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ENGINEERING GEOLOGICAL ASSESSMENT OF SOME SOILS FROM SOUTHWESTERN NIGERIA AS MINERAL SEALS IN SANITARY LANDFILLS

Olusegun O. Ige
Department of Geology and Mineral Sciences, University of Ilorin, P.M.B 1515, Ilorin, Nigeria

ABSTRACT: This study investigated the geotechnical properties of five soils from southwestern Nigeria for their use as mineral seals in sanitary landfill. The required parameters for soils to be considered as mineral seal such as grain size distribution, Atterberg consistency limits, maximum dry density (MDD) and the coefficient of permeability were determined. Results obtained show that the specific gravity values range from 2.60 to 2.73, the percentage of fines range from 54% to 82%, liquid limits values range from 40.6% to 68.0% and the indices of plasticity values range from 18.6% to 44.0%. The MDD values for the soil obtained using the standard Proctor energy of compaction range between 1.74t/m^3 and 1.96t/m^3 while those obtained using the modified Proctor energy range between 1.91t/m^3 and 2.12t/m^3. The highest coefficient of permeability value obtained for all soils investigated is 1.83×10^{-9}m/s. All these values compare favourably with those suggested by regulatory agencies and several investigators. Consequently, the soils are suitable for use as mineral seals in sanitary landfills.

INTRODUCTION

The disposal of solid waste in sanitary landfills is now increasingly gaining acceptance in many nations of the world (Montgomery, 2000). This is because of air, water, soil and other environmental pollution effects commonly associated with other methods of waste disposal (Asiwaju-Bello and Akande, 2000; Montgomery, 2000;Onipede and Bolaji, 2004; Seo, 2004 and Kurian *et al;* 2005*)*. In developing countries where incineration is mostly practiced, importation of incinerators as well as expertise for the installation and initial maintenance are issues of concern. However, most of the materials required for the construction of sanitary landfills are naturally occurring and in abundance in the sampled localities. Also, equipment (scrapers, bulldozers, graders etc) required for the construction of sanitary landfill are readily available in the country and are used for other earth engineering works.

This study aims at assessing the geotechnical properties of some lateritic soils formed through the weathering of some Basement Complex rocks for use as mineral seals in sanitary landfills. The soils are derived from Granite gneiss (IG1), Migmatite (IG2), Amphibolite (IG3), Quartschist (IG4) and Granite (IG5) and were collected from different localities within the southwestern Nigeria.

Seal in Sanitary Landfills

Seals are natural clayey soils or artificial (geomembrane) impermeable materials used in sanitary landfills to prevent migration of waste leachate into groundwater body. The seal is placed within the top sealing system to prevent percolation of run-off and precipitation into the waste column and within the bottom sealing system to prevent migration of generated leachate into the groundwater bodies (Fig. 1). Different types of seals such as clayey soils, synthetic membranes (artificially manufactured mixtures: bentonite, asphalt, cement) have been extensively studied by Bagchi (1994). The usefulness of lateritic clayey soils is emphasized in this report because of the because of the fact that it naturally occur in abundance at the studied localities.

MATERIALS AND METHODS OF TESTING

Five soils from different Basement Complex rocks were collected from soil profiles and used in this study. The localities of the soils are as shown in Figure 2 and Table 1. Three of the samples were collected by horizontal trenching into road cut exposures while the other two were collected from pits (Table 1). Fresh samples were collected from the lateritic horizon of the typical soil profile. The horizon has been reported, not only as the most extensive of the soil profile, but soils from this zone have been useful as fills and subbase material in road construction (Ogunsanwo, 1988). The lateritic soils studied vary in texture, depth of sampling and color (Table 1).

Several soil samples from the study area have been investigated as suitable for different purpose of engineering construction such as fill in dams, base and sub-base material in roads and as material in building constructions. However, emphases have been little with respect to assessing the soils for suitability as mineral seal in waste containment facilities

