159.

Clayton, K.C. and Huie, J. M., 1973. Solid Waste Management, The Regional Approach. Ballinger Publishing Company, Cambridge.

Dada, S. S., Briqueu, I. and Birek, J. L., 1998. Primodial Crustal Growth in Northern Nigeria: Preliminary Rb-Sr and Sm-Nd Constraint from Kaduna Migmatite Gneiss Complex. J. Min. Geol. 34(1): 1 - 6.

Daniel, D. E.., 1993b. Clay liners. In: D.E Daniel (ed) Geotechnical Practice For Waste Disposal. Chapman and Hall, London, Pp. 137-163.

Department of the Environment (D.O.E.), 1995. Landfill Design, Construction and Operational Practice Vol. 1 and 2 Waste Management Papers 26B. Her Majesty's stationery office, St. Clements House 2-16 Colegate, Norwich NR 3 IBQ.UK

Elueze, A. A., 2000. Compositional Appraisal and Petrotectonic Significance of the Imelu Banded Ferruginous Rock in the Ilesha schist belt, south western Nigeria, J. Min. Geol., 36(1) : 8-18.

Federal Ministry of Housing and Environment, 1983. Solid waste management in fifteen cities and urban areas in Nigeria, Journal on the state of the environment, Monograph No. 2

Gettinby, J. H., Sarsby, R. W. and Nedwell, J. C., 1996. The composition of leachate from land filled refuse. Journal of Proc. Instn. Civil. Engrs. Mun. Engr.,115: 47-59

Ghosh, D. P., 1971. Inverse Filter Coefficients for the Computation of Apparent Resistivity Standard Curves for a Horizontal Stratified Earth. Geophy. Prospecting 19, Pp769-775.

Jones, H. A . and Hockey, R. D., 1964. The Geology of Part of Southwestern Nigeria, Bull. Geol. Survey of Nigeria no. 31.

Jongmans, D., Campillo, M. and Demanet, D., 1990. The Use of Surface Wave Inversion and Seismic Reflection Methods for Engineering Applications. Proc. 6th int. I.A.E.G. Conf., Amsterdam (Price D. G., (ed) A. A. Balkema, Rotterdam, 2 : 979 - 985

Lambe, T. W., 1951. Soil Testing for Engineers. John Wiley and Sons Inc. N.Y 162p

National Population Commission, 1991. National Population Commission Census '91 Final Results for Oyo state, Published by the National Population Commission.

Ogunsanwo, O. and Mands, E., 1999. The Role of Geology in the Evaluation of Waste Disposal Sites. Journal of Mining and Geology. Vol. 35(1): 83 - 87.

Orellana, E. and Mooney, H. M., 1966. Master Tables for Vertical Electrical Soundings over Layered Structures, Interciencia, Madrid.

Parasnis, D. S., 1986. Principles of Applied Geophysics. Chapman and Hall, London, 3rd Edition, 275p.

Rahaman, M. A., 1998. Recent Advances in the Study of the Basement Complex of Nigeria, Precambrian Geology of Nigeria, Publ. of the Geological Survey of Nigeria, Kaduna, p. 11-41.

SF Consultants Nig., 1979. Ajoda Newtown Master plan, Oyo State of Nigeria. Published by Ajoda Newtown Development Corporation 14p

Sittig, M., 1979. Landfill Disposal of Hazardous Wastes and Sludges. Noyes Data Corp. Park Ridge, New Jersey. 365p.

Tchobanoglous, G., Theisen, H. and Eliassen, B., 1977. Solid Waste Engineering Principles and Management Issues. McGraw Hill Book Company, N.Y. USA.

Tchobanoglous, G., Theisen, H. and Vigil, S., 1993. Integrated Solid Waste Management, McGraw Hill Book Company, N.Y. USA. 282p

Tomlinson, M. J., 1963. Foundation Design and Construction. Pitman Publishing Ltd., 39 Parker street, London WC2B 5PB.770p

Uchegbu, S. N., 1998. Environmental Management and Protection. Precision Printers and Publishers. Enugu. 224p.

W.H.O Expert Committee, 1970. Solid Waste disposal and control Technical transactions. No. 484, W.H.O Geneva.

Wilson, R. C., 1922. The Geology of the Western Railway. Bull. Geol. Survey, Nig. Vol. 2, Pp 152.

Zohdy, A. A. R., Eaton, G. P. and Mabey, D. R., 1974. Application of Surface Geophysics to Groundwater Investigation. U.S.G.S Techniques of Water Resources Investigations, Book 2, Chapter D1.