A MODEL FOR ELECTROKINETIC TRANSPORT IN CONTAMINATED CLAY

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ABSTRACT

The demand for innovative remediation technologies stimulated the development of electrokinetic treatments in the last twenty years as a valuable tool for decontamination of clayey soils (see, e.g. [1]). The application of a low voltage DC electric field (of the order of 100 V / m) promotes different species transport mechanisms, namely diffusion, electromigration and electroosmotic advection, allowing for partial or total decontamination of the treated soil. Although the technology has already proven to be effective, the different interplaying coupled physico-chemical processes involved in electrokinetic transport need further inspection, mainly because of their dependency on many factors such as soil mineralogy, porosity and tortuosity of the soil skeleton, pore fluid composition and conductivity and electrochemical properties of the species in the pore fluid (e.g. [2], [3]).

It is well recognised that a paramount role on electrokinetic treatment efficiency is played by the time evolution of soil pH [4], due to the advance of the acid front generated at the anode and of the alkaline front generated at the cathode from electrolysis reactions which dominate the chemistry at the boundaries of the treated soil. Cation exchange capacity of the soil minerals or specific buffering procedures at the electrodes will then condition desorption, adsorption and precipitation mechanisms, together with transport of species through the soil, hence determining the overall efficiency of the electrokinetic treatment. Experimental tests are necessary in general to study the effects of electrokinetic treatment of a given soil, and to optimise the conditioning procedures to enhance decontamination efficiency. Measurements performed during and after the electrokinetic tests may help in understanding the prevailing mechanisms governing the overall process, and to formulate conceptual models for prediction purposes.

This contribution is aimed at providing a predictive numerical model for electrokinetic transport in saturated clayey soils, considering all the relevant physico-chemical mechanisms involved in a decontamination process. A system of coupled balance equations for linear momentum of the whole continuum, energy, hydraulic and electrical flux, and mass transport of the single species in the solution is formulated. A finite element discretisation is performed and a monolithic approach is adopted to solve the fully coupled system of equations in time. With respect to previous works (see e.g. [5]), new features of the model stem in the introduction of the temperature field and the soil skeleton displacements field to complete the description of the coupled problem. The temperature field is inherently linked to changes

in electrical conductivity, as experimental results demonstrate. Deformability of the soil skeleton is introduced to model correctly the coupled evolution of local effective stress and pore pressure, in turn affecting time variation of water flux.

The model is validated by comparison with the results of laboratory experimental tests. Samples of natural and lead contaminated Pisa clay were subjected to one dimensional filtration in an electrokinetic cell designed by Musso [6], for a period of time long enough to allow for a two pore volumes outflow from the sample. Tests were run under constant current density control, in order to determine the amount of electric charge passed, and under controlled hydraulic boundary conditions, which kept fully saturated conditions throughout the whole duration of the test. Time evolution of potential drop and temperature were measured continuously by means of different probes placed along the sample. A differential pressure transducer was provided in the catholyte reservoir to measure the water volume outflow. At the end of the tests, pH and lead concentration were measured on slices cut from the sample, allowing for a final profile of the two quantities to be drawn. Both unconditioned and conditioned tests were performed. In the latter, a buffering solution of acetic acid and sodium acetate was added into both the anolyte and the catholyte reservoir, in order to maintain a low pH environment so as to avoid lead precipitation. Relevant results of the experimental programme are presented and compared to the finite element model simulations to highlight the predictive capabilities of the numerical model.

REFERENCES

[1]   Y.B. Acar and A.N. Alshawabkeh "Principles of electrokinetic remediation". *Environ. Sci. Technol.*, Vol. **27**, 2638–2647, 1993.

[2]   A.P. Shapiro and R.F. Probstein "Removal of contaminants from saturated clay by electroosmosis ". *Environ. Sci. Technol.*, Vol. **27**, 283–291, 1993.

[3]   A.T. Yeung, C.-N. Hsu and R.M. Menon "Physicochemical soil-contaminant interactions during electrokinetic extraction". *Journal of Hazardous Materials*, Vol. **55**, 221–237, 1997.

[4]   G.R. Eykholt and D.E. Daniel "Impact of system chemistry on electroosmosis in contaminated soil". *J. Geotech. Engrg. ASCE*, Vol. **120**, 797–815, 1994.

[5]   M.Y. Corapcioglu "Formulation of electro-chemico-osmotic processes in soils ". *Transport in Porous Media*, Vol. **6**, 435–444, 1991.

[6]   G. Musso *Electrokinetic Phenomena in Soils*, PhD Thesis, Politecnico di Torino, 2000.