E-ISSN: 111 – 2716 P-ISSN: 3026 – 8214
MPRI-JAAER | INTERNATIONAL JOURNAL OF APPLIED & ADVANCED ENGINEERING RES.
VOL. 11 NO. 5 JANUARY, 2026

CHARACTERIZATION AND COMMINUTION ENERGY DETERMINATION FOR FAYA BENTONITE CLAY TOWARDS OIL AND GAS DRILLING MUD PRODUCTION

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DOI: https://doi.org/10.70382/mejaaer.v11i5.054

Abstract

The aim of the study is to characterize and determine the comminution energy for Faya bentonite clay towards oil and gas drilling mud production. Nigeria possesses vast reserves of bentonite clay yet it's application in the oil and gas industry remains limited, due to its predominantly calcium-potassium base, which makes it unsuitable for drilling mud formulation. Faya clay located in Langtang south local government area of plateau state Nigeria is one such underutilized resource.

Sample of Faya- bentonite, Azara barite in Nasarawa State, Odogbola feldspar from Kogi state and kujama granite from Kaduna state were collected and prepares. The chemical analysis of the head sample of Faya bentonite clay using X-ray fluoresce (X.R.F) showed that it contains ;38.7% BaO 35.6% SiO_2 and 16.6% Al_2O_3 as the major oxides. The major mineral compounds in Faya bentonite clay are, Quartz, Dickite, Geothite and muscovite as revealed by the X-Ray diffractometer(XRD) analysis. The assay-size

Keywords: Bentonite, Clay, Drilling Mud, Barite Granite, feldspar, characterization.

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analysis of the head sample of Faya clay revealed that the size at which most of the BaO value preferentially report to 125 µm. the work indices of the clay were determined using modified Bonds method with Azara Barite, odogbola feldspar and Kujama granite as reference minerals. The work Index was found to be 4.9 kWh/t. The study has significant implication towards enhanced mineral characterization by utilizing modern analytical tools and technologies, ensuring accurate identification of mineral phases and work index determination.

Introduction

Bentonite and barite clays are the major ingredients in the oil and gas drilling mud formulation. Bentonite is often preferred based on design indices. Barite is usually the alternative in cases of challenges such as circulation loss, formation damage and caving in problem, associated with the wells Mu'azu *et al*,(2020)The low level of research studies of the Nigerian Bentonite clay coupled with the rising Bentonite need of the Nigerian oil and gas industry lead to importation of foreign clays to meet their demand. Afolabi *et al,* (2017). Bentonite clay deposits span the length and breadth of the Nigerian nation. Some regions of the country may have more deposits than the other (Ahmed *et al,2012*). Bentonite clay is predominantly light colored and expands when mixed with water. (Bergaya *et al,* 2006). Estimates of clay deposits according to the Nigeria Mining Cooperation and the Raw Materials Research Development Council (RMRDC), in Nigeria has been modestly projected to be above 700 million metric tons. (Noveke *et al,* 2015). Reserves of Bentonite have been identified in Plateau State, Edo State, Adamawa State, and Borno State (NGSA, 2010). Besides the proven reserve of Bentonite deposits in different parts of Nigeria that have been found, there is the need to undertake thorough reserve estimation, quantification, and characterization of these clay deposits for industrial application (Alabi *et al*, 2021). Bentonite cannot be used directly in its crude form; hence, it must be processed before its various applications.

Work Index is the comminution parameter which expresses the resistance of the material to crushing and grinding. It is the energy per unit weight required to reduce a mineral/material from theoretically infinite feed size to 80% passing 100 µm (NB)). The concentration technique includes, the gravity separation which is the separation of two or more minerals of different specific gravity by their relative movement in response on the force of gravity and one or more other forces (such as the centrifugal forces, magnetic forces, buoyant forces), one of which is resistance to motion. Froth floatation, which is also a concentration technique is an important concentration process. This process can

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be used to separate any two different particles by the use of surface chemistry of the particles. Other concentration techniques are the electrostatic separation, ore sorting and the magnetic separation. Magnetic separation is a process whereby magnetically susceptible material is extracted from a mixture using a magnetic force. (Morrison, 2022). Faya is an area in Langtang south local government area of Plateaus state, Langtang south as shown in figure 2.1 is a local government area in plateau state, Nigeria. Its headquarter are in the town of Makurdi. It has an area of 838 km^2 and a population of 106,305 at the 2006 census (Mustapha, 2024). The Jos plateau is thought to be an area of younger granite which was intruded through an area of older granite rock, making up the surrounding states. These younger granites are thought to be about 160 million years old.

