Remediation of Chlorinated Solvent Source Zones Using ZVI-Clay in Conjunction with Soil Mixing (ZVI-Clay)

Presented at the RTDF Permeable Reactive Barrier Action Team Meeting
Albuquerque New Mexico, October 26, 2004

By

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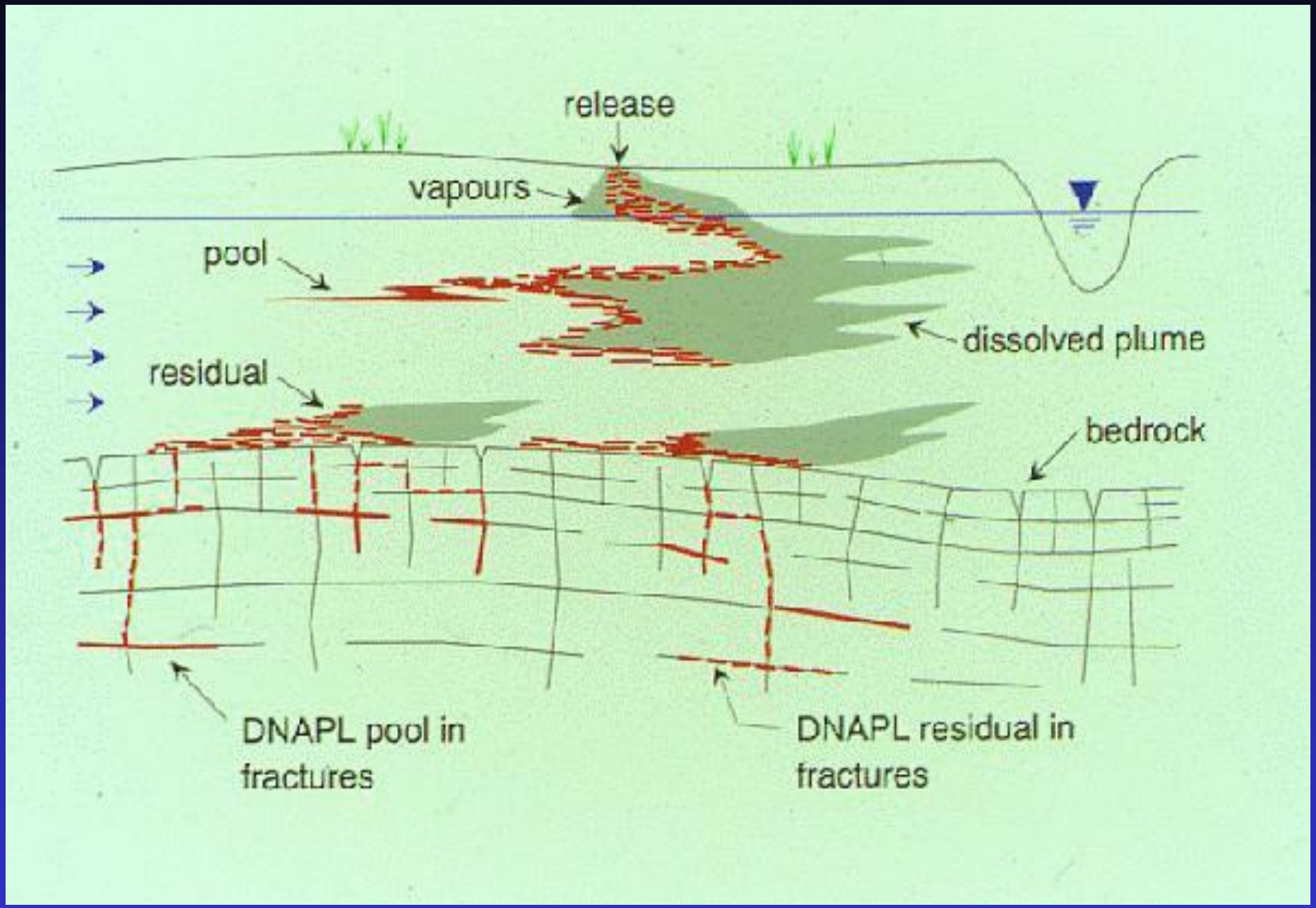
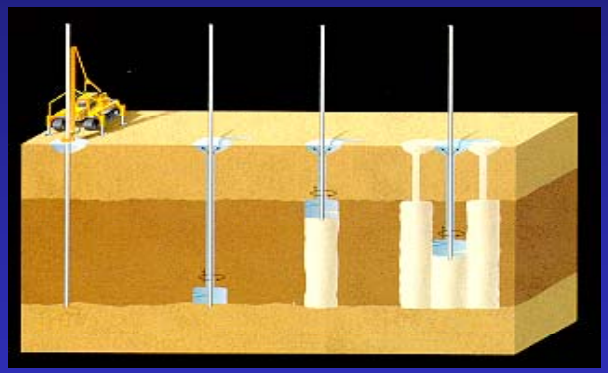
Presentation

- Process
- Laboratory Results
- Field Results
- Future Plans
- Questions



Conceptual chlorinated solvent source zone (Kueper et al., 1993).

ZVI-Clay



November 2003 DuPont Technology Donation to Colorado State University
Batchelor et al., 1998 and 2002. United States Patent nos. 5,789,649 and 6,492,572 B2.

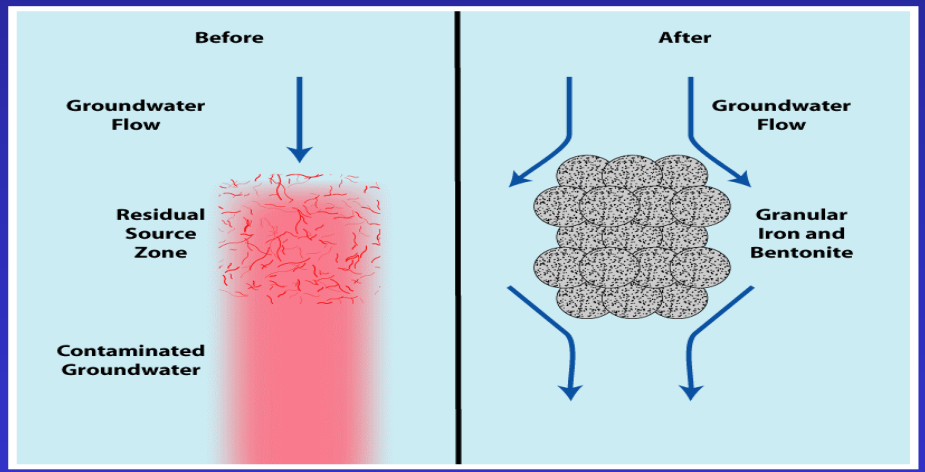
ZVI

<u>Reactive Media (Zero-Valent Iron) -</u>Drives reductive dechlorination (Gillham and O'Hannesin, 1994).

(1) $Fe^0 \rightarrow Fe^{2+} + 2e^-$

(2) $CCl_4 + 2e^- + H^+ \rightarrow CHCl_3 + Cl^-$

Clay



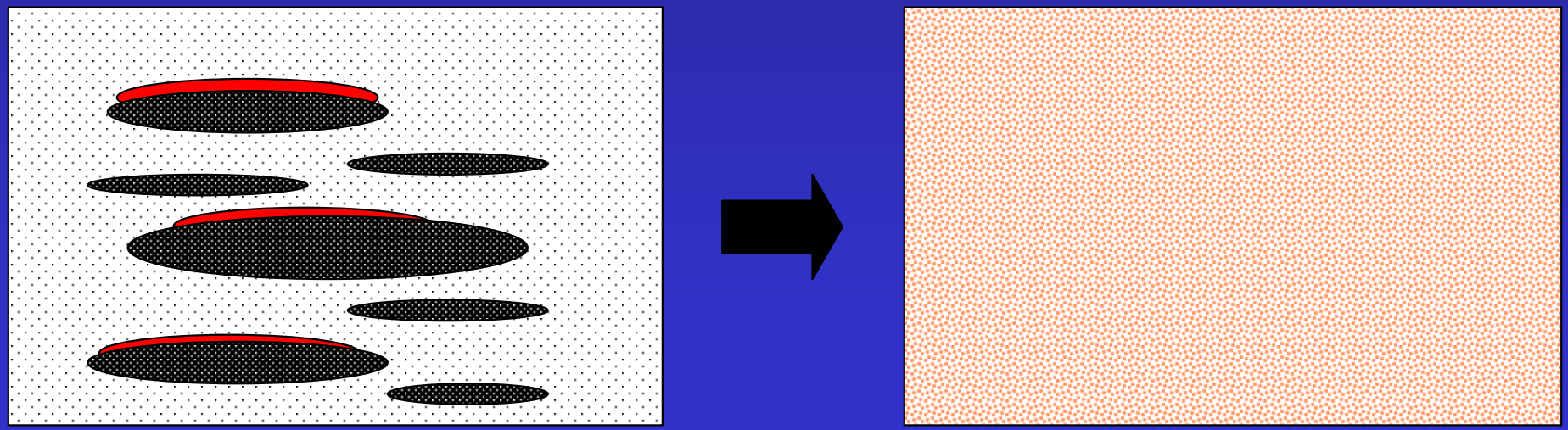
Effect of stabilization of a source zone (ETI 2004)

