

## Former Alameda Naval Air Station Site 26

### In Situ Chemical Oxidation—Biostimulation/Bioaugmentation—Monitored Natural Attenuation

**Site Name:** Former Alameda Naval Air Station, Western Hangar Zone, Installation Restoration Site 26

**Site Location:** Alameda, California

**Technology Used:**

- In Situ Chemical Oxidation (ISCO) (Fenton's Reagent Using Chelated Iron and Iron Activated Sodium Persulfate)
- Biostimulation (4% Sodium Lactate and 49.9 ± 2% Soybean Oil.)
- Bioaugmentation (BAC-9™)
- Monitored Natural Attenuation (MNA)

**Regulatory Program:** U.S. EPA Superfund NPL Site

**Remediation Scale:** Full

**Project Duration:** July 2008 to present

**Site Information:** The former Naval Air Station in Alameda, now referred to as Alameda Point, was operated as an active naval facility from 1940 to 1997. Site 26 is rectangular in shape and comprises approximately 32 acres. It is covered by concrete and asphalt pavement, four former aircraft hangars, a building that formerly housed paint and finishing operations, and several ancillary buildings (NFEC 2006). Groundwater contamination is associated with former aircraft washdown areas.

**Contamination:** Fuel-related contamination at the site is being addressed by the Alameda Total Petroleum Hydrocarbons program. The program is under the direction of the San Francisco Bay Regional Water Quality Control Board and is not a part of the Superfund remedial action.

Groundwater is contaminated with trichloroethene (TCE), 1,2-dichloroethene (DCE), and vinyl chloride (VC) with maximum concentrations detected of 51, 530, and 18 µg/L respectively. The plume is estimated to be approximately 100 by 200 ft wide and 15 ft deep.

**Hydrogeology:** Surface and near-surface soil at Alameda Point consists of artificial fill emplaced

during historical filling of the tidal marshlands and the subtidal area of San Francisco Bay during site development. Artificial fill is encountered at Site 26 from beneath surface pavement to a depth of approximately 12 to 18 ft below ground surface (bgs). The artificial fill material is predominantly poorly graded, fine- to medium-grained sand with silt and clay.

The fill is underlain by the Bay Sediment Unit. The upper low-permeability part of the Bay Sediment consists of an estuarine deposit of stiff, dark, olive-gray clay with discontinuous silty and clayey sand layers. This unit acts as an aquitard and varies in thickness from approximately 12 to 35 ft (ITS 2007). Groundwater occurs in the fill at 2-6 ft bgs and extends to a depth of approximately 18 ft. The flow is radial since Alameda Point is located on an island. The vertical hydraulic gradient is in an upward direction. Groundwater flow in the vicinity of the VOC plume is generally to the northeast (NFEC 2006).

**Project Goals:** The remedial action objectives for groundwater are to protect human health by preventing exposure of potential residents and occupational workers to VOCs in indoor air that have migrated from groundwater. The remediation goal for *cis*-1,2-DCE in groundwater is 6 µg/L, 5 µg/L for TCE, and 0.5 µg/L for VC. These goals will leave the property in an unrestricted use condition. The Navy will also implement institutional controls at the site until remediation goals are met, which is expected to be within 3 years (NFEC 2006).

Soil at Site 26 was determined to not require further action under Superfund.

**Cleanup Approach:** A full-scale ISCO program was designed and implemented between July 2008 and February 2009 following a 6-month pilot study. The first phase of the full-scale application - the peroxide phase - was performed

from July 14 through August 25, 2008. It consisted of injecting a solution of 8% hydrogen peroxide containing 3.8 g/L of citric acid stabilizer into 17 multi-level injection point locations distributed across the approximately 2,800 ft<sup>2</sup> treatment area. Injections during the first phase were performed in two rounds: the first round from July 15 through July 29, 2008, and the second round from August 11 through August 25, 2008. It was necessary to perform the injections in two rounds to allow the groundwater level and subsurface temperature to return to baseline levels because of frequent surfacing of groundwater and elevated temperatures caused by the peroxide reaction (Battelle 2010).

Approximately 30,000 gallons of hydrogen peroxide was injected into the intermediate (7 to 11 ft bgs) and deep zones (11 to 15 ft bgs) of the aquifer during the first phase of the ISCO application. The injection zones were based on the depths where highest concentrations of chlorinated VOCs in groundwater were detected (Battelle 2010).