MATERIALS AND METHODS

The test sample (Faya Bentonite Clay), weighing 40 kg, was sourced from Faya in Langtang south Local Government of Plateau State. 10 kg sample was collected each from the four pits, having coordinates;1(Lat 9° 9'1.00'', Long 9°42'13''), 2 (Lat 9°8'23.97'' , Long 9°42'44.37''), 3 (Lat 9°8'27.28' , Long 9°43'24.83'), and 4 (Lat 9°8'27.28' , Long 9°43'31.26 ''). The samples were collected from the points at a dimension of 7.5 meters length by 75 meters breath by 15 meters dip, 120 meters apart and it is of commercial quantity. They were homogenized and crushed with laboratory crusher (Atico), and subjected to desliming, by scrubbing to remove free silica. The deslimed sample was ground using laboratory ball mill, (model x 509 Shambavi impact), a facility of Kaduna Polytechnic. The crushed and ground sample was further sampled using conning and quartering in the laboratory to obtain about 10kg head sample, a representative fraction of the Clay from the four pits. 2 kg representative fraction of the Clay was taken to the laboratory for the Clay's composition study while 8 kg was used for the bench work. The reference Mineral samples used in this work are Odogbola Feldspar, Azara Barite and Kujana Granite. Odogbola feldspar was sourced from stockpile of National Steel Raw Materials Exploration Agency, Kaduna, and Azara Barite, from Azara in Nasarawa State, while Kujana Granite, was sourced from mineral stockpile of the Department of Mineral and Petroleum Resource Engineering, Kaduna Polytechnic. The reference samples were also taken to the laboratory, comminuted, and deslimed.

Chemical Characterization

The test sample was subjected to XRF analysis using an X-MET 5100, model x Mds 26700. The head sample of the Clay was subjected to slicing thereafter, it was loaded unto the sample holder and x-rays were irradiated unto the sample resulting in spectrum accusation for element identification and quantification.

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Mineralogical characterization

The head sample of Faya Bentonite Clay was subjected to XRD analysis. XRD 6000 Schmadzu XRD instrument of National Steel Raw Materials Exploration Agency Kaduna was used for this work. The sample was ground to powder size and subjected to pressing slicing. The pressed sample was aligned and centered. x-ray beam was irradiated on the sample, and this led to production of diffraction pattern to enhance the peak, and phase identification.

Work Index Determination

The representative sample of Faya Clay weighing 500 g, was subjected to crushing and grinding to the required size and homogenized. 100 g of the ground sample was weight and mass of the initial sample recorded. A Set of sieves arrange according to √2 sieves selection factor with the control sieve on top. It was mounted on a rotab sieve shaker and weighed sample introduce unto the control sieve, agitated until it recorded about 100 % passing. The sieve fractions were collected, weighed, and recorded.

Azara barite, Odogbola Feldspar and Kujama granite were crushed and ground under the same condition as with the size analysis of Faya Bentonite. 100 g each of the ground samples was weighed and used to carry out size analysis towards the determination of the mesh of grinds. The feeds to the ball mill were subjected to the sieving test as well. The modify Bond's relationship was used to calculate the work indices of Faya Bentonite Clay.

$$W_{ir} = W_{it} = W_{ir}\left[\frac{\left(\frac{10}{\sqrt{Pr}} - \frac{10}{\sqrt{Fr}}\right)}{\left(\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{Ft}}\right)}\right]$$

where:

Fr and Ft are the 80% passing feeds to ball mill for but test and reference sample.

Pt and Pr are the 80% passing products of milling for test and reference sample respectively.

