# Evaluation of the Effectiveness and Cost Benefits Analysis of Nigerian Barite as a Substitute for Imported Barite in Drilling Fluid Formulation

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***Abstract*—Nigeria's economy is solely based on the export of crude oil; however, with the present decline in oil prices, the economy of the country has to diversify to boost its GDP. Focusing on the expansion of solid mineral processing is vital to boost the country's economy. In light of this, it's crucial to properly analyze Nigeria's vast barite deposits, therefore, it is important to do a thorough investigation on the use of Nigerian Barite in drilling fluid composition. As a result, we sought to evaluate the performance of locally produced barite as a replacement for imported barite in drilling fluid composition.100% imported Barite was used to formulate drilling fluid and the properties of the mud were determined using API standard method for testing water base mud. After this, a mixture of 75/25, 50/50, 25/75, and 100/0 local to imported Barites was used for mud formulation. The results showed that as the percentage of local Barite increases, drilling fluid density/weight also increases. The highest density in this analysis was seen to be 9.95 ppg when pure local Barite (100%) was used in drilling fluid formulation. In addition, the cost-benefit analysis indicates that as the percentage of local barite increases the percentage of cost saved increases. With a maximum percentage of the saved cost of 16.92 occurring when 100% of local barite was used to formulate drilling fluid. The outcome of this analysis proved that local Barite performs better economically and technically than imported Barite.**

***Keywords*—local Barite, foreign Barite, Cost-benefit analysis, drilling fluid, drilling mud**

## 1. Introduction

Drilling fluids design and formulation are of utmost importance because of its critical roles in drilling operations. Over the years, Nigerian firms engaged in designing and formulating drilling fluids for the oil and gas sector have imported various raw materials for the mud systems or, in some circumstances, imported formulated drilling mud. Companies in this sector change the drilling fluid's properties in each case to meet the formation requirement of the drilling site, typically with the use of additives that are also imported. This has been a major challenge, especially to the indigenous companies involved in this sector because of the high cost of importation of these materials and hence, hinders them from competing favorably with their foreign counterparts.

Generally, for drilling fluid to function efficiently during drilling operations and, prevent technical and financial losses, such drilling fluids must have a number of attributes that must be managed and maintained (Chen, 2002). The three essential characteristics of such fluid reported by King, (2020) includes rheology, density, and filtration. Other properties include electrical stability, toxicity, lubricity, and pH control. The weight and density of mud are frequently used interchangeably and it defines the hydrostatic pressure applied in the wellbore as well as serves as the foundation to regulate formation pressure while drilling. The density of the fluid constitutes a crucial component of drilling fluid; a very low mud weight can cause an influx of formation fluids which could result in a blowout if not adequately managed while extremely high mud weight can cause formation fracturing as well as lost circulation.

Barite is a solid mineral containing majorly barium and sulfur with molecular formula $BaSO_4$ (Yau *et al.*, 2015). Barite is predominantly used to increase the weight of drilling fluid due to its high specific gravity, softness, and inertness. These properties prevent damage to drilling equipment during drilling operations and also acts as a lubricant (Ebunu *et al.,* 2021). In Nigeria, there are vein and cavity-type deposits of barite and filling types. These deposits are usually found in a variety of rocks, including sandstone, migmatite, limestone, shale, mudstone, and porphyritic granite. According to Yang *et al*., (2020), barite is frequently found combined with other minerals such as fluorite, magnetite, calcite, quartz, siderite, galena, and dolomite. Although Barite has several industrial applications, it is primarily employed as a mud-weight additive in the Petroleum industry in Nigeria (REF). The market for Barite will continue to rise as long as investment in the petroleum and natural gas industries remains stable. In 2003, the Nigerian government bound the importation of barite into the country to allow the local barite sector to develop (Mills, 2005). However, in 2013, the International Oil Companies (IOCs) operating in Nigeria requested a relaxation of the limitation on imported barite on the grounds that locally-produced barites were of poorer quality compared to the imported ones (Industrial Minerals Form and Research, 2017).

