BENCH TESTING AND ALTERNATIVE EVALUATION FOR OXIDATIVE AND REDUCTIVE SEQUENTIAL TREATMENT FOR A SOLVENT SOURCE AREA

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Site Background

Site: Not Disclosed

Sources: former industrial operations has resulted in surficial aquifer contamination with TCE. Sources present at:
- S and E of former maintenance pad
- NW and SW corners northern building

Lithology : Silt, clay, silty clay and clayey silt dominate the surficial aquifer, with some sand stringers present. An extensive sand lens is present at 25 ft bgs, with thickness of 3 – 15 ft. Groundwater migration is towards W and SW, slow due to low permeability and little hydraulic gradient.

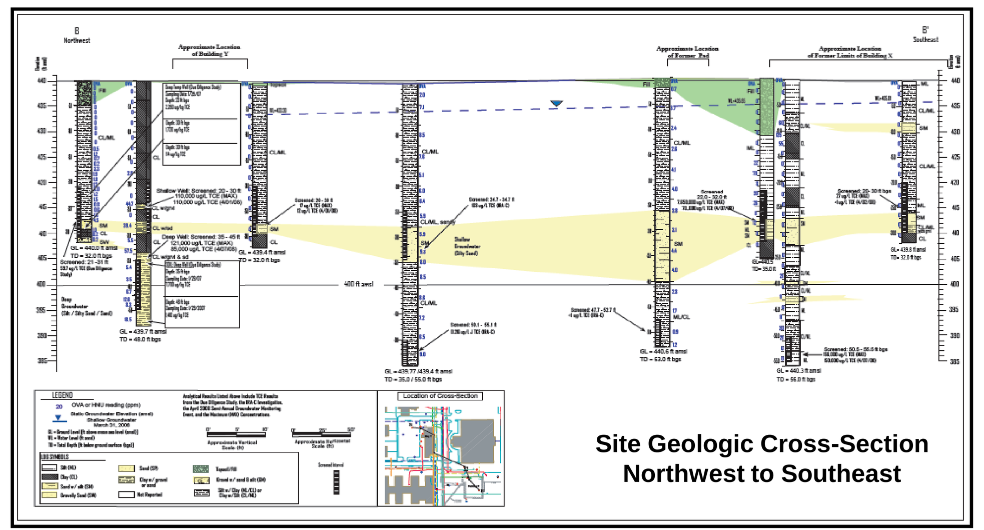
Nature and Extent: Four high concentration source areas with a surrounding low concentration dissolved phase plume.

Source Area	Max TCE Concentration	
	Soil (mg/kg)	GW (mg/L)
S of maint. Pad	62.0	7,650
E of maint. Pad	0.25	900
NW corner Bldg.	11.6	110
SW corner Bldg.	0.3	32

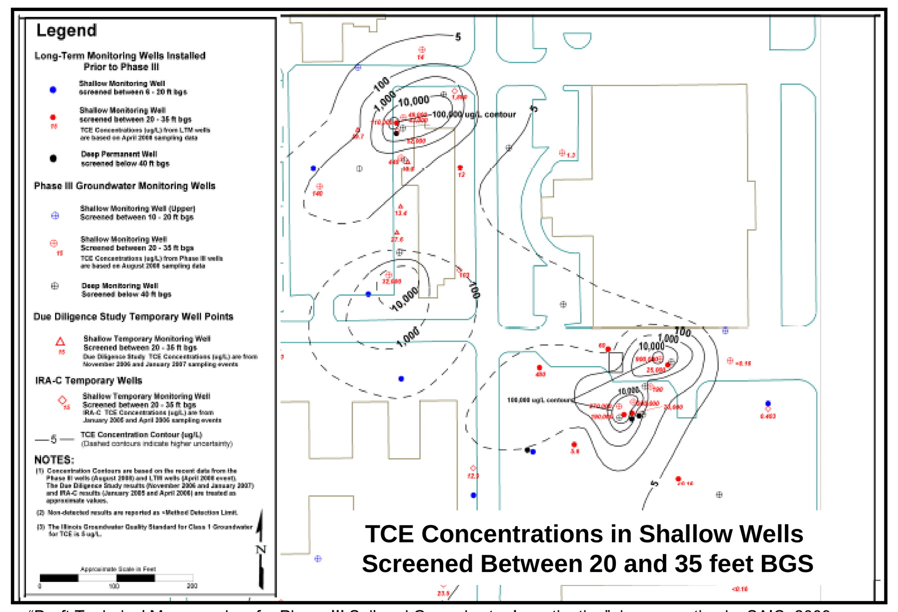
Solubility limit of TCE is 1,100 mg/L

Site Risks:
- Contaminant exposure for site construction and utilities workers at source areas
- Potential risk for vapor intrusion at nearby occupied structures

