Environmental Solutions

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Evaluation of Potassium Persulfate as a Permeable Reactive Barrier at Three Different Sites

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Outline

- Introduction to Klozur® persulfate

  KLOZUR® SP

  KLOZUR® KP

- Oxidative and reductive pathways from a single technology
- Bench studies and field demonstrations
- Questions

Klozur® Persulfates

KLOZUR® SP

- Environmental grade sodium persulfate

KLOZUR® KP

- Environmental grade potassium persulfate

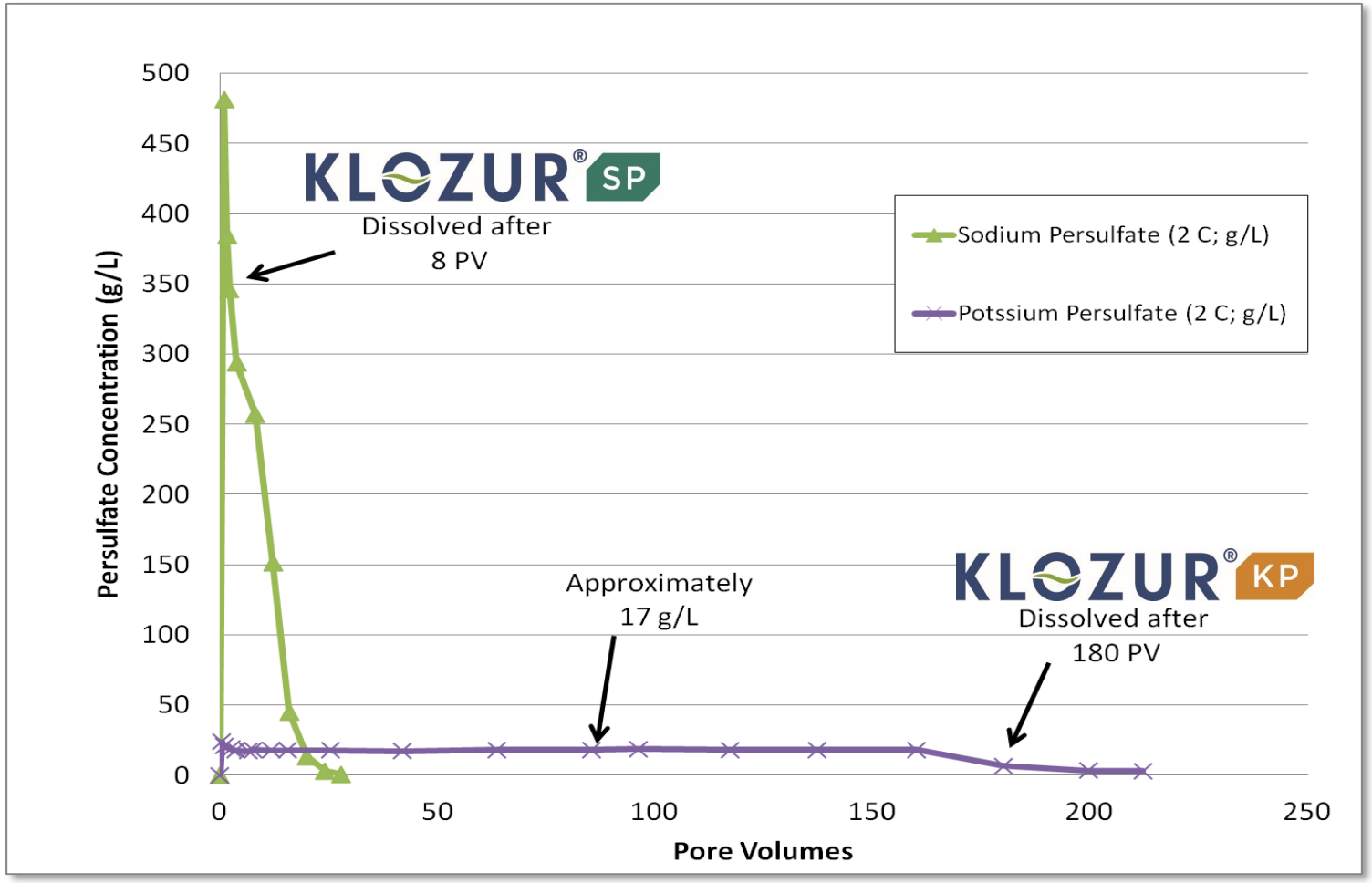
Key Differences:

- Solubility
- Na^+ vs K^+ residual

Temperature (◦C)	Klozur SP		Klozur KP	
	wt%	g/L	wt%	g/L
0	36.5	480	1.6	17
10	40.1	540	2.6	29
20	41.8	570	4.5	47
25	42.3	580	5.7	59

Characteristic	SP	KP
Formula	$Na_2S_2O_8$	$K_2S_2O_8$
Molecular Weight	238.1	270.3
Crystal density (g/cc)	2.59	2.48
Color	White	White
Odor	None	None
Loose bulk density (g/cc)	1.12	1.30

Permeable Reactive Barrier: Column Study



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KLOZUR® SP

Classic: Applied at thousands of sites, the high solubility of Klozur SP is ideal for:

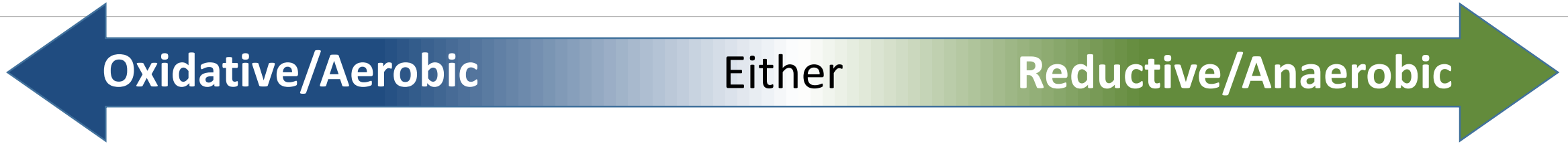
- Source zone treatment
  - Delivery of significant oxidative mass into the target area
  - Highly contaminated sites including non-aqueous phase liquids
  - High concentration applications

KLOZUR® KP

New: Low solubility and extended release can help address some of the previous technical challenges :

- Extended Release
  - Tight soils / clays – matrix diffusion
  - Permeable reactive barrier applications
  - Diffusive aqueous phase contaminants (plumes, aqueous phase contaminants, etc)

Degradation Pathways



Petroleum Hydrocarbons

BTEX

PAHs

Oxygenates

1,4-dioxane

Chlorinated Ethenes

Chlorobenzenes

Phenols

Select Pesticides

Select Fluorinated Compounds

PCBs

Select Energetics

Dichloroethenes

Select Pesticides

Select Energetics

Carbon Tetrachloride

1,1,1-Trichloroethane

Dichloroethanes

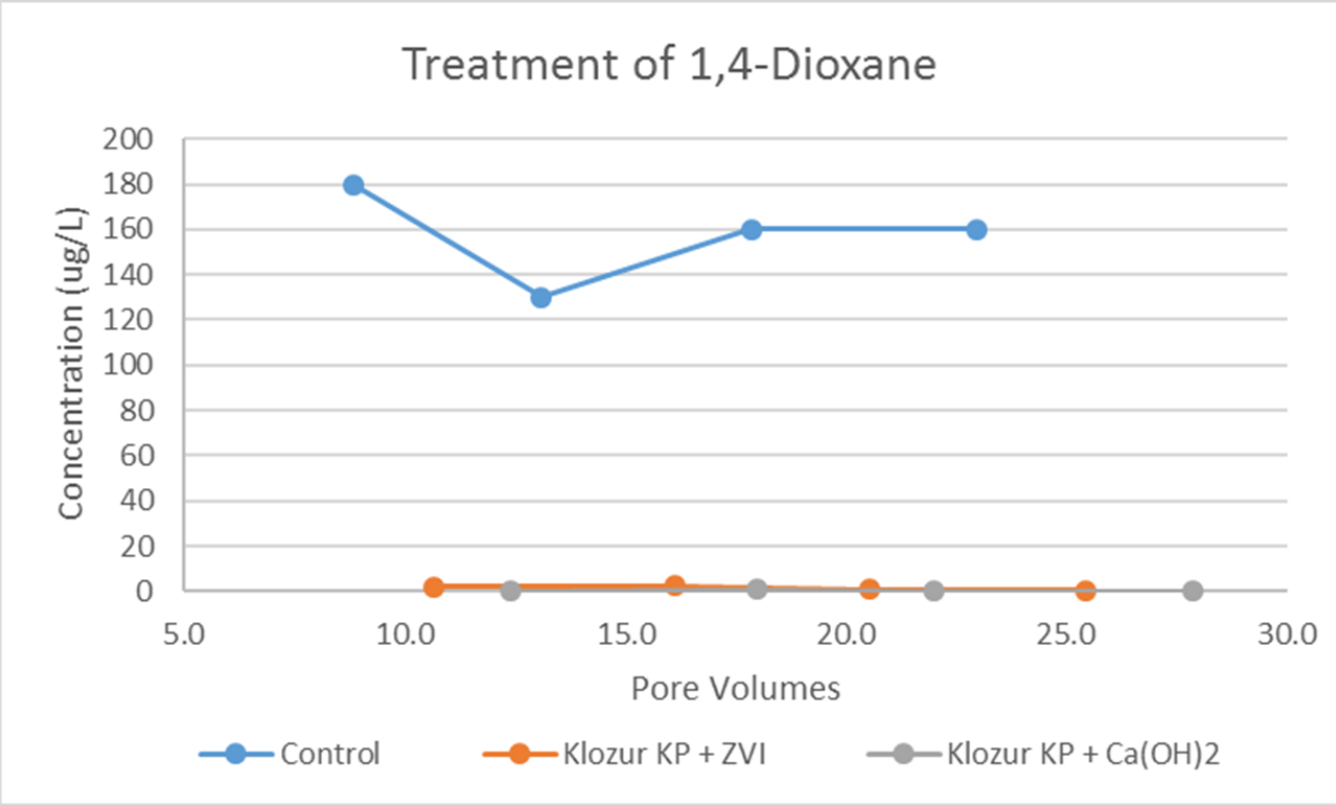
Sites

- Klozur® KP as a permeable reactive barrier was evaluated at three sites:
  - Site 1: Weston Solutions Superfund site in the New England
  - Site 2: ERM Private site located in the Pacific Northwest
  - Site 3: AECOM Former manufacturing facility located in Northeast

Site 1: New England Superfund Site

- Consultant: Weston Solutions
- Former chemical waste storage and bulking facility
- Residual 1,4-dioxane and 1,1,1-Trichloroethane (1,1,1-TCA) daughter products
  - 1,1-Dichloroethane (1,1-DCA)
  - 1,2-Dichloroethane (1,2-DCA)
  - 1,1-Dichloroethene (1,1-DCE)
- Soil matrix of clayey till was bench tested. Site includes sand lenses.

