



### Site

Former Roofing Products  
Manufacturer,  
Queens, New York

### Contaminants of Concern

VOCs (BTEX) & SVOCs (PAHs and naphthalene) related to MGP coal tar in soil & groundwater

### Clean-up Objectives

- Reduce contaminant mass from 10-22 ft bgs to enable issuance of Certificate of Completion (COC);
- Reduce groundwater contaminant flux.

### Treatment Program

- VeruTEK's Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO®) with VeruSOL® and alkaline-activated sodium persulfate;
- Wavefront's Primawave pressure-pulsing injection enhancement process;
- RemMetrik characterization process.

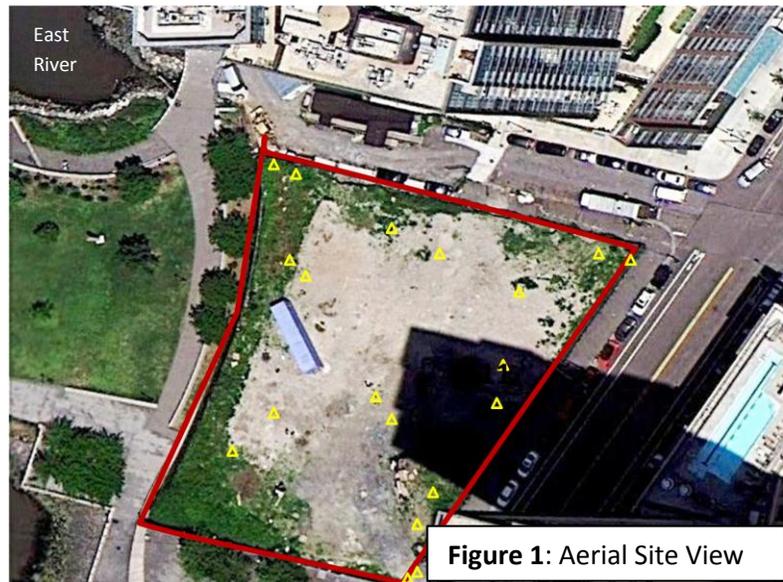
### Results

- *Soil:* Destroyed >90% of total contamination targeted, including 95% of naphthalene;
- *Groundwater:* Reduced on and off-site concentrations; no NAPL mobilized; adjacent river protected throughout;
- *Soil Vapor:* Significant VOC & SVOC reductions, including 100% benzene & naphthalene, and 98% BTEX;
- *Technology Fusion:* Successful combination of S-ISCO with pressure-pulse technology.

## Case Study

### S-ISCO® REMEDIATION OF COAL TAR CONTAMINATION AT NYC BROWNFIELD

QUEENS, NEW YORK



### Introduction

VeruTEK Technologies (VeruTEK) successfully destroyed coal tar contamination at a former roofing products manufacturing site in New York City using Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO). The urban site, surrounded by dense residential and commercial development along the shores of the East River, was contaminated with coal tar repurposed from a nearby Manufactured Gas Plant (MGP) for the roofing manufacturing process. VeruTEK conducted five months of S-ISCO injections that destroyed greater than 90% of coal tar-related contaminants including BTEX, PAHs and naphthalene in the targeted interval. The treatment consisted of injections of VeruSOL, VeruTEK's patented plant-based surfactant and co-solvent mixture, and alkaline-activated sodium persulfate that were augmented by Wavefront Technology Solutions US Inc's (Wavefront) Primawave pressure-pulsing injection enhancement technology, as well as the RemMetrik<sup>SM</sup> process to quantify subsurface contamination, optimize the treatment and measure its effectiveness

S-ISCO was an integral part of the remedial implementation that will enable redevelopment of the Brownfield site as a public library and park ranger station. The New York State Department of Environmental Conservation (NYSDEC) has issued a Certificate of Completion to confirm the success of the cleanup. The successful destruction of MGP-related coal tar at the urban Brownfield site demonstrates the effectiveness of S-ISCO as a remedy for MGP-related contamination.

