A Solution to a Frustrating Obstacle: Electrokinetics In-Situ Groundwater Remediation at the Winona Site

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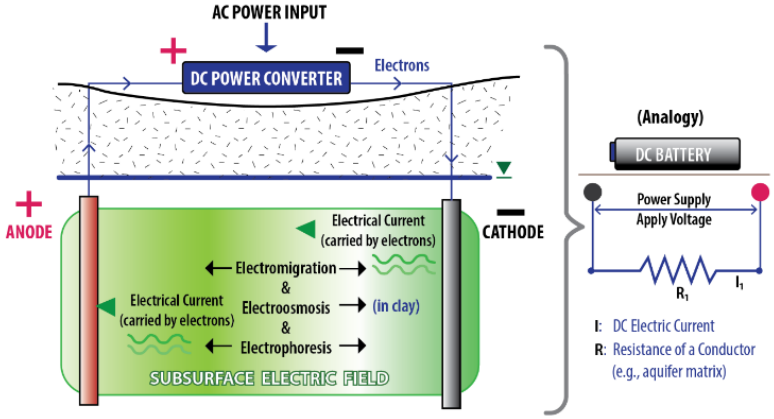
The Winona Groundwater Contamination Superfund Site (a Minnesota state Superfund site) is a former dry-cleaning facility in Winona, Minnesota. Chlorinated volatile organic compounds (cVOCs), primarily tetrachloroethylene (PCE) and its daughter products trichloroethylene (TCE), cis-1,2-dichloroethylene (cDCE), and vinyl chloride (VC), have been detected at the site indicating a dissolved-phase groundwater plume of more than 4,000 feet (ft) to the east-northeast. Past remedial efforts have been challenged by a low-permeability (low-K) clay unit under the groundwater table that was inaccessible to excavation, and, consequently, a portion of cVOC source mass remains within the clay unit representing a long-term source for groundwater contamination. The site occupies a corner lot on a busy commercial thoroughfare – outwardly similar to many brownfields. The inability of conventional remediation technologies to cost-effectively address the contaminant sources in this case renders the otherwise valuable property unavailable for beneficial uses and development.

Recognizing the challenge of remediating the low-K clay unit, the Minnesota Pollution Control Agency (MPCA) evaluated and selected electrokinetic enhanced *in situ* chemical oxidation (EK-ISCO) as a cost-effective source remediation approach for the site. EK-enhanced amendment delivery for *in situ* remediation entails the use of electrodes and direct current (DC) electrical power to establish an electric field in the subsurface. The DC electric field is then the driving force for transporting remediation reagents, including electron donors for *in situ* bioremediation and chemical oxidants for ISCO, through low-K soils or heterogeneous formations. One reason that EK represents a fundamentally more effective delivery technique in low-K materials compared to conventional advective hydraulic approaches is the relatively uniform electrical property of various soil materials.



Concept of EK Enhanced *In Situ* Remediation
(Source – USEPA Document EPA/600/R-23/329)

The MPCA contracted Geosyntec Consultants, Inc. (Geosyntec) in 2020 to conduct a bench-scale treatability study to evaluate the feasibility of EK-ISCO for the site. The successful treatability study led to the Focused Feasibility Study (FFS), and, subsequently, an EK-ISCO pilot test was completed in 2022 by Geosyntec at the site. The pilot test found the following:

- The pilot test demonstrated the EK transport of a selected oxidant, persulfate ($S_2O_8^{-2}$), in both clay materials and sand materials within the target area.

EK-ISCO Pilot Test System at Winona Site

- The pilot test was safely completed without health and safety incidents. The equipment and instruments used for the pilot test are all commercially and readily available. The electrical power existing at the on-site groundwater treatment system was sufficient to support the pilot test.
- The electrical current setting applied during the pilot test operation (approximately 1.5 to 1.7 amps) can be considered a minimum electrical setting for a full-scale remedy. The full-scale system should be designed to deliver target currents at approximately 80 to 100 volts.

Based on the findings of the FFS and the 2022 Pilot Test, the MPCA issued Minnesota Decision Document Amendment #3 in May 2023, focusing on remediation of the remaining cVOC mass in soil and groundwater present at an approximate depth interval between 14 to 30 ft bgs in the source areas. Geosyntec prepared an EK-ISCO remedial design to guide the implementation of a full-scale EK-ISCO remedy at the site. The design includes:

- A network of 20 electrode wells, 10 used as cathode wells and 10 as anode wells;
- A conveyance system to connect the electrode wells with the remediation system control center;
- An amendment supply system controlled by the system control center;
- A DC power supply unit to power the electrodes in electrode wells;
- A remediation system operation, monitoring, and maintenance (OM&M) program; and
- A remediation performance monitoring program.

Electrode Wellhead

The full-scale remedy is planned to commence in 2025. Additional information regarding EK-enhanced *in situ* remediation technologies can be found in a recent USEPA document entitled "*Electrokinetic (EK) Enhanced In Situ Remediation*" (EPA/600/R-23/329 at https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=361645&Lab=CESER).