Sustainable Surfactant Enhanced Aquifer Remediation (SEAR) Combined With Multi-Phase Extraction (MPE) of Coal Tar LNAPL and DNAPL Impacted Brownfield Site







REMITECH 2021 October 13-15, 2021

Canadian Brownfields Network Beatty Room 13:40-14:10 CMT











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Happy 20 Anniversary REMIECH October 2001 – October 2021





I like to think of a contaminated site like a medical patient. It's sick or not well, needs to be evaluated and treated... As such I often use medical analogies when understanding and healing sites...





Our Products Are Free of Unwanted Impurities PFOA & PFOS Free 1,4 Dioxane Free Dioxins, Furans, and PCB Free Tested and Free For USEPA Regulated Compounds

The new Ivey-sol formulation called PFAS-SOL[®] is effective for aiding in-situ PFAS remediation



Sources: UST, AST, Pipelines, Surface Spills, Truck Rollovers, Sabotage, Off-shore Spills, etc.



LNAPL DNAPL NAPL PSH Free Product

<u>Non-aqueous phase liquids (NAPL)</u> that do not dissolve, or easily mix with water (hydrophobic), include: Petroleum Hydrocarbons, Chlorinated Solvents, Organometallics, etc.

- Light NAPL [LNAPL] have a lower density than water so they will tend to float on the groundwater table.
- Dense NAPL [DNAPL] have higher density than water so will tend to sink below groundwater table.
- > NAPLs are immiscible in or do not dissolve in groundwater.
- Become trapped in pore spaces (Interfacial tension) causing pathway interference and become <u>sorbed on to soil surfaces</u>.
- Phase Partitioning to Sorbed, Globule, or NAPL phases actually limits their 'Availability' for all forms of remediation.



NAPL Density Affects Its Behavior In Soil, Groundwater, and Vapor Phase Intrusion



Knowing how contaminants, like NAPL, tend to behave allows us an opportunity to improve how we investigate and remediate impacted sites.

Allowing us to take a more forensic approach...

NAPL Behavior A Closer Look



Interfacial Tension Between Phases



reorganize to cause a net increase in NAPL Interfacial Tension to >>30 Dynes!!

Contaminant Agglomeration

Contaminant <u>agglomeration</u> is the sticking (cohesive or adhesive) of organic molecules to one another, onto surfaces (**Sorption**), can increase in thickness....a natural phenomenon.

(like dissolves like & like attracts like)

Agglomeration may be viewed as unwanted surface Sorption, to the buildup of Globules or Ganglia, to LNAPL and DNAPL layer formation. (medical analogy - clogging of arteries)

Within geology, this causes caking, bridging, and/or blockage of effective pathways = 'Pathway Interference' (hence delivery or extraction issues!)



Phase Partitioning → NAPL Formation, Globules, and Sorption Limit Contaminant 'Availability' for Remediation



SORPTION

Hydrophobic organic chemicals exhibit limited solubility in groundwater. As a result the contaminants *Phase Partition* and sorb onto the soil surfaces and form NAPL (Globules or Layers) = Reduced Availability for Remediation.

Sorbed, Globule, or NAPL Phase With Limited Availability For Remediation



Sorption Literature Reference



The growing concern regarding contaminant sorption, and its reduced availability for remediation, has been well cited in literature as demonstrated by the following quotation:

"During the past decade, much discussion has centered on the unavailability of absorbed compounds to soil microorganisms; it is generally now assumed that desorption and diffusion of bound contaminants to the aqueous phase is required for microbial degradation."

(W.P. Inskeep, J.M. Wraith, C.G. Johnston, Hazardous Substance Research Center, 2005).

FACT

Sorption Limits Contaminant Availability For Remediation

Sorption or NAPL Formation Limits Contamination Availability For All Forms of Remediation Ivey-sol Overcomes This Limitation To Improve Their Remediation!



Sorption / NAPL limits the 'Availability' of Contaminants for in-situ and ex-situ remediation by *limiting their mobility*. As a result, they are:

Less 'Physically Available' for

Multi-Phase Extraction (MPE), Pump & Treatment, and Soil Washing;

- Less 'Biologically Available' for
- Less 'Chemically Available' for

Bioremediation (Aerobic or Anaerobic); &

Chemical Oxidation or Reduction



How >99% of surfactants work by encapsulating contaminants hindering their 'Availability' for remediation, and impedes waste water

treatment .