Site 1: Treatment of 1,4-Dioxane



1,4-Dioxane treated by oxidative pathway

- Treated to below the detection limit by both ZVI and hydrated lime activated persulfate
- Persisted for theoretical design period

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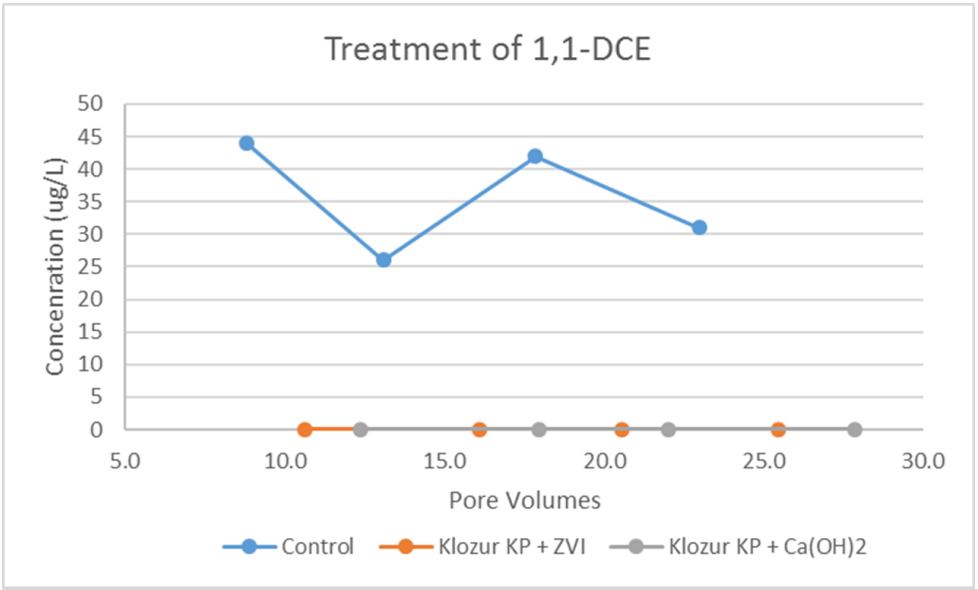
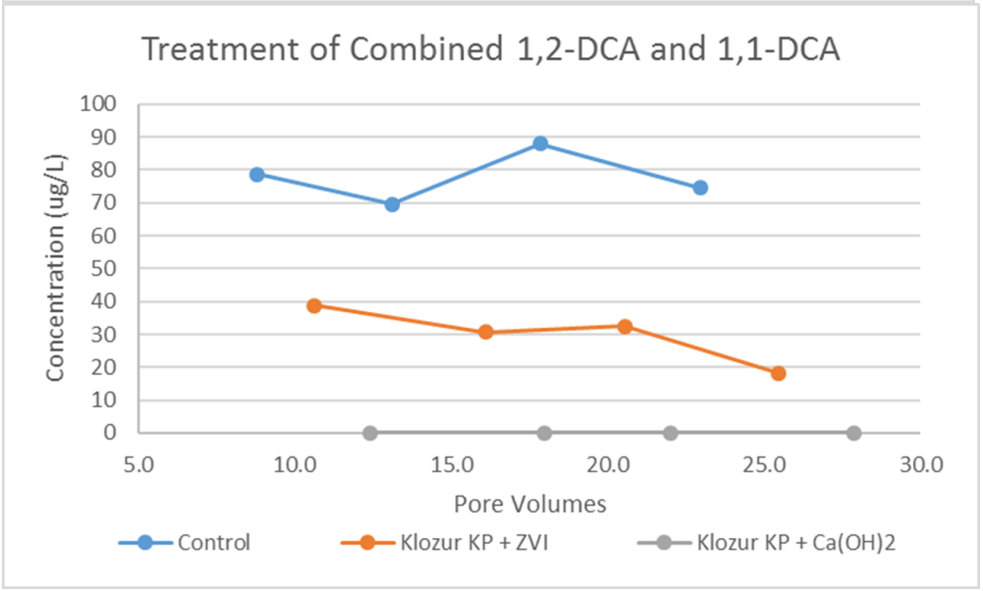
Site 1: Treatment of CVOCs

- DCE can be treated by both oxidative and reductive pathway
- DCAs are primarily treated by a reductive pathway
  - Treated to below the detection limit by hydrated lime activated persulfate
  - Partial reduction by ZVI activated persulfate





