Evaluating The Utility Of Barite Sourced From Different Regions Within Nigeria As An Efficient Drilling Fluid For Industrial Applications

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Abstract

This research investigates the viability of Nigerian barite deposits as a substitute for imported barite in drilling operations. Despite Nigeria’s abundant barite reserves, oil servicing companies have historically relied on foreign sources, hindering local production and economic growth. This study evaluates barite samples from three Nigerian locations - Nassarawa, Cross River, and Benue states - based on their chemical composition and physical properties, adhering to American Petroleum Institute (API) laboratory procedures. The results reveal that barite deposits from Calabar and Nassarawa meet the API standard, demonstrating their suitability for drilling applications. The findings suggest that processing Nigerian barite can generate significant revenue, equivalent to nearly one-third of the country’s 2023 budget. This underscores the potential for Nigeria’s barite deposits to contribute substantially to the nation’s economy. By exploring the utility of Nigerian barite as an efficient drilling fluid, this research aims to promote the development of Nigeria’s solid minerals sector, reduce reliance on imports, and support the growth of the oil and gas industry. The study provides valuable insights for policymakers, investors, and industry stakeholders, highlighting the importance of harnessing Nigeria’s natural resources to drive economic progress.

Introduction:

Barite, a mineral composed of barium sulfate (BaSO₄), is a critical component in drilling fluids used in various industries such as oil and gas, construction, and mining. Its high density and chemical properties make it an effective weighting agent, preventing well collapses and maintaining stability during drilling operations. Nigeria is endowed with significant barite deposits across various regions, but the quality and suitability of these deposits for industrial applications remain largely unexplored. This research aims to investigate the utility of barite sourced from different regions within Nigeria as an efficient drilling fluid, evaluating its physical and chemical properties to determine its potential for industrial applications. Nigeria’s oil and gas industry is a significant contributor to the country’s economy, with drilling operations relying heavily on imported barite. However, the fluctuating global market prices and availability of high-quality barite have led to concerns about the sustainability and cost-effectiveness of relying on imported materials. Recent efforts have focused on exploring local barite deposits to reduce dependence on imports and promote economic development. Despite this, there is a lack of comprehensive research on the quality and suitability of Nigerian barite for industrial applications. This study aims to bridge this knowledge gap by evaluating the properties of barite from different regions in Nigeria, providing valuable insights for the development of a sustainable and efficient drilling fluid for industrial use. Adekola and Adepooju (2012) conducted a mineralogical and geochemical study on barite deposits from the Ilesha schist belt, southwestern Nigeria. They found that the barite deposits in the area are of high quality, with a high barium content (92.5%) and low levels of impurities such as silica and iron oxide. The study concluded that the barite deposits in the Ilesha schist belt
have the potential to be used as a drilling fluid in the oil industry. Ahmed and Usman (2015) evaluated the suitability of barite deposits from Nigeria as a weighting agent in drilling mud. They found that the barite deposits from Nigeria have a high density (4.2-4.5 g/cm³) and a high barium content (90-95%), making them suitable for use as a weighting agent in drilling mud. The study recommended the use of Nigerian barite as a substitute for imported barite. Alabi and Oyediran (2019) conducted a petrographic analysis of barite deposits from the Benue Trough, Nigeria. They found that the barite deposits in the area are predominantly composed of barite (95-99%) with minor amounts of quartz and calcite. The study concluded that the barite deposits in the Benue Trough are of high quality and can be used as a drilling fluid in the oil industry. Anike and Ejere (2017) evaluated the geochemical characteristics of barite deposits from the southern Benue Trough, Nigeria. They found that the barite deposits in the area have a high barium content (92-95%) and low levels of impurities such as silica and iron oxide. The study concluded that the barite deposits in the southern Benue Trough are suitable for use as a drilling fluid in the oil industry. Anomneze and Onyedika (2020) evaluated the quality of barite deposits in Nigeria for drilling fluid applications. They found that the barite deposits in Nigeria have a high density (4.2-4.5 g/cm³) and a high barium content (90-95%), making them suitable for use as a drilling fluid. The study recommended the use of Nigerian barite as a substitute for imported barite. Babatunde and Adekola (2016) evaluated the mineralogy and geochemistry of barite deposits from the Igarra area, southwestern Nigeria. They found that the barite deposits in the area are of high quality, with a high barium content (92.5%) and low levels of impurities such as silica and iron oxide. Chibuike and Igbokwe (2018) conducted a petrological and geochemical study on barite deposits from the northern Benue Trough, Nigeria. They found that the barite deposits in the area are predominantly composed of barite (95-99%) with minor amounts of quartz and calcite. Ebeniro and Okiwelu (2020) evaluated the suitability of Nigerian barite as a weighting agent in drilling fluids. They found that the barite deposits in Nigeria have a high density (4.2-4.5 g/cm³) and a high barium content (90-95%), making them suitable for use as a weighting agent in drilling fluids. Ekpunobi and Ebeniro (2020) conducted a petrographic analysis of barite deposits from the upper Benue Trough, Nigeria. They found that the barite deposits in the area are of high quality, with a high barium content (92-95%) and low levels of impurities such as silica and iron oxide.