## Site Background

Located on a bank of the East River in a densely developed residential and commercial area in New York City, this 0.73-acre parcel is part of an urban revitalization project and will be redeveloped as a public library and park ranger station. As part of the history of roofing products manufacture at the parcel, MGP coal tar that was brought onto the site leaked into the subsurface, contaminating the soil and groundwater with benzene, toluene, ethylbenzene, and total xylenes (BTEX), naphthalene, and polycyclic aromatic hydrocarbons (PAHs). Contaminant concentrations in the soil and groundwater exceeded the NYSDEC regulatory limits, including in a number of groundwater locations by orders of magnitude. The majority of contamination was present as residual non-aqueous phase liquid (NAPL) held within the pore spaces of the predominately sandy and silty soil that also included lenses of silt and silty clay. Traditionally these NAPL droplets, especially in fine soils such as the silts and clays present at this site, present a challenge to *in situ* treatments.

### Technology Background

**S-ISCO**<sup>®</sup> is one of VeruTEK's innovative Coelution Technologies that combines biodegradable, plant-based surfactant & co-solvent mixtures (VeruSOL) with free-radical oxidant systems to desorb and destroy NAPL and other strongly sorbed contaminants. Because oxidative destruction of NAPLs only occurs in the aqueous phase, traditional *in situ* chemical oxidation (ISCO) is limited by the immiscibility (resistance to dissolving in water) of organic contaminants. VeruSOL overcomes this limitation by desorbing and emulsifying the NAPL for destruction by a coeluted oxidant.

**The Pressure-Pulsing Process** uses a sidewinder tool to generate subsurface pressure waves that open soil pore spaces. Particularly in clayey and silty soils, this enhances the uniformity of chemical dispersion and the treatment's radius of influence

The S-ISCO technology was approved as part of the Brownfield Cleanup strategy for the site after the results of VeruTEK's bench-scale treatability tests and pilot-scale field implementation demonstrated that Surfactant-enhanced *In Situ* Chemical Oxidation (S-ISCO) could effectively contact and destroy contamination at the site, including sorbed NAPL. The laboratory and field-scale testing indicated that a S-ISCO treatment composed of VeruSOL-3 and alkaline-activated sodium persulfate was the optimal remedy for site contaminants, while the results of the pilot test also indicated that the incorporation of Primawave pressure-pulsing with S-ISCO injections enhanced the radius of influence and uniformity of dispersion for the injected chemistry.

## Implementation

S-ISCO implementation took place between October 2010 and March 2011, and consisted of injections of VeruSOL-3, sodium persulfate and sodium hydroxide<sup>1</sup> into 34 wells located in the areas in which the greatest contamination had been identified<sup>2</sup>. These wells were variably screened across 6 – 7 foot intervals between 10 and 22 ft bgs in order to target approximately 64,000 pounds of contamination. Injections took place at an average rate of 8 gallons per minute (GPM) per well to 4 wells at a time (32 GPM overall), and were augmented by the Primawave pressure-pulsing tool. **Table 1** summarizes the injection parameters.

Chemical	Amount	Injected Concentration (g/L)
VeruSOL <sup>®</sup>	29,545 kg	5 g/L
Sodium Persulfate	152,000 kg	25 - 50 g/L
Sodium Hydroxide	61,950 kg	20 g/L
<b>Total Fluid</b>	1,201,900 gal	--

<sup>1</sup> Sodium hydroxide was injected to create alkaline conditions to activate the sodium persulfate.

<sup>2</sup> Additional wells were installed when interim soil sampling revealed a previously un-identified area of contamination.

