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On the use of electrokinetic in the kaolinite soil decontamination

A. Ben Hassine [1, 2*], H. Souli [1], Ph. Dubujet [1], M. Trabelsi-Ayadi [2]

[1]Laboratiore de Tribologie et Dynamique des Systèmes (UMR 5513 / ECL/ ENISE/ CNRS) Ecoles Nationale d'ingénieurs de Saint Etienne, 58 rue Jean-Parot, 42023 Saint Etienne Cedex.
[2]Laboratoire d'Application de la Chimie aux Ressources et Substances Naturelle et à l'Environnement (LACReSNE), Faculté des Sciences de Bizerte

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[*]Corresponding Author. E-mail: benhassine_abdelkader@yahoo.fr; Tel: (+33611388244)

Abstract

This paper presents the results of the depollution of a kaolinite using the electrokinetical method. The electrokinetical process was applied on the sample for des duration equal to 48h, 72h, 96h, 120h, 168h and 192h. The results show that as function of time, the electrical intensity decreases and the potential difference increases. This behaviour is accompanied with a progressive diminution of the conductivity suggesting a migration of lead during the test. The electroosmotic flow is stabilized after duration equal to 168h. The measurements of the pH values after the tests show that the pH of the sample is acidic. For the acidic pH values, the lead is presented as free Pb^{2+} and its elimination is easier than when it's present at other forms.

Keywords: Kaolinite, lead, electrokinetic, conductivity.

Introduction

Electrokinetic extraction of heavy metals from soils is based on the application of direct electric current across electrodes in saturated soil resulting in transport by electro-osmosis and ionic migration [1]. Electro-osmosis causes the transportation of the pore fluid to flush the soil system, usually toward the cathode. The ionic migration separates the negative and positive ionic species by their transport to the anode and cathode, respectively [2]. In a saturated medium, the electric current application results in electrolysis at the electrodes producing protons at the anode, dropping the pH to below 2, and hydroxyl ions at the cathode, increasing the pH to above 10 [3]. In these conditions, the protons transport is delayed by the soil buffering capacity, the soil between the electrodes will be acidified due to higher ionic mobility of the proton compared to hydroxyl ion and retarded transport of hydroxyl ions due to electro-osmosis. This acidification results in solubilization of heavy metals by desorption and dissolution. Once contaminants are present in ionic form in soil pore fluid, they migrate to the electrode opposite in polarity, leading to their extraction. Extraction and removal are accomplished by electrode position, precipitation or ion exchange either at the electrodes or in an external extraction system.

In this work, the aim is to evaluate the efficiency of this method when it is used for the decontamination of a lead polluted kaolinite.

2. Materials and methods

2.1. Preparation of soil samples

The kaolinite was selected because is one of the most present soil in real soils. It's known that the presence of clay plays an important role in the retention of heavy metals. The electrokinetic tests were realized on a kaolinite polluted by lead. For the preparation of the samples, kaolinite powder is mixed with a $Pb(NO_3)_2$ solution at a concentration of 0,03M.

2.2. Electrokinetic experimental device

The electrokinetic cell used for the experiments for this study is shown in Figure 1. The cell is composed by two graphite electrodes (E1, E2), power supply (1), anodic reservoir (2), cathodic reservoir (3), two metal electrodes in stainless steel for measuring the potential difference of the sample during the electrokinetic (E3, E4), pump (4) and a multimeter for difference potential and the current measurements (5, 6). The imposed voltage gradient is equal to 1 V/cm. In the cathodic and the aniodic compartments a solution of citric acid (0,1M) was used. The tests were realized at ambient temperature.

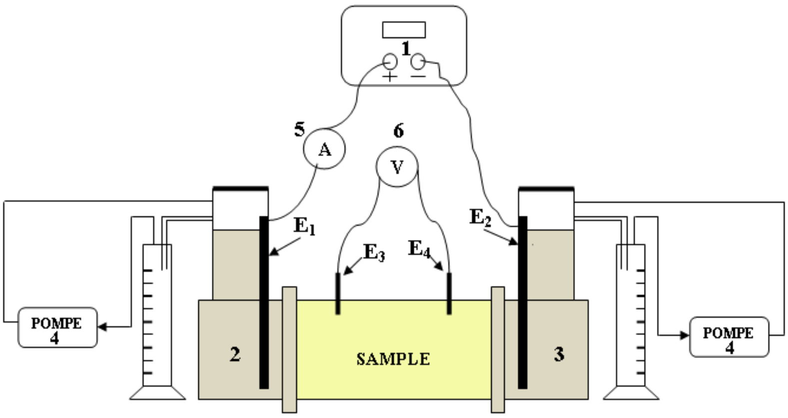

Figure1: Electrokinetic cell

3. Results and discussion

3.1. Evolution of the parameters during the electrokinetic test

Voltage (U) and electric current (I): The figure 2 and 3 show the evolution of the potential difference and the electric intensity respectively. The results correspond to the lead polluted sample. These results show that the potential difference increases and the electric intensity decreases during electrokinetic test.

