



Proof-of-Concept Evaluation Process Destruction of DNAPL Through A Green Technology PCE (cVOC) Source Area Bioremediation

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Presentation Outline

- Introduction to On-Site Proof-of-Concept Process
- PRS Deployment Units
- BioStryke[®] ERDenhanced
- In-Situ Biostimulating Amendment cVOC Biotransformation Enhancement
 - Leverage existing Site Conditions
 - Residual Source Mass Control Strategy
 - Plume Stabilization/Contraction
 - Maximize MNA Advantage
- Evaluation Methods
 - Discuss PRS Based Pilot Study Protocols
 - Provides Low-Cost, Low-Risk Evaluation
 - Provides On-Site Performance Confirmation
- Case Study Examples
 - **Questions and Answers**





Evaluation Process Overview

PRS Deployment Units

- Passive Release Sock
- Selectively Permeable Fabric
- Fit Into Existing 2-inch GW Monitoring Well
- Constructed w/ Grommets to Extend Length

• Low-Cost, Low-Risk

- Amends Saturated Column of Impacted MW
- Passive-Aggressively Releases Over-Time
- Performed Under Actual Site Conditions
- No Long-Term Impact to Site Geochemistry

Performance Sampling

- Baseline GW Monitoring & Sample Collection
- Performance GW Monitoring, Sampling, Analysis
- Field Parameters and Contaminant COC's
- Baseline Conditions Foundation from which Additive Performance Efficacy Determined





Reductive Dechlorination = Substitution of H⁺ for Cl⁻

- Environmental Conditions
 - Anaerobic (<0.5 mg/L DO)</p>
- Chemically Reducing (<50 mV ORP)</p>
- Hydrogen ("Fuel" for Dechlorination)
- Enhanced Additive Mechanisms
 - Biostimulation of Native Microbial Populations
 - Co-metabolic 'Surfactant Effect'
 - Metabolic (Dehalorespiration)*

Reductive Dechlorination





Dichloroethene (DCE)

The Terminal Electron Ladder





Pilot Study Program

- Additive Evaluated (*BioStryke*[®] ERDenhanced [®]) Deployed Using Passive Release Socks (PRS)
- PRS deployment unit fits directly into existing 2-inch GW monitoring well
- Provides Conservative/Representative 'Go-no-Go' on-Site Evaluation
- Baseline + 3 Performance Sampling Events
 - cVOC Sites Sample Events Every 6-8 Weeks
 - Total Evaluation Time 5-6 months
- Field Indicator Parameters Recorded Every Sampling Event: Baseline/Performance
- ORP, DO, pH, temperature, conductivity; NO₃, SO₄, dissolved Mn/Fe; Ethane, Methane, Ethene, and cVOC's
- PRS Units Replaced Each Sampling Event





Pilot Study Program

- Baseline Sample Event Traditional Protocols
- Performance Sample Events Utilize Non-Purge Techniques
- PRS Pilot Study Generates Limited AOI
 - Typically < 2 meters
- Purging of GW Monitoring Well Adversely Skews Study Results
 - Removes Amended Groundwater
 - Removes Biostimulated Microbial Population
- Evaluation Utilized to Confirm Amendment Efficacy, Not Regulatory Compliance Reporting
- PRS Based Pilot Study Evaluation Confirms Presence Dehalorespiring Microbial Populations





Pilot Study Process Confirms Biostimulation as a Source Control Strategy

Anticipated Observations - Geochemical

- Decreased Oxygen Reduction Potential (ORP)
- Increased Reduction of Alternative Electron Acceptors
 - Nitrate
 - Sulphate
 - Manganese/Iron
- Rapid Attainment of Methanogenic Conditions
- Additive Components Stimulate Microbial Populations, enhancing Volatile Fatty Acid (VFA) production
- Sustainable Reducing Environment Within the Treatment Zone
- Variable decrease in pH values within Treatment Zone



Pilot Study Process Confirms Biostimulation as a Source Control Strategy

Anticipated Observations - Contaminants

- Rapid biotransformation of Dissolved Phase cVOC contaminants
- Reduced [Parent cVOC] creates major Concentration Gradient between GW and Residual Source Mass in saturated soils
- Natural Flux (desorption) of cVOC residual source mass
- Increased VFA production creating 'Surfactant Effect' resulting in sustainable enhanced desorption of residual source mass
- Increased contaminant bioavailability: 2° increase in dissolved phase [cVOC]
- Enhanced biotransformation of Parent cVOC's to Daughter Products; each with significantly Lower Sorption Coefficients, further facilitating source destruction
- Cost-Effective Confirmation of Additive Enhanced Source Contaminant Destruction