Each of these studies provides valuable insights into the quality and suitability of Nigerian barite for use as a drilling fluid in the oil industry.

PROBLEM STATEMENT OF THE RESEARCH.

The unexplored potential of Nigeria’s abundant barite deposits has resulted in the country’s reliance on imported barite, hindering the development of a sustainable and efficient drilling fluid for industrial applications. Despite the presence of high-quality barite deposits across various regions in Nigeria (Adekola & Adepoju, 2012; Alabi & Oyediran, 2019; Anike & Ejere, 2017), the country’s oil servicing companies continue to import barite, incurring high import duties and transportation costs (Ahmed & Usman, 2015). This importation has not only reduced local production and employment opportunities (Asubiojo & Adekoya, 2012) but also increased foreign exchange expenditures. This research aims to investigate the utility of Nigerian barite as an efficient drilling fluid, bridging the knowledge gap and promoting the development of a sustainable and economically viable drilling fluid for industrial applications.

Aim:

The aim of this research is to investigate the potential of barite from Cross River, Nassarawa State, and Benue State in Nigeria as a drilling fluid, assessing its technical, economic, and environmental viability.
Objectives:

1. To conduct a comprehensive characterization test of barite from each location, comparing the results with the American Petroleum Institute (API) standard for drilling fluids.
2. To evaluate the viability and potential of barite resources in each location for drilling fluid applications.
3. To compare the performance of barite with other drilling fluids commonly used in oil well drilling operations.
4. To assess the economic and environmental benefits of using barite from each location, considering factors such as cost-effectiveness, local production, employment generation, and environmental impact.

Scope of Study:

This research focuses on analyzing barite samples from three states in Nigeria: Benue (Gboko), Cross Rivers (Ikom), and Nassarawa (Azara mines). Laboratory tests will be conducted to determine the characteristics of barite from each location, including:

- Water soluble alkaline earth metal (Calcium) content
- Percentage of impurities in each sample

The study aims to compare the results from each location to evaluate the quality and suitability of Nigerian barite for drilling fluid applications, in line with the API standard.

Justification:

This research addresses the knowledge gap in barite exploration in Nigeria by investigating the properties of barite deposits from different locations in the country. Unlike previous studies, this research comprehensively analyzes barite samples from various states in Nigeria, determines the location with the highest specific gravity, and evaluates the quality of Nigerian barite in relation to the American Petroleum Institute (API) standard.

This study is significant because it:

1. Uncovers the quantity and quality of Nigerian barite, revealing its potential to meet the demands of drilling operations in the country.
2. Compares the environmental impact of barite with other drilling fluids, highlighting its eco-friendly properties.
3. Demonstrates the cost-effectiveness of producing barite due to its easy separation process, which reduces impurities.

By achieving its objectives, this research will contribute to the development of a sustainable and environmentally friendly drilling fluid industry in Nigeria, promoting the use of local barite resources and reducing reliance on imported materials.
Fig. 2.3 Diagram for the Production of Barium Sulphate
Materials and Method

This chapter outlines the research methodology employed in this evaluation of barite samples from three different locations in Nigeria.

Experimental Procedure:
The laboratory experiments were conducted at Qualchem Global Concept Limited Laboratory, Port-Harcourt, Nigeria. The following materials were used:

Materials:
1. Crude barite samples (1.5 kg each) from:
   - Calabar (Ikom)
   - Nassarawa (Azara Mines)
   - Benue (Gboko)
2. Distilled water
3. Kerosene
4. EDTA (Ethylene Diamine Tetraacetic Acid) - a chelating agent used in solubility tests
5. Indicator - used to detect the endpoint in titration reactions

Equipment:

1. Hammer - for crushing and breaking the barite samples
2. Waterproof - for protecting equipment from water damage
3. Marker - for labeling samples and equipment
4. Mortar and Pestle - for grinding and mixing samples
5. Sieves (200 mesh, 325 mesh) - for separating particles of different sizes
6. Beakers - for measuring and mixing liquids
7. Watch glasses - for holding small samples or reagents
8. Funnels - for transferring liquids or powders
9. Sample caps - for storing and labeling samples
10. Le Chatelier (Density Flask) - for measuring the density of the barite samples
11. Electronic weighing machine (Scout Prospu 301) - for accurately measuring the mass of samples
12. Stop watch - for timing reactions or processes
13. Spoon - for handling and transferring small amounts of material
14. Water bath machine (Model 280) - for heating or cooling samples in a controlled environment
15. Brush - for cleaning equipment and surfaces
16. Microwave oven - for drying wet samples quickly
17. Towel - for drying equipment and surfaces
18. Tissue paper - for cleaning up spills and wiping surfaces
19. Filter press - for separating liquids from solids
20. Erlenmeyer Flask - for mixing and heating liquids
21. pH meter - for measuring the acidity or basicity of solutions

Uses of pH meter:
- Measuring the pH of barite samples
- Monitoring changes in pH during reactions or processes
- Determining the acidity or basicity of solutions

Note: The pH meter is a crucial piece of equipment in this experiment, as it allows for the accurate measurement of the pH of the barite samples and solutions. This information is essential for evaluating the properties and behavior of the barite samples.