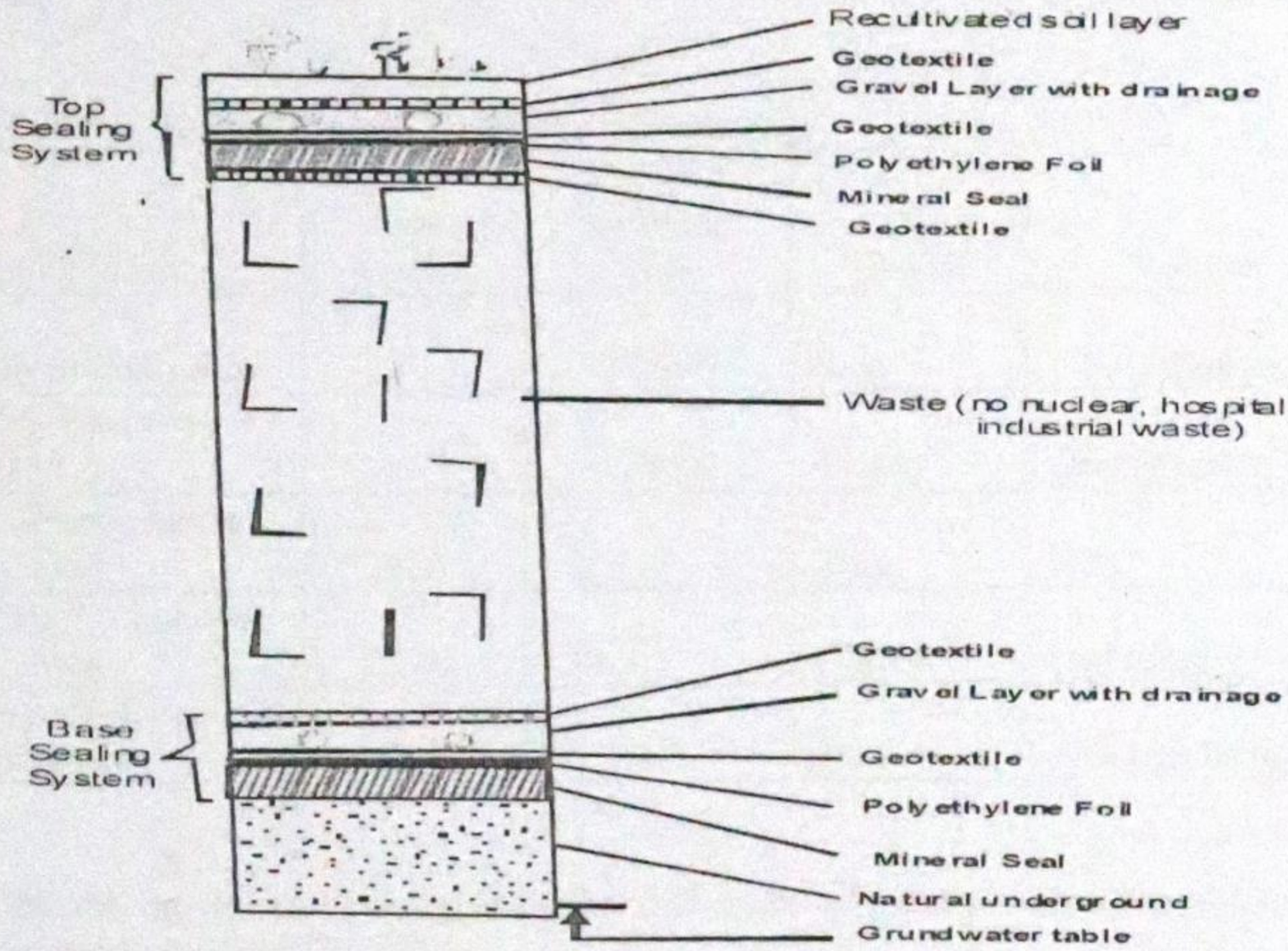


Fig. 1: Section through a landfill (Ogunsanwo, 1996)

