

Electro-kinetic processes in low permeable porous media: A Numerical approach

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Introduction

Electro osmosis process is important for groundwater contaminant remediation, water and salt extraction. It combines hydraulic, concentration, and electric field effects (**Figure 1**), so it is a multiphysic coupling problem. In this study, we analyze the transient behavior of the pressure distribution, the concentration distribution and the electrical potential distribution in a homogeneous clay sample. The research consist of two parts:

- 1) Darcy scale numerical modeling of the fully coupled equations
- 2) A laboratory experiment for model validation

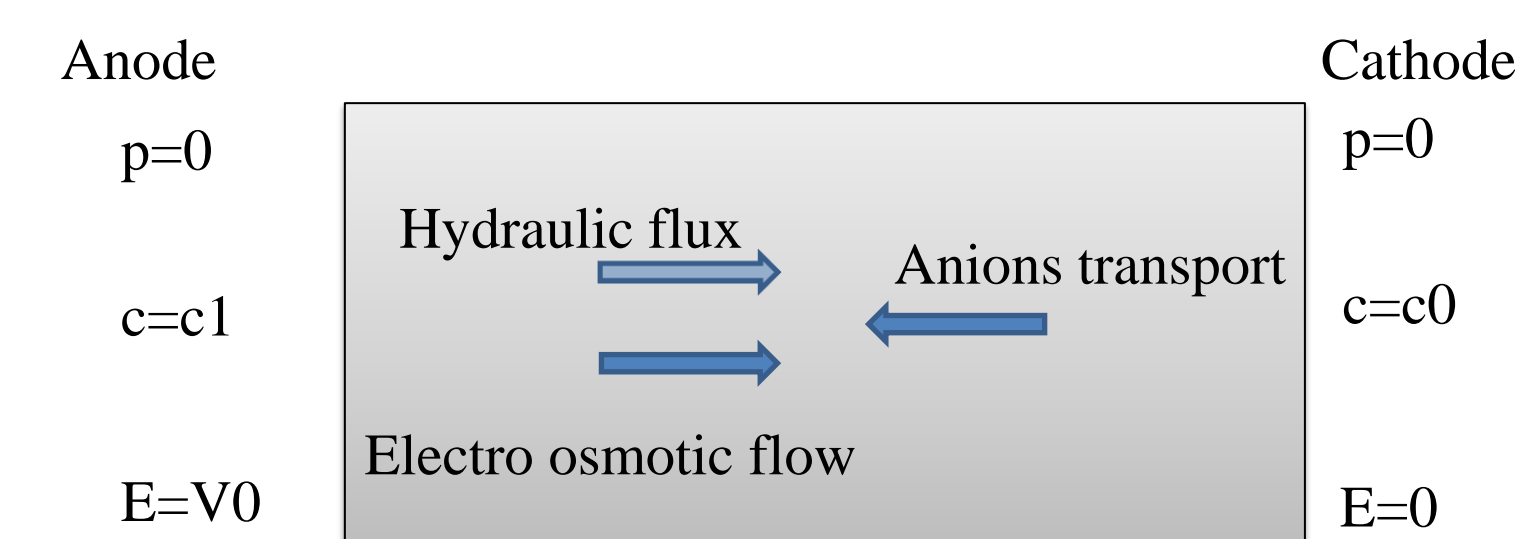


Figure 1. Schematic map of Electro-kinetic process

The ultimate goal of the research is to determine the dependence of electro-osmotic parameters on e.g. ion concentration, pressure and potential.

This will be achieved by using a pore scale network model to obtain the aforementioned function relationships. The experiment displays in **Figure 2**.

