

Geologic And Geotechnical Evaluation Of An Open Landfill For Sanitary Landfill Construction In Ilorin, Southwestern Nigeria.

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Abstract
The disposal of solid waste in sanitary landfills is now increasingly gaining acceptance in many nations of the world. This is because of air, water, soil and other environmental pollution effects commonly associated with other methods of waste disposal. This study investigates the geologic and geotechnical characteristics of a selected functional open landfill with a view of converting to a modern sanitary landfill. Required parameters for soils to be considered usable in such containment facility were evaluated. Results show that the site is locally underlain by unfractured migmatite which is fresh and competent enough to provide sufficient supports for modern sanitary landfill. Geotechnically, lateritic soil samples over the site have largest grain size of 10mm, average clay portion of 33%, sand of 51% and gravel size of 3.75%. The samples have low to medium plasticity and clay activity of 0.39. The average Maximum Dry Density and coefficient of permeability are 1.80g/cm^3 and 1x 10^{-8} m/s at lighter energy of compaction.
This study shows that conversion of the exiting open landfill to modern one is possible since all geologic and geotechnical criteria are suitably present.

1.Introduction
The city of Ilorin is the capital town of Kwara State, Nigeria. It has total land coverage of over 400km^2 and a population estimate of 847,582 people (Onokerhoraye 2007) that are responsible for the generation of wastes. The wastes are often deposited in open spaces, river banks, road side etc. thereby degrading the quality of the environment. In attempt to alleviate environmental pollution within the city, 3 unengineered final waste disposal sites (open dumpsite) were strategically located at the outskirt of the city (Fig. 1).

However, disposal of solid waste in sanitary landfills is now increasingly gaining acceptance in many nations of the world (Fig. 2). This is because of air, water, soil and other environmental pollution effects commonly associated with other methods of waste disposal (Onipede & Bolaji 2004; Seo 2004 & 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 at the investigated site. 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 lateritic soils formed through the weathering of some Basement Complex rocks as useful material in sanitary landfills.

2. Study Area
2.1 *Site Characteristics*
The study area (Ita-Amoo waste disposal site) is located within latitude 8^0 25$^'$ N and 8^0 30$^'$ N and longitude 4^0 20$^'$ E and 4^0 30'E (Fig. 1). The approximate area extent of the dumpsite is 3.63x10^{6}m^2 with average dump height of about 7.7m. The site inhabits and still occupies several farm land area. The hydrologic setting of the area studied is typical of what is obtained in other basement complex area where the availability of water is a function of the presence of thick-little clay overburden material and presence of water filled joints, fracture or faults within the fresh basement rocks. Soil samples from clayey units have been reported, not only as the most extensive of the soil profile, but have been useful as fills and subbase material in road construction (Ogunsanwo1988). However, emphases have been little with respect to assessing the soils for suitability as usable material in waste containment facilities. The humid tropical climate of Ilorin has particularly encourage relatively deep weathering of the near

surface rocks to produce porous and permeable material that allows groundwater accumulation as shallow aquifer which is recharged principally through infiltration of rainwater. At the investigated dumpsite, the waste leachate may also infiltrate to pollute the shallow groundwater.

3. Materials and Methods

A 2-phase approach was used in this study; the geological and geotechnical investigations. These were preceded by desktop and reconnaissance studies for the purpose of site identification and familiarization. Geologic study involves location of outcrops identification, description of featured characteristics, collection and labeling and of samples using standard geologic equipment. Geotechnical analysis of 4 representative samples involves collection of disturbed soils from trial pits within the dumpsite. Properties tested include the particle size distribution, Atterberg limits, compaction and permeability potentials. Sample collection, preparation and analyses were carried out in accordance with the British Standard BS 1377:990.

4. Geology

The study area lies within the southwestern part of the Precambrian Basement Complex of Nigeria. The detailed geology can be grouped into surface and subsurface geology. The surface geology is characterized by clay, lateritic soil and the crustal top layers. This differs from place to place but in most places, the lateritic soil obscure most of the underlying geology of the area. The subsurface geology is made up of rocks of the crystalline basement complex including gneisses, granites, migmatites and quartzites (Annor *et al.* 1996 & Oluyide *et al.* 1998). However, the geology of the study area was mapped with respect to suitability of underlying lithology to provide adequate support for the waste containment structure. The following rocks were encountered in the study area (Fig. 3).

