Field Testing of Nanoscale Zero-Valent Iron Particle Technology for In-Situ Groundwater Treatment in Fractured Bedrock

Gheorghiu, F., Golder Associates Inc.; Walata, L. GlaxoSmithKline; Venkatakrishnan, R., Golder Associates Inc.; Zhang, W., Lehigh University; and Glazier, R.E., Golder Associates Inc.

Abstract

As part of a RCRA Corrective Measure Study (CMS) at a facility located in Research Triangle Park, North Carolina, field testing of nanoscale zero-valent iron particle technology for n-situ treatment of groundwater in fractured bedrock was completed. The study area is located in the Durham subbasin of the Deep River Triassic Basin and is underlain by interbedded siltstone and sandstone sequences. Groundwater underlying portions of the site has been impacted by historical industrial activities conducted by previous owners; groundwater contaminants consist mainly of chlorinated volatile organic compounds. Golder conducted an initial review of potentially applicable remediation technologies, and retained the nanoscale zero-valent iron technology for further evaluation and recommended the implementation of a field pilot test using bimetallic nanoscale particles (BNP). BNP consists of nanoscale particles of zero-valent iron (Fe^0) with a trace coating of palladium. The rapid destruction of a wide range of recalcitrant contaminants is based on a surface-catalyzed redox process where the contaminant serves as an electron acceptor and BNP as the electron donor and can be accomplished either in situ or ex situ (Wei-xian Zhang, 1997, 1999, 2000). This study presents the field demonstration of the BNP effectiveness to treat in-situ chlorinated volatile organic compounds (VOCs) in a complex fractured bedrock aquifer setting. During the pilot test, 11 kilograms of BNP mixed in water-based slurry were injected into the shallow bedrock groundwater suspected to contain dense non-aqueous phase liquids (DNAPLs). The results of the test indicated rapid treatment of chlorinated VOCs 20 feet to 40 feet around the injection well. In addition, the oxidation-reduction potential (ORP) and dissolved oxygen (DO) values have decreased and persisted for more than six months at very low levels of -450 millivolts and less than 0.001 milligrams per liter, respectively, indicating favorable conditions for reductive dechlorination. Interpretation of pre- and post-test data on the in-situ microbiological community in the test area indicate changes in ORP and DO that would be expected to favor inhibition of aerobic bacteria and stimulation of anaerobic bacteria known to degrade chlorinated solvents. Redox-induced mobilization of naturally occurring inorganics from the aquifer solids was not detected. Treatment efficiencies closely correlate with predictions from bench scale tests, suggesting that very little reagent interacted with non-target constituents within the aquifer matrix. Nanoscale zero-valent iron in-situ treatment technology has the potential to reduce significantly the remedial costs in comparison to the conventional treatment systems.

Biographical Sketches

Mr. Gheorghiu is a Principal in Golder Associates, and directs numerous environmental projects requiring numerical groundwater flow and solute transport modeling, particularly supporting in-situ remedial systems. He was the Project Director for design and implementation of a large bedrock remedial system at Modern Landfill that received the Year 2000 Outstanding Groundwater Remediation Project Award from NGWA. Golder Associates Inc., 1951 Old Cuthbert Road, Cherry Hill, New Jersey 08034, Tel: (856) 616-8166, Fax: (856) 616-1874, email: florin@golder.com

Lindsey Walata is an Environmental Engineer at GlaxoSmithKline. Her primary responsibilities include direction of RCRA corrective actions activities. Ms. Walata is a registered professional geologist in North Carolina and has extensive experience with environmental investigations and evaluations.) GlaxoSmithKline, Five Moore Drive, NTH-P.1165.1C RTP USA 3000, Research Triangle Park, NC 277, Tel: (919) 483-4640, FAX, 919-315-5713, email lw11065@gsk.com

Dr. Venkatakrishnan is a Principal in Golder Associates. As practice leader in the firm he directs geologic and hydrogeologic aspects of site investigation at mine developments, subsurface exploration for civil, geotechnical and environmental investigations. He serves as a peer reviewer for geologic and hydrogeologic projects in the Golder's northeast region. Golder Associates Inc., 1951 Old Cuthbert Road, Cherry Hill, New Jersey 08034, Tel: (856) 616-8166, Fax: (856) 616-1874, email: ramesh@golder.com

Dr. Zhang is an Associate Professor of Civil and Environmental Engineering at Lehigh University. Dr. Zhang is the leading expert on the manufacture, treatment mechanics, and use of the BNP technology and has led successful field demonstrations of BNP treatment of chlorinated VOCs at an industrial site in Trenton, New Jersey. Dr. Zhang is also working on a part-time basis with Golder Associates Inc. Lehigh University, 13 East Packer Avenue, Bethlehem, PA 18015, Tel: (610) 758-5318, email: wez3@Lehigh.edu

Mr. Glazier is an Associate in Golder Associates and is responsible for development and implementation of project strategy for remediation projects under CERCLA, RCRA, State, and Voluntary Corrective Action programs and provides a broad perspective of regulatory approaches to site remediation and is well-versed in risk assessment, indoor air pathway evaluations. Golder Associates Inc., 1630 Heritage Landing, Suite 103, St. Charles, Missouri, 63303, Tel: (636) 936-1554, Fax: (636) 936-1135, email: rglazier@golder.com