Large, Dilute Solvent Plumes

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TAB/TIFSD

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Large, Dilute Plumes

- Prevalent Problem Set
- Pose characterization and remediation challenges

One Perspective on L&D Plumes: SERDP Research Program

What conditions create L&D plumes?

Permeable aquifers, generally with low organic carbon contents

Aerobic systems where influx of electron acceptors makes it difficult to establish and maintain reducing conditions

Attenuation processes are generally slow (e.g., degradation half-lives more than 1 to 2 years)

Often deep

Often affected by mass transfer in/out of less-transmissive compartments (clay/silt layers)

Key Insights

- Plumes are heterogeneous
  - Not uniform ‘blobs’

- 90% of contaminant mass may be sorbed to the matrix in the volume commonly thought of as ‘dissolved phase’
  - Manifests as early ‘spikes’ in contaminant concentration – sometimes >initial concentrations - following ISCO as contaminants desorb from matrix (NOT late stage ‘rebound’)

DOE Examples

M-Area – DOE Savannah River Site (TCE, approximately 2 square miles and extending to 200 feet deep, initial source concentration → DNAPL)

200 Area – DOE Hanford Site (Carbon tetrachloride, approximately 3 square miles and extending to 350 feet deep, initial source concentration → DNAPL)

Northwest Plume – DOE Paducah Gaseous Diffusion Plant (TCE, approximately 1 square miles extending 75 feet deep, initial source concentration → DNAPL)

Test Area North – DOE Idaho National Laboratory (TCE, approximately 1 square mile and extending to 350 feet deep, initial source concentration → DNAPL)

Many DOD examples (Hill AFB, Tinker AFB, etc.) and industrial facilities

‘Desperately Seeking…’

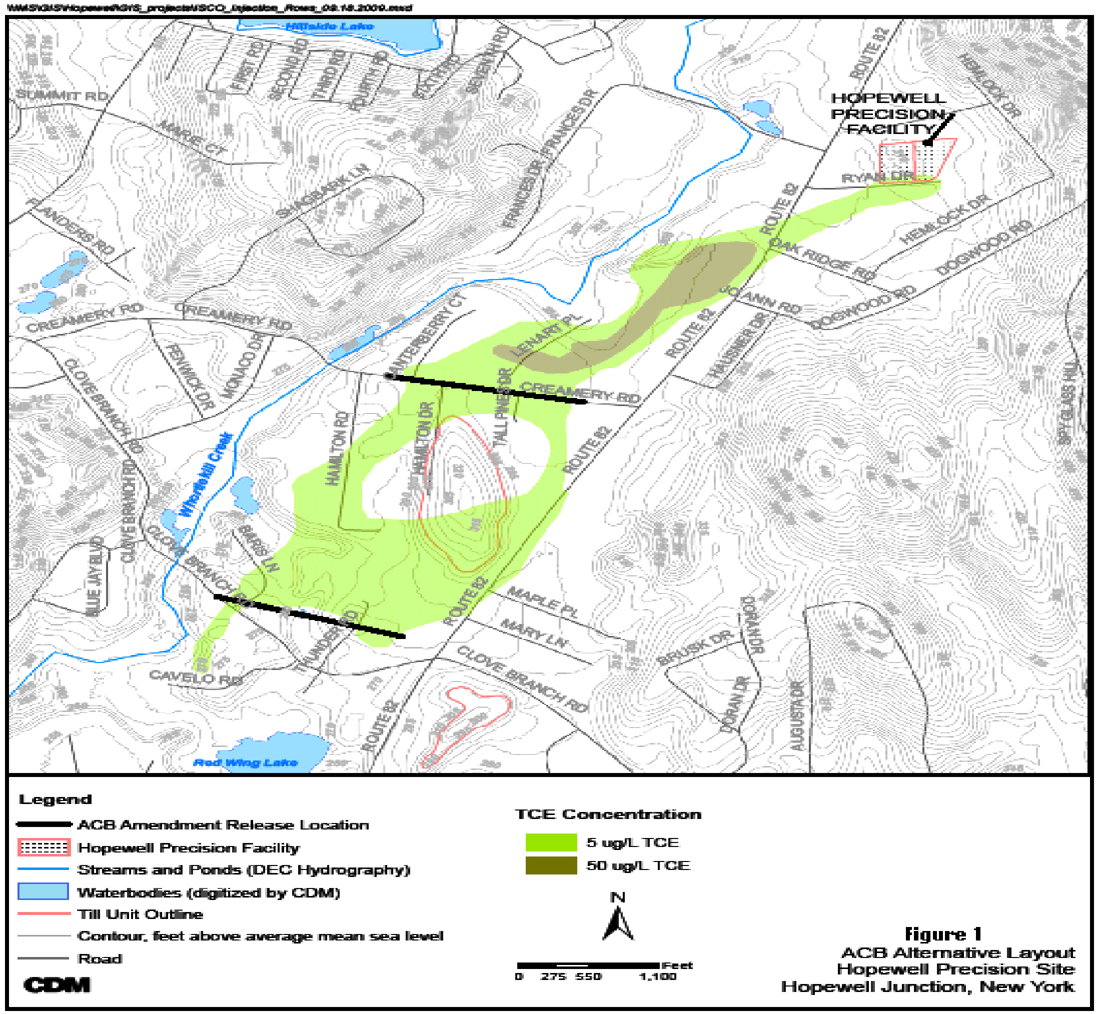
- Least Cost Amendments
- Least Cost Delivery Mechanisms
- Exploitable subsurface hydro/ bio/ geological conditions to ‘help’…