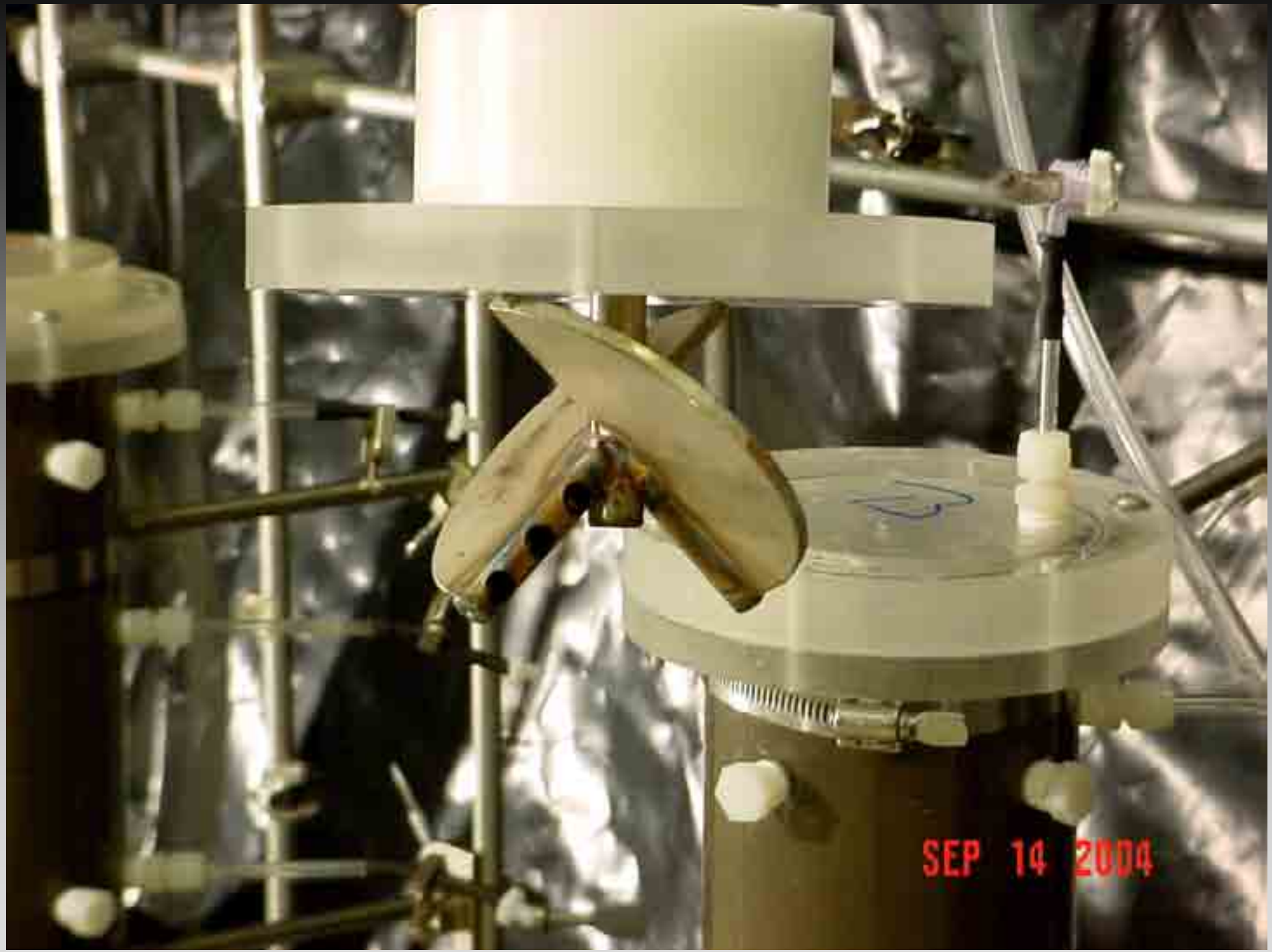
- Reduces discharge of water through source
  - Reduced downstream contaminant discharge
  - Increased time for reactions to proceed
  - Reduced inflow of oxygen and other electron acceptors
- Facilitates mixing
  - High viscosity suspension for uniform iron delivery
  - Reduced energy for soil mixing

Mixing

Homogenates source zone:

- Reagent distribution
- Contaminant distribution
- Sediments
- Dispersal of DNAPL pools

