Aerobic Cometabolic Bioremediation to Address a Large, Dilute, Solvent Plume

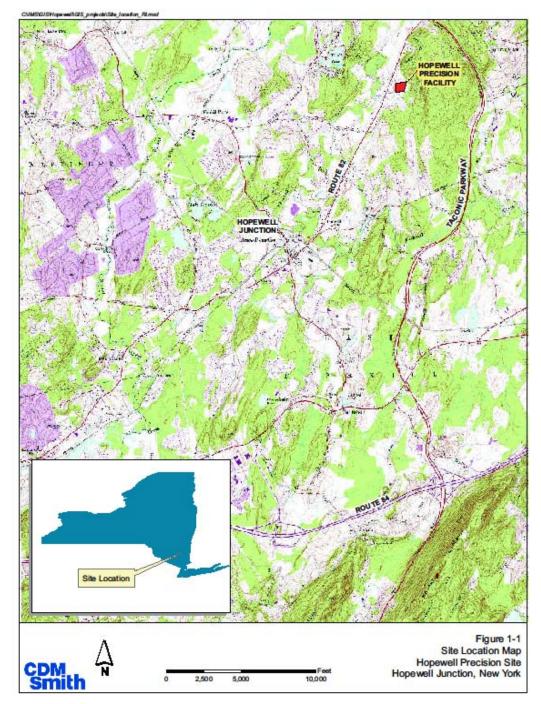
Jim Cummings, TIFSD/TAB/USEPA

Federal Remediation Technologies Roundtable June 2012

Presentation

- Introduction
- Hopewell Precision site description
- Overview of Aerobic Cometabolic Bioremediation (ACB)
- Activities to Date
- Conclusions and Next Steps

Hopewell Site Location Map



Hopewell Site Location Map



Hopewell Precision Site

- <u>7000'</u> dilute, shallow aerobic TCE plume
 No source(s) (found)
- TCE contaminant levels generally <100 ppb (#'s appear to be declining)
 - But Note: Possible plume core(s) w higher #'s
- MCL exceedances and Vapor Intrusion impacts
 - Mitigation as required for residences

Driving Aerobic Plumes Anaerobic

- A Fool's Errand?
 - 2010 U Mass Amherst Soils Conf: Presenter started off describing Sisyphean effort to 'push the boulder uphill', and then proceeded to provide gory details of a <u>failed</u> effort
- On the Other Hand...
 - 6/6/12 SiRem BioAugmentation Webinar: Presenter described adding donor to create an 'anaerobic bubble' to sustain Bio-aug w/ DHC
 - 6/18/12 Follow-up disc w/ Presenter "We do it all the time."
- Any (Other) Experiences/Expectations?

When <u>Not</u> to Try to Drive an Aerobic Plume Anaerobic

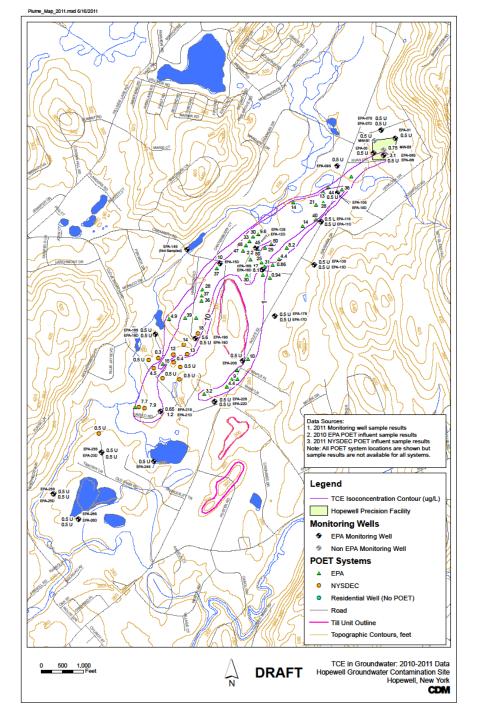
- High(er) DO levels/ORP
- High(er) GW flow regimes (continuing to bring DO into treatment zone)
- Low(er) solvent concentrations (100 ppb (?))
- Large(r) plumes But not necessarily fun for Aerobic either

Hopewell Precision Site

• Listed on NPL in April 2005

- OU 1 and OU 2 RODs Specify:
 - Possible use of Aerobic Cometabolic
 Bioremediation to restore resource (9-28-09 OU 1 ROD)
 - Alternative Water Supply (9-30-08 OU 2 ROD)

TCE Isoconcentra tion Contour Plume Map (as of April 2011)



TCE Isoconcentration Contour Plume Map (as of July 2007)

