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Effect of Quartz (Free Silica) Removal on the Quality of Nigerian Bentonitic Clays for application in Drilling Fluid Formulation

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ABSTRACT

The Nigerian Bentonitic clay samples with excess crystalline silica (quartz), that causes abrasion of the drilling equipment , affects circulation of the mud, decreases the drilling rate and pipe sticking during drilling operations were investigated. The Particle size distribution analyses (PSD) of the raw and Beneficiated Nigerian Bentonitic clay samples were carried out. The removal of excess crystalline silica from the samples was achieved through wet beneficiation method. The PSD results after wet beneficiation of the clay samples indicated that the sand content in Garin Hamza Futuk, Pindiga, Tongo, Bulabulinmaiduwa and Sabongarin Ngalda samples reduced from 48, 54, 48, 49 and 52 % to 21, 17, 15, 17 and 21% respectively, while the clay content significantly increased from 38, 42, 24, 24 and 24% to 73, 73, 63, 61 and 63 % respectively. The Bentonitic clay samples have texturally transformed to clay after thorough wet beneficiation, hence they can be used for drilling fluid formulation.

Key words: Bentonitic clay, Quartz, PSD, Beneficiation and Drilling fluid

INTRODUCTION

Drilling has evolved from vertical, inclined, horizontal to sub-sea and deep-sea drilling. These specialized drilling processes require specialized drilling fluids to fulfil the objectives. Since reservoir type and the drilling process adopted to exploit the reservoir fluid is unique, the drilling fluid has to be customized to suit the drilling process and reservoir conditions. (Sabhash et al., 2010).

Nigeria is ranked the seventh largest exporter of crude oil in the world. On a daily basis it produces over two million barrels of crude Oil from hundreds of Oil wells drilled in the Niger Delta area. Not a single of these Oil wells are drilled without the use of Bentonite. Hundreds of millions of dollar is being spent by the oil companies on importation of Bentonite from overseas while Nigeria has enough reserve of Bentonitic clay deposit all over the country which requires just a little beneficiation to meet the required standard for use as a drilling mud in oil well drilling operations. This will translate into retaining the large sum of money sent overseas for importation of foreign Bentonite, create employment opportunities, bring external investment and boost the country's economy (Arabi et al., 2011).

Bentonite is a rock formed of highly colloidal and plastic clays composed mainly of montmorillonite, a clay mineral of the smectite group, and is produced by in situ devitrification of volcanic ash. In addition to montmorillonite, bentonite may contain feldspar, cristobalite, and crystalline quartz.

The special properties of bentonite are an ability to form thixotrophic gels with water, an ability to absorb large quantities of water, and a high cation exchange capacity. The properties of bentonite are derived from the crystal structure of the smectite group, which is an octahedral alumina sheet between two tetrahedral silica sheets. Variations in interstitial water and exchangeable cations in the interlayer space affect the properties of bentonite and thus the commercial uses of the different types of bentonite.

A successful drilling operation is tied to the selection of the drilling fluid and composition (Williamson, 2013). Deposits of bentonite have been found to be available in the Northern parts of Nigeria like Borno, Yobe, Adamawa, Bauchi, Gombe, Sokoto and Kebbi. But as stated most are non-swelling bentonite and contain some non-clay mineral materials which are impurities affecting their quality for application, which require some processing or beneficiation studies and formulation to improve their swelling capabilities, remove impurities and increase their montmorilonite content by converting calcium bentonites to sodium bentonites by treating with sodium salts in order to exchange the calcium ions for sodium ions, to meet the requirements of a standard clay material (James et al.,2008).

This research is aimed at enhancing the quality of the Nigerian Bentonitic clay through removal of impurities such as excess quartz (crystalline silica) and feldspars that causes abrasion of drilling equipment and make the fluid quite unsuitable for oil and gas drilling operations.

MATERIALS AND METHODS

Methodology for Silica Removal

The raw Bentonitic clay samples were collected from five different locations (Figure 1) of the marine environment of upper Benue trough, north eastern Nigeria and were brought to the Department of Material Science laboratory, Centre for Energy Research and Training (CERT) for further analysis.

