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Assessment of Chemical and Geotechnical Properties for Optimal Selection of Nigerian Laterite Soil as Liner Material in Solid Waste Landfills

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Abstract

Examining the applicability of laterite clay for landfill and other engineering applications is critical due to the daily challenges that practitioners face as a result of material property variation. The suitability of seven selected laterite deposits in southwestern Nigeria as usable liner material in solid waste landfill construction was investigated in this study, taking geotechnical properties and chemical composition into account. Purposive samples were collected and tested in accordance with ASTM standard procedures for analyzing geotechnical properties. X-ray diffraction analysis was used to determine the soil's clay mineral composition. The clay mineral composition of the soil was determined using X-ray diffraction analysis. The geotechnical analysis revealed the following ranges for the samples: gravel particle size percentage (3.7% to 34.0%), fines particle size percentage (17.4% to 71.7%), liquid limit (28.1% to 65.8%), plasticity index (3.95 to 45.53), activity (0.44 to 0.81), coefficient of permeability (6.75 x10-10 m/s to 5.80 x 10-6 m/s), specific gravity (2.639 to 2.768), and maximum dry density (1462 kg/m3 to 2065 kg/m3). X-ray diffraction test revealed that the clay minerals content in the seven location clay deposit varies depending on location. The study revealed that the clay mineralogical composition affects the suitability of the soil as a landfill liner material. Four among the seven clay deposits considered in this study were found suitable as a liner for solid waste landfills as compared with landfill material standard specifications.

1. Introduction

Waste disposal is one of the most difficult challenges that provinces and municipalities face around the world. Humans generate waste every day, which, if not properly managed with the increase in population, can lead to health and environmental problems. Landfill destinations are made and controlled by the public authority for legitimate garbage removal [1]. Adeoye et al. mentioned that a landfill site is an area of land designed for the safe deposition of waste materials [2]. They also noted that such land is designed to protect the environment from pollution and contaminants, which may be released from waste material decay. Buekens indicated that landfill liners are the low permeable barrier, which is laid down under engineering landfill sites that retards the migration of leachate, and its toxic byproducts into topsoil, and guards against penetration into underlying aquifers or nearby rivers [3]. Daramola and Ilasanmi explained that choosing liner material for landfill is of great importance and requires strict specifications when selecting the material to be

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used [4]. Many researchers studied soil suitability with a view to identify and recommend selection criteria for various soil used as liners [5-11]. The works focus on the selection of natural soil in southwest Nigeria [2, 4, 12]. Their study revealed the possibility of using selected Nigeria laterite with defined specification as liner material in landfilling. Ige assessed lateritic soils from the dumpsite in Ilorin (Southwestern Nigeria) as liners in sanitary landfills using the geotechnical properties of the soil samples [12]. His study revealed that the soils in the case study area are suitable for use as liners in sanitary landfills as 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. The study also revealed that the soils are less affected by waste chemicals and also less susceptible to shrinkage due to the classification of the soil as inactive clayey soils. Fatoyinbo et al.'s study ascertained that the investigation of lithological, hydrological, geotechnical, and topographical factors, including land-use criteria, are important in the selection of appropriate solid waste landfill sites with minimal environmental contamination potential or threat. They determine suitable areas within the Akure metropolis with residual soils of excellent geotechnical properties as landfill [13].

Omoniyi et al. also evaluated the geotechnical and mineralogical properties of four lateritic soil samples derived from different parent rocks in southwest Nigeria and concluded their suitability as construction material [14]. Adeoye et al. also evaluated some selected lateritic soils in southwestern Nigeria as liner material for sanitary landfill using geotechnical properties of the soil and concluded that the soils are suitable for use as liners in a sanitary landfill [2]. Daramola and Ilasanmi evaluated some selected lateritic soils from Ore, Ondo state, southwestern Nigeria as liners in landfills using geotechnical properties of the soils [4]. The work revealed that the soils are suitable for use as liners in landfills. Previous research work on southwest Nigeria laterite as liner material suitable for land filling had neglected the influence of clay mineral in the laterite on the material strength and characteristic. According to Broderick et al. and Stern et al.'s works, soil material with less reactive clay minerals such as kaolinite, illite, and attapulgite (palygorskite) has low hydraulic conductivity that makes them unaffected by chemical solutions [5, 11]. They also noted that the hydraulic conductivity of soil that contains majorly active clay minerals such as montmorillonite (smectite) can increase drastically if the soil is permeated with chemical solutions due to the relatively high reactivity of these clay minerals [11].

Clay minerals are known as secondary silicates because they are formed from the weathering of primary rock-forming silicate minerals. Clay minerals have small particle sizes usually less than 0.002-millimeter with very fine-grained and flake shaped. Clay mineral grains are separated from sand, gravel, and silt due to the negative electrical load on the crystal edges and positive electrical load on the face. Coulthard and Bell attributed the variation in the engineering properties of clays to the degree of weathering that they have undergone [15]. Laterite, according to Tardy, is a product of intense weathering made up of mineral assemblages that may include iron or aluminum oxides, oxyhydroxides or hydroxides, kaolinite, and quartz, and characterized by a ratio $Si0_2$ to $Al_20_3+Fe_20_3$ in defined assemblage [16]. He also explained laterite soil to be a weathered product of the intertropical zone. Oyelami and Van Rooy noted that laterite commonly contains all size fractions from clay to gravel and sometimes even larger material [17]. Onyelowe and Okafor, also noted that laterite soil is the term used to describe all reddish residual soil that is rich in aluminum oxides (gibbsite), iron oxides (goethite), and low fraction of silicates. Such soil type is the product of an in-situ weathering process of the basement rock, under tropical climate conditions [18]. The geotechnical properties and clay mineral content of laterite soil vary with location due to the depositional difference which is responsible for their difference in engineering usage [19]. Adebisi et al. carried out studies on the importance of clay contents of lateritic soil for engineering projects and their study revealed that clay particle size controls the engineering performance of lateritic soils [20]. Etim et al. investigated the effect of oyster shell ash on the geomechanical properties of Nigerian lateritic soil. They indicated that oyster shell ash can be used to improve Nigerian lateritic soil [21]. Obianyo et al. studied the stabilization of lateritic soil using a combination of agro-waste ashes, such as bone ash and palm bunch ash. Their study showed that these ashes can be used to stabilize lateritic soil at a 2% concentration [22]. Ojuri and Oluwatuyi found that lateritic soil samples from southwest Nigeria, when stabilized with compressed sawdust, ash, and lime, might not be suitable for use as landfill liners [23].