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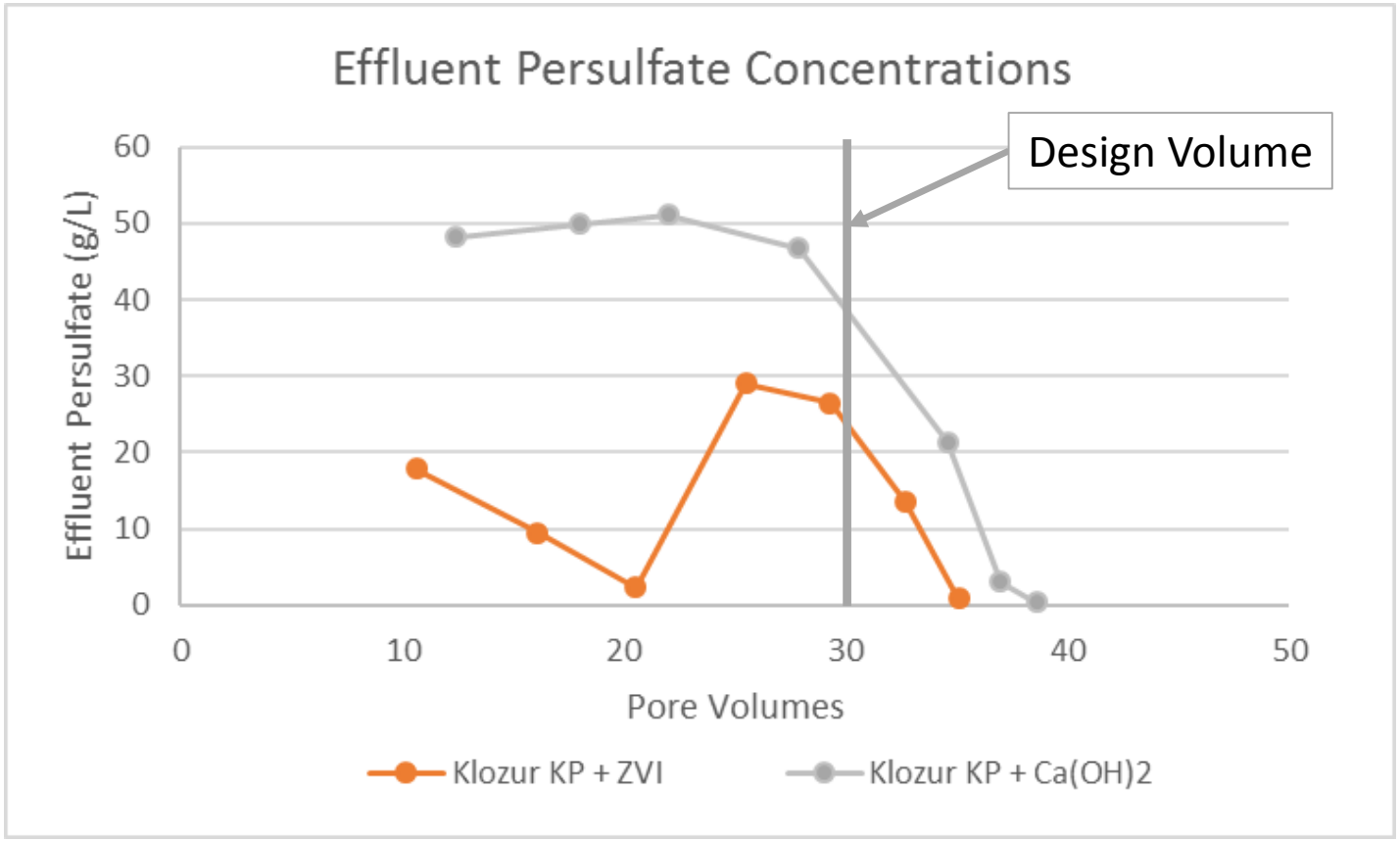
Site 1: Extended Release of Klozur® KP

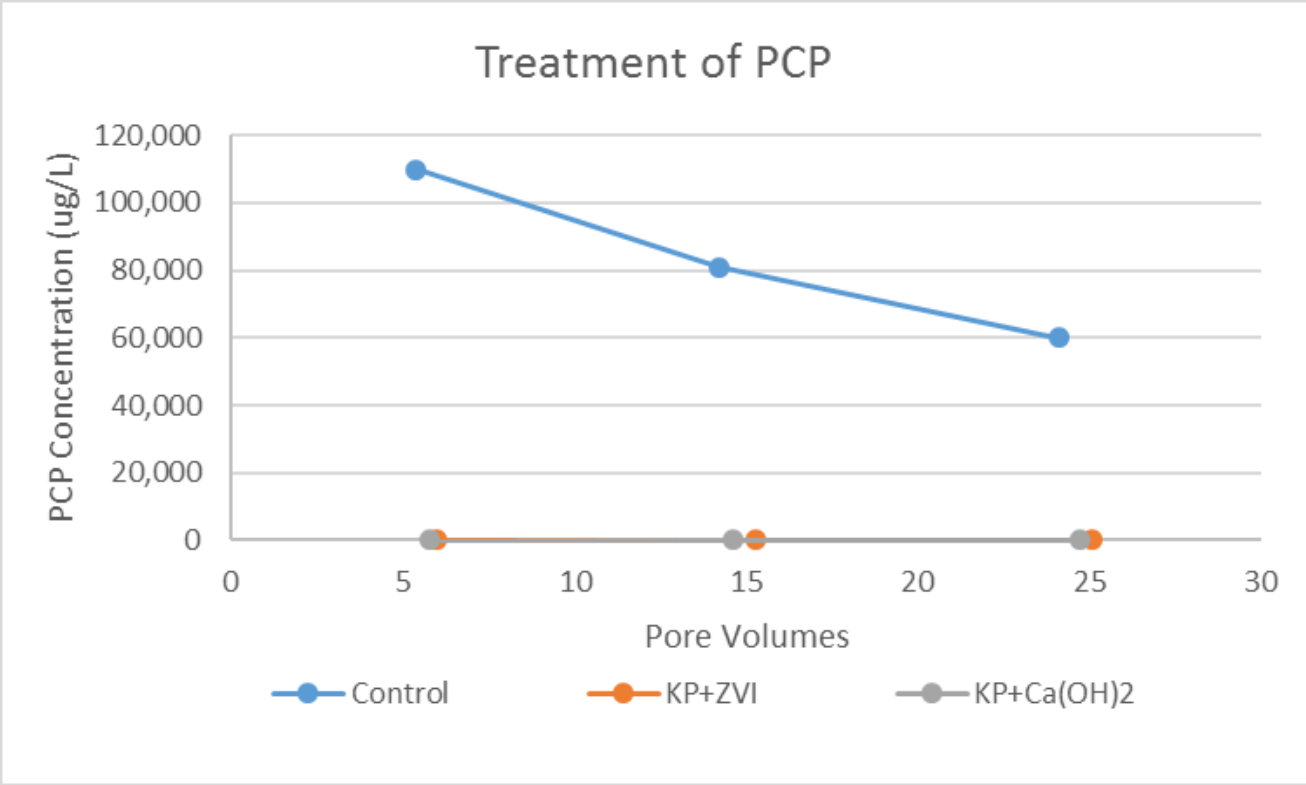
- Klozur® KP persisted in both reactors for longer than the design period
  - Hydrated lime lasted longest
  - ZVI activation showed more consumption of persulfate, but effective treatment for design life