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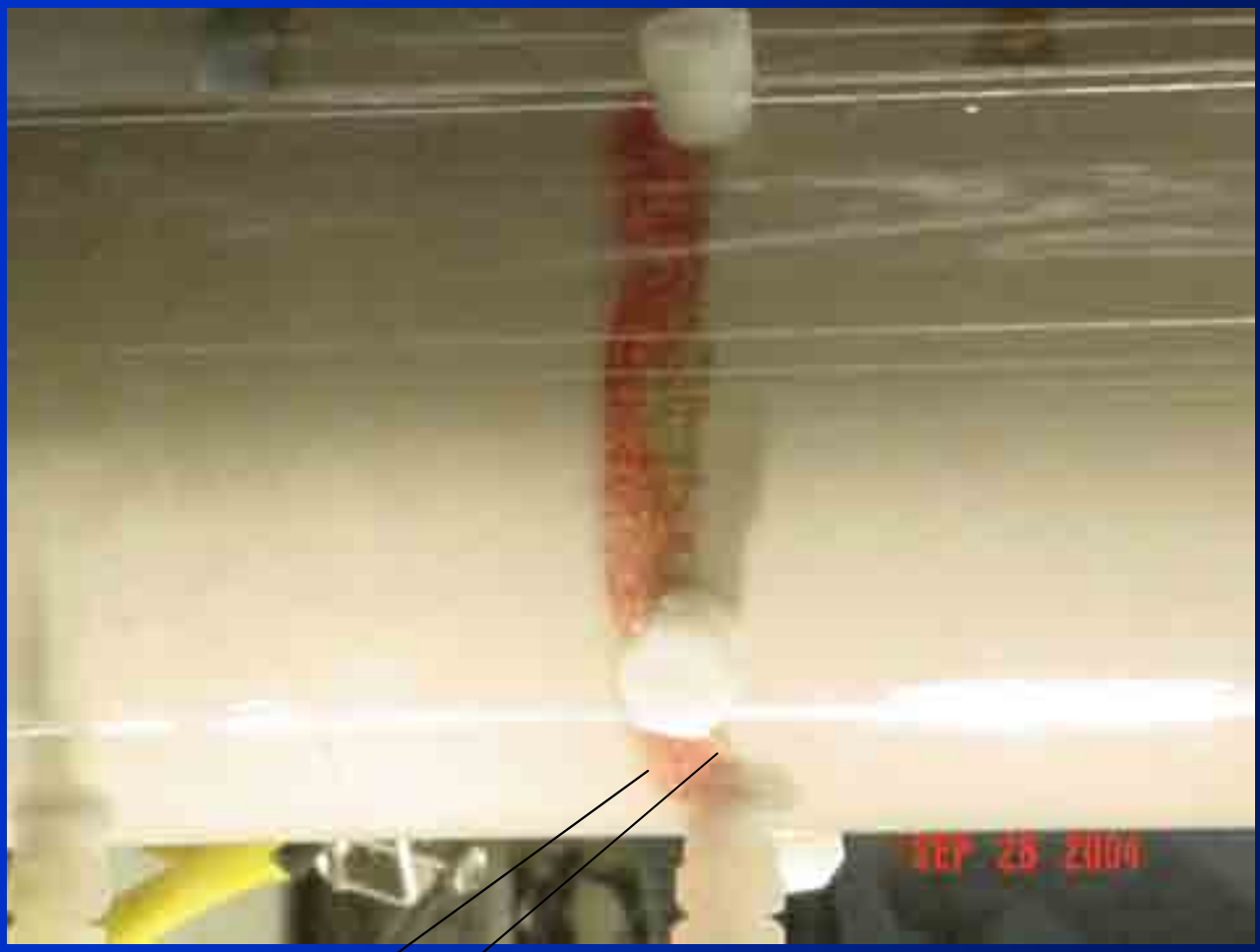
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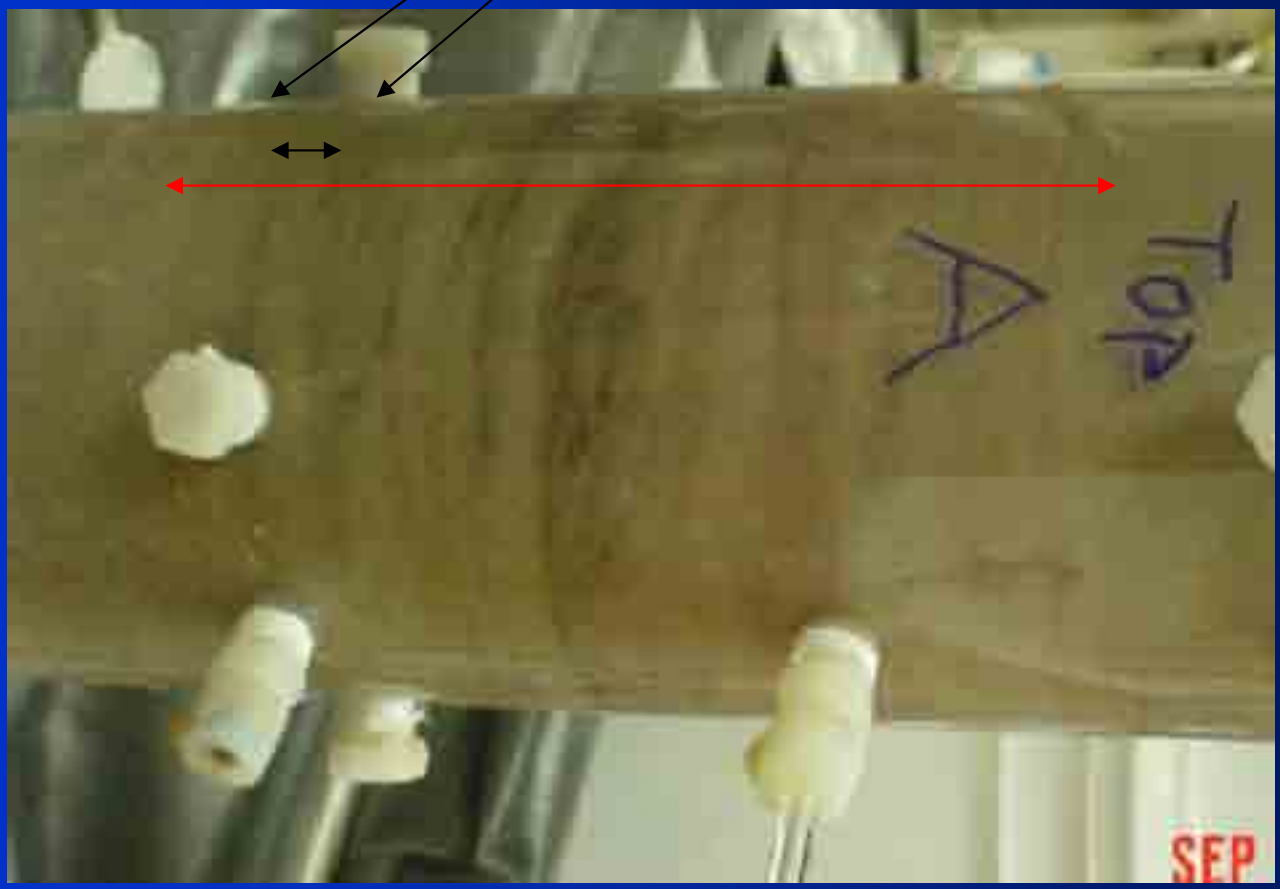
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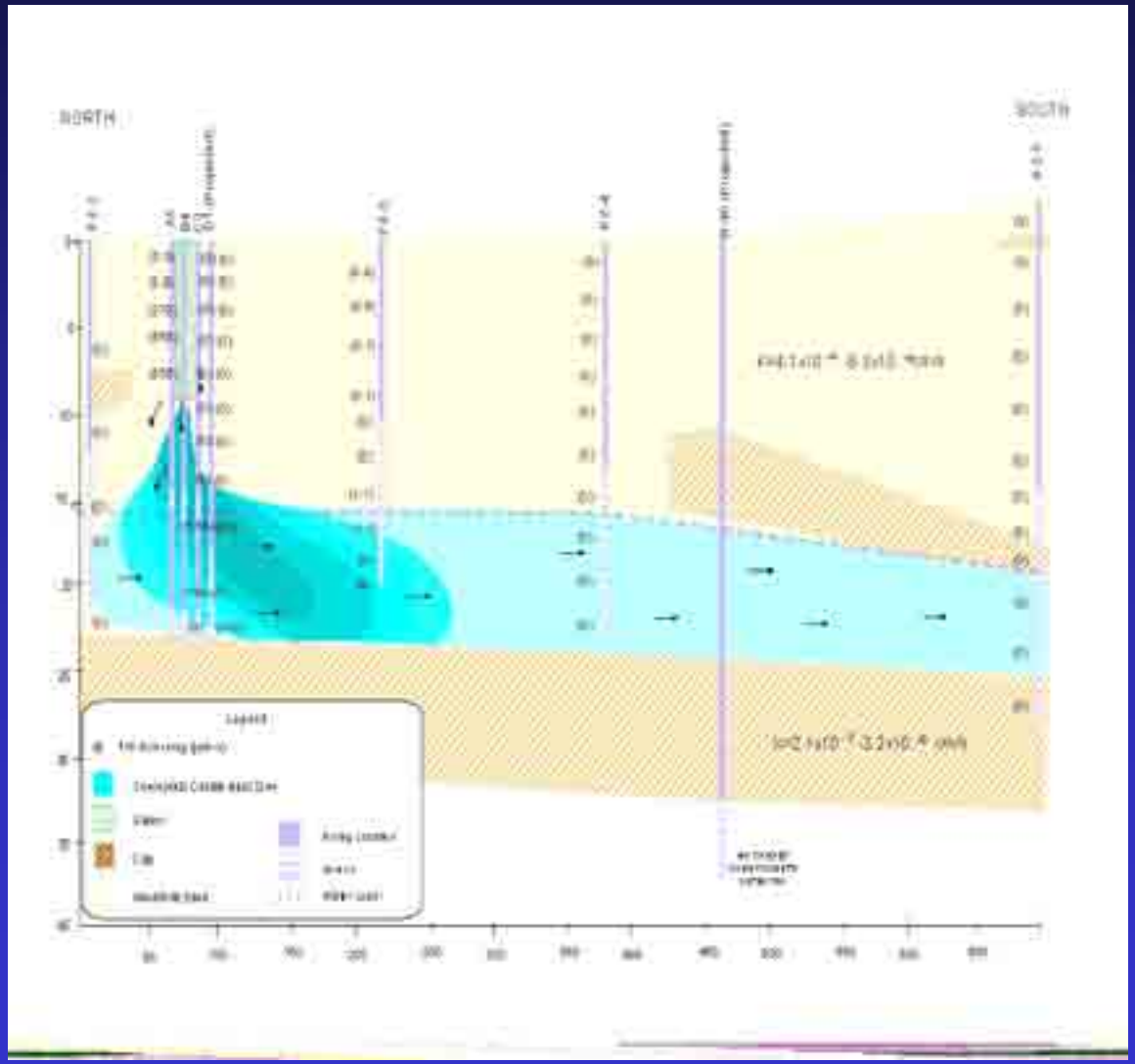
9/28 - Initial

9/28 – Post Mixing

9/30 Two Days

South Carolina Site

- Small release
- Shallow alluvium
- Active contaminant attenuation
- Located within an industrial property