4.1 *The Gneisses*

Varieties of gneiss occur at the northern, center and southeastern parts of the study area. They occur as chains of inselbergs around Idofian, Alaya and Lajiki towns. The biotite gneiss mapped is restricted to the southeastern corner where it underlies the investigated site and is probably the least variable of the occuring gneisses. In some locations, there are foliations which are marked by parallelism of the mica flakes. In some other locations, such foliations are weak with fabric tending towards homogeneity.

They occur as isolated inselbergs, low ridges or as large boulders. Their contacts with other rock types are obscured and are covered by thickly vegetated soil. In hand specimen, coarse gneissic foliation and fine to medium equigranluar texture are the major characteristics. The foliation planes are commonly marked by mica flakes. The tendency towards digestion of the original layering indicates that the granite-gneisses are from a sedimentary origin (Annor & Freth 1985).

4.2 *Migmatite*

This rock type covers about 70% of the total area. The continuity is interrupted variously by granitic masses, which separate the migmatites into smaller bodies with consistent north–south orientation. This type of migmatite has earlier been described as lit-par-lit type, having shown a parallel arrangement of the paleosome and meosome (Oluyide *et al.* 1998) The paleosome has high colour index and dominated by dark colour minerals such as biotite which exceeds 30% while the meosome is usually leucocratic, medium to coarse grained and massive. The width varies along the length and no band persists more than a meter. The mineral component is essentially, microcline with biotite and muscovite as the common accessory minerals.

4.3 *Granites*

Two forms of granites were encountered in the mapped area. These include the coarse grained porphyritic granite and fine - medium grained granite. The fine-medium grained granite restrictively outcropped at the Northwestern corner and volumetrically lesser than other rock types It probably occur as intrusive body into existing host migmatite and other granitic rocks.

5.Geotechnical Characteristics of soil Samples

Four (4) soil samples were collected from varying depth of test pits over the investigated site. This was aimed at assessing its suitability as mineral seals (barrier) in sanitary landfill. Required parameters such as grains distribution, Atterberg limits determination, compaction and permeability characteristics were tested and values were compared with standard recommendations.

5.1 ***Grain Size Distribution***
In the soils investigated the largest grain has diameter ≤ 6.3mm (Fig. 3). This is very small compare to 63mm suggested by ÖNORM S 2074 (1990) and less than 50mm suggested by Daniel 1993. The percentage of clay contained in the soil range between 41% - 51% Table 1. These values are much higher than 15% proposed by ÖNORM S 2074 (1990) and less than 30% suggested by Daniel (1993), Rowe (2005) and Mohammedzein (1998). Oeltzcshner (1992) preferred soils with clay fraction of greater than 20%.

The percentage of gravel recommended by Daniel 1993 and Rowe (1995) is less or equal 30% of the soil mass. The highest proportion of gravel from the investigated soil sample is 6% with an average value of 3.75% over the whole area. The specific gravity also ranges between 2.61% and 2.69% which is better than 2.2 recommended by ÖNORM S 2074 (1990).

5.2 ***Atterberg Consistency Limits***
The results of the liquid limits tests (L_l) for the soil range between 35.34% and 40.56% while the index of plasticity (Ip) range between 17.15% and 20.55% (Table 2). These are higher than recommendations of several previous workers. From the results, the Casangrande plasticity chart was plotted for all the soils. All the soil samples fall within the inorganic clay of intermediate plasticity (Fig. 4**)**. This is a good result when compared to the recommendations of Hughes *et al* (2005) and Jagger & Ash (2008). Clay activities (A_C) of the soils were also evaluated to determine the reactivity of the soil. The values range between 0.35 and 0.40. It therefore suggested that the soil contain essentially kaolinitic clay mineral type which are non-reactive and non-expansive (Withlow 1998). They are less attack by chemical and withstand volumetric shrinkage (Taha and Kabir 2006).

