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Characterization and Comparative Analysis of the Physicochemical Properties of Anthill Clays from Selected Locations in Nigeria

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Abstract— *Clay has been identified as an adequate raw material for most dominant industrial applications other because of the important characteristics of clays which are focused on the industrial requirements. Anthill clay is a mixture of clay and other substances that ants use to create raised nests out of dirt or sand for their homes. Therefore, the investigation for important characteristics of the selected anthill clay from this region is mandatory before its selection for the relevant applications. Atomic Absorption Spectroscopy (AAS) and X-Ray Diffraction (XRD) analysis revealed the mineralogical composition of the anthill clays. Kaolinite was identified as the dominant clay mineral in both KK1 and UE1 samples, with varying amounts of albite, illite, and muscovite also present. Quartz was the primary non-clay mineral identified. In contrast, CB2 exhibited montmorillonite as the principal clay mineral with minor calcite.Physical property analysis focused on specific gravity, specific surface area, water absorption capacity (WAC), swelling index (SI), and cation exchange capacity (CEC). The results demonstrated significant differences between the anthill clays and the commercial bentonite. The WAC values for KK1 and UE1 were 120% and 200%, respectively, considerably lower compared to CB2's 610%. Similarly, the SI analysis showed minimal swelling behavior in KK1 and UE1 (0ml) compared to the pronounced swelling observed in CB2 (29.5ml). These findings suggest that anthill clays from this region possess properties more suited for applications requiring high-temperature stability, such as refractory materials and high-temperature clay production. Conversely, their limited swelling characteristics make them less suitable for applications like drilling fluid formulation.*

Keywords— *Clay, anthill clay, specific gravity, swelling index refractories.*

I. INTRODUCTION

Clays are a distinct class of soil particles renowned for their unique physico-chemical properties. These properties, including fine particle size, water-induced flocculation, and deformation of wetted masses, contribute significantly to their diverse industrial applications [1, 2]. In contrast, anthills (Figure 1) represent a composite material constructed by ants using soil and other materials from their environment. While these structures provide shelter for the ant colony, their burrowing activity can become a nuisance in agricultural settings, impacting infrastructure and disrupting rural communities [3, 4].

Interestingly, the binding agent for anthill clay is not solely mineral-based. The saliva secreted by ant workers acts as a natural cement, enhancing the strength, hardness, and refractoriness of the constructed mounds through its adhesive properties [2]. Notably, the abundance of anthills varies geographically, with a higher prevalence observed in Africa and Australia. Research suggests a strong correlation between the surrounding soil composition and the resulting properties of the anthill clay [5, 6]. This implies that anthill clays from Nigeria, likely sourced from distinct soil environments, are expected to exhibit unique characteristics compared to those found elsewhere.

While historical research has primarily identified Silicon (Si), Iron (Fe), Aluminum (Al), Calcium (Ca), and trace elements, alongside silicate and iron minerals, as the dominant constituents of clays [4], [7], a crucial understanding exists regarding the inherent variability in clay composition. This variation can be attributed to several factors, including: The clay deposit's origins and geological environment, rainfall patterns, humidity, and other variables that affect the clay's makeup through weathering processes, surrounding geological features, such as rock weathering, which contribute to the clay's unique composition, and the presence of plants and animals in the local environment, which may further impact the clay's composition.

This inherent variability has driven the evolution of clay applications beyond their traditional mechanical uses. Modern research explores the diverse functionalities of various clay types. A prominent example lies in the water treatment industry, where clays have emerged as a valuable tool to address the growing concern of water pollution [3]. Recent research, as highlighted in literature reviews [1], emphasizes the development of several key approaches utilizing clays for water treatment: removal of heavy metals from contaminated water, elimination of pathogens from polluted water sources and removal of unwanted or hazardous ions from wastewater. These advancements demonstrate the expanding role of clays in addressing critical environmental challenges [8], [9].

