Indonesian Journal of Environmental Management and Sustainability
e-ISSN:2598-6279 p-ISSN:2598-6260

Research Paper

Study of the Characteristic of Clay from Muratara Regency as Subtituent Materials for API Bentonite for Drilling Mud based on API RP 13B

Azka Roby Antari[1]*, Machmud Hasjim[1], David Bahrin[1]

[1] *Mining Engineering, Sriwijaya University, Palembang, Indonesia, 30139*
***Corresponding author e-mail**: azkarobya@gmail.com

Abstract

Bentonite, especially Sodium (Na) Bentonite is a type of clay that is used as a basis for water-based drilling mud in the of oil and gas wells drilling throughout the world including Indonesia, bentonite used in Indonesia is still partially imported from abroad. Sodium Bentonite can be substituted with ordinary clay which is treated by beneficiation throught addition of Na_2CO_3. The area of Musi Rawas Utara (Muratara) Regency of South Sumatra Province contains clay reserves resulting from pyroclastic deposit which will be investigated as potential subtitutional materials of imported API Bentonite. Clay samples from 6 different locations were prepared by first looking for the best % swell of sample beneficiation combination from all over the 36 combinations through the free swell test, the results obtained that the 4% BWOC Na_2CO_3 combination gave the best % swell. From this, 24 samples were prepared for various measurements of mud properties using standard equipment and procedures following the API RP 13 B for water-based mud with drilling grade Na-bentonite (API Bentonite) as standard material. The test includes 7 properties divided into 16 parameters namely density, rheology, filtration, solid-liquid content, sand content, pH and methylene blue capacity. The test result shows that 4% Na_2CO_3 was the best concentration of beneficiation which is able to change ionically the characteristics of Muratara clay, but from the aspect of suitability, the value of each test parameter compared to the standard value shows none of the samples has minimum of 80% suitability, thus technically, it is very small chance for Muratara clay to be able to be used as a substituent material to the standard API Bentonite.

Keywords

beneficiated clay, clay of Musi Rawas Utara, API bentonite subtitution

Received: 20 February 2020, Accepted: 13 March 2020
https://doi.org/10.26554/ijems.2020.4.1.1-9

1. INTRODUCTION

Bentonite is included in the clay rock group with montmorillonite as its main mineral, consisting of Sodium (Na) Bentonite and Calcium (Ca) Bentonite, Sodium Bentonite type has a high swelling ability, widely used in oil well drilling as a basis subtance for drilling mud, the ionic bonding properties are used to control viscosity while maintaining the stability of borehole walls, while Calcium Bentonite is often used as bleaching material in the palm oil industry and in handling textile waste (API, 1997; Abdullahi et al., 2011; Apugo-Nwosu et al., 2011).

The world's leading bentonite mine is in Wyoming, United States. The characteristics of Wyoming bentonite are internationally-known standard used in oil and gas industry which then called as "API Bentonite" or "Wyoming Bentonite". It is being exported worldwide to supply the demands from oil producing countries. While in Indonesia, bentonite reserves were found at several area on the island of Java, such as in Pacitan, Boyolali, Tasikmalaya and on Sumatra island such as in Merangin, Bangko, Pangkalan Brandan, but most are Ca-bentonite or low grade bentonite, only a few are Na-bentonite, a natural bentonite mine that has been in production state is in the Pacitan Regency, East Java. BPS (National Buereu o Statistics) 2013-2016 export / import publications state that the need for bentonite in the Indonesian oil industry was still widely supplied from abroad, from this it can be obtained an idea to substitute imported materials with local products with similar specifications (Bilal et al., 2016; Singh and Sharma, 1994). If this can be realized and supported by government policies, many excesses will emerge either in the form of reducing imports volume, creating new jobs, and increasing local content in the oil industry (Nasir et al., 2013).

South Sumatra Province has several areas where clay deposits are mined, in OKI and Banyuasin Regencies, clay is dig up to supply landfill material needs, Muara Enim Regency, Musi Banyuasin and Musi Rawas Utara, clay sediments are used as the main material for making bricks, while in OKU, clay is an additional material in cement industry. However, in this study, the sample used is clay from North Musi Rawas (Muratara) Rgency by considering that the bentonite rock genes are pyroclastic sediments, and the location of the sediment is also closer to the original source, the Bukit Barisan volcanic belt.

The characteristics of local clay Muratara are not suitable to be used directly to substitute bentonite, but with certain beneficiation treatment can ionically change clay characteristics to resemble the characteristics of API Bentonite. This study tries to compare the properties of drilling mud between Na_2CO_3-beneficiated mud against API Bentonite mud.

2. EXPERIMENTAL SECTION

2.1 Type of Research

This type of research is experimental research with quantitative methods. Quantitative method is a research method which its analysis focused on numerical data that is processed using statistical methods. This study will analyze how the beneficiation of various Na_2CO_3 concentrations influence the values of of Muratara clay mud properties compared to the standard API Bentonite mud properties.

2.2 Date and Location of Research

The study was conducted at the end of 2019, sampling activities from Muratara Regency starts in August and preparation of clay samples from drying to data processing took approximately 5 weeks in October - December , followed by research reports.

The measurement of physical and chemical properties of clay conducted at the Drilling Fluid Analysis Laboratory in Palembang, while the basic material (clay) samples is taken from the area of Muratara Regency. The sample from Muratara was chosen primarily because of the Researcher's curiosity to further study the potential of local natural resources, also because of considerations :

1. Alternative materials from previous studies; some previous studies such as in Nigeria (Omole et al., 2013; Nweke et al., 2015; Dewu et al., 2011, 2016), India (Singh and Sharma, 1994), Turkey (Karagüzel et al., 2010; Hassan and Abdel-Khalek, 1998) and others, taking clay material from the type of bentonitic clay (low grade Ca-bentonite) to be beneficiated with various types of additives into a drilling grade API bentonite (Na-bentonite) as drilling mud subtance, where similar research has never been done in Indonesia, existing research uses clay (Nasir et al., 2013) and natural bentonite /organobentonite from various regions (Sarolangun (Taher et al., 2018a,b)) and Gresik (Ramadhan et al., 2015) not used for drilling fluids, but as ceramic filter material, alcohol dehydration catalyst and as purifying agent in the CPO industry and in handling textile waste.
2. Similarity of raw clay genesis with bentonite genesis; clay is the result of weathering process of pyroclastic deposits that have undergone alteration where these deposits are found in the Kasai Formation in Muratara (Kusdarto and Sutandi, 2006), especially around the district of Surulangun and Rawas Ulu where the sample is excavated, it is known that there are pyroclastic deposits on the edge of the Bukit Barisan mountain range (Sjahril et al., 2004), which are geographically adjacent to areas where there are known bentonite reserves, Sarolangun and Merangin in the north and Muara Rupit in the south.