***The electric conductivity σ*:** Figure 4 shows the electric conductivity variation in kaolin soil for different treatment durations. The electric conductivity is calculated using the equation (1):

$$\sigma = \frac{I\,L}{A\,U} \qquad \text{(eq.1)}$$

I: current intensity (A), L: distance between electrodes (cm), A: cell section (cm²), U: measured voltage (V).

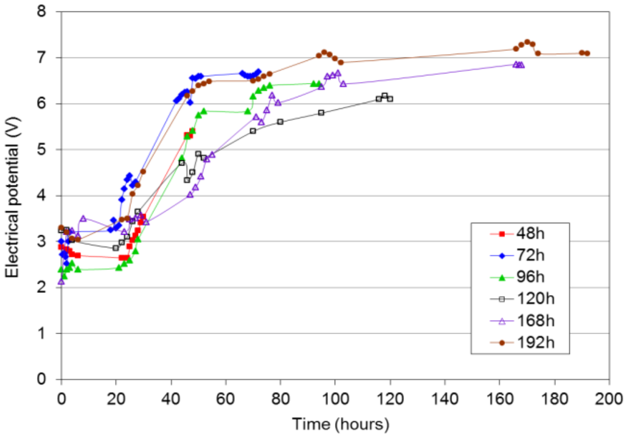

Figure 2: Time evolution of Voltage (U), during the electrokinetic experiments

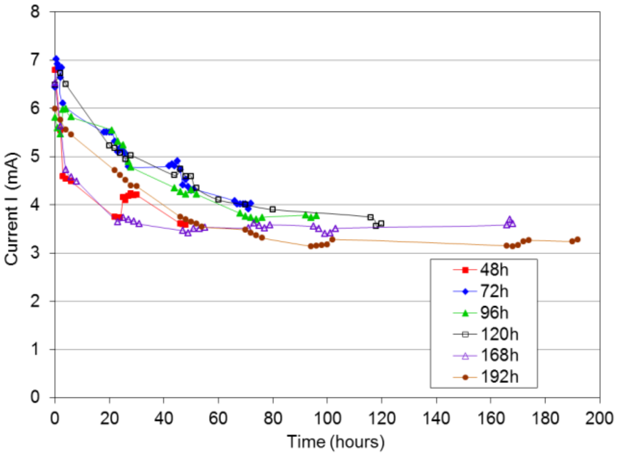

Figure 3: Time evolution of electric current intensity (I), during the electrokinetic experiments

The results show that the conductivity increases slightly in the few first hours after the application of the current and then decreases. A stabilization is observed at low values after about 100 hours. It's known that the conductivity is proportional to the dissolved species in the solution. During the electrokinetic, the electric conductance decreases with decreasing dissolved species, therefore, the electric current decreases. This result suggests also that the lead migrated through the sample. Indeed, during the electrokinetic treatment, the lead is progressively replaced by the H^+ cations. This replacement is the origin of the decrease of conductivity of the sample [4].

