VeruTEK®
TECHNOLOGIES

Project Facts

Site
Former Manufacture Site, New York

Contaminants of Concern
VOCs (BTEX) & SVOCs (PAHs) in soil and groundwater

Clean-up Objectives
Attain NYSDEC Criteria; Redevelop site as a public library

Treatment Program
- VeruTEK's Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO®) , using VeruSOL®, sodium persulfate, and sodium hydroxide ; and
- Wavefront Technologies Primawave™ pressure-pulsing process to enhance injections.

Results
- Destroyed as much as 93.7 % of VOCs & SVOCs, and 73.1 % overall, in soils of treated areas;
- No NAPL was mobilized;
- Adjacent river was not impacted;
- Reduced VOCs and SVOCs in soil vapour; and
- The Primawave™ pressure pulsing process enhanced the control and subsurface dispersion of injections.

Case Study

S-ISCO® and Primawave™ Pilot Test for Creosote Contamination

Queens, NY

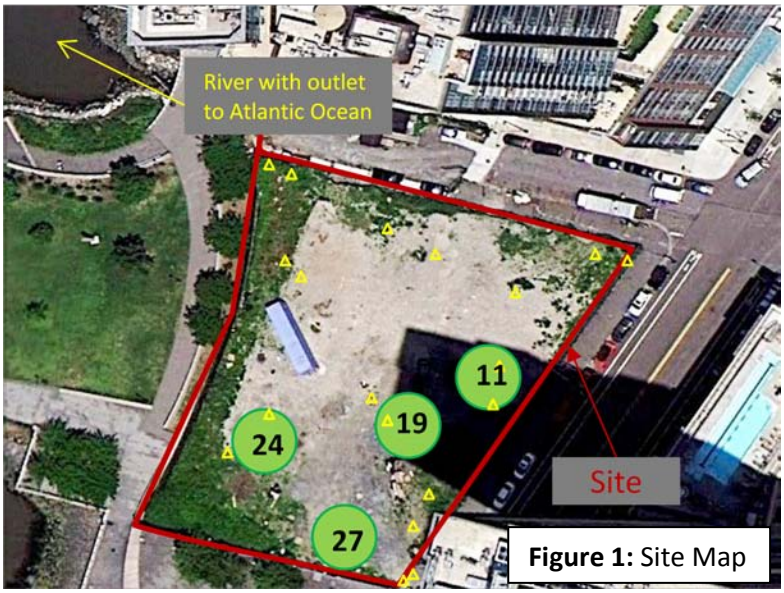


Figure 1: Site Map

Introduction

Between February and May 2010, VeruTEK demonstrated the safety and effectiveness of Surfactant-Enhanced *in situ* Chemical Oxidation (S-ISCO®) combined with Wavefront Technologies' Primawave™ pressure-pulsing process to remediate creosote-related contamination on a site in New York City that is part of an urban revitalization project. Contamination at the site, a tidally-influenced location on the shores of the East River, was related to the manufacture of roofing products that formerly took place there, and included benzene, toluene, ethylbenzene, and total xylenes (BTEX); naphthalene; and polycyclic aromatic hydrocarbons (PAHs). Contamination was present as residual non-aqueous phase liquid (NAPL) held within the pore spaces of the predominately sandy and silty soil matrix, including a lens of silt and silty clay between approximately 17 and 21 ft-bgs. Contaminant concentrations in the soil and groundwater exceeded the New York State Department of Environmental Conservation (NYSDEC) regulatory limits, including, in some groundwater locations, by orders of magnitude. More than 80% of the site's contaminant mass was located below the water table, between 8 to 10 and 24 feet below ground surface (bgs).

On the site VeruTEK conducted a pilot test to evaluate the combination of the Primawave™ pressure-pulsing process and S-ISCO® as an *in situ* chemical oxidation remedy in four areas of the site, Cells 11, 19, 24 and 27 (shown on **Figure 1)**, and to obtain the site-specific information necessary to design a full-scale implementation to treat the entire site.