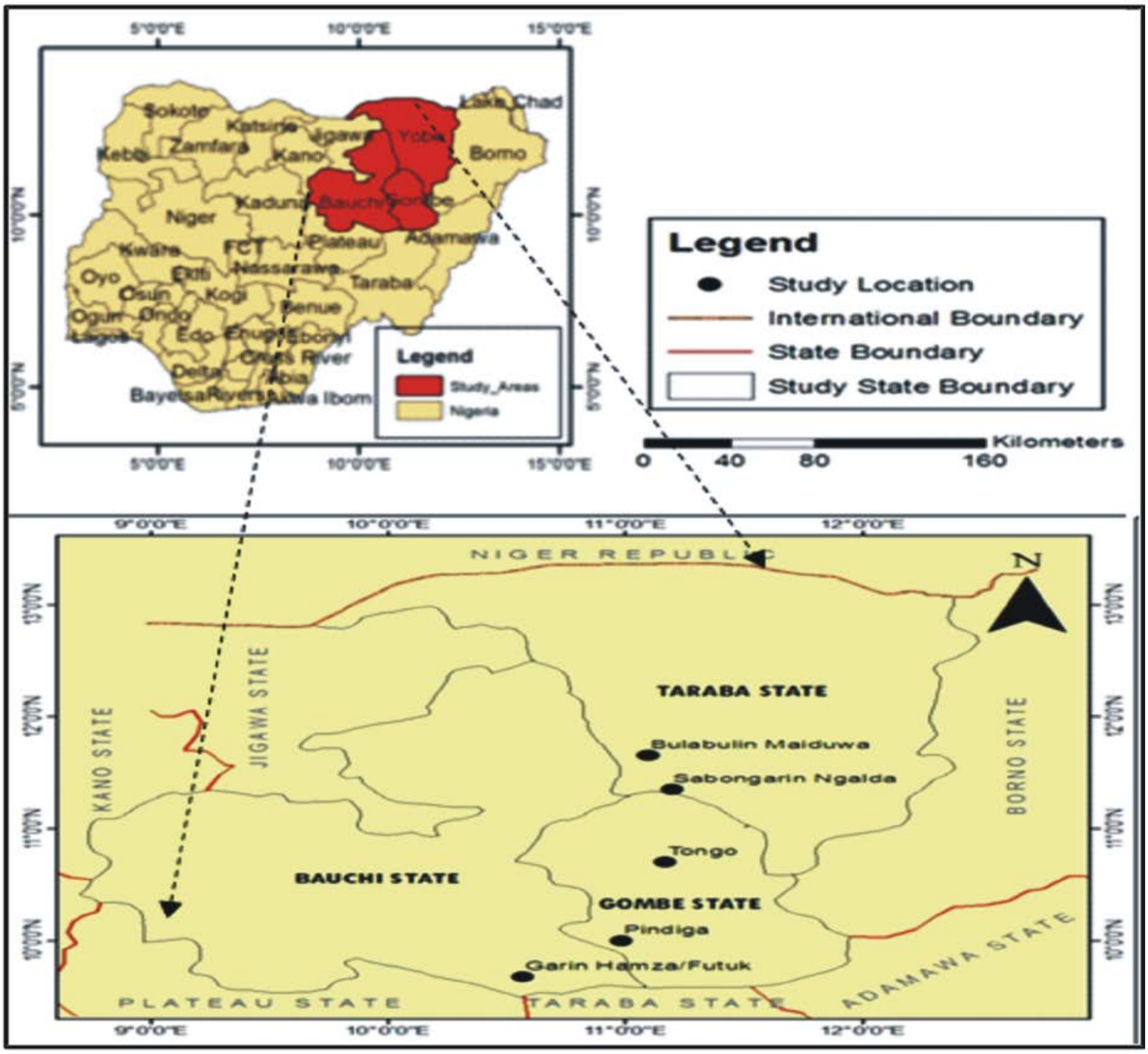


Figure 1: Map of study area showing sample locations

The raw Bentonitic clay samples were wet-beneficiated in order to purify them from physically and chemically combined impurities such as metallic oxide, grits and to reduce the excess silica. The raw clays were dried at room temperature and crushed to less than 125 µm particle size usingball mill machines. Then, the crushed samples were dissolved in water (clay-water ratio 2:5) by stirring until no lumps were present, the mixture was allowed to stay for 24 hours after which clay slurry settled into three distinct layers, the bottom coarse particles, the middle fine clay particles and the top supernatant water layer. The middle layer (clay portion) was collected for further activity after decanting the supernatant water, while the bottom coarse particles considered to be excess quartz were discarded.

The fine clay slurry was sieved using Tyler sieve of mesh size 230 (63 µm aperture opening) so as to further separate the fine grits present in the fraction. The resulting clay slurry was allowedto settle and the supernatant water layer was removed by leaving it for 48 hours in clay pot. Then finally the solid clay cake was dried in an oven at 60^{o}C for 48 days to completely dry the samples ready for Na activation.