While traditional clay applications were primarily mechanical in nature, modern industry recognizes clays as valuable raw materials across a broad spectrum of uses. This shift is driven by the inherent properties of clays that align well with various industrial requirements [10]. Understanding the specific composition of different clay types, and the resulting exceptional characteristics, is crucial for selecting the most suitable clay for a given application. In this context, a thorough investigation into the key characteristics of the anthill clay found in this region becomes mandatory before its potential for industrial applications can be accurately assessed [10]. This characterization process will not only reveal the specific compounds present in the anthill clay but also shed light on the exceptional properties it possesses, ultimately determining its suitability for various industrial uses.

Figure 1: Anthill [1]

Nigeria's heavy reliance on imported raw materials for industrial processes, particularly in ceramics and drilling fluids, has created a significant burden on the nation's foreign exchange reserves in recent decades. This vulnerability has been further amplified by the recent global oil price slump, which has dramatically reduced national revenue and tightened financial constraints on import-dependent industries. In response to this critical situation, the present study seeks to characterize and compare the physicochemical properties of selected Nigerian anthill clay samples with a commercially available bentonite clay. Our primary objective is to evaluate the potential of these anthill clays as a locally sourced alternative for industrial applications. This research directly aligns with the core tenets of the Nigerian Content Act, which prioritizes the development of domestic resources and promotes their utilization within Nigerian industries. By exploring the potential of anthill clays, this study aims to contribute to a more sustainable and self-reliant industrial sector in Nigeria.

II. MATERIALS AND METHODS

X-ray Diffraction (XRD) and Atomic Absorption Spectroscopy (AAS) analyses, coupled with the Ignition Loss Method, were utilized to elucidate the mineralogical and chemical compositions of the three clay samples (CB2, KK1 and UE1). Additionally, a comprehensive investigation into their physical properties and cation exchange capacity was conducted. This included measurements of specific gravity, pH, swelling index, calculated surface area, and water absorption capacity. These parameters provided a robust characterization of each clay sample, allowing for a thorough evaluation of their potential suitability for various industrial applications, such as drilling fluid formulation and ceramics production.

2.1 Materials

To ensure the accuracy of subsequent analyses, three clay samples were collected following established protocols:

- *Samples:*
    - Anthill clay from Kono Town, Khana Local Government Area (KK1) and Umuebulu, Etche Local Government Area (UE1), Rivers State, Nigeria.
    - Commercial bentonite clay (CB2) (assumed to be imported).
- Collection Procedures:
    - Samples were collected during dry climatic conditions to minimize moisture content variations.
    - Non-metallic tools, thoroughly cleaned beforehand, were used for collection to avoid contamination.
    - Samples were stored in polyethylene bags to maintain their integrity and minimize exposure to external elements.
- Sample Preparation:
    - To get rid of any remaining moisture, raw anthill clay specimens were baked in an oven for 24 hours at 110°C.
    - The dried samples were then pulverized using a mortar and pestle to achieve a uniform powder form.
    - To ensure consistent particle size for analysis, the powdered samples were sieved through a 90 micrometer manual sieve.

2.2 Methods

Standard methods and instruments, as described in Table 1, were used to analyze the essential physical and chemical properties of unrefined ant hill clays.

TABLE 1. Physico-chemical characterizations of the clays

S/No	Parameters	Instruments and methods
1	Specific gravity	Specific gravity bottle or Le Chatelier flask method
2	Water Absorption Capacity (WAC)	This test method DIN 18132 was used to determine the water absorption capacity of clay samples
3	Swelling index (SI)	ASTM-D5890 was utilized to determine the swelling index
4	Calculated surface area	Methylene blue adsorption method
5	Cation Exchange Capacity (CEC)	Methylene blue adsorption method
6	Chemical properties	Perkin Elmer AAnalyst 400AA Spectrometer
7	pH	Mixing the samples in distilled water and using a pH strip to determine the acidity or alkalinity.
8	Characterization of samples	Rigaku D/MAX X-ray Diffractometer

2.2.1 Determination of Physical Properties of the Clay Samples

The key characteristics of the clay samples were calculated using the equations listed below:

- *Specific gravity*

This test was carried out to determine the specific gravity of soil samples using a Specific gravity bottle or Le Chatelier flask method as per IS: 2720 (Part III/Sec 1) – [11].