Technology Background

S-ISCO® is one of VeruTEK's innovative and patented Coelution Technologies™ that is capable of completely or near completely destroying the amount of NAPL in soils. Whereas traditional in situ chemical oxidation (ISCO) fails to treat NAPL contamination because oxidative destruction of NAPLs will only occur in the aqueous phase (that is, when the NAPL is dissolved), S-ISCO® overcomes this limitation by enabling the NAPL to become solubilized into an immobile, fixed emulsion for immediate destruction in-place, and in a safe and controlled manner, by co-eluted oxidant. S-ISCO® incorporates biodegradable, US FDA generally recognized as safe (GRAS) surfactants and co-solvents to dissolve and oxidants to subsequently destroy contaminants.

The Primawave™ Wavefront Process uses a sidewinder tool to generates subsurface pressure waves and open pore space in soil. Particularly in clayey and silty soils, this enhances the uniformity with which the S-ISCO® chemicals are dispersed and expands the treatment's radius of influence.

Implementation

Injections

The S-ISCO® treatment consisted of injections of sodium persulfate, VeruSOL® and sodium hydroxide, enhanced by the pressure-pulsing action of the Primawave™ sidewinder tool. The S-ISCO® chemical formulation was based on the results of a laboratory treatability study VeruTEK conducted using soil and groundwater from the site[1].

Injections took place at four locations, shown on **Figure 1,** two using permanent well clusters (IW-24 and IW-27) and two using a Geoprobe injection tip (IW-11 and IW-19). Each well cluster consisted of a 2-inch diameter well with an upper and lower interval screened from 10-16 ft below ground surface (bgs) and 16-22 ft bgs, respectively. At each Geoprobe location, the probe was advanced to the desired treatment depth and withdrawn as the material was injected, applying the oxidant dosage evenly over the treatment interval (approximately 10 to 27 ft bgs).

Table 1: Injection Summary

Chemical	Amount	Average Injected Concentration (g/L)
VeruSOL®	130 gal	5 g/L
Sodium Persulfate	21,763 lbs	100 g/L
Sodium Hydroxide	1,040 gal	10 g/L
Water	22,800 gal	--
Total Fluid	26,000 gal	--

Injections took place over 12 days, according to **Table 1**.

Monitoring

Monitoring was conducted before, during and after the S-ISCO® injections to track the progress and performance of the injected chemistry in the subsurface, including its reactions with contaminants and radius of influence; to confirm the safety of the implementation to sensitive receptors, including the adjacent river and community members in the vicinity of the site; and to evaluate the effectiveness of the treatment in destroying contamination. The monitoring schedule is shown in the **Attachment.**

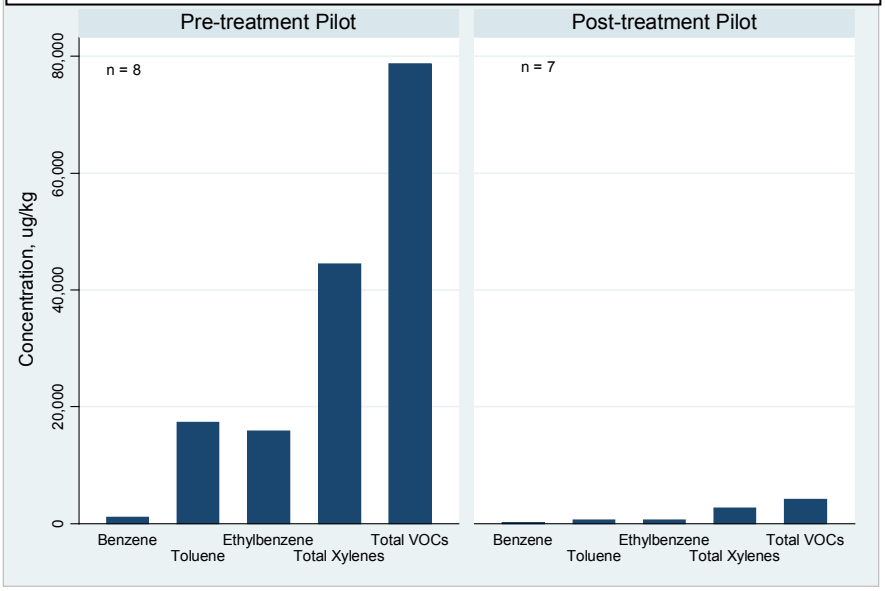
Results

COC Destruction

[1] In the laboratory, this formulation achieved up to 95% destruction of contamination present.