Clay sampling method is carried out randomly, in-situ samples taken from a depth of more than 1,5 meters from the surface soil in order to be free from impurities or detritus material such as leaves, tree roots, humus or others. Sampling locations in Muratara Regency are shown in Figure 1:

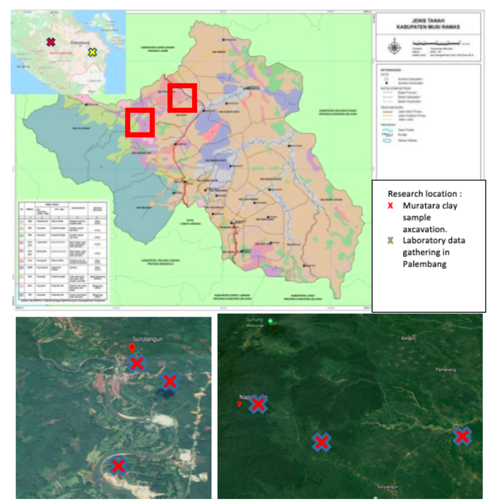

Figure 1. Location Points of Clay Samples Taken

Muratara Regency is located in the west part of South Sumatra Province, covering an area of 600,865.51 km^2, geographically located at 103°23'30"E - 102°6'0" E and 2°10'0"S - 3°12'0"S, the sampling points themselves have the coordinates as listed in the following table 1.

2.3 Tools and Materials

The tools used in this study as per American Petroleum Institute RP-13 Series specifications and standard procedures, are :

1. Raw material size reduction equipment : Grinders and Sieve shaker.
2. Equipments for making slurry samples : Mechanical mixer and Measuring cups.
3. Mud properties testing equipments : Mud Balance to measure density; viscometer/ Rheometer to mea-

Table 1. Samples Location Coordinates

No	Sample Code	Coordinate	Elev. (masl)	Location
1	A	2°41'43.3"S 102°23'06.9"E	163	Napal Licin Village, Rawas Ulu District
2	B	2°41'43.3"S 102°23'08.5"E	147	Napal Licin Village, Rawas Ulu District
3	C	2°42'33.2"S 102°26'00.2"E	126	Muara Kulam Village, Rawas Ulu District
4	D	2°37'45.5"S 102°48'18.1"E	67	Lesung Batu Muda Village, Rawas Ulu District
5	E	2°36'47.4"S 102°45'44.5"E	78	Pasar Surulangun, Surulangun District
6	F	2°33'02.5"S 102°45'29.9"E	70	Simpang Nibung Village, Surulangun District.
7	Ca-Ben	-	-	Palembang
	Na-Ben	-	-	Palembang

sure apparent viscosity plastic viscosity, gel strength, yield point, marsh Funnel to measure Funnel viscosity; LPLT Filter Press to measure the volume of filtrate and mud cake thickness, solid and liquid retort Kit to measure the percentage of solid and liquid content; Sand Content Kit to measure the percentage of sand content; pH Meters and pH strips to measure pH; Methylene Blue Test Kit to measure cation exchange capacity.

Clay samples obtained from Muratara Regency are then processed through a series of processes in order to get samples that are ready to be tested in the laboratory.

1. Muratara Clay

   Muratara clay samples have physical characteristics in the form of color; white gray, reddish white to whitish/ bright brown, grain size ; clay to sand, clay textured in wet conditions, pH ranges from 4 - 5, often used by local people for brick, tile and backfilling materials.

   Chemical composition of Muratara clay in this study is unknown because XRD analysis was not carried out due to various obstacles, but based on literature studies, the chemical composition of bentonitic clay from various parts of the world are generally the same, namely Al2O3, SiO2, CaO, MgO, Fe2O3, K2O, Na2O and associated minerals, it differs only in varying percentages, which depend on environmental conditions at the moment it was formed such as temperature, pressure and associated minerals. Some research results which analyze the chemical composition of bentonitic clay from all over the world are presented Fig. 2.

   The graph above shows that the similarity of the dominant pattern of bentonitic clay chemical composition, despite being in different locations, in general the main composition of clay are the same dominated by silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3) and a little of other oxide salts. The composition of the Bentonite API itself is basically the same, on the graph the concentration of some components appears to be lower, but still within range.

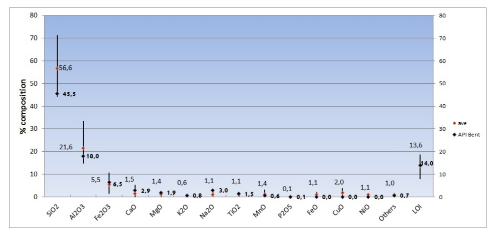

Figure 2. Distribution of the average percentage of the chemical composition of bentonitic clay

   The clay sample is processed through a series of processes to get the sample ready for laboratory test, the sample is first air dried for one month to reduce its water content, then crushed to reduce the grain size, the sample then washed with clean water to form slurry, aqueous conditions help facilitate the dozing of granules which are still large in size as well as removing impurities that are still left behind (degritting), then carried out leaching, where the sample is washed by settling the sample overnight (24 hours) so it is deposited, then the water is drained by first removing dirt (stone or remnants of roots) and filtering out clay deposits using a screen. Then the sample is dried naturally by drying in the sun or heating in the oven, the dried sample is then again crushed to remove lumps, the results of the grinding process are processed to the next stage of sieving, the sample is sieved using a sieve shaker in order to obtain a uniform sample size, sample powder that passes 200 mesh (74 μm) will be used for this test sample, so that it is proportional

Table 2. Beneficiation agent in several studies

No	Beneficiation agent/ Activator	Material	Researcher
1	Drispac and Potash	Local clay form Abbi, Ndokwa, Nigeria	Omole et al. (2013)
2	Sodium Dithionite and Sodium Sulphite and Oxalic acid	Raw bentonit of Bavnagar, Gujarat, India	Singh and Sharma (1994)
3	Na_2CO_3	Ca-Mg bentonite from Abu Zeneima, Sinai, Egypt	Hassan and Abdel-Khalek (1998)
4	Na_2CO_3	Local bentonit from south Eastern Nigeria	Nweke et al. (2015)
5	Na_2CO_3	Ca-bentonit form north eastern Nigeria	Abdullahi et al. (2011)
6	Na_2CO_3, MgO, dan combination of both	Na- dan Ca-bentonite from Sankiri, Turkey	Karagüzel et al. (2010)
7	HCl	Natural bentonite form Merangin	Nasir et al. (2013)
8	NaCl	Ca-bentonit from Trenggalek, Jatim	Wilfred and Akinade (2016)
9	NaCl, $AgNO_3$, CaCl, Poly(ethylene) Oxyde	Na-bentonit and Ca-bentonit from Germany	Prassl and Wolfgang (2006)
10	Dabco (1,4 Diazabicyclo [2.2.2]-octane) and NaCl	Ca-Bentonite from Sarolangun, Jambi	Taher et al. (2018a)
11	Titanium (IV) Propoxyde	Ca-Bentonit from Sarolangun, Jambi	Taher et al. (2018a)
12	Thermal (calcination 400 F) and chemical (H2SO4)	Ca-Bentonit from Sarolangun, Jambi	Taher et al. (2018b)

to the size of a standard bentonite sample. The final sample is in the form of ready-to-use clay powder then stored in a container. The steps of preparing these samples briefly described in Figure 3
The process stages above are standard bentonite preparation processing patterns.