Several studies have been carried out by various researchers [2, 12, 26, 27] on the engineering application of lateritic soils in Southwest Nigeria but the knowledge gap between clay material mineralogical property and its suitability for landfill applicability had been given less consideration. This study aims to investigate the suitability of seven selected laterite deposits from Osun, Ekiti, and Ondo states in southwestern Nigeria as potential liner materials for solid waste landfills. The research evaluates both the geotechnical and mineralogical properties of these laterite deposits to determine their effectiveness in landfill applications. This approach not only assesses traditional soil characteristics but also incorporates advanced mineralogical analyses to provide a comprehensive evaluation of the material's performance as a landfill liner. By integrating these aspects, the study seeks to offer a detailed and innovative assessment of local lateritic materials, contributing to more sustainable waste management practices in the region.

2. Material and Methods

Table 1 and Figure 1 show disturbed soil samples taken from depths of 1 to 3 m from seven different laterite deposits in southwestern Nigeria. The test pits were dug and excavated using a digger and shovel, and 15-20 kg of each sample was collected in nylon bags, sealed, and transported to the laboratory for analysis. Figure 2 presents the flowchart of the work.

2.1. Geology of the Study Area

Nigeria's geology is characterized by a wide range of geological features, including Precambrian basement complexes, sedimentary basins, and volcanic formations [26]. Our investigation centers on the geological characteristics of the states of Osun, Ekiti, and Ondo, which are located in the southwestern region. The states mentioned are located inside the Nigerian Basement Complex, which is distinguished by the presence of old Precambrian rocks predominantly consisting of granite, gneiss, schist, and quartzite (Figure 3).

Table 1. Sampling localities and horizons of sampling

Sample ID	Latitude	Longitude	Sample depth (m)	Sample colour
Loc.1	07^{0}14.94’N	05^{0}13.32’E	2	Yellowish red
Loc.2	07^{0}7.38’N	04^{0}51.9’E	3	Mottled yellowish red.
Loc.3	07^{0}10.85’N	05^{0}35.32’E	3	Yellowish.
Loc.4	07^{0}44.99’N	04^{0}34.42’E	1	Reddish brown.
Loc.5	07^{0}39.45’N	04^{0}43.29’E	2	Reddish
Loc.6	07^{0}35.50’N	05^{0}13.13’E	2	Brownish red.
Loc.7	07^{0}36.67’N	05^{0}17.58’E	1	Brownish red