Particle Size Distribution Analysis

The particle size distribution analysis using hydrometer method as described by Bouyoucos, (1962) was used for the particlesize distribution analysis of the various bentonite clay samples. The powdered clay samples were sieved to obtain 2 mm size which is the required specification for this analysis (Shuwa, 2010; Adamu, 2013). 100 mL of sodium hexametaphosphate (dispersant) was added to 50 g of the clay sample and shaken for 15 minutes using a mechanical shaker. The bottle was gently agitated and its content was transferred into a 1 liter measuring cylinder. Water was then added to the cylinder to the 1 liter mark. A thermometer was used to determine the temperature of the sample. A plunger was used to mix the sample properly. An ASTM soil hydrometer was immediately placed inside and a stop clock set on. At exactly 40 seconds the reading where the level of water coincides with the calibration on the hydrometer was taken. Another hydrometer reading was taken after 2 hours. Blank reading was initially taken for the control sample using water and sodium hexametaphosphate. This procedure was carried out on all the clay samples and the following formulas were used in calculating the particle size distribution.

For 2 hour reading:

$$\%\ \text{Clay} = R - B + \Delta T * 0.36 * 2 \quad \ldots\ldots \;\ldots .1$$

$$\%\ \text{Silt} = R - B + \Delta T * 0.36 * 2 - \%\ \text{Clay} \ldots 2$$

For 40 seconds reading:

% Sand = {100 – (% Clay+ % Silt)}…..........3

where:

R = hydrometer reading (2 hours or 40 seconds)

B = blank hydrometer reading

ΔT= Ts- Tstd

Ts = 24^{o}C (temperature of the sample), Tstd = 20^{o}C standard temperature.

Their textural classification was derived from the United States Department of Agriculture (USDA) soil texture triangle chart depicted in Figure 2.

Figure 2: USAD Soil Texture Triangular Chart, by The University of Idaho (2014) modified from Gee and Bauder (1986), available at http://www.oneplan.org/Water/soil-triangle.asp

RESULTS AND DISCUSSION

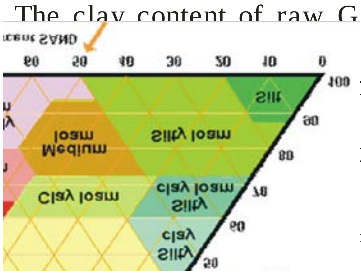
Particle Size Distribution Analysis Results

The particle size distributions of the locally sourced Bentonitic clays were determined using hydrometer test as described above. The size of all the clay materials ranges from clay (< 0.002 mm), to silt (0.002 – 0.05mm) to sand (0.05 – 2mm) at various proportions.

The particle size analysis was carried out for both the raw and pre-treated (silica removed). It was noticed that the raw samples have excess sand (quartz/silica) compared to standard (40% sand). The clay contents in all the samples are also relatively below standard (52% clay). Raw Garin Hamza and Pindiga wer found to be sandy clay from textural classification. Because of relatively low clay content of 38% and 42% respectively, and relatively high sand content of 48% and 54% respectively. Tongo, Bulabulinmaiduwa and Sabongarin Ngalda are Sandy loamy clay according to soil textural classification. These samples contain a little amount of organic matter that originated from the environment of deposition.

S. No	Sample Name	Particle Size Distribution of Raw Samples Corrected to 20 °C (%)				Particle Size Distributionof Silica RemovedSamples Correctedto 20°C (%)			
		Clay <0.002mm	Silt 0.002-0.05mm	Sand 0.05-2mm	Textural Class	Clay <0.002mm	Silt 0.002-0.05mm	Sand 0.052mm	Textural Class
1	API Standard	-	-	-	-	52	8	40	Clay
2	Garin Hamza	38	14	48	Sandy Clay	73	6	21	Clay
3	Pindiga	42	4	54	Sandy Cay	73	10	17	Clay
4	Tongo	24	28	48	Sandy Clay Loam	63	22	15	Clay
5	Bulabulin Maiduwa	24	27	49	Sandy Clay Loam	61	22	17	Clay
6	S/Garin Ngalda	24	24	52	Sandy Clay Loam	63	16	21	Clay

The samples from which crystalline silica was removed showed significant increase in the clay content and decrease in sand content. The clay content of raw Garin Hamza Futuk,



aiduwa and Sabon n 38, 42, 24, 24 and 63 % respectively, ed from 48, 54, 48, and 21% respectively. This has proved that the sand contents have drastically reduced due to quartz (crystalline silica) removal through wet beneficiation and the samples have texturally improved to clay.

CONCLUSION

The Particle size distribution analysis (PSD) results of the raw Bentonitic clay samples have shown that there is presence of excess crystalline silica (quartz), which after wet beneficiation the sand content in Garin Hamza Futuk, Pindiga, Tongo, Bulabulinmaiduwa and Sabongarin Ngalda reduced from 48, 54, 48, 49 and 52 % to 21, 17, 15, 17 and 21% respectively, while the clay content significantly increased from 38, 42, 24, 24 and 24% to 73, 73, 63, 61 and 63 % respectively. The Bentonitic clay samples have texturally transformed to clay after wet beneficiation, thus making them better suited to be used for drilling fluid formulation.

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