Abstract 2E-09, in: A.R. Gavaskar and A.S.C. Chen (Eds.), *Remediation of Chlorinated and Recalcitrant Compounds—2004.* Proceedings of the Fourth International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2004). ISBN 1-57477-145-0, published by Battelle Press, Columbus, OH, www.battelle.org/bookstore.

DEMONSTRATION OF ZERO-VALENT IRON INJECTION FOR IN SITU REMEDIATION OF CHLORINATED SOLVENTS AT HUNTERS POINT SHIPYARD

John McCall (Tetra Tech EMI, Philadelphia, PA)
Greg Swanson (Tetra Tech EMI, San Diego, CA)
C. Hwakong Cheng (Tetra Tech EMI, San Francisco, CA)
Patrick Brooks (U.S. Navy, Southwest Division, San Diego, CA)
D.B. Chan (U.S. Navy, Naval Facilities Engineering Service Center, Port Hueneme, CA)
Steve Chen (ARS Technologies, Inc., New Brunswick, NJ)
Julie Menack (California Regional Water Quality Control Board, Oakland, CA)

Ferox^{sm} injection is a patented technology of ARS Technologies, Inc. (ARS) for in situ subsurface remediation of chlorinated volatile organic compounds (VOC). The Ferox^{sm} technology involves injection of liquid atomized zero-valent iron (ZVI) powder into targeted subsurface zones, using a straddled packer system to isolate discrete depth intervals within open boreholes. A ZVI slurry is delivered to the subsurface in a liquid atomized form using nitrogen gas as a carrier fluid. As needed, ARS uses pneumatic fracturing technology before the Ferox^{sm} injections to enhance the bulk permeability of the formation, promoting more efficient dispersion and distribution of the movement of the slurry. Introducing ZVI into the subsurface facilitates chemical reduction and dechlorination of VOCs.

To evaluate the Ferox^{sm} technology's capability and performance in treating chlorinated VOCs, the U.S. Department of the Navy conducted a Ferox^{sm} injection technology demonstration at Remedial Unit C4 (RU-C4) in Parcel C at Hunters Point Shipyard in San Francisco, California. At RU-C4, an approximate 10-foot layer of artificial fill overlies fractured bedrock. At RU-C4, chlorinated VOCs, primarily trichloroethene (TCE), are present in both soil and groundwater. Before treatment began, TCE concentrations in groundwater were as high as 88,000 micrograms per liter. Pneumatic fracturing was employed, and ZVI was injected into four boreholes to treat soil and groundwater contamination in the vertical profile from the groundwater table (about 7 feet below ground surface) to about 32 feet below ground surface. Approximately 16,000 pounds of ZVI was injected.

Following ZVI injection, very strong reducing conditions in groundwater were observed out to a radius of 15 feet from each of the four injection boreholes. Within this 15-foot radius, which was considered to be the area of full treatment, the average oxidation-reduction potential decreased from +87.4 millivolts (mV) before injection to -372 mV after injection. The depth of the treatment zone was estimated to extend from the top of the water table (about 7 feet bgs) to about 32 feet bgs. Thus, the treated area covered approximately 1,800 square feet and the treated subsurface volume was approximately 1,700 cubic yards.

The results from three rounds of post-injection groundwater monitoring demonstrated nearly complete reductive dechlorination of all chlorinated VOCs of concern. Reduction of TCE, the predominant contaminant, to ethene and chloride was rapid and nearly complete, with a reduction efficiency reaching 99.2 percent within the treatment zone. No significant increases in TCE degradation intermediates cis-1,2-dichloroethene and vinyl chloride were observed. Significant rebound of chlorinated VOC concentrations did not occur even at the last sampling event, which was three months after the ZVI injection. A statistical analysis of changes in contaminant concentrations outside of the treatment zone further supports the conclusion that TCE and other chlorinated VOCs were destroyed rather than displaced as a result of the injections. Thus, it was concluded that the Ferox^{sm} injection technology provided very effective in situ remedial treatment of chlorinated VOCs at this site. The potential for plume displacement due to injection, and mobilization of metals were also evaluated as part of the monitoring program; no significant impacts due to either potential plume displacement or metals mobilization were observed. The total cost of the field-scale implementation of the Ferox^{sm} injection technology at RU-C4 was $289,274, or $172 per cubic yard of the treatment zone. Excluding costs for sampling, analysis, and management of demonstration-derived wastes, the total cost was $196,665, or $117 per cubic yard. Economies of scale for certain cost elements, such as mobilization and demobilization, could result in somewhat lower unit costs for larger-scale applications.