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Electrokinetic and rheological properties of Na-bentonite in some electrolyte solutions

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ABSTRACT

Electrokinetic and rheological properties of Na-bentonite suspensions were investigated in the presence of various electrolyte solutions including LiCl, NaCl, KCl, NH_4Cl, $NaClO_4$, CH_3COONa, $NaNO_3$, Na_2SO_4, Na_3PO_4, $CuCl_2$, $MnCl_2$, $CaCl_2$, $BaCl_2$, $NiCl_2$ and $AlCl_3$. It was found that divalent cations (Cu^{2+}, Mn^{2+}, Ca^{2+}, Ba^{2+} and Ni^{2+}) and trivalent cation (Al^{3+}) were potential determining cations for the Na-bentonite suspensions. Trivalent cation, Al^{3+}, changed the surface charge of Na-bentonite from negative to positive. The zeta potential measurements showed that monovalent counter-cations and mono-, di- and tri-valent anions were indifferent ions for the Na-bentonite suspensions. The plastic viscosity and the Bingham yield stress values of the Na-bentonite suspensions were also determined in the presence of electrolyte solutions.

1. Introduction

Bentonite, a smectite type clay mineral, is highly available for the usage in different industrial fields due to its swelling, colloidal and rheological properties. The smectites 2:1 structural units are three-layer clay minerals (Fig. 1). Its general formula is $(Na)_{0.7}(Al_{3.3}Mg_{0.7})Si_8O_{20}(OH)_4.nH_2O$. The elementary layer is constituted from two tetrahedral layers of silicon oxide $(SiO_4)^{4-}$ and one octahedral layer formed by aluminum, magnesium, or iron oxide. The particles have negative charges on their faces due to isomorphic substitutions which are Al^{3+} for Si^{4+} substitution in tetrahedral sites and Mg^{2+} for Al^{3+} substitution in octahedral sites [1].

Smectites have very small particle size, a high specific surface area and a cation exchange capacity values [2]. Due to these characteristics, smectites can show complex electrokinetic and rheological properties when they are dispersed in aqueous media, especially with electrolyte species. The pH of suspension and the electrolyte type in the suspension affect the colloidal behavior of bentonite suspensions causing variations in the electrokinetic and rheological properties that should be characterized to determine the best product for each application.

The zeta potential is defined as the potential between the slipping plane and the bulk solution [3]. It is the measure of the stability of a clay solution. Zeta potential can be used to estimate the effect of the particle charge on such as aggregation, flow, sedimentation and filtration behaviors. Also it can be used to estimate the likely effect of various reagents on the properties of the colloid suspension [4].

The knowledge of electrokinetic and rheological properties of the colloidal particles is very important to obtain the optimal conditions of a well-dispersed system in the clay/water suspensions [5]. The electrokinetic properties of small particles in the aqueous solutions play a significant role in understanding the adsorption mechanism of inorganic and organic species at the solid/solution interface. They also govern the flotation, coagulation and dispersion properties in suspension systems [6,7].

There are some studies published in the literature related with the electrokinetic properties of various clay suspensions. Ersoy et al. [8] performed a series of systematic zeta potential measurements to determine the effect of mono- and multi-valent salts such as NH_4Cl, $CaCl_2$ and $Al(NO_3)_3$ on the zeta potential of clinoptilolite. They reported that clinoptilolite had no isoelectric point in the pH range of 2 and 12 and multivalent cations had a greater influence on the zeta potential of clinoptilolite than those of monovalent cations. The effect of some heavy metal ions such as Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+} and Cd^{2+} on the zeta potential of magnetite was investigated by Erdemoğlu and Sarıkaya [9]. They used the zeta potential data obtained for the magnetite suspensions to develop a model representing the adsorption of heavy metal ions onto magnetite. Zhao et al. [10] studied the electrokinetic properties of alumina based ceramic microfiltration membrane using electro-osmosis measurements in the presence of various electrolyte solutions. They reported that there were significant differences between measured zeta potential values in the presence of different

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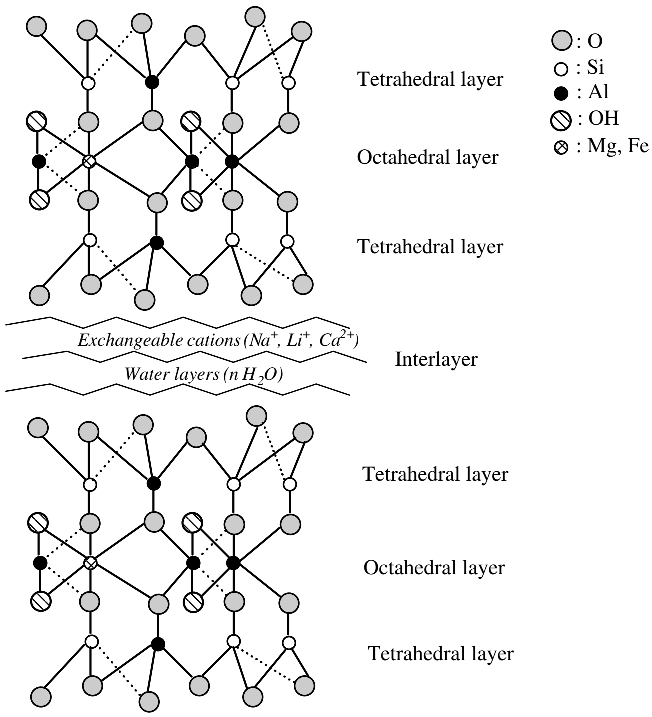

Fig. 1. The structure of bentonite.

inorganic electrolytes. In the other studies, Alkan et al. [7] and Doğan et al. [11] investigated the electrokinetic properties of sepiolite and perlite suspensions, respectively, in the presence of some electrolytes by microelectrophoresis technique.