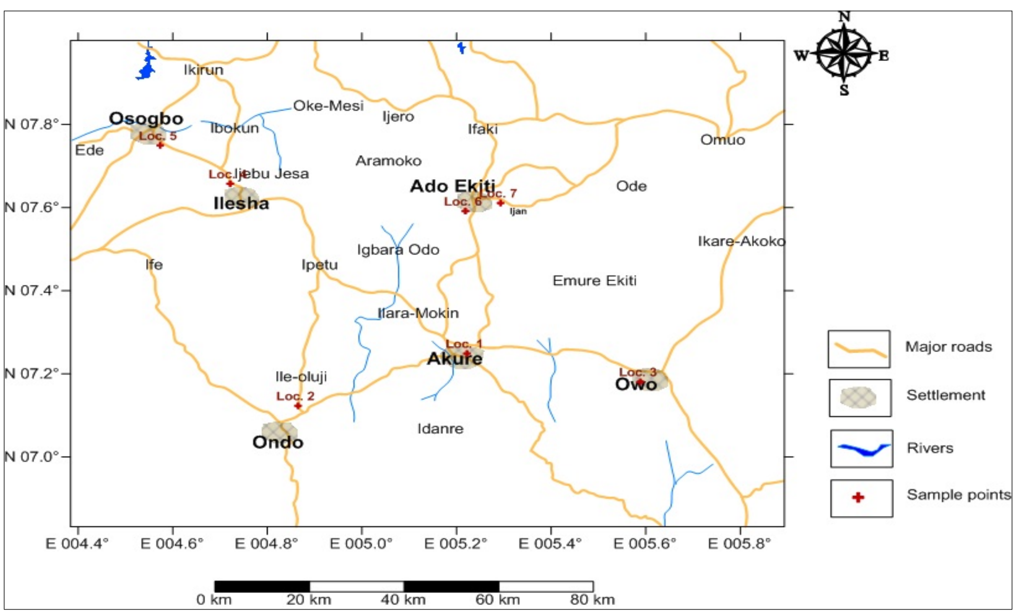


Figure 1. Location map showing sample locality

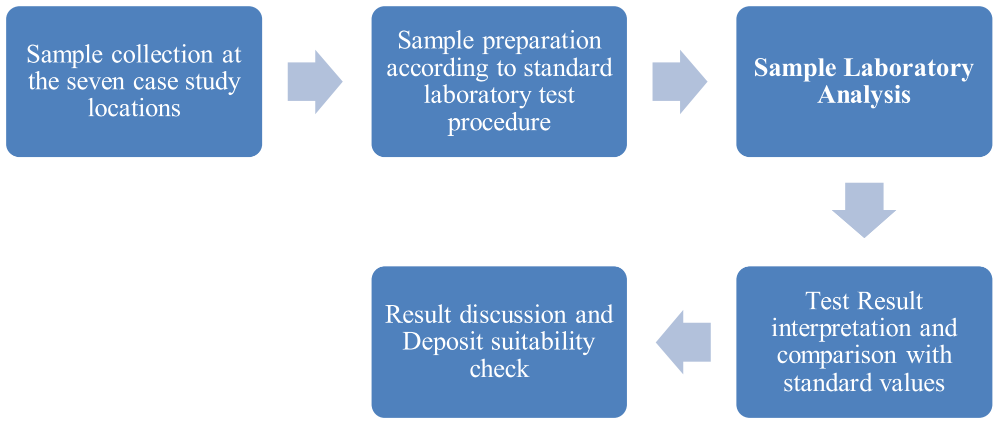


Figure 2. A flowchart of the work

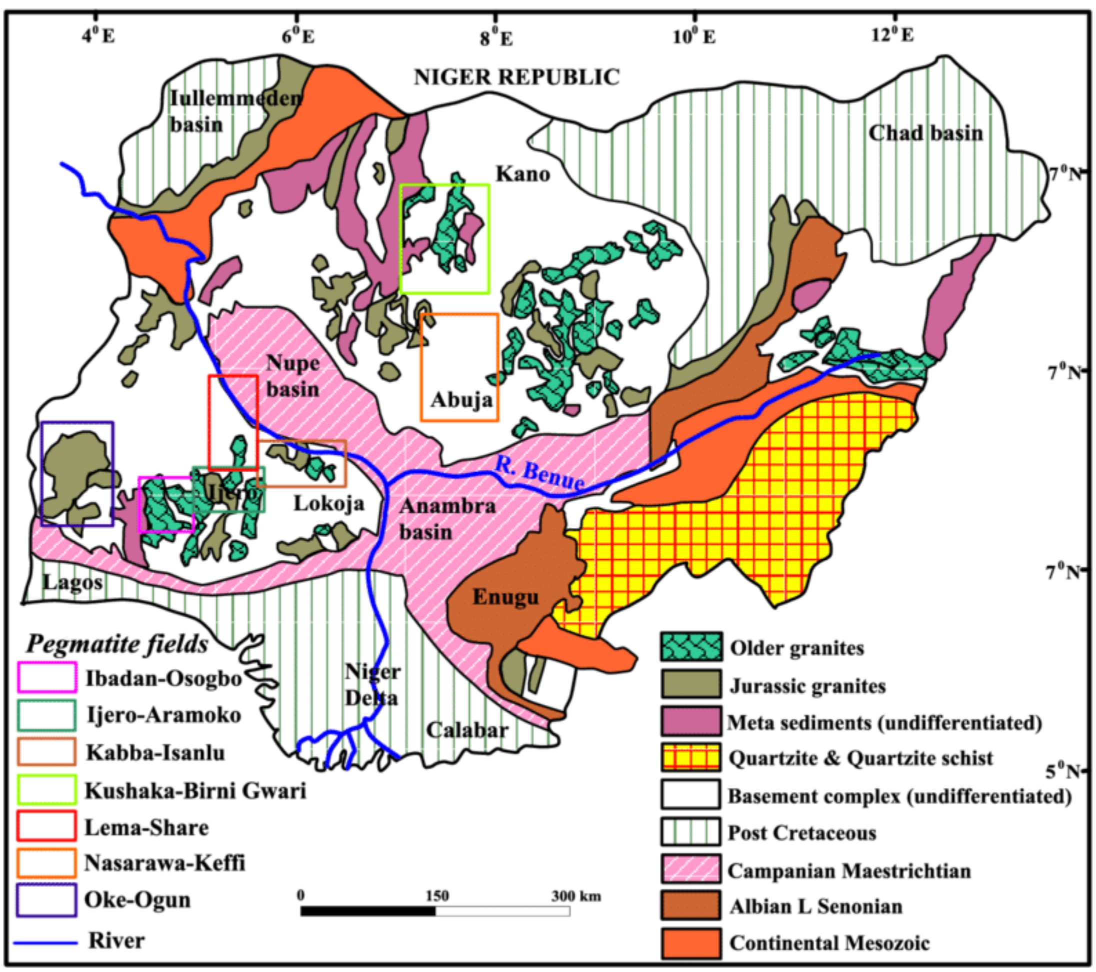


Figure 3. Geological Map of Nigeria showing the formations

The region has seen several tectonic events, such as the Pan-African orogeny, which occurred some 600 million years ago and influenced its current geological structure [27]. The Ilesha Schist Belt in Osun is renowned for its huge reserves of gold and other valuable minerals. Ekiti is renowned for its intricate migmatites and gneisses, which are characteristic of intense metamorphism at a high degree. Ondo is characterized by the presence of large amounts of granitic intrusions and gneisses, which give rise to its rough and uneven terrain. The production of laterite, a prominent geological characteristic in these nations, is a result of strong weathering caused by tropical environment. The laterites found in Osun, Ekiti, and Ondo are abundant in iron and aluminum oxides. These laterites are formed as a result of the gradual removal of silica and other soluble minerals from the original rocks through leaching over an extended period of time. This process yields the characteristic reddish soil, which is essential for both construction and agriculture. The geology of Osun, Ekiti, and Ondo showcases a diverse history of tectonic movements and erosion, which have played a significant role in shaping the economic and environmental characteristics of southern Nigeria (Figure 3).

2.2. Laboratory Analysis

The geotechnical properties of the soil samples including grain sizes analysis, Atterberg limit, permeability, specific gravity, and compaction were tested for the seven locations. Additionally, the clay mineral composition of each sample was determined using the X-ray diffraction analysis technique. The grain size analysis of each location sample was carried out in accordance with ASTM D 422-63 standard procedure. This aimed at determining the percentage of different grain particle sizes contained within the soil using sieve analysis and hydrometer method [28]. Atterberg limits including plastic and liquid limits tests were carried out on the samples in accordance with ASTM D-4318 [29]. The plasticity index (PI) of each sample was estimated using Eq. 1 and the activity of the samples was determined with Eq. 2.

$$PI = LL - PL \quad (1)$$

Where PI is plasticity Index, LL is liquid limit, and PL is plastic limit.

$$\text{Activity} = \frac{Plasticity\ Index}{\%\ Clay\ Content} \quad (2)$$

Permeability and Specific gravity test were performed on the samples in accordance with ASTM D 2434 [30] and ASTM D 854-00 [31].

Also, the moisture content, the dry density of the soil samples, and the compaction test were performed in accordance with ASTM D 698 for a specified loading effort [31]. The clay mineral composition was analyzed using an X-ray diffractometer in accordance with the procedure described by Brown and Brindley [33].

3. Results and Discussion

3.1. Grain Size Analysis Result

The grain-size analysis test results conducted on the samples are presented in Table 2 and Figure 3. The engineering properties of soil material are highly affected by the distribution of grain sizes. The grain analysis of the soil samples as presented in grading curves (See Figure4) covers several log cycles of the semi-log paper towards the coarse grain region. This indicates the case study clay materials contain a variety of particle sizes and are well-graded.

Table 2. Summary of grain-size analysis test results

Sample	% Gravel size particles	% Sand size particles	% Fines	% Silt size particles	% Clay size particles	< 2 µm	< 20 µm	> 20 µm
Loc.1	10.6	47.2	42.1	26.6	15.6	15.6	16.4	68
Loc.2	3.7	48.0	48.3	26.8	21.5	21.5	16.5	62
Loc.3	34.0	48.7	17.4	9.4	8.0	8.0	3.0	89
Loc.4	4.6	23.6	71.7	15.7	56.1	56.1	9.9	34
Loc.5	8.6	39.0	52.4	14.4	38.0	38	9.0	53
Loc.6	10.6	41.2	48.2	16.1	32.1	32.1	9.9	58
Loc.7	6.7	46.4	46.9	14.5	32.4	32.4	9.6	58

Oeltzschner indicated that soil sample is considered suitable for liners in landfills when the clay fraction is greater than or equal to 20% (≥20%) and the largest grain size particle must be less than 25mm (< 25mm) [6], [29]. According to [7] and [30], the percentage of gravel size particles must be less than 30% (<30%) and the percentage of fine size particles must be at least 30% (≥30%). The result of the grain size analysis shows that all the samples except Loc.1 and Loc.3 formation have a clay fraction of more than 20%. Also, the entire sample's largest grain size particle is less than 25mm as shown in Table 2 and Fig 3. In addition, all the samples except Loc.3 formation have gravel size particle percentage less than 30%. Furthermore, all the samples except Loc.3 have fine size particles of more than 30%. Thus, all the laterite deposits of the samples except Loc.1 and Loc.3 meet the grain size analysis requirements specified by previous researchers.