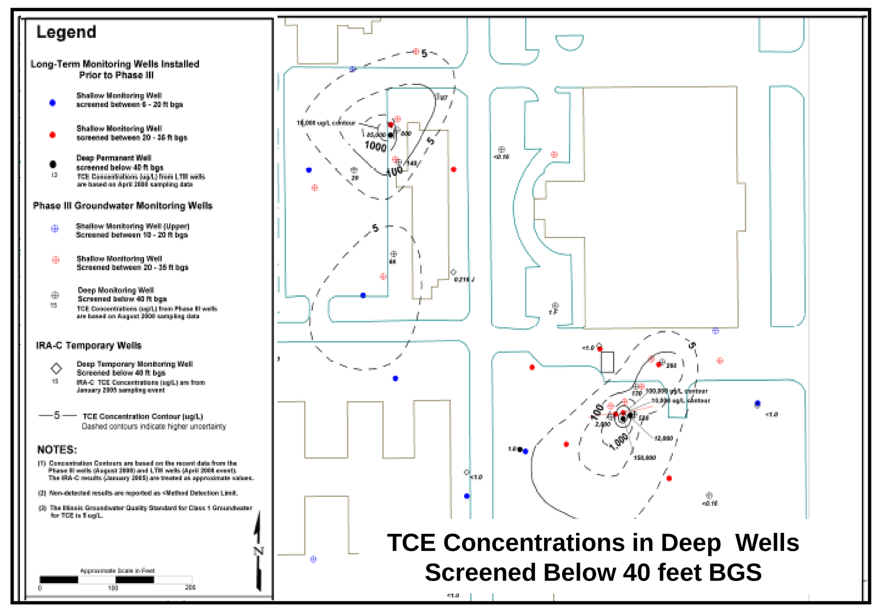
Site Remediation Objective: perform site remediation to abate high concentration source areas, and to decrease high concentration dissolved plume areas



Site Geologic Cross-Section Northwest to Southeast



TCE Concentrations in Shallow Wells Screened Between 20 and 35 feet BGS



TCE Concentrations in Deep Wells Screened Below 40 feet BGS

Data from "Draft Technical Memorandum for Phase III Soil and Groundwater Investigation", in preparation by SAIC, 2009.

Bench Testing

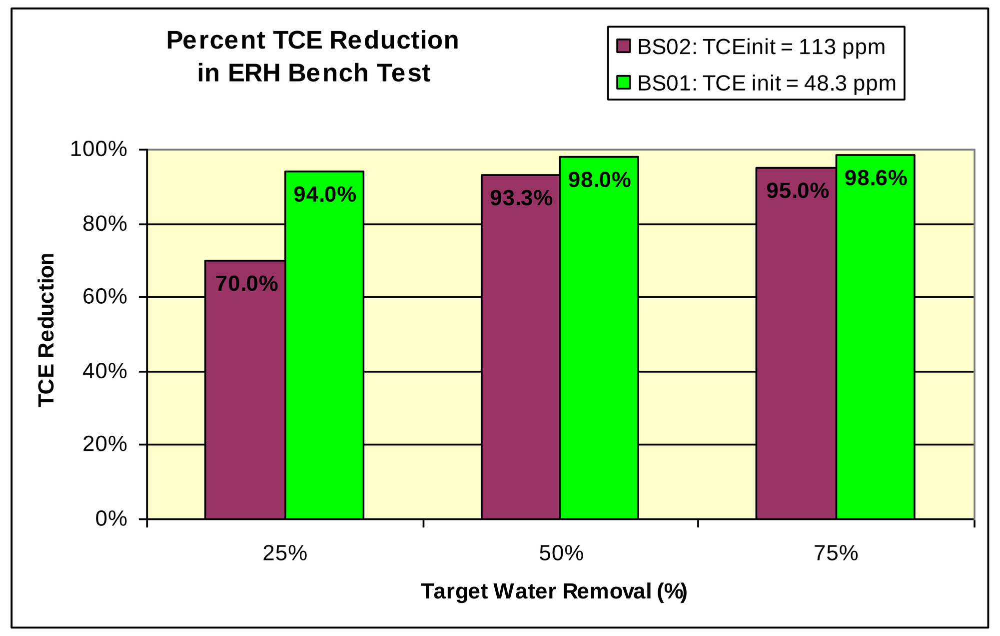
Bench Testing Objective: Test several different in situ technologies to determine their efficacy for TCE removal or destruction from site specific soil and groundwater samples

Bench Testing Technologies: Technologies were chosen for bench testing based upon their applicability to TCE removal or degradation, and capability to be implemented in situ

Electrical Resistive Heating

Process Description: soil and groundwater is heated by electrical current passed between evenly spaced electrodes. Heating to 100 °C causes water and volatile contaminant to vaporize. Contaminant and steam are collected by vapor extraction.