Site-specific factors noted during the first phase required the ISCO strategy to be reevaluated and modified to improve the likelihood of achieving site remedial goals (RGs). These site-specific factors included surfacing of groundwater and reagents during injection due to the generation and trapping of gas in the subsurface, discovery of a small hydrocarbon plume within the treatment area, failure of injection points resulting from high pressures generated in the subsurface, and a rapid return of groundwater to anaerobic conditions within days of ceasing injections (the peroxide should have provided an oxygen rich environment). Performance monitoring also indicated that the peroxide treatments were not reducing the contaminant concentrations in parts of the aquifer.

As a result, the system was redesigned to apply iron activated sodium persulfate and target the intermediate layer, where the majority of the contamination remained after application of the hydrogen peroxide (Battelle 2010). The sodium persulfate application was performed from Feb-

ruary 12 through 19, 2009. The design utilized a recirculation approach consisting of seven injection points and 18 extraction points. Each injection point was surrounded by extraction points to ensure containment of the injected reagent and prevent displacement of contaminated groundwater outside of the treatment area (Battelle 2010).

Site groundwater was amended with a total of 15,400 lb of sodium persulfate that produced an average persulfate concentration of 53 g/L in groundwater. Ferrous sulfate was used at a concentration of 0.6 mg/L to provide the iron necessary to activate the persulfate (i.e., create the highly oxidizing sulfate radical). Citric acid, at a concentration of 0.6 mg/L, was added to maintain the iron in solution. A total of approximately 34,800 gallons of groundwater was injected, amended, and recirculated over 6 days.

Post ISCO monitoring did not detect the presence of the *Dehalococcoides* bacteria. This observation modified the remediation plan to include injecting bioaugmentation in addition to the biostimulant. Enhanced in situ bioremediation (EISB) began on October 1, 2010. Biostimulation was performed using emulsified vegetable oil (EVO). EVO was injected from October 1 through October 8, 2010. Bioaugmentation was performed by injection of *Dehalococcoides* sp. bacteria within a BAC-9™ culture. The injection was completed from November 1 through November 5, 2010.

EVO was introduced into the aquifer through 45 points using a direct push technology (DPT) rig (Figure 1). The EVO was injected into all points in an interval extending from 7 to 15 ft bgs. Up to six points were injected into at a given time. Injection was performed in 2-ft-long intervals using a top-down approach. All six points were pushed to the first depth (7 to 9 ft bgs), the EVO was introduced, and anoxic site chase water was recycled into the points to facilitate displacement of the EVO. The points were then pushed to the next depth (Battelle 2011). The site used a recirculation well system to ensure proper coverage of the EVO.