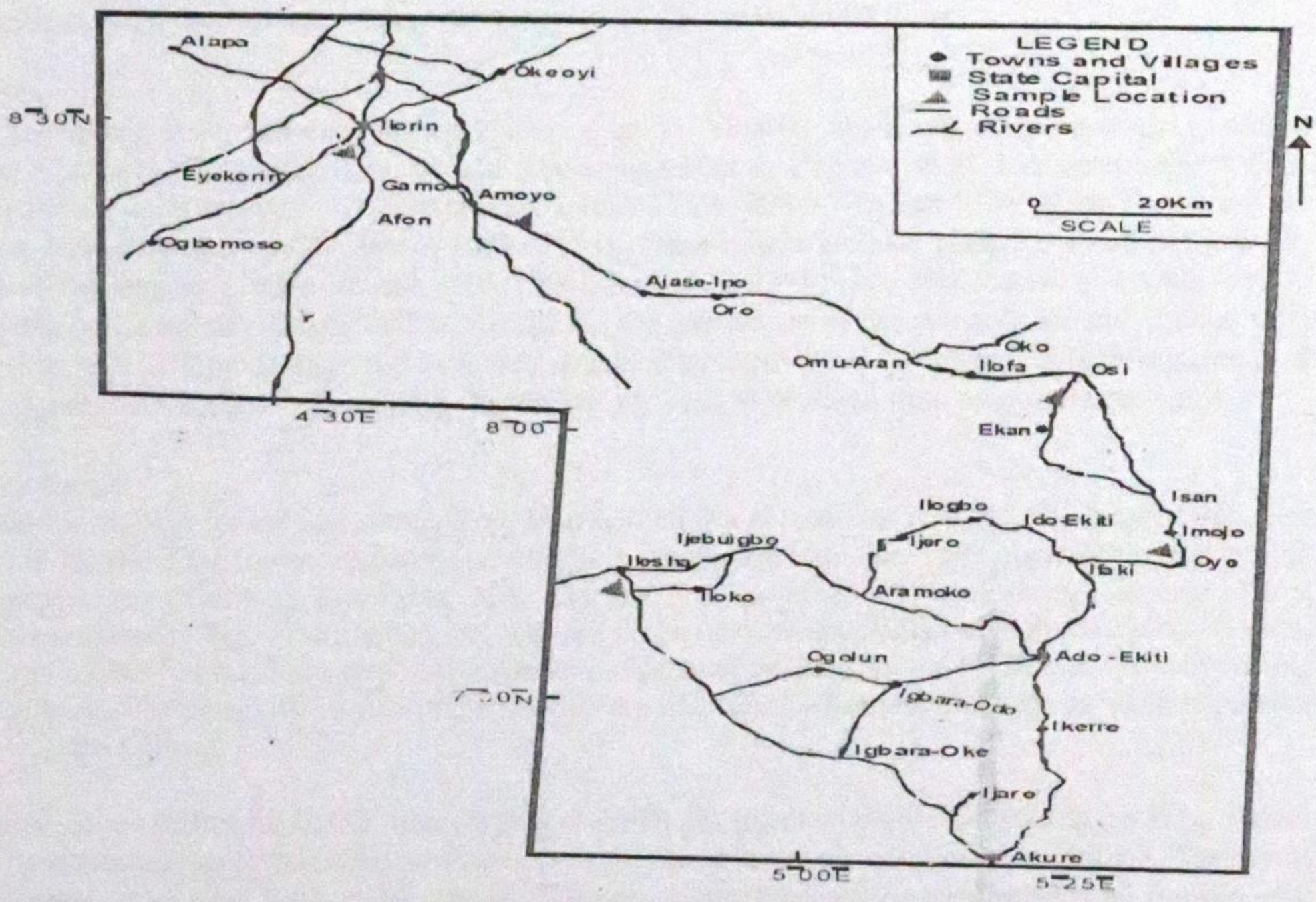


Fig. 2: The Samples Locality Map

Table 1: Sampling localities and horizons of sampling

Symbol	Parent material	Sampling locality	Depth of road-cut(m)	Depth of sampling (m)	Texture	Colour
IG1	Granite gneiss	Asa dam road (Ilorin)	-	2.7(pit)	Silty	Reddishbrown
IG2	Migmatite	2.3km, Osi- Etan road (kwara state)	-	1.2(pit)	Clayey	Orangebrown
IG3	Amphibolite	1.1km, Ilesha- Akure road	11.3	7.0	Silty	Pink
IG4	Quartzschist	8.3km, Ilorin- Lokoja road	1.8	1.3	Clayey	Lightbrown
IG5	Granite	5.4km, Ayede- Oye road (Ekiti state)	2.4	2.0	Clayey	Orangebrown

(Ogunsanwo, 1996). The index properties, the Proctor compaction (standard and modified) and permeability test were carried out in accordance with the British Standard BS 1377 (1990).

RESULTS AND DISCUSSION

Several limits have been proposed by various researchers with respect to the geotechnical properties of soil to be useful as mineral seals. Such limits are presented here along with the results obtained from this study.