5.3 ***Moisture Content - Density Relationship***
The results of compaction tests carried out at different energies of compaction to obtain the soils optimum moisture content (OMC) and the corresponding maximum dry density (MDD) is presented in the Table 3. Benson & Trast (1995) reported that the coefficient of permeability is sensitive to compactive effort and molding water content. The soil MDD values for standard Proctor energy of compaction range between 1.77t/m^3 and 1.84t/m^3 while MDD at modified Proctor energy range between 1.9t/m^3 and 2.2t/m^3. These values are higher than 1.7t/m^3 stipulated in ÖNORM S 2074 (1990). They are also better than 1.45t/m^3 (standard Proctor) and 1.64t/m^3 (modified Proctor) of MDD recommended by kabir & Taha (2006) for soils produced from Basement complex rocks to be useful as barrier in landfills.

5.4 ***Coefficient of Permeability (k)***
The coefficient of permeability is the key parameter affecting most soils to be useful as barrier in landfill. Thus great attention is focused at ensuring a low permeability is achieved. Several investigators and waste management agencies have recommended 1x10^{-9}m/s as the minimum allowable value for soil to be useful for this purpose. From Table 5, values lower than recommendation of several authors (Mark 2002; Joyce 2003.and Jagger & Ash 2008) were obtained from all the soil investigated with both standard and modified Proctor energies. It was also observed that the coefficient of permeability decreases with increased compactive energy (Table 3). This is because there is a decrease in the frequency of pores resulting from the structural rearrangement of soil particle in the soil mass (Acar & 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.

6. Conclusion
The following conclusions were made on structure of sanitary landfill and the geotechnical evaluation of the investigation area for development on sanitary landfill in Ilorin, Nigeria.
The structure of a sanitary landfill is simple and the materials for the component are locally abundantly available in the country. The earth moving equipment needed in the construction of landfills such as bulldozers, trucks, etc. are easily available as they are already being used for road and other engineering construction works.

The overall engineering characteristics of the soil samples recovered from test pits, irrespective of the depth of recovery, show that the soils are inorganic clay with low to medium plasticity. Generally, these types of soils possess desirable characteristics to minimize hydraulic conductivity of compacted soils. The indices properties (liquid limit, plastic limit, percentage fine, percentage gravel, activity etc) of the soil samples satisfy the basic requirements as barrier materials in landfills. They are inactive clayey soils. Thus, the soils will be less affected by waste chemical and also less susceptible to shrinkage. The soils have hydraulic conductivity of less than 1×10^{-9} m/s when compacted with both modified and standard Proctor compaction efforts.

These results compared favorably with the recommendations of several researchers. It can be concluded, from the favorable results, that construction of a sanitary landfill is viable in Ilorin, Nigeria.

7. Acknowledgements

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REFERENCES

Acar, Y. & Oliveri I. (1989), "Pore fluid effects on the Fabric and Hydraulic Conductivity of Laboratory Compacted Clay". *Transportation Research Record*, **1219**, 144- 159.

Annor, A.E., & Freeth, S. J. (1985), "Thermotectonic evolution of the Basement Complex around Okene, Nigeria, with special reference to deformation mechanism". *Precambrian Research.* ***28,*** 268-281.

Onokerhoraye, A. G. (2007), "Population and Demography of Nigeria". *Africa Atlass-Nigeria*. 2nd Edition. 156p.

Daniel, D.E. (1993a), "Landfills and impoundments". In: Daniel, D.E. (ed.) - *Geotechnical Practice for Waste Disposal*. Chapman and Hall, London, 97-112.

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

Farquar, G.J. (1994), "Experiences with liners using natural materials". In: Christensen T.H. et al (eds.). Landfilling *of Wastes: Barriers*, E. & F.N. Spon, London, 37-53.