Site 2: Pacific Northwest Site

- Consultant: ERM
- Former wood treatment facility
- Residuals include PAHs, TPH, and Pentachlorophenol
  - Pentachlorophenol (PCP) primary COC at proposed PRB boundary
- Soil matrix: Sand lens below a confining silt lens

Site 2: Treatment of Pentachlorophenol



PCP treated by oxidative or reductive pathway

- Influent was spiked
- Concentrations reduced by greater than 99.9% passing through both ZVI and hydrated lime activated persulfate systems
- Reductive pathway beneficial in dechlorinating PCP

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Site 2: Extended Release of Klozur® KP

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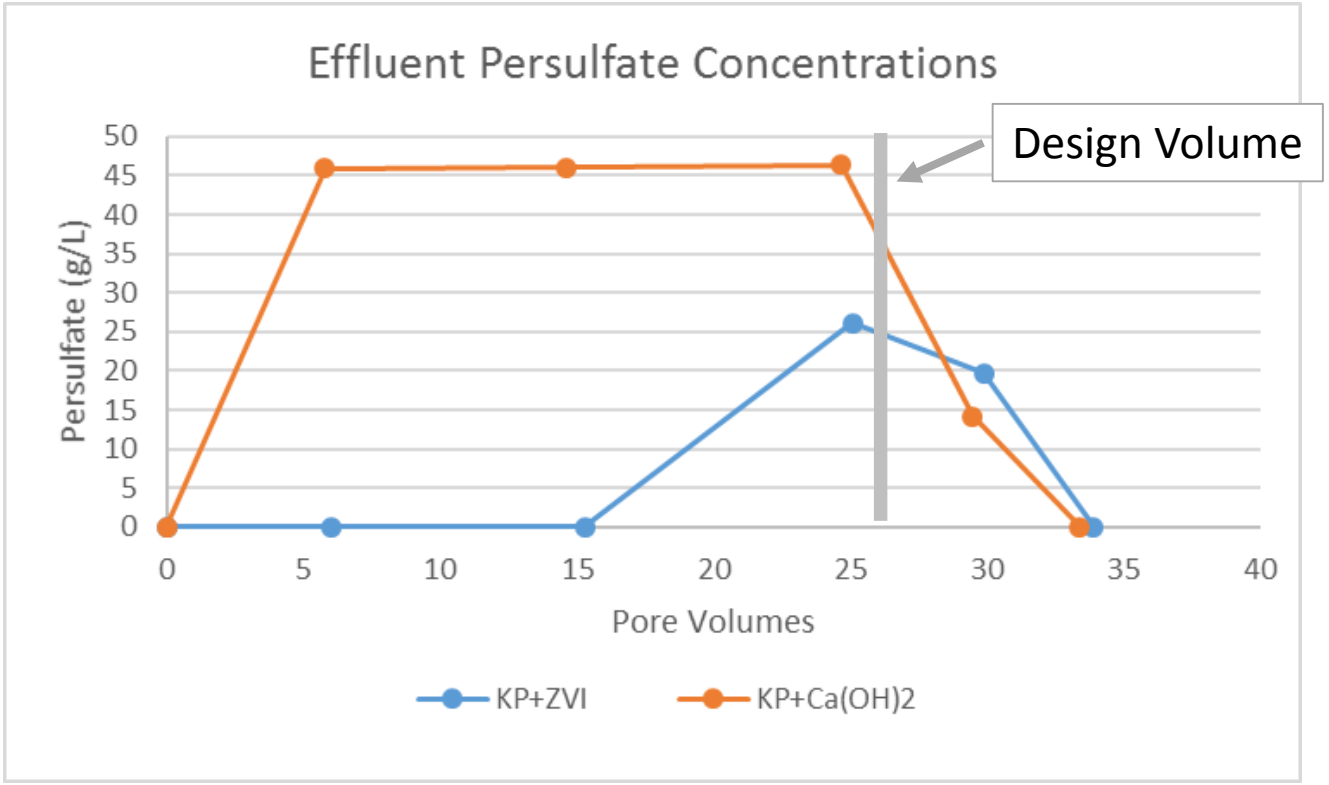
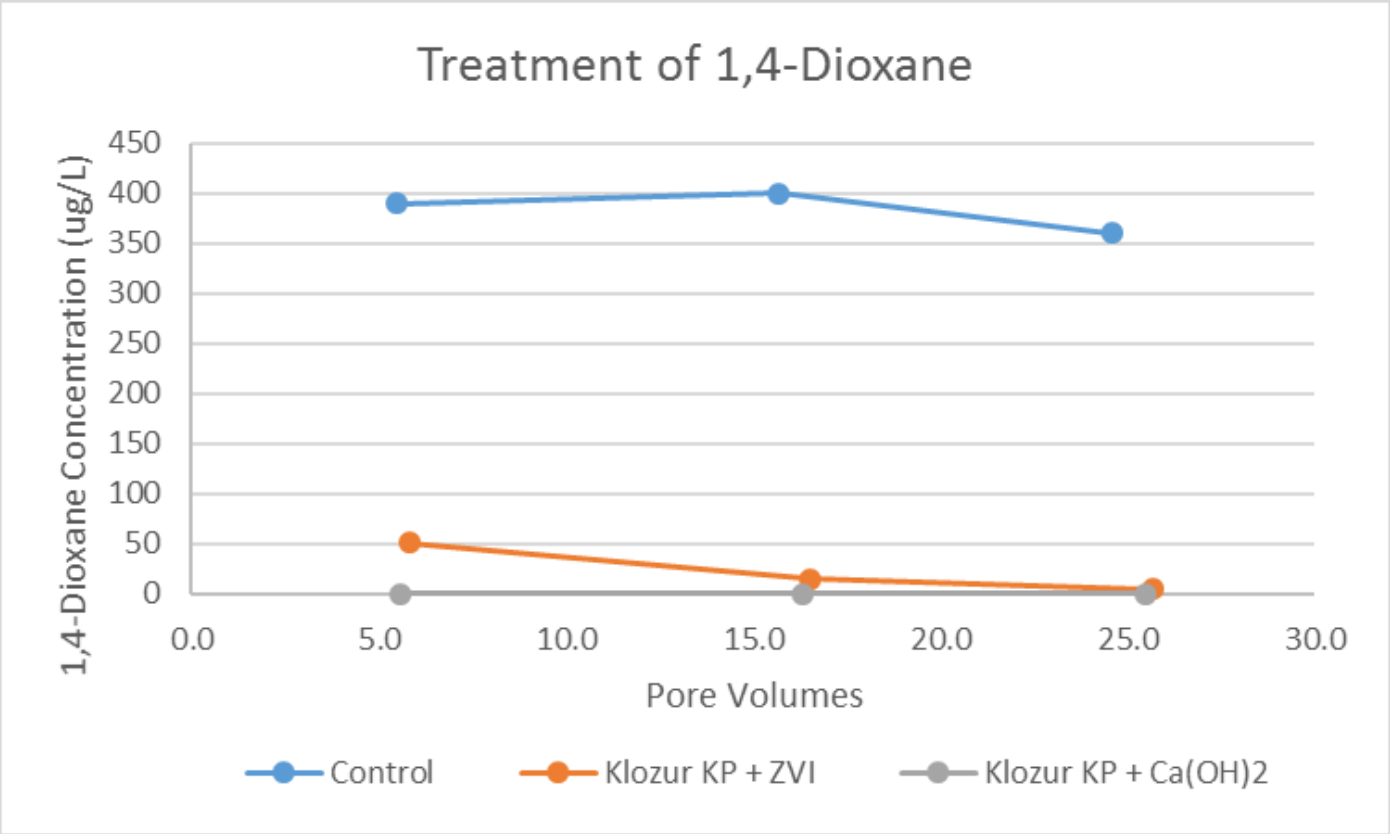
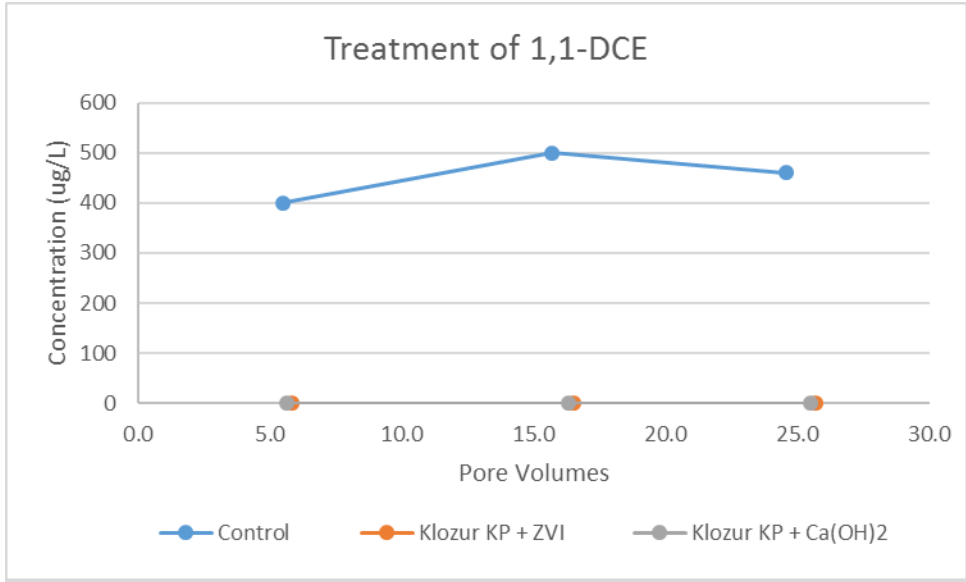