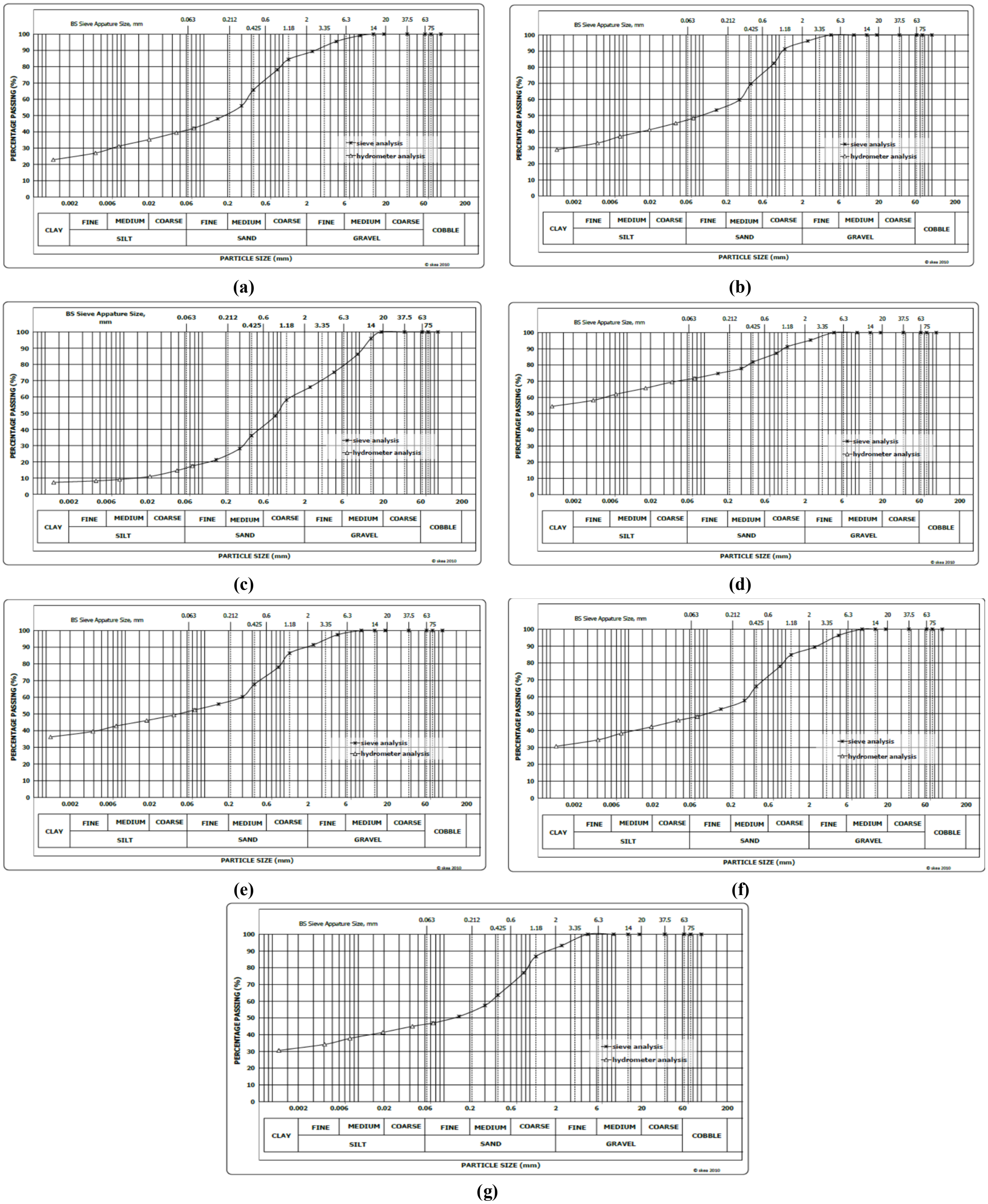
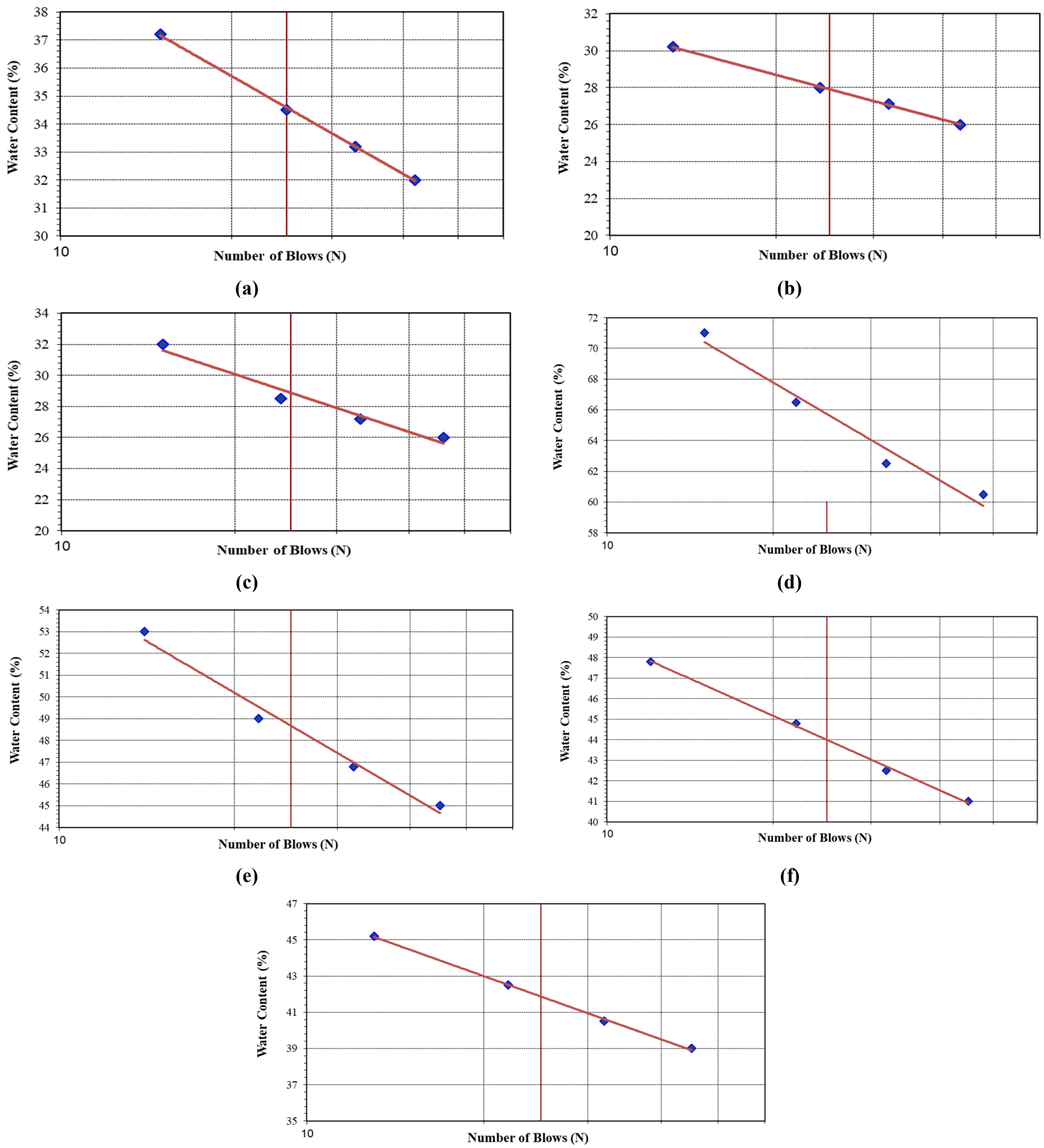