Ige, O. O. (2010), "Landfill site Selection for Municipal solid waste and Assessment of soils as mineral seals around Ilorin, southwestern, Nigeria". A PhD Thesis submitted to the University of Ilorin. 254p

Gartung, E. & Quenzler, H. (1993), "Eigungsprufung fur mineralische Filter und Dranmaterialen" *Veroffentlichungen des Grundbau Institutes der Landesgewerbeanstalt Bayern*. H. **67** 221- 262.

Jagger, D.E. & Ash J.S. (2008), "Geotechnical considerations at landfill site". *Jagger Hims Ltd.* www.jaggerhims.com, 27p.

Jessberger, H.L. (1994), "Geotechnical design and quality control of mineral liner systems". In: Christensen T.H. et al (eds.) – *Landfilling of Waste Barriers, E. & F.N. Spon, London*, 55-68.

Joyce, M. P. E. (2003), "A study of the merit and effectiveness of alternate liner systems at Illinois landfills". A research paper submitted in fulfillment of house resolution 715 State of Illinois 92nd General Assembly. 46p.

Kurian, J; Nagendran. R. & Palanivelu. P. (2005), "Open Dumps to Sustainable Landfill". *Centre for Environmental Studies*, Anna University, Channai,India.www.serd.ait.ac.th/sidaSWM/project .

Mark, Y. (2002), "Geology and geotechnical investigation of the proposed Canterbury regional landfill, Kate Valley, North Canterbury" Transwaste Canterbury Ltd. 97p**.**

Lumbsden, T.K. (2002), "Pattern of waste management in developed countries". *International Journal of Water and Sediment Contamination.* **49(**2), 63-68.

Mohamedzien, Y. A. M., Al-Rawas, A. A., Al-Aghbari, M.Y., Qatan, A.& Abdul-Hamid A. (2005), "Assessment of Crushed Shales for use as compacted landfill liners". Journal of Engineering Geology, **80**, 271- 281.

Oeltzschner, H. (1992), "dAnforderung an die Geologie, Hydrogeologie und Geotechnik Beim Bau von Deponie". In: Thorme-Kozmiensky K.J. (ed.) - Abdichtung von Deponien und Altlasten. E.F. Verlag fur Energie und Umwelttechnik GmbH, Berlin, 53-82.

Oluyide, O.P., Nwajide, C.S. And Oni, A.O. (1998), "The Geology of Ilorin area". *Ministry of Solid Mineral and Development. Bulletin of Geological Survey of Nigeria, No. 42.*

Onorm,S 2074. (1990), "Geotechnik in Deponieb au-Erdarbeiten". *Osterreichisches Normungsinstitut, Wien*

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

Oweis, I.O. & Khera, R.P. (1990), "Geotechnology of Waste Disposal". *Butterworths, London*.

Rowe, R. K. (2005), "Long-term performance of contaminant barrier systems". *Geotechnique* **55** (9), 631-678.

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

Taha, M.R. & Kabir, M.H. (2003), "Sedimentary Residual Soil as a Hydraulic Barrier in Waste Containment Systems", In: *Proceedings of the International Conference on Recent Advances in Soft Soil Engineering and Technology*, 2-4 July 2003. Putrajaya, Malaysia.

USDOE, (1995), "Landfill Design, Construction and Operational Practice". *Waste Management Papers* 26B, HMSO, St. Clement's House, 2-16, Colegate, Norwich NR 3 IBQ.

Withlow, R. (1998), "Basic Soil Mechanics". 3rd Edition. Longman Group Ltd. 557p.