Ivey-sol® mechanism <u>selectively desorbs</u> NAPL <u>below the CMC</u> Increasing Physical, Biological and Chemical Availability For Enhanced Remediation



Selective Below CMC on Sorbed, NAPL, Dissolved and Vapor Phases

- Ivey-sol[®] 103 BTEX, Jet Fuel, Gasoline
- Ivey-sol[®] 106 Diesel (Light-Medium-Heavy), PAH's, Heating Oils
- Ivey-sol[®] 106 (CI) Chlorinated Solvents
- Ivey-sol[®] 108 Motor Oil, Lubricants, Bunker-C
 - DECON-IT[®] Equipment Decontamination Product

Dilute 1:50+ With Water So A Little Will Goes A Long Way ---> To Increasing Availability





Water Is A 3-Dimensional '*Cluster' -* With Surface Tension of 73 Dynes Water Cluster Size Limits (K) It's Ability To Move In Finer Texture Geology

Ivey-sol[®] Makes Water Clusters Smaller So Enter And Move More Easily Through Finer Grain Soils (Lower Surface Tension < 30 Dynes)



Ivey-sol Reduces The Size of Water Clusters Improving (Lower Surface Tension from 73 Dynes to < 30 dynes) Access & Regress within Fine Grain Soil Textures ~ Improving K





Ivey-sol Overcomes Low K and Retardation In Finer Grain Soil Improving Access, Regress, and Remediation





Overcoming Interfacial Tension





Overcoming Interfacial Tension & Increasing NAPL, Sorbed, Dissolved Contaminant 'Availability' For Remediation

In-situ Ivey-sol[®] 'Push-Pull' & 'Sweep' Applications





3 Dimensional Animations In-situ 'Push-Pull' Ivey-sol® Application Options Link For PDF Version To See Ivey-sol Animations: http://www.iveyinternational.com/videopresentation



Recovery Injection Well J Well #1

Injection Well #3 Injection Well #2

Injection Well #4

Ivey-sol® Injection and Recovery Well

Groundwater Table





Abbreviated Presentation Version. Contact IVEY for full version if interested.

Sustainable outcomes with Ivey-sol® surfactant enhanced aquifer remediation (SEAR) of coal tar NAPL

Daniel Hirth, CEnvP

BlueSphere Environmental Pty Ltd 113 Ferrars Street Southbank, VIC 3006 Australia





Background

- Rural gasworks from 1889-1973
- Coke, tar and ammonia by-products generated
- Soil and groundwater impacted.



Modern

Gas Holders With Coal Pile.

Retort House With Coal Pile

Also produced waste as coke debris, hydrogen cyanide (prussian blue), spent iron-oxide filter wastes.

Impacts to soil and groundwater. Gross soil impacts remediated in mid to late 1990's.

Site groundwater impacts by organics. Ammonia and cyanide are further widespread.

Background

Two source zones: former tar/liquor disposal wells. Plan shows dissolved naphthalene as an indicator of NAPL (LNAPL & DNAPL).

Legend

DTF Parcel Boundaries

- Site 28 Pilmer Street (Former Bacchus Marsh Gasworks)
- 26 Pilmer Street (Former Provenzano Property (DTF))
- DTF McGrath Street
- Newly Installed Well
- Shallow Aquifer Well
- Deep Aquifer Well
- Private Well

Naphthalene Concentration (µg/L)

- 100
- 1000

Objective

<u>lssues</u>:

- Non-aqueous phase liquid (NAPL) presence
- Dissolved chemicals of concern: naphthalene, benzene, ammonia, cyanide (free), sulfate.

Site objective:

- Remove/reduce contamination liability
- Limit impacts to adjoining sensitive receptors including residences
- Divestment of surplus land

Remediation Objective:

- Reduce source zone contaminant mass, so far as reasonably practicable. <u>NAPL Conceptual Model</u>:
- Over 100 wells installed, half in the source zones.
- Alluvial aquifer 16 28 feet BGL (5 8.5 mBGL);
- Clayey lignite lower confining unit (Werribee Fm);
- Distributed NAPL beneath tar wells, minor LNAPL

Methodology

 $\frac{Process}{ROA} \rightarrow Trials \rightarrow RAP \rightarrow Approvals \rightarrow Application \rightarrow Closure$

Surfactant Enhanced Aquifer Remediation (SEAR)

We used a non-ionic, selective surfactant (Ivey-sol) engineered for use with long-chain hydrocarbons to *lower the surface tension* (not to emulsify).

Sub-critical micelle application Applied through injection and recirculation NAPL continuously removed form recirculated water

Last stage is to extract surfactant and treat

- 1) re-injection (limited by cyanide concentrations)
- 2) trade waste (primary method of disposal)
- 3) Off-site transport

Ivey-sol only needs to form a partial micelle. So lower dosage and greater SEAR economics.