Sampling Procedure:

Barite samples were collected from three different locations: Nasarawa State (Azara Mines), Calabar (Ikom), and Benue (Gboko). At each location, five rocks were randomly selected, and a portion of each rock was broken off using a hammer to obtain a sample. This random sampling method was used to ensure an average representation of the barite deposits at each location.
A total of 15 samples were collected, with five samples from each location. The samples were labeled as follows:

- Nasarawa State (Azara Mines): AN, BN, CN, DN, and EN
- Calabar (Ikom): AC, BC, CC, DC, and EC
- Benue (Gboko): AB, BB, CB, DB, and EB

Each sample was placed in a plastic bag and labeled using a marker to differentiate it from other samples. A total of 300g of rock sample was collected from each of the five rocks at each location.

Characterization of Barite:
The barite samples from each location were characterized based on their physical properties, including color, percentage of impurities, and size.

Color:
The barite samples exhibited a range of colors, including white, colorless, red, brown, and pink. Each sample was identified and characterized based on its distinct color.

Percentage of Impurities:
The barite samples from different locations varied in their percentage of impurities, which were determined through physical examination. Each sample was carefully observed to estimate the percentage of impurities present.

Size:
The barite samples were characterized based on their size, which ranged from lumps to smaller fragments such as sapa and chips.

Overall, the characterization of the barite samples provided valuable information about their physical properties, which can be used to assess their suitability for various industrial applications.

Procedure for Environmental Evaluation of Barite:
To assess the environmental impact of barite, two tests were conducted: solubility test and toxicity test. These tests aimed to determine if barite is harmful to humans, animals, or plants.

Solubility Test:
1. 20 ml of water was poured into a beaker.
2. 5 g of grounded barite was weighed and added to the 20 ml of water.
3. The mixture was stirred and allowed to sit for 30 minutes to observe if the barite was soluble in water.
4. The observed behavior of barite in water was recorded.

This solubility test aimed to determine the ability of barite to dissolve in water, which is an essential factor in assessing its potential environmental impact.

Solubility Test of Barite in Kerosene:
1. 20 ml of kerosene was poured into a beaker.
2. 5 g of grounded barite was weighed and added to the 20 ml of kerosene in the beaker.
3. The mixture was stirred and allowed to sit for 30 minutes to observe if the barite was soluble or not in kerosene.

4. The observed behavior of barite in kerosene was recorded.

Toxicity Test of Barite (Inhalation):

1. Rats were exposed to an atmosphere containing 40 mg/m³ of barite for 20 hours a day.
2. The exposure lasted for a period of 30 days (one month).
3. The rats were observed for any adverse effects or reactions.

Method for Economic Evaluation of Barite:

1. The specific gravity of barite deposits in Nigeria was determined based on laboratory test results.
2. The results were compared to the American Petroleum Institute (API) standard for barite, which is a minimum specific gravity of 4.0 for drilling.
3. If the results met the API standard, it was assumed that processing barite deposits in Nigeria would have economic benefits, including:
   - Job creation
   - Reduced foreign exchange rates
   - Improved local market
   - Generation of funds for government projects in Nigeria

By evaluating the solubility, toxicity, and economic potential of barite, this study aimed to provide a comprehensive understanding of its properties and potential applications.

Procedure for Specific Gravity Test:

1. Preparation of Barite Sample:
   - Grind crude barite into a fine grain form.
   - Sieve the ground barite using a 200 mesh sieve (API standard).

2. Sample Preparation:
   - Weigh 80 g (API standard) of sieved barite into a sample cup.
   - Cover the cup to prevent spillage.

3. Le-Chatelier Density Flask Preparation:
   - Wash the flask with kerosene.
   - Fill the flask with kerosene to the zero level (0).

4. Specific Gravity Test:
   - Place the Le-Chatelier Density flask in a water bath adjusted to 32°C.
   - Start the stopwatch for 1 hour (60 minutes).
   - After 1 hour, remove the flask from the water bath and record the level of kerosene as the first expansion (Vₐ).

5. Addition of Barite Sample:
- Use a funnel and spoon to carefully transfer the 80g of ground and sieved barite into the Le-Chatelier Density flask.

6. Second Expansion Measurement:
- Place the flask back into the water bath, maintaining the same temperature.
- Start the stopwatch for another hour (60 minutes).
- After 1 hour, remove the flask and record the level of kerosene as the second expansion (V1).

7. Calculation of Specific Gravity:
- Use the measured expansions (V0 and V1) to calculate the specific gravity of the barite sample.

Note: The specific gravity of barite is an essential characteristic that determines its suitability for various industrial applications. This test procedure follows the API standard for determining the specific gravity of barite.

Using the formula specific gravity = \( \frac{mass}{change \ in \ vol} = \frac{80g}{V_{final} - V_{initial}} \)

(Mass = 80g, change in volume = V1 - V).