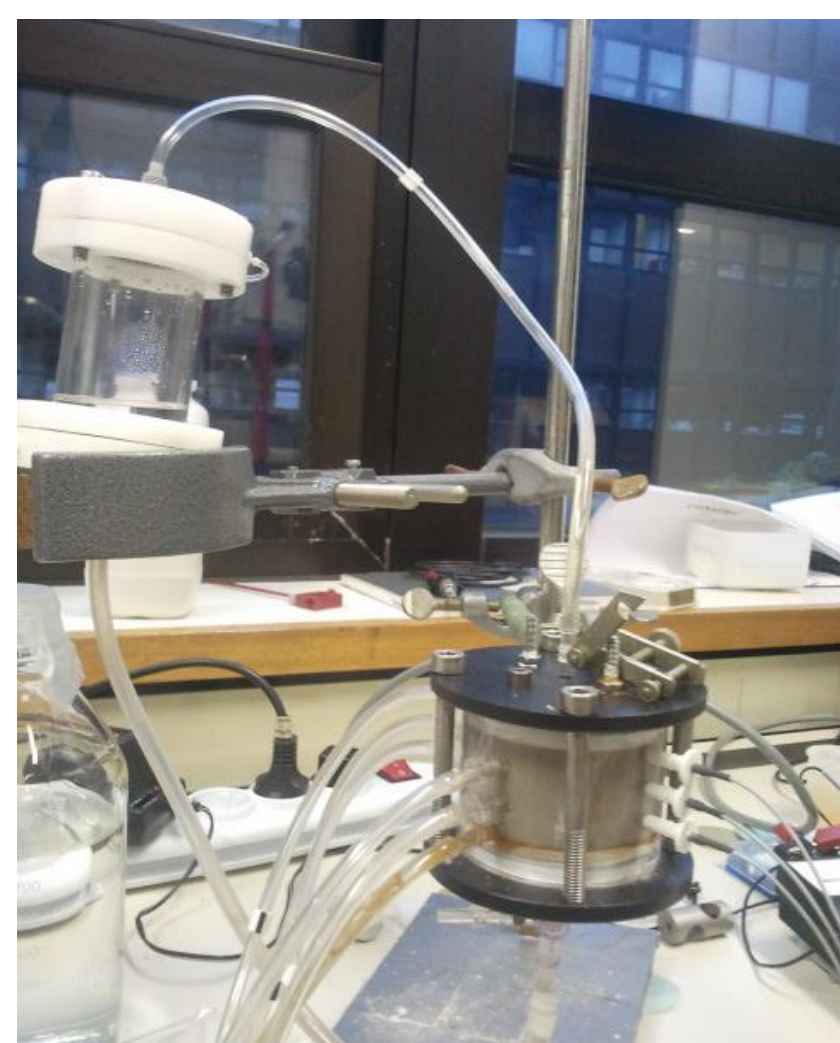


Figure 2. Photograph of Electrokinetic experiment.

Theory and method

The governing flux equations is

$$\begin{aligned} 1) J_w &= -\frac{\kappa}{\mu} \frac{\partial P}{\partial x} - k_{eo} \frac{\partial \Phi}{\partial x} \\ 2) J_c &= J_w C - D \frac{\partial C}{\partial x} - F z u C \frac{\partial \Phi}{\partial x} \\ 3) I &= F z D \frac{\partial C}{\partial x} + \sigma \frac{\partial \Phi}{\partial x} \end{aligned}$$

Where k_{eo} is electro osmotic permeability [$\text{m}^2/(\text{V}\cdot\text{s})$], F is Faraday constant [F/m], z is valence number [-], u is ions mobility [$\text{m}^2/(\text{V}\cdot\text{s})$], Φ is electric potential [V].

The hydraulic boundary condition for our study experiment cell is assumed to be Dirichlet boundary condition. Initially, hydraulic pressure across the sample and two reservoir is set to 0Pa. The solute concentration in the anode side is $0.3[\text{mol}/\text{m}^3]$, the background solution inside sample and cathode side is $0.1[\text{mol}/\text{m}^3]$.

The external applied electric field is $1[\text{V}/\text{cm}]$. The parameter of the model is presented in **Table 1**.