Figure 4. Particle Size distribution curve Loc 1 (a), Loc 2 (b), Loc 3 (c), Loc 4 (d), Loc 5 (e), Loc 6 (f), Loc 7(g)

3.2. Atterberg Limit Test Results

Atterberg limits test was performed in this research to determine the plastic and liquid limits of the laterite samples and to estimate their plasticity index and activity. Table 3 presents the summary of the results of the Atterberg limit test and activity conducted on the samples.

Figure 5 illustrates the relationship between moisture content and the number of blows in a compaction test. This plot helps in understanding how moisture levels affect the compaction effort required to achieve a specific density. A higher number of blows typically corresponds to varying moisture contents, which can indicate the optimal moisture range for effective soil compaction.



(g)

Figure 5. Moisture Content against Number of Blows (a) Loc 1, (b) Loc 2, (c) Loc 3, (d) Loc 4, (e) Loc 5, (f) Loc 6, (g) Loc 7

Figure 6, on the other hand, shows a plot of the plasticity index (PI) against the clay content of the soil on the activity chart. This graph is used to assess the soil's plasticity characteristics in relation to its clay content. The plasticity index, which measures the range of moisture content over which the soil remains plastic, is crucial for understanding the soil's behavior under different moisture conditions. By analyzing this chart, one can evaluate the soil's consistency and stability, which are important for construction and engineering applications. The activity chart can also help identify whether the soil falls into categories of low, moderate, or high plasticity, providing insights into its suitability for various uses.

For the soil sample to be considered as a liner in a solid waste landfill, the liquid limit must be at least 30% (≥30%) as indicated by Oeltzschner [6] and Daniel [7]. Also, the plasticity index must be at least 10% as noted by Rowe et al. [10]. The result of the Atterberg limit test shows that all the samples except Loc.3 have a liquid limit of more than 30%. More so, the plasticity index of all the samples except Loc.1 and Loc.3 is more than 10% (Table 3).

As indicated by Murphy and Garwell [36] and Benson et al. [8] for the activity of soil to be considered suitable for liner material, such soil activity must be more than 0.3 (> 0.3). The results of the seven location soil activity show that all the samples have activity value more than 0.3 as shown in Table 3. Furthermore, the plotting of the plasticity index against the clay content on the activity chart shows that Loc.1 and Loc.3 samples are low expansive soil which is a clear indication of the low clay content in the soil. Loc.2 and Loc.7 are medium expansive soils which is an indication of the balance in content between the coarse particle size and fine size particles of the soils. Loc.5 and Loc.6 are high expansive soils while Loc.4 is a very high expansive soil indicating more clay content in the soil. Thus, all the laterite deposits of the samples except that of Loc.1 and Loc.3 meet both the Atterberg limits and activity requirements for liner material.

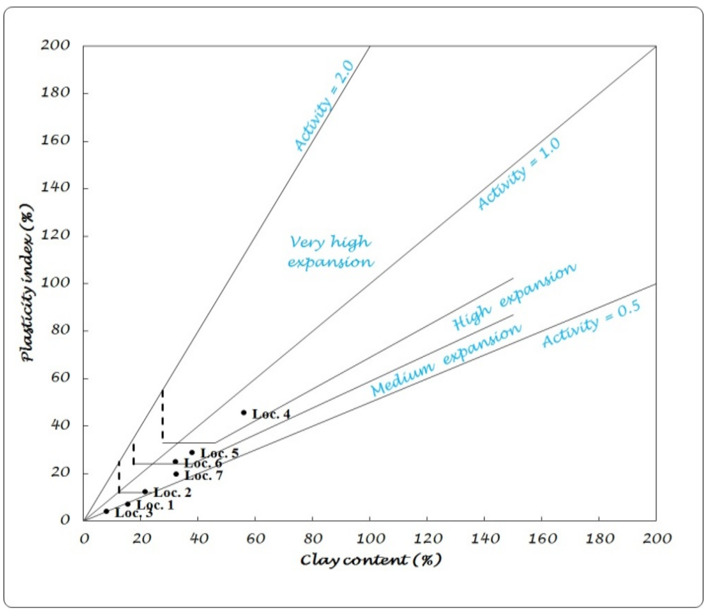


Figure 6. Location of samples on activity chart

Table 3. Atterberg Limits Test and Activity Results

Sample	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plastic Index (PI)	Clay content (%)	Activity
Loc.1	34.3	27.4	6.95	15.6	0.44
Loc.2	39.6	27.4	12.20	21.5	0.56
Loc.3	28.1	24.2	3.95	8.0	0.49
Loc.4	65.8	20.3	45.53	56.1	0.81
Loc.5	48.3	19.5	28.85	38.0	0.76
Loc.6	44.0	19.2	24.80	32.1	0.77
Loc.7	41.8	22.2	19.60	32.4	0.61

For the soil sample to be considered as a liner in a solid waste landfill, the liquid limit must be at least 30% (≥30%) as indicated by [6] and [7]. Also, the plasticity index must be at least 10% as noted by [10]. The result of the Atterberg limit test shows that all the samples except Loc.3 have a liquid limit of more than 30% (Table 3). More so, the plasticity index of all the samples except Loc.1 and Loc.3 is more than 10% (Table 3).

As indicated by [36] and [8] for the activity of soil to be considered suitable for liner material, such soil activity must be more than 0.3 (>0.3). The results of the seven location soil activity show that all the samples have activity value more than 0.3 as shown in Table 3. Furthermore, the plotting of the plasticity index against the clay content on the activity chart shows that Loc.1 and Loc.3 samples are low expansive soil which is a clear indication of the low clay content in the soil. Loc.2 and Loc.7 are medium expansive soils which is an indication of the balance in content between the coarse particle size and fines size particles of the soils. Loc.5 and Loc.6 are high expansive soils while Loc.4 is a very high expansive soil indicating more clay content in the soil. Thus, all the laterite deposits of the samples, except that of Loc.1 and Loc.3, meet both the Atterberg limits and activity requirements for liner material.