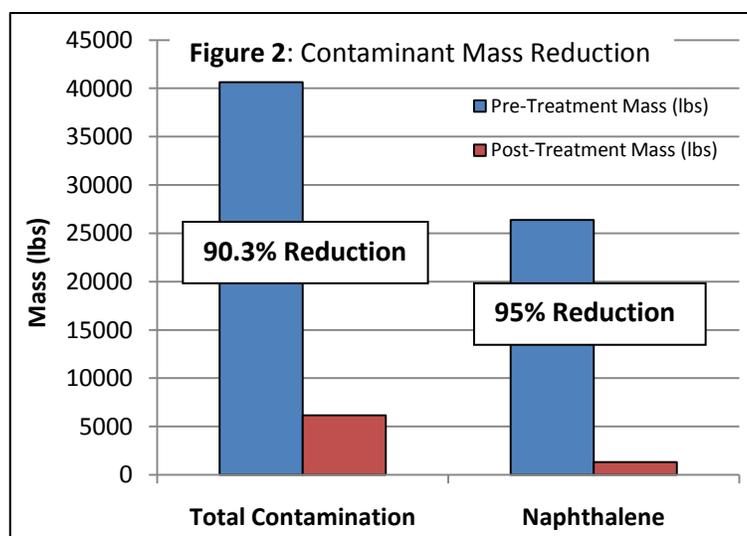
## Monitoring

Monitoring was conducted before, during and after S-ISCO injections to track the progress and performance of the injected chemistry in the subsurface and to confirm that the treatment was not negatively impacting sensitive receptors, such as the adjacent river. Monitoring included: continuous tracking of water quality parameters using *in situ* data loggers; collection of groundwater samples for analysis in VeruTEK's on-site laboratory; observation of all wells on and off-site for indications of NAPL; and collection of soil and groundwater samples for contaminant analysis.

## Results

### Contamination Destruction

Approximately 5 months after the completion of injections, when the results of groundwater monitoring indicated that the sodium persulfate reactions had subsided, VeruSOL had largely degraded and pH conditions were approaching pre-injection levels, 114 soil grab samples were collected from the treatment area and analyzed for total VOCs and SVOCs<sup>3</sup>. These results were used to calculate the mass of contamination remaining that was then compared to the mass calculated before treatment. This analysis indicated that the S-ISCO treatment destroyed 90.3% of the mass of total VOCs and SVOCs present before treatment, including more than 95% of the naphthalene present. Naphthalene, a principal component of coal tar, was one of the primary SVOCs affecting the site soils and groundwater; it accounted for almost 65% of the total pre-treatment contaminant mass. **Table 2** shows additional reductions for priority contaminants, including benzene, toluene, ethylbenzene and total xylenes (BTEX).



Contaminant	Pre-Treatment Mass (kg)	S-ISCO Reduction
Naphthalene	26,389	95 %
Benzene	30	85 %
Toluene	267	81 %
Ethylbenzene	348	75 %
Total Xylenes	1,028	60 %
BTEX	1,674	67 %
Total SVOCs & VOCs	40,621	90.3 %

### Groundwater

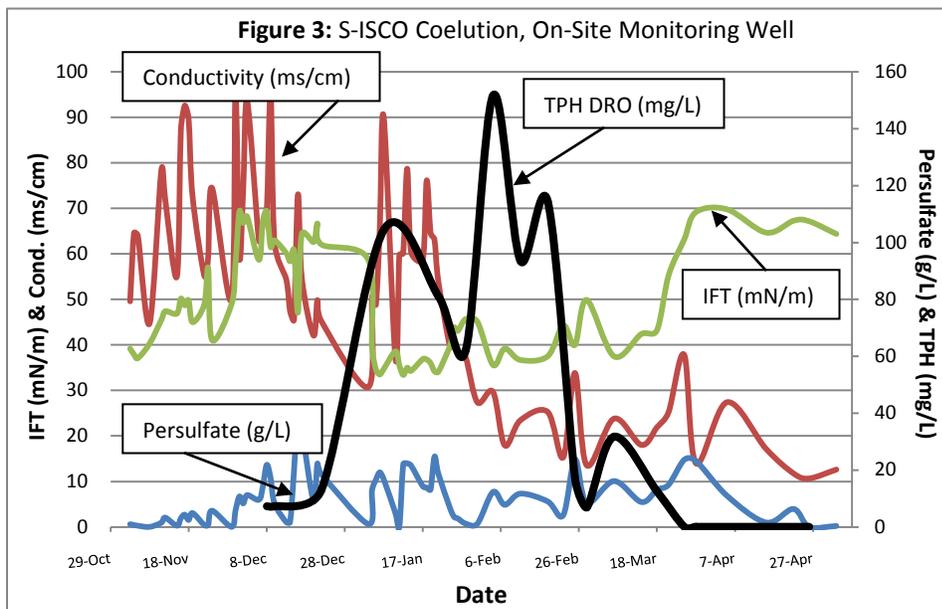
#### Controlled Desorption & Destruction Process

