USING AquaBupH™ TO ADJUST AQUIFER pH: ESTCP-FUNDED PROJECT AT CHARLESTON NAVAL WEAPONS STATION

Prime Consultant — Solutions-IES, Inc.

Problem

The United States Department of Defense found elevated TCE beneath a solid waste disposal area at the Charleston Naval Weapons Station. Low aquifer pH stalled effective *in situ* bioremediation.

Project Goal

- Inject biodegradable organic substrate in an aquifer that will enable naturally-occurring bacteria to effect *in situ* anaerobic reductive dechlorination
- Control pH changes to enable long-term performance
- Achieve regulatory remediation levels of 5 µg/L TCE in groundwater and 53 µg/kg TCE in soil.

Methodology

Test effectiveness of unbuffered and buffered emulsified oil substrates (EOSPRO [formerly EOS 598B42] and AquaBupH™).

Phase I

- Sixteen wells, 18ft deep, 5ft on center
- Wells paired to inject and recirculate EOSPRO
- Post-injection performance monitoring for 29 months

Phase II

- Twenty direct push points to inject AquaBupH
- Post-injection performance monitoring for 13 months

Substrate Quantities for Phases I and II:

- EOSPRO (1,260 lbs)

EOS Remediation, LLC

Elevated levels of trichloroethene (TCE) were found in groundwater at a Department of Defense (DoD) facility in Charleston, SC. Under an ESTCP-funded* in situ *technology demonstration project , the Navy had been effectively remediating contamination until a drop in aquifer pH caused dechlorination rates to decline. Solutions-IES responded with a study and application of buffered substrate to adjust the aquifer pH and restart bioremediation.

The Challenge

The DoD's Charleston Naval Weapons Station (NWS) found up to 18,000 µg/L TCE in groundwater beneath an area used for surface disposal of solid waste, oils and missile components between 1950 and 1978. The 180ft X 90ft rectangular-shaped source is located in a remote wooded area near a power line easement over a shallow, but relatively tight silty clay formation. The groundwater potentiometric surface is flat with minimal tidal influence. Depth to water table varies seasonally between 0.5ft and 6ft below ground surface (bgs). Hydraulic conductivity of the surficial aquifer is on the order of 1 to 10 ft/d. Groundwater flow velocity is only 1 to 5 ft/yr. Although tight silty clays hampered proper distribution, emulsified oil substrate proved effective to stimulate removal of TCE and formation of *cis*-1,2-dichloroethene (*c*DCE) until a drop in aquifer pH below 6 caused dechlorination rates to decline.

The Strategy

Solutions-IES selected emulsified oil substrate, EOSPRO (formerly EOS 598B42), because of its proven track record for promoting *in situ* reductive dechlorination in groundwater. With approval from South Carolina Department of Health and Environmental Control (SCDHEC), a 20x20 ft. pilot-study treatment grid was established to observe EOSPRO, first unbuffered in a paired well recirculation system, followed by a second phase with AquaBupH (buffered substrate) using push injection technology. Solutions-IES monitored performance over 42 months comparing biodegradation, geochemical and microbial performance parameters.

The Design

Phase I

Sixteen 18-ft deep injection wells, 5-ft on center **(FIG. 1)**, were paired to inject and recirculate; then pairs reversed for more injection and recirculation (approx. 84 hrs). Total injected = 165 gal EOSPRO (1260 lbs) diluted in water 1:4. Post-injection performance monitoring for 29 months.

Phase II

Injected 326 gal (3030 lbs) of AquaBupH via 20 direct push points 5-ft. on center within the existing grid. Post-injection performance monitoring for 13 months.

