

## **DNAPL Remediation at Camp Lejeune Using ZVI-Clay Soil Mixing**

*Christopher Bozzini, P.E.*, and Tom Simpkin, Ph.D., P.E. (CH2M HILL); Tom Sale (Colorado State University); Daniel Hood, (NAVFAC Mid-Atlantic) and Bob Lowder, (Camp Lejeune EMD)

**ABSTRACT:** Site 88 at Camp Lejeune, NC is the former Base dry cleaners. Historical activities have resulted in a release of dry cleaning solvents especially perchloroethene (PCE). A 10,000 square foot source area was delineated using membrane interface probe (MIP) technology, and soil and groundwater sampling. The contamination extended from the water table (roughly 7 feet below ground surface (bgs)) down to 20 feet bgs. At 20 feet bgs, there is a clayey-silt layer that prevents further downward migration of dense-nonaqueous phase liquid (DNAPL). The estimated volume of contaminated soils was 7,000 cubic yards. DNAPL was observed in several wells at the site.

Soil mixing with zero-valent iron (ZVI) clay addition was implemented at the site in February 2005. The ZVI treated the chlorinated solvents, while the clay created a low permeability zone that limited flow of groundwater into and out of the treated area. A treatability study indicated a PCE half-life on the order of 30 days would be achieved with ZVI concentration of 2 percent and bentonite of 1 percent.

The project included site preparation, removing and re-routing utilities, abandoning monitoring wells, removing soil and concrete debris, soil mixing, site stabilization, utility installation, construction of a parking lot, and monitoring. Since the site was located in a highly developed portion of the base, monitoring well and utility removal had to be complete prior to mixing.

The soil mixing was completed during a 17-day period in February 2005. A crane was used to turn a 10-ft auger while injecting the slurry of ZVI and clay. A total of 200 tons of ZVI and 100 tons of bentonite were mixed to create 146 overlapping columns. Off-gas was treated with activated carbon. After allowing approximately six weeks for settlement, 196 tons of cement were added to the top five feet of soil over the treatment area to stabilize the site for a parking lot.

The results of the treatment are encouraging. One year after the treatment, PCE soil concentrations were significantly reduced with average concentrations of over the entire treatment area being reduced by 82%, with a median concentration reduction of 99%. Reductions were lower in about 1/5 of the area where mobile DNAPL had been present prior to treatment. Reductions in soil concentrations were 61% in this area and were 99% in the remaining 4/5 of the treated area. Overall reduction based on a weighted average of these results is 91%. ZVI was still present in the treatment area, so that continued treatment should occur. Groundwater concentrations of PCE were reduced by greater than 96% in the treatment area, but DCE concentrations did increase significantly in one groundwater well.

Downgradient water quality improved after the treatment, with PCE reduction of 67 and 90%. Hydraulic conductivity within the treatment area was reduced 50 to 400 times (one to two orders of magnitude) with a post-treatment hydraulic conductivity of 0.013 ft/day, so that there should be a significant reduction in mass flux from the treated area.