Calculations:

$$\text{Specific gravity } (g/cm^3) = \frac{W_2-W_1}{(W_2-W_1)-(W_3-W_4)\ X\ 0.82} \qquad (1)$$

Where W_1 = weight of empty flask
W_2 = weight of flask + clay sample
W_3 = wight of flask + clay sample + kerosene
W_4 = weight of flask + kerosene
0.82 = specific gravity of kerosene

- *Water Absorption Capacity* (WAC)

The test method DIN 18132 was used to determine the water absorption capacity of clay soils [12].

Calculations:

$$\text{WAC (\%)} = \frac{M_2}{M_1} * 100 = \frac{\rho(V_1-V_2)}{M_1} * 100 \qquad (2)$$

Where M_1 = weight of dry clay sample (g)
M_2 = weight of clay sample after soaking at room temperature for 24 hours (g)
V_1 = Initial volume of distilled water used for soaking (ml)
V_2 = Final volume of distilled water after soaking and filtering (ml)

- *Swelling Index* (SI)

The Swell Index test method was used to ascertain the general swelling properties of sodium bentonite clay. The test method ASTM-D5890 [13], is utilized to determine the swell index. The clay sample of dried and finely ground bentonite clay is distributed into a 100 ml graduated cylinder in 0.1 g increments to conduct this experiment. To allow for complete hydration and settlement of the clay to the bottom of the cylinder, at least 10 minutes should pass between each 0.1g addition. The 2g sample is completely added to the cylinder by adding 0.1g at a time. For 16 to 24 hours, the specimen is then covered and shielded from disruption, after which the level of the settled and expanded clay is measured to the closest 0.5 mL.

- *Calculated Surface Area*

The calculated surface area of the studied samples was determined using the methylene blue adsorption method [14].

Calculations:

$$\text{Surface Area } ((m^2/g) = \left(\frac{Methylene\ Blue\ (ml)}{Mass\ of\ Clay\ Sample\ (g)}\right) x\ 782.9 \qquad (3)$$

- *Cation Exchange Capacity* (CEC)

The cation exchange capacities of the studied samples were determined using the methylene blue adsorption method [14].

Calculations:

$$\text{CEC}(meq/100g) = \left(\frac{Methylene\ Blue\ (ml)}{Mass\ of\ Clay\ Sample\ (g)}\right) \qquad (4)$$

2.2.2 Determination of Chemical Composition Using AAS

The elemental composition of the anthill clay and bentonite samples was determined using a Perkinelmer aanalyst 400aa spectrometer, which employs the principles of atomic absorption spectroscopy (AAS). AAS relies on the fundamental principle that free, unexcited atoms can absorb specific wavelengths of electromagnetic radiation. this absorption occurs when the sample is atomized, and the exact wavelength absorbed is characteristic of the element being analyzed [15, 16]. An AAS instrument typically consists of three key components: an atomization device, a light source emitting element-specific wavelengths, and a detector to measure the intensity of the transmitted light. during analysis, the prepared sample solution is nebulized and introduced into a flame (often air-acetylene or nitrous oxide-acetylene) for atomization. the detector measures any decrease in light intensity caused by atomic absorption within the flame. This decrease can be calibrated to quantify the elemental concentration in the sample, with detection limits reaching the Mg/L Level [15, 16].

pH

The pH of the clay samples was determined by mixing the samples in distilled water and using a pH strip to determine the acidity or alkalinity [9].

2.2.3 Sample Characterization

X-Ray Diffraction (XRD) Analysis

The mineralogical composition of the clay samples was investigated using a Rigaku D/MAX X-ray Diffractometer. X-ray diffraction (XRD) is a powerful technique that allows for the identification of crystalline phases within a material. The interaction between X-rays and the crystalline lattice structure of the minerals in the sample forms the basis of the study. The key parameter used for identification is the d-spacing, which represents the distance between adjacent atomic planes within the crystal lattice [17, 18]. As X-rays bombard the sample, they diffract at specific angles based on the arrangement of atoms within the minerals present. The resulting diffractogram displays characteristic peaks for each mineral phase, enabling the identification and quantification of the crystalline components in the clay samples [17, 18].