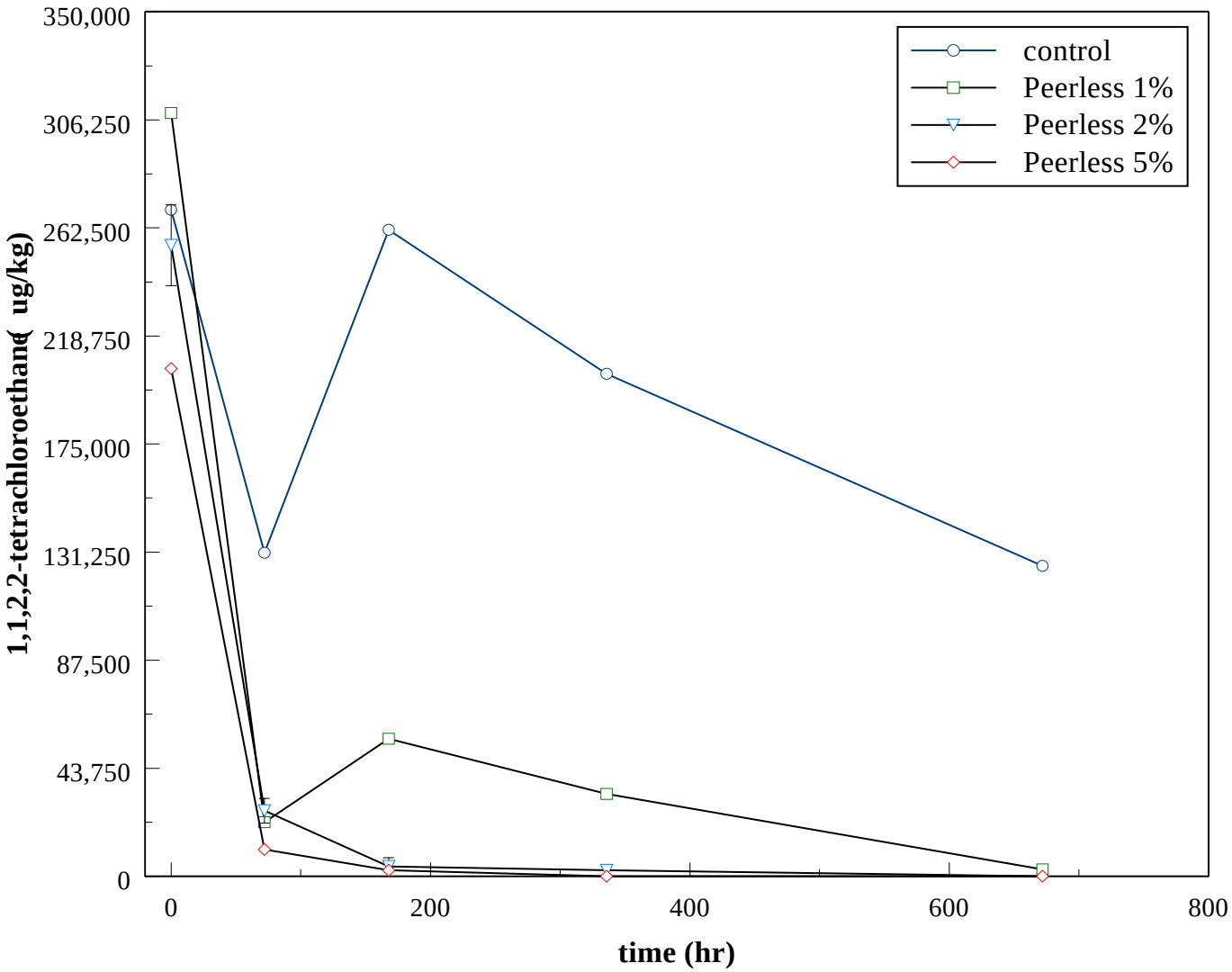
Geochemical Studies

(South Carolina)

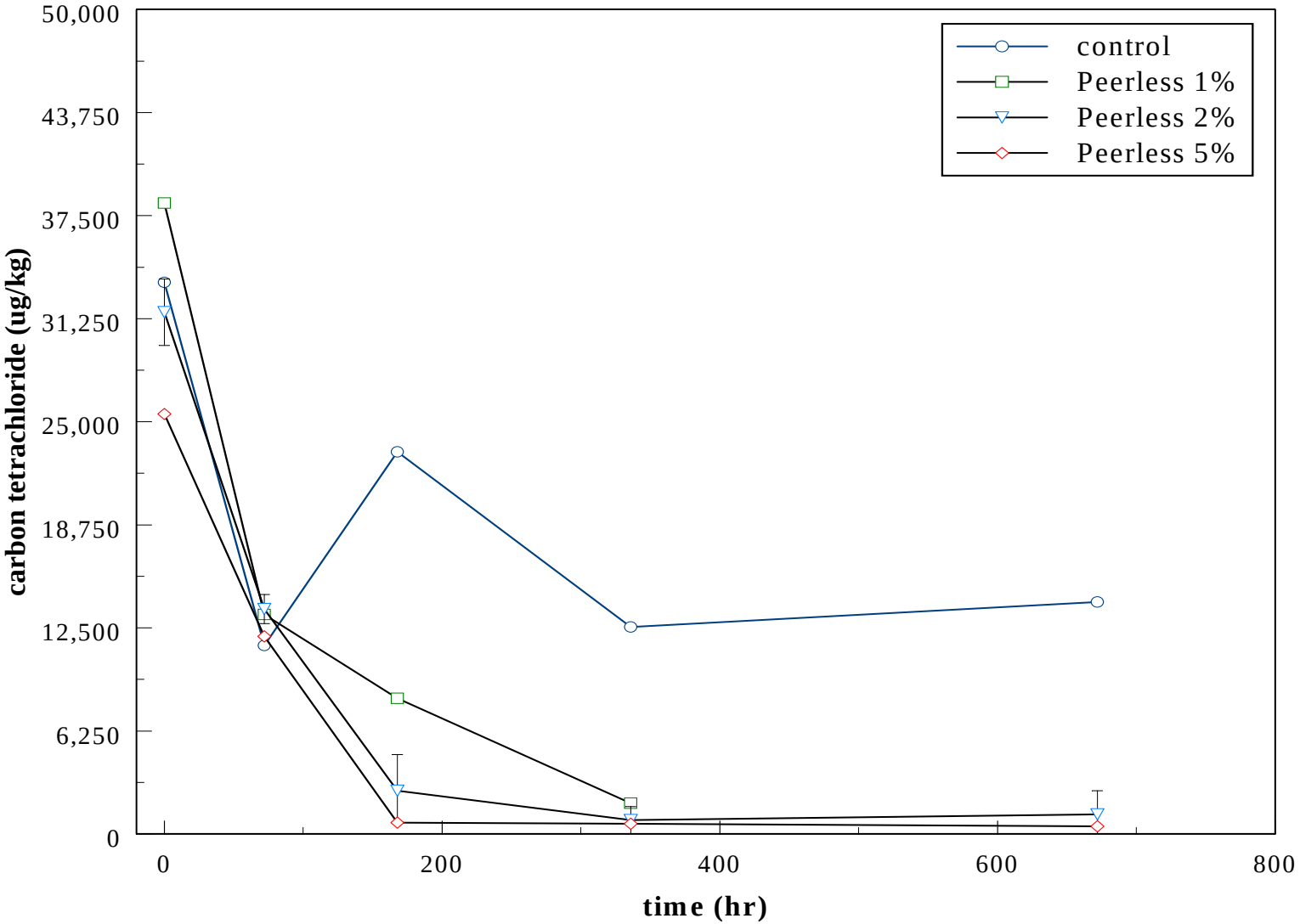
Spike sample study matrix

			3 days (CSU)	7 days (CSU)	14 days (CSU)	28 days (CSU)	28 days (Outside lab)
Spiked and Dried Samples	0% Fe Control	w/ clay	CC-0-3	CC-0-7	CC-0-14	CC-0-28	CC-0-28L[A]
	1% Fe		S-1-3	S-1-7	S-1-14	S-1-28	S-1-28L
	2% Fe	A	S-2A-3	S-2A-7	S-2A-14	S-2A-28	S-2A-28L
		B	S-2B-3	S-2B-7	S-2B-14	S-2B-28	
		C	S-2C-3	S-2C-7	S-2C-14	S-2C-28	
		D NAPL Spike	CF-0-3	CF-0-7	CF-0-14	CF-0-28	
	5% Fe		S-5-3	S-5-7	S-5-14	S-5-28	
	2% GMA Fe[B]		S-2G-3	S-2G-7	S-2G-14	S-2G-28	S-2G-28L
	2% Connelly Fe		S-2C-3	S-2C-7	S-2C-14	S-2C-28	