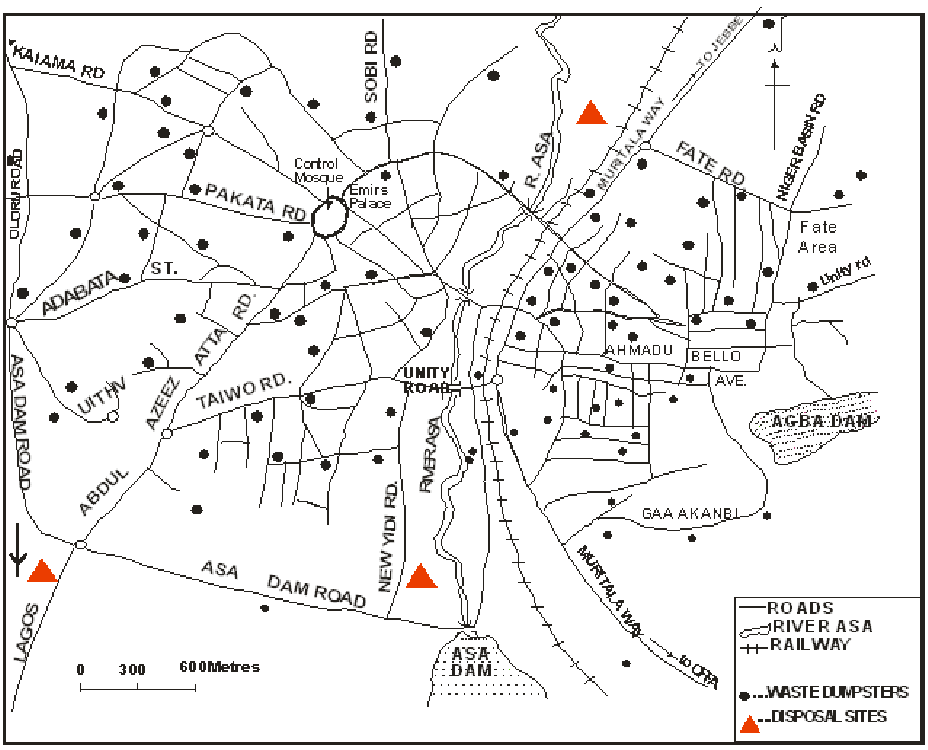

Fig. 1: The Locations of waste dumpsters and final disposal site in Ilorin.

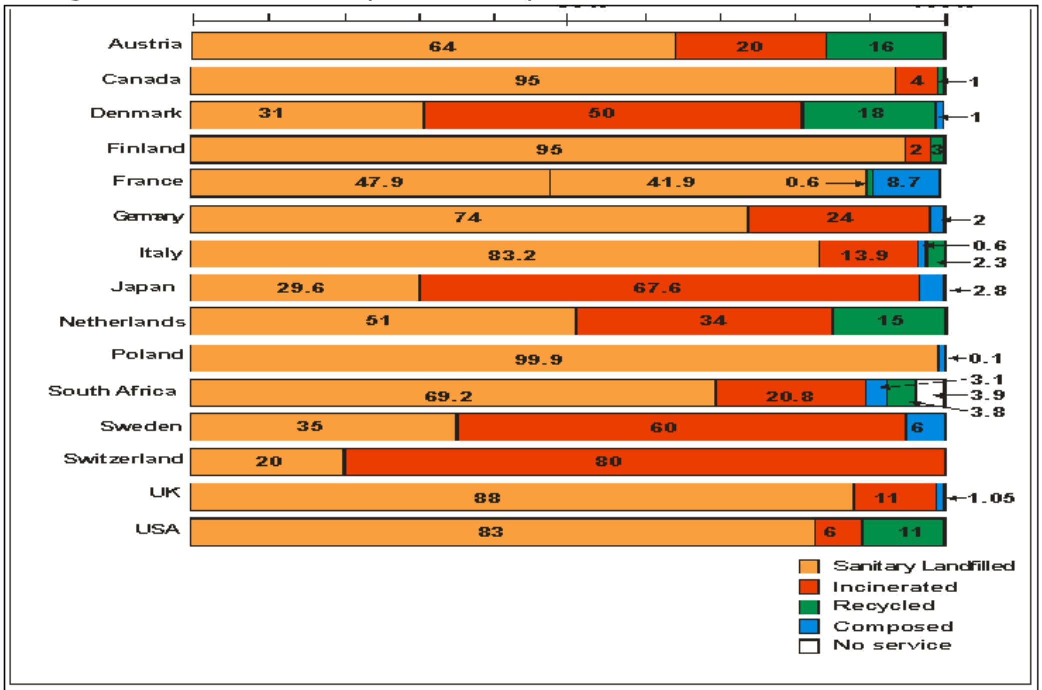

Fig. 2: Proportion of Municipal Solid Waste handled by various disposal methods in selected countries (Lumsden, 2002).