III. RESULTS AND DISCUSSION

3.1 Physical Properties of clay samples

The physical properties of the anthill and bentonite clay samples were investigated and the results obtained are presented in Table 2.

TABLE 2. Comparison of Physical properties of anthill and bentonite clay samples

Parameters	CB2	KK1	UE1
Specific Gravity	2.20	2.24	2.26
Swelling Index (ml)	29.50	0.00	0.00
WAC (%)	610.00	120.00	200.00
CEC $(meq/100g)$	100.00	5.40	5.80
pH	10	7	7
Calculated Surface Area (m^2/g)	782.90	42.28	45.41

3.1.1 Specific gravity

As shown in Table 2, the specific gravities of the anthill clay samples (UE1 and KK1) and the bentonite clay (CB2) were comparable, with values of 2.20, 2.26, and 2.24, respectively, determined using Equation (1). Generally, higher specific gravities (around 2.7 or above) are indicative of a greater concentration of denser clay minerals like montmorillonite, as opposed to lighter impurities such as quartz or organic matter [19]. In the context of drilling fluids, an acceptable specific gravity for bentonite clay typically falls within the range of 2.6 to 2.8 [20]. This range ensures an optimal balance between achieving the desired mud weight and avoiding excessive bentonite use, which can negatively impact other drilling fluid properties [20]. It's important to note that specific gravity can vary depending on factors like the target mud weight. The values obtained in this study (>2) are consistent with those reported in previous literature [19, 20, 21, 22]. While the specific gravities of the anthill clays are comparable to commercial bentonite, further investigation into their overall suitability for drilling fluids is necessary due to the potential influence of other properties.

3.1.2 Water Absorption Capacity (WAC)

Bentonite clay is renowned for its exceptional water absorption capacity (WAC), often exceeding its own weight (up to 1000%) [20]. This property translates to significant swelling upon contact with water, making bentonite ideal for sealing applications. As shown in Table 2 and calculated using Equation (2), the commercial bentonite (CB2) exhibited a WAC of 610%, which falls within the acceptable range for drilling fluid formulations as reported in previous studies [8], [19]. Generally, high-quality bentonite clays for various applications typically possess a WAC between 300% and 700% by weight [19]. This high WAC is fundamental to bentonite's swelling, sealing, binding, filtration, and thickening properties, contributing to its versatility across numerous industries [23]. Notably, the anthill clay samples (UE1 and KK1) displayed significantly lower WAC values of 200% and 120%, respectively. This disparity suggests a potential absence of exchangeable cations like Na^+ and Ca^{2+} within the anthill clay structure, as documented in [21]. The presence of these cations is known to contribute significantly to bentonite's swelling behavior [21].

3.1.3 pH

The inherent negative surface charge on bentonite clay particles is a result of their structural arrangement [19]. The extent of this charge is influenced by the surrounding solution's pH. In acidic environments, protons (H+) can neutralize some of the negative charge on the clay surface. Conversely, under basic conditions, hydroxyl ions (OH-) are attracted to the surface, enhancing the negative charge [19]. This pH-dependent behavior plays a critical role in bentonite's functionality across various applications [4, 22].

The measured pH values in this study were 7 for both UE1 and KK1, while CB2 exhibited a value of 10. This indicates that CB2 is alkaline and falls within the reported range of 8-10 for bentonite clays [8, 19]. However, the ideal pH range for bentonite can vary depending on the specific application. For instance, drilling fluids often perform best in a slightly alkaline range (pH 7.5-9), whereas some pollution remediation processes may necessitate a more acidic environment (pH 5-6) as documented in [9, 22]. Considering the anthill clays' (UE1 and KK1) neutral pH of 7, their suitability for drilling fluids may be limited compared to the commercially available bentonite (CB2) with a pH of 10. Further investigations are necessary to determine their effectiveness in other applications where a neutral pH might be advantageous.

