

Assessment of Some Lateritic Clayey Soils from Azara Northcentral Nigeria as Liners in Sanitary Landfill

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Abstract
This study investigates the geotechnical properties of Azara clayey soils from Northcentral Nigeria for its potential use as liner in sanitary landfill. Six (6) samples were taken at about 2.5m interval each along exposed cliff and subjected to laboratory analyses. The required parameters for soils to be considered as mineral seal such as grain size distribution, Atterberg consistency limits, maximum dry density and hydraulic conductivity were determined using the BS 1377 1990 standard. Results obtained show that the grain size analysis of the soils samples are silty clayeysand and clayeysand. The results of Atterberg limit show that the samples can be grouped as low clay soils and medium clay soils. Compaction test analysis shows that sample 3 has the highest optimum moisture content (OMC) value of 10.25%. Sample 2 has the highest maximum dry density (MDD) value of 1.95g/cm^3 while samples 3 have the least MDD value of 1.52g/cm^3 for modified compaction test. The results of hydraulic conductivity (K) reveal that sample 6 has the least value of 1.2 x 10^{-8} cm/s, and sample 1 has the highest value of 3.0 x 10^{-7} cm/s which falls within value of various waste regulatory agencies. In addition, three samples have adequate basic geotechnical properties and strength characteristics which suggest the potential suitability of the soils as mineral seal in containment facility for disposal of solid waste materials.
Keywords: Geotechnical, Landfill, Mineral seal, Hydraulic conductivity, Nigeria.

1. INTRODUCTION

Waste generation is as old as the earth itself, urbanization, industrial and agricultural activities has contributed immensely to waste generation. Open refuse dumps, where waste disposal is unsorted and unregulated, are characteristic of many countries of the developing world, and represent an increased risk to groundwater quality. In such settings, waste separation and sorting for reuse and recycling is often conducted on an informal basis either at points of collection or at the dump itself. (Allen, 2002).

Also, population increase leads to an increment in consumption; waste disposal has become one of the most serious of modern environmental problems in developed and developing countries all over the world. One of the preferred methods of dealing with this kind of environmental problem is to dispose the waste in sanitary landfills (Arasan and Yetimoglu, 2008).

Encapsulation of waste in a lined landfill, minimizes the rate of degradation of the waste by isolating it from the natural agents of degradation, particularly rainwater - the main catalyst of degradation, (i.e. the waste is kept dry). This will have the effect of prolonging the activity of the waste and inhibiting its stabilization to an inert state. Potentially the period of aftercare and monitoring of the landfill after closure could be prolonged for many tens or even hundreds of years (Allen, 2001).

Investigations by Jessberger (1994), Edelman (1999), Jones and Dixon (1997) have demonstrated that optimization of landfill barrier design cannot be achieved without specific geotechnical properties and landfill liners take a very crucial part in having a sanitary landfill that will prevent the leachate from contaminating the groundwater.

Commonly use mineral seals are composed of natural inorganic clays or clayey soilss. The low hydraulic conductivity of the compacted clayey soilss combined with their availability and relatively low cost make them potential materials to use as mineral seals in sanitary landfills for environmental protection. Since it is desirable for containment system to achieve its purpose at minimum cost; careful consideration should therefore be given to the choice of materials for the construction of the mineral seal. The mineral seal is to control or restrict the migration of pollutant into the environment (Ige and Ogunsanwo, 2009). The environmental and health hazards associated with “unengineered” landfills are well known (Asiwaju-Bello and Akande, 2004; Onipede and Bolaji, 2004,). In the U.S.A, Lee and Jones (2005) asserted that 75% of unengineered landfills pollute adjacent water body with leachate. This study will be on the assessment of clayey soils as sanitary landfill liners.

2. SAMPLES LOCATION AND GEOLOGY

Azara is located in Awe Local Government Area of Nasarawa State which shares boundaries with Plateau, Taraba and Benue State of Nigeria with latitude of 8° 22' 0 N and a longitude of 9° 15' 0 E. It is located in the Middle Benue trough and an average elevation of 205 meters above the sea figure 1.