Bench Test Process:
- Pre-test moisture content determined by gravimetric analysis
- Moist soil samples heated in microwave for specific durations
- Post-heating samples analyzed for residual moisture and TCE



Bench Test Conditions

Sample	Initial TCE (mg/kg)	Moisture Content (wt %)
BS01	48.3	25%
BS02	113	15%

Bench Test Conclusion: ERH process is very effective for reduction of TCE contaminant levels in moist soil. This bench test is relatively similar to native conditions, however removal of very high groundwater TCE concentrations was not tested.

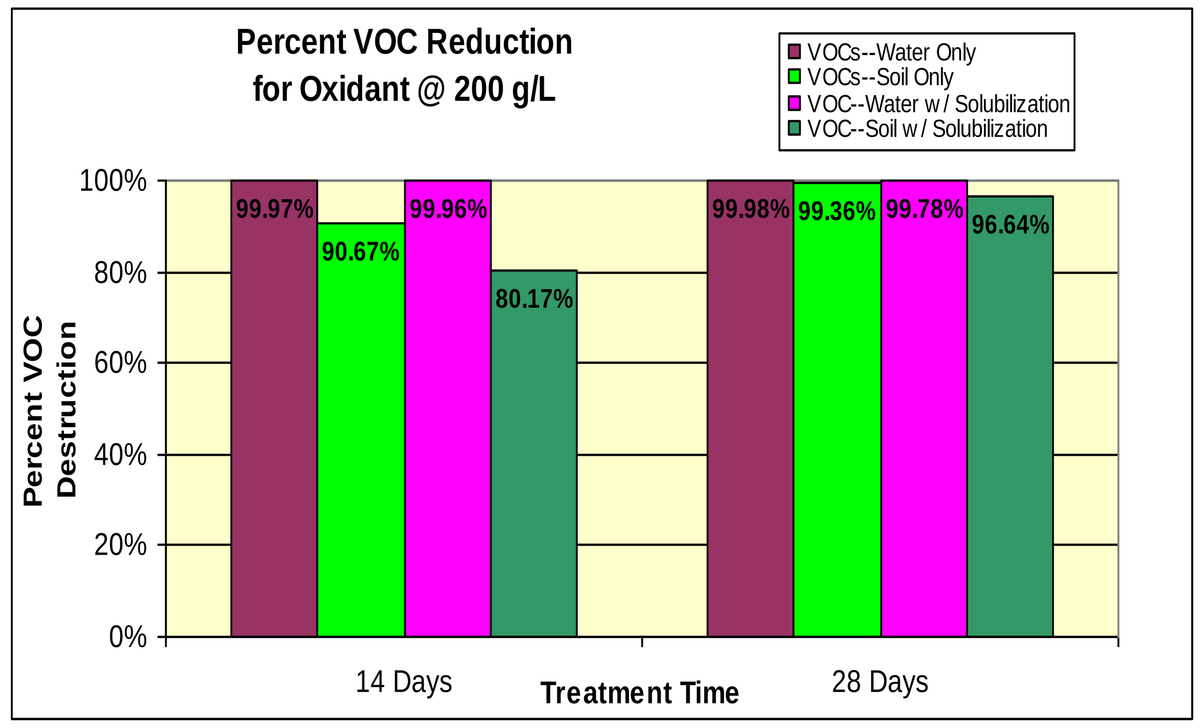
Data from "ERH Bench Test Report" prepared by Thermal Remediation Services, 2008.

In Situ Chemical Oxidation

Process Description: strong chemical oxidants are injected into the aquifer where they act to chemically oxidize solvent contaminants to innocuous by-products. The process effectiveness depends on longevity of the oxidant, oxidation strength, and subsurface conditions that affect distribution of the oxidant solution.

Bench Test Process:
- Evaluated solubilization agent to enhance TCE release from clayey soils
- Evaluated ISCO treatment of soil and groundwater slurries, analyzing for residual TCE in each phase separately

Chemical Oxidant Selection: alkaline-activated sodium persulfate chosen based upon oxidant strength, relative ease of chemical handling, and oxidant lifetime.



Initial Conditions: TCE in soil 42.5 mg/kg avg; TCE in GW 19.5 mg/L avg

Bench Test Conclusion: ISCO is quite effective in TCE destruction in a well mixed soil/groundwater slurry. Effectiveness in native conditions was not tested in this bench test.