3.1.4 Swelling Index (SI)

The measured swelling index (SI) for the commercial bentonite (CB2) was 29.5 ml, which falls within the acceptable range of 24-36 ml established for standard commercial bentonite according to ASTM D5890 [13]. It's important to note that the ideal SI for bentonite clay can vary depending on the specific application. In the context of drilling fluids, a typical acceptable range for SI is generally between 20 ml and 40 ml [13]. This range strikes a balance between effective sealing and filtration control, optimal rheological properties, and cost-efficiency. Within a wellbore, bentonite's swelling ability is critical for sealing any gaps and controlling fluid filtration into the formation [19]. In contrast, the anthill clay samples (UE1 and KK1) exhibited a zero SI. This complete absence of swelling behavior renders them unsuitable for applications that rely on this property, such as drilling fluids. Utilizing anthill clays with no swelling potential in drilling fluids could lead to wellbore instability and problematic fluid loss [19]. Therefore, while the anthill clays possess other properties worth exploring, their lack of swelling significantly limits their applicability in drilling fluids.

3.1.4 Calculated Surface Area

Equation (3) was employed to calculate the specific surface area of the clay samples. The commercial bentonite (CB2) exhibited a significantly larger surface area (782.9 m^2/g) compared to the anthill clays (KK1: 42.28 m^2/g and UE1: 45.41 m^2/g). This substantial difference aligns with previous observations reported in [4, 23] that correlate higher surface area with increased reactivity in clays. A larger surface area translates to a greater number of available sites for interaction with other substances, enhancing the clay's overall reactivity.

3.1.5 Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) refers to a clay's ability to adsorb and retain positively charged ions (cations) such as sodium (Na+), calcium (Ca2+), or potassium (K+) on its surface [7]. This property allows bentonite to interact with various cations present in surrounding solutions. The CEC of the commercial bentonite (CB2) was determined to be 100 meq/100g using Equation (4). This value falls within the reported range of 80-150 meq/100g/ for montmorillonite clays [24]. In contrast, the CEC values for the anthill clay samples, KK1 and UE1, were significantly lower at 5.4 meq/100g and 5.8 meq/100g, respectively. These values fall within the typical range of 3-10 meq/100g for kaolinite clays [24]. The observed disparity in CEC between the commercial bentonite and the anthill clays suggests a difference in their dominant clay mineral composition.

3.2 Chemical properties of clay samples from AAS analysis

TABLE 3. Comparison of the chemical properties of Anthill and Commercial Bentonite clay samples

Chemical Component	**CB2**	**KK1**	**UE1**
SiO_2 (wt%)	66.80	56.38	54.66
Al_2O_3 (wt%)	20.50	21.24	20.60
Fe_2O_3 (wt%)	4.08	7.65	6.88
TiO_2 (wt%)	0.15	1.04	0.09
CaO (wt%)	1.69	3.45	0.03
MgO (wt%)	4.15	1.46	0.10
K_2O (wt%)	0.60	0.94	1.60
Na_2O (wt%)	1.65	1.28	0.21
P_2O_5 (wt%)	0.08	0	0
SO_3 (wt%)	0.008	0.115	0.131
MnO (wt%)	0.03	0.02	0.01
SiO_2/Al_2O_3 ratio	3.26	2.65	2.65
LOI	0.04	10.24	9.75

As shown in table 3, the x-ray diffraction (XRD) analysis revealed that silica (SIO_2) and alumina (al_2o_3) are the dominant constituents of the anthill clay samples (KK1 and UE1). This suggests a classification within the aluminosilicate family with a siliceous nature. the high silica content observed (56.38% for KK1 and 54.66% for ue1) is well above the typical 46.51% for clay minerals, potentially indicating a higher tolerance for high temperatures compared to standard clays [6]. While exceeding the ideal composition for ceramic and glass production (as reported in [1] and table 4), the silica content aligns with the requirements for high melting clay and aluminosilicate fiber glass manufacturing ([1]). These applications typically require alumina oxide (AL_2O_3) content within the ranges of 16-29% and 12-17%, respectively, this aligns with that reported by [1]. Further investigations are warranted to explore the suitability of these anthill clays for high melting clay and aluminosilicate fiber glass production.