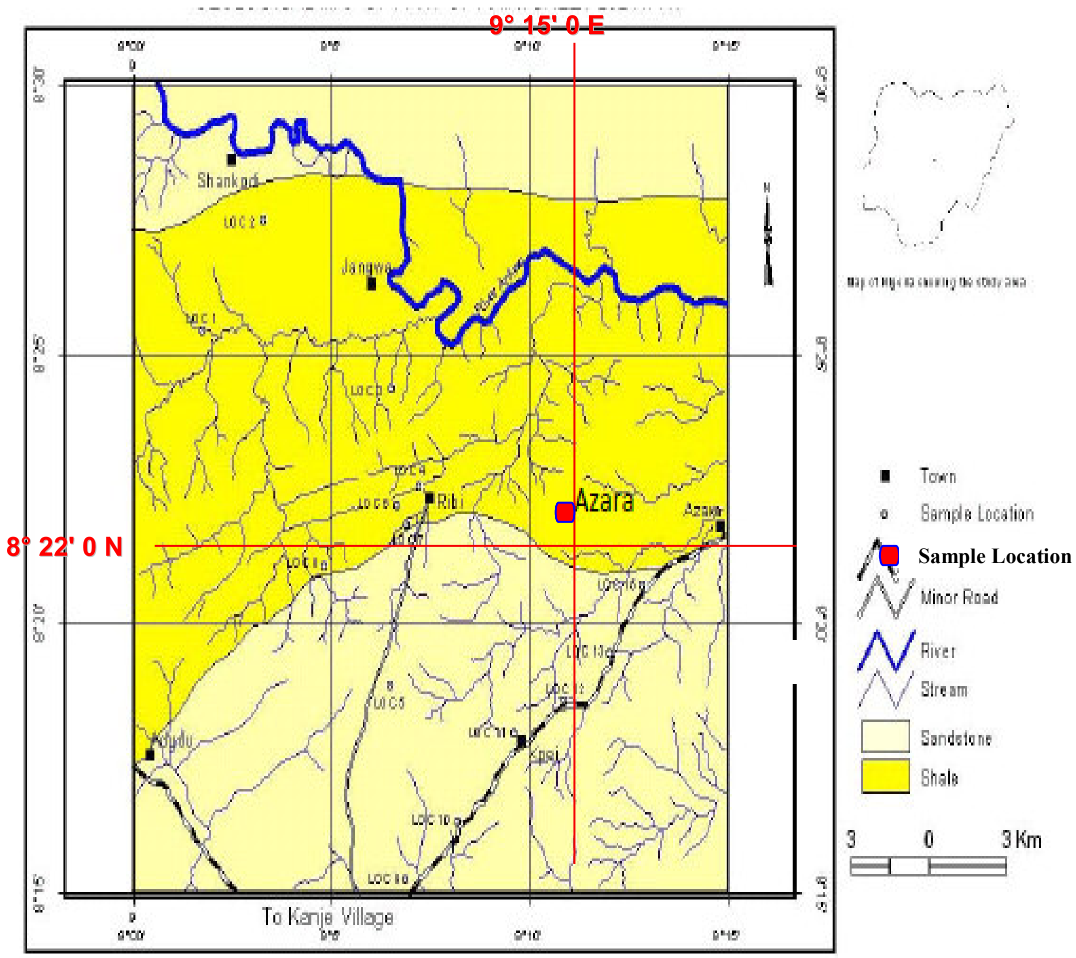

Figure 1: Road Map of the study area (Adapted from Chaanda, 2008).

The area is Upper Cretaceous, lithogenic formations comprise the stratigraphic succession. This succession is made up of Albian Arufu, Uomba and Gboko Formations, generally referred to as the Asu River Group (Nwajide, 1990). These are overlain by the Cenomanian – Turonian Keana and Awe Formations and the Cenomanian – Turonian Ezeaku Formation.

The lithologic composition of the Asu River Group comprises limestones, shales, micacous siltstones, mudstones and clays (Obaje, 1994). The average thickness is estimated to be about 1,800 m. The formation consists of flagy, whitish, medium to coarse grained calcareous sandstones, carbonaceous shales and clays. The Keana Formation resulted from the Cenomanian regression which deposited fluviodeltaic sediments. The formation consists of cross-bedded, coarse grained feldsparthic sandstones, occasional conglomerates, and bands of shales and limestones towards the top. Massive outcrops occur at Keana, Noku, Chikinye, Jangerigeri, Azara, and Daudo.

