Article Number: 4AF7158

A Paper presented at the 39th CSN Annual International Conference, Workshop and Exhibition, Rivers State University of Science and Technology, Port Harcourt, Nigeria.
18th – 23rd September 2016

http://www.proceedings.academicjournals.org/

ACADEMIC JOURNALS
expand your knowledge

Conference Proceedings

Full Length Research Paper

Assessment of physicochemical properties of clay samples obtained from Ashaka, Potiskum and Tango (NIGERIA) and a commercial bentonite obtained from Kofar Ruwa Market

Abdullahi S. L.[1*] and A. A. Audu[2]

[1]Kano State Polytechmic, Kano State, Nigeria.
[2]Department of Pure and Applied Chemistry, Bayero University, Kano State, Nigeria.

Samples of clays suspected to be bentonite were obtained from Ashaka, Tongo and Potiskum, Nigeria and a commercial bentonite obtained from Kofar Ruwa market, Kano State were investigated for some of their physicochemical properties. These determinations were carried out on the wet beneficiated clay samples. The results were compared with results obtained from other studies on bentonite clays. The moisture content, pH, density and swelling power were between 4 to 7%, 7.78 to 9.89, 1.21 to 1.82 g/cm^3 and 10 to 13 ml/2 g, respectively. Cation exchange capacity (CEC) was between 61 and 72 meq/100 g; Ca^{2+} and Na^+ were the main exchangeable cations (20.87 to 39.752 and 26.55 to 33.18 meq/100 g, respectively) with calcium ion as the dominant. The chemical composition of the clays indicates high percentages of CaO 1.155 to 14.850 wt%. The silica and alumina contents of the samples were in the ranges of 40.705 to 49.873 wt% and 14.856 to 16.744 wt%, respectively. Fe_2O_3 content of the samples was in the range of 4.802 to 5.606 wt%. The results of the physicochemical analysis of the samples when compared with the results from other studies on bentonite may suggest that the samples are bentonite clays.

Key words: Bentonite, montmorillonite, smectite, cation exchange capacity (CEC), swelling power, chemical composition.

INTRODUCTION

Moisture content is not a relevant parameter or indicator of bentonite performance. Preliminary limiting (maximum) value for water (moisture content) was set to 13% (Trauger, 1994). The moisture contents of the four samples obtained in this study were in between 4 and 7%. These values fall within the range reported by Ahonen et al. (2008). The pH values of the clays were similar to the pH reported by Nweke et al. (2015), Shah et al. (2013), and James et al. (2008) and were within the range given for both Na and Ca bentonite (8.5 to 10.5

*Corresponding author. E-mail: slabdullahi39@gmail.com.

Table 1. Physical characteristics of the samples.

Parameter	G_A	G_T	K_R	P	James et al.(2008)
Moisture (%)	6.7	6.9	4.7	5.4	NA
pH	8.78	7.89	9.89	7.78	8.82
Density (g/cm^3)	1.26	1.35	1.21	1.82	0.961
Swelling Test (ml/2 g)	11	13	10	13	NA

NA: Not available.

Table 2. The physical characteristics of the samples compared with other studies in a range.

Parameter	This study	Nweke et al. (2015)	Ahonen et al. (2008)
Moisture (%)	4-7	NA	6.0-16.0
pH	7.89-9.89	7.8-9.3	NA
Density (g/cm^3)	1.21-1.82	1.45-1.68	NA
Swelling test (ml/2g)	10.0-13.0	NA	23-30

NA: Not available.

Table 3. Exchangeable cations and cation exchange capacity of the samples. CEC was calculated as sum of exchangeable cations (Meq/100 g).

Parameter	G_A	G_T	K_R	P	James et al. (2008)
K^+	8.1	9.2	6.45	7.025	1.26
Na^+	30.169	20.87	39.752	21.643	1.37
Ca^{2+}	33.183	32.378	26.546	33.183	27.86
Mg^{2+}	0.028	0.037	0.019	0.037	1.08
CEC	71.480	62.485	72.767	61.888	31.57

and <8.5), respectively.

The density values for the samples were higher than the value obtained by James et al. (2008) (Table 1), but similar to the values reported by Nweke et al. (2015) (Table 2).

A moderately swelling bentonite will produce 15 to 20 ml/g gel, a good variety 25 ml and an excellent grade will produce 30 ml or more (Ahonen et al., 2008; Shah et al.,2013). **A**ll the samples in this study have lower swelling index <15 ml/2 g, but higher than the value reported by Shah et al. (2013) of 7 ml/2 g for Ca-bentonite. The weak swelling properties are thought to buttress the presence of low expansive montmorillonite, most probably the calcium variety. Variation in exchangeable cations affects the maximum amount of water uptake and swelling.

