Naval Submarine Base Kings Bay Site 11

Pump and Treat—In Situ Chemical Oxidation—Biostimulation—Monitored Natural Attenuation

Site Name: Naval Submarine Base Kings Bay Site 11
Site Location: Camden County, Georgia
Technology Used:

- Pump and Treat (P&T)
- In Situ Chemical Oxidation (ISCO) (Fenton's Reagent)
- Biostimulation
- Monitored Natural Attenuation (MNA)

Regulatory Program: RCRA Corrective Action
Remediation Scale: Full
Project Duration: 1993 to present

Site Information: The former Camden County Landfill site ("Site 11") is part of Kings Bay Naval Submarine Base in southeastern Georgia. The 25-acre site was used for municipal waste disposal from 1973 until 1980. Waste was disposed by digging trenches, filling with waste, and covering with fill.

Contaminants: Chlorinated solvents that were disposed of in the landfill have become source material for a groundwater contaminant plume. In January 1999, representative concentrations of the contaminants of concern in monitoring well USGS-3 were 50 µg/L tetrachloroethene (PCE), 550 µg/L trichloroethene (TCE), 1,300 µg/L *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and 4,500 µg/L vinyl chloride (Figure 1). Profiling with direct push equipment indicated there were two distinct source areas. The extent of the contaminant plume was estimated to be 700 ft long, 200 ft wide, and 30 to 40 ft deep.

Hydrogeology: The site is underlain by marginal marine sediments of barrier island and back-barrier lagoon origin. The most permeable sand underlying the site exists between 32 and 42 ft below ground surface (bgs). This permeable zone is underlain and overlain by finer-grained sand and clay of back-barrier lagoon origin, which is characterized by lower hydraulic conductivity (Chapelle et al. 2005). A layer of organic-rich sand (Figure 2) overlies the aquifer. As precipitation passes through this organic layer, it becomes anaerobic, thereby forming a naturally occurring anaerobic biodegradation system. Groundwater is encountered at about 6 ft bgs. An important feature of the groundwater chemistry is that the sulfate reducing conditions predominate near the landfill while iron reducing conditions exist farther downgradient. The sulfate-reducing conditions favor degradation of PCE, TCE, and DCE, while the iron-reducing conditions favor degradation of vinyl chloride.

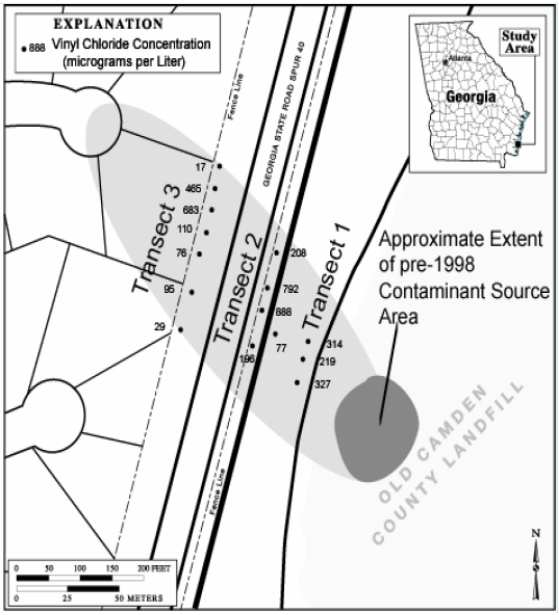

Figure 1. Vinyl Chloride Plume Before Cleanup
Courtesy USGS

Project Goals: The ultimate goal of remedial action at the landfill is to reduce contaminant concentrations in the groundwater plume to levels below the maximum contaminant levels established by the Georgia Environmental Protection Division (GEPD).

Figure 2. Organic-Rich Layer at Outcrop
Courtesy USGS

Cleanup Approach: A P&T system was initially chosen to contain and treat the groundwater plume, and ultraviolet (UV) oxidation was selected to treat the extracted groundwater. The P&T system, which was installed in 1993, was expected to operate for at least 50 years to meet GEPD's cleanup goals. This projection was based on the high concentrations of chlorinated compounds at the site and their low solubility, and on P&T performance data. Such a period is representative of the extended remedial duration required for remedies that rely solely on groundwater pumping.

Using Natural Attenuation Software, it was estimated that Maximum Contaminant Levels (MCLs) could be attained at the property line by MNA if the concentrations from the source area could be reduced to approximately 100 µg/L. A modified Fenton's reagent solution was selected to treat the source zone.