Hopewell Site, NY

- 7000' solvent plume – mainly TCE
- Concentrations generally < 100 ppb

- But…
  - MCL exceedances in private wells
  - Vapor Intrusion above acceptable levels

Heterogeneous Lithologies, Permeabilities and Geometries



Hopewell, NY - Additional Complications

- Shallow <u>aerobic</u> plume
  - Therefore ERD N/A
  - Efforts at other sites to change redox have often been ‘ugly’

- Plume depiction accuracy uncertain
  - Based on a variety of monitoring and water supply wells with differing screened intervals

Hopewell, NY - Components of Remedy

- Point of use water systems
- Abate Vapor Intrusion
- Aerobic cometabolic bioremediation to restore plume

Aerobic Co-metabolic Bio

- Much initial research done by Dr John Wilson and his wife at ORD/Ada
- Micro-organisms produce an enzyme which fortuitously destroys contamination
- No toxic daughter by-products (e.g., VC)
- Not widely used heretofore due to slow(er) degradation rates
- “Burn-out” problem

ACB – Necessary Ingredients

- Presence - or addition - of *Pseudomonas*
- Substrate addition to promote microbial proliferation
- Oxygen to support biodegradation (6-8mg/L)

“Burn-out”

- Enzymatic process is uncomfortable to micro-organisms (equiv to a ‘hot-foot’) so there is natural selection away from the desired organisms

Implementation Challenges*

- **Biofouling** – microbial proliferation around injection point(s) (Solution: H_2O_2 as O_2 source)
- **Competitive Inhibition** – substrate competes with contaminants for activation sites
- **Deactivation** – Process stops when substrate consumed (requires continuing addition)

- **Source: Air Force Research Lab Installation Restoration Program –** ***AFRL ML-TY-TR-1998-4530***

Table 3-1. Efficiency of Chlorinated Aliphatic Hydrocarbon Removal Obtained at the Moffett Federal Airfield Site with Different Primary Substrates (after Hopkins and McCarty, 1995)

Primary Substrate	Substrate Concentration (mg/L)	%Removal				
		TCE	1,1-DCE	c-DCE	t-DCE	Vinyl Chloride
Methane	6.6	19	NE	43	90	95
Phenol	12.5	94	54	92	73	>98
Toluene	9	93	NE	>98	75	NE

Key:

TCE = Trichloroethylene
t-DCE = trans-1,2-Dichloroethylene
c-DCE = cis-1,2-Dichoroethylene
1,1-DCE = 1,1-Dichloroethylene
NE = Not Evaluated
mg/L = Milligrams per liter

Source: Air Force Research Lab Installation Restoration Program – *AFRL ML-TY-TR-1998-4530*

Aerobic Co-metabolic Bio

- Recent work by DOE/SRS on substrates which increase biodegradation rates

- At least one commercial firm – CL Solutions – has done field scale work (vendor claims >100)
  - Includes bio-augmentation (*Pseudomonas*) w/ dextrose substrate addition
  - But small footprints to date

ACB

- Recent ES&T article reports use of Compound Specific Stable Isotope Ratio (CSIR) analysis to confirm ACB of TCE and DCE in a fractured rock aquifer system

Summary of Screening Information

Throughout the nation:

80 to 100% of the wells at most sites screen positive for significant numbers of organisms that are expressing the enzymes necessary for cometabolism

Therefore, cometabolism is occurring in all of the aerobic plumes tested to date

Current research focuses on why* and kinetics (rates)

*** how are these organisms living in oligotrophic aquifer systems? What is the carbon source?**

Summary of Rate Information

Throughout the nation:

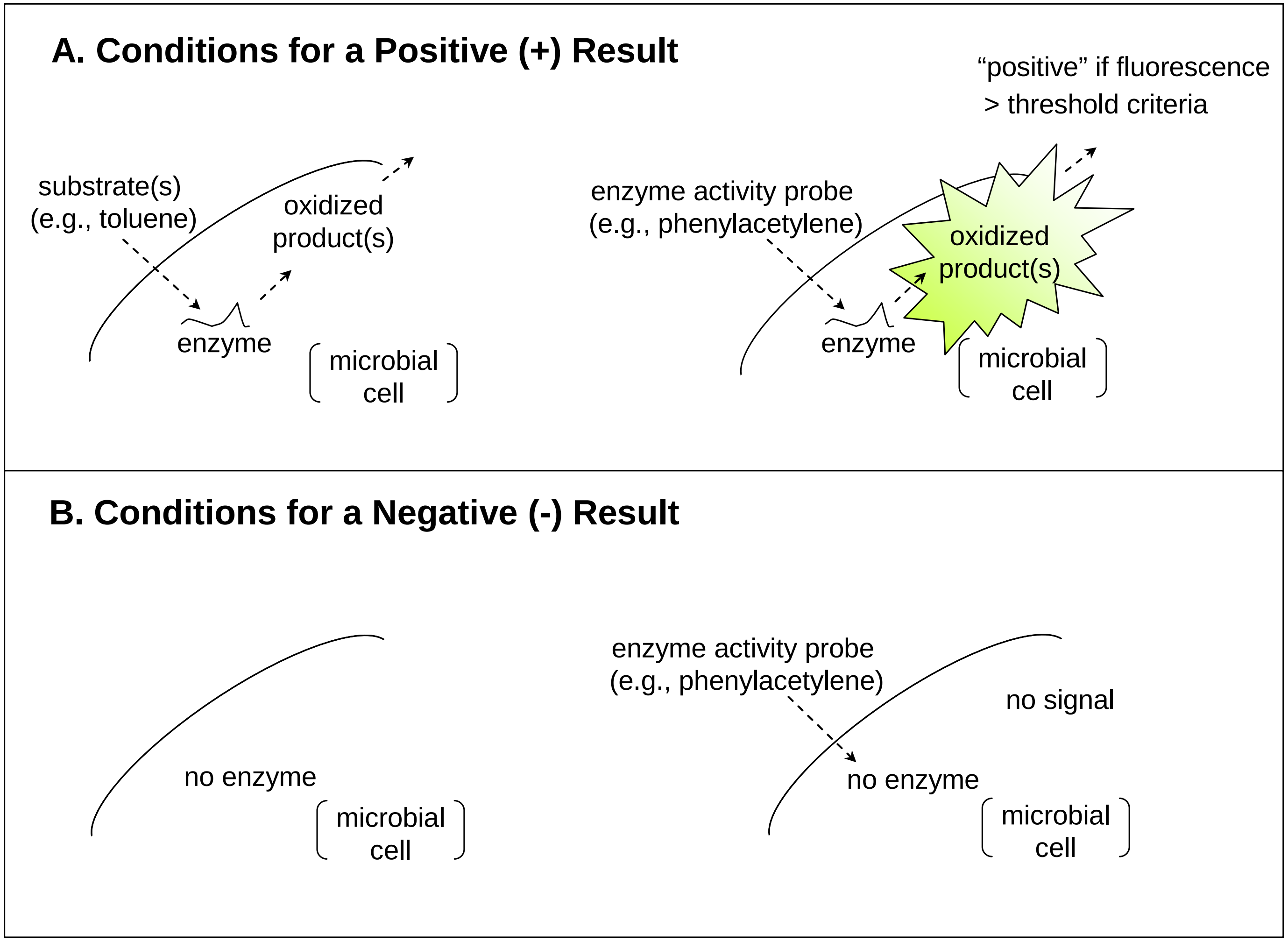
Half lives of about 8 to 31 years have been measured