2. Standard bentonite
Commercial bentonite samples used as standard were purchased from bentonite suppliers, both Ca-bentonite and Na-bentonite have similar characteristics, Ca-bentonite color variations ranging from grayish white to whitish or bright beige, having density 2,2–2,8 gr/cm^3, weak acid pH 4-7, while darker colored Na-bentonite tends to be brownish beige, density 2,4-2,6 gr/cm^3, base pH 8-10. The size of both types of commercial bentonite is very fine (200 mesh), inorganic, does not cause skin irritation, non-toxic but can interfere with the respiratory tract if inhaled. It is sold the market in sacks of 25 kg and 50 kg (local bentonite) contents per sack or 50 lb (22,5 kg) and 100 lb (45,4 kg) per sack (imported bentonite).
3. Beneficiation agent ; Na_2CO_3 An alkaline, Na_2CO_3, was chosen as the beneficiation agents in this study due to it is easily obtained in the market, also is needed to change the characteristics of low pH / acid (pH 4-5) clay samples ionically, in addition, Na_2CO_3 is most popular material used in previous studies because it is

Figure 3. Steps of clay samples preparation

Figure 4. bentonites and beneficiation material

known to be easily absorbed by clay. Previous studies have used various types of beneficiation agents, some of which are presented in the following Table 2:
The type of beneficiation and the purpose of clay modification makes beneficiation materials/ activator more diverse from time to time, but generally known material that is often used (common practice) in research is Na_2CO_3 for base beneficiation and HCl for acid beneficiation.

2.4 Type of Data

2.4.1 Free Swell Data

Ready-to-use samples are sorted based on the percentage concentration of Na_2CO_3. The concentrations used are 0%, 2%, 4%, 8%, 10%, 12% and 15% By Weight of Clay (BWOC), clay samples for each experiment as standard API RP 13B is mixture of 22.5 grams of clay and 350 ml of water. The variation in the percentage of Na_2CO_3 is an option, with a maximum 15% limitation because if larger than 15%, it is feared that changes in clay pH (4-5) will exceed the standard bentonite pH (8-10) and so that will potentially cause problems, such as unstability of mud properties and also under slurry conditions that are too alkaline, the performance of beneficiation agents/additives is relatively less optimal. In addition, based on the results of previous similar studies, the concentration of clay beneficiation with Na_2CO_3 is best at 1-5%. The details of sample combinations are shown in Table 3.

2.4.2 Mud slurry properties data

Density, Rheology (FV, PV, YP, AV and Gel Strength), Filtration dan Mud Cake Thickness, Liquid and Solid Content, pH, Sand Content and Methylene Blue Capacity.

The slurry sample weight used in this property test uses standard API measures, where the commonly used units are grams for weight and cm^3 for volume. The conversion from lb/bbl to gram/cm^3 is:

$$\frac{1lb}{1bbl}x\frac{454gr}{1lb}x\frac{1bbl}{42gal}x\frac{1gal}{3785ml}=\frac{1gr}{350ml}$$

1 gram of sample is put into 350 ml of water is equivalent to 1 lb of material into 1 barrel of water. To obtain standard properties, API RP 13B standardizes the addition of 22.5 grams of bentonite in 350 ml of water. The range of alternative values in the range of 17.5-28 grams in 350 ml of water is also widely practiced (common practices) in several similar studies.

2.5 Data gathering method

Data gathering method conducted first by investigating literatures such as scientific research papers, books, magazines, and various scientific documents. Research papers related to bentonite were obtained from various national and international journals, data were collected by studying the literature and linking all variables related to research.

The reference standard used to determine whether the desired clay test value has been achieved, in this investigation using the API RP 13-B standard, the standard set by the API that is internationally accepted in the analysis of water-based drill mud properties (water- based).

2.5.1 Laboratory Test

Laboratory testing data collection done by direct observation or measurement of a sample. Performed in a laboratory where there is adequate property testing equipment, to obtain the data needed in the property analysis, the data then becomes input for data processing and analysis.

The data collection of this research was conducted in a series of:

1. Steps in slurry sample gathering.
   Sampling is determined through excavation of in-situ clay, at a depth of 1.5 meters from the ground surface. Samples come from several locations in the Muratara region, where clay excavation materials can be obtained in-situ; The excavation is put into a sack and then proceed with the drying process of approximately 1 month and grinding to obtain a size of 200 mesh so that the comparison with standard materials (API Bentonite) to be equivalent and continued with making slurry and given beneficiation treatment up to ready to be tested in the laboratory.
2. Steps in slurry parameters data gathering.
   Slurry which has been divided into several samples with different treatments, then tested using different equipments to obtain the required test parameters, this measurement procedures follows API Standard 13-B; One by one the test results are then recorded and tabulated.

2.6 Data analysis

From the results of laboratory tests, the measurement results of each parameter obtained are then recorded and tabulated and then compiled into graphs to get a comparison between the sample and the standard, so that the conclusions from this study can be drawn whether the beneficiated clay can be used as a substitution of the Bentonite API and also a recommendation for further study.

Table 3. Free swell test sample combinations

Sample		1 Na_2CO_3		2 Na_2CO_3		3 Na_2CO_3		4 Na_2CO_3		5 Na_2CO_3		6 Na_2CO_3	
Type	22,5 gr	0% BWOC	0 gr	4% BWOC	0,9 gr	8% BWOC	1,8 gr	10% BWOC	2,25 gr	12% BWOC	2,7 gr	15% BWOC	3,37 gr
Clay from	A	A0%		A4%		A8%		A10%		A12%		A15%	
Muratara	B	B0%		B4%		B8%		B10%		B12%		B15%	
	C	C0%		C4%		C8%		C10%		C12%		C15%	
	D	D0%		D4%		D8%		D10%		D12%		D15%	
	E	E0%		E4%		E8%		E10%		E12%		E15%	
	F	F0%		F4%		F8%		F10%		F12%		F15%	
Comercial	Ca-ben							0% Na_2CO_3					
Bentonite	Na-ben							0% Na_2CO_3					

3. RESULTS AND DISCUSSION

3.1 Free Swell Test (% Swell Analysis)

Free Swell Test carried out to measure how the material volume changes or swelling when hydrated by a fluid. It is expected that the results of the combination of beneficiation with the best swelling ability can be identified so that it can be used as a reference for the next property test. API published that standard Bentonite has a swelling capability of up to 30% of its initial volume. Free swell test results on 36 samples can be seen in Figures 5-7.

