The Use of Electrokinetic Technology to Enhance Chemical and Biological Remediation of Contaminated Sands and Soils

Brian Wartell (baw9@njit.edu), Michel Boufadel, PhD, Lucia Rodriguez-Freire, PhD, and Lisa Axe, PhD (New Jersey Institute of Technology, Newark, NJ, USA)
Stewart H. Abrams, PE, and Ali Ciblak, PhD (Langan Engineering, Lawrenceville, NJ, USA)

Background. Electrokinetics (EK) is a remediation technology where a DC voltage is applied to porous media to enhance the transport of specific compounds by electroosmosis, electrophoresis, and electromigration processes. EK can be used to remediate pollutants chemically and biologically, and also can effectively make contaminants, nutrients, electron acceptors and electron donors more accessible to enhance biodegradation. Dyes can be used to determine migration patterns of chemicals in an EK system. Anionic dyes can be used to mimic anionic chemicals or metals in solution and can give an estimate for their electromigration rates. Other dyes, such as *Spirulina* Blue, are amphoteric in nature, meaning they have sufficient ability to both donate and accept electrons and function as an anionic, non-ionic, or cationic, depending upon the pH at a given point. This type of dye can be used to analyze migration abilities for the removal of other amphoteric compounds that are quite toxic in nature, such as Congo Red and Acid Blue dyes. These may also prove useful in modeling migration patterns of emerging hormone contaminants and pharmaceutical byproducts.

Objectives. This study investigates different rates of electrokinetic phenomena, primarily electromigration, and compares dyes with different charge properties and how their migration rates changed accordingly. Moreover, it looks at pH gradients within an electrokinetic system and how they change over time and the effects of polarity reversals and other mitigating factors.

Approach. Four unique electrokinetic experiments researching dye migration patterns were conducted. Two dyes, an anionic red dye and a green dye with both anionic and cationic properties, were studied in these experiments. The red dye was a food coloring primarily consisting of FD&C Red 40 and the green dye, also a food coloring, contained a mixture of turmeric and *Spirulina* Blue, with the latter being the primary migrating compound. Following this, a confirmation experiment of the green dye in sand and a subsequent measurement of a developing pH gradient were investigated.

Results. The red dye was found to migrate in sand 10 times more than clay, consistent with literature findings. For the green dye, or specifically the migrating compound of *Spirulina* Blue (C-Phycocyanin), electromigration was also readily apparent in sand, seemingly due to its initial anionic nature and at a rate close to that observed by the red dye. In an effort to explain this, the second set of studies showed that the pH gradient demonstrated in the literature is not immediate, in fact, it shifts over time. A minimal migration of the green dye in clay, however, was left unresolved if the phenomenon was as a result of cationic electromigration or electroosmosis, although diffusion was ruled out as a primary factor. In this experiment, the pH measured in the reservoirs hit extreme values in a very short period of time, indicating the need for buffers in any future or in situ system.