The value of the work index obtained was used to establish the energy required for the comminution process, from the Bond's energy equation.

$$W = W_{it}\left(\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{Ft}}\right)$$

where W is the energy input to the mill (Kwh/t)

W_{it} is the Bond work index (Kwh/t)

Pt and Ft are the 80% passing the mesh sizes of the product and feed respectively.

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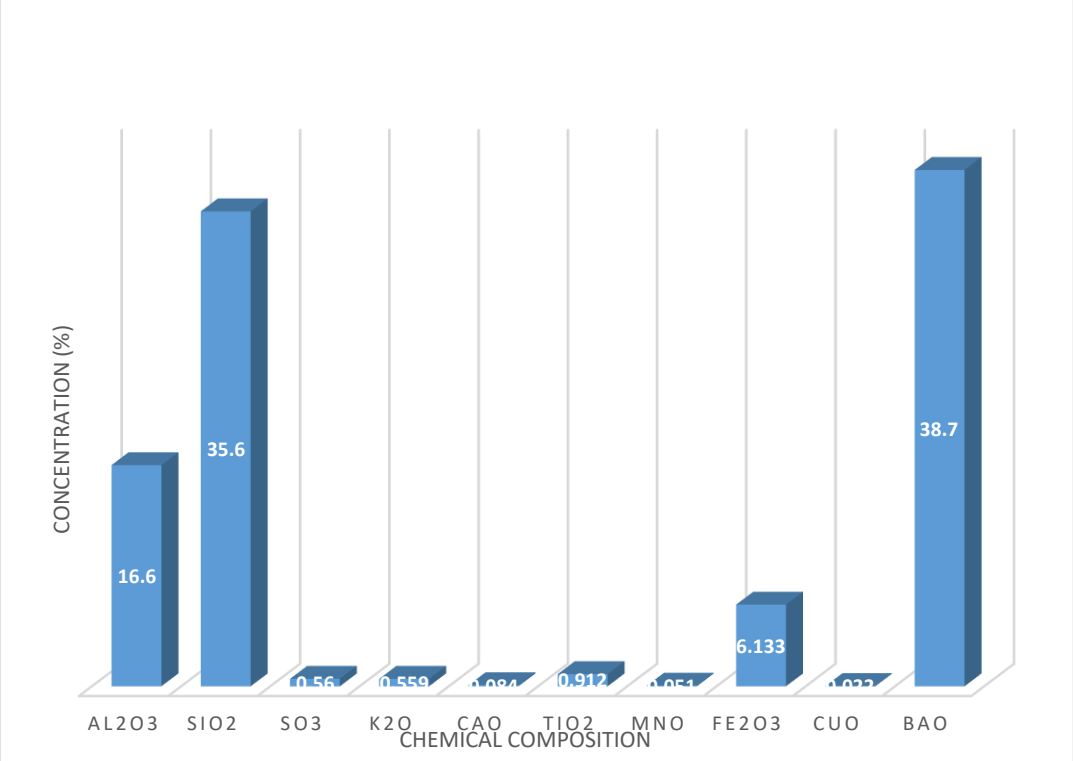
RESULTS