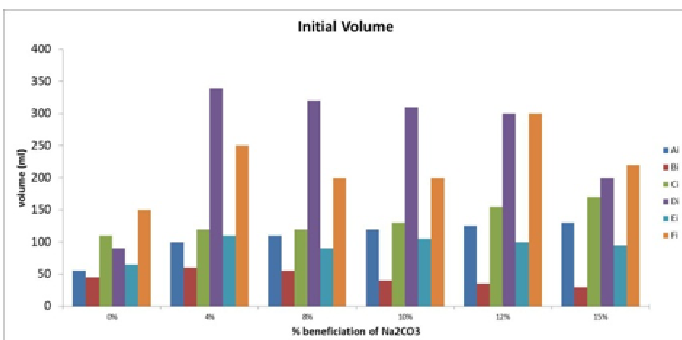

Figure 5. The initial volume of the Free Swell Test

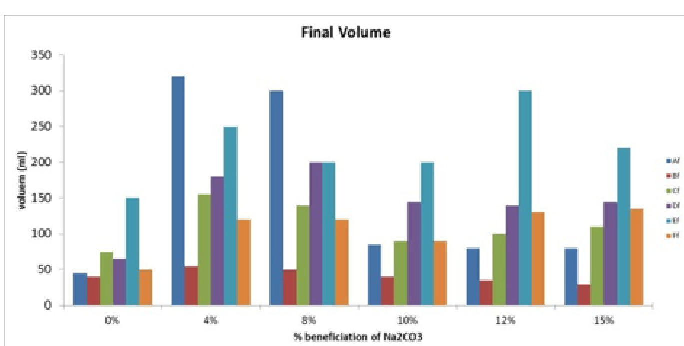

Figure 6. Final volume after 24 hours of Free Swell Test

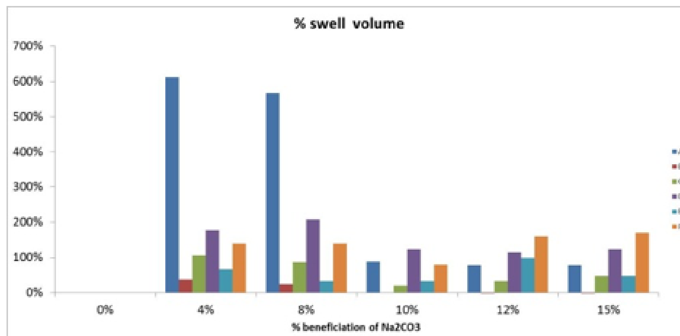

Figure 7. % Swell of each combination

Laboratory test results show that all samples respond to a variety of hydration, but it is clearly seen that there is an expansion in volume (% swell) which is the nature of bentonite, where the volume with beneficiation is greater than the volume without beneficiation, this may arise due to exchange post hydration ions and adding Na_2CO_3. However, clay mud does not exhibit thixotropic properties as standard bentonite, so it may be assumed that Muratara clay samples have a similarity closer to Ca-bentonite or low yield bentonite.

Figure 7 shows that samples with an additional concentration of 4% and 8% Na_2CO_3 have the best swelling levels compared to other concentrations, but in total free swell combination sample 4% is greater than 8%, the researcher chooses 4% based on consideration of having to choose one of them to avoid oversamples that will turn the research period becomes longer. Another consideration is that this 4% value is within the percent range of the most commonly used Na_2CO_3 concentration (common practices) from various previous studies of 1-5%. In terms of the total % swell aspect, sample A shows the best swell then followed by sample D. Based on this result, the concentration of adding 4% becomes the benchmark in comparative testing with standard bentonite, by grouping the combination of sludge property test sample shown in Table 4.

Table 4. Mud properties test sample combinations

Sample Combination	Clay (gr)	Water (ml)	% Na_2CO_3 BWOC	Na_2CO_3 (gr)
1	22.5	350	0%	0
2	22.5	350	4%	0.9
3	25	350	4%	1
4	28	350	4%	1.12
Ca-Bentonite	22.5	350	-	-
Na-Bentonite (API Bentonite)	22.5	350	-	-

3.2 Mud Property Analysis

The water-based mud properties test standard API RP 13B is a series of test procedures and recording the results of measurements made in the mud circulation system during the operation period of oil and gas well drilling. The default provides guidelines for measuring at least 19-24 test parameters. But in the realm of practice, water-based sludge samples based on water and API bentonite (drilling grade) are directly scooped up from several points such as the return line, shale shakers, and mixing tanks are routinely checked for only 8-14 parameters (daily basis), the rest is done in certain situations or on request. Clay samples in this study were first tested for free swelli, only then were samples tested by API RP 13-B testing procedures to obtain their properties, laboratory test results were analyzed in the following description.

3.2.1 Density

The test results of four sample combinations show that the density changes with volumetric changes, both under atmospheric and pressurized conditions compared to Na-bentonite density (API Bentonite) as standard material.

Measurement using atmospheric mud balance produces density data as Fig. 8 and 9.

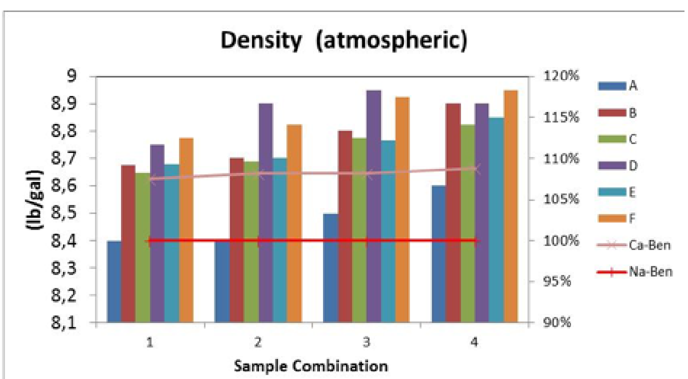

Figure 8. Atmospheric density

The pattern of increasing density graph above shows how mud density changes with volumetric changes in the sample. Of all samples, the density of sample A (A1 and A2) is close to the standard value but with the note that in the initial conditions without beneficiation, the density of both is indeed lower than the standard density, while the density of other samples is entirely greater than the density of Na-bentonite.

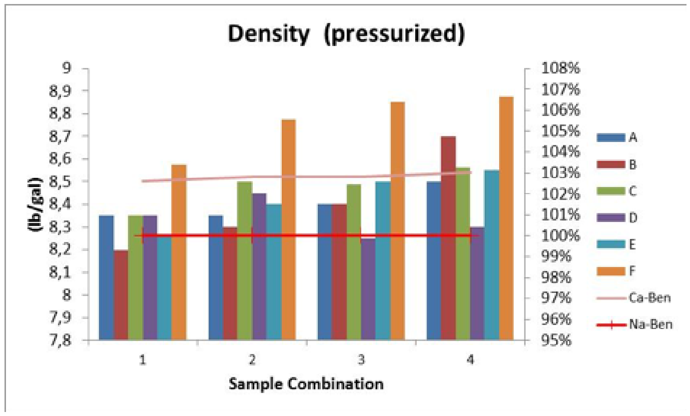

Figure 9. Pressurized density

When compared to the density under conditions without additional pressure, the application of pressure into a pressurized mud balance device clearly has the effect of decreasing density, almost all the sample density values decrease compared to their athmospheric values, but almost all exceed the Na-bentonite density values. Only sample D3 has exactly the same or close value, but in general all of them are above the standard value. Density greatly affects the hydrostatic pressure of the sludge, this pressure works against the formation pressure so that the stability of the borehole is maintained, the density value of the sludge base material can be regulated by adding additive treatment.