3.3. Permeability Result

Permeability refers to the ease with which water can flow through soil (hydraulic conductivity). As a result, it is a critical parameter when evaluating soil as landfill liners. Table 4 shows a summary of the permeability test results.

When soil is used as an engineering material, it is said to be compacted soil if it has low hydraulic conductivity to control waste leachate. Among other authors, [36-38] proposed a maximum coefficient of permeability of 1×10^{-9} m/s for liners soil suitability.

The permeability test results show that, with the exception of Loc.1 and Loc.3, all of the samples have a coefficient of permeability less than 1×10^{-9} m/s. Thus, with the exception of Loc.1 and Loc.3, the entire sample deposit meets the permeability requirement for liner material

3.4. Specific Gravity

Specific gravity is expressed as the proportion of the mass of a unit volume of soil material to the mass of a similar volume without gas-free distilled water. Table 4 presents the summary of the specific gravity test result.

Table 4. Permeability and specific gravity test result for the seven locations

Sample	α (η_T / η_{20})	Coefficient of Permeability (m/s)	Specific Gravity
Loc.1	0.8287	8.789×10^{-8}	2.639
Loc.2	0.8287	4.25×10^{-9}	2.659
Loc.3	0.8287	5.80×10^{-6}	2.652
Loc.4	0.8287	6.75×10^{-10}	2.768
Loc.5	0.8287	2.95×10^{-9}	2.710
Loc.6	0.8287	4.25×10^{-9}	2.681
Loc.7	0.8287	4.68×10^{-9}	2.670

According to Rowe [9], the specific gravity of soil used as liners must be at least 2.22. The specific gravity test results show that the entire sample has a specific gravity greater than 2.22, indicating that all seven soil formations meet the specific gravity requirement for liner material.

3.5. Compaction Test Results

A compaction test was performed to determine the relationship between the moisture content and the dry density of soil for a specified compaction effort. The summary of the compaction test results is presented in Table 5 and Figure 7.

Table 5 Compaction test results for the seven locations

Sample	Optimum Moisture content (%)	Maximum Dry Density (kg/m^3)
Loc.1	14.3	1963
Loc.2	16.4	1890
Loc.3	11.3	2065
Loc.4	28.7	1462
Loc.5	21.4	1744
Loc.6	18.4	1819
Loc.7	17.5	1851

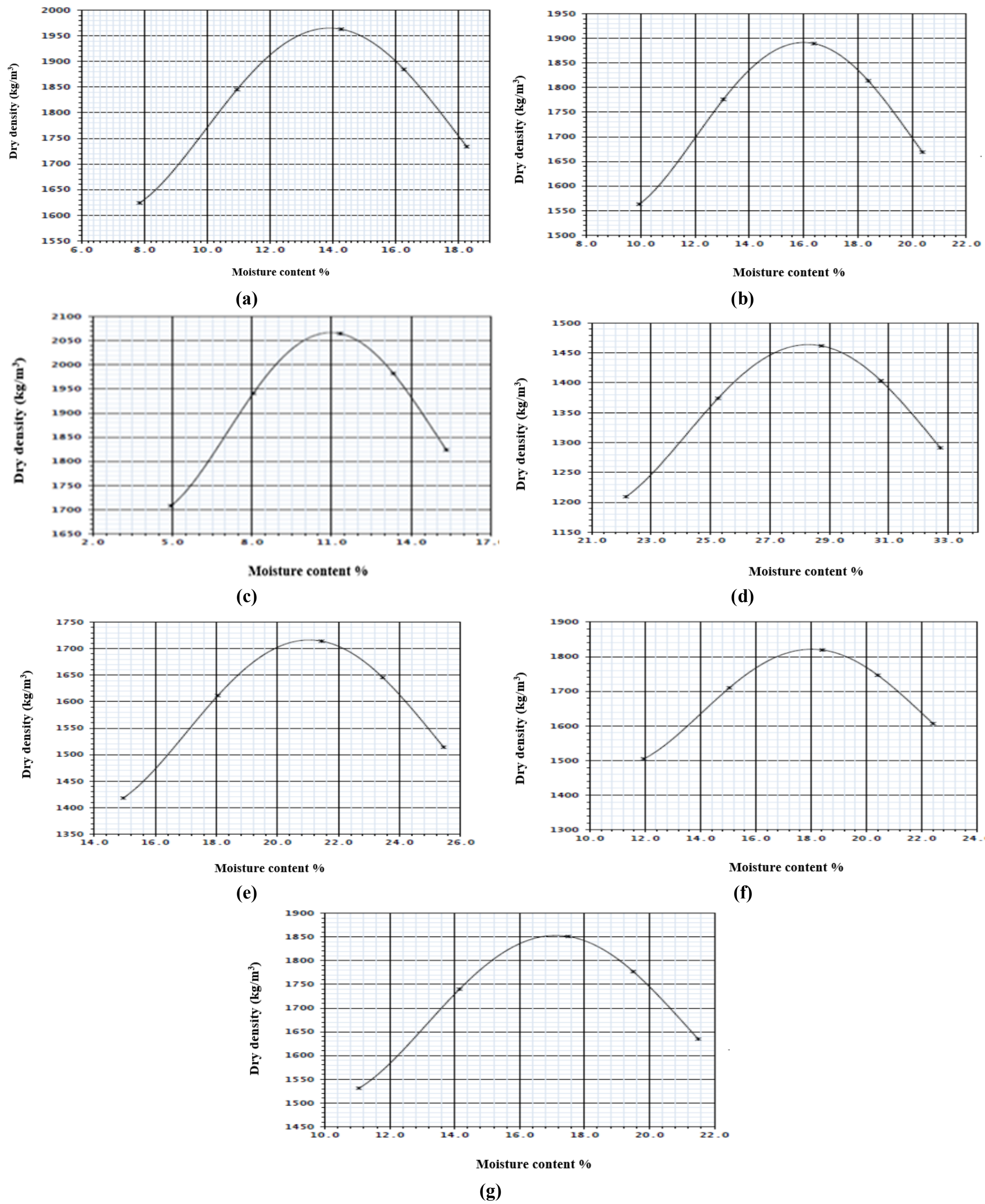


Figure 7 A Plot of Dry density against Moisture Content Loc 1 (a), Loc 2 (b), Loc 3 (c), Loc 4 (d), Loc 5 (e), Loc 6 (f), Loc 7 (g)

Kabi and Taha mentioned that for soil to be considered suitable for liner material in solid waste landfills, its maximum dry density must be at least 1.74 mg/m^3 [39]. The results of the compaction test as presented in Table 5 revealed that the entire sample has a maximum dry density of more than 1.74 mg/m^3 except for Loc.4; thus, all the laterite deposits except that of Loc.4 meet the maximum dry density requirement for liner material.

3.6. Mineralogical Composition Result

Table 6 and Figure 8 show a summary of the X-ray diffraction test results. In this study, the data presentation technique proposed by [33] was used as a guide for the identification of clay minerals.