In line with the API standards and best practice, the specific gravity of barite should be 4.2 and above for application as a drilling mud additive. The specific gravity of local barite ranges from 3.5 to 4.5 depending on the source (Ebunu et al., 2021). The Geological Survey of Nigeria Report No. 1266, documented the presence of barites in Benue and Plateau States. Five of the eighteen veins in Azara field, Nasarawa State studied by the Nigeria Mining Corporation, in 1987 reported a deposit of about 730,000 tons of barite.

Nigeria's economy has been entirely dependent upon the export of crude oil for decades but with the current fluctuations in oil prices, the nation's economy needs to diversify. In order to improve the nation's economy, it is necessary to also concentrate on the growth of other sectors like solid mineral processing. Hence, it's important to carefully consider Nigeria's enormous barite reserves. Hence proper study on Nigerian Barite in drilling fluid formulation application is pertinent. Therefore, we aimed at evaluating the effectiveness of local Barite as a substitute for imported Barite in drilling fluid formulation.

## 2. Materials and Methods

All experimental procedure including the specification of equipment used in this analysis were in line with the API standards.

### 2.1 Materials

The materials employed for this investigation include barite, bentonite, $CaCO_{3,}$ biocide and soda ash.

### 2.2 Equipment

The equipment/apparatus used for this analysis consists of oven, desiccator, Le Chatelier flask and others include constant temperature bath, high accuracy balance as well as glass wares, absorbent, weighing dish and thermometer.

### 2.3 Experimental Procedure

Firstly, 100% foreign barite was used to formulate mud and the properties of the mud were determined using a suitable method as described by Achadu and Osadolor (2022). Also, the following ratios 75% foreign Barite and 25% local Barite, 50% foreign Barite and 50% local Barite, 25% foreign Barite and 75% local Barite, and finally, 100% local Barite were used for mud formulation.

### 2.4 Formulation of Drilling Mud

The formulation of the drilling mud and the determination of the rheological properties and mud weight were carried out based on the API drilling mud formulation standards. Fresh water and various raw materials were placed in a mud mixing cup (measured in grams using a graduated cylinder and +electronic weighing balance). The raw materials were added in a mixing order in an interval of 5 minutes into the mixer cup except barite with a mixing time of 30 minutes. The application of the raw materials was carried out in descending order as presented in Table 2.

| S/N | Chemicals Used | Unit | Amount Used | Function |
|---|---|---|---|---|
| 1 | 15 PPB Bentonite | BBL | 0.889 | Viscosifier |
| 2 | Soda Ash | PPB | 0.25 | Shale Inhibition |
| 3 | Caustic Soda | PPB | 0.25 | pH Adjuster |
| 4 | Calcium Carbonate (Coarse, Medium, Fine) | PPB | 10 | Bridging Agent |
| 5 | Biocide | PPB | 0.5 | Bacteria Inhibition |
| 6 | Barite | PPB | 150 | Weighting Agent |

**Table 2: Water-Based Drilling Mud Formulation System**

### 2.5 Testing Procedure

#### 2.5.1 Determination of Mud Weight, Rheological properties and Fluid Loss

The procedure for the determination of mud weight, rheological properties (plastic viscosity, yield point and gel strengths – 10 minutes and 10 seconds) and fluid loss followed the methods specified in the study conducted by Osadolor et al. (2022), Achadu and Osadolor (2023) and Achadu et al (2023). The processes were repeated for the different ratios of foreign – local barite combinations.

## 3.0 Results and Discussion

### 3.1 Results

The results of the investigation are presented in tables and graphs. Tables 3, 4, and 5 are Barite Quality Analysis Test Results, the Effect of varying the percentage of both imported and local Barite, and Barite Cost Benefit Analysis while Figures 1 and 2 represent the Effect of variation in the percentage of local and imported Barite on the density(weight) of the drilling fluid and Percentage of cost saved against percentage of local barite, respectively.