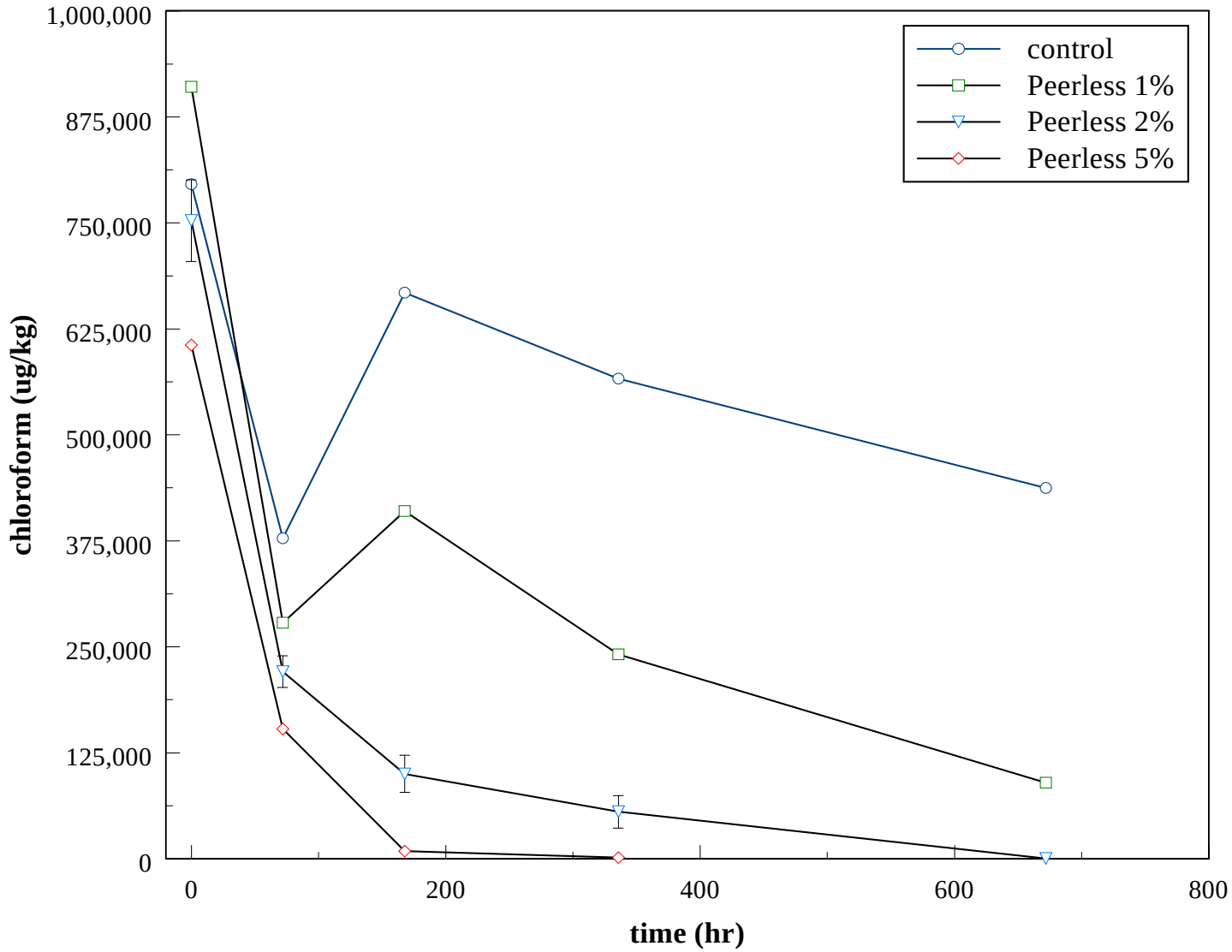
Rapid degradation of 1,1,2,2-TCA with similar endpoints 680 hours (26 days)



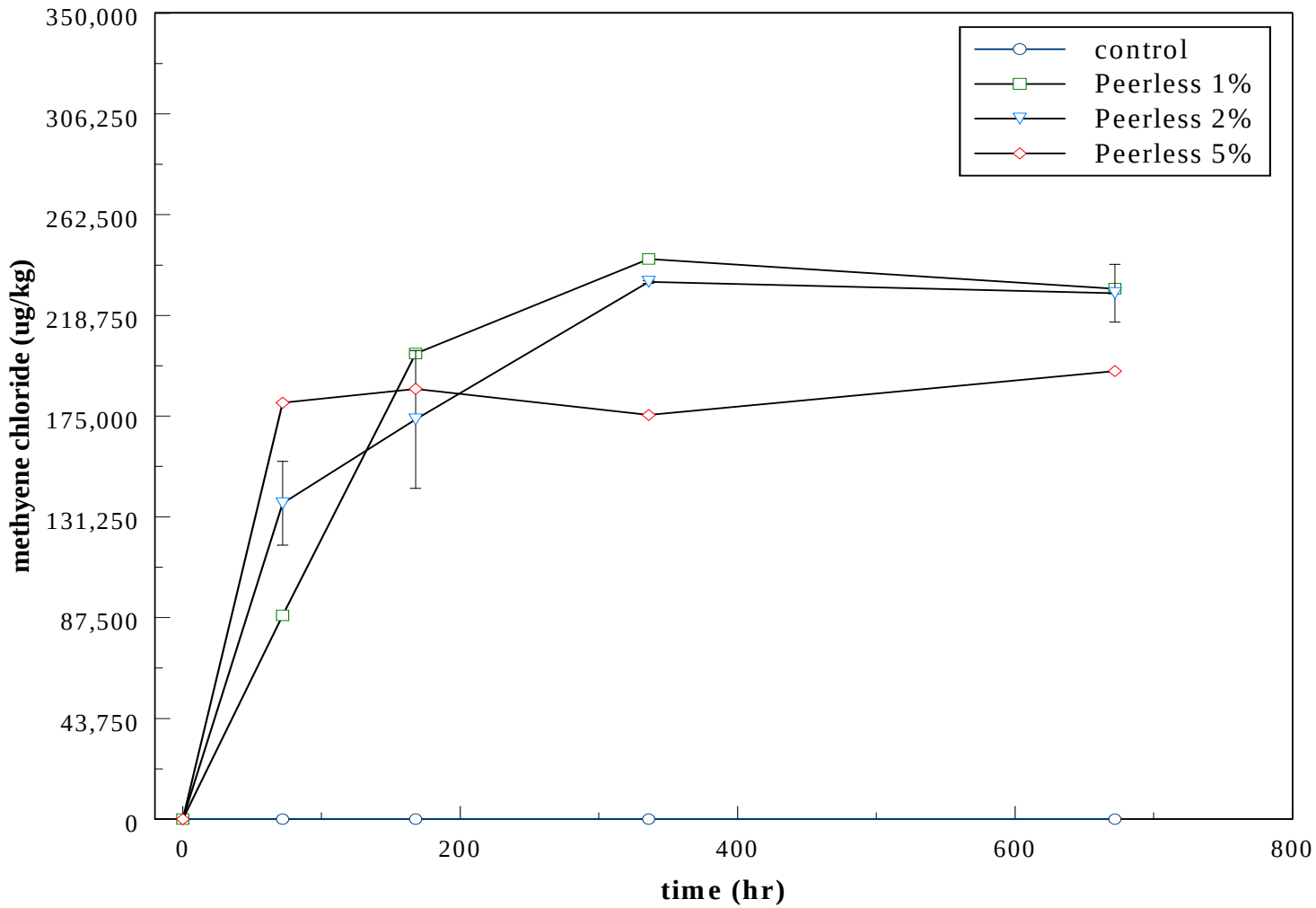
Rapid degradation of Carbon Tetrachloride with similar endpoints 680 hours (26 days)



