# Fractured Bedrock Characterization for Improved ISCO Design and Implementation

*By Susanne Borchert* (susanne.borchert@ch2m.com; CH2M HILL, Chicago, Illinois)

Permanganate is commonly used during *in situ* chemical oxidation (ISCO) applications for groundwater remediation. Experience gained from most permanganate sites in the United States is from applications in unconsolidated aquifers. This presentation focuses on ISCO applications in fractured, competent bedrock environments. It discusses bedrock characterization tools that have been used to aid ISCO design and to overcome the challenges that differ in a bedrock matrix compared to unconsolidated subsurface applications.

Examples of unique characterization tools of bedrock include hydraulic connectivity tests and effective permeability tests to help predict and optimize distribution of the permanganate. Another example is analyzing the fracture apertures (Paillet ranking method) to determine the percentage of open fractures per linear foot. This not only allows estimating the quantity and distribution of groundwater in the bedrock matrix, but also helps predict the amount of contact the permanganate oxidant will have with contaminants in the estimated groundwater volume, and with the bedrock surface. These factors are important in calculating permanganate dosing during remedial designs.

Knowledge gained from a variety of characterization approaches, ISCO designs (dosage), and remediation implementation (delivery, post-ISCO sampling) will be presented for a number of case studies. In particular, the open borehole field tests that were conducted at several Department of Defense (DoD) sites prior to permanganate injection will be discussed. The tests included isolated vertical chlorinated solvent profiling with packers, fluid temperature and resistivity, hydraulic testing for connectivity and permeability, and down-hole geophysical logging. These and other data were used to develop the injection volumes, rates, and pressures; the injection method, the permanganate mass requirements; the permanganate concentrations per linear foot; and the amount of chase water per boring. Lessons learned and site parameters that contributed to optimizing the injection design for permanganate into the fractured bedrock will be conveyed. Suggestions for research needs for the application of ISCO in fractured bedrock will also be conveyed.