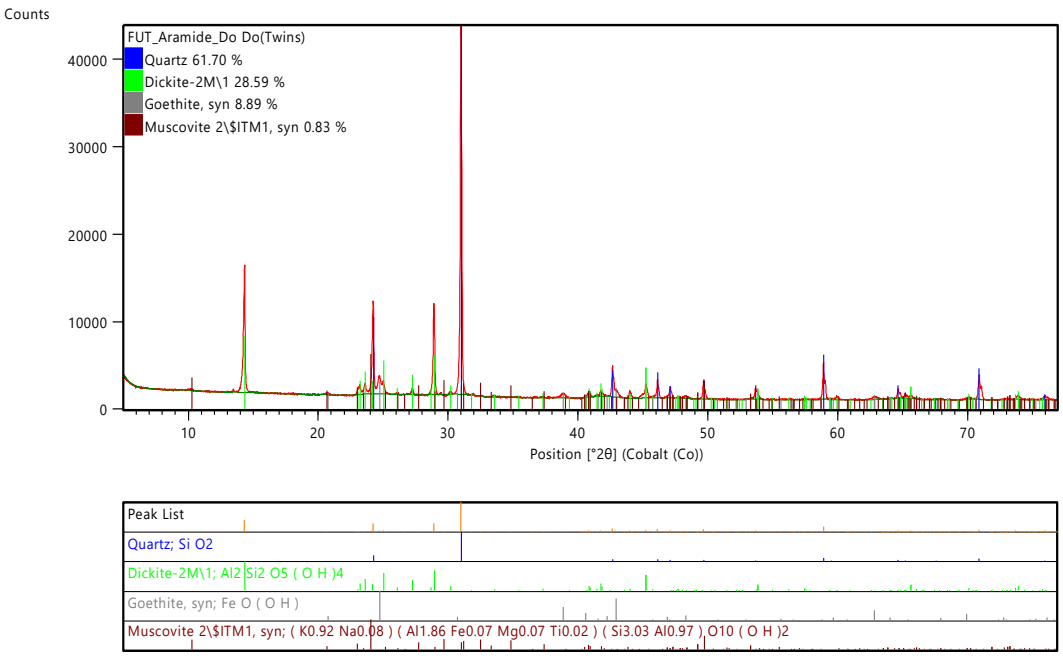


Figure 1: Result of Chemical Composition of the head sample of Faya Bentonite

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Figure 2: XRD phase diffraction parttern with the peaks list of the various mineral compounds of the sample.

Table 1: Result of fractional sieve size analysis of Product of Reference Sample (Kujama Granite)

Sieve Size Range (μm)	Norminal Aperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
+355	355	3.94	02	02	98
-355 +250	250	5.91	03	05	95
- 250 +180	180	15.76	08	13	87
-180 +125	125	29.55	15	28	72
-125 +90	90	55.16	28	56	44
-90 +63	63	47.28	24	80	20
-63 +45	45	21.67	11	9.1	09
-45 +32	32	13.79	07	9.8	02
-32	Pan	3.94	02	100	00.00
		Total=197			

Table 2: Result of fractional sieve size analysis of Feed of Reference Sample (Kujama Granite)

Sieve Size Range (μm)	Norminal Apperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
+355	355	1.96	01	01	99.0
-355 +250	250	52.92	27	28	72.0
- 250 +180	180	17.64	09	37	63.0
-180 +125	125	29.40	15	52	48.0
-125 +90	90	15.68	08	60	40.0
-90 +63	63	37.24	19	79	21.0
-63 +45	45	27.44	14	93	07
-45 +32	32	7.84	04	97	03
-32	Pan	5.88	03	100	00.00
		Total=196			

Table 3: Result of fractional sieve size analysis of Product of Test Sample (Faya Bentonite)

Sieve Size Range (μm)	Norminal Aperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
+355	355	0.99	0.5	0.5	99.5
-355 +250	250	2.97	1.5	0.2	98.0
- 250 +180	180	5.94	03	0.5	95.0
-180 +125	125	13.86	07	12	88.0
-125 +90	90	15.84	08	20	80.0

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Sieve Size Range (μm)	Norminal Aperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
-90 +63	63	53.46	27	47	53.0
-63 +45	45	63.36	32	79	21.0
-45 +32	32	33.66	17	96	04
-32	Pan	7.92	04	100	00.00
		Total=198			

Table 4: Result of fractional sieve size analysis of Feed of Test Sample (Faya Bentonite)

Sieve Size Range (μm)	Norminal Aperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
+355	355	2.925	1.5	1.5	98.5
-355 +250	250	51.675	26.5	28	72.0
- 250 +180	180	19.50	10	38	62.0
-180 +125	125	19.50	10	48	52.0
-125 +90	90	19.50	10	58	42.0
-90 +63	63	25.35	13	71	29.0
-63 +45	45	21.45	11	82	18.0
-45 +32	32	31.20	16	98	02.0
-32	Pan	3.90	02	100	00.00
		195			

Table 5: Result of fractional sieve size analysis of Product of Reference (Azara Barite)