TABLE 4. Chemical composition of minerals for industrial applications

Compositions	Ceramics	Refractory Bricks	High melting clay	Glass	Paper	Paint
SiO_2	60.5	51.7	53 – 73	80 – 95	45 – 45.8	45.3 – 47.9
Al_2O_3	26.5	25 – 44	16 – 29.0	12 – 17.0	33.5 – 36.1	37.9 - 38.4
Fe_2O_3	0.5 – 1.2	0.5 – 2.4	1 – 9.0	2 – 3.0	0.3 – 0.6	13.4 – 13.7
CaO	0.8 – 3.0	0.1 – 2.0	0.5 – 2.6	4 – 5.0	0.03 – 0.6	0.03 – 0.6
LOI	8 – 18.0	8 – 18.0	5 – 14.0	0	0	0

The XRD analysis results in Table 3 reveal a higher SiO_2/Al_2O_3 ratio (3.26) for the commercial bentonite (CB2) compared to the anthill clay samples (UE1 and KK1), which share a ratio of 2.65. This aligns with the expected composition of montmorillonite, the primary clay mineral in CB2 [4, 7]. The lower ratio in the anthill clays suggests a possible composition of varying proportions of kaolinite, illite-muscovite, illite-smectite, and anatase, as documented in previous studies [4, 7]. Further corroborating the mineralogical differences, the Na_2O content of CB2 (1.65%) is significantly higher compared to KK1 (1.28%) and UE1 (0.21%). This higher Na_2O content in CB2 is indicative of a greater presence of montmorillonite, while the lower values in the anthill clays suggest minimal or absent montmorillonite content [20].

The analysis also yielded a $\{(Na_2O+K_2O)/(CaO + MgO)\}$ ratio of 0.32% for the bentonite sample (CB2), classifying it as Ca-bentonite based on established criteria [25]. Notably, both KK1 and UE1 exhibit high Fe_2O_3 content (6.88% and 7.65%, respectively), potentially indicating the presence of halloysites within these anthill clay samples [24]. The moderate alumina (Al_2O_3) content of the anthill clays (21.24% for KK1 and 20.60% for UE1) is noteworthy [26]. The MgO content observed is 0.1% for UE1 and 1.46% for KK1, with CB2 exhibiting a higher value of 4.15%. The high Loss on Ignition (LOI) values in the anthill clay samples suggest a significant presence of impurities, water, and organic matter [26]. Lastly, the neutral pH of 7 observed in both UE1 and KK1 contrasts with the alkaline nature of CB2 (pH 10). This aligns with the reported pH range of 8-10 for bentonite clays [5, 27]. The observed differences in chemical composition and element ratios highlight the distinct mineralogical profiles between the commercial bentonite and the anthill clay samples.

Due to their inherent reactivity with water or moisture, metallic elements are typically found in the form of oxides within geological materials [7]. Iron (Fe) oxides are not classified as toxic or hazardous and, according to leading research on water treatment technologies, Fe-bearing minerals have been identified as effective sorption materials for various heavy metals [4]. Consequently, the iron oxide mineralogy of clays plays a significant role in characterizing their suitability for advanced industrial applications such as water treatment and resource recovery. As shown in Table 3, the anthill clay samples (KK1 and UE1) exhibit Fe oxide contents of 7.65% and 6.88%, respectively. These values fall within the acceptable range for the industrial production of high melting clay, as outlined in Table 4. This suggests potential applicability of the anthill clays in this specific industrial context. Further investigations are necessary to determine their effectiveness in iron oxide-based water treatment processes.

