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UTILIZATION OF TREATED MALAYSIAN LOCAL BENTONITE FOR DRILLING MUD MATERIAL COST SAVING

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ABSTRACT

Based on the result of Geological Survey Department Malaysia investigation, the bentonite resource in Sabah is huge. In order to reduce the overall cost in oilwell drilling and completion, the development of Sabah bentonite as drilling mud material has been initiated. Mineralogically of the samples were characterized as low grade Ca-Mg smectite. The dominant gangue mineral is ferrous with small amounts of kaolinite, quartz, illite, muscovite and hematite. Iron is present as magnetite and as amorphous oxides and hydroxides. Characterization of these samples indicated that the bentonite response for Na-exchange was poor while their hydration, plastic and rheological properties were inferior to those of reference bentonite (WY-BEN). The sample was processed by crushing followed by aero cyclone to optimum produced pre-concentrates, which were extracted with diluted oxalic acid. Application of such simple flow sheet effectively removed the majority of the associated ferrous ion. These concentrates were further refined by a series of organic acid prior to their evaluation as industrial bentonite. The mineralogy, chemical and physical properties analysis of final concentrates successfully match the required specifications for drilling mud industrial material. Utilization of this bentonite, after their extracting, can represent a value added to the Malaysian economy (60.71 % cheaper) by minimizing the imported bentonite used by oil and gas industry.

Keyword: Bentonite; mineralogy; extraction; organic acid; drilling mud

I. INTRODUCTION

Bentonite $(Al_{0.2693}\ Fe^{2+}_{0.7212}\ Mg_{0.1374})\ (Si_{3.5808}\ Al_{0.4192})\ X_{0.5855}\ nH_20$ is by far the most abundant of the smectite clay minerals. In drilling industry, bentonite is generally classified as sodium (Na) or calcium (Ca) types, depending on dominant exchangeable ion. The major problems facing the utilization of Sabah bentonite is their low concentration of smectite, high level of iron contaminant and inconsistent composition. Previous studies on some Sabah bentonite suggested that, without utilization, they were unsuitable for drilling mud material. Response of this bentonite to Na-exchange was poor and their hydration, plastic and rheologycal properties were inferior to that reference bentonite [1]. Several attempts were made to upgrade to meet OCMA/API specification for drilling fluid and other industrial uses. [2,3,4]. This paper presents utilization of treated malaysian local bentonite for drilling mud material cost saving. The tests were conducted on run-of-mine (ROM) and chemically activated samples. Chemical methods involve extracting of the mineral with organic acid also cation exchange capacity measurement.

2. EXPERIMENTAL WORK

Bentonite sample

In this study, two groups of local bentonite samples were collected, namely SA5-1, SA5-3, SA5-4 and SA5-7 (N4^{0}18.97'- E 117^{0}57.37') from Andrassy area in Tawau district and M4 (N5^{0}7.35'- E118^0 12.03') from Mansuli area in Lahad Datu district. The SA5-1and SA5-3 sample were collected exactly at 0.5 m depths, SA5-4 and SA5-7 sample was collected at 1.0 – 1.5 m depths and M4 at 0.3 m depths. The field sampling from Mansuli area were taken mainly in area underlain by the Ayer Formation, which collectively

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from the Segama Group and is interpreted to be Miocene in age The Andrassy area is underlain mainly by the high level of alluvium and volcanic rock, and occur in a bed underlying by Pleistocene to Holocene in age [1].

2.1. Experimental Procedure

2.1.1. Utilization process

Bentonite samples from the field will be dried in the oven at 35°C for four hours until reach moisture content less than 10%. Then the sample will be crushed using a Jaw crusher to 100% below 75 μm in size. This was followed by aero cyclone model EPC100P [5], to disintegrate the smectite from its associating gangue minerals. Both the aero cyclone underflow (coarser than 75 μm) and the overflow fractions (finer than 75 μm) were filtered dried at 55°C and weighed. Underflow fractions, which were heavily contaminated with iron and free-silicon impurities, were discarded. Meanwhile, the overflow fractions were used as bentonite pre-concentrates. The latter products were further upgraded by extracting, their residual iron impurities, with 7.1 kg m^{-3} oxalic acid solutions for 2 h with 80 °C temperature. The bentonite was beneficiated to improve its smectite content by removing the associated gangue minerals (mainly iron and free-silicon).