3.2.2 Rheology

The results of three types of viscosity (FV, PV, AV) tests showed that the viscosity of all clay sample combinations including Ca-bentonite was below the standard Na-bentonite viscosity. None of the clay samples had funnel viscosity values that matched or were close to the standard Na-bentonite values, all showed a large enough difference of up to 20 seconds / quart or about 50% lower, as well as the PV value, the combination of sample F that had PV greater than any other sample combination it is still 50% lower than standard PV. So that it can be said that there is no clay sample whose viscosity resembles the standard bentonite viscosity, but in terms of the YP / PV ratio, all samples are still within the scope of the YP / PV API ratio of 3 (API, 1997, 2010).

The results of the measurement of mud rheological properties are funnel viscosity, plastic viscosity, yield point, YP / PV Ratio and gel strength for the four combinations of clay samples and standard bentonite samples shown in the Fig. 10.

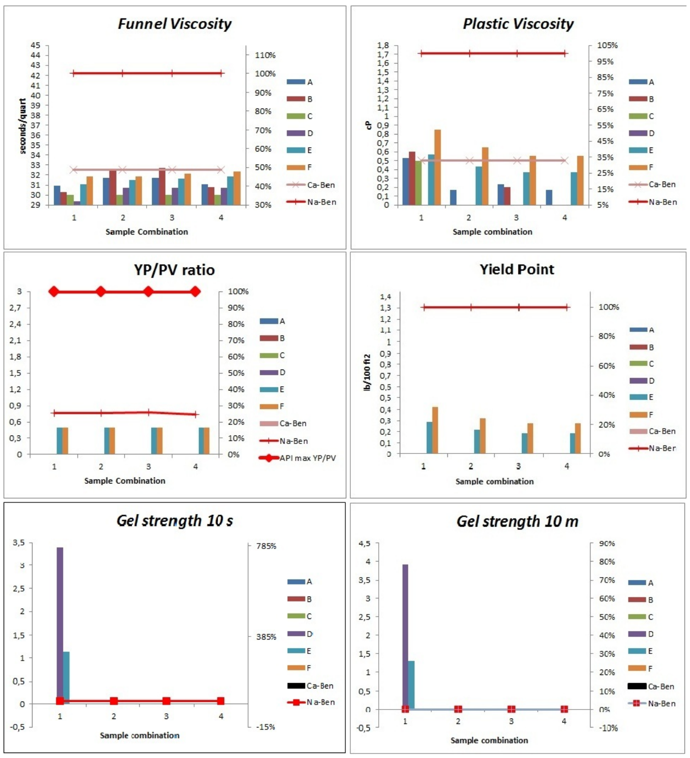

Figure 10. Rheological test results

All samples showed almost zero gel strength except for samples D1 and E1 (initial combination without beneficiation) which is around 3-4 lb/100ft^2 above the standard bentonite gel strength, but decreased immediately to 0 lb/100ft^2 after beneficiation, Na-bentonite itself in this measurement has a very low strenght gel. Gel strength is the last property measured in the mud rheological measurements reflecting the tensile force of particles when the mud is stationary/static, it can also be interpreted as the stress required for the mud to move back.

Rheological test results show that the viscosity value of the beneficiated clay is lower than the standard, in the sense that the low flow resistance makes clay mud relatively more easily circulated / pumped, but on the other hand, with a low gel strength value, thixotrophic properties are not built up so that the solid suspension / solids in the liquid mud will soon be released, so that the solids contained will drop and accumulate at the bottom of the borehole. When this happens, this can have a dangerous impact on drilling operations such as key seating and stuck pipes. Previous studies found that even high grade bentonite (90% montmorillonite) still requires the addition of Na_2CO_3 to improve the quality of its rheological properties.

3.2.3 Filtration

Filtration test or circulation loss test is carried out to determine the rate of penetration of the circulation mud component into the formation, Murchison (1988) states that low filtration is needed to minimize the effect of tight holes if mud cakes are too thick, while high filtration helps facilitate drillability. Mud filtration test is carried out using standard API LPLT Filter Press with 350 ml cup size, pressured 100 psi for 30 minutes. API sets the maximum filtration value of the bentonite standard as 15 ml.

(a) (b)

Figure 11. (a) Mud cakes ; Na-ben at left and clay at right and (b) Filtrate

Figure 12 shows the measurement results, the filtration rate of the Na-bentonite sample was 15 ml/ 30 min, whereas

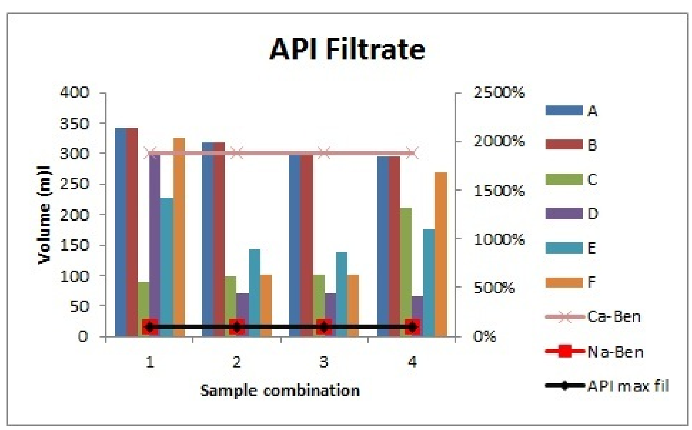

Figure 12. API filtration test result

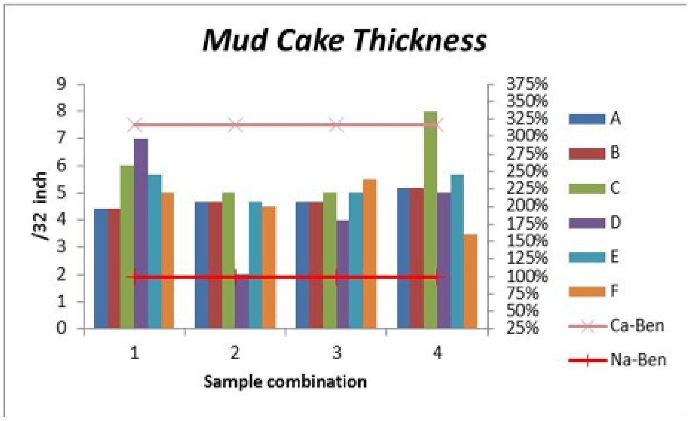

Figure 13. Mud cake thickness test result

all other samples showed different filtration values but far above the standard, it seemed that the D2 sample value dropped dramatically after adding Na_2CO_3 to near the Na-bentonite filtration value. In general, the filtration value of all samples is below the Ca-bentonite value, this indicates that beneficiation with Na_2CO_3 clearly influences the clay filtration rate, but the value is still not equivalent to the standard bentonite value.