According to [40], the amount and type of minerals present in clay soil have a strong influence on its geotechnical properties. It was discovered that quartz is the most abundant non-clay mineral in the case study samples. Unlike Kaolinite minerals, the availability of smectite minerals in soil was observed by [40] to contribute to the improvement of soil interlayer expansion variation during wet and dry conditions. As a result of this, samples Loc.1, Loc.2, and Loc.3 were identified to contain less reactive clay minerals which make them suitable as liners for landfill. The high percentage of coarse material in the Loc.3 sample makes it unsuitable for liner construction because of its high possibility to permit liquid waste flow. Loc.5, Loc.6, and Loc.7 samples is dominated by inactive clay mineral which makes them suitable as liner material for landfills. Loc.4 has high clay percentage and the major clay mineral in the sample is smectite which supports a drastic increase in hydraulic conductivity as noted by Stern and Shackelford [11]. Thus, all the laterite, deposits except that of Loc.3 and Loc.4, are suitable and can be extracted as liners for solid waste landfills.

Table 6. Mineralogical Composition of the Study location of Laterite Soils

Sample	Non clay Minerals	Major Minerals	Minor Minerals	Accessory Minerals
Loc. 1	Quartz	Kaolinite	Palygoskite	-
Loc. 2	Quartz	Kaolinite	Sepiolite	Illite
Loc. 3	Quartz	Kaolinite	Sepiolite	-
Loc. 4	Quartz and Almandine	Smectite	Illite	-
Loc. 5	Quartz	Kaolinite	Vermiculite	Illite
Loc. 6	Quartz	Kaolinite	Illite	Smectite
Loc. 7	Quartz	Kaolinite	Smectite	Illite

4. Discussion summary

Loc.1 sample has gravel percentage less than 30%, fines percentage more than 30%, liquid limit more than 20%, activity more than 0.30, specific gravity more than 2.22, maximum dry density more than 1.74 mg/m^3 and it has kaolinite and palygorskite as its major and minor clay minerals respectively, but its plasticity index is less than 10% and the coefficient of permeability value is more than 1 x 10^{-7} which make the deposit unsuitable for extraction as a liner for solid waste landfills.

Loc.2 sample has gravel percentage less than 30%, fines percentage more than 30%, liquid limit more than 20%, plasticity index more than 10%; coefficient of permeability value less than 1 x 10-7, activity more than 0.30, specific gravity more than 2.22, maximum dry density more than 1.74 mg/m^3 and it has kaolinite, sepiolite, and illite as its clay minerals. Thus, the sample deposit can be extracted as a liner as it meets all the recommendations of soil suitable for a liner in solid waste landfills.

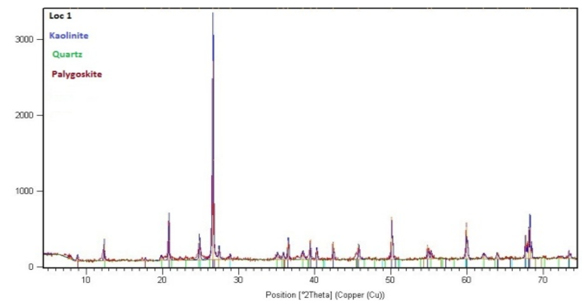
Loc.3 sample has a liquid limit of more than 20%, activity more than 0.30, specific gravity more than 2.22, maximum dry density more than 1.74 mg/m3 and has kaolinite and sepiolite as its major and minor clay minerals respectively, but the gravel percentage is more than 30%, fines percentage is less than 30%, plasticity index is less than 10%, and coefficient of permeability value is more than 1 x 10^{-7} which make the deposit unsuitable for extraction as a liner for solid waste landfills

Loc.4 sample has gravel percentage less than 30%, fines percentage more than 30%, liquid limit more than 20%, plasticity index more than 10%; coefficient of permeability value less than 1 x 10^{-7}, activity more than 0.30, and specific gravity more than 2.22 but its maximum dry density is less than 1.74 mg/m3 and it has smectite (montmorillonite group) as the major clay mineral and with the percentage of clay content equal to 56.1%; this can easily increase drastically the hydraulic conductivity of the soil if permeated with chemical solutions due to relatively high reactivity of these clay minerals [11]. Thus, the deposit is unsuitable to be extracted as liner material for solid waste landfill.

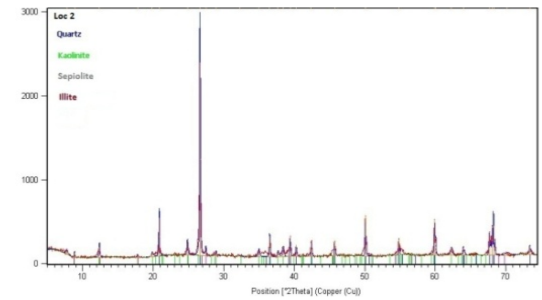
Loc.5 sample has gravel percentage less than 30%, fines percentage more than 30%, liquid limit more than 20%, a plasticity index more than 10%; coefficient of permeability value less than 1 x 10^{-7}, an activity more than 0.30, specific gravity more than 2.22, maximum dry density more than 1.74 mg/m^3 and has kaolinite, vermiculite, and illite as its clay minerals. Thus, the sample deposit can be extracted as a liner as it meets all the recommendations of soil suitable for a liner in solid waste landfills.

Loc.6 sample has gravel percentage less than 30%, fines percentage more than 30%, liquid limit more than 20%, plasticity index more than 10%; coefficient of permeability value less than 1 x 10^{-7}, activity more than 0.30, specific gravity more than 2.22, maximum dry density more than 1.74 mg/m^3 and has kaolinite and illite as its major and minor clay minerals respectively. Thus, the sample deposit can be extracted as a liner as it meets all the recommendations of soil suitable for a liner in solid waste landfills.

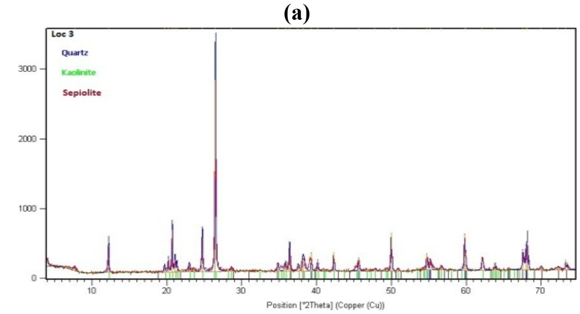
Loc.7 sample has gravel percentage less than 30%, fines percentage more than 30%, liquid limit more than 20%, plasticity index more than 10%; coefficient of permeability value less than 1 x 10^{-7}, activity more than 0.30, specific gravity more than 2.22, maximum dry density more than 1.74 mg/m^3 and has kaolinite as its major clay mineral and smectite as the minor. Thus, the sample deposit can be extracted as a liner as it meets all the recommendations of soil suitable for a liner in solid waste landfills.