Grain Size Distribution

In the soils studied, the largest grain has diameter of 2.6mm (Fig. 3). This is very small compare to the ≤ 63mm suggested by ONORM S 2074 (1990) and between 30 and 50mm suggested by Daniel (1993). The percentage of fines (silt and clay) contained in the soils are: IG1 = 74%, IG2 = 54%, IG3 = 78%, IG4 = 77% and IG5 = 82%. The values are much higher than the ≥ 15% proposed by ONORM S 2074 (1990). These results are also greater than the value (≥30) suggested by Daniel (1993b), Bagchi, (1994), Benson *et al* (1994), Rowe *et al* (1995) and Mohammed and Antia (1998). Oeltzschner (1992) prefer soil with clay faction >20%. Except for the granite gneiss derived soil, all soil studied have >20% amount of clay (Table 2). The percentage of gravel recommended by Daniel (1993), Bagchi (1994) and Rowe *et al* (1995) is ≤ 30%. The highest percentage of gravel from the studied soils is 6% obtained from migmatite derived soil.

Atterberg Consistency Limits

The results of the liquid limits (W_L) for the soils range from 40.6% to 68.0% at localities IG4 and IG1 respectively. The index of plasticity (Ip) is 18.6% in the lower boundary and 44.0% in the highest boundary from quartzschist and granite gneiss derived soils respectively (Table 3). From this, IG2, IG4 and IG5 fall in the CL zone (inorganic clay of low plasticity) on the plasticity diagram (Fig. 4) while IG1 and IG3 fall in the CH (Inorganic clay of high plasticity. Three of the samples are favoured by the low-medium plasticity boundary suggested by Bagchi (1994). Daniel (1993) is of the opinion that inorganic clay of high plasticity may form clods when dry and sticky when wet, but may be workable on the field at controlled water water content.

All samples studied have values >20% for liquid limit (W_L) and ≥ 10% for index of plasticity (Ip) suggested by Daniel (1993), Bagchi (1994) and Rowe *et al* (1995). Clay activities (A_C) for the soils are also presented in Table 3. The results obtained show that the soils range form 0.44 - 1.10. These values are higher than ≥ 0.3 recommended by Benson *et al* (1994).

Specific Gravities

In the soils studied, the specific gravity values obtained are: 1G1 = 2.60, 1G2 = 2.67, 1G3 = 2.63, 1G4 = 2.73 and 1G5 = 2.62. These values are much higher than ≥ 2.2 recommended by ONORM S 2074 (1990) for soils to be suitable for use as mineral seal in sanitary landfills.