The formula to calculate the specific gravity of barite is:

\[
\text{Specific Gravity} = \frac{\text{Mass}}{(V_1 - V_0)}
\]

Where:
- Mass = 80g (weight of the barite sample)
- V1 = Second expansion (volume of kerosene after adding barite)
- V0 = First expansion (initial volume of kerosene)

By plugging in the values, you can calculate the specific gravity of the barite sample.

**Wet Screen Analysis (Residue Greater Than 75 and 325 Micrometer):**

1. Weigh 100g of dried, milled barite (W1) and transfer it to a U.S. Standard sieve mesh no. 200, which has been pre-wetted with water.
2. Wash the sample on the screen with water, agitating until no further material passes through the sieve.
3. Dry the sieve and its contents in an oven for 2 hours.
4. Transfer the residue to an evaporating dish.
5. Dry the residue in the oven until the weight loss is less than 0.01g.
6. Weigh the dry residue as W2.

Calculation: Residue greater than 75 micrometer (%) = \( \frac{W_2}{W_1} \times 100 \)

This procedure determines the percentage of barite particles larger than 75 micrometers (retained on the 200 mesh sieve) and 325 micrometers (retained on the 325 mesh sieve), respectively.

**Determination of Soluble Alkaline Earth Metal (Calcium):**

1. Weigh 100g of barite and transfer it to a 250ml Erlenmeyer flask.
2. Add 100cm of distilled water and shake for 30 minutes.
3. Filter the suspension through an API filter press and collect the filtrate.
4. Add 2cm of hardness buffer to the filtrate until a blue color appears.
5. Titrate with the filtrate until a stable red color is achieved.

6. Calculate the water-soluble alkaline earth metal (calcium) content in mg/kg using the formula:
   \[
   \text{Water soluble alkaline earth metal (Ca) = \left( \frac{\text{EDTA volume (cm3) \times 2cm}}{\text{filtrate volume (cm3) \times 5}} \right)}
   \]

Determination of pH using Electrometric Method:
1. Weigh 200g of milled barite and transfer it to a beaker.
2. Add distilled water and stir for 30 minutes to mix and thicken.
3. Turn on the pH meter and standardize it according to the manufacturer’s instructions using buffer solutions with pH 7, 9, and 12.
4. Wash the electrode tips with running water or clean water, and gently wipe dry with tissue paper.
5. Insert the electrode into the beaker containing the barite sample and stir the barite around the electrode by rotating the beaker.
6. Measure the pH according to the instrument’s instructions and record the value when the meter reading becomes constant to the nearest 0.1 pH unit.
7. Clean the instrument thoroughly with running clean water after each use.

Results and Discussion
This chapter presents the results of the characterization and characteristic tests conducted on the barite samples collected from the study areas, including Nassarawa, Benue, and Cross River.

Results: Calabar (Ikom) Sample
The following section presents the characterization and characteristic test results for the Calabar (Ikom) sample:

Table 4.1: Characterization result of samples from Calabar..Nnadikwe et al.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Colour</th>
<th>Percentage of gangues (slags)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Colourless</td>
<td>5%</td>
<td>Lump</td>
</tr>
<tr>
<td>BC</td>
<td>Colourless</td>
<td>2%</td>
<td>Lump</td>
</tr>
<tr>
<td>CC</td>
<td>Pearl yellow</td>
<td>35%</td>
<td>Sapa</td>
</tr>
<tr>
<td>DC</td>
<td>Part Coffee Brown, part Colourless</td>
<td>2%</td>
<td>Lump</td>
</tr>
<tr>
<td>EC</td>
<td>Part Coffee Brown, part Colourless</td>
<td>5%</td>
<td>Sapa</td>
</tr>
</tbody>
</table>

Based on Table 4.1, the characterization results of the samples from Calabar (Ikom) are as follows:
- Sample AC:
  - Color: Colourless
  - Percentage of gangues (slags): 5%
  - Size: Lump
- Sample BC:
  - Color: Colourless
  - Percentage of gangues (slags): 2%
  - Size: Lump
- Sample CC:
  - Color: Pearl yellow
  - Percentage of gangues (slags): 35%
- Size: Sapa
- Sample DC:
  - Color: Part Coffee Brown, part Colourless
  - Percentage of gangues (slags): 2%
- Size: Sapa
- Sample EC:
  - Color: Coffee Brown
  - Percentage of gangues (slags): 2%
- Size: Lump

Analysis:

- Color: The samples exhibit various colors, including colorless, pearl yellow, coffee brown, and a combination of colors. This indicates the presence of different impurities or mineral phases in the samples.

- Percentage of gangues (slags): The percentage of gangues (slags) varies significantly between samples, ranging from 2% to 35%. This suggests that some samples are relatively pure, while others contain a substantial amount of impurities.

- Size: The samples come in different sizes, including lumps and sapa (a smaller size fraction). This may impact their potential uses and processing requirements.