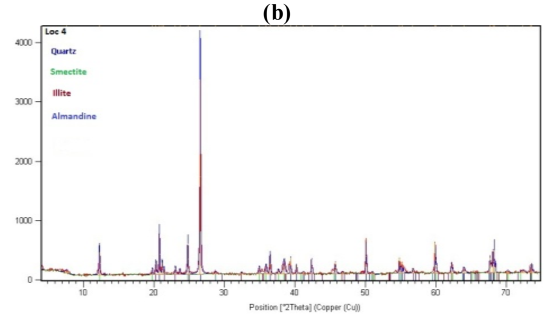
(a)



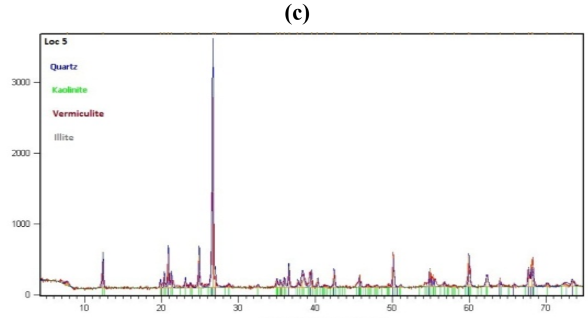
(b)



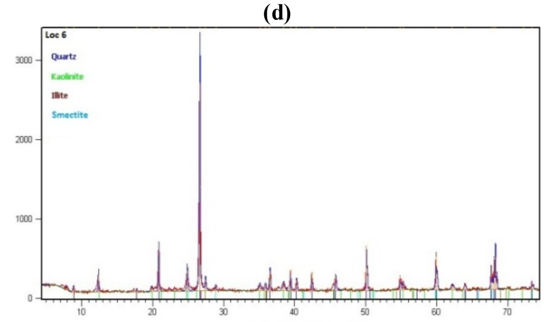
(c)



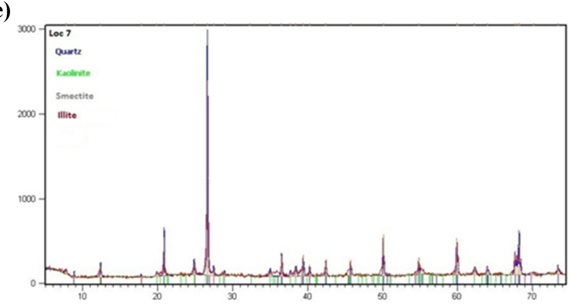
(d)



(e)



(f)



(g)

Figure 8. X-ray patterns of clay mineral in sample Loc 1 (a), Loc 2 (b), Loc 3 (c), Loc 4 (d), Loc 5 (e), Loc 6 (f), Loc 7 (g)

5. Conclusions

The results obtained from the geotechnical properties and X-ray diffraction tests conducted on the laterite samples in this study revealed significant variations in both geotechnical properties and clay mineral compositions across different locations. These findings corroborate earlier studies [12, 2, 19-26], which also reported similar variability in laterite soils.

Upon detailed analysis and evaluation of the geotechnical properties and clay mineral compositions using various research methodologies, it was determined that the laterite deposits at Loc.1, Loc.3, and Loc.4 are not suitable as liners for solid waste landfills. This conclusion stems from their inadequate geotechnical characteristics and unfavorable clay mineral content for effective landfill barrier applications.

In contrast, the laterite deposits at Loc.2, Loc.5, Loc.6, and Loc.7 exhibited favorable geotechnical properties and suitable clay mineral compositions, making them suitable candidates for use as landfill liners. These locations can potentially provide effective barriers against leachate migration and maintain structural integrity over time, meeting the required standards for landfill liner materials.

These findings underscore the importance of site-specific evaluations when considering laterite soils for engineering applications, particularly in landfill construction where the effectiveness of containment systems relies heavily on the intrinsic properties of the liner materials. Further research and monitoring may be necessary to optimize the selection and utilization of laterite deposits in landfill engineering projects.

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ارزیابی خواص شیمیایی و ژئوتکنیکی برای انتخاب بهینه خاک لاتریت نیجریه به عنوان ماده پوششی در محل های دفن زباله جامد

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چکیده:

بررسی قابلیت کاربرد خاک رس لاتریت برای دفن زباله و سایر کاربردهای مهندسی به دلیل چالش های روزانه ای که پزشکان در نتیجه تنوع خواص مواد با آن مواجه هستند، حیاتی است. مناسب بودن هفت کانسار لاتریت منتخب در جنوب غربی نیجریه به عنوان مواد پوششی قابل استفاده در ساخت و ساز محل دفن زباله جامد در این مطالعه با در نظر گرفتن خواص ژئوتکنیکی و ترکیب شیمیایی مورد بررسی قرار گرفت. نمونه های هدفمند مطابق با روش های استاندارد ASTM برای تجزیه و تحلیل خواص ژئوتکنیکی جمع آوری و آزمایش شدند. برای تعیین ترکیب معدنی رسی خاک از آنالیز پراش اشعه ایکس استفاده شد. ترکیب معدنی رسی خاک با استفاده از آنالیز پراش اشعه ایکس تعیین شد. تجزیه و تحلیل ژئوتکنیکی محدوده های زیر را برای نمونه ها نشان داد: درصد اندازه ذرات شن (۳.۷٪ تا ۳۴.۰٪)، درصد اندازه ذرات ریز (۱۷.۴٪ تا ۷۱.۷٪)، حد مایع (۲۸.۱٪ تا ۶۵.۸٪)، شاخص پلاستیسیته (۳.۹۵ تا ۳.۹۵٪). ۴۵.۵۳)، فعالیت (۰.۴۴ تا ۰.۸۱)، ضریب نفوذپذیری (۶.۷۵ x10-10 m/s تا ۵.۸۰ x 10-6 m/s)، وزن مخصوص (۲.۶۳۹ تا ۲.۷۶۸)، و حداکثر چگالی خشک (۱۴۶۲ kg/m3 تا ۲۰۶۵ کیلوگرم بر متر مکعب). آزمایش پراش اشعه ایکس نشان داد که محتوای کانی‌های رسی در کانسار هفت محله رسی بسته به مکان متفاوت است. این مطالعه نشان داد که ترکیب کانی‌شناسی خاک رس بر مناسب بودن خاک به‌عنوان ماده لاینر دفن زباله تأثیر می‌گذارد. از میان هفت کانسار خاک رس در نظر گرفته شده در این مطالعه، چهار مورد به عنوان پوششی برای محل دفن زباله جامد در مقایسه با مشخصات استاندارد مواد دفن زباله مناسب یافت شدند.

کلمات کلیدی: لاتریت، دفع زباله، دفن زباله، بررسی کننده تناسب خاک، اموال ژئوتکنیکی.