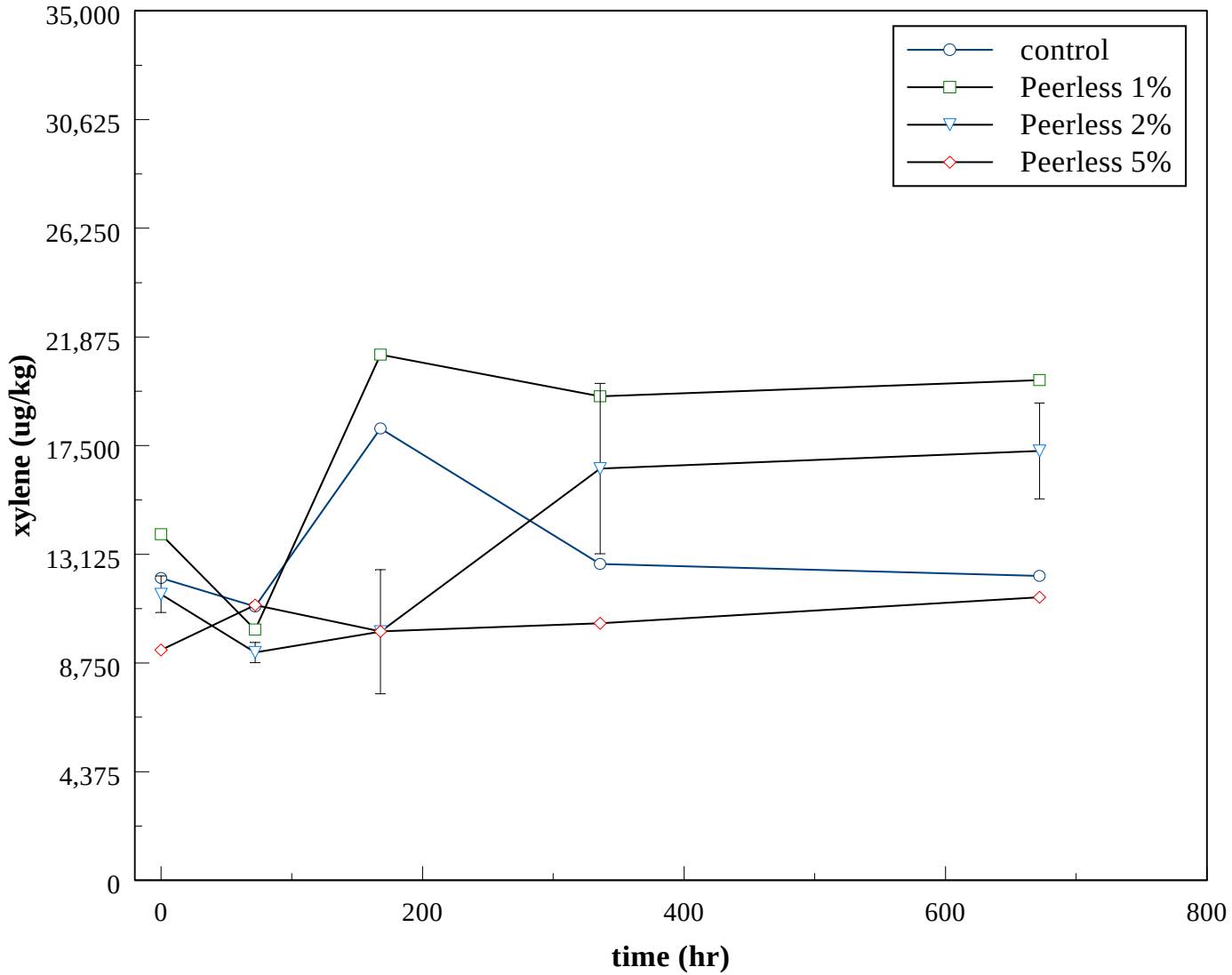
Rapid degradation of Chloroform



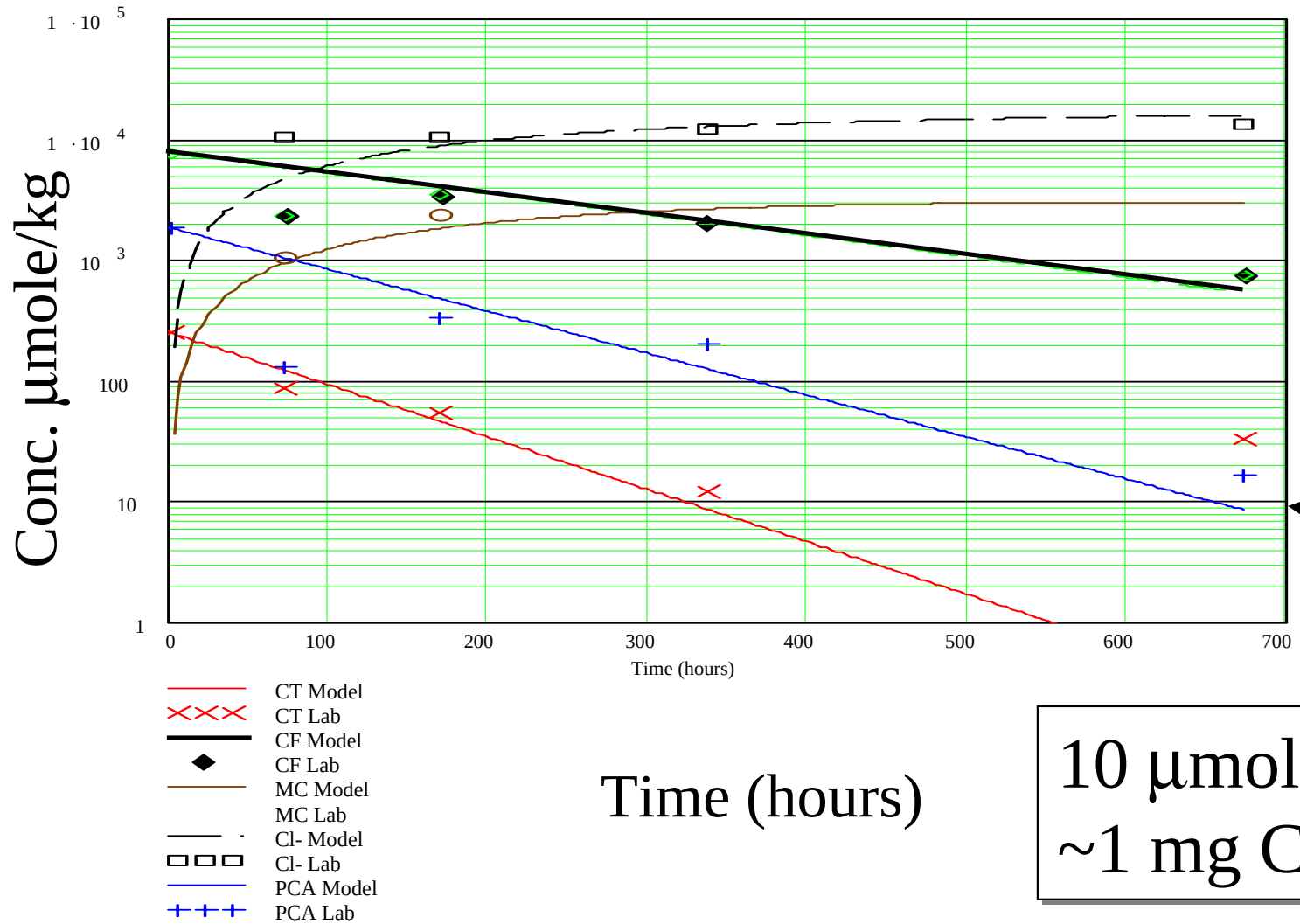
Apparent slow degradation of MC



Xylene – little removal in 28 days

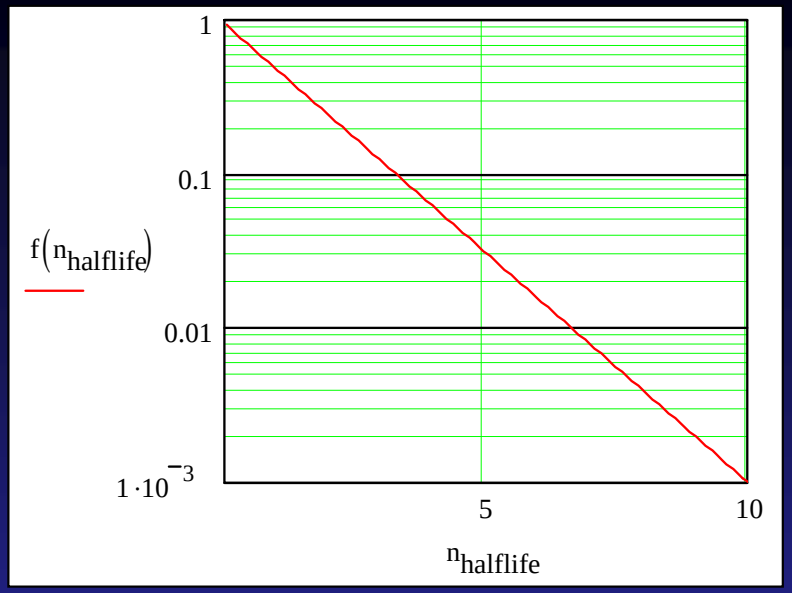


Modeling – Irreversible first order reactions (Eykohlt, 1999)