BioStryke[™] PRS Based Pilot Study Former Dry Cleaner Facility Burlington, Ontario

- Former Dry Cleaner located within neighborhood strip mall
- Operated for over 30-years as family run business with on-site PCE use & storage
- Property assumed by current Owner as a result of bankruptcy
- Several Owner sponsored Site Investigations identified both on- and off-site concerns
- [PCE] in source area in excess of 13,000 ppb, no daughter products present
- PRS Based Pilot Study Evaluation Performed With MOE Approval and Oversite

























BioStryke[™] PRS Based Pilot Study Active Dry Cleaner Facility Stoney Creek, Ontario

- Dry Cleaner Facility, No-Longer with On-Site Production, Within Active Business Zone
- Family Operated for over 40-years: Past Activities Include On-Site PCE Use & storage
- Owner Looking for Redevelopment Opportunity Sale
- Several Owner Sponsored Site Investigations Documented On and Off-Site Dissolved Phase Chorinated Volatile Organic Compound (cVOC) Plume Concerns
- [PCE] in source area in excess of 4,200 μg/L
- Performance of Several Previous In-Situ Efforts Not Favorable for Continued Application
- PRS Based Pilot Study Evaluation Performed Under MOE Oversite and Approval









BioStryke[™] PRS Based Pilot Study Active Dry Cleaner Facility Stoney Creek, Ontario

(µg/L)	12-21-11	1-13-12	2-17-12	4-19-12	6-5-12	7-18-12	8-14-12
Chloride (µg/L)	NR	183,000	175,000	132,000	292,000	77,100	129,000
ORP	185	199	-228	-130	-110	-87	-147
DO	NR	13.4	1.1	3.4	0.2	1.3	0.9
рН	6.5	6.7	6.2	5.8	5.7	5.7	5.2
тос	NR	5,200	4,710,000	3,600,00	7,810,000	6,370,000	11,400,000

General Increase in Chloride Concentrations Indicative of Biotransformation

ORP/DO Readings Indicate Amendment Enhancement to Reducing Conditions

Geochemical Readings Indicate Advection Into Limited Treatment Zone

TOC Levels Indicate Amendment Availability/Consumption

Pilot Study Results Assist Evaluation of Geochemical Needs



BioStryke[™] PRS Based Pilot Study Active Dry Cleaner Facility Stoney Creek, Ontario

(µg/L)	12-21-11	1-13-12	2-17-12	4-19-12	6-5-12	7-18-12	8-14-12	% Reduction
PCE	4,700	2,600	1,200	4,200	4,500	1,100	840	82.1%
TCE	1,700	820	470	600	1,300	310	120	92.9%
cis-DCE	720	580	380	2,100	610	190	140	80.1%*
Vinyl								
Chloride	<1.7	<1.7	<6.8	16	<1.7	<6.8	<1.7	100%
Total cVOC	7,120	4,000	2,050	6,913	6,410	1,600	1,100	84.6%

Demonstrated Effective Residual Source Mass Desorption and Destruction

- Demonstrated 84.8% Reduction in Total cVOC Molar Mass
- * 93.3% Reduction in cis-DCE from Highest Recorded Concentration

Demonstrated Presence of Native Microbial Dehalorespiring Bacteria
Confirmed Treatment Zone Suitable for Cost-Effective Biostimulation



Active Dry Cleaner, Stoney Creek Ontario PRS Based Pilot Study





BioStryke[™] PRS Based Pilot Study Dry Cleaner Facility, Stoney Creek Ontario Notable Conclusions