**Table 3: Barite Quality Analysis Test Result**

| Parameter | Test Results | | API Specification/Requirement |
|---|---|---|---|
| | Foreign | Local | |
| **DENSITY** | 4.1 | 4.23 | 4.2b/ml threshold limit |
| **RESIDUE > 75μ (%)** | 0.58 | 0.74 | Maximum mass fraction: 3% |

**Table 4: Effect of percentage variation of imported and local Barite on the drilling fluid properties**

| | Barite (Imported: Local) | | | | |
|---|---|---|---|---|---|
| | **100:0 (control)** | **75:25** | **50:50** | **25:75** | **0:100** |
| **SG** | 4.10 | 4.13 | 4.17 | 4.20 | 4.23 |
| **Density** (Ppg) | 9.6 | 9.62 | 9.66 | 9.8 | 9.95 |
| **PH** | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 |
| **API Fluid Loss (ml)** | 10 | 10 | 10 | 10 | 10 |
| **Water (%Volume)** | 58 | 58 | 58 | 58 | 58 |
| **Solids (%Volume)** | 42 | 42 | 42 | 42 | 42 |
| **600** | 57 | 57 | 57 | 57 | 57 |
| **300** | 39 | 39 | 39 | 39 | 39 |
| **200** | 31 | 31 | 31 | 31 | 31 |
| **100** | 22 | 22 | 22 | 22 | 22 |
| **6** | 7 | 7 | 7 | 7 | 7 |
| **3** | 6 | 6 | 6 | 6 | 6 |
| **PV** | 18 | 18 | 18 | 18 | 18 |
| **YP(Lbs/100ft$^2$)** | 21 | 21 | 21 | 21 | 21 |
| **10secs Gel** | 9 | 9 | 9 | 9 | 9 |
| **10min Gel** | 19 | 19 | 19 | 19 | 19 |

**Table 5: Barite Cost Benefit Analysis**

| Mud Properties | Result | | | | |
|---|---|---|---|---|---|
| **Percentage (Imported: Local)** | **100:0** | **75:25** | **50:50** | **25:75** | **0:100** |
| **SG** | 4.10 | 4.13 | 4.17 | 4.20 | 4.23 |
| **The density of Mud (PPG)** | 9.6 | 9.6 | 9.6 | 9.6 | 9.6 |
| **Mass Concentration of Mixture (PPB)** | 150 | 150 | 150 | 150 | 150 |
| **Cost of Mixture (USD)** | 23.814 | 22.964 | 22.113 | 21.263 | 20.412 |
| **Mass Concentration of Mixture Used (PPB)** | 150 | 148.91 | 147.48 | 146.43 | 145.39 |
| **Cost of Mixture Used (USD)** | 23.814 | 22.80 | 21.742 | 20.757 | 19.785 |
| **Cost Saved (USD)** | 0 | 1.014 | 2.072 | 3.057 | 4.029 |
| **% Cost Saved** | 0 | 4.26 | 8.70 | 12.84 | 16.92 |