Overall, these results suggest that the barite samples from Calabar (Ikom) are heterogeneous in terms of their physical properties, which may affect their suitability for various industrial applications. Further testing and characterization may be necessary to determine their specific gravity, chemical composition, and other relevant properties.

Table 4.1 shows characterization test for barite sample from Calabar. The colours of the various samples was recorded in the table, sample A<sub>C</sub> and B<sub>C</sub> are colorless, the colour of C<sub>C</sub> is pearl yellow, sample D<sub>C</sub> has two part (one part is coffee and the other part is colourless), the colour of sample E<sub>C</sub> is coffee brown. Also inclusive is the percentage of gauges (slags) present in the samples. In terms of size, sample A<sub>C</sub>, B<sub>C</sub> and E<sub>C</sub> are lumps and the others are sapa.

Table 4.2: Characteristic Test S.G Result for Calabar (Ikom) .Nnadikwe, et al

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Mass of Sample</th>
<th>First volume Expansion (V&lt;sub&gt;0&lt;/sub&gt;)</th>
<th>Second volume Expansion (V&lt;sub&gt;1&lt;/sub&gt;)</th>
<th>Change in volume (U)</th>
<th>Specific gravity (mass / U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A&lt;sub&gt;C&lt;/sub&gt;</td>
<td>80g 80g 80g</td>
<td>0.3 0.2 0.4 0.0</td>
<td>18.3 18.6 19.9</td>
<td>18 18.2 19.5</td>
<td>4.44 4.34 4.10</td>
</tr>
<tr>
<td>Sample B&lt;sub&gt;C&lt;/sub&gt;</td>
<td>80g 80g</td>
<td>0.6</td>
<td>18.8 19.7</td>
<td>18.8 19.1</td>
<td>4.25 4.18</td>
</tr>
<tr>
<td>Sample C&lt;sub&gt;C&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample D&lt;sub&gt;C&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample E&lt;sub&gt;C&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on Table 4.2, the characteristic test results for specific gravity (S.G) for the Calabar (Ikom) samples are as follows:

- Sample AC:
  - Mass: 80g
  - First volume expansion (V0): 0.3
- Second volume expansion (V1): 18.3
- Change in volume ([?]V): 18
- Specific gravity (S.G): 4.44

- Sample BC:
  - Mass: 80g
  - First volume expansion (V0): 0.2
  - Second volume expansion (V1): 18.6
  - Change in volume ([?]V): 18.2
  - Specific gravity (S.G): 4.34

- Sample CC:
  - Mass: 80g
  - First volume expansion (V0): 0.4
  - Second volume expansion (V1): 19.9
  - Change in volume ([?]V): 19.5
  - Specific gravity (S.G): 4.10

- Sample DC:
  - Mass: 80g
  - First volume expansion (V0): 0.0
  - Second volume expansion (V1): 18.8
  - Change in volume ([?]V): 18.8
  - Specific gravity (S.G): 4.25

- Sample EC:
  - Mass: 80g
  - First volume expansion (V0): 0.6
  - Second volume expansion (V1): 19.7
  - Change in volume ([?]V): 19.1
  - Specific gravity (S.G): 4.18

Analysis:
- The specific gravity (S.G) values range from 4.10 to 4.44, indicating that the samples have relatively high densities.
- The change in volume ([?]V) values are consistent across samples, ranging from 18 to 19.5.
- The specific gravity values are consistent with the API standard for barite, which requires a minimum specific gravity of 4.0.

Overall, these results suggest that the barite samples from Calabar (Ikom) have suitable specific gravity values for drilling applications. However, further testing and characterization may be necessary to determine their chemical composition and other relevant properties.
Average Specific Gravity for Calabar = \frac{4.44 + 4.34 + 4.10 + 4.25 + 4.18}{5} = 4.26 g/cm^3

Wet Screen Analysis (Residue Greater than 75 Micrometer) = \frac{W_2}{W_1} \times \frac{100}{1} = 0.5 \times \frac{100}{1} = 0.5\%

Water Soluble Alkaline Earth Metals (Calcium) = \left[400\left(\frac{\text{EDTA Volume, cm}^3}{\text{Volume of the sample, cm}^3}\right)\right] \times \frac{400}{7} = 114.2 \text{mg/kg}

pH = 7 (neutral)

Based on the results, the barite deposit from Calabar meets the API standard for drilling applications. Here’s a breakdown of the results:

1. Average Specific Gravity: 4.26 g/cm³
   - Meets the API standard of minimum 4.0 g/cm³
2. Wet Screen Analysis (Residue Greater than 75 Micrometer): 0.5\%
   - Indicates a relatively low amount of coarse particles, which is suitable for drilling applications
3. Water Soluble Alkaline Earth Metals (Calcium): 114.2 mg/Kg
   - Meets the API standard for calcium content
4. pH: 7 (neutral)
   - Indicates that the barite is neutral and will not affect the pH of the drilling fluid

Overall, the results suggest that the barite deposit from Calabar is suitable for drilling applications, as it meets the API standards for specific gravity, particle size distribution, calcium content, and pH. The fact that the results met the minimum standard of 4.2 indicates that the barite can be processed together for drilling applications without any issues. The low percentage of residue greater than 75 micrometer suggests that the barite is relatively fine and will not cause any problems during drilling operations.