Loss on Ignition (LOI) was determined for the anthill clay samples (KK1 and UE1) as the percentage of mass lost upon ignition, reflecting the amount of moisture the clay can hold. This value can also be interpreted as the weight reduction due to the removal of volatile components, potentially offering insights into the grain structure and fineness of the clay material. The LOI values obtained (10.24% for KK1 and 9.75% for UE1) fall within the acceptable range documented by [1] for the production of ceramics, refractory bricks, and high melting clay (as shown in Table 4). However, as noted by [10], lower LOI values are generally preferred to minimize the influence of porosity on the final product properties. Therefore, while the LOI values suggest potential applicability in these areas, further investigations are warranted to assess the impact of porosity on the performance of the final products derived from these anthill clays.

3.3 Characterization and comparative analysis of samples

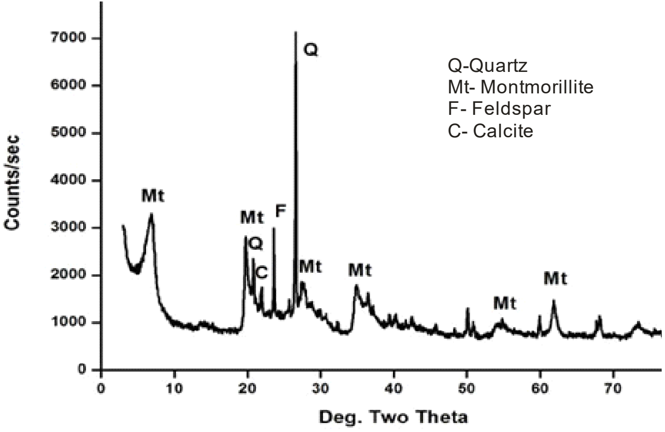

Figure 3: XRD Pattern of CB2

Sample : KK I
Comment : Qualitative
Method : 2nd differential
File : Sg2～1.ASC
Memo
Typica width : 0.070 deg.
Date : July I7 09:16:10
Min. Height
Operator :
500:00 c p s

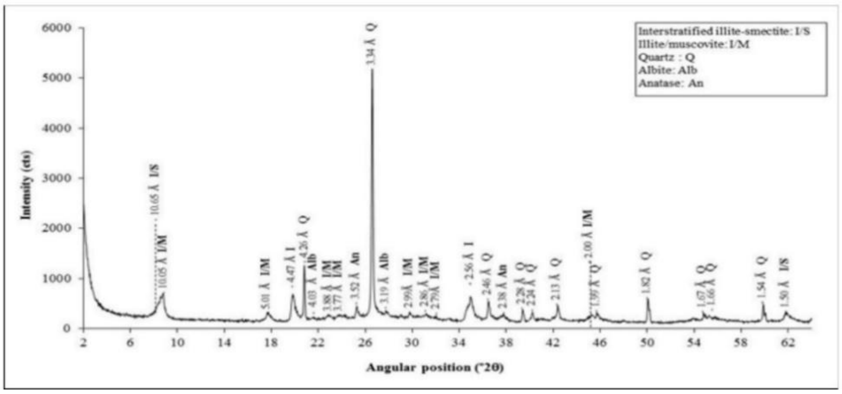

Figure 4: XRD Pattern of KK1

Sample : UE I
Comment : Qualitative
Method : 2nd differential
File : Sg2～1.ASC
Memo
Typica width : 0.070 deg.
Date : Jul I7 09:10:32
Min. Height
Operator :
100:00 c p s