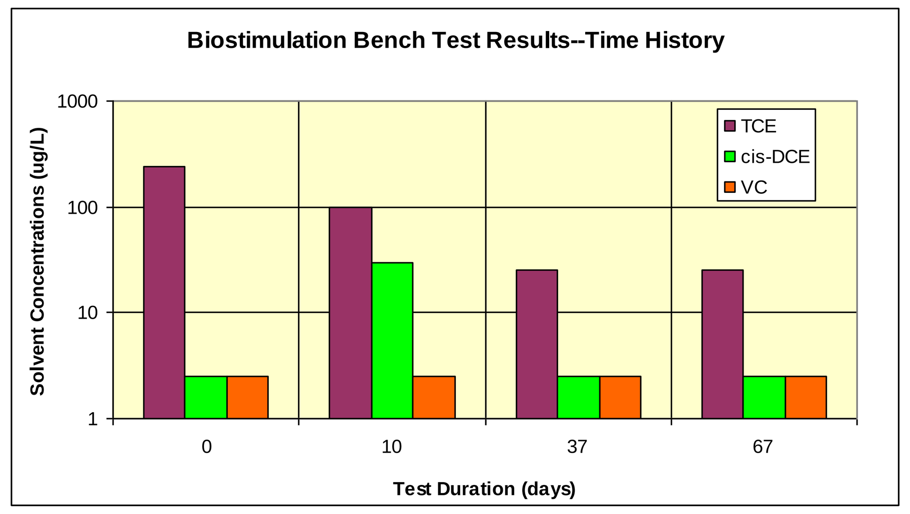
Data from "Engineering Optimization/Treatability Study" prepared by VeruTEK Inc, 2008.

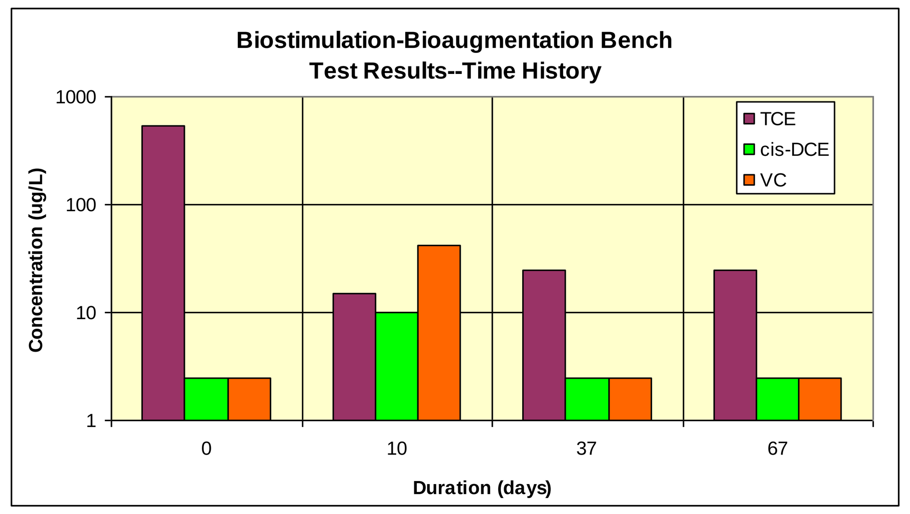
Biostimulation

Process Description: a carbon source is injected into the aquifer, creating over time low redox (ORP) conditions necessary for anaerobic reductive dechlorination of TCE and its daughter products. This process is most applicable to medium to low TCE concentrations.

Bench Test Process:
- Microcosm tests (120 day) conducted using soil and groundwater slurries with a carbon source added.
- Samples from microcosms collected at specific times for TCE and daughter product analysis
- One test condition also included a bioaugment (added bacteria)

Carbon Source Selection: emulsified vegetable oil chosen for carbon source. This material, which includes 4% lactate in an aqueous emulsion of soybean-based vegetable oil, provides both a short and long-term source of carbon to drive the reductive dechlorination process.





Initial Conditions: Initial TCE 780 µg/L; spiked to TCE of 2,500 µg/L on day 30

Bench Test Conclusion: Biostimulation with emulsified vegetable oil is reasonably effective in simulated groundwater conditions with moderate TCE concentrations. Addition of a bioaugment did not produce significantly different results.

Data from "Anaerobic Reductive Dechlorination Treatability using EOS 450 Emulsified Oil Substrate and EOS BAC-9 Augmentation" prepared by RespirTek, 2008.

Remedy Evaluation

Site Specific Considerations for Technology Comparison Process:
- Depth of contamination (beyond reasonable extent for excavation)
- Proximity to buildings, office personnel, and some residential area
- Heterogeneous soil/aquifer lithology

Technology	Technology Considerations	
	Pros	Cons
ERH	Very effective in heterogeneous media	High electrical cost, requires treatment system for extracted vapor and condensed groundwater
ISCO	Easy to implement, quick TCE destruction	Chemical cost may be high, and reapplication may be required, effectiveness may be reduced by soil heterogeneity
Biostimulation	Easy to implement	TCE reduction proceeds relatively slowly, reapplication may be required, not applicable to residual DNAPL concentrations, effectiveness may be reduced by soil heterogeneity