Based on current conceptual model –

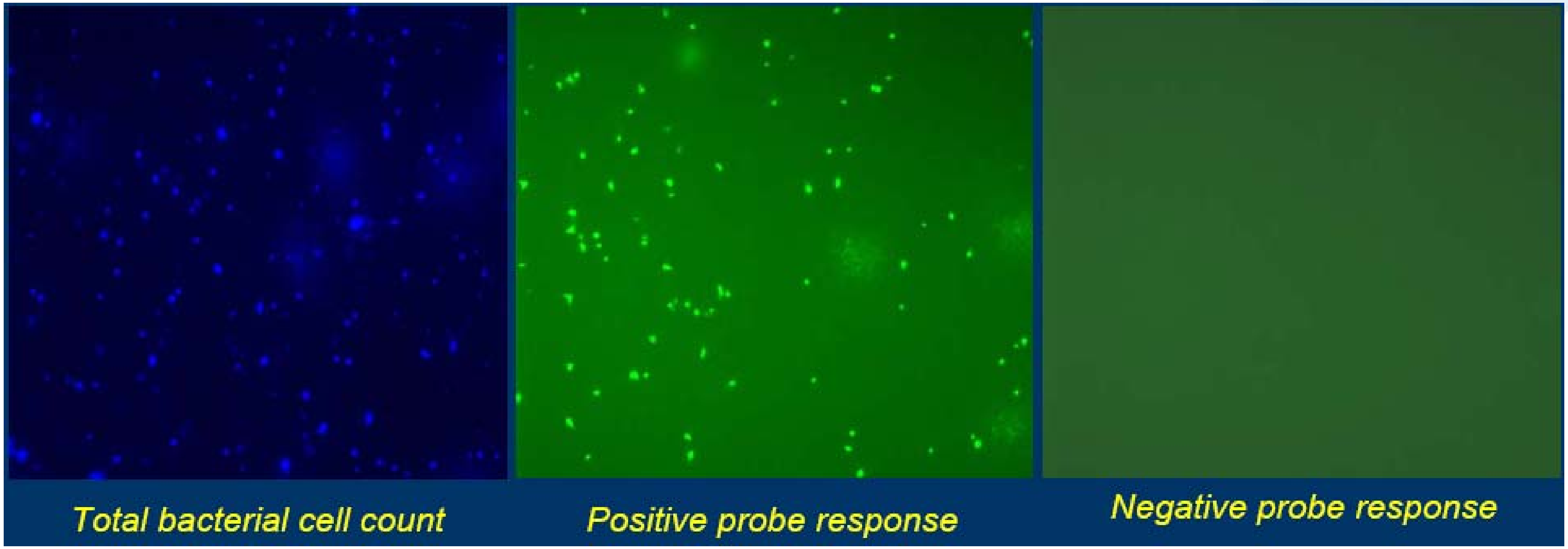
- **process is sustainable**
- **long-lived amendments (natural organic matter) may be deployable on a large scale to enhance rates**