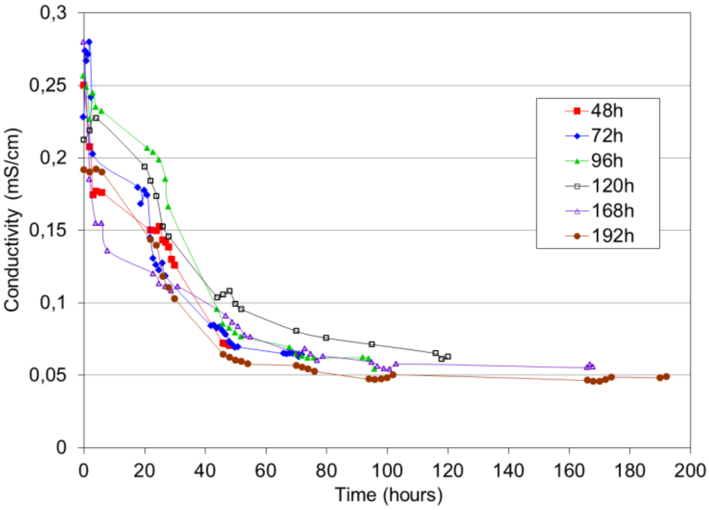

Figure 4: Electrical conductivity profiles

Electroosmotic flow: The cumulative electroosmotic flow was calculated by measuring the volume accumulated in the cathode reservoir during the test. As shown in Figure 5, the Electroosmotic flow increases with time for all the tests (i.e, 120, 168 and 192 h). The results show that the slope of the curve is the same after 168 and 192h. This observation suggests that after 168h of treatment a stabilisation of the characteristics of the sample is observed. The result suggests that the electroosmotic flow towards the cathode. The result suggests also that the pH is above the zero point charge (ZPC) and that the surface possess a negative zeta potential [5].

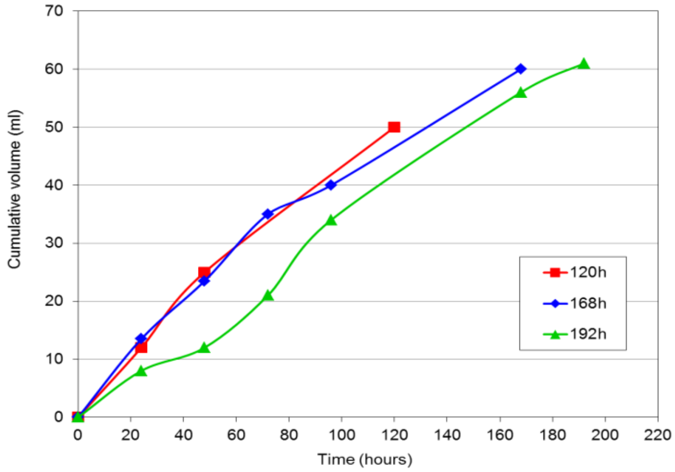

Figure 5: Cumulative EO flow vs. time.

3.1. Parameter measurements after electrokinetic: pH

pH variation with the distance from anode for all the experiments is presented in the Figure 6. Acid front moved towards cathode (H^+ protons are transported with the electro-osmotic flow).Thus, the pH of the kaolin sample decreased with distance from anode and with time. After 192 hours, the pH decreases and reaches acidic values. The acidic pH value enhances the migration of Lead as free Pb^{2+}. At this form, the lead migrate easier than when it's at another form like PbO^- for example [6].

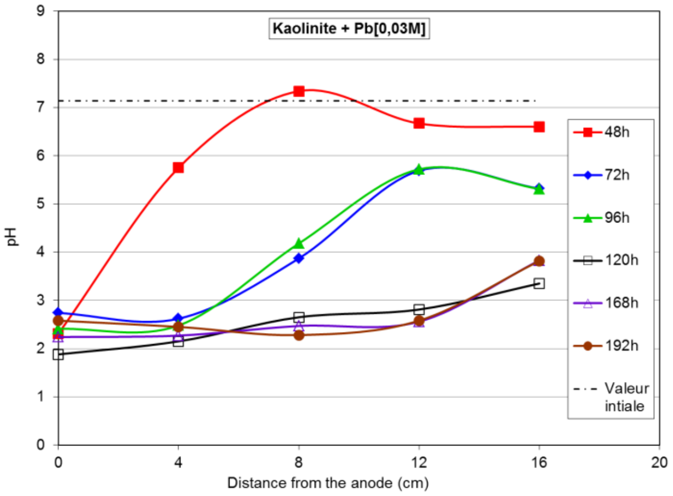

Figure 6: pH profile: after electrokinetic

Conclusion

In this study, the results of lead removal from kaolin soil by electrokinetic method are presented. The tests duration affects the variation of different parameters such as the current intensity, the pH, the conductivity and the electroosmotic flow.

The results show that the current intensity decreases as function of time. However, the voltage increases. The conductivity derived from these two parameters shows a decrease.

The decrease of the conductivity is due to the progressive remove of lead cations as function of time. These cations are replaced by H^+ cations.

The electroosmotic flow moves towards the cathode. The results suggest that the initial pH of the sample is located above the zero point charge (ZPC) and the material surface presents a negative zeta potential.

The measurements of the pH after the electrokinetic tests show that for the tests conducted for long durations, for example, after 168 hours and 192 hours the pH of the sample became acidic. The result suggests that the lead cations present in the sample are eliminated and replaced by H^+ cations. Indeed, the acidic conditions enhance the presence of lead as Pb^{2+} which is easier eliminated.

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