Figure 13 shows how the thickness of the mud cake is inversely proportional to the filtration rate, this is indeed the case because the mud cake serves to provide a protective layer of the hole wall to control fluid in and out, all samples (except C4) are in the range of 7.5/32 inch (Ca-bentonite) and 2/32 inch (Na-bentonite). The value of all beneficiated clay samples shows the saddle pattern of the horse and it can be seen that almost all samples show the same mud cake thickness value which is ± 5/32 inch in combination 2 and 3, but only the D2 sample whose mud cake thickness approaches the standard value.

From the filtration test results it can be concluded that the initial treatment of clay beneficiation with Na_2CO_3 is proven to change the filtration value, away from the Ca-bentonite value, close to the Na-bentonite value, but still not as low as the standard value (15 ml). In real operations, a large filtration rate has the potential to cause a loss of a volume of mud fluid into the formation (circulation loss).

3.2.4 Solid and Liquid Content

Solid and liquid content test aims to measure the percentage of liquid content and solids in drill mud, Bourgoyne (1986) states that for formation treatment, water-based mud generally contains 60-90% of the liquid. Each sample was measured as much as 10 mL using a retort ki, producing data as presented in Figures 14.

It seems logical on the graph that increasing the mass of the sludge increases the percent solid content. The solid content of standard Na-bentonite samples is relatively stable in the range of 2-3%, while Ca-bentonite is in the range of

Figure 14. Test results for pH strips

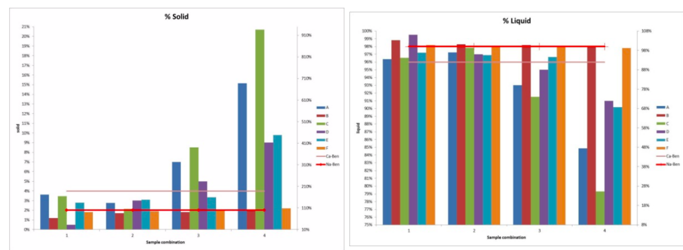

Figure 15. Solid and liquid content test result

4%, while the beneficiated clay samples percentages increases along with the addition of the mass of the base material.

Of the whole sample, the value of the combination 2 was between the values of the two comparators, the other combination samples had significantly different values. The test results above, in addition to showing a linear relationship between the addition of solid mass with % solid content, on the other hand shows how the water suspension with clay solids is not perfectly developed.

3.2.5 pH

The pH test is carried out to find out the concentration of hydrogen ions in solution, the API 13B API standard test uses a pH strip and pH meter. The pH degree when measured by pH strips can be known through visual color correlation with standard color observations, while the pH meter (dipped) will provide a more accurate measurement number than the pH strips up to 0.1 accuracy. The pH of the drilling mud is set to tend to be alkaline, this is to accommodate the performance of most additives which are difficult to function in acidic conditions, as well as to validate the condition of the formation layer when drilling penetrates rock layers which contain a lot of formation water which tends to be acidic.

The graphs at Figure 16 of pH measurement results shows the response of clay samples to Na_2CO_3 beneficiation, this strengthens the evidence of previous research on the effect of Na_2CO_3 beneficiation on clay mud (Abdou et al., 2013). pH acid then turned into a base due to the beneficiation, but the distribution of pH changes from clay samples was very varied, the results of beneficiation showed that only sample E had the same pH value as the standard bentonite

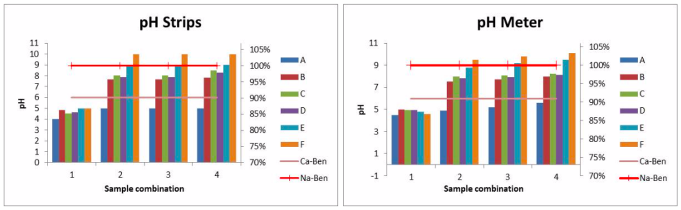

Figure 16. pH test result

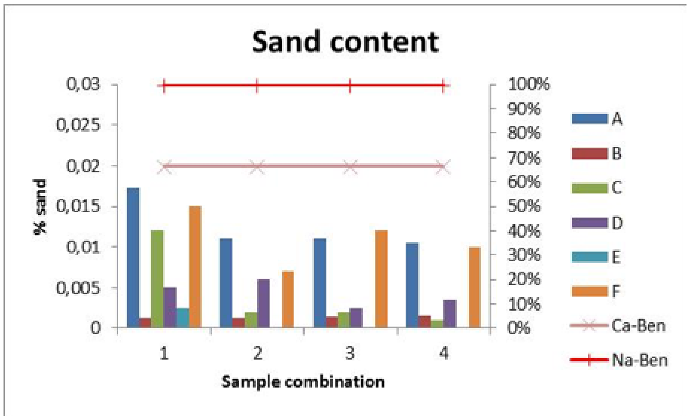

Figure 17. Sand content measurement result

pH. Slurry Na-bentonite itself is classified as alkaline with a pH ranging from 8-9 (Omole et al., 2013).

3.2.6 Sand Content

Sand content test is carried out to measure the percentage of sand content in mud. The sample test results are described at Figure 17.

Figure 17 shows the results related to the results of mud rheological tests in terms of the adsorbance of mud to sand-sized solids (Nasser et al., 2013). The value of % sand content of all beneficiated clay samples is far below the value of Na-bentonite% sand content (0.03%) and Ca-bentonite (0.02%), such low sand content may be caused because the sand tends to settle on the bottom not carried away in the sample although circulation/ agitation was carried out due to the coagulation nature of the clay mud suspension which was not sufficiently tough to carry the sand up to surface against gravity (low cutting carrying capacity). Even so, from the aspect of pumping circulation mud, the relatively low percentage of sand content of all samples is considered good because it means the risk of pump internal damage is also low, the maximum safe sand content value is 2% (Prassl and Wolfgang, 2006).

3.2.7 Methylene Blue Test

MBT determines the transition capacity (cation exchange capacity) of clay/bentonite particles equivalent to methylene blue organic reagents/dyes, this test aims to estimate the equivalent of bentonite particles that are hydrated in mud,

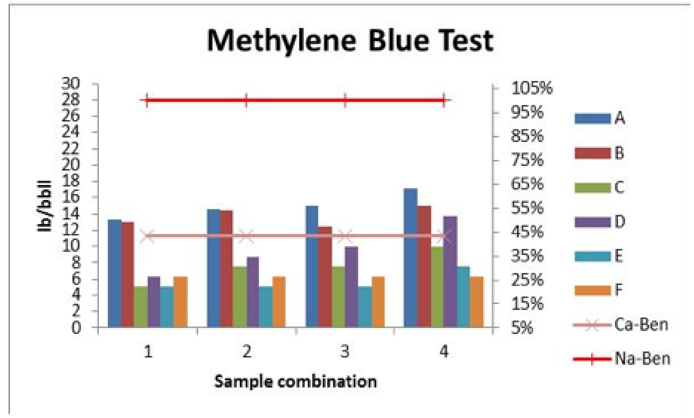

Figure 18. MBT measurement results

ion exchange capacity is equivalent to ml of the MBT solution used per ml of sample to reach the end point (Bourgoyne et al., 1986).