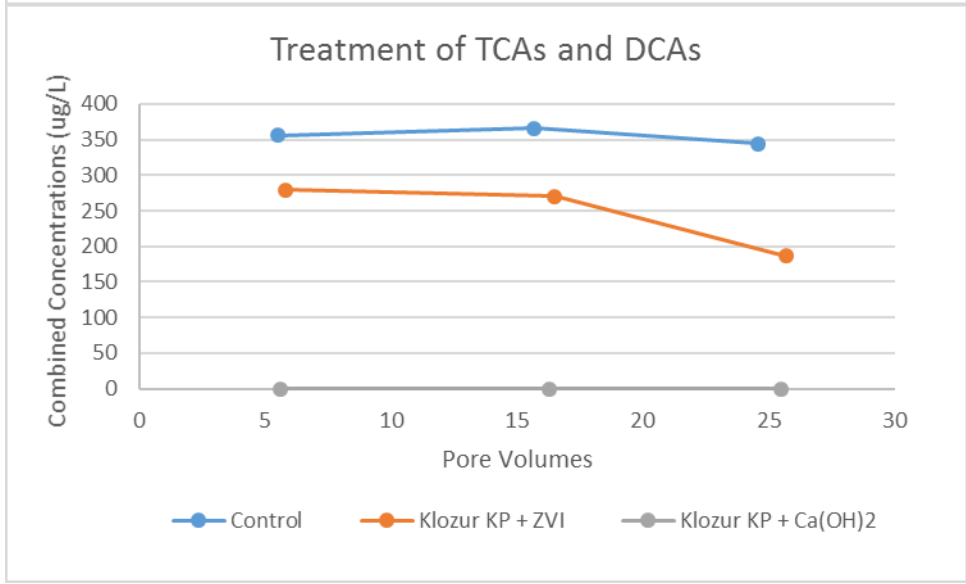
Site 3: Former Industrial Facility in the Northeast

- Consultant: AECOM
- Residual 1,4-dioxane, TCA , and TCA daughter products
  - 1,1,1-Trichloroethane and 1,1,2-Trichloroethane (TCAs)
  - 1,1-DCA and 1,2-DCA
  - 1,1-DCE
- Silty soils with sand lenses

Site 3: Treatment of COCs







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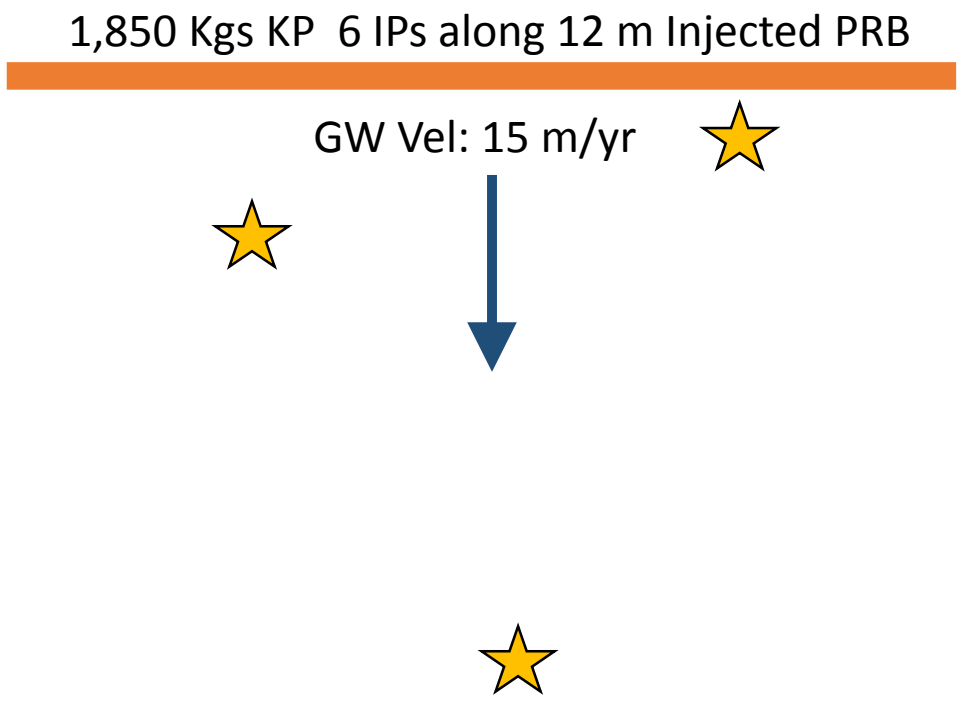
Site 3: Pilot Study