Time (hours)

10 µmole CT/kg
~1 mg CT/kg



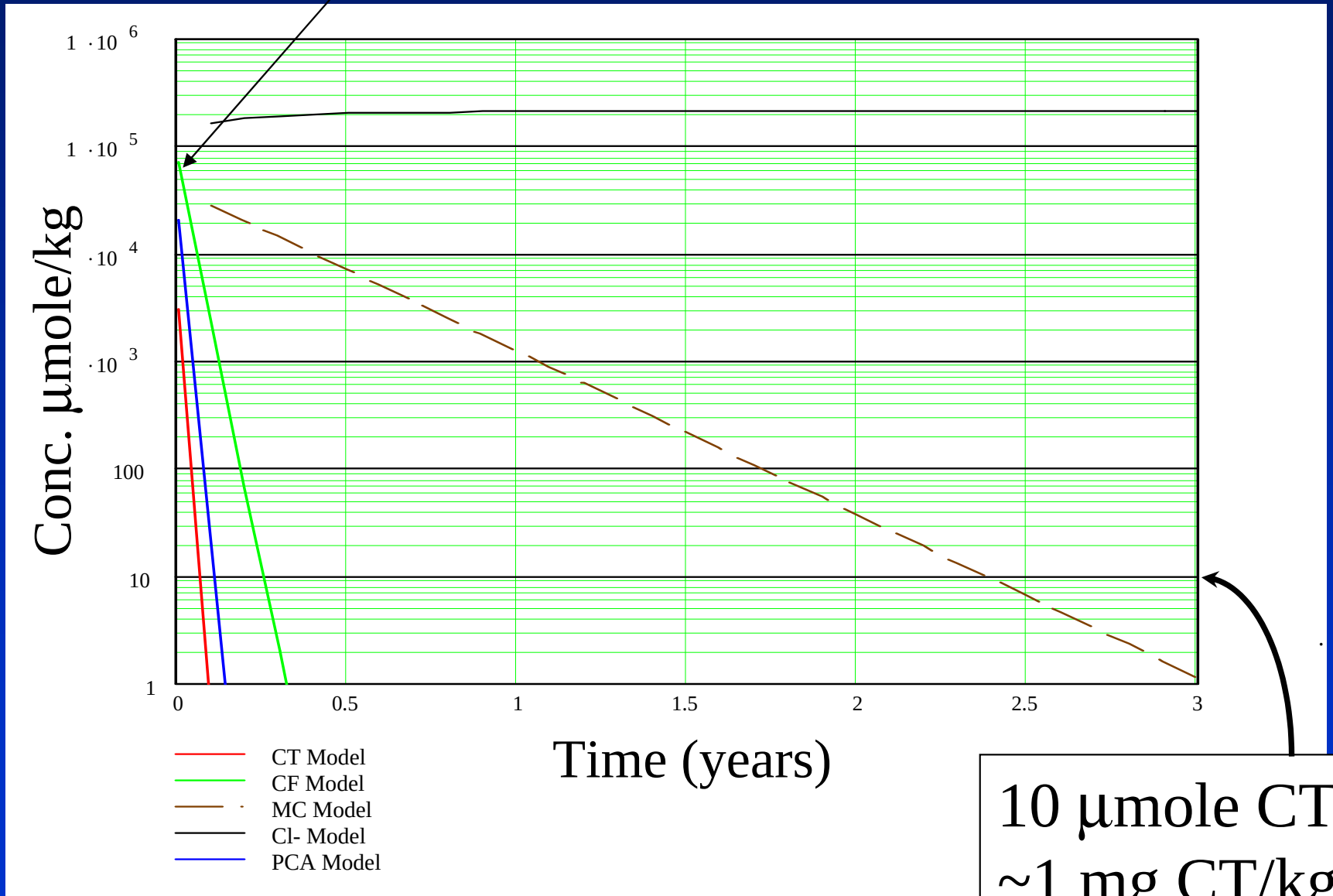
Ten half lives = Three order of magnitude

Estimated first order reaction rates and contaminant half lives

Treatment	CT		CF		MC		PCA	
	k(1/hr)	$t_{1/2}$ (hr)	k(1/hr)	$t_{1/2}$ (hr)	k(1/hr)	$t_{1/2}$ (hr)	k(1/hr)	$t_{1/2}$ (hr)
1% Peerless	0.005	140	0.002	350	0.0002	3500	0.004	170
2% Peerless	0.006	120	0.005	140	0.0002	3500	0.015	46
5% Peerless	0.008	87	0.01	69	0.0002	3500	0.015	46
2% GMA	0.003	230	0.02	35	0.0002	3500	0.08	9

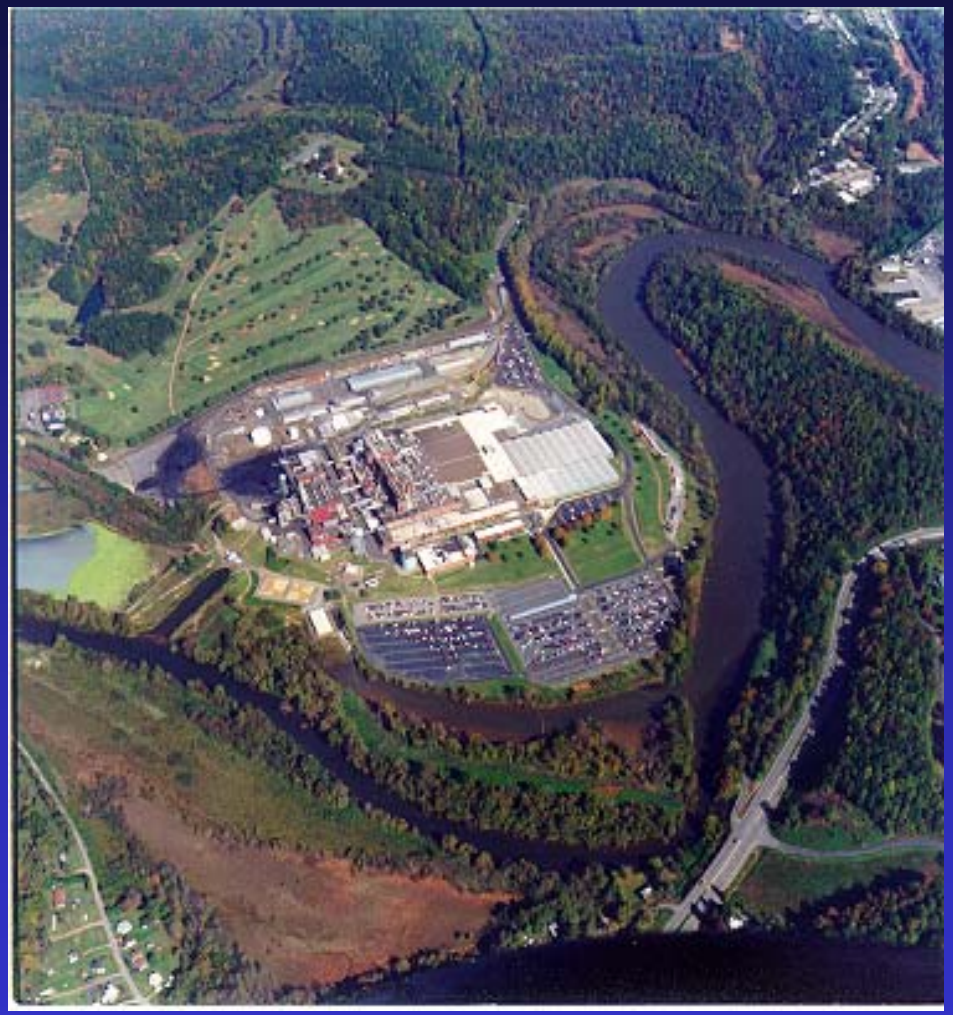
Four orders of reduction magnitude reduction after 3-years?