- Demonstrated >82% Reduction in [PCE] over 8-month Pilot Study Evaluation Period
- Reduced [PCE] to <1% Solubility Creating Concentration Gradient in Groundwater
- First 4-months Residual Source Mass Destroyed 72% (Parent Mass Removed)
- Next 2-months concentration gradient and VFA production enhanced flux of residual Source Mass as evidenced by increased [PCE] mid-way through evaluation
- Pilot Evaluation Performed Proximate to Source Area with Peak [cVOC]
- Full-Scale Residual Source Zone cVOC Destruction Estimated within 12-18 months.
- Total Pilot Study Costs Supported by City of Hamilton Ontario ERASE Program
- Total Full-Scale Amendment Cost Estimated at <\$12.00 per treated ton.</p>



Former Chrysler Facility ERDENHANCED

- 99.8% Decrease in [TCE]
- 95.0% Decrease in Total [cVOC]
- Increased Dissolved [Iron] indicative of enhanced iron reduction
- Greater Methane Production Indicative of Stimulation of Methanogenesis
- 400% Increase in [Ethene] Indicating Complete Parent cVOC Transformation
- [Chloride] Increased while other locations stable/decreased indicating enhanced biostransformation

PRS Based Pilot Study – Kenosha Wisconsin Amendment Comparison Evaluation

	ERDENHANCED	Carbon Carbohydrate Blend	Hydrogen Based Compound
Total [TCE]	99.8%-	97.5%-	99.9%-
Total [cVOC]	95.0%-	80.2%-	69.8%-
Dissolved Iron	+	NC	NC
Methane	+++	+	+
Ethene	+400%	NC	NC
Ethane	+99%	NC	NC
Chloride	+	-	NC



Summary of Evaluation Process Benefits – Limitations

- PRS Based Evaluation Studies Proven Cost Effective Saving Laboratory Based Treatability Fees
- Low-Impact, Low-Risk Minimal to NO Long-Term Impact to Site Geochemistry
- Performed on-Site Under Actual Site Geochemical Conditions Providing "Go-no-Go" Evaluation Process
- Provides Owners/Generators, Practitioners, & Regulators Confidence Prior to Commitment to Amendment Based Remedial Strategy
- Requires Scheduled, Consistent and Accurate Field Monitoring, Groundwater Sampling and Laboratory Analytical Testing
- Assists in Established of Full-Scale Amendment Demand and Cost
- Approved by Ministry of Ontario Environment, USAF, NASA, Numerous United State Environmental Regulatory Agencies, International

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Thank You ?? Questions ??



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First Use of ERDENHANCED™ as a Source Control Measure

Conceptual Site Model

- Up to ~35 feet Silty Clay, w/Two Sand & Silt Units (18-25 feet bgs; 30-33 feet bgs):
 - Laterally Continuous
 - Hydraulically Conductive
- Baseline Contaminant Signature:
 - Total Parents: ~100 ppm; PCE, TCE
 - Total Daughters: ~0.25 ppm; 1,1-DCE (DCEs), VC
 - Molar Parent Ratio: >99%
- Dissolved-Phase Plume Emanating from Residual Source
- Dissolved-Phase Plume Migrating Off-Site > Action Levels

Performance Goal: <1 mg/L TCE, >99% Reduction





Direct Push Injection (DPT) Program

Injection Grid Centered on Source Area

- Cost-Effective
- Passive-Aggressive Reduction in Plume Contribution

25 DPT Injection Nodes

- 18 to 25 feet bgs
- o 30 to 35 feet bgs
- 2,600 Pounds Slurry-Phase Electron Donor
- 100 Pounds Electron Donor/Node
- Selected Additive BioStryke[™] ERDenhanced[®]
 - Superior Complex Organic Carbon
 - Highly Saturated (H⁺) Carbohydrate
 - Proprietary Blend of Macro-Micro Nutrients







Site Plan





Phase One - Dissolved Phase Concentration Reductions













Minimal Secondary Contaminant Concerns







Notable Conclusions

- One of Earliest ERD Projects for DNAPL Source Zone Control
- 99.99%_{Reduction} [TCE], achieving Performance Goals within 5 Years
- Allowed for Seamless Transition to \rightarrow MNA
- Minimal [VC] & Significant [Ethene] Production Concurrent with DCE generation
- 2011 [COD] ~2,000 mg/L = ~11 yrs Additive Residence Time
- Total Remedial Cost <\$100K</p>
- No Observed Rebound in [cVOC]s after 11-years
- BioStryke[™] ERDenhanced[®] = Sustainable Green Remediation
- BioStryke[™] ERDenhanced[®] = DNAPL Source Control