Several studies have also been performed to assess the effect of surfactant molecules [12], polymers [13,14] and some electrolytes such as NaCl, KNO_3, $MnSO_4$ and $CaCl_2$ [15–19] on the rheological properties of bentonite suspensions.

The aim of this study was to determine the influence of some mono- and multi-valent salts including LiCl, NaCl, KCl, NH_4Cl, $NaClO_4$, CH_3COONa, $NaNO_3$, Na_2SO_4, Na_3PO_4, $CuCl_2$, $MnCl_2$, $CaCl_2$, $BaCl_2$, $NiCl_2$ and $AlCl_3$ on the electrokinetic and rheological behaviors of Na-bentonite suspensions.

2. Experimental

2.1. Material

Bentonite sample was obtained from Balıkesir, Turkey (Zafer Mining Ltd.). NaCl, KCl, $NaClO_4$ and CH_3COONa were purchased from Sigma, LiCl, NH_4Cl, $CuCl_2.2H_2O$, $MnCl_2.2H_2O$ and $CaCl_2.2H_2O$ from Merck, and $BaCl_2.2H_2O$, $NiCl_2$, $AlCl_3$, $NaNO_3$, Na_2SO_4 and $Na_3PO_4.12H_2O$ from Aldrich. All other chemicals were reagent grade. Deionized water was used in all experiments.

2.2. Method

2.2.1. Purification of Na-bentonite

After raw bentonite were grounded and sieved, the purification of bentonite was carried out according to the method described by Tributh and Lagaly [20] with some modifications. Sodium acetate–acetic acid (pH 4.8) buffer solution was used to remove carbonates from clay sample. Iron oxides were removed by a sodium citrate, sodium bicarbonate, sodium chloride and sodium dithionate buffering system (pH 8.3). Organic material was oxidized with hydrogen peroxide solution at 90 °C.

Purified samples were dried at 110 °C for 24 h, grounded and sieved by 100 μm sieve. The final product was used in the further experiments.

2.2.2. Characterization of Na-bentonite

X-ray diffraction (XRD) measurement was performed using a Shimadzu XRD-6000 model diffractometer. The XRD pattern of bentonite was given in Fig. 2. Chemical composition of bentonite was analyzed by X-ray fluorescence (XRF) spectrometer and results were given in Table 1. These measurements were carried out by the Scientific and Technological Research Council of Turkey (TUBITAK). As seen in Fig. 2, purified bentonite sample is constituted by mainly montmorillonite and small amounts of feldspat and crystobalite. Purified bentonite contains essentially Al^{3+}, Mg^{2+}, Fe^{3+}, Na^+ and Ca^{2+} (Table 1). Bentonite sample was named as Na-bentonite, because the amount of sodium in the sample was higher than the amount of calcium as seen from Table 1.

The cation exchange capacity and the density of Na-bentonite were determined by ammonium acetate method and picnometric method, respectively.

The particle size distribution and the specific surface area (N_2 adsorption isotherm method) of Na-bentonite sample were determined by Mastersizer 2000 model of particle size analyzer (Malvern) and Quantachrome Autosorb-1-C/MS, respectively. These measurements were carried out by Central Laboratory of Middle

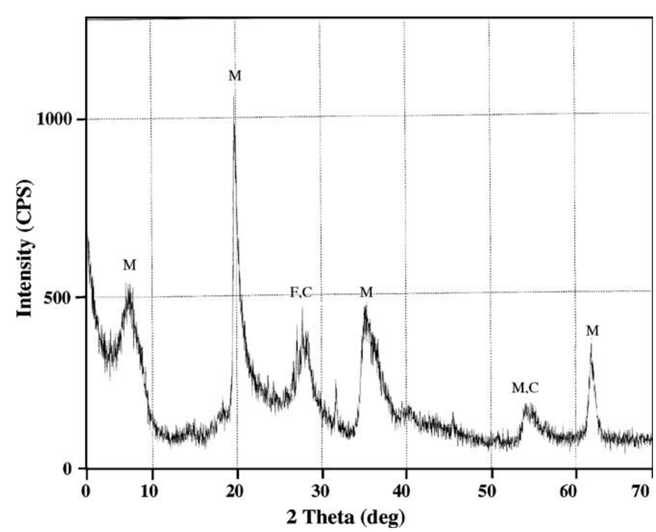

Fig. 2. XRD pattern of Na-bentonite.

Table 1
Chemical composition of Na-bentonite

Compound	Na-bentonite (%)
Na_2O	3.94
MgO	6.65
Al_2O_3	19.87
SiO_2	65.54
P_2O_5	0.05
K_2O	0.29
CaO	1.24
TiO_2	0.10
MnO_2	0.02
Fe_2O_3	2.21
ZnO	0.01
ZrO_2	0.02
BaO	0.04
PbO	0.01
ThO	0.01