METHODOLOGY

The Na, K, Ca and Mg concentrations in the extracts were determined using flame emission spectrometer/atomic absorption spectrometer (FES/AAS). The CEC was calculated as sum of exchangeable elements (Na^+, K^+, Mg^{2+} and Ca^2+) and given as cmol+/kg (centimoles of charge per kilogram of material, which corresponds with the also commonly used CEC meq/100 g).

RESULTS AND DISCUSSION

The result in Table 3 for the four samples revealed Ca^{2+} and Na^+ as the main exchangeable cations with calcium ion as the dominant cation. Calcium was higher in three of the samples (G_T, G_A and P) and also higher than the values reported by Ahonen et al. (2008), but lower than those reported by Nweke et al. (2015) (Table 4). The calcium content reflects both the interlayer cation and the calcite content of the samples. The other sample (K_R) has higher sodium content which also reflects the interlayer cation. The values of Mg^{2+} among the exchangeable cations in all the samples were the lowest. The values obtained in Table 3 for Na^+, Ca^{2+}, K^+, Mg^{2+} and CEC when compared with the values obtained by James et a. (2008), were found to be higher except Mg^{2+} values which were lower. The K^+ cations present in the samples were in the range of 6.45 to 9.2 meq/100 g which was

Table 4. Exchangeable cations and cation exchange capacity (Meq/100 g) of the samples in a range compared with other studies.

Parameter	This study	Nweke et al. (2015)	Ahonen et al. (2008)
K^+	6.45-9.2	1.49-3.66	0.5-2.6
Na^+	20.87-39.752	11.1-16.6	46.5-81.3
Ca^{2+}	26.546-33.183	28.8-38.6	12.2-28.7
Mg^{2+}	0.019-0.037	4.3-6.7	7.2-13.2
CEC	61.89-72.77	45.69-65.56	85-104.3

Table 5. Chemical composition (wt-%) of bentonite samples presented as oxide; analyzed by XRF.

Chemical oxide	Sample (wt%)				Shah et al. (2013)	James et al. (2008)
	GA	GT	KR	PK		
Na_2O	1.655	1.426	2.269	1.551	0.24	0.14
MgO	2.075	2.077	5.257	8.561	6.71	1
Al_2O_3	14.856	14.981	15.93	16.744	17.99	13.58
SiO_2	48.164	49.873	43.717	40.705	59.59	58.79
P_2O_5	1.061	1.014	1.201	1.201	NA	0.04
K_2O	1.595	1.759	1.411	1.394	1.02	0.94
CaO	1.155	1.806	8.692	14.85	1.59	1.11
TiO_2	0.937	0.874	0.826	0.77	0.32	1.36
Fe_2O_3	4.802	5.124	5.192	5.606	2.9	7.06

NA: Not available.

higher than the values obtained by Nweke et al. (2015) and Ahonen et al. (2008). Potassium content is associated with smectites as an exchangeable cation and may also be considered as an indication of the presence of feldspar or micas in the samples. Natural clays rich in montmorillonite generally contain a mixture of exchangeable cations, including Mg^{2+}, K^+ and Fe^{3+}, although Na^+ and Ca^{2+} predominate but in varied proportions.

The typical CEC range of pure smectite is from 80 meq/100 g to 150 meq/100 g (Grim, 1968). According to Gomes (1988), the CEC of the montmorillonite clays is between 40 and 150 meq/100 g of clay. The CEC values in this study ranged from 61 to 72 meq/100 g, sample K_R with the highest value. CEC values published for MX-80 purified sample are 76 meq/100 g (Madsen, 1998); 102 to 140 meq/100g; 88 to 110 meq/100 g (Pusch, 1999, 2001); 97 meq/100 g (Neaman et al., 2003); and 84 to 109 cmol+/kg (Carlson, 2004). CEC values for other studied samples are: Friedland clay, 60 and 40 meq/100 g (Pusch, 1999, 2001); Rokle bentonite, 62 meq/100 g (Pusch, 2001). The lower values are in good accordance with values received in this study.

The results for the chemical analysis of the samples are presented as percentage of oxides (Table 5). The silica and alumina contents of the samples were in the ranges of 40.705 to 49.873 wt% and 14.856 to 16.744 wt%, respectively, the values were close to the reported values by Ahonen et al. (2008) and Nweke et al. (2015) for Wyoming bentonite (45 and 17 wt%, respectively). Ahmed et al. (2012) reported a literature value of 13.33 wt% alumina content for Ca-bentonite. The iron content of the samples in this study was in the range of 4.802 to 5.606 wt% which falls within the range reported from other studies (Table 6). The method does not differentiate between divalent and trivalent iron, therefore the values of Fe_2O_3 obtained for each sample represent its total iron content. Sample P and K_R have values higher than values obtained from reported studies (14.692 and 8.850 wt%), samples G_T and G_A have values similar to reported values by James et al. (2008); Ahonen et al. (2008), Shah et al. (2013) and Nweke et al. (2015).

