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

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Environmental Solutions

Outline

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- Introduction to Klozur® persulfate

  KLOZUR® SP

  KLOZUR® KP

- Oxidative and reductive pathways from a single technology
- Column Studies
- 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

Klozur SP and Klozur KP: Application Opportunities

KLOZUR® SP

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

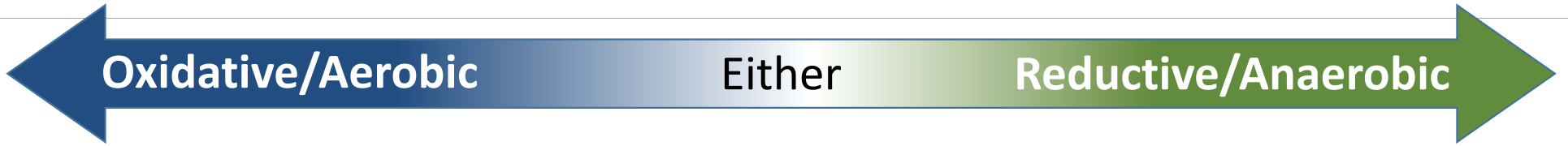
- Delivery of significant oxidative mass into the target area
- Source zone treatment
- Highly contaminated sites including non-aqueous phase liquids
- High concentration applications

KLOZUR® KP

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

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

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

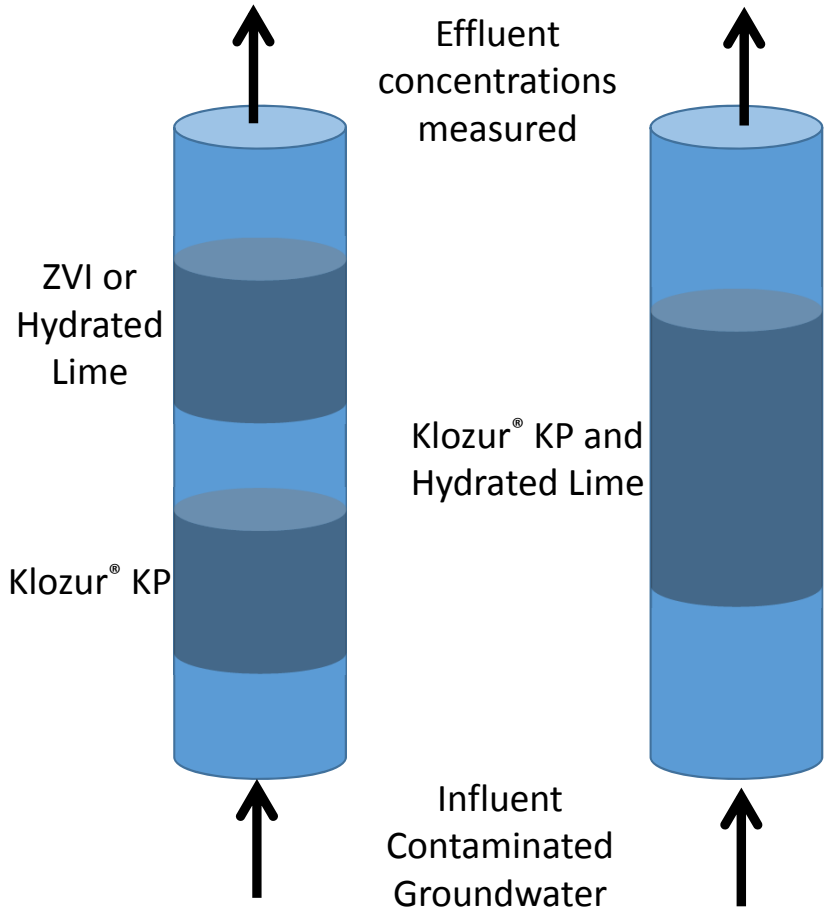
Dichloroethanes

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: AECOM Former manufacturing facility located in Northeast
  - Site 3: ERM Private site located in the Pacific Northwest

Treatability Column

- Up flow column reactors:
  - Klozur® KP and Hydrated Lime [$Ca(OH)_2$] mixed together
  - Klozur® KP and ZVI in separate sections due to incompatibilities
- Columns run at 20 °C
- Continuous feed of contaminated site groundwater



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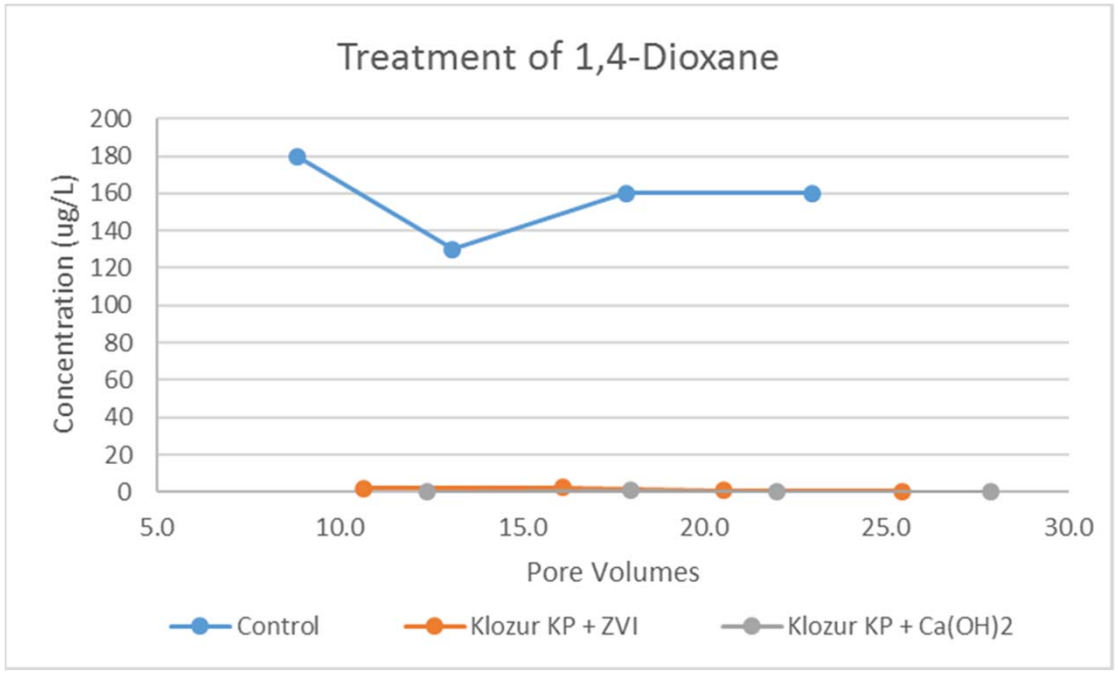
Site 1: New England Superfund Site

- 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