In November 1998, two extraction wells and six process monitoring wells were installed along with 23 specially designed injection wells that were placed in and around the source area (Figures 3 and 4). The monitoring wells were sampled twice each day and analyzed for pH, specific conductance, alkalinity, iron, sulfate, sulfide, dissolved hydrogen, and dissolved oxygen, as well as any change in contaminant concentrations.

The modified Fenton's reagent containing 50% hydrogen peroxide was injected in two phases. Phase one of the ISCO treatment focused on the central part of the contaminant plume, while phase two focused on the downgradient areas that were not treated during phase one. Following phase two, during which 21 new injectors were added, elevated contaminant concentrations (1,700 µg/L) were detected outside the plume near one of the injectors used during phase one, indicating the presence of a previously unidentified contamination source area. Thus, two more phases were added to the treatment process. The last treatment phase was administered in November 2001.

Figure 3. ISCO Well Field
Courtesy U.S. Navy

Since adding Fenton's reagent to an aquifer can change both the geochemistry and the microbial population, monitoring was performed. Measurements in one monitoring well showed an increase in dissolved oxygen from non-detect before injection to over 7 mg/L after injection. Also, microbial activity decreased after each injection. Dissolved hydrogen concentrations indicated that the injection of the ferrous iron activator had shifted the microbial activity from sulfate and iron reducing to a more purely iron reducing environment. To reverse this trend, a solution of emulsified vegetable oil (35% soybean oil with lecithin and 65% water) was injected into the aquifer after phases three and four to return the subsurface environment to an anaerobic state and potentially restore some of the sulfate-reducing activity that increases PCE and TCE degradation. Microbial activity generally rebounded within a few months of each Fenton's reagent injection (Chapelle et al. 2005).

Figure 4. ISCO Control Trailer

Courtesy U.S. Navy

In all, about 48,000 gallons of 50% hydrogen peroxide solution and a similar volume of ferrous sulfate catalyst were injected into the aquifer—principally in the more permeable zone between 32 and 42 ft bgs. In addition, about 25,000 gallons of the emulsified soybean oil solution was injected following Fenton's reagent application phases three and four.

Project Results: The plume size shrank by about 70% (Figure 5). Levels of total chlorinated hydrocarbons in the most contaminated area decreased from nearly 200,000 µg/L in 1999 to 120 µg/L in 2002. Currently, chlorinated hydrocarbon levels range from <1 to 13.9 µg/L.

As of May 2003, no additional exceedances of MCLs occurred in any of the offsite monitoring wells, and many of the onsite monitoring wells had no measurable levels of contaminants. As a result, the P&T system was shut off two months after the phase two ISCO treatment, and MNA has been implemented as the final corrective action for the landfill. There was no need for further treatment with UV oxidation. Shutting down the P&T system slowed the transport rate of contaminants downgradient, which increased the effectiveness of the biodegradation process.

The estimated cost of the remedial action from 1991 to 1997 was $9.8 million. The estimated cost for the ISCO and biostimulation is approximately $5 million. This represents a $9 million savings over the estimated $15 million that the P&T system would have cost (Spinner 2004).

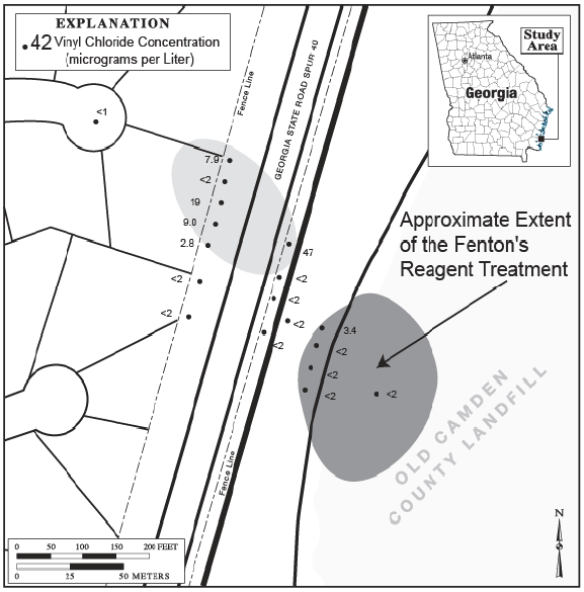

Figure 5. Vinyl Chloride Plume after Cleanup (2009)

Courtesy: USGS

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Project Contacts:

Anthony Robinson, Remedial Project Manager
NAVFAC SouthDiv
Phone: 843-820-7339
Email: robinsonab@efdsouth.navfac.navy.mil

Mary Brown
Georgia Department of Natural Resources
Phone: 404-656-0101
Email: Mary_Brown@dnr.state.ga.us