2.1.2. Physical and Chemical Properties Determination

Common chemical property of bentonite is pH, cation exchange capacity (CEC) and specific surface area (SSA). pH value were measured by pH meter Model Hanna H18424, which adapted generally from the BS1377:Part3: 1900:9 [6]. SSA was measured using methylene blue spot test [7]. In addition, the physical properties determinations include the Atterberg limit such as liquid limit (LL), plastic limit (PL) and plasticity index (PI), moisture absorption (MA), moisture content (MC) and ignition loss (IL). Methylene Blue Test (MBT) is used to estimate the CEC. A sodium-based bentonite should have a CEC value same as that of bentonite (80 –10 meq/100 grams). Approximately 1 gram of bentonite sample will be tested in 50 ml of distilled with about 0.5 ml of 5 N sulfuric acid added. The bentonite solution will than boiled gently for 10 minutes. The CEC is measured by conductomercial titration after cation exchange, meq/100grams. The standard testing method for liquid and plastic limit according to ASTM D4318-84 [8]. Liquid limit and plastic limit also refer as Atterberg limit, which depending on the moisture content of sample. The liquid limit provides the moisture content at which the clay changes from plastic to the liquid state. While the plastic limit was simply the moisture content at which a ball of clay when rolled to a diameter of 1/8 inch. On the other hand, plasticity index is the difference between liquid limit and plastic limit. In addition, the moisture adsorption (MA), moisture content (MC) and ignition loss (IL) of sample will also be determined since the qualitative mineral content of sample can be studied. Moisture adsorption (MA) is defined as the percentage of water lost when clay from a saturated atmosphere (around 20°C) is dried in an oven at 105°C. The analysis of moisture content followed the ASTM. Committee D4318-00 Moisture adsorption (MA) value can be used to predict the mineralogy nature for clay. Moisture content (MC) is the percentage of water lost when clay from normal room temperature atmosphere (at around 20°C) is dried at 105°C. While the ignition loss is the percentage of weight lost when a dried clay (at 105°C) is fired to 1000°C in furnace.

2.1.3. Mud rheological tests

In testing the rheological properties of the activated products, the suspension were re-agitated for 5 min, using a mixer, and then transferred to the viscometer at a rotor speed of 600 rpm. The readings of the viscometer were recorded at 5 min intervals until a stable reading was attained. This procedure was repeated at a rotor speed of 300 rpm. The reading of the viscometer at 600 rpm is taken as the apparent viscosity (A.V.) while the difference between the readings taken at 600 and 300 rpm represents the plastic viscosity (P.V.). The yield point (Y.P.) is calculated from the difference between the reading of viscometer at 300 rpm and plastic viscosity. Fig. 1 shows a simplified flow sheet for the beneficiation scheme. Testing of the samples as a raw material for drilling fluid was carried out according to Section 11 of the API specifications 13A. [10].

3. RESULTS AND DISCUSSION

3.1. The Mineralogy

After organic acid beneficiation, the mineral composition of the Andrassy and Mansuli samples (see Table 1 and Table 2) changed with SA5-4 sample 68% improvement and M4 samples 17% increment, respectively. From quantitative analysis, the overall montmorillonite composition in the bentonite slightly changed. It is clear that the beneficiation by using oxalic acid had successfully removed iron content as impurities in the sample and the quantity of the montmorillonite in the all sample are improved.

