Overcoming Persistent Organic Contaminant Back-Diffusion Using Adsorptive Technologies

BEST – Whistler, BC
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Kevin French, Vertex Environmental Inc.
Presenter

**Kevin French, P.Eng**
- Vice President, Vertex Environmental Inc.
- B.A.Sc., Civil/Environmental Engineering, University of Waterloo
- 30+ years environmental engineering; 25 in consulting and last 6 as a remedial contractor

**Vertex Environmental Inc.**
- Founded in 2003
- Specialized Environmental Remediation Contracting (In-Situ & Ex-Situ)
- High Resolution Site Characterization (HRSC)
- Treatment Systems
Vertex Environmental Inc.

- In-Situ Remediation
- Ex-Situ Remediation
- High Resolution Characterization
- Treatment Systems
- Remedial Design
- Bench-Scale Testing
Presentation Overview

• Common Organic Contaminants
  – What They Are and How to Find Them
  – Why Are They a Problem?
  – Common Approaches to Remediation
  – Trap & Treat® Technology

• Case Studies
  – Neighbour to Former Dry Cleaner
  – Former Underground Storage Tank
  – Former on-Site RFO “Quickie”

• Closing Thoughts
• Questions
Common Organic Contaminants
Common Organic Contaminants

- **Petroleum Hydrocarbons (PHCs)**
  - Lighter than water ("floaters", LNAPL)
  - Gasoline, diesel, motor oil, fuel oil, etc.
  - Sources include ASTs and USTs, spills, pipelines, etc.

- **Chlorinated Solvents (cVOCs)**
  - Heavier than water ("sinkers", DNAPL)
  - Tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1,1-trichloroethane (TCA), etc.
  - Were commonly used for dry cleaning, degreasing, etc.
Why They Can be so Problematic

Source - Dr. Jim Barker, UW
Why They Can be so Problematic

Diffusion into the Soil or Bedrock Matrix
During Remediation – Back Diffusion

Source: Beth Parker
Why They Can be so Problematic

Contaminant Back Diffusion (cause of “rebound”)

Source – Colorado State University
High Resolution Methods to Find Organic Contaminants

Laser Induced Fluorescence (LIF)
- Free Phase PHCs / LNAPL

Membrane Interface Probe (MIP)
- Dissolved Phase PHCs and VOCs

Hydraulic Profiling Tool (HPT)
- Subsurface Permeability and Conductivity Est.
High Resolution Methods to Find Organic Contaminants

• Three detectors:
  – Photoionization Detector (PID) PHCs cVOCs
  – Flame Ionization Detector (FID) PHCs
  – Halogen Specific Detector (XSD) cVOCs

• Detection of VOCs:
  – Petroleum Hydrocarbons (BTEX, PHCs)
  – Chlorinated Solvents (TCE, PCE, TCA, etc.)

• Electrical Conductivity
  – Classify soil
High Resolution Methods to Find Organic Contaminants
High Resolution Methods to Find Organic Contaminants

Typical CVOC MIP Log with PID and XSD mirroring each other

Typical PHC MIP Log with FID and PID mirroring each other
High Resolution Methods to Find Organic Contaminants
High Resolution Methods to Find Organic Contaminants
Common Remediation Approaches

• “Do Nothing” / Monitored Natural Attenuation
• Excavation and Off-Site Disposal
• Chemical Oxidation & Reduction
• Permeable Reactive Barriers (PRBs)
• Adsorption-based (Trap & Treat®)
• Enhanced Bioremediation (aerobic & anaerobic)
• Systems Technologies & Phase Separation
• Sub-Slab Depressurization (vapour intrusion mitigation)
• Risk Assessment / Risk Management
• Combinations of the above
Trap & Treat® Technology

Remedial Amendments
- Trap & Treat® BOS 100® - for cVOCs
- Trap & Treat® BOS 200® - for PHCs
- Application using temporary points or by direct soil mixing
- Plume remediation or PRB applications

Mechanisms of BOS 100® and BOS 200®
- “Trap” the contamination within the AC matrix
- “Treat” within the matrix using amendment

Benefits
- Usually Single Application
- Long-Term Solution
- Back Diffusion Control = Prevents “Rebound”
Trap & Treat® Technology
Activated Carbon-Based Technology for In Situ Remediation

Remedial Technology Fact Sheet – Activated Carbon-Based Technology for In Situ Remediation

Introduction

At a Glance
- An emerging remedial technology combining adsorption by activated carbon (AC) and degradation by reactive amendments.