Legend

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- Stream Staff Gauges
- Surface Water Sampling Locations
 - Streams and Ponds (DEC Hydrography)

Monitoring Wells (MW) Piezometers (PZ)

- Road
- Topographic Contour, feet above mean sea level (amsl)
- Potentiometric Surface Contour, feet amsl (dashed where inferred)

Surface Water Bodies

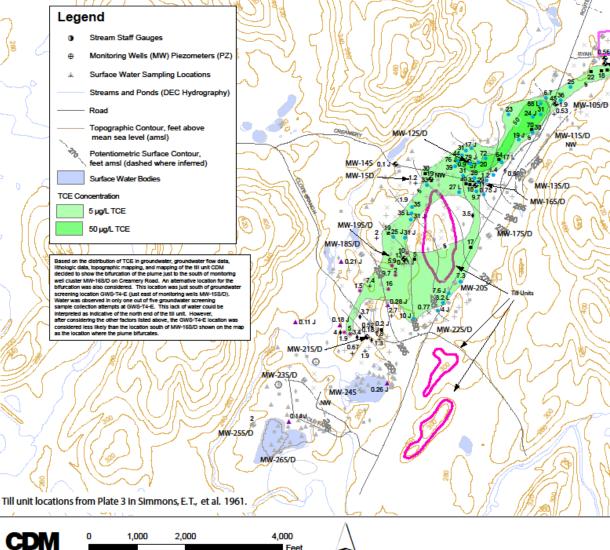
TCE Concentration

- 5 µg/L TCE
- 50 µg/L TCE

as the location where the plume bifurcates.

CDM

Based on the distribution of TCE in ground ter flow data, ater, grou and mapping of the till unit CDM Ithologic data, topographic mapping decided to show the bifurcation of the plume just to the south of monitoring well cluster MW-16S/D on Creamery Road. An alternative location for the bifurcation was also considered. This location was just south of gro screening location GWS-T4-E (just east of monitoring wells MW-158/D). Water was observed in only one out of five groundwater screening sample collection attempts at GWS-T4-E. This lack of water could be interpreted as indicative of the north end of the till unit. However, after considering the other factors listed above, the GWS-T4-E location was considered less likely than the location south of MM-15S/D shown on the may



Hopewell Precision Facility

Groundwater Data

MW-B3

MW-85/1

- TCE Hits, Residential Wells, depths <= 100 feet, July-August 2007
- TCE U and UJ values, Residential wells, depths <= 100 feet, July-August 2007
- TCE Hits, Residential Wells, depths > 100 feet, July-Aug. 2007
- TCE U and UJ values, Residential wells, depths > 100 feet, July-August 2007
- TCE Hits, Residential Wells, depths unknown, July-Aug. 2007
- TCE U and UJ values, Residential wells, depths unknown, July-August 2007
- ٠ TCE Hits, Monitoring Wells (MW, EPA, PZ), July 2007
 - TCE U values, Monitoring Wells (MW, EPA, PZ), July 2007 4
 - NYSDEC POET TCE Hits July 2007
 - NYSDEC POET TCE U values July 2007
- NYSDEC Residential Well U values, July 2007 0
- EPA Removal Program Sampling Locations, Hits, June 2007
- EPA Removal Program Sampling Locations, U values, June 2007
- TCE Hits, GWS Locations, September/October 2006
- TCE U values at GWS Locations, September/October 2006
- TCE Hits, Surface Water Samples, August 2008
- TCE U values, Surface Water Samples, August 2006
- NW No Water at groundwater screening location
- U Not detected
- UI Not detected
- Estimated
- L Estimated, biased low (EPA Data Qualifier)

TCE Isoconcentration Contour, micrograms per liter, dashed where inferred

The highest detection is posted next to each location. If no data is posted then TCE was not detected at this location. Detection limits ranged from 0.5 to 5 micrograms per liter.



How Accurate is the Depiction? (Data from a <u>variety</u> of sources**)

• NEWS FLASH: 'Plumes are Not (Necessarily) Blobs'

• Plume Cores: '90% of mass may be in as little as 10% of the cross-section' (*Parker et al*)

– But, can you <u>find</u> them?

** The norm (?)

Hopewell Precision NPL site

- Complex site hydrogeology and innovative technology require a <u>team</u> approach
 - Lorenzo Thantu, RPM EPA R 2
 - CDM Smith R 2 contractor
 - Dr Kent Sorenson
 - Ryan Wymore
 - Joan Knapp
 - Dr John Wilson, EPA/ORD Ada, Ok
 - Dr. Brian Looney, DOE/SRNL
 - Jim Cummings, TIFSD, EPA Hq

Aerobic Co-metabolic Bioremediation (ACB)

- Dr. John Wilson and wife of EPA's Ada lab were among first to discover
- Carefully orchestrated addition of substrate and oxygen
- Limited utilization since advent of Enhanced Reductive Dechlorination (ERD) due to slow rates

ACB

- In process of digesting substrate, microorganisms exude enzyme which fortuitously degrades TCE
 - No metabolic benefit to bugs
 - TCE epoxide gives the bugs a 'hot foot' thus may evolve away from capability – requiring repeated bioaugmentation
 - Not thought to be a problem at Hopewell due to lower starting concentrations (?)