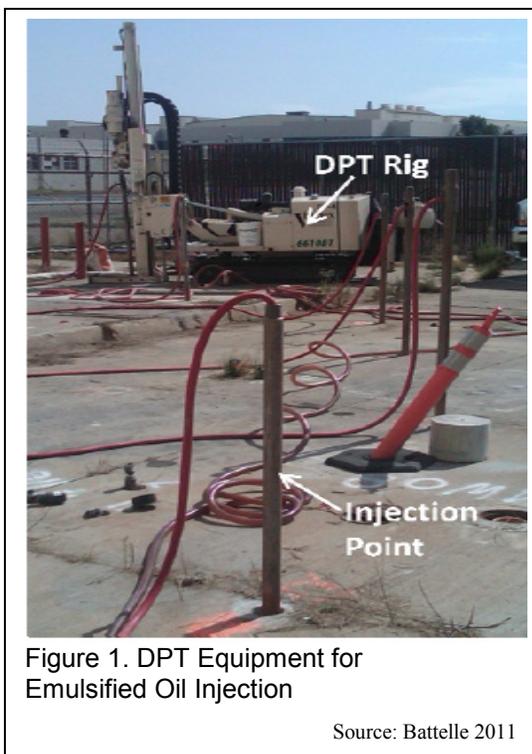


Figure 1. DPT Equipment for Emulsified Oil Injection

Source: Battelle 2011

After completing the EVO injections, the site was monitored to ensure that the appropriate reducing conditions needed to support bioaugmentation with the BAC-9™ culture were established. The BAC-9™ culture was supplied as a liquid suspension in two slightly pressurized stainless steel canisters. Each canister was placed on a portable dolly to easily move it between injection points. A cylinder of nitrogen gas also was placed on the dolly. The nitrogen gas was used to 1) purge all air from the lines prior to injecting the microbial culture, and 2) provide the driving force (pressure) needed to inject the microbial culture into the aquifer (Figure 2). 38 injection points were used to deliver the BAC-9™ culture into the intermediate (7 to 11 ft bgs) and deep (11 to 15 ft bgs) zones (Battelle 2011). Performance monitoring was conducted at the site 8 and 21 weeks following the culture injections. The EVO is expected to keep the site conditions favorable to reductive dechlorination for approximately three years.

The site is in a monitored natural attenuation mode to ensure bioremediation is occurring at an acceptable rate

**Project Results:** The ISCO applications performed at the site achieved a significant reduction of the principal CoCs. Approximately 60%, 79%, and 65% reductions in the average concentration of TCE, DCE, and VC in groundwater, respectively, were determined based on the results obtained from post-injection monitoring, which was performed about 17 months after completing the injections. The estimated total reduction in the treatment area (mass in soil and groundwater combined) were 67%, 64%, and 45% for TCE, DCE, and VC, respectively (Battelle 2010). Figure 3 shows the baseline concentrations of TCE in November 2007. Figure 4 shows the TCE concentration contours as of July 2010.

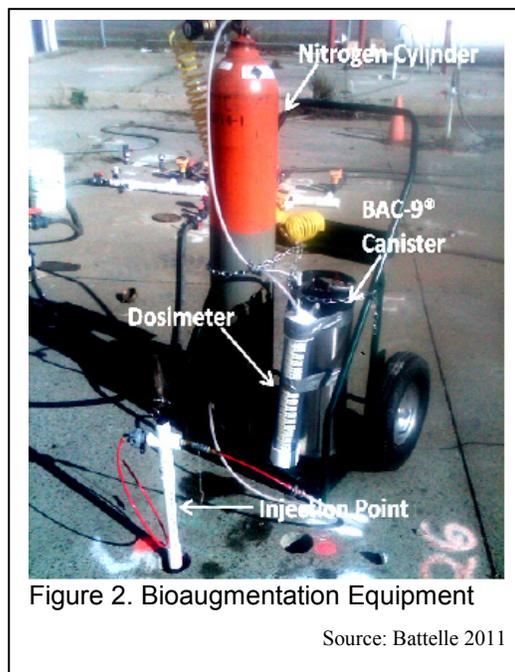


Figure 2. Bioaugmentation Equipment

Source: Battelle 2011

Though ISCO applications resulted in a significant reduction of chlorinated ethenes, the plume footprint containing the chlorinated ethenes at concentrations greater than their RGs increased slightly (Battelle 2011). EISB injections have resulted in a significant reduction of the footprint that contains the chlorinated ethenes in excess of their respective RGs. In particular, the area containing TCE greater than its RG of 5 µg/L decreased by 26% based on the results of the first post-EISB monitoring event in January 2011 and has been completely eliminated based on the results of the second post-EISB monitor-

ing event in April 2011. The areas containing DCE and VC at concentrations exceeding their RGs (i.e., 6 µg/L and 0.5 µg/L, respectively) also have exhibited significant decreases (48% and 27%, respectively, during the first post-EISB monitoring event; 73% and 45%, respectively, during the second post-EISB monitoring event). The mass of TCE, DCE, and VC in groundwater also exhibited significant reductions after applying the EISB amendments, ranging from 33% to 87% reduction during the first post-EISB monitoring event, and from 38% to 100% in the second monitoring event. Concentration reductions are shown in Table 1 (Battelle 2011). Figure 4 shows the pre-EISB TCE concentration contours and Figure 5 shows the TCE concentration contours as of April 2011.

The site is now in an MNA monitoring mode. Site closeout is expected in 2013.

**Sources:**

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Battelle, 42 pp.

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Figure 4. TCE July 2010 Post-ISCO and Pre-EISB

Source: Battelle 2011



Figure 5. TCE April 2011 (20 weeks past EISB Injection)

Source: Battelle 2011