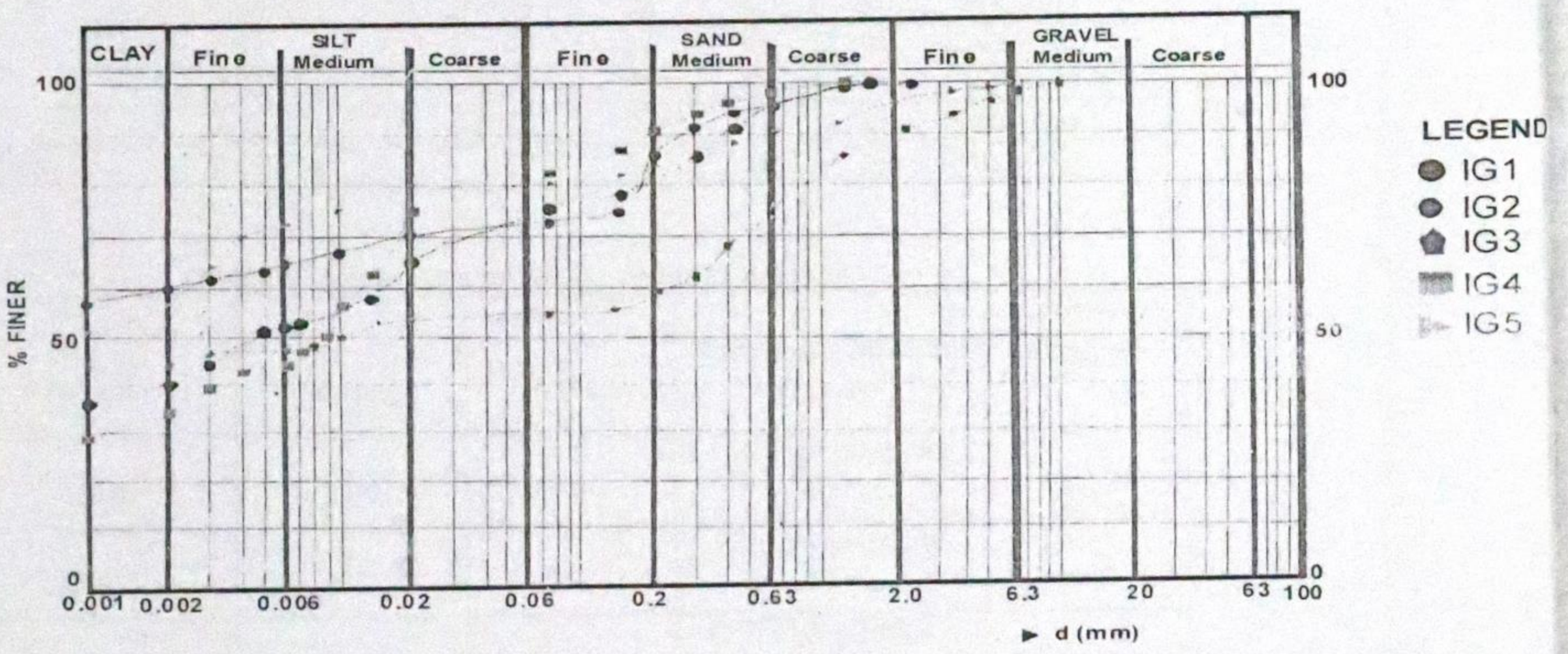


Fig. 3: Grain size distribution curves for soil samples

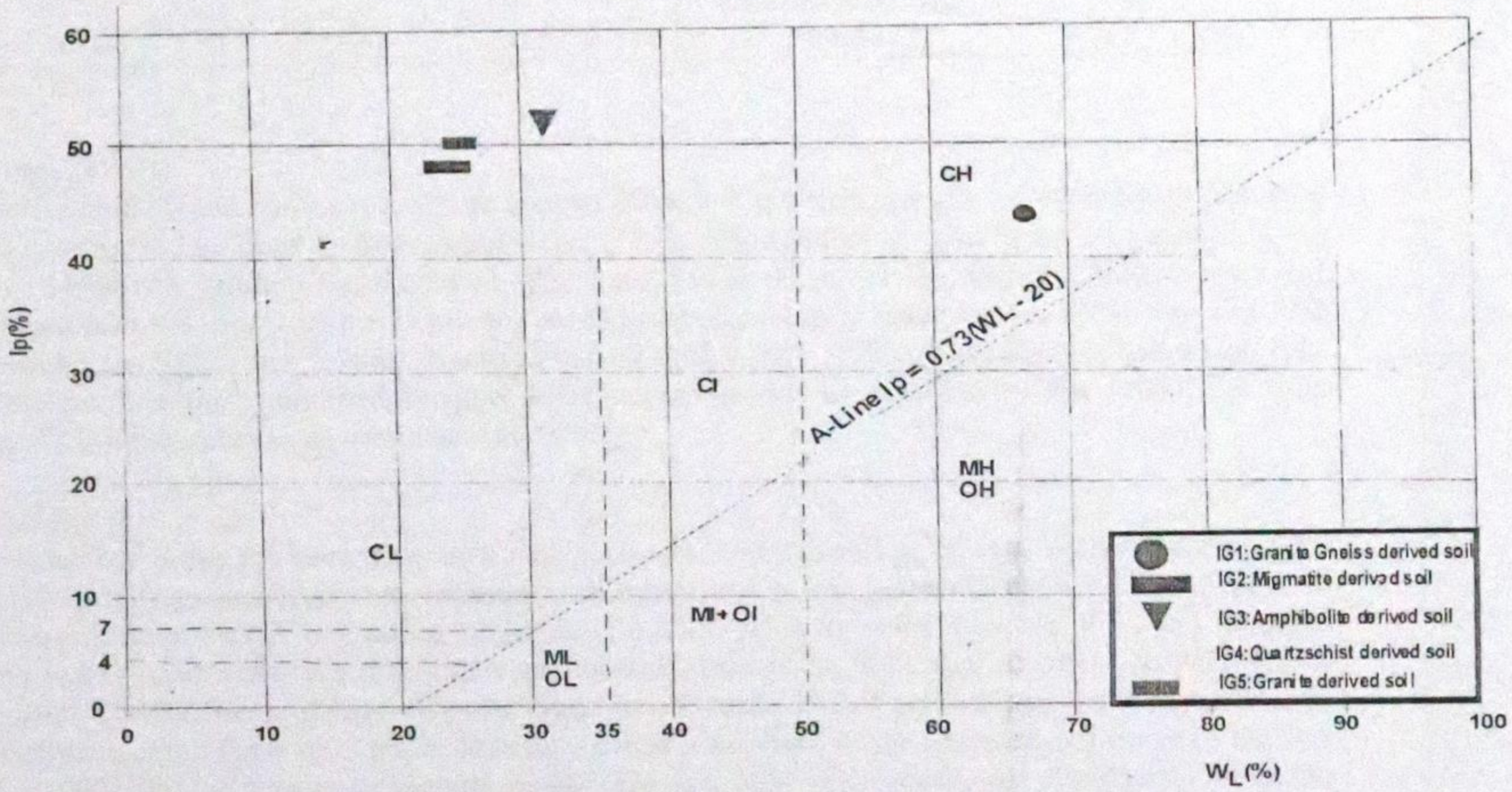


Fig. 4: Plasticity Chart showing plots of soil samples

Table 2: Grain size analysis of the soil samples

Symbol	Natural density(Mg/m^3)	Specific gravity	Grain size analysis (%)					
			Gravel	Sand	Fine	Clay	Silt	Soil group
IG1	1.96	2.60	1	25	74	40	34	Clayey silt
IG2	1.62	2.67	6	40	54	44	10	Sandy clay
IG3	1.54	2.63	3	18	78	57	21	Clayey silt
IG4	1.72	2.73	1	22	77	42	35	Sandy clay
IG5	1.88	2.62	1	17	82	56	26	Silty clay

Table 3: Atterberg consistency limits of the soils

Symbol	W_L (%)	W_P (%)	I_P (%)	Plots on the plasticity diagram	Activity of clay(Ac)
IG1	68.0	24.0	44.0	CH: high plasticity clay	1.10
IG2	49.0	23.3	25.7	CL: low plasticity clay	0.58
IG3	53.0	20.4	32.4	CH: high plasticity clay	0.57
IG4	40.6	22.0	22.6	CL: low plasticity clay	0.14
IG5	50.0	23.3	25.7	CL: low plasticity clay	0.47

Maximum Dry Densities (MDD)

The maximum dry density (MDD) and optimum moisture content (OMC) at different energies of compaction (standard and modified Proctor) is presented in Table 4. Benson and Trust (1995) reported that the coefficient of permeability is sensitive to compactive effort and molding water content. The soils' MDD values for the standard Proctor energy of compaction range between 1.74 t/m^3 and 1.96 t/m^3 while the modified Proctor energy range between 1.91 t/m^3 and 2.00 t/m^3 (Table 4). These values are higher than 1.7t/m^3 stipulated in ONORM S 2074 (1990). They are also better than 1.45 t/m^3 (standard Proctor) and 1.64 t/m^3 (modified Proctor) MDD recommended by Kabir and Taha (2003) for soils produced from Basement Complex rocks to be useful as mineral seal.

Coefficient of Permeability (k)