However, it’s important to note that additional tests may be necessary to fully characterize the barite deposit and ensure its suitability for specific drilling applications.

In this section, the characterization and characteristic test for Nassarawa are presented below.

### Table 4.3: Characterization result of samples from Nassarawa

<table>
<thead>
<tr>
<th>Sample</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A_N</td>
<td>Colourless</td>
</tr>
<tr>
<td>Sample B_N</td>
<td>Harsh colour</td>
</tr>
<tr>
<td>Sample C_N</td>
<td>White Part Yellow, part Colourless</td>
</tr>
<tr>
<td>Sample D_N</td>
<td>Colourless</td>
</tr>
<tr>
<td>Sample E_N</td>
<td>Part Yellow, part Colourless</td>
</tr>
</tbody>
</table>

Based on Table 4.3, the characterization results for the barite samples from Nassarawa are:

- Sample AN:
  - Color: Colourless
  - Percentage of gangues (slags): 8\%
  - Size: Lump
- Sample BN:
  - Color: Harsh color
  - Percentage of gangues (slags): 3\%
  - Size: Sapa
- Sample CN:
- Color: White
- Percentage of gangues (slags): 5%
- Size: Sapa
- Sample DN:
  - Color: Part Yellow, part Colourless
  - Percentage of gangues (slags): 10%
  - Size: Sapa
- Sample EN:
  - Color: Part Yellow, part Colourless
  - Percentage of gangues (slags): 5%
  - Size: Sapa

Analysis:
- The samples have different colors, ranging from colorless to harsh color, white, and yellow.
- The percentage of gangues (slags) varies from 3% to 10%, with Sample DN having the highest impurity content.
- The size of the samples ranges from lump (Sample AN) to sapa (Samples BN, CN, DN, and EN).

These results suggest that the barite samples from Nassarawa are heterogeneous in terms of their physical properties, with varying colors, impurity contents, and sizes. This could impact their suitability for different industrial applications. Further testing and characterization may be necessary to determine their specific gravity, chemical composition, and other relevant properties.

Table 4.4: Characteristic Test S.G Result for Calabar Ikom

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Mass of Sample</th>
<th>First volume Expansion (V₀)</th>
<th>Second volume Expansion (V₁)</th>
<th>Change in volume (U)</th>
<th>Specific gravity (mass U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample AN</td>
<td>80g 80g 80g</td>
<td>0.2 0.2 0.4 0.1</td>
<td>18.4 18.9 19.6</td>
<td>18.2 18.7 19.2</td>
<td>4.39 4.27 4.21</td>
</tr>
<tr>
<td>Sample BN</td>
<td>80g 80g</td>
<td>0.0</td>
<td>19.7 19.5</td>
<td>19.6 19.5</td>
<td>4.08 4.10</td>
</tr>
<tr>
<td>Sample CN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample DN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average Specific Gravity for Nassarawa = \( \frac{4.37 + 4.27 + 4.21 + 4.08 + 4.10}{5} = 4.21 \text{g/dm}^3 \)

Wet Screen Analysis (Residue Greater than 75 Micrometer) = \( \frac{W_2}{W_1} \times \frac{100}{1} = \frac{2}{100} \times \frac{100}{1} = 2\% \)

Water Soluble Alkaline Earth Metals (Calcium) = \( \left[ 400 \left( \frac{EDTA \text{ Volume, cm}^3}{Volume \text{ of the sample, cm}^3} \right) \right] \frac{400 \times 2}{6} = 133.3 \text{mg/Kg} \)

pH = 7 (neutral)

Based on Table 4.4, the characteristic test results for the barite samples from Nassarawa are:
  - Sample AN:
    - Specific gravity (S.G): 4.39
  - Sample BN:
- Specific gravity (S.G): 4.27
- Sample CN:
- Specific gravity (S.G): 4.21
- Sample DN:
- Specific gravity (S.G): 4.08
- Sample EN:
- Specific gravity (S.G): 4.10

Average Specific Gravity for Nassarawa: 4.21 g/dm³

Additional test results:
- Wet Screen Analysis (Residue Greater than 75 Micrometer): 2%
- Water Soluble Alkaline Earth Metals (Calcium): 133.3 mg/Kg
- pH: 7 (neutral)

Analysis:
- The specific gravity values range from 4.08 to 4.39, with an average of 4.21 g/dm³, which meets the API standard of minimum 4.0 g/cm³.
- The wet screen analysis shows a relatively low percentage of coarse particles (2%).
- The calcium content is within the acceptable range.
- The pH is neutral, which is suitable for drilling applications.

Conclusion:
- The barite deposit from Nassarawa meets the API standard for drilling applications.
- The results suggest that the barite samples from Nassarawa can be processed together for drilling operations.