As shown in Figure 18, the concentration of clay sample concentration is directly proportional to the concentration of Na_2CO_3 beneficiation, the highest value of samples A and B and has reached the value of Ca-bentonite, but many are still in accordance with the standard Na-bentonite (only 50%). From this parameter, it can be concluded that Na_2CO_3 beneficiation shows the effect on the concentration of equivalent bentonite which means ion exchange occurs, however, this effect still does not produce sufficient viscosity and cutting carrying capacity as produced by standard Na-bentonite mud.

3.2.8 Summary of Property Suitability of All Samples

The Muratara Regency clay mud property test which was beneficiated with the addition of Na_2CO_3 gave mixed results in each of its parameters. The series of test results above are tabulated to get the best candidate clay samples that have the eligibility to become API substitution materials Bentonite (Table 5).

The proximity value of each clay sample with the standard bentonite value can be known by using the standard deviation value of the sample, the value entered in the range deviation is categorized the same, outside the range means not the same or the difference is far.

The table above shows the results of the 16 parameter test of all sample combinations, highlighted in red indicating the same value or close to the standard Na-bentonite value. Density of sample A has the most similar value with Na-bentonite in both atmospheric and pressurized conditions, also has the same gel strength of 10 seconds and 10 minutes at 0 lbs/100 ft^2, but in other rheology parameters of sample A, the viscosity is much lower than standard, this means that the binding capacity of water to solid particles is low, so it is relatively lacking in carrying capacity. Other sample A parameters, namely filtration, solids, liquid, sand, pH and

Table 5. Recapitulation of Overall Test Result Parameters

Sample code	(4%) Na_2OH_3 BWOC	mass (gr)	Density atm (lb/gal)	Density pres (lb/gal)	FV (cp)	PV (cp)	YP Lbs/100 ft^2	YP/AV	GS 10s Lbs/100 ft^2	GS 10m Lbs/100 ft^2	Filtrate (ml)	MCT (/32 inch)	% Solid	% Liquid	Sand Content (%)	pH	MBT (lb/bbl)
			1	2	3	4	5	7	8	9	10	11	12	13	14	15	16
A1	0	22,5	8,4	8,4	30,9	0,53	0	0	0	0	343	4	4%	96%	2%	4	13
A2	0,9	22,5*	8,4	8,4	31,7	0,17	0	0	0	0	318	5	3%	97%	1%	5	15
A3	1	25*	8,5	8,4	31,7	0,33	0	0	0	0	298	5	7%	93%	1%	5	15
A4	1,12	28*	8,6	8,5	31,1	0,17	0	0	0	0	295	5	15%	85%	1%	5	17
B1	0	22,5	8,7	8,2	30,3	0,6	0	0	0	0	343	4	1%	99%	0%	5	13
B2	0,9	22,5*	8,7	8,3	32,6	0	0	0	0	0	318	5	2%	98%	0%	8	15
B3	1	25*	8,8	8,4	32,7	0,5	0	0	0	0	298	5	2%	98%	0%	8	13
B4	1,12	28*	8,9	8,7	30,8	0	0	0	0	0	295	5	2%	98%	0%	8	15
C1	0	22,5	8,6	8,4	30,0	0,5	0	0	0	0	90	6	3%	97%	1%	5	5
C2	0,9	22,5*	8,7	8,5	30,0	0	0	0	0	0	98	5	2%	98%	0%	8	8
C3	1	25*	8,8	8,5	30,0	0	0	0	0	0	102	5	9%	92%	0%	8	8
C4	1,12	28*	8,8	8,6	30,0	0	0	0	0	0	210	8	21%	79%	0%	9	10
D1	0	22,5	8,8	8,4	29,4	0	0	0	3,4	3,9	300	7	1%	100%	1%	5	6
D2	0,9	22,5*	8,9	8,5	30,7	0	0	0	0	0	70	2	3%	97%	1%	8	9
D3	1	25*	9,0	8,3	30,7	0	0	0	0	0	70	4	5%	95%	0%	8	10
D4	1,12	28*	8,9	8,3	30,7	0	0	0	0	0	65	5	9%	91%	0%	8	14
E1	0	22,5	8,7	8,3	31,0	0,6	0,3	0,5	1,1	1,3	227	6	3%	97%	0%	5	5
E2	0,9	22,5*	8,7	8,4	31,5	0,4	0,2	0,5	0	0	143	5	3%	97%	0%	9	5
E3	1	25*	8,8	8,5	31,7	0,4	0,2	0,5	0	0	137	5	3%	97%	0%	9	5
E4	1,12	28*	8,9	8,6	31,8	0,4	0,2	0,5	0	0	175	6	10%	90%	0%	9	8
F1	0	22,5	8,8	8,6	31,9	0,9	0,4	0,5	0	0	325	5	2%	98%	2%	5	6
F2	0,9	22,5*	8,8	8,8	31,9	0,7	0,3	0,5	0	0	100	4,5	2%	98%	1%	10	6
F3	1	25*	8,9	8,9	32,2	0,6	0,3	0,5	0	0	100	5,5	2%	98%	1%	10	6
F4	1,12	28*	9,0	8,9	32,4	0,6	0,3	0,5	0	0	270	3,5	2%	98%	1%	10	6
Ca-Ben	0	22,5	8,6	8,5	32,5	0,50	0	0,00	0	0	300	7,5	4%	96%	2%	6	11
Na-Ben	0	22,5	8,4	8,3	42,2	1,70	1,3	0,76	0	0	16	2	2%	98%	3%	9	29

MBT content, are all below the standard value. Of the 16 parameters, sample A has 4 parameters that are the same or close to the standard value but 12 other parameters do not, the same thing also occurs in samples B, C, D, E, and F. The clay sample with the most similar characteristics is sample B (sample from Napal Licin Village, the last village at the top of the Bukit Barisan mountains at South Sumatra and Bengkulu provincial border), so that it can be considered as a candidate for further research. Whereas in terms of parameter values, the similarity of samples with standards is found in the parameters of pressurized density, gel strength, and liquid and solid content.