Sieve Size Range (μm)	Norminal Aperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
+355	355	3.92	02	02.0	98.0
-355 +250	250	7.84	04	06.0	94.0
- 250 +180	180	3.92	02	08.0	91.0
-180 +125	125	13.72	07	15.0	85.0
-125 +90	90	23.52	12	27.0	73.0
-90 +63	63	56.84	29	56.0	44.0
-63 +45	45	41.16	21	77.0	23.0
-45 +32	32	41.16	21	98.0	02.0
-32	Pan	3.92	02	100	00.00
		196			

Table 6: Result of fractional sieve size analysis of Feed of Reference (Azara Barite)

Sieve Size Range (μm)	Norminal Aperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
+355	355	2.96	1.50	1.50	98.5
-355 +250	250	36.45	18.5	20.0	80.0
- 250 +180	180	41.37	21.0	41.0	59.0
-180 +125	125	43.34	22.0	63.0	37.0

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Sieve Size Range (μm)	Norminal Aperture (μm)	Weight (g)	Weight (%)	Commulative (%)	
				Over Size	Under Size
-125 +90	90	25.61	13.0	76.0	24.0
-90 +63	63	21.67	11.0	87	13.0
-63 +45	45	17.73	09.0	96.0	04.0
-45 +32	32	05.91	03.0	99.0	01.0
-32	Pan	01.97	01.97	100	00.00
		197			

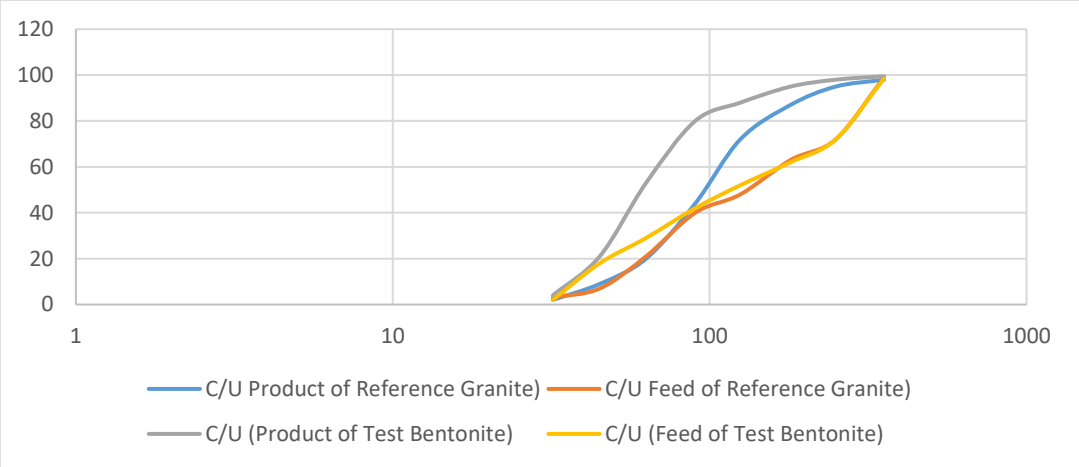

Figure 3: PSD Lines for Test and Reference Sample (Kujama Granite)