3. MATERIALS AND METHODS

Six samples were collected from the cliff at interval of 2.5m each. The samples range from, silty clayeysand and clayeysand which is predominant among the samples. GPS coordinates at the top of the cliff were recorded to determine the height of the cliff. [N 08^0 18 97, E 09^0 14 86 Elevation 498 Ft (151.8m), N 18^0 12 00, E 09^0 48 74 Elevation 547 Ft (166.7m)].

The approach to this study essentially involves detailed sample collection and laboratory analysis. The laboratory aspect involves the geotechnical tests which are Grain size distribution using wet sieve and hydrometer, Atterberg consistency limits, Specific gravity, Bulk density and dry density, Permeability test using the falling head parameter, and Compaction (moisture-density relation) involving both standard and modified proctor were carried out following the guidelines of the British Standard (BS 1377 1990). The data of the index properties were used to classify the soils following the Unified Soils Classification System (USCS).

4. RESULTS AND DISCUSSIONS

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

4.1 Grain-Size Analysis

The grain size analysis is principally carried out to determine the relative proportions of grain sizes in a soils mass, and is one of the oldest soils tests applicable in the specification of soilss for airfields, roads, earth dam, embankment constructions (Cheng and Jack, 2000).The result of grain analysis is presented in table1. Based on this analysis, the soilss are grouped as follows; sample 1 and 2 as silty clayey sand, sample 3 - 6 as clayey sand. Soils can be used as barrier when the fine ≥30% (Rowe et al, 1995, Daniel and Wu, 1993; Benson et al., 1994) and 15% clay (Benson et al, 1994). (ÖNORM S 2074, 1990; Daniel, 1993; Bagchi 1994; Benson et al., 1994; Rowe et al., 2000; 1996; Ogunsanwo, 1996; Taha and Kabir, 2006). Benson et al (1994) proposed three basic conditions that are necessary:

a. The percentage of fines must be > 30%
b. The percentage of clay must be > 15%
c. The percentage of gravel must be < 10%

Bagchi (1994) recommended a clay fraction content of 18-25% and grain size distribution curve of a slant type as this soils type can easily be compacted. Daniel (1993) prefers soilss with largest grain diameter of between 25 and 50mm and a gravel fraction 30%. Oeltzschner (1992) is in favour of soils with clay fraction >20%.All the sample 2-6 meet the aforementioned specifications, and they can be used as liners.

Table 1: Grain size distribution

Sample	Grain Size Distribution					Soils Type (Unified Standard)
	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fines (%)	
1	12	53	20	15	35	Silty clayeysand
2	7	53	20	20	40	Silty clayeysand
3	6	54	17	23	40	Clayey sand
4	5	60	15	20	35	clayey sand
5	6	44	20	30	50	clayey sand
6	6	39	20	35	55	Clayey sand

4.2 Atterberg Limit Consistency

The Atterberg consistency (degree of firmness) limits tests evaluate the relationship between moisture content and soils consistency. The results of Atterberg limits test are presented in Table 2.

4.2.1 Liquid Limits (LL)

Liquid limit is an important index property since it is correlated with various engineering properties. Soils with high liquid limit generally have low hydraulic conductivity. Liquid limit of the sample are as follow; (sample 1: LL 37%, sample 2: LL 40%, sample 3: LL 36%, sample 4: LL 35%, sample 5: LL 41%, sample 6: LL 47%,). Soils with high liquid limit generally have low hydraulic conductivity. Benson *et al* (1994) recommended that the liquid limit of mineral seal material be at least 20%. The soils has liquid limit which is more than the specification and appears to be promising for use as mineral seal.

4.2.2 Plasticity Index (PI)

The plasticity index of the soils which is the difference in water content between the liquid and plastic limits is a measure of the affinity of a soils for water. It is an indicator of the plasticity of a soils. The greater the plasticity index, the more plastic and com-pressible and the greater the volume change characteristics of the soils.

Table 2 (sample 1 IP 17.2%, sample 2 IP 19.3%, sample 3 IP 14.6 %, sample 4 IP 13% sample 5 , IP 23.2%, sample 6 , IP 28.9%,). According to Bagchi (1994), a lateritic clayey soils with liquid limit (LL) ≥30% and plasticity index (PI) ≥ 15% is recommended. Clayey soils with liquid limit (≥35%) and plasticity index of >15% are good for consideration as mineral seal (Oeltzschner, 1992). Oweis and Khera (1998) suggested inorganic clay of high plasticity. With respect to clay activity, Daniel (1993) suggested PI of 7% - 30% because of possible clodding by higher percentage of PI. Taha and Kabir (2006), recommended a PI of <33% and PL of 35% for a granite derived lateritic soils. Clayey soils with < 10% liquid limit and plasticity index, >65% liquid limit and >75% plasticity index will be difficult to compact on the field (Ash and Jagger, 2008). These samples meet the requirements stated above and can be used as liners.