The results of groundwater analysis for S-ISCO performance parameters<sup>4</sup>, as well as regular inspection of all on and off-site wells for the presence of either NAPL or the injected chemistry, confirmed that the S-ISCO desorption and destruction process proceeded in a safe, controlled and effective manner. Specifically, while the injected VeruSOL desorbed and emulsified NAPL

and sorbed contaminants, these contaminants were subsequently destroyed by the coeluted persulfate oxidant. **Figure 3** shows the coelution process at a shallow well in the treatment area. The coelution process is explained in greater detail in the **Attachment**.

<sup>3</sup> TCL SVOCs (Method 8270) and TCL VOCs (Method 8260).

<sup>4</sup> S-ISCO performance parameters include interfacial tension (IFT), an indication of VeruSOL, electrolytic conductivity, and concentrations of sodium persulfate and total petroleum hydrocarbons (TPH).



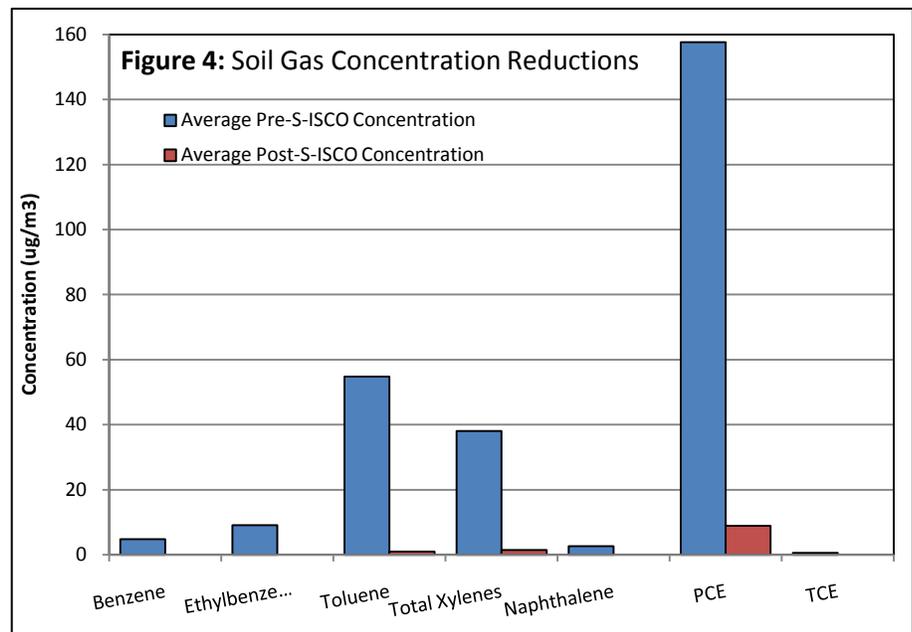
In addition, at no time during injections was any indication of either the injected chemistry or the targeted contamination, including NAPL, solubilized NAPL, odors or sheen, observed in off-site groundwater.

**Contaminant Reductions**  
Groundwater samples from the nine on-site monitoring wells screened across the treatment interval (10-22 ft bgs) were analyzed before

and after treatment. This data indicated that the S-ISCO treatment achieved significant VOCs reductions, including 92% for xylenes, 87% for benzene, the most toxic and mobile VOC at the site, 90% for ethylbenzene, and 91% for BTEX.