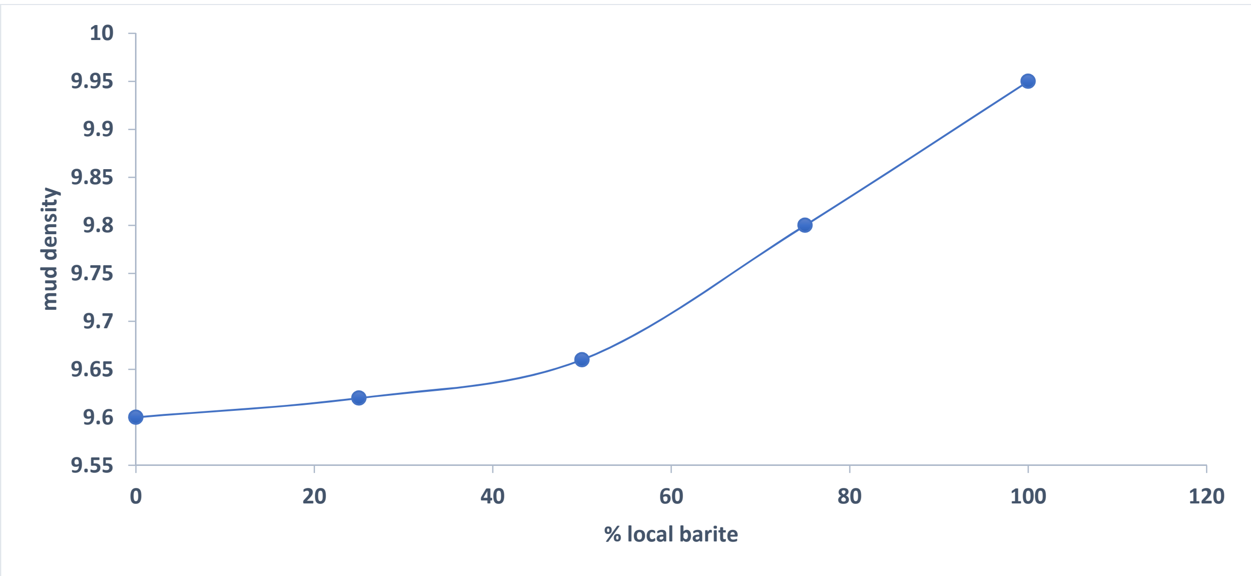


**Figure 1: Mud Density against % of Local Barite**

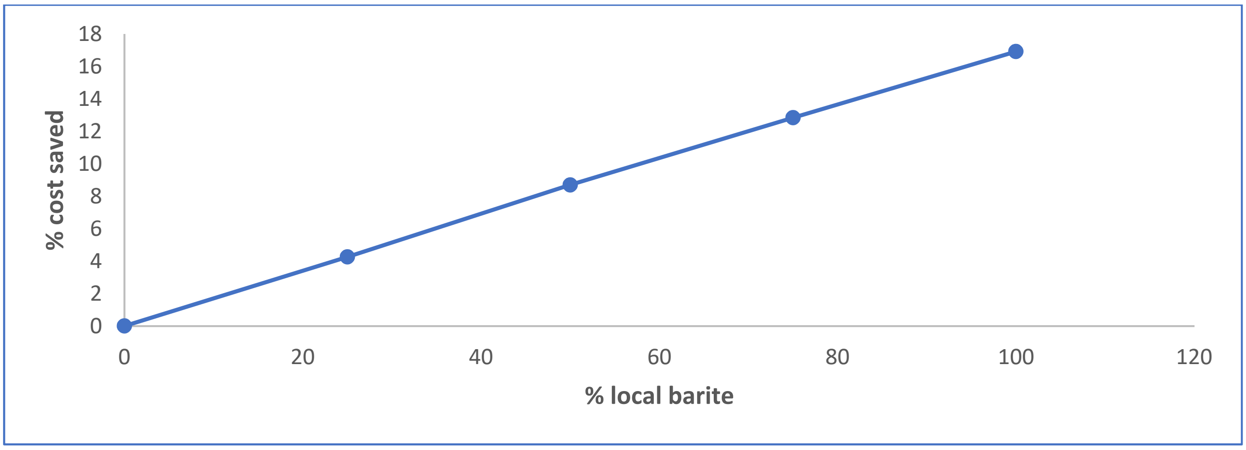


**Figure 2: Percentage of cost saved against percentage of local barite**

### 4.2 Discussion

#### 4.2.1 Mud Density

According to (ADCO, 2005) and (Amoco, 2006), mud density is utilized to support the wellbore and regulate subsurface pressures. It serves as a measure of the Mud's weight. Due to its high specific gravity, softness, which prevents damage to drilling equipment during operations, and ability to act as a lubricant, barite is commonly as an additive to boost the weight of drilling fluid (Ebunu et al., 2021). The Petroleum industry uses almost all of the barite that is sourced as a weighting agent in drilling fluid. Since drilling processes involve high reservoir pressure, this calls for a dense circulating fluid that must counter the high-pressure zones of the formation in order to regulate the pressure in the reservoir and prevent blowout. (Ebunu, et al., 2021; Dhorgham, et al., 2016).