3.2. Physical Properties

MC, MA, IL

The MC, MA and IL results of beneficiated Andrassy and Mansuli are as shown in Table 3. It is observed that the MC for the beneficiated sample had been increased in the range of 9.92 % to 63.33 % of the original values. The beneficiated M4 sample from Mansuli area, had been dramatically increased i.e., 63.33 % of the original value because of reduced free-silicon content. It is indicated that the beneficiated SA5-3 sample has a very low MC as compared to other bentonite samples due to low water adsorption and cation exchange since its closer to plastic kaolin region. The water in the lattice of bentonite mineral is important as an agent of chemical reaction such as ion exchange and adsorption into the mineral. The mineral moisture distribution is important for the sorption characteristics because mineral with higher specific gravity are transported in solution. The reference bentonite sample shows higher moisture content and plasticity index compared to beneficiated Andrassy and Mansuli samples. The low moisture content in Andrassy and Mansuli samples was due to the low percentage of montmorillonite mineral as shown in Table 1 & Table 2. There are some improvements in MA values as shown in Table 3 due to reducing iron and free-silicon content in the samples, i.e. increment of 3.42 % to 79.26% which is still not as good as the reference bentonite. The IL values Andrassy and Mansuli samples are higher than raw bentonite sample, except for SA5-3 sample. Since the water molecules in SA5-3 sample is located within the tetrahedral and octahedral sheets of bentonite crystal structure.

Atterberg Limit

Generally, after beneficiation Andrassy samples show improvement in liquid limit with increment varying from 89.82 % to 229.63 % of the original values, as shown in Table 3. These samples also showed improvement in plastic limits, with increment varying from 0.40 % to 37.13 %. This again proved that the montmorillonite mineral plays an important role that influences the plasticity of a sample. These results show that the iron and free-silicon content as impurities in the raw bentonite decreased, but the improvement still not as good as reference bentonite. As shown in Table 3, after beneficiation, the plasticity index of beneficiated Andrassy and Mansuli sample had also been improved with increment varying from 181.78% and 582.57 %. This means that the water absorption capabilities of these samples are better than those raw one. The low percentage of bentonite mineral in the sample has resulted in lower moisture content and plasticity index.

3.3. Chemical Properties

CEC

From the Table 4, we can see that the CEC of beneficiated Andrassy and Mansuli samples had been improved. This will have a positive impact to the hydration and swelling capability when used as a material in drilling mud. However, their CEC values still much less than the reference bentonite (CEC of 80 meq/100 g).

Specific Surface Area

Specific surface area is shown in Table 4. It is clearly seen that the beneficiated Andrassy samples show some improvement in specific surface area. The treatment with oxalic acid had successfully remove an iron in the sample therefore the specific surface area of all sample improved. This proved that the SA5-4 sample (640 m^2/g) is the most satisfies sample that has a specific surface area closed to the reference bentonite (660.37 m^2/g). However, it is still has insufficient absorption capability since the specific surface area still not to compared to the reference bentonite due to its low content of montmorillonite mineral in the local sample. The SA5-1, SA5-7 and M4 samples also exhibit increment in specific surface area. Since there is only limited or small amount of montmorillonite mineral, these beneficiated samples still failed to reach the specific surface area of reference bentonite (660.37 m^2/g). As for SA5-3 sample, due to its low content of montmorillonite mineral an increment of specific surface area of 17 % is considered encouraging.

4. Drilling Mud Performance

As shown in Table 5, the beneficiated Andrassy and Mansuli sample still failed to meet the API specification 13A except for YP/PV ratio and moisture content. However, it is clearly seen that the beneficiated samples show improvement in two important parameters; viscometer 600 rpm dial reading and filtrate loss, i.e., around 380 % to 700 % of viscometer 600 rpm dial reading and, 60% to 85 % of fluid loss reduction. This generally caused by not all impurities had been removed from the sample and less amount of montmorillonite content for the local bentonite samples, especially the SA5-3 sample. Hence, it is desirable to find a solution and the possible solution is to add some polymer extender that can improve the viscosity generated.