Table 1. Parameter values

Length	0.025[m]	l
Density	1110[kg/m ³]	ρ
Dynamic viscosity	1e-3[Pa*s]	μ
Porosity	0.5[1]	θ
Permeability	7.895e-16[m ²]	κ
Electric conductivity	1e-1[S/m]	σ
Electro osmotic conductivity	4.5e-9[m ² /(V*s)]	k_{eo}

Early time, the profile is dominated by diffusion which approaches the cathode, the electric field mainly affect solute transport process.

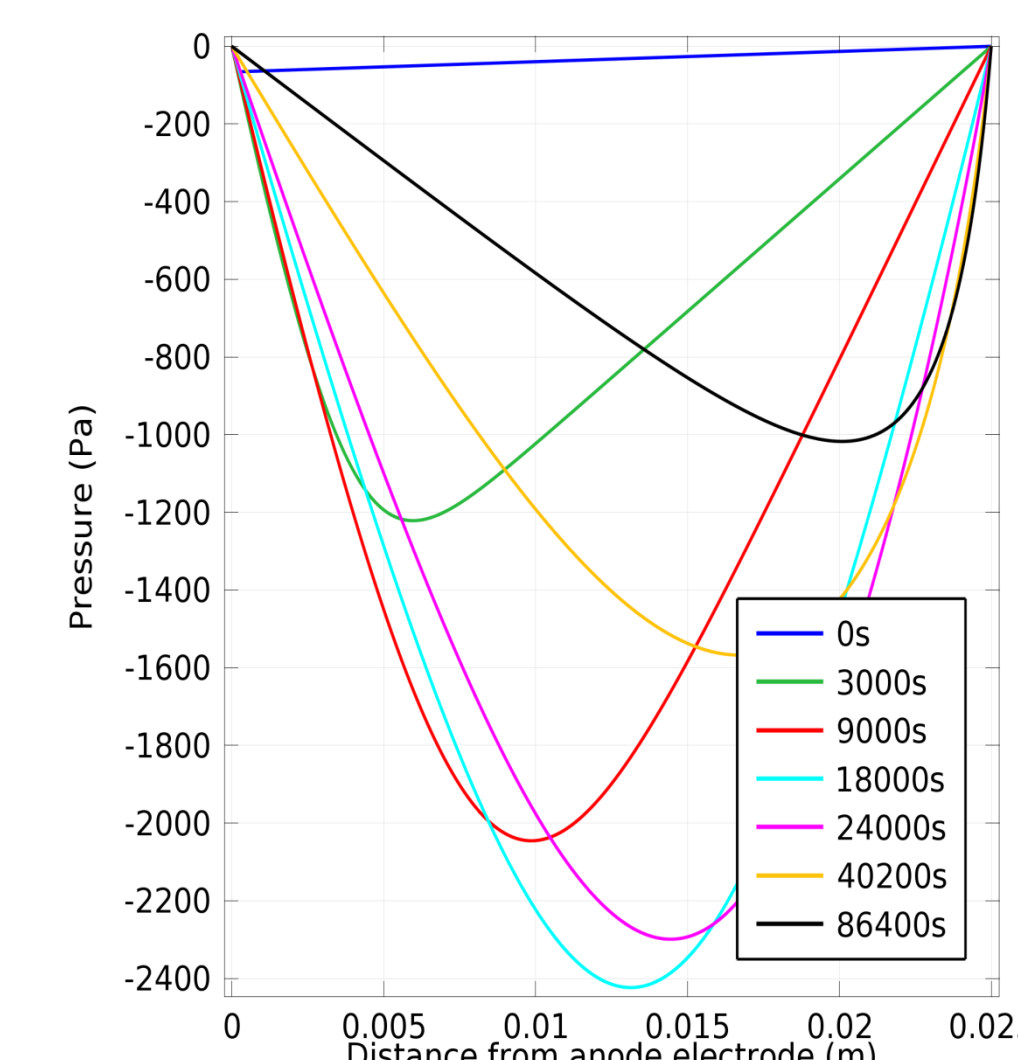


Figure 3a. Pressure distribution

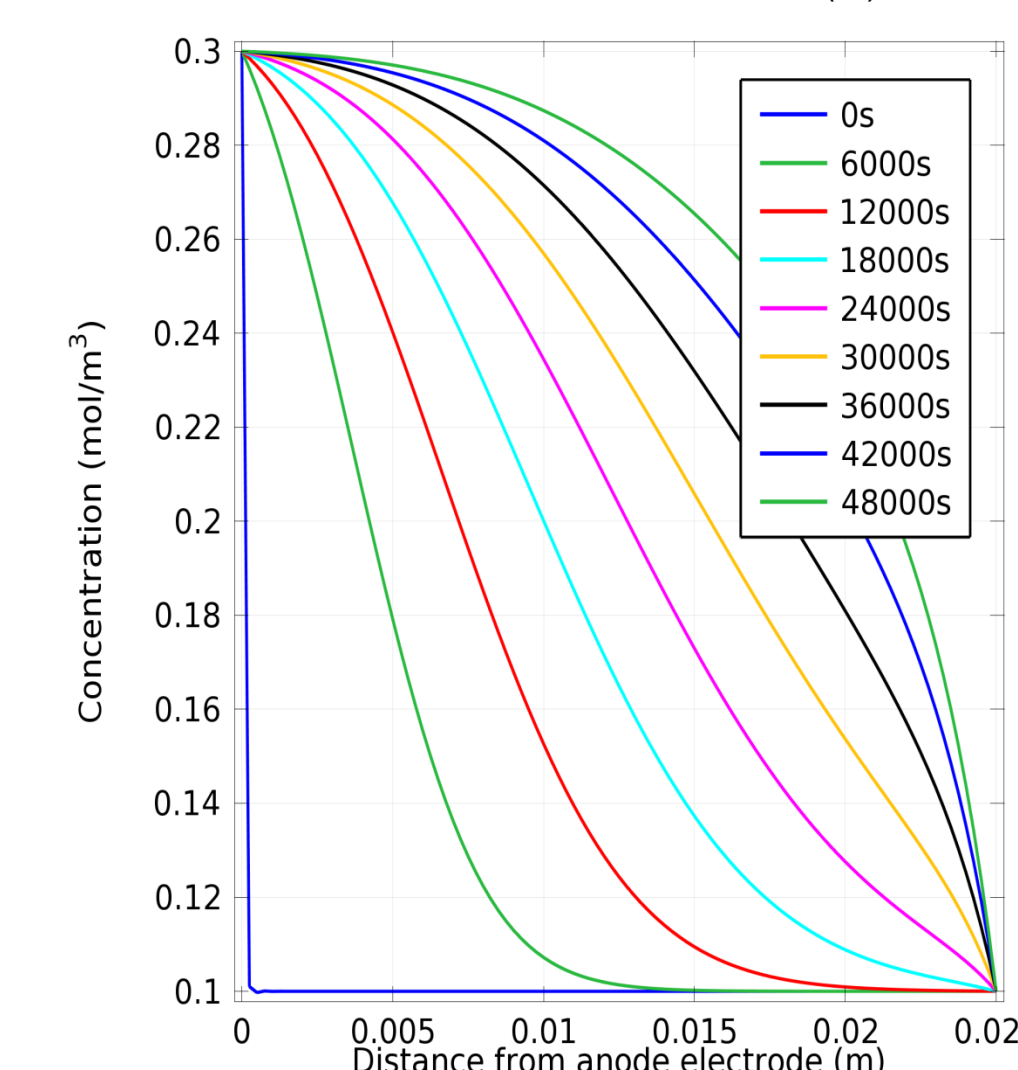


Figure 3b. Concentration distribution

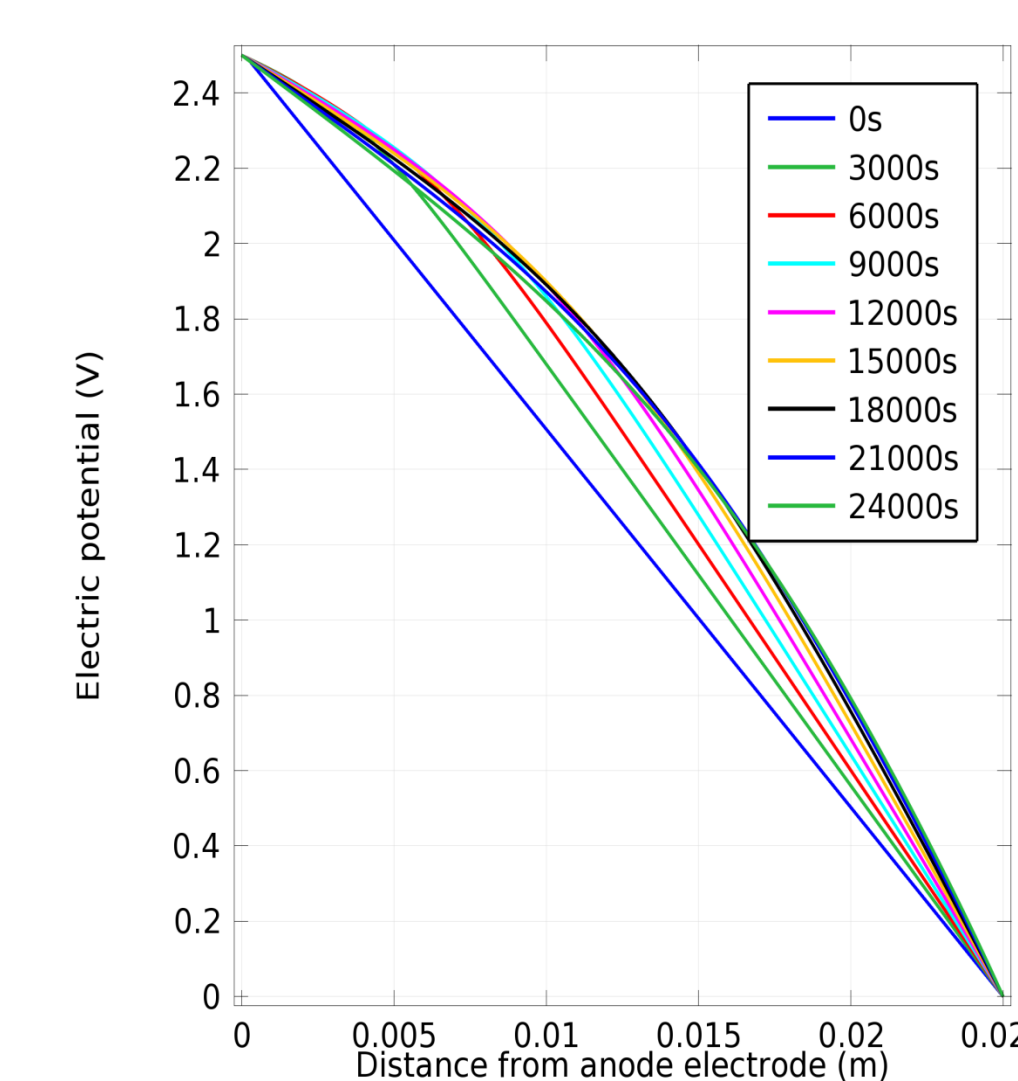


Figure 3c. Electric Potential distribution

Figure 3. Evolution of pressure, concentration and potential across the sample

The electric field gradient is close to constant as can be observed in **Figure 3c**, and increases slightly with concentration change. When the ions diffuse into the column, the apparent electric conductivity decreases a little close to the anode. The potential will reach equilibrium when the solute is uniformly distributed inside sample.

Conclusions

In the modeling result, we clearly observe the effects of the interaction between the ion migration and the electrical field. Initially the concentration front movement is dominated by diffusion and at later times by electric effects.

The minimum pressure across the sample goes down first and move up later. The potential distribution also have same trend.

In the lab, we investigate the distribution of pH value and monitor the variable continuous, which will validate the numerical result.

References

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For further information

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