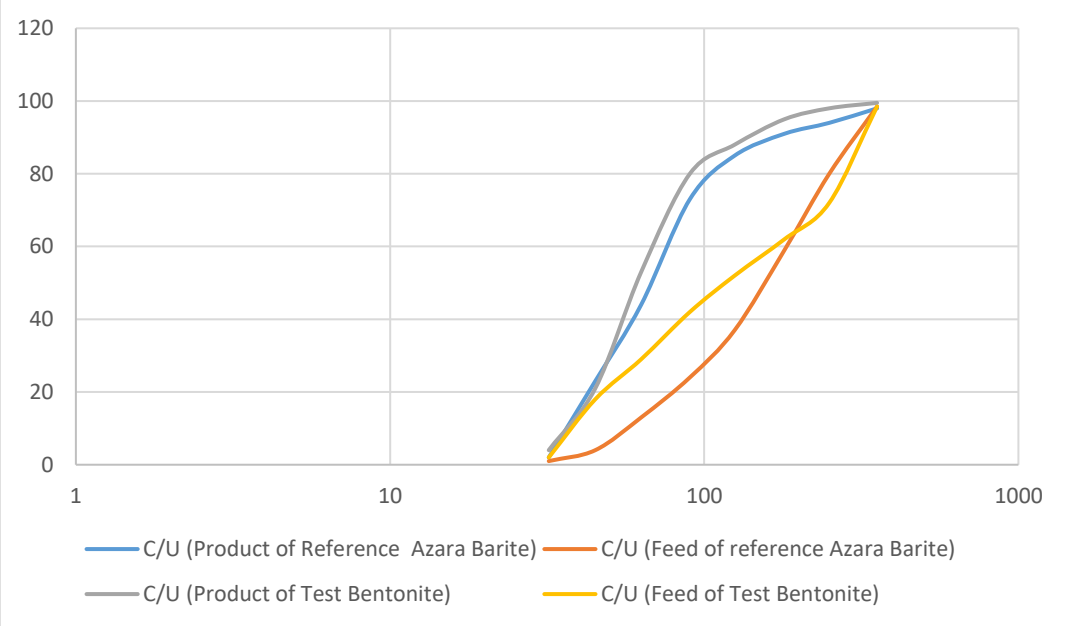

Figure 4: PSD Lines for Test and Reference Sample (Azara Barite)

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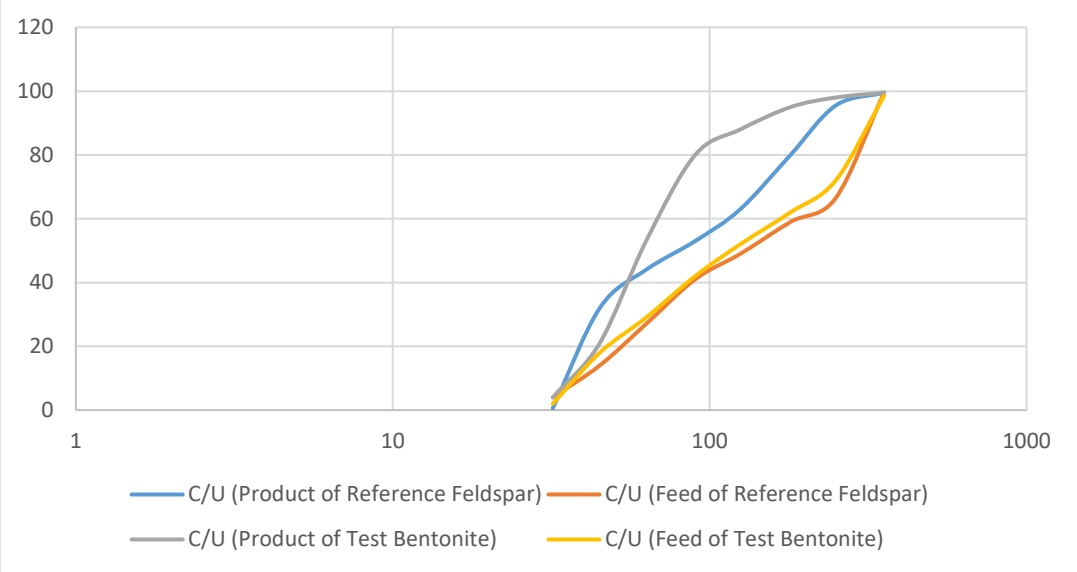

Figure 5: PSD Lines for Test and Reference Sample (Odogbola Feldspar)

Work index of Faya Bentonite was calculated to be;

Wi test $= 4.91$ **kWh/t**

CONCLUSIONS and RECOMMENDATION

From the findings of this work, it can be concluded that Faya bentonite clay contains **16.6% Al_2O_3, 35.6% SiO_2, 0.559% K_2O, 0.084% CaO, 6.133% Fe_2O_3, 0.912% TiO_2, and 38.7% BaO**. The dominant mineral phases in the clay are **28.59% wt Dickite, 8.89% wt Goethite, 61.7% wt Quartz, and 0.83% wt Muscovite**. The work index of Faya Bentonite clay is **4.91 kWh/t,** energy input for the grinding operation is 5.7 kWh/t and **energy efficiency** of the grinding operation is **0.86**. The study has significant implication towards **enhanced mineral characterization** by utilizing **modern analytical tools and technologies,** ensuring accurate identification of mineral phases and work index determination.

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