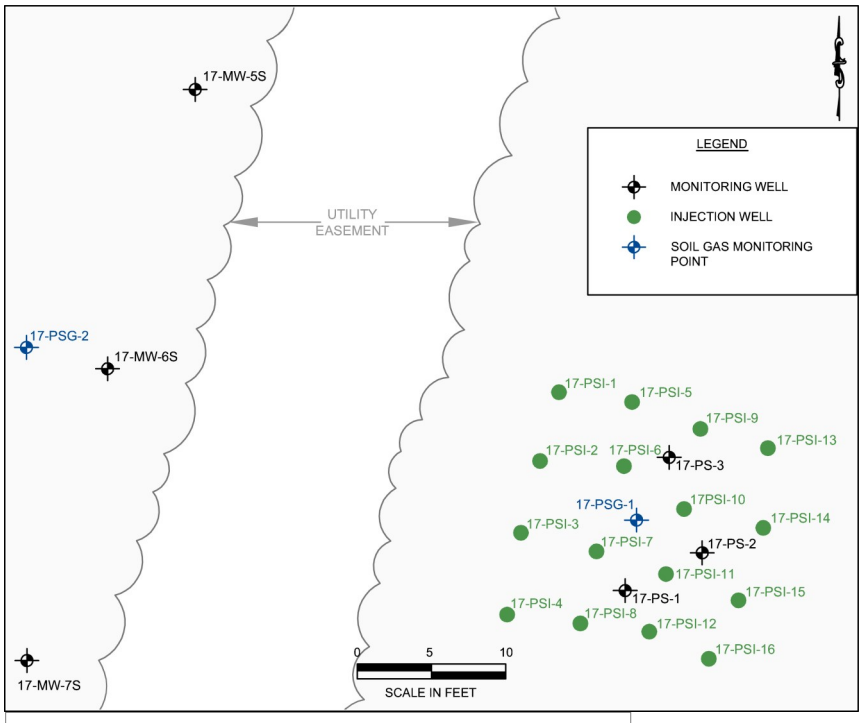

FIG. 1 — Phase I Injection and Monitoring Wells

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Results

Injection of buffered substrate using AquaBupH overcame the stall in bioremediation caused by low pH. Phase I unbuffered injections resulted in up to 99% TCE reduction, but with little formation of vinyl chloride or ethene. Phase II buffered injections stimulated the reductive dechlorination process resulting in substantial increases in both VC and ethene.

42 Months Post-injection:

- Sustained pH increase stimulated the bioremediation process
- TCE was reduced to < 5 µg/L
- VC and ethene increased

62 Months Post-injection:

- TCE & cDCE were undetectable
- VC was still trending downward

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www.eosremediation.com/resources/library/

EOS Remediation, LLC

Results

Substrate Injection: The Phase I approach of recirculation via injection wells in the low permeability environment was complicated and time consuming **(FIG. 2)**, yet successfully distributed substrate throughout the treatment grid. Low pressure direct injection through the Geoprobe® injection tool during Phase II **(FIG. 3)** overcame the challenges of injecting into the relatively low permeability silty clay, although some groundwater mounding and substrate breakout occurred.

FIG. 2 — Phase I Injection / Recirculation

FIG. 3 — Phase II Hopper to Geoprobe

Geochemical Changes: Adding substrate during Phase I resulted in dissolved oxygen (DO) removal, decrease in oxidation-reduction potential (ORP) and ferrous iron (Fe^{+2}) production. With the addition of AquaBupH in Phase II, ORP decreased further and methane was produced; Fe^{+3} complexes formed after pH increased.

Electron Donor Supply: Within 20 days of Phase I injections, total organic carbon (TOC) and volatile fatty acids (VFAs) increased with effective distribution of the substrate's more soluble components. TOC increases occurred again shortly after Phase II buffered injections with pH improvements from 4.9-5.3 to 6.4-7.7 in soil samples . After three months, injection wells and monitor wells showed increases to pH 6.2 and 8.5, respectively. After one year, these wells remained close to pH 6.0 and 7.5, respectively.

Biodegradation: TCE was reduced by 86% and 99% in injection wells and monitoring wells, respectively, over 29 months following Phase I with cDCE concentration increases 11-fold and 9-fold in the same wells. However, there was relatively little vinyl chloride (VC) or ethene formation. After Phase II injections with AquaBupH , pronounced stimulation of the reductive dechlorination process occurred with substantial increases in VC and ethene concentrations **(FIG. 4)**. Five years after original injection, TCE and cDCE were undetectable in injection zone and VC was trending downward.

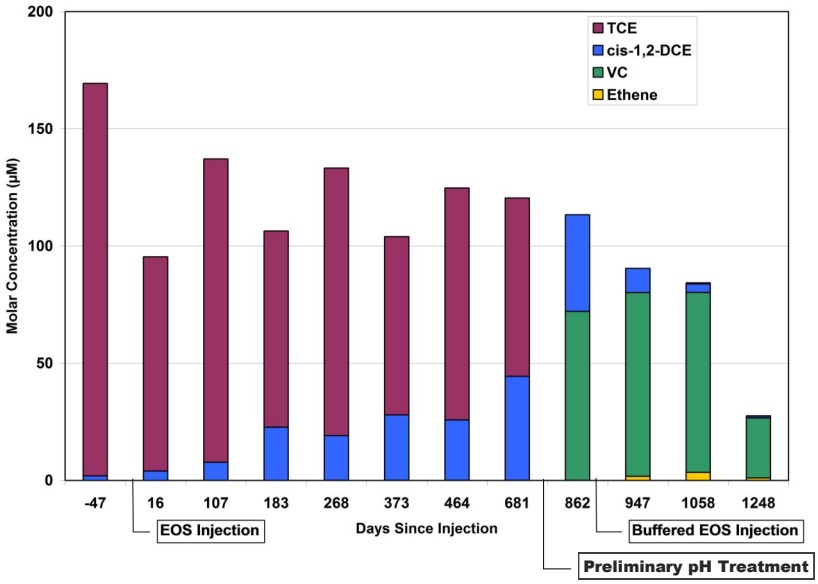

FIG. 4 — Micromolar Concentrations of TCE and Biodegradation Daughter Products

Mass Flux: Prior to treatment, the total mass flux through the pilot test area was 0.63 kg/yr (4.76 mole/yr) of TCE and 0.02 kg/yr (0.17 mole/yr) of *c*DCE. Following treatment, the total mass flux was reduced to 0.01 kg/yr (0.055 mole/yr) of TCE and below detection for *c*DCE.