5. CONCLUSION

The bentonite beneficiated based on organic acid treatment can be achieved by applying at organic acid concentration of 7.1 Kg m^{-3}, pH less than 2, 80°C temperature and 2 hours stirring time. It was found that the highest CEC is 72 meq/100 g from original value of 41 meq/ 100 g. In addition, Sabah bentonite can not meet API Spec 13A of drilling mud material. Otherwise, the beneficiated bentonite performance as drilling mud material can be improved by 3% wt Tannathin addition.

REFERENCES

1. Yusairi Hj. Basiran & Yan, A.S.W., 1995, "Investigation of bentonite (montmorillonite clay) resources in The Andrassy area, Tawau, Sabah". Jabatan Penyiasatan Kajibumi Malaysia.
2. Aidil Mohamed Osman Hussein, 2001. "*Study Of Malaysian Local Bentonite As An Oilwell Cement Additive*". Master Thesis. Faculty of Chemical and Natural Resources Engineering, UTM, Malaysia.
3. Ariffin Samsuri, Radzuan Junin and Adil Mohamed Osman Hussein, 2001. "The Utilization Of Malaysian Local Bentonite As An Extender And Free Water Controller In Oil-Well Cement Technology". *SPE paper no. 68674.*
4. Zanariah Mohamed, 2000. "*Kesesuaian Bentonite Lahat Datu Sebagai Bahan Tambah Lumpur Penggerundian Menggunakan Proses Rawatan Natrium*". Bachelor Thesis, Faculty Chemical And Natural Resources Engineering. UTM, Malaysia.
5. Koch, W.H., and Licht, W., 1979. "New Design Approach Boost Cyclone efficiency". *Chem. Eng.* 84, 79-89.
6. British Standards Institution. (1990). *"Part.3:9.0. pH Analysis*". London:BS1377.
7. Santamarina J.C., Klein K.A., Wang Y.H. and Prencke E. 2002. *"Specific Surface: Determination and Relevance."* Canada: Canada Geotech Journal. 39. 233 - 241.
8. ASTM D4318-84 (1993), *"Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils."* U.S.A.: American Society for Testings and Materials.
9. ASTM. Committee D4318-00 on Soil and Rock (2001), *"ASTM Standards Test Method for Moisture Content, Moisture Absorption and Ignition Loss of Soils."* United States.
10. American Petroleum Institute, 1993. *"Specifications For Drilling Fluids"*. Spec. 13A, 10th edition. pp. 1–3.

Table 1. Semi-quantitative analysis of beneficiated Andrassy and Mansuli samples

Mineral Composition	Commercial Bentonite	Beneficiated Bentonite Samples				
		SA5-1	SA5-3	SA5-4	SA5-7	M4
Montmorillonite	****	*	*	**	**	*
Quartz (SiO_2)	**	*	*	*	*	*
Kaolinite(($Al_2Si_2O_5(OH_4)$)	nd	*	*	*	*	tr
Illite ((K, H_3 O) (Al, Mg,Fe)2 (Si,Al)$_4O_{10}$)	*	*	*	*	*	*
Others	** Feldspar $KAlSi_3O_8$	* feldspar	tr feldspar	tr feldspar	nd	* feldspar

Keys: ****: dominant, ***: major, **: minor, *: appreciable; tr: trace; nd: not detect

Table 2. Quantitative analysis of beneficiated Andrassy and Mansuli samples

Montmorillonite content (%Volume)	SA5-1	SA5-3	SA5-4	SA5-7	M4
	43.78	47.74	53.76	53.89	44.83
Percentage of change after beneficiation process (%)	35	31	68	65	17

Table 3. MC, MA and IL values and Atterberg Limit of beneficiated Andrassy and Mansuli samples