A comparison of the masses of combined VOCs and SVOCs present in each pilot trial injection area before and after injections indicates that contamination was reduced by up to 93.9 % (in Cell 27), and 73.1 % (overall). The BTEX destruction achieved in Cell 27 is shown on **Figures 2. Figure 3** (see **Attachment**) shows SVOC destruction. The variability of reductions is linked to the low mass and volume of treatment chemistry injected into the given test areas, relative to the full-scale dose. To align with the budget and time constraints of the project, on average, only 7.7% of the full-scale volume and 3% of the full-scale chemical mass were injected during the pilot test.

Figure 2: IW-27 Pre & Post-Injection BTEX Results



No Mobilization

Daily and weekly monitoring of groundwater wells located on and off this tidally-inlfuenced site demonstrated that the treatment did not have any impact on the neighboring body of water and that contamination was not mobilized. In addition, probing of all wells on the Site as well as others between the Site and the neighboring river, daily during the injection period and weekly after injections ceased, indicated that no NAPL mobilization took place. **Figure 5** in the **Attachment** shows the fluctuation of the site's groundwater level due to tides.

Soil Gas Contamination Reductions

The results of soil vapor monitoring conducted in the vicinity of Cells 11 and 24 before, during and after injections indicate that the S-ISCO® treatment decreased the maximum soil gas COC concentrations on the site by as much as 96.5%. **Table 2** highlights these reductions.

Table 2: Soil Vapor COC Reductions

Contaminant	% Reduction
Tetrachloroethylene	96.5
Benzene	96.0
Chlorinated VOCs	93.7
Trichloroethylene	90.7
BTEX	55.9

Wavefront Injection Enhancement

The results of groundwater performance monitoring indicate that the Wavefront pressure pulsing enhanced the distribution of the injected chemistry in the subsurface and reduced the predominance of density-driven transport of the injected fluid. Cells 11, 24 and 27, where the sidewinder was used, exhibited better distribution of the injected chemistry throughout the lateral treatment interval than Cell 19, where the sidewinder was not used and density-driven transport predominated. Because 80% of the total contamination on the site is located between 8 and 24 ft bgs, it is imperative that density driven transport does not dominate dispersion of S-ISCO® chemicals in the full-scale implementation.

In addition the pressure-pulsing achieved a sustainable injection rate of 12.6 GPM, or two times the rate expected, based on experience using conventional techniques in similar media.

Pilot Test Outcomes

The pilot test demonstrated the success that full-scale implementation can attain at this Site. The full-scale implementation will take place over months, rather than days, and use increased masses and volumes of oxidant to treat the entirety of the contaminated area into which it is injected. Pressure pulse technology and permanent injection wells will be used at all locations, ensuring consistent and reliable dosing, transport and contact.

To maintain contact of the oxidant with contamination in the subsurface and avoid density driven transport, the oxidant will be injected at a lower concentration, ranging from 25 to 50 g/L rather than 100 g/L. To raise the pH more quickly and in a more sustained manner, at full scale sodium hydroxide will be injected at a higher dose, beginning at 20 g/L and increasing based on pH measurements. The same surfactant dosage used during the pilot test (5 g/L) will be used during full scale.

The results of the pilot test demonstrated to both the NYSDEC and the client that a S-ISCO® and Wavefront remedy can effectively treat contamination across the entire site within a reasonable timeframe without the odor, traffic and noise associated with an excavation remedy. VeruTEK began on-site full scale implementation in October, 2010