The coefficient of permeability is the key parameter affecting most soils to be useful as mineral seals (Benson, 1987; Daniel and Benson, 1990), thus great attention is focused at ensuring that a low permeability is achieved. Several investigators have recommended $\leq 1 \times 10^{-9}$m/s as the minimum allowable value for soils to be useful for this purpose. From Table 4 however, values lower than recommended were obtained from all the soils studied when compacted with both standard and modified Proctor energy. It was also observed that the coefficient of permeability generally decreases with increasing compactive energy (Table 4). This is because there is a decrease in the frequency of pores in the soil mass (Acar and Oliveri, 1990). For the purpose of sanitary landfill, the least achievable coefficient of permeability on the field is preferred. Therefore, the higher-energy (modified Proctor) of compaction is recommended.

Table 4: Maximum dry density (MDD), Optimum moisture content (OMC) and the coefficient of permeability (*k*) values

Symbol	MDD(t/m^3)		OMC (%)		Coefficient of permeability(*k*)m/s	
	Standard Proctor	Modified Proctor	Standard Proctor	Modified Proctor	Standard Proctor	Modified Proctor
IG1	1.79	1.93	16.50	14.40	$2.38X10^{-9}$	$9.6X10^{-11}$
IG2	1.96	2.12	13.80	11.30	$9.15X10^{-10}$	$1.98X10^{-10}$
IG3	1.89	2.00	12.50	12.50	$1.37X10^{-9}$	$2.28X10^{-10}$
IG4	1.74	1.91	14.30	14.30	$1.83X10^{-9}$	$1.21X10^{-10}$
IG5	1.81	1.95	12.9	12.90	$8.60X10^{-10}$	$3.18X10^{-10}$

CONCLUSION

The results obtained from the five soil samples studied show that the geotechnical properties of the soils, irrespective of their parent material, compare favourably with the recommendations of several researchers. Therefore, they are useful as mineral seals in sanitary landfill for disposal of solid waste. However, high plasticity at IG1 localities may require some pre- application treatment. Higher energy of compaction is recommended because it gives lower values of coefficient of permeability.