Bentonite Sample	MC		MA		IL		LL (%)		PL (%)		PI (%)	
	%	% of change	%	% of change	%	% of change	%	% of change	%	% of change	%	% of change
Reference Bentonite	16.732	-	24.51	-	5.43	-	700	-	65	-	635	-
SA5-1	12.58	33.97	21.35	79.26	11.45	10.95	259.8	165.62	55.75	6.17	204.05	266.01
SA5-3	11.99	0.42	17.62	0.46	11.25	-0.18	120.25	89.82	32.25	0.40	88	181.78
SA5-4	12.65	33.30	22.85	6.13	11.45	1.24	278.5	126.72	49.25	5.57	229.25	365.48
SA5-7	14.85	9.92	22.98	3.42	7.52	3.72	458.98	134.05	58.65	15	400.33	582.57
M4	12.07	63.33	16.4	72.45	10.287	10.49	267	229.63	40.85	37.13	226	341.32

Table 4. CEC and Specific surface area of beneficiated bentonite sample

Bentonite Sample	CEC (meq / 100 g)		Specific Surface (m^2/g)	
		% of change		% of change
Reference Bentonite	80	660.37	-	-
SA5-1	65	540	70.35	58.54
SA5-3	60	340	17	22.45
SA5-4	72	640	47.13	33.33
SA5-7	68	400	36.52	44.68
M4	36.05	300	104.50	50.21

Table 5. Suspension properties of beneficiated Andrassy and Mansuli samples

Polymer Dispersant		Viscometer dial reading		Gel ($lb/100ft^2$)		pH	Filtrate (ml)	PV (cP)	YP ($lb/100ft^2$)	YP/PV
		300 rpm	600 rpm	10second	10minute					
SA5-1 Tannathin (% wt)										
	1.00%	4	7	0	0	8.5	18	3	1	0.3
	2.00%	6	11	0	0	8.5	15	5	1	0.2
	4.00%	10	15	0	0.5	8.5	14.5	5	5	1
CMC (% wt)	1.00%	3.5	6	1	17	8.5	32	2.5	1	0.4
	2.00%	7.5	12	0	0	8.5	24	4.5	3	0.7
	4.00%	10.5	16	0	0	8.5	20	5.5	5	0.9
SA5-3 Tannathin (% wt)										
	1.00%	6	10	0	0	8.5	15	4	2	0.5
	2.00%	10	15	0	0	8.5	14	5	5	1
	4.00%	11	18	0	0	8.5	12	7	4	0.6
CMC (% wt)	1.00%	9.5	15	4	20	8.5	32	5.5	4	0.7
	2.00%	16.5	23	7	35	8.5	20	6.5	10	1.5
	4.00%	16	25	8	45	8.5	17	9	7	0.8
SA5-4 Tannathin (% wt)										
	1.00%	7.5	12	0	8	8.5	14	4.5	3	0.7
	2.00%	16	23	3	12	8.5	12	7	9	1.3
	4.00%	9	14	2	10	8.5	10	5	4	0.8
CMC (% wt)	1.00%	14	19	8	36	8.5	28	5	9	1.8
	2.00%	21	28	12	38	8.5	14	7	14	2
	4.00%	19	30	15	40	8.5	15	11	8	0.7
SA5-7 Tannathin (% wt)										
	1.00%	6	9	0	9	8.5	14	3	3	3
	2.00%	10	15	2	12	8.5	11	5	5	5
	4.00%	7	13	2	9	8.5	9	6	6	1
CMC (% wt)	1.00%	5.5	8	7	17	8.5	25	2.5	2.5	3
	2.00%	7.5	10	11	25	8.5	20	2.5	2.5	5
	4.00%	11	18	8	45	8.5	15	7	7	4
M4 Tannathin (% wt)										
	1.00%	3	5.5	3	4	8.5	19	2.5	0.5	0.2
	2.00%	8	13	2	3	8.5	18	5	3	0.6
	4.00%	5	10	0	0	8.5	15	5	0	0
CMC (% wt)	1.00%	2	4	6.5	9	8.5	45	2	0	0
	2.00%	4	6	0	0	8.5	35	2	2	1
	4.00%	5	8	0	0	8.5	25	2	2	0.7