Ivey-sol does not need to emulsify contaminants. As selective below the CMC = greater precision and accuracy for in-situ SEAR applications.

Methodology SEAR (Ivey-sol) - MPE system

Picture of site during setup. Actual footprint used 2/3 of the Site once Wastewater Treatment Plant (WTP) installed. WIROPACIFIC

Results

What we observed: Very rapid NAPL coalescence (~15min); and NAPL mobilisation for enhanced recovery (both LNAPL & DNAPL)

Both visual and quantitative NAPL mass recovery over four (4) month Ivey-sol SEAR application. Realizing Effective NAPL mass removal.

Conclusions

- **SEAR (Ivey-sol)** with groundwater extraction can be a viable remediation method for tar NAPL in aquifers that have:
 - Limited human and environmental receptors
 - Unconsolidated sediments
 - Sufficient effective permeability for NAPL entry,
 - And sufficient, interconnected permeability for NAPL extraction.

Sustainability

Walletin Zacke hold where an

- Economic: <cost than other possible methods (e.g. co-solvent, thermal, stabilisation, ISCO)
 Social: low noise, no odour, reduced street traffic
 Environmental: Biodegradable Ivey-sol surfactant,
- reduced wastewater generation, reduced filter media requirements
- Significant time and cost savings

- Audit CUTEP completion by late 2020.
 With land returned to normal use-redevelopment.
- Remediation system was turned off late 2020 for regulatory closure in 2021.

Steps To Using Ivey-sol At Petroleum, Chlorinated, and PFAS Remediation Sites

Step #1 (Evaluation)

Ney-sol * Surfact	tant Technology	Ivey International Inc. Suite 61-2955-156 St, Surrey, BC, Canada V3S 2W Tel: 1-800-246-2744 Fax: 1-888-640-3622
1-800-246-2744 • 1	www.iveyinternational.com	Email:budivey@iveyinternation
G	eneral Site Information Form	
Client Information		
Date:	Ivey Contact:	
Company name:	Contact Person:	
Email:	Phone:	
Fax:	Cellular:	
Street address:		
Shipping address:		
Project Information:		
Project Name:		
Project Location:		
Project Number:		
Regulatory Agency:		
Land Use and Zoning (Circle): OPar	kland OAgricultural OResidential OC	ommercial OIndustrial
Site Information:		
Remediation Objectives:		
Contaminant(s) of concern (TPH, BT	EX, TCE, PCB, etc.)	
Soil Impacted: Yes / No Gro	oundwater Impacted: <u>Yes / No</u>	Vapor Impacts: <u>Yes / No</u>
Is NAPL Present:	Time Since Release:	
Soil Type(s):	Soil Porosity:	
Depth to Groundwater:	Hydraulic Conductivity (H	<):
Hydraulic Gradient:	Groundwater Flow Direct	tion:
Area of Contamination:	Maximum Depth of Cont	amination:
Current Remediation Activities:		
Monitoring Well Network Inform	nation:	
Number of Existing or Proposed Mor	nitoring Wells:	
Number of Proposed Injection Wells	:	
Number of Proposed Extraction Well	s:	
Please Provide the Following:		
 Site location map or drawing Site map showing source/treatm Site map showing monitoring an Table summinizing well construct 	nent area and isoconcentration contou Id injection well locations and ROI est tion details and GW level bistory	ırs (if available) imates

- Table summarizing well compared to the summarizing set of the summarizing set of the summarized s
- Pilot test results (if available)
- Geologic cross section
 Copy of laboratory analytical results or summary table of contaminants of concern
- Site photographs
 Site investigation report

Site investigation report

lease complete this site information form and return to: <u>budivey@iveyinternational.com</u> ©Ivey International Inc.

Step #2 (In-situ/Ex-situ Application Model Development)

Step #3 (Ivey-sol Selection)

Contaminant of Concern (COC)	Ivey-sol [®] Formulation Required	
BTEX, Gasoline, Jet Fuel	103	
Diesel (Light-Medium Heavy), PAH	106	
Chlorinated Solvents (DNAPL, API <10)	106 (CL)	
Motor Oil, Lubricants, Bunker-C	108	

Note: For contaminants of concern (COC) not listed above contact IVEY directly.

Step #4 (Dosage Determination)

If Sorbed or Dissolved Phase ≤ 2%

If LNAPL or DNAPL Phase Apply ≤ 4% Ivey-sol.

Step 5 (Proposal)

CONTACT INFORMATION

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