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation, concerns an emerging remedial technology that applies a combination of activated carbon (AC) and chemical and/or biological amendments for in situ remediation of soil and groundwater contaminated by organic contaminants, primarily petroleum hydrocarbons and chlorinated solvents. The technology typically is designed to carry out two contaminant removal
AC is produced from carbonaceous source materials
(coconut husk, wood, coal, etc)
Trap & Treat® Technology

How AC-based Amendments Work

1. Adsorption
2. Degradation
3. Regeneration

Trap & Treat

Adsorption
AC-based Remedy
Degradation

Organic acids, CO₂

Degradation sites
Contaminant

Activated carbon
Micropore
Macropore
Mesopore

Trap

Treat
Trap & Treat® Technology

BOS 100® - for cVOCs
Activated Carbon & Iron

BOS 200® - for PHCs
Activated Carbon & Nutrients & Microbes
Case Studies
Case Study #1
Neighbour to Former Dry Cleaner
Case Study #1: Neighbour to Former Dry Cleaner

Site Background
- Site adjacent to former dry cleaner property
- Full remediation required

Contaminant Situation
- Plume of cVOCs flowing through the Site (entering and leaving)

Remedial Objective
- Generic groundwater standards

Obstacles
- Minimize disruption to tenants (only one injection event; therefore must prevent back diffusion or “rebound”)
- Old (leaky?) sewer easement passes through Site (non-mobile amendment needed)
Case Study #1: Neighbour to Former Dry Cleaner
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- Source Area
- Impermeable Barrier
- BOS 100® PRB
- GW Flow
- Sewer Line
- BOS 100® Reactive Zones
Case Study #1: Neighbour to Former Dry Cleaner
Case Study #1: Neighbour to Former Dry Cleaner

Remedial Approach

- **BOS 100® injection** program
  - Combined carbon adsorption and chemical reduction for cVOCs

Work Completed

- **Pilot-Scale Testing:**
  - Injected ~450 kg of BOS 100®
  - ~5,000 L suspension
  - Seventeen (17) temporary injection points
  - Completed over 2 working days (1 day in each test plot)
Case Study #1: Neighbour to Former Dry Cleaner

- Direct Push Rig
- Top-down Injection Rod Setup
- Injection Tip Selection is Important
- Decommission with Bentonite
- Interlocking Intervals of Amendment
Case Study #1: Neighbour to Former Dry Cleaner
Case Study #1: Neighbour to Former Dry Cleaner

- Target injection interval originally identified as 1.5 to 6.7 mbgs
- Pilot-scale injection testing completed
- Boreholes advanced to collect forensic soil cores for QA/QC testing
- Evaluated BOS 100 distribution

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<th>Test Area</th>
<th>Test Hole</th>
<th>Target BOS 100® Injection Range</th>
<th>Apparent BOS 100® Presence Range</th>
<th>Percent Depth Coverage</th>
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Case Study #1: Neighbour to Former Dry Cleaner
Case Study #1: Neighbour to Former Dry Cleaner

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<th>Post-Injection (1 month)</th>
<th>Post-Injection (2 months)</th>
<th>Post-Injection (3 months)</th>
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<td>99.2%</td>
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Case Study #1: Neighbour to Former Dry Cleaner

Contaminant Concentrations vs Time

Test Area #2 Data

- PCE, TCE, DCE
  - Standard = 1.6 ppb
- VC
  - Standard = 0.5 ppb

Time (months since injection)
Case Study #1: Neighbour to Former Dry Cleaner

Full-Scale Remediation Plan:

- Physical isolation of Site from source property by impermeable barrier
- **Trap & Treat® BOS 100® approach** selected for sewer easement PRB and plume using RZs
- Design work completed to calculate theoretical loading rate
- **Pilot-scale testing, interim monitoring & forensic soil cores completed**
- Demonstrated feasibility of approach in Test Area #2
- **Adjustments / refinements made** to full-scale BOS 100® approach
- Tighter control over vertical distribution of injections
- Full-scale site remediation about to start
Case Study #2
Former Underground Storage Tank
Case Study #2: Former UST

Site Background
- **Tenant occupied** light industrial site for over 25 years
- Former diesel fuel UST for truck fleet removed and soil / groundwater remediated in 1998
- **Lease expiring** and tenant vacating property

Contaminant Situation
- PHC impacts in soil and groundwater (vs current standards)
- Soils a mixture of granular fill, clayey silt, silty clay, silty sand, silt, sand

Remedial Objective
- Complete remediation of site prior to lease expiry
- Allow for **“four quarters clean”** verification sampling (therefore prevent back diffusion or “rebound”)
- **Generic regulatory standards**
Case Study #2: Former UST
**Case Study #2: Former UST**