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REFERENCES

Acar, Y. and Oliveri, I. (1990). Pore fluid effects on the Fabric and Hydraulic Conductivity of Laboratory Compacted Clay. Transportation Research Record, 1219: 144 – 159.

Bagchi, A. (1994). Design, Construction, and Monitoring of landfills. 2nd Edition, A Wiley-Interscience Publication. U. S. A, 361p

Asiwaju-Bello, Y. A. and Akande, O. O. (2004). Urban groundwater pollution: Case study of a Disposal sites in Lagos metropolis. Journal of Water Resources. 12: 22 – 26.

Benson, C. H. and Trust, J. M. (1995). Hydraulic Conductivity of Thirteen Compacted Clays, clays and clay minerals, vol. 43 (6): 669 – 681.

Benson, C. H., Zhai, H. and Wang, X. (1994). Estimating Hydraulic Conductivity of clays liners. Jour of Geo. Eng. ASCE, 120 (2): 366 – 387.

BS1377 (1990). Method of Testing soil for Civil Engineering purposes. British Standard Institute, London.

Daniel, D. E. (1987). Earthen Liners for Land Disposal Facilities. Geot. Practice for Waste Disposal. 87, 13, (R.D Woods, Ed), New York ASCE, 21 – 39.

Daniel, D. E. (1993). Clay Liners. In Geotechnical practice for waste Disposal, (ed. Daniel, D. E.) Chapman Hall, London, UK, 137 – 163.

Daniel, D. E. and Benson, C. H. (1990). Water Content – Density Criteria for Compacted soil liners Jour. of Geot. Eng. ASCE, 116 (12): 1811 – 1830.

Kabir, M. H. and Taha, M. R. (2003). Assessment of Physical Properties of Granite Residual Soil as an Isolation Barrier. Electronic Journal of Geotechnical Engineering (EJGE). Malaysia.

Kurian, J., Nagendran, R. and Palanivelu, P. (2005): Open Dumps to Sustainable Landfill. Centre for Environmental Studies, Anna University, Channai, India SWM/project .

Langer, M. (1995). Engineering Geology and waste disposal. Scientific report and recommendations of the IAEG commission.14 (32): 5 29.

Mohammed, A. M. O. and Antia, H. E. (1998). Geoenvironmental Engineering. Elsevier Science, Amsterdam, 329p

Montgomery, W. M. (2000): Environmental Geology, 5th Edition, McGraw Hill, 546p.

Oeltzschner, H. (1992). Anforderin an die Geologic, Hydrogeologie Und Geotechnik beim Bau von Deponie. In: Thorme-kozmiensky K. J. (ed), Additictung Von Deponien and Altlastlen. E. F. Verlag fiir Gnergie und Umwelttechnik combit, Borlin, 53 – 82.

Ogunsanwo, O. (1988). Basic Geotechnical Properties, Chemistry and Mineralogy of some Laterite soils from SouthWestern, Nigeria. Bullettin of I.A.E.G. 37: 131 – 135.

Ogunsanwo, O. (1996). Geotechnical investigated of some soils from southwestern Nigeria for use as mineral seals in waste disposal landfills. Bulletin of I.A.E.G. 54: 119 – 123.

Onipede, M. A. and Bolaji, B. O. (2004). Management and disposal of industrial wastes in Nigeria. Nigerian Journal of Mechanical Engineering. 2 (1): 49 63.

ONORM S 2074 (Teil 2), (1990). Geotechnik in Deponiebau-Erdarbeiten. Osterrichisches Normungsinstitut. Wein.

Rowe, R. K. Quigley, R. M. and Booker, A. P. (1995). Clayey barrier Systems for waste disposal facilities. E and FN Spon, New York.

Seo, S. (2004). Environmental impact of solid waste treatment methods in Korea. Journal of Environmental Engineering. 130 (1): 81 – 89.