Attachment

Figure 3: IW-27 Pre & Post-Injection SVOC Results

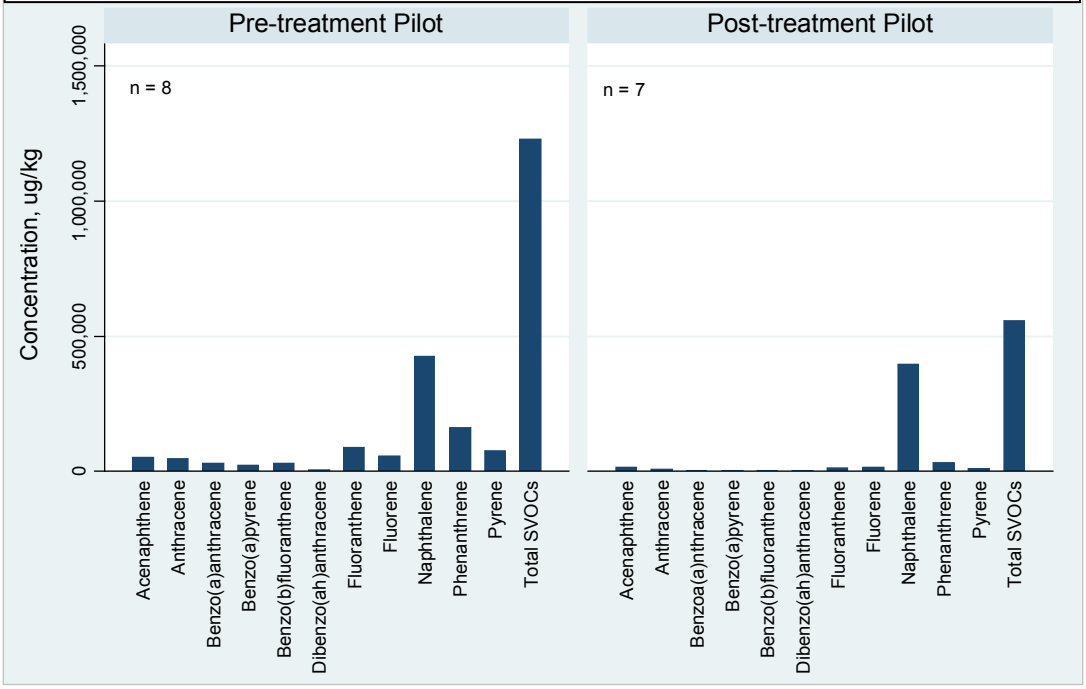


Figure 4: Wavefront Sidewinder Tool *(foreground);* **Proximity of Site to the Tidally Influenced River** *(background)*

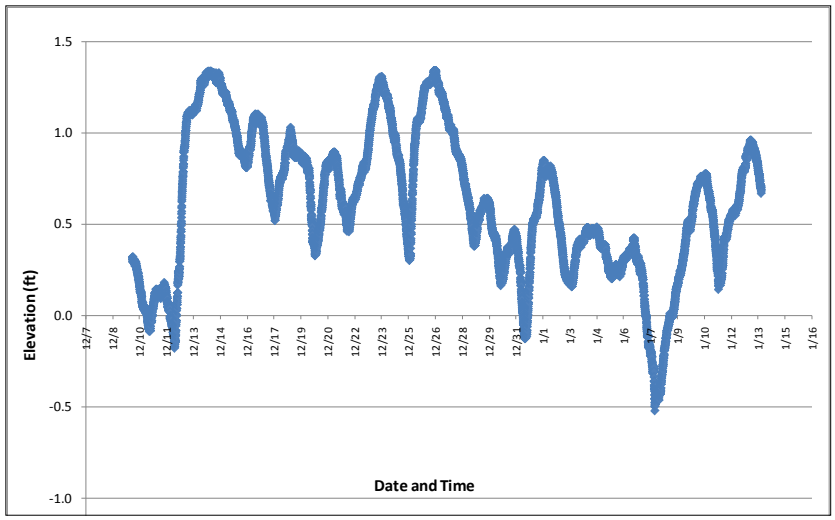


Figure 5: Fluctuations in Site Groundwater Elevation due to Tides

Table 3: Monitoring Schedule

Monitoring Type	Parameters	Frequency	Analysis Location
Groundwater Well Sampling for Contaminant Analysis	VOCs, SVOCs, TPH	Before & 6 weeks after injections	Third-party Accredited Laboratory
Soil Sampling for Contaminant Analysis	VOCs, SVOCs, TPH	Before & 6 weeks after injections	Third-party Accredited Laboratory
DNAPL probing	DNAPL presence	Daily during injections; weekly after	DNAPL Probe
Groundwater Performance Monitoring	Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity, IFT, persulfate & NaOH	Daily during injections; weekly for 2 months after	VeruTEK's Laboratory & in situ monitoring devices
Soil Vapor Analysis	VOCs (USEPA Method TO-15)	Before, during and after injections	Third-party Accredited Laboratory
Process Monitoring	Flow rate, pressure, temperature, pulsing frequency	Hourly during injections	Injection System
Radius of Influence	Electrolytic Conductivity (EC)	Before, during and after injections	EC Probe