<table>
<thead>
<tr>
<th>DEPTH m BGS</th>
<th>STRATIGRAPHIC DESCRIPTION &amp; REMARKS</th>
<th>DEPTH m BGS</th>
<th>Monitoring Well</th>
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<td>Sand</td>
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<td>2.13</td>
<td>SM - SILTY SAND; very dense; fine grained; poorly graded; brown; moist; slight odour</td>
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<td>2.43</td>
<td>MU/CL - SILT AND CLAY; very stiff; low plasticity; brown; moist; slight odour</td>
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<td>3.66</td>
<td>CH - CLAY; with silt; soft; high plasticity; grey with dark staining; moist; strong odour</td>
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<td>3.66</td>
<td>CH - CLAY; with silt; very stiff; high plasticity; poorly graded; grey; wet; strong odour</td>
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<td>4.57</td>
<td>End of Borehole @ 4.57m BGS</td>
<td>4.57</td>
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Mixed geology of sands, gravels, silts and clays.
Case Study #2: Former UST

The Goal:

- Uniform Distribution
- Intimate contact between remedial amendment and contaminants
## Case Study #2: Former UST

### Soil

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<tr>
<th>Locations</th>
<th>Date</th>
<th>Depth</th>
<th>B</th>
<th>T</th>
<th>E</th>
<th>X</th>
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<td>&lt;0.02</td>
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### Groundwater

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<td>150</td>
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**Main Concern**
Case Study #2: Former UST

Remedial Approach
- Full-scale **BOS 200® injection** program
  - Combined carbon adsorption and anaerobic biodegradation for PHCs

Obstacles
- **Excavation** approach (“cut & fill”) would require **shoring & dewatering**
- Relatively small work area with **lots of truck traffic**
- Limited disruption allowed = **no multiple injection events**
  - ISCO or bio alone would have required at least 2 to 3 injection events
  - Client anxious to ensure site is remediated before end of lease
  - Therefore, **certainty in approach was a priority**
Case Study #2: Former UST
Work Completed

- Impacted area 100 m² by 2 m thick with soil and groundwater impacts
- 2,000 kg of BOS 200®, 800 kg gypsum & microbes in 10,000 L of slurry injected
- Approx. 40 temporary injection points advanced via Geoprobe
  - 1.5 m lateral spacing for points
  - Vertical injection intervals from 2.1 to 4.5 mbgs
- Completed over 3 working days on-Site
Case Study #2: Former UST

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MOECC Standards (Table 3) | 44 | 18000 | 2300 | 4200 | 750 | 150 | 500 | 500

Pre-injection groundwater analytical data

Four rounds of post-remediation groundwater analytical data
F2 PHCs in Groundwater (ppb)

Pre-Remediation

Post-Remediation

Detection Limit

1 Month Post-Injection
Case Study #2: Former UST

Project Summary:

• Client **required certainty** prior to end of lease
• Trap & Treat® BOS 200® approach selected
• **Design work was essential**
  • Calculation of carbon and sulphate demand
  • Designed lateral and vertical injection spacing to ensure uniform distribution in the subsurface
• Full-scale application completed as planned
• Remedial objective achieved – **below Generic Standard**
• **PHCs remain low (mostly ND) one year after injection event!**
“Quickie” Case Study
“Quickie” Case Study – Former On-Site RFO

Impact Area
“Quickie” Case Study – Former On-Site RFO

Project Summary:

• Commercial property with former on-Site RFO from 1970s-1990s
• Excavation completed in May 2018 to remove PHC impacted soils
• Backfilled soils were sand and gravel fill
• **Post-remediation groundwater quality failed** at 1 of 4 MWs in backfill
• Trap & Treat® BOS 200® approach selected for **fast and sustained remediation and to prevent “back-diffusion”**
• **One day injection** completed in July 2018
  • 216 kg BOS 200® plus microbial amendment
  • 1,800 L over six temporary injection points
“Quickie” Case Study – Former On-Site RFO

Impacted Area
“Quickie” Case Study – Former On-Site RFO

SUBSURFACE PROFILE

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description</th>
<th>Symbol</th>
<th>Type</th>
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</table>

Vapour Data

- (% LEL)
- (ppm)
- (ppm)

BOS 200® Injection Interval (1.2 – 4.5 m)
"Quickie" Case Study – Former On-Site RFO

PHC Concentrations vs Time

F1 PHC Standard = 750 ppb
F2 PHC Standard = 150 ppb
Benzene Standard = 44 ppb

PHCs were all ND after 9 days!
Benzene Standard = 44 ppb

F2 PHC Standard = 150 ppb

Met Generic Standard!
Closing Thoughts
Overcoming Persistent Organic Contaminant Back-Diffusion Using Adsorptive Technologies

- Adequately understand Site conditions (the “problem”)
- Collect additional site characterization data, if needed
  - Traditional Phase II ESA, HRSC and/or RDC
- Use bench-scale and/or pilot-scale testing, if needed
- Select the right remedial amendment and apply it properly
  - BOS 200® for PHCs or BOS 100® for CVOCs
  - The right amounts in the right places to ensure contact
- Monitor and re-evaluate as remediation progresses
  - Interim QA/QC (groundwater sampling, forensic soil cores)
- Allow for future re-application of sulphate & microbes or iron for long-term PRB applications
Questions?

Thank You for Your Time

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