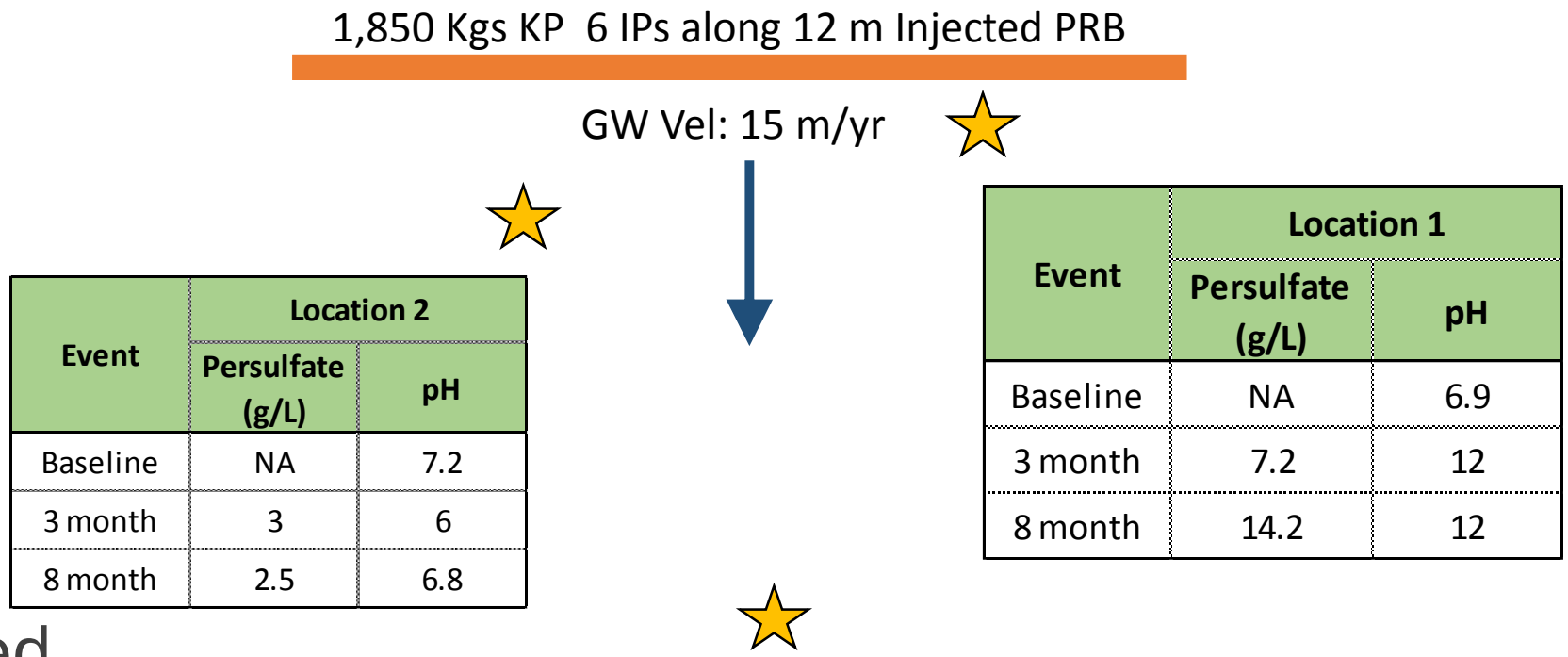
- Pilot Conducted December 2017

- Injected PRB (12 m)
  - Solid slurry
  - 6 DPT points
  - 6 to 9 m bgs
  - Designed for 6 month persistence



Site 3: Persistence and Distribution

- Reagents:
  - Klozur KP
  - Klozur SP
  - Hydrated Lime
  - 25% NaOH
- Monitoring wells downgradient in targeted vertical interval:
  - Location 1 (~1 m)
  - Location 2 (~3 m)
  - Location 3 (~8 m)



Event	Location 2	
	Persulfate (g/L)	pH
Baseline	NA	7.2
3 month	3	6
8 month	2.5	6.8

Event	Location 1	
	Persulfate (g/L)	pH
Baseline	NA	6.9
3 month	7.2	12
8 month	14.2	12

Event	Location 3	
	Persulfate (g/L)	pH
Baseline	NA	7.2
3 month	NA	NA
8 month	8	6.5

Site 3: Treatment

1,850 Kgs KP 6 IPs along 12 m Injected PRB

GW Vel: 15 m/yr

Event	Location 2: Contaminant Concentrations (µg/L)				
	DCA	DCE	1,4-Dioxane	VOCs*	Reduction VOCs (%)
Baseline	44	72	55	184	0%
3 month	10	11	nd	26	86%
6 month	16	nd	16	34	82%

* Detected VOCs not including acetone

Event	Location 1: Contaminant Concentrations (µg/L)				
	DCA	DCE	1,4-Dioxane	VOCs*	Reduction VOCs (%)
Baseline	21	40	30	115	0%
3 month	0.2	nd	nd	0.2	99.8%
6 month	0.2	nd	nd	0.2	99.8%

* Detected VOCs not including acetone

Event	Location 3: Contaminant Concentrations (µg/L)				
	DCA	DCE	1,4-Dioxane	VOCs*	Reduction VOCs (%)
Baseline	89	270	200	610	0%
3 month	46	82	69	216	65%
6 month	63	30	110	230	62%

* Detected VOCs not including acetone

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Site Status

- Site 1 (New England-Weston Solutions)
  - Evaluating natural attenuation. Treatment with Klozur KP is an alternative if natural attenuation is not successful.
- Site 2 (Pacific Northwest-ERM)
  - Pilot test conducted in September 2018
- Site 3 (Northeast-AECOM)
  - Full scale implemented in August 2018

Canadian Applications

- Geo Tactical
  - One of the original contractors
- Vertex
  - PRB case study that has taken chlorobenzenes to non-detect
- Nexxgen Environmental
- Technilab Environment
- Geosyntec
- Tetra Tech
- Quantum Murray

Conclusion

- Klozur KP's unique physical characteristics (low solubility) opens ISCO to new types of applications
  - Klozur SP: Source Area
  - Klozur KP: PRBs, low permeable soils, etc
- Builds off same powerful chemistry expanding the versatility of activated Klozur persulfate
- Versatility expanded by activation methods that can create both oxidative and reductive pathways (alkaline, heat, and H_2O_2)
  - Complex-comingled plumes

Questions

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