Conclusion

This study assessed the physicochemical properties of some clay samples suspected to be bentonite from Ashaka, Tango, Potiskum and commercial bentonite clay. All the results of the analysis in this study were similar with the results obtained from other studies on bentonite samples, although there were some variations. Physicochemical properties of bentonite clays typically vary both within and between deposits due to differences

Table 6. Chemical composition (wt-%) of bentonite samples presented as oxide; analyzed by XRFcompared with other studies in a range.

Chemical oxide	This study	Nweke et al. (2015)	Ahonen et al. (2008)
Na_2O	1.426-2.269	0.68-1.98	1.9-3.0
MgO	2.075-8.561	0.32-2.02	2.3-3.8
Al_2O_3	14.856-16.744	19.90-25.08	14.1-18.7
SiO_2	40.705-49.873	50.10-58.96	43.1-56.6
P_2O_5	1.014-1.201	ND	0.04-0.79
K_2O	1.394-1.759	0.52-1.40	0.1-1.1
CaO	1.155-14.850	1.00-5.42	1.3-5.6
TiO_2	0.77-0.937	1.10-2.10	0.16-1.82
Fe_2O_3	4.802-5.606	3.80-4.67	3.5-11.4

ND: Not detected.

in the degree of substitution within the smectite structure and the nature of the exchangeable cations present and also due to type and amount of impurities present, hence, the variations observed as such. Therefore, the samples could be concluded as bentonite clays.

The quality and grade of bentonites are related to the physicochemical properties and smectite content of the clay sample and its measure of likely industrial application. This study did not report the mineralogical and geotechnical properties of the samples, therefore, further analyses such as FTIR, XRD, SEM, TEM, TGA, liquid limit, plastic limit, shrinkage limit, viscosity, porosity, particle size, etc., would be required in order to obtain more information on the mineral content and quality of the samples. Usually, the quality of bentonite can be improved by activation with Na_2CO_3 in order to convert the Ca-bentonite into Na-bentonite.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ahmed AS, Salahudeen N, Ajinomoh CS., Hamza H, Ohikere A (2012). Studies on the Mineral and Chemical Characteristics of Pindiga Bentonitic Clay. Petroleum Technology Development Journal (ISSN 1595-9104). An International Journal 1:1-8

Ahonen L, Korkeakoski P, Tiljander M, Kivikoski H, Rainer L 2008). Quality Assurance of the Bentonite Material. POSIVA OY Working Report 33 https://inis.iaea.org/collection/NCLCollectionStore/_Public/43/063/43063368.pdf

Carlson L (2004). Bentonite Mineralogy. Part 1: Methods of Investigations – A Literature Review; Part 2: Mineralogical Research of Selected Bentonites. Posiva Oy, Working Report 02.

Grim RE (1968). Clay Mineralogy. 2nd Edition, McGraw- Hill, New York 596 p.

James OO, Adediran MM, Adekola FA, Odebunmi EO, Adekeye JID (2008). Beneficiation and Characterisation of a Bentonite from North-Eastern Nigeria. Journal of the North Carolina Academy of Science 124(4):154-158.

Madsen FT (1998). Clay Mineralogical Investigations Related to Nuclear Waste Disposal. Clay Minerals 33:109-129.

Neaman A, Pelletier M, Villieras F (2003). The Effects of Exchanged Cation, Compression, Heating and Hydration on Textural Properties of Bulk Bentonite and its Corresponding Purified Montmorillonite. Applied Clay Science 22:153-168.

Nweke OM, Igwe EO, Nnabo PN 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

Pusch R (1999). Is Montmorillonite-rich Clay of MX-80 Type the Ideal Buffer for Isolation of HLW? SKB Technical Report TR-99-33.

Pusch R (2001). The Buffer and Backfill Handbook. Part 2: Materials and techniques. SKB Technical Report TR-02-12, 198 p.

Shah LA, Khattak NS, Valenzuela MGS, Manan A, Valenzuela di´az FR (2013). Preparation and Characterization of Purified Na-activated Bentonite from Karak (Pakistan) for Pharmaceutical Use. Clay Minerals 48:595-603.

Trauger RL (1994). The Structure, Properties and Analysis of Bentonite in Geosynthetic Clay Liners. Geosynthetic Resins, Formulation and Manufacturing. Proceedings of 8th GRI Conference.