4.2.3 The Clay Activity

Sample **1**: 0.52, sample **2:** 0.73, sample **3:** 0.9, sample **4:** 1.31, sample **5:** 1.4, sample **6**: 1.49. A clayey soils of activity less or equal to 1.25 will have low permeability and will be suitable as mineral seal in sanitary landfill. Inactive clayey soils are the most desirable materials for compacted soils mineral seal (Rowe et al, 1995). In order to achieve a hydraulic conductivity ≤ 1×10-7 cm/s for the soils mineral seal, soils with an activity of > 0.3 has been recommended (Benson et al, 1994, Rowe et al, 1995). An activity is an index of the surface activity of the clay fraction. Soils with higher activity are likely to consist of smaller particles having larger specific surface area and thicker electrical double layers (Taha and Kabir, 2006).

Table 2: Atterberg and Shrinkage Limits of the Studied Samples.

Sample	Liquid Limit (WL%)	Plastic Limit (PL%)	Plasticity Index (IP %)	Shrinkage Limit (SL%)
1	37.0	19.8	17.2	3
2	40.0	20.7	19.3	3
3	36.0	21.4	14.6	4
4	35.0	22.0	13.0	4
5	41.0	17.8	23.2	5
6	47.0	18.1	28.9	7

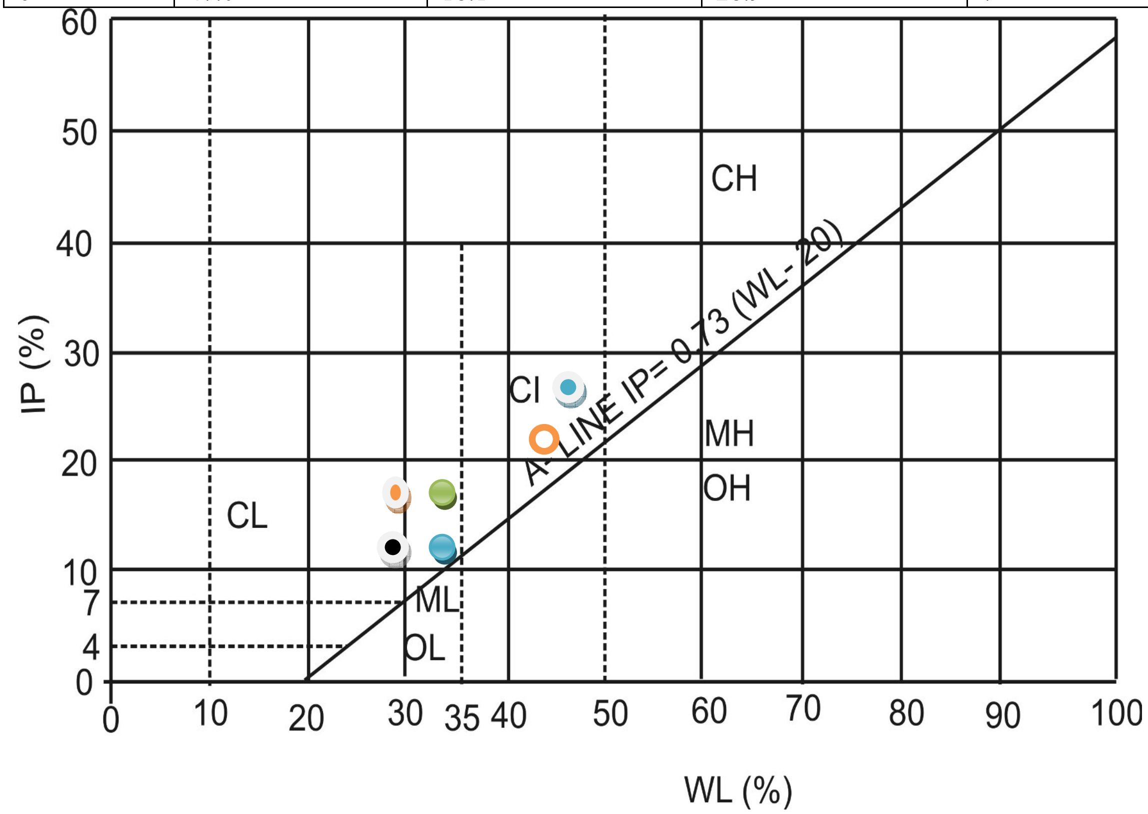

Figure 3: Casagrade soils chart.