Remedial Design

 Mantra – "Cheapest Possible Substrate, Cheapest Possible Delivery Mechanism(s)"

• Remedial Strategy:

- Identify and address hot/warm spot(s) to reduce mass and mass discharge
 - Refine CSM through use of vertically discrete sampling
- Explore/exploit abiotic and biotic natural attenuation mechanisms to 'polish' the plume

Candidate Substrates

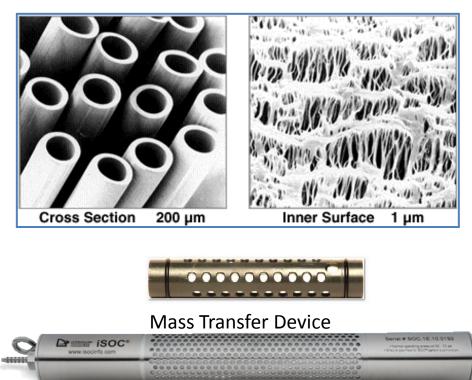
- Gases
 - Propane
 - Butane
 - Methane
- Liquid
 - Under development by SRNL

Candidate Delivery Mechanisms

- Waterloo Emitter
- Tersus ISOC
- Tersus Ex-Situ Infusion system
- Currently contemplating <u>recirculating</u> well configuration

Gas inFusion[™] iSOC[®] Technology

700 Microporous Hollow Fibers

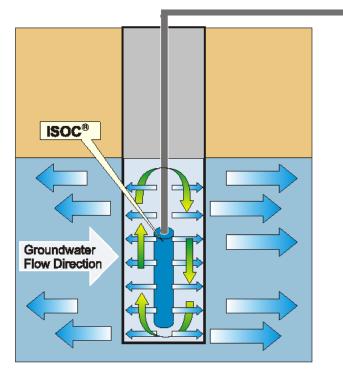


Diameter: 1.62 inches (4.1 cm) Height: 12.65 inches (32.1 cm)

- Large surface area for mass transfer (7000 sq. ft per cu ft)
- Mass transfer occurs when gas pressure is less than GW
- High DO supersaturates treatment well, no sparging
- High DO migrates to biomass
- Microbes degrade targeted compounds

iSOC[®] Gas inFusion Process

Regulated O₂ Supply to Multiple Devices



Direct aerobic treatment example:

- Uses industrial grade pure oxygen
- Supersaturates well DO (40+ PPM depending on groundwater depth)
- Convection current fills well with uniform DO
- DO disperses into groundwater stimulating bioremediation

iSOC[®] Dissolved Gas Concentrations

Gas Type	Water Column Depth in Feet (Dissolved Gas in ppm)				
	5'	10'	15'	20'	50 '
Oxygen	42	55	62	69	111
Methane	22	30	33	37	59
Propane	66	88	99	110	175
Hydrogen	2	2	3	3	5
Ethane	57	75	85	95	150
Carbon Dioxide	1,660	1,875	2,090	2,300	3,590

Injection Well Concentrations

Technology	Dissolved Oxygen (ppm)			
iSOC®	40 - 60			
Peroxygens	3			
Oxygen Emitters	10 - 13			
Air Sparging	8 - 11			

Ex-Situ Gas inFusion





Waterloo Emitter



'Wild and Crazy...' Ideas

 'Proletariat Pump and Treat' – Put (some) private wells to use in remedial effort (??)

- Use <u>both</u> ERD <u>and</u> ACB
 - ERD for plume core(s)
 - ACB for lower contaminated zones

Natural Attenuaton - Abiotic

• Initial work by Dr. Wilson indicates promising presence of *magnetite*

 Exploring geophysical tools to allow more definitive determination of volumetric prevalence of magnetite

Natural Attenuation - Biotic

- Utilizing various quantitative Bio tools to determine presence and prevalence of appropriate organisms
 - e.g., Contracting with INEL to conduct Enzyme Activity Probe (EAP) analyses

Conclusions and Next Steps

- Additional characterization planned vertical profiling tools
- ACB cost, performance and duration TBD
- Hope that pilot will have a major impact on plume longevity
- Competing for funding in time of declining budgets