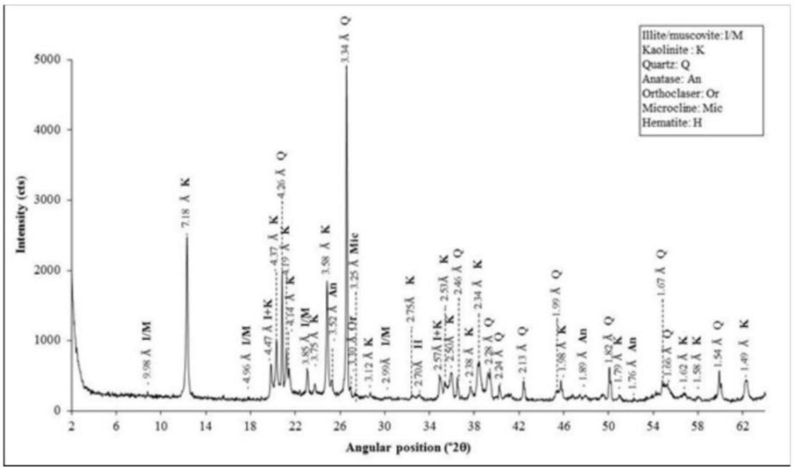

Figure 5: XRD Pattern of UE1

TABLE 5. Comparison of X-ray Diffraction Analysis of CB2, KK1, and UE1 Samples

Mineral (%)	CB2	KK 1	UE 1
Montmorillonite	51.96	0	0
Kaolinite	0	37	48
Quartz	35.25	40	40
Calcite	7.64	0	0
Smectite	0	2	4
Albite	0	5	2
Anatase	0	0	2
Feldspar	5.15	0	0
Chlorite	0	0	1
Illite	0	8	2
Muscovite	0	8	1

Figures 3 -5 showed the results from X-ray Diffraction for CB2, KKI and UE1[17], [18]. Mineralogical analysis of CB2, KK1, and UE1 samples as presented in Table 5 showed that montmorillonite is the major component of CB2 as expected with 51.96%, while both UE1 and KK1 showed no presence of montmorillonite. In the oil and gas industry, montmorillonite is a key component of drilling mud. The clay helps to suspend drill cuttings, lubricate the drill bit, and cool the borehole, hence the anthill clay sample in this study may not be suitable for application as drilling mud [19].

All three samples had quartz as a major non-clay component as expected with both KK1 and UE1 having it at 40% while CB2 having it at 35.25%. Quartz, in the form of silica, is the primary ingredient for glass [1]. Due to its abundance and high silicon dioxide content (SiO2), it forms the foundation for countless glass products, from windows and containers to intricate lab equipment. Crushed quartz finds use as an aggregate in concrete and road construction, due to its high melting point and resistance to heat, quartz is a key component in refractory materials like bricks and linings for furnaces and kilns [2]. Quartz sand, with its hardness, is a great abrasive for sandblasting, grinding, and cutting operations [2]. Consequently, the anthill clays in this study can be applied for the above-mentioned industrial purposes.

KK1 has Kaolinite at 37% as a major clay mineral component, while UE1 has it at 48%. Kaolinite, another clay mineral like montmorillonite, boasts a range of valuable properties that make it a key player in numerous industries: Paper Production, it enhances printability, smoothness, and opacity by acting as a coating and filler material [1]. In paints, kaolinite acts as an extender for pigment (particularly titanium dioxide) and controls gloss levels. It also serves as an additive in plastics to modify their properties [2].

From the mineralogical analysis of the studied samples, the major mineralogical difference among the samples is the presence of montmorillonite in the CB2 sample only, and the presence kaolinite in both UE1 and KK1.

IV. CONCLUSIONS

The following are the general conclusions drawn from this study include:

1. The high kaolin, alumina (Al_2O_3), and silica (SiO_2) content of the studied anthill clays makes them suitable for the production of alumino-silicate refractory material
2. The chemical composition results of studied anthill clays suggest that they are suitable for the production of high melting clays.
3. The absence of montmorillonite and very low WAC, SI, CEC makes the studied anthill clays not suitable for application in the formulation of drilling fluids.

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ABBREVIATION

LGA	Local Government Area
KK1	Kono, Khana LGA
UE1	Umuebulu, Etche LGA
CB2	Commercial Bentonite
AAS	Atomic Absorption Spectroscopy
XRD	X – Ray Diffraction
WAC	Water Absorption Capacity
SI	Swelling Index
CEC	Cation Exchange Capacity
LOI	Loss On Ignition