Characterization of a clay-polymer composite using the infrared spectroscopy

Zuka Maniania B.*, Mbungu Tsumbu J. P. * and Mulaba Bafubiandi A. F**

Abstract— Clay-composite ion exchangers have been used. The clays used originated from the vicinity of Kinshasa in the Democratic Republic of Congo while organic polymers were purchased. Clays were dispersed into an organic polymer solution to form the composite material. The clay-polymer composite could be used for the remediation of mine waters and purification of hydrometallurgical effluents. The polymer used in this work was the sodium alginate. X-ray diffraction spectra obtained on the clay samples show that these clays are mixtures of several clay minerals. We have studied infrared spectra of clays, infrared spectra of a polymeric membrane and those of clay-polymer composite. It was observed that the main infrared vibrations are the same in all the clay samples. The main vibration bands observed in the polymeric material are different from those observed in clays. Infrared spectra of the composite clearly show vibration lines of the polymeric component hiding those of the clay components. It is concluded that the polymer component covers completely the surface of the clay crystallites. Thus, clay particles coated by polymer could prevent the clay crystallites to form aggregates [1, 2]. The composite material made of clays and polymer may be used for adsorption properties from the large specific surface of the clay crystallites and the presence of exchangeable ions on the surface provided by the polymer.

Keywords— Clay, polymer organic, ion exchangers, clay-polymer composite system.

I. INTRODUCTION

The accumulation of mining waters and hydrometallurgical effluents are a major environmental problem affecting industrialized countries. Several authors proposed techniques based on hybrid processes combining membrane filtration and adsorption / ion exchange for the treatment of wastewater and secondary effluents. Sarah Khiarani [3], for example, has focused his work to the treatment of organic compounds in effluents by coupling a microfiltration or ultrafiltration membrane with an adsorbent or an ion exchanger. He has used a resin as an ion exchanger and as adsorbents a clay (montmorillonite) and a powdered activated carbon (PAC). Nechad A. [4] has developed a membrane for water filtration based on low density polyethylene (LDPE) and Bouzgaga gypsum. He studied the proportion of each component to obtain the most efficient membranes for the treatment of wastewater. Boulehdid Hanae [5] has developed a cationic membrane with selectivity for monovalent cations by chemically modifying an ETFE film (ethylene-tetra fluorohydrin). He has characterized this membrane for the use in electrodialysis. In an electrodialysis unit, the cationic membranes and anionic membranes are parallel and alternately arranged. Under the action of an electric field, the cationic membranes block anions and let cations to go through, while the anionic membranes block cations and anions can pass through. There is then created alternating compartments of concentration and dilution. Solutions are continuously renewed in the compartments by flowing parallel to membranes.

Many scientists [6, 7, 8, 9, 10, and 11] are interested in hybrid processes combining membrane filtration and adsorption / ion exchange. They developed and studied systems with clays, organic polymers and membranes. We would like to develop ion exchangers from local clays collected near Kinshasa in the DRC. Clays are mixed with an organic polymer to form a composite ion exchanger. The composite could thus be applied in the treatment of mine water and hydrometallurgical effluent in Democratic Republic of Congo.

II. EXPERIMENTAL PROCEDURES

We study a clay-polymer composite by infrared spectroscopy. The clay samples were collected in the DRC around Kinshasa and have not undergone any purification treatment. We have applied a sodium alginate gel on a polished flat surface of glass, and we have obtained a thin polymeric membrane after drying in open air during 72 hours. The sodium alginate gel was obtained as follows: 2g Sodium Alginate was dispersed in 50 ml of water; the suspension was then stirred for 24 hours at 30 ° C using a magnetic shaker. The composite system was obtained by simultaneously dispersing 2g Sodium alginate and 0.5 g of clay (25% of the amount of sodium alginate) in 50 ml of water. The mixture was then stirred as for the obtaining the sodium alginate gel. A thin membrane of composite was obtained in the same manner as the polymeric membrane.

X-ray diffraction spectra have been measured by using an Ultima IV/ RIGAKU spectrometer. Table I and Table II show X-ray diffraction characteristics for clays and the polymeric membrane.

The study of the samples was carried out by using an
Infrared Fourier transform spectrometer NICOLET IS10/Thermo Scientific. Infrared spectra were measured at room temperature. Fig. 1 shows the spectra obtained for different clay samples, while Fig. 2 shows spectra for the polymeric membrane and clay-polymer composites.

III. RESULTS AND DISCUSSION

The X-ray diffraction spectra show several clay minerals in the samples (Table I). We observe structures of Keatite, Quartz, orthoclase, Nacrite, Sodalite, Birnessite, Carnegieite, Kaolinite, Clinohypersthene, and of Alumino-phosphate.