SRNL™

Enzyme Activity Probes (EAP) look for Key Enzymes



Sample Images



Least Cost Amendments

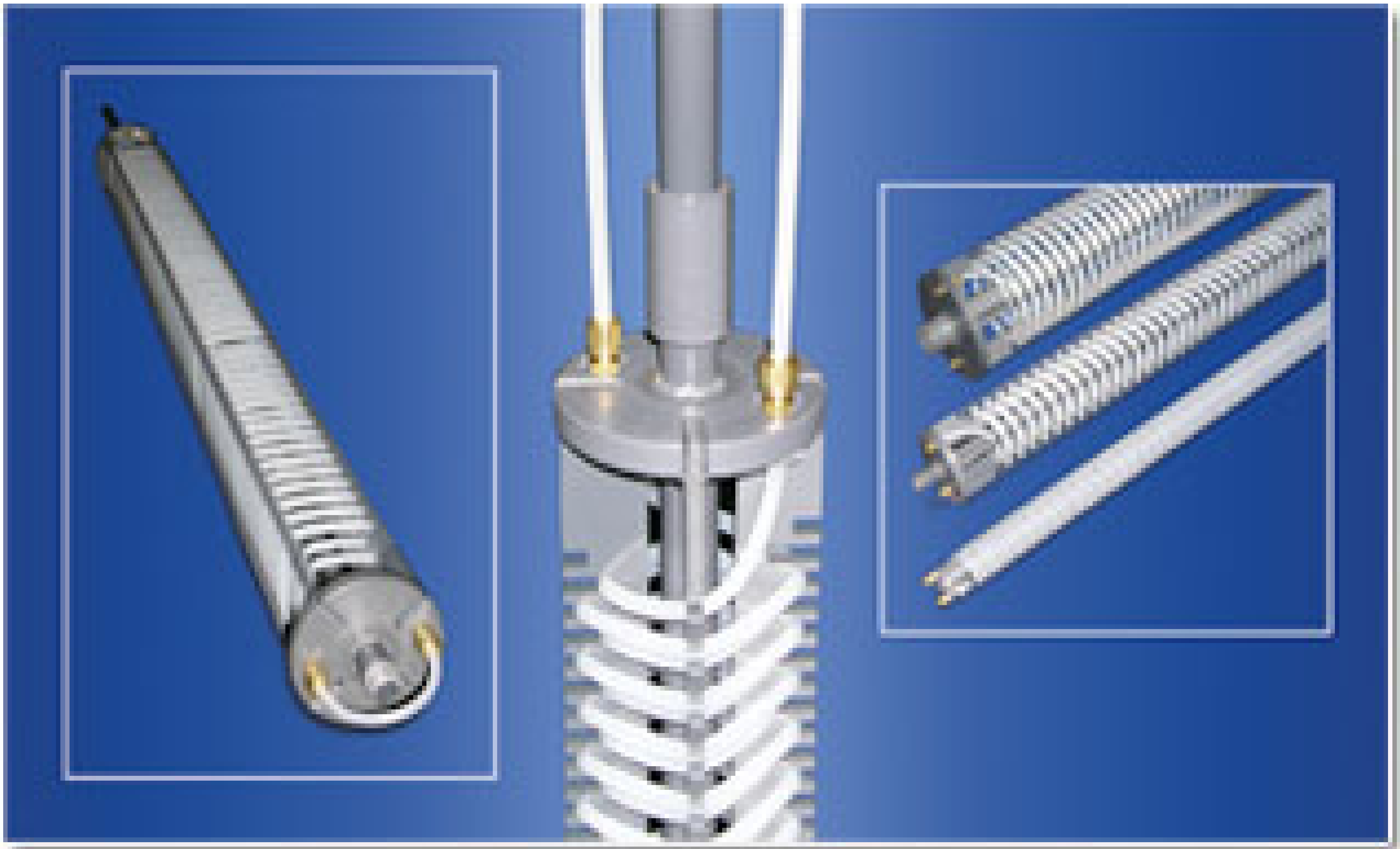
- Gases would be the cheapest
- But: Amendments suggested by DOE are liquids

Amendments

- **Oxygen** for aerobic bioremediation
- **Toluene, Methane, Propane** – possible gaseous substrates

Least Cost Delivery Mechanisms

Waterloo Emitter



Simple Technology

- PVC frame wrapped with tubing that can be pressurized to obtain the desired diffusive transfer of gas
- <u>No pumps required</u>
- Sized for 2", 4" and 6" wells
- Units can be stacked in a well and joined from one well to another, to allow the controlled continuous diffusion of gas into the plume
- BUT: Limited to gases

Other Possible Delivery Mechanisms

- Horizontal Biosparge Wells

Cost Comparison – 20 acre facility 400'x70'x20'deep plume

Remedial Alternative	Capital Cost	Annual Cost	Present Worth
Ozone/Air Sparging	$ 460 – 680	63 – 123	630 – 1,120
Fenton's Reagent Injection	$ 625 – 900	22 – 46	720 – 1,260
KMnO4 Injection	$1,100 – 1,600	22 – 46	1,300 – 1,900
Iron PRB Installation	$ 760 – 1,110	22 – 46	1,250 – 2,120
Horizontal Biosparge Well	$ 350 – 490	57 – 91	550 – 950

Cost Effectiveness of Horizontal Biosparge Well Application for Aerobic Co-Metabolic Groundwater Remediation

Mark M. Mejac, Hal W. Taylor, and Jeanne M. Tarvin, STS Consultants, Ltd.

Ongoing Cogitation

- Hopewell - How, what (and where) to inject…in progress
- Numerous expressions of interest from DOD facilities to DOE ESTCP ACB site selection survey

The ACB 'Brain Trust'

- John Wilson – ORD/Ada Ok
- Brian Looney- DOE/SRNL
- Hope Lee – DOE/INEL