The locally sourced barite showed higher specific gravity than the imported one as depicted by the results in Table 3. Also, because of the direct relationship between density and specific gravity, it follows that barite with a high specific gravity will impact greater effects on the drilling fluid's mud density, as shown in Table 4 and Figure 1. Table 4 demonstrates that the drilling fluid with a 100% local Barite formulation produced mud with a higher density of 9.95ppg while the drilling fluid formulated with 0% local Barite (100% imported Barite) produced mud with a lower density of 9.6ppg. According to the trend, the specific gravity of the resulting Barite mixtures increases as the amount of local Barite increases, resulting in a higher mud density.

More so, because of the inertness of Barite, it has no effect on the rheology, pH, and filtration properties of the drilling fluid. These outcomes conform to the findings of (Dhorgham, et al., 2016; Ebunu, et al., 2021). Furthermore, the outcome of Figure 1 indicates that mud density increases as the percentage of local barite increases. Hence, local Barite outperformed imported barite.

### 4.3 Cost Benefit Analysis

Nigeria imports barite worth $300 million a year (Vanguard-News, 2021). Nigeria's barite reserve is more than 21 million tons (Kolawole, et al., 2019; Ebunu, et al., 2021; Okonkwo, 2021). Nigeria has a sizable resource of barite, but it only generates 10,000 tonnes per year and uses 23,000 tonnes, creating a shortage of about 13,000 tonnes. Because of this, Nigeria has been forced to rely on importing barite from nations like China, the Netherlands, Morocco, Egypt, and India. According to data that was made available, Nigeria imports 13,000 tons per year (Kolawole, et al., 2019; Okonkwo, 2021). The average cost of imported barite in Nigeria is $350 per metric tonne and that of local barite is $300 per metric ton.

For the cost-benefit analysis, a formulated drilling fluid with a mud density of 9.6 ppg will be taken as a reference point. In this analysis, 150 PPB of imported barite was used to formulate drilling fluids. In Table 5, we noticed that as the percentage of imported barite decreased and the percentage of local barite increased, the cost of the resultant barite mixture decreases. A drilling fluid formulated with the100% local barite happens to be the cheapest compared to others. Additionally, the mass of the barite mixture needed to formulate a mud 9.6ppg decreases as the percentage of the local barite increased from 25% to 100%, hence the cost of the required barite also decreases. This is a desirable outcome because a drilling fluid requires a minimum solid content to deliver optimum results. Mud with higher solid content has many negative side effects on the performance of drilling fluid, such as drill pipe damage due to abrasion, pump damage resulting from excessive drag force, etc.

Furthermore, the percentage of cost saved increases as the percentage of local barite increase from 25% to 100%. The maximum saved amount of $4.029 per barrel can be seen when 100% local barite was used to formulate drilling fluid. The outcome of Figure 2 demonstrates that as the percentage of local barite increases the percentage of cost saved increases. With a maximum percentage of the saved cost of 16.92 occurring when 100% of local barite was used to formulate drilling fluid. Conclusively, it is more profitable and cost-effective to use locally sourced barite to formulate drilling fluid compared to imported barite.

## 4Conclusion

**The study on the applications of locally and foreign sourced barite for the formulation of drilling mud proved the following:**

- ✓ Local Barite is be superior to the imported Barite
- ✓ It is more economical to formulate a drilling fluid using locally sourced barite.
- ✓ Based on the properties of the well to be drilled, a giving ratio of additive (as demonstrated from this study) that will minimize cost and give optimum performance to the drilling fluids can be chosen.
- ✓ Sequel to the high performance of the locally sourced barite investigated over the imported ones, it is recommended that the importation of barite should be minimized or stopped.

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