### Soil Gas Contamination Reductions

Soil vapor samples collected from three areas adjacent to the site were analyzed before (October 2010) and after (April 2011) injections<sup>5</sup>. Because regular measurement of soil gas pressure<sup>6</sup> indicated that the injected oxidant was not causing any measurable increase in pressure, additional rounds of vapor sampling during injections were deemed



unnecessary. Reductions in soil gas concentrations are summarized in **Table 3** and shown in **Figure 4**, and included 100% for benzene, ethylbenzene, naphthalene and TCE. Improvement in soil gas contamination included reductions at a sampling location more than 100 feet from the southeastern corner of the injection area, indicating that the effects of the treatment extended far beyond the immediate injection area.

<sup>5</sup>Samples were collected from the 4 to 6 ft bgs interval and analyzed using Method TO-15 plus naphthalene.

<sup>6</sup> 4,440 soil gas readings were taken throughout the injection process.

<b>Table 3: Soil Gas Concentration Reductions</b>			
<b>Contaminant</b>	<b>Pre-S-ISCO Average</b>	<b>Post-S-ISCO Average</b>	<b>% Reduction</b>
Benzene	4.83	ND	100%
Ethylbenzene	9.10	ND	100%
Toluene	54.80	0.97	98%
Total Xylenes	38.10	1.43	96%
Naphthalene	2.67	ND	100%
PCE	157.67	8.90	94%
TCE	0.56	ND	100%

### *Conclusions*

---

The successful destruction of MGP-related coal tar at this urban Brownfield site demonstrates a clear success for S-ISCO and its safety and effectiveness as a remedy for MGP-related contamination. The five month S-ISCO treatment successfully contacted, desorbed and destroyed NAPL contaminants and reduced soil vapor contamination in a controlled process without impacting the adjacent water body (the East River) or the local community.

## Attachment

### Tracking Coelution

Implementations of S-ISCO include comprehensive groundwater monitoring programs designed to track the progress and performance of the injected chemistry and ensure the success of the coelution process. This monitoring includes laboratory analysis of groundwater samples for parameters including interfacial tension (IFT), conductivity and concentrations of oxidant (such as persulfate and peroxide) and TPH.

- **Increased oxidant concentrations** indicate effective transport and sufficient dosage of the oxidant.
- **Increased conductivity measurements** indicate the presence of oxidative reactions, and also that the oxidant has been successfully activated and is entering into reactions with contaminants.
- **Reductions in IFT** indicate the presence and effective transport of VeruSOL.
- Accompanied by **increases in TPH concentration**, decreases in IFT indicate that VeruSOL has desorbed and solubilized immiscible contaminants.
- Subsequent **decreases in TPH**, in the presence of elevated conductivity, indicate that the desorbed contaminants have been oxidized.

**Figure 3** (above) shows the results of groundwater monitoring conducted during S-ISCO treatment. This shallow well, screened from 11 to 22 feet below ground surface (bgs), was down-gradient to four injection wells into which VeruSOL and alkaline-activated sodium persulfate were injected during the period from October 2010 to the end of February 2011.

At the start of injections, the persulfate (blue) and conductivity (red) fronts arrive, indicating the presence of the injected oxidant (persulfate) and its entrance into reactions with dissolved contaminants present. The activity of the persulfate also indicates its successful activation. The VeruSOL front (green) follows, shown by the drop in IFT in early January. The rise in TPH that accompanies this decrease in IFT indicates that the VeruSOL is successfully desorbing and solubilizing contamination into the aqueous phase. The corresponding spike in conductivity and subsequent reduction in TPH indicates that the solubilized TPH is reacting with the activated persulfate. The IFT remains low as VeruSOL injections continue and the surfactant continues to desorb and emulsify additional TPH contaminants. As injections end, the persulfate remains in the subsurface but its reactions with the dissolved contamination slow as the alkaline conditions used for its activation become more acidic. Nevertheless, continued elevations in conductivity as well as continued decreases in TPH indicate that oxidative reactions are on-going.