Sample 1 , sample 2 , sample 3 , sample 4 , sample 5 , sample 6

4.3 Compaction Test.

In the construction of barriers, compaction is done to achieve a soils layer of improved engineering properties. Compaction of soils results in homogenous mass that is free of large, continuous inter-clods voids; increase their density and strength, and reduce their hydraulic conductivity. Hydraulic conductivity is the key design parameter when evaluating the acceptability of a barrier material. Low hydraulic conductivity is achieved when the soils is compacted close to its maximum dry density and corresponding optimum water content for a soils under a specific compactive effort Ige 2010. Compaction test can be grouped into standard proctor and modified proctor, for standard proctor sample 3 the highest Optimum moisture content (OMC) which is 18%, and sample 1 has the lowest OMC of 10.25%, sample 1 has the highest value of 1.95g/cm^3 for MDD, and sample 3 has the lowest value of maximum dry density (MDD) which is 1.52 g/cm$^{3.}$ Kabir and Taha 2006 recommended MDD ≥1.6g/cm^3 All the samples meet this requirement when modified compaction test is carried out on them except sample 3.

Table 5 :Compaction test

Sample	Standard Compaction		Modified Compaction	
	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)
1	10.25	1.42	9.00	1.65
2	13.00	1.56	12.00	1.95
3	18.00	1.42	15.5	1.52
4	17.00	1.40	16.00	1.60
5	17.00	1.48	16.00	1.64
6	17.00	1.42	17.50	1.63

4.4 Permeability

The hydraulic conductivity of the sample analysed are these: Sample **1**: 3 x 10^{-7} cm/s, sample **2**: 1.736 x 10^{-7}cm/s, sample **3**: 1.62 x 10^{-7}cm/s, sample **4**: 1.053 x 10^{-7}, sample **5**: 1.0 x 10^{-7}cm/s, sample **6**: 1.2 x 10^{-8} cm/s. There is no preferred trend with depth for the hydraulic conductivity with depth, sample 1 has the highest hydraulic conductivity of 3.0 x 10^{-7} cm/s while sample 6 has the least hydraulic conductivity of 1.2 x 10^{-8} cm/s. Sample 4,5 and 6 analysed meet the standards to be used as liners in accordance with the findings of Mark (2002) Joyce (2003), Fred and Anne (2005) Daniel and Wu (1993), and Rowe et al., (1995) which stated that the samples must have a maximum permeability of 1x10^{-7} cm/s. The hydraulic conductivity (k) is the main parameter that determines the competence of a clayey soils as mineral seal (Daniel, 1990; Benson and Daniel, 1990; Benson et al., 1994). The general mechanical properties of clay depend on several interacting factors such as mineral composition, percentage of amorphous material, absorbed cation, distribution and shape of particles, pore fluid chemistry, soils fabric, degree of saturation etc. The effects on the mechanical properties of soils due to a change in any of these factors have been predicted qualitatively using physico-chemical theories (Bagchi, 1994).

On the suitability of compacted clay soils as mineral seals in sanitary landfill, several recommendations have been proposed Seymour and Peacock, 1994; USEPA, 2005; Taha and Kabir, 2006; ÖNORM S 2071(1990) preferred k-value of 1x10^{-9}m/s;

5. CONCLUSION

The following conclusions can be drawn from the investigation of Azara clayey soils.

The soils are low-medium clay and inorganic clay. Generally, these types of soils possess very low hydraulic conductivity but sample 4, 5 and 6 possess desirable hydraulic conductivity to be used for the construction of compacted soils mineral seals. The index properties (liquid limit, plastic limit, % clay content, % fines, activity etc.) of the soils satisfy the basic requirements as a mineral seal. The soils is inactive clayey soils, thus, the soils will be less affected by waste leachate. Also, the soils will not get clodded during the in-situ permeability test because the plastic index is not very high.

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