The final results of the API 13B API standard test series and data processing can be concluded that from the entire Muratara clay test sample with Na_2CO_3 beneficiation, none of the samples had sufficient property suitability with the bentonite API, viewed from the aspect aspect at most only 5 out of 16 parameter (30%) where this is very low than expectations, which is 80%, the best suitability is of course 100% the same as the standard, but this is difficult to achieve. If the suitability reaches 80% then it is enough to be considered suitable as a substitute material, the 80% number is an acceptable and familiar number in the oil and gas industry for example the optimum value of oil and gas reserve recovery, the efficiency of artificial lift pumps, and safety factors in a variety of operating contexts drilling. With such a low percentage of suitability of sample properties to standard API properties, technically, the chance for Muratara clay beneficiated with Na_2CO_3 to be used as a substitute for API bentonite for drilling mud base material is very small.

4. CONCLUSIONS

The reasearch derive three conclusions ; first, Muratara clay responds to water in the free swell test in the form of swelling volumes after experiencing hydration, the best combination of % swell is at a concentration of 4% Na_2CO_3 addition. Then, the beneficiation using Na_2CO_3 clearly gives changes in the physical properties of the mud compared to the initial conditions, all the parameters of the beneficiated clay-based mud undergo changes according to their respective concentrations. The most obvious change in the parameters of density, viscosity, filtration, sand content and pH, but not much changes in MBT, which indicates that the reactive solid cation exchange capacity is not much affected by Na_2CO_3 beneficiation. Finally, overall (24 combinations) samples of mud made from Muratara clay beneficiated with Na_2CO_3 have undergone property changes, but none have sufficient property suitability with the bentonite API. Thus, technically, the chance for Muratara clay beneficiated with Na_2CO_3 to be used as a substitute for API bentonite for drilling mud base material is very small.

REFERENCES

Abdou, M., A. Al-Sabagh, and M. Dardir (2013). Evaluation of Egyptian bentonite and nano-bentonite as drilling mud. *Egyptian Journal of Petroleum*, **22**(1); 53–59

Abdullahi, A. S., A. Ibrahim, M. Muhammad, M. Kwaya, and S. Mustapha (2011). Comparative evaluation of rheological properties of standard commercial bentonite and a locally beneficiated bentonitic clay from a marine deposit in upper benue basin, Nigeria. *British Journal of Applied Science & Technology*, **1**(4); 211

API (1997). *Standar Practice for Field Testing Water-Based Drilling Fluids, API RP 13B-1 2nd Ed.* Washington DC

API (2010). *Purchasing Guideline Handbook, API RP 13A 18th Edition*. Washington DC

Apugo-Nwosu, T., I. Mohammed-Dabo, A. Ahmed, G. Abubakar, A. Alkali, and S. Ayilara (2011). Studies on the suitability of ubakala bentonitic clay for oil well drilling mud formulation. *British Journal of Applied Science & Technology*, **1**(4); 152

Bilal, S., I. Mohammed-Dabo, B. Dewu, O. Momoh, I. Funtua, M. Oladipo, A. Arabi, and T. Muhammad (2016). Study of the physicochemical properties of nigerian bentonitic clay samples for drilling fluid formulation. *Journal of Scientific and Engineering Research*, **3**(2); 171–176

Bourgoyne, J., T. Adam, Millheim, Chenevert, and S. Young (1986). *Applied Drilling Engineering, 1st Printing*. ociety of Petroleum Engineers, Richardson, Texas

Dewu, B., S. Arabi, M. Oladipo, I. Funtua, I. Mohammed-Dabo, and A. Muhammad (2011). Improvement of rheological properties of bentonitic clays using sodium carbonate and synthetic viscosifiers. *International archive of applied science and technology*, **2**(2); 43–52

Dewu, B., M. Oladipo, A. Arabi, M. Tukur, I. Funtua, S. Bilal, and I. Muhammed-Dabo (2016). Iron removal from local bentonitic clay and its effect on clay rheology. *Petroleum Technology Development Journal*; 66–77

Hassan, M. and N. Abdel-Khalek (1998). Beneficiation and applications of an Egyptian bentonite. *Applied Clay Science*, **13**(2); 99–115

Karagüzel, C., T. Çetinel, F. Boylu, K. Çinku, and M. Çelik (2010). Activation of (Na, Ca)-bentonites with soda and MgO and their utilization as drilling mud. *Applied Clay Science*, **48**(3); 398–404

Kusdarto, M. S. and A. Sutandi (2006). Inventory and Evaluation of Non Metallic Mineral Materials in Musi Rawas and Musi Banyuasin Regency, South Sumatra Province. *Center for Geological Resources*

Nasir, S., S. Budi, I. Silviaty, et al. (2013). Application filters from natural clay-based ceramics and zeolites in wastewater treatments of laundry industry effluents. *Bumi Lestari*, **13**(1); 45–51

Nasser, J., A. Jesil, T. Mohiuddin, M. Al Ruqeshi, G. Devi, and S. Mohataram (2013). Experimental investigation of drilling fluid performance as nanoparticles. *World Journal of Nano Science and Engineering*, **2013**

Nweke, O., E. Igwe, and P. Nnabo (2015). Comparative evaluation of clays from Abakaliki Formation with commercial bentonite clays for use as drilling mud. *African Journal of Environmental Science and Technology*, **9**(6); 508–518

Omole, O., J. O. Adeleye, O. Falode, S. Malomo, and O. Oyedeji (2013). Investigation into the rheological and filtration properties of drilling mud formulated with clays from Northern Nigeria. *Journal of Petroleum and Gas Engineering*, **4**(1); 1–13

Prassl and F. Wolfgang (2006). *Drilling Engineering, Curtin University of Technology*. Perth

Ramadhan, A., M. I. Fathurrohman, and B. Soegijono (2015). Chemical modification of upgraded bentonite as filler of natural rubber/organobentonite composite. *Procedia Chemistry*, **16**; 85–90

Singh, P. K. and V. Sharma (1994). Beneficiation of low grade bentonite clay by chemical methods and their utilization in oil industries. *Indian Journal of Engineering dan Material Sciences*

Sjahril, M. Raja, and C. Karangan (2004). Inventory and Evaluation of Non Metallic Mineral Materials in Lahat and Musi Rawas Districts, South Sumatra Province, Subdit. Non-Metallic Minerals, Center of Minerals, Coal, and Geothermal. *Ministry of Energy*

Taher, T., D. Rohendi, R. Mohadi, and A. Lesbani (2018a). Preparation and Characterization of Dabco (1, 4-Diazabicyclo [2.2. 2] octane) modified bentonite: Application for Congo red removal. In *IOP Conference Series: Materials Science and Engineering*, volume 299. IOP Publishing, page 012055

Taher, T., D. Rohendi, R. Mohadi, and A. Lesbani (2018b). Thermal and Acid Activation (TAA) of bentonite as adsorbent for removal of methylene blue: A kinetics and thermodynamic study. *Chiang Mai Journal of Science*, **45**(4); 1770–1781

Wilfred, O. C. and A. E. Akinade (2016). Comparative study of basic properties of mud prepared with nigerian local clay and mud prepared with foreign clay: A case study of abbi clay deposit. *International Journal of Engineering and Technologies*, **8**; 61–71