<table>
<thead>
<tr>
<th>N°</th>
<th>Samples</th>
<th>clay minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1</td>
<td>Keatite, 80% ; Quartz SiO₂; 11% Orthoclase, K(AlSi₃O₈), 9%</td>
</tr>
<tr>
<td>2</td>
<td>A2</td>
<td>Orthoclase, K(AlSi₃O₈), 62%; Quartz, SiO₂; 32%</td>
</tr>
<tr>
<td>3</td>
<td>A3</td>
<td>Nacrite, Na₂Si₂O₅(OH)₄, 65%; Quartz, SiO₂; 35%</td>
</tr>
<tr>
<td>4</td>
<td>A4</td>
<td>Sodalite, Na₈(Al₆Si₆O₂₄), 84%; Quartz, SiO₂; 9.4%; Birnessite, KO₄Mn₁.94O₅.18; Carnegieite, Na₄AlSiO₄, 3.8%</td>
</tr>
<tr>
<td>5</td>
<td>A5</td>
<td>Kaolinite, Al₂(Si₂O₅)(OH)₄, 75% ; Quartz, SiO₂; 25%</td>
</tr>
<tr>
<td>6</td>
<td>A6</td>
<td>Clinohypersthene, Mg₀.₃₁Fe₀.₈₇, 80%; Alumino-phosphate, Al(PO₄)₄, 8.9%; Quartz, SiO₂; 11.1%</td>
</tr>
</tbody>
</table>

Infrared spectra for clays show characteristics of particular vibrations (Fig. 1). These are vibrations of bands between 500 cm⁻¹ and 1300 cm⁻¹, 1300 cm⁻¹ and 1800 cm⁻¹, and between 3000 cm⁻¹ and 3800 cm⁻¹.

Infrared spectra of clays show a large amplitude vibration around 1000 cm⁻¹. They also show vibrations between 675 cm⁻¹ and 784 cm⁻¹, around 909 cm⁻¹, 1634 cm⁻¹, 3386 cm⁻¹ and 3678 cm⁻¹. In agreement with the previous results obtained for kaolinitic clays [8], we can assign the vibrations around 1000 cm⁻¹ and those between 675 cm⁻¹ and 784 cm⁻¹ to vibration of valence bands Si-O-Si and Si-O-Al, and vibration of deformation bands Si-O-Al. We can also assign vibration at 909 cm⁻¹ to vibration of deformation bands Al-OH, while those at 3678 cm⁻¹ can be attributed to the vibrations of valence bands Al-OH. According to the same study, the deformation band at 1634 cm⁻¹ and the large absorption around 3386 cm⁻¹ are characteristic of OH vibrations of water of clay hydration.

The infrared spectra of the polymeric membrane and those of clay-polymer composite indicate the same vibration lines (Fig. 2) but with different intensities. These spectra are characterized by vibration bands of great intensity between 950 cm⁻¹ and 1200 cm⁻¹, between 1200 cm⁻¹ and 1500 cm⁻¹, between 1500 cm⁻¹ and 1600 cm⁻¹, and a broad vibration band between 2500 cm⁻¹ and 3700 cm⁻¹. The observed band around 1000 cm⁻¹ is shifted to higher values, while the similar band observed in clays is shifted towards lower values. The bands between 1200 cm⁻¹ and 1500 cm⁻¹ and between 1500 cm⁻¹ and 1600 cm⁻¹ do not nearly exist in clays. The broad band between 2500 cm⁻¹ and 3700 cm⁻¹ is very intense and covers all the vibrations observed in clays. Infrared spectra for composite show the vibration lines of the polymeric membrane while masking those for clays. Other authors such Benchabane Adel et al. [1] Jörn Dau et al. [2] who worked with clay-polymer composites have also found the same results. Despite clays are hidden, there is an interaction between the clay and polymer. It is necessary that we study this interaction in next section.
IV. CONCLUSION

A clay-polymeric membrane composite was fabricated for its potential use as an ion exchanger. FTIR vibrations for the original polymer and those of the composite material covered those of clays. It was noticed that the signals attributable to clays were masked by those of the polymer component in the composite. It was also observed that the infrared spectrum of the composite clays-polymer differs from that of clays. The infrared spectrum of the composite resembles that of the polymer in all the vibration domains, but differs in the intensities. It is therefore concluded that the clays interact physico-chemically with the polymer to form the composite. This is in agreement with the findings of many other scientists [3, 4, and 5]. The mechanisms of such interactions will be elucidated in a separate work.

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REFERENCES