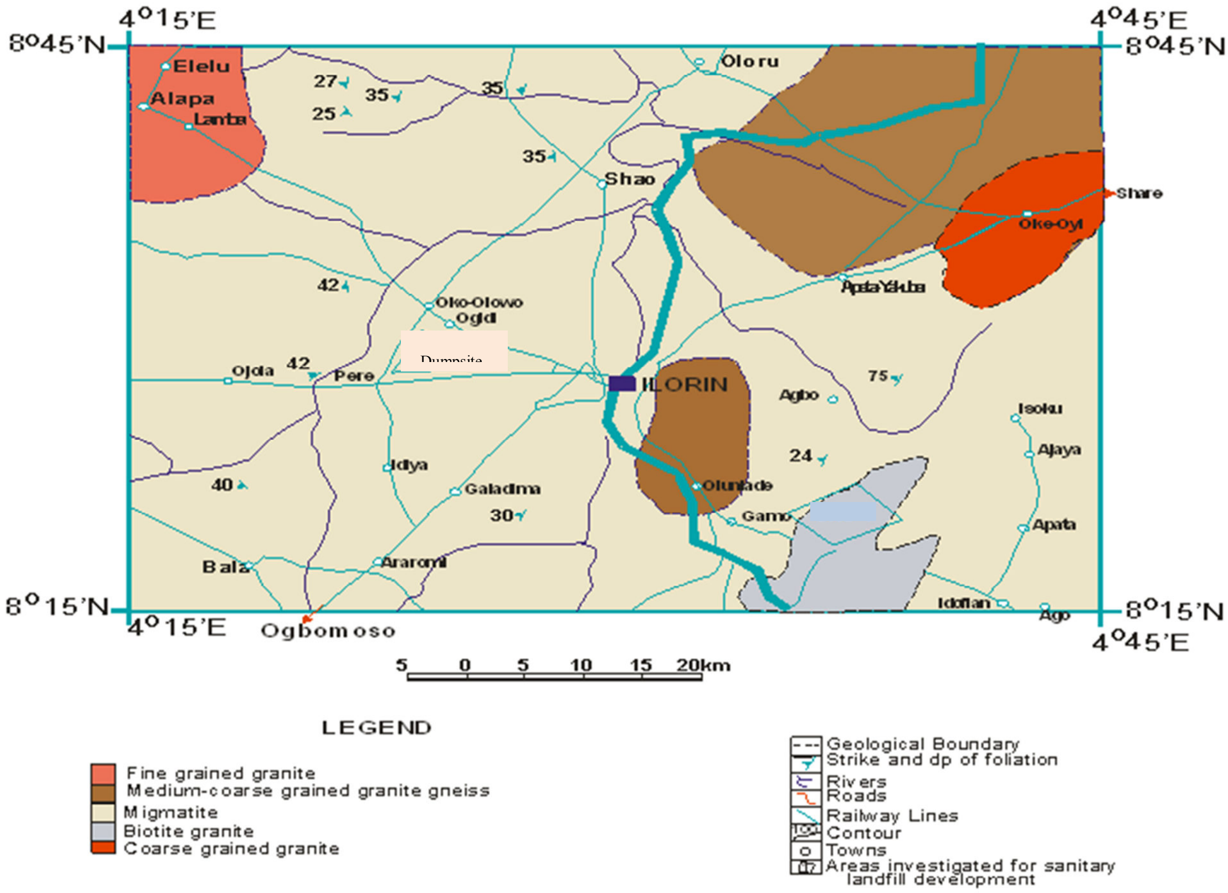

Fig. 3 : Geological Map of Study area showing invstigated sites

Table 1: Grain size analysis of soil samples

S/N	Well No	Depth(m)	Natural Density(t/m^3)	Specific Gravity	Gravel Size (%)	Sand (%)	Clay (%)	Silt (%)
1	W1	1.15	2.04	2.69	4	64	18	14
2	W2	2.70	1.67	2.64	5	61	28	6
3	W3	4.50	1.60	2.63	0	33	45	21
4	W4	3.10	1.91	2.61	6	47	41	6
		Average	**1.81**	**2.64**	**3.75**	**51.25**	**33**	**11.75**