Initial field concentrations



10 µmole CT/kg
~1 mg CT/kg

Martinsville Virginia

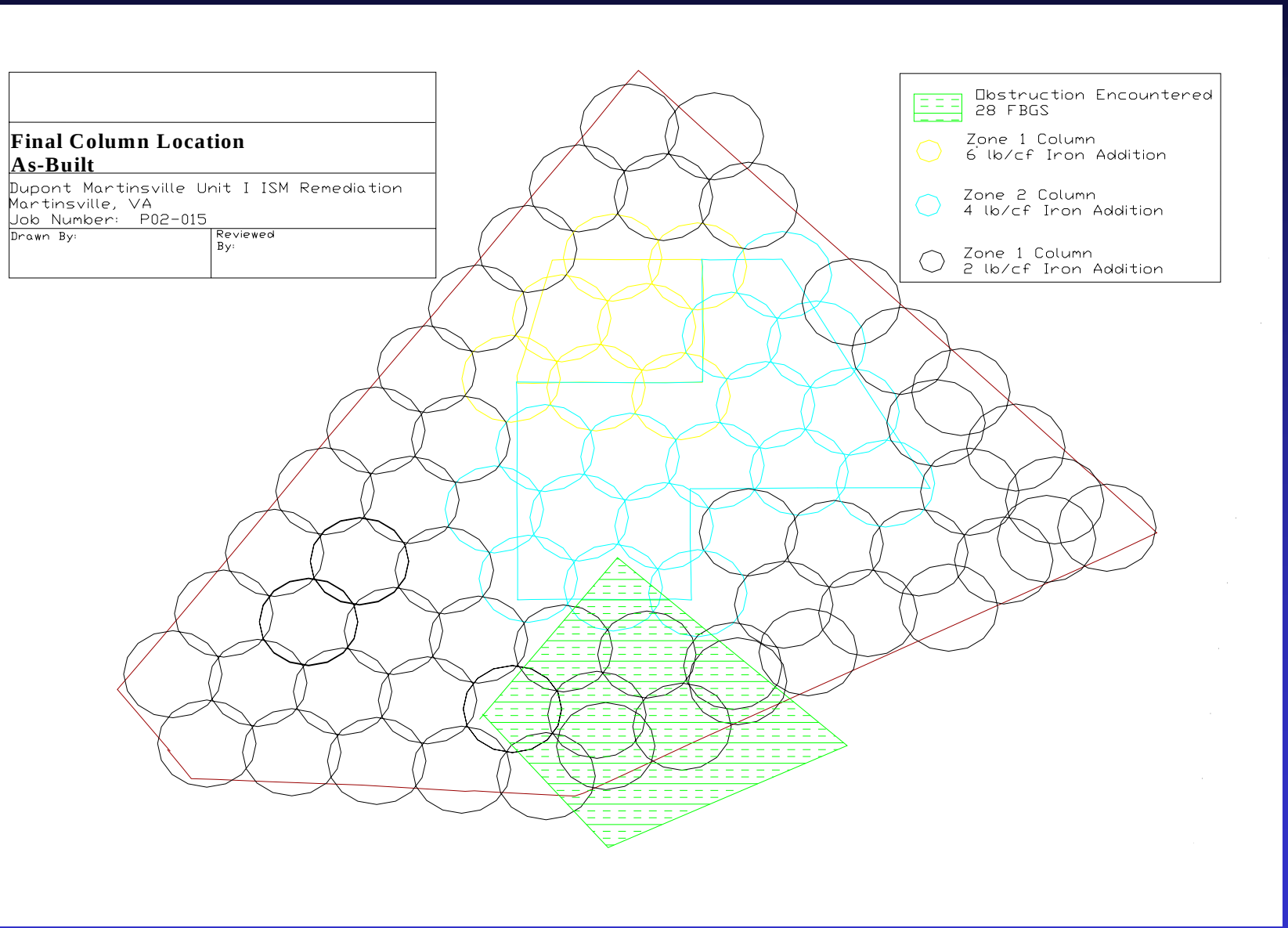


- ~ 20 tons Carbon Tetrachloride
- 8,000 Yards
- Initial ~ 4,000 mg/kg
- 2-6 lbs Fe / ft^3 soil
- 99.99 % removal CT in 1 year
- 99% removal of total chlorinated compounds in 1 year

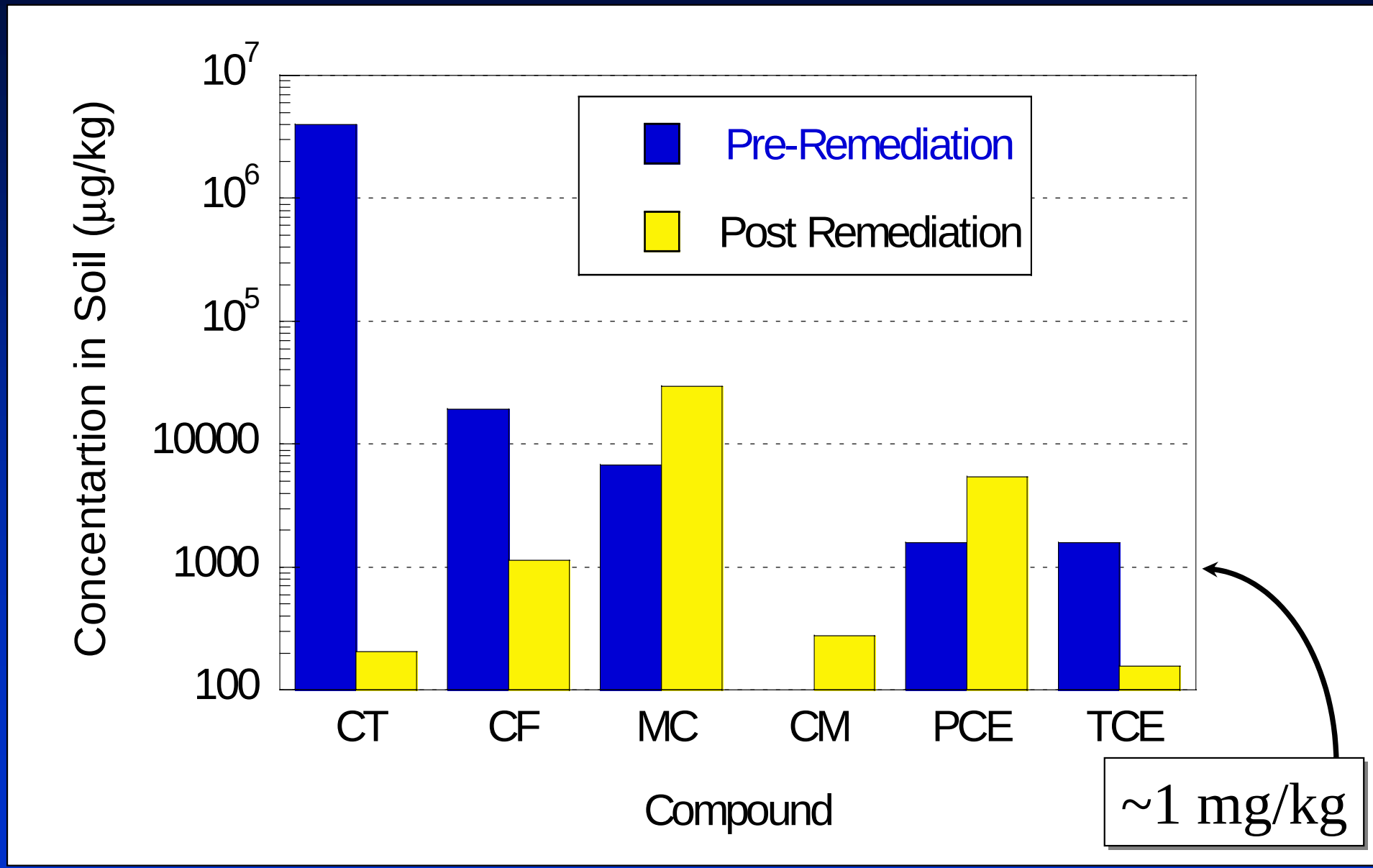
Shackelford et al (2004)

Implementation

As built mixing and ZVI content



Martinsville VA - Initial and 1 Year Data



Year 2 Sampling

ZVI Clay Niche

- Chlorinated Compounds
- Mixable alluvium
- Best with limited overhead and/or buried obstructions
- Desire for quick results

Issues

- Longevity of the iron as a function of iron amount and size
- Losses of iron to potentially unproductive reactions
- Process controls (reactions rates, diffusion, biological processes)
- The ability to treat DNAPL
- Field-scale performance monitoring techniques

Acknowledgements

- DuPont
- Solvents-in-Groundwater Research Consortium

Questions