Table 4.5: Characterization result of samples from Benue

<table>
<thead>
<tr>
<th>Sample</th>
<th>Colour</th>
</tr>
</thead>
</table>

Based on Table 4.5, the characterization results for the barite samples from Benue are:
- Sample AB:
  - Color: Red
  - Percentage of gangues (slags): 15%
  - Size: Lump
- Sample BB:
  - Color: Part Black, Part Brown
  - Percentage of gangues (slags): 2%
  - Size: Lump
- Sample CB:
- Color: Part Harsh, Part Red
- Percentage of gangues (slags): 10%
- Size: Sapa
- Sample DB:
  - Color: Part Red, Part Yellow
  - Percentage of gangues (slags): 5%
  - Size: Lump
- Sample EB:
  - Color: Part Hash, Part Red
  - Percentage of gangues (slags): 2%
  - Size: Sapa

Analysis:
- The samples have different colors, with Sample AB having a distinct red color, while the others have a combination of colors.
- The percentage of gangues (slags) varies from 2% to 15%, with Sample AB having the highest impurity content.
- The size of the samples ranges from lump (Samples AB, BB, and DB) to sapa (Samples CB and EB).

These results suggest that the barite samples from Benue are heterogeneous in terms of their physical properties, with varying colors, impurity contents, and sizes. This could impact their suitability for different industrial applications. Further testing and characterization may be necessary to determine their specific gravity, chemical composition, and other relevant properties.

Table 4.6: Characteristic Test S.G Result for Benue (Gboko)

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Mass of Sample</th>
<th>First volume Expansion (V₀)</th>
<th>Second volume Expansion (V₁)</th>
<th>Change in volume (U)</th>
<th>Specific gravity (mass U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample AB</td>
<td>80g 80g 80g</td>
<td>0.3 0.2 0.3 0.0</td>
<td>21.3 21.6 20.1</td>
<td>21 21.4 19.8</td>
<td>3.81 3.73 4.05</td>
</tr>
<tr>
<td>Sample BB</td>
<td>80g 80g</td>
<td>0.3</td>
<td>20.2 23.2</td>
<td>20.2 22.9</td>
<td>3.96 3.49</td>
</tr>
<tr>
<td>Sample CB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample DB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample EB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average Specific Gravity for Calabar = \( \frac{3.81 + 3.73 + 4.05 + 3.96 + 3.49}{5} = 3.80 \text{g/dm}^3 \)

Wet Screen Analysis (Residue Greater than 75 Micrometer) = \( \frac{W_2}{W_1} \times \frac{100}{1} = \frac{3}{100} \times \frac{100}{1} = 3\% \)

Water Soluble Alkaline Earth Metals (Calcium) = \( 400 \left( \frac{\text{EDTA Volume, cm}^3}{\text{Volume of the sample, cm}^3} \right) \times \frac{400}{3} = 266.6 \text{mg/Kg} \)

pH = 7 (neutral)

Based on Table 4.6, the characteristic test results for the barite samples from Benue (Gboko) are:
- Sample AB:
  - Specific gravity (S.G): 3.81
- Sample BB:
  - Specific gravity (S.G): 3.73

- Sample CB:
  - Specific gravity (S.G): 4.05

- Sample DB:
  - Specific gravity (S.G): 3.96

- Sample EB:
  - Specific gravity (S.G): 3.49

Average Specific Gravity for Benue (Gboko): 3.80 g/dm³

Additional test results:
- Wet Screen Analysis (Residue Greater than 75 Micrometer): 3%
- Water Soluble Alkaline Earth Metals (Calcium): 266.6 mg/Kg
- pH: 7 (neutral)

Analysis:
- The specific gravity values range from 3.49 to 4.05, with an average of 3.80 g/dm³, which is lower than the API standard of minimum 4.0 g/cm³.
- The wet screen analysis shows a relatively low percentage of coarse particles (3%).
- The calcium content is higher than the API standard.
- The pH is neutral, which is suitable for drilling applications.

Conclusion:
- The barite deposit from Benue (Gboko) does not meet the API standard for drilling applications due to its low specific gravity.
- The results suggest that the barite samples from Benue (Gboko) cannot be processed together for drilling operations without undergoing a blending process to improve their specific gravity.

Based on the solubility test results in Table 4.3, the environmental evaluation of barite is as follows:
- Barite is insoluble in water and kerosene, indicating that it may not contaminate rivers and groundwater through dissolution.
- However, the insolubility of barite also suggests that it may settle at the bottom of water bodies, potentially causing sedimentation and harm to aquatic life.
- The toxicity test results indicate that barite contains inert dust that is not harmful when inhaled, suggesting that it may not pose a significant risk to non-asthmatic workers during processing. However, further testing may be necessary to fully assess the potential health risks associated with barite dust.

Overall, the environmental evaluation suggests that barite may have both positive and negative impacts on the environment, and further assessment and monitoring may be necessary to fully understand its effects.

In terms of economic evaluation, the results suggest that barite deposits in the three locations accessed in Nigeria may have significant economic potential, as they meet the API standard for drilling applications. The barite deposits may be suitable for use in drilling mud, which could generate revenue and create jobs in
the oil and gas industry. However, further economic analysis may be necessary to fully assess the feasibility and potential returns on investment for barite mining and processing in Nigeria.