Table 2: Atterberg Consistency limits of the soil samples

Symbol	WL (%)	WP (%)	IP (%)	Plots on Plasticity chart	Ac
W1	35.34	18.19	17.15	CL	**0.35**
W2	39.14	20.80	18.34	CL	**0.41**
W3	39.80	21.31	18.49	CL	**0.39**
W4	40.56	20.01	20.55	CL	**0.42**
Average	**38.71**	**20.01**	**18.63**	**CL**	**0.39**

KEY: WL = Liquid Limit WP = Plastic Limit
IP = Index of Plasticity Ac = Activity of Clay

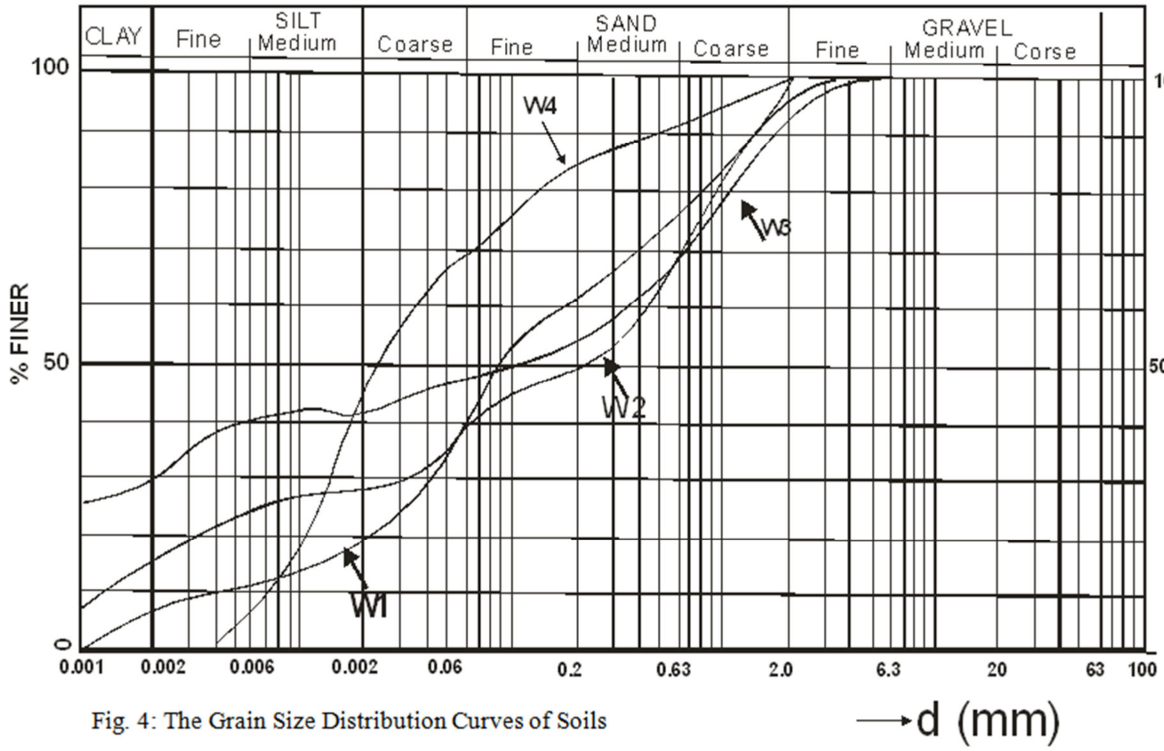

Fig. 4: The Grain Size Distribution Curves of Soils

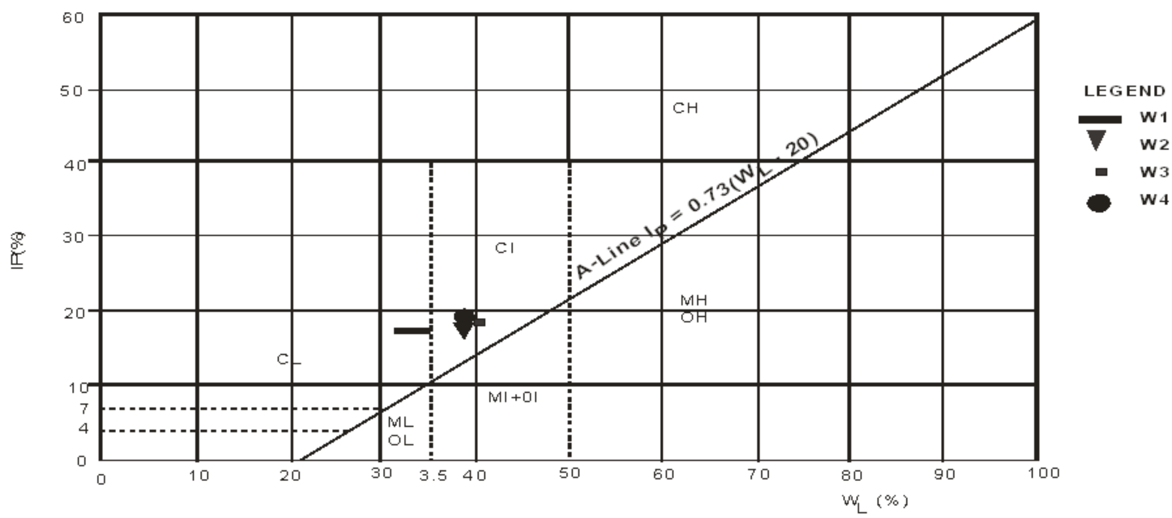

Fig. 5 : Position of soil samples on the Casagrande's Plasticity chart.

Table 3: Maximum Dry Density and Coefficient of Permeability of the soil Samples.

WELL SYMBOL	STANDARD PROCTOR		MODIFIED PROCTOR		COEFFICIENT OF PREMEABILITY(*K*)cm/s	
	OMC (%)	MDD (t/m³)	OMC (%)	MDD (t/m³)	STANDARD PROCTOR	MODIFIED PROCTOR
W1	13.4	1.84	10.8	2.2	1.1×10^{-9} m/s	3.4×10^{-11} m/s
W2	14.0	1.78	10.3	1.9	4.0×10^{-9} m/s	5.1×10^{-11} m/s
W3	14.2	1.77	10.0	2.1	5.3×10^{-8} m/s	3.6×10^{-11} m/s
W4	16.7	1.80	12.5	2.0	3.7×10^{-9} m/s	2.3×10^{-11} m/s
AVERAGE	**14.6**	**1.80**	**10.9**	**2.1**	**3.53×10^{-9} m/s**	**1.6×10^{-11} m/s**

OMC = Optimum Moisture Content MDD = Maximum Dry Density

Author's Biography

Olusegun Omoniyi IGE (PhD) was born in Ekiti State, Nigeria. His primary and post primary schools were in Ayede – Ekiti, Nigeria. He obtained his Ph.D., M.Sc. and B.Sc. degrees in the University of Ilorin, Ilorin, Nigeria in 2010, 2003 and 1998 respectively. He joined several professional bodies such as International Solid Waste Association (ISWA in 2007), International Association of Engineering Geologists (IAEG in 2005), Council of Mining Engineers and Geoscientists (COMEG in 2007), Nigerian Mining and Geoscientists Society (NMGS in 2003), Nigerian Association of Hydrogeologists (NAH in 2000). He is currently the Vice president, Nigerian Association of Engineering Geologists and the Environment (NAEGE). Dr. Ige is an academic staff in the Department of Geology and Mineral Sciences, University of Ilorin, Nigeria. He teaches Hydrogeology and Engineering Geology. He is interested in evaluation of geological materials as sealants in Sanitary Landfills. His current research interest includes hydro-environmental pollution and control measures (Email: vickyige2002@yahoo.com)

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