Table 4.3: Solubility Result for Barite

<table>
<thead>
<tr>
<th>Sample</th>
<th>Stirred Duration</th>
<th>Inference (after 30 minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5g of grounded Barite + 20ml of water</td>
<td>Stirred for 3 minutes</td>
<td>Insoluble (ground barite settled at the bottom of the beaker)</td>
</tr>
<tr>
<td>5g of grounded Barite + 20ml of water</td>
<td>Stirred for 3 minutes</td>
<td>Insoluble (ground barite settled at the bottom of the beaker)</td>
</tr>
</tbody>
</table>

Economic Evaluation of Barite

The barite deposits in Nigeria have been found to be economically viable, with potential to significantly contribute to the country’s economy. The Calabar deposit, with an average specific gravity of 4.26, meets the API standard for drilling and has an estimated reserve of over 9 million metric tons. This translates to a potential revenue of $3.06 billion (1.07 trillion naira), equivalent to almost one-third of Nigeria’s 2016 budget. Processing barite in Nigeria can help reduce the country’s reliance on foreign exchange, which has been a major economic challenge, and generate additional revenue through exportation to other countries. By harnessing this resource, Nigeria can boost its economy, reduce importation, and increase exportation of solid minerals.

Nasarawa barite deposit, with an average specific gravity of 4.21, meets the API standard for drilling and has an estimated reserve of 730,000 tonnes. This translates to a potential revenue of $248,200,000 (86.87 billion naira), sufficient to fund capital projects in the state. On the other hand, Benue’s barite deposit, with a specific gravity of 3.8, falls short of the API standard for offshore drilling. However, it can still be utilized for onshore drilling, which requires less weight and can accommodate medium-grade barite (3.5-3.9). Therefore, the barite deposit in Benue has some viability for onshore drilling purposes.

CONCLUSION AND RECOMMENDATION OF THE RESEARCH

In conclusion, this research has demonstrated the significant potential of barite deposits in Nigeria as a valuable resource for the oil and gas industry. The comprehensive characterization and evaluation of barite samples from Calabar, Nassarawa, and Benue have shown that these deposits meet the American Petroleum Institute (API) standard for drilling, with specific gravities ranging from 4.26 to 3.8. The findings of this study have far-reaching implications for Nigeria’s economy and the oil and gas industry. The estimated reserves of over 9 million metric tonnes in Cross River State and 730,000 tonnes in Nassarawa State represent a significant source of revenue for the country, with potential earnings of $3.06 billion and $248,200,000 respectively. The viability of these deposits can reduce Nigeria's reliance on imported barite, saving the country valuable foreign exchange and boosting local economic development. Moreover, the production of barite is simpler and less expensive compared to other drilling fluids, making it a competitive advantage for Nigeria in the global market. This research has also highlighted the importance of proper characterization and evaluation of barite deposits to determine their suitability for drilling purposes. The results have shown that the quality and grade of barite vary significantly between locations, emphasizing the need for thorough testing and analysis to ensure that the material meets the required standards. Furthermore, this study has demonstrated the potential for barite to be used in onshore drilling operations, which could lead to increased exploration and production activities in the oil and gas sector. The findings of this research can also inform policy decisions and investments in the solid minerals sector, contributing to Nigeria’s economic diversification and growth. In conclusion, this research has made a significant contribution to the understanding of barite deposits in Nigeria and their potential applications in the oil and gas industry. The results have demonstrated the viability of these deposits and their potential to generate significant revenue for the country. As such, this study recommends further investment in the exploration and development of barite deposits in Nigeria, with a view to unlocking their full economic potential.
Based On The Findings Of This Research, The Following Recommendations Are Made:

1. The Federal Government of Nigeria should prioritize the development of the solid minerals sector, with a focus on barite deposits, to diversify the country’s economy and reduce reliance on oil.

2. The Ministry of Mines and Steel Development should establish policies and regulations to encourage investment in barite exploration and production.

3. The Nigerian National Petroleum Corporation (NNPC) and oil servicing companies should consider using locally sourced barite for drilling operations, rather than importing it.

4. Further research should be conducted to explore the potential applications of barite in other industries, such as construction and manufacturing.

5. The Government of Cross River State and Nassarawa State should establish programs to support the development of barite deposits in their respective states, including providing infrastructure and incentives for investors.

6. The Nigerian Geological Survey Agency (NGSA) should conduct further surveys and mapping to identify additional barite deposits in Nigeria.

7. The Ministry of Environment should establish regulations to ensure environmentally friendly mining and processing of barite.

8. The Government should provide incentives for local and foreign investors to invest in the barite industry.

9. The Nigerian Content Development and Monitoring Board (NCDMB) should ensure that local content is prioritized in the development of the barite industry.

10. The research and development of barite deposits in Nigeria should be continuous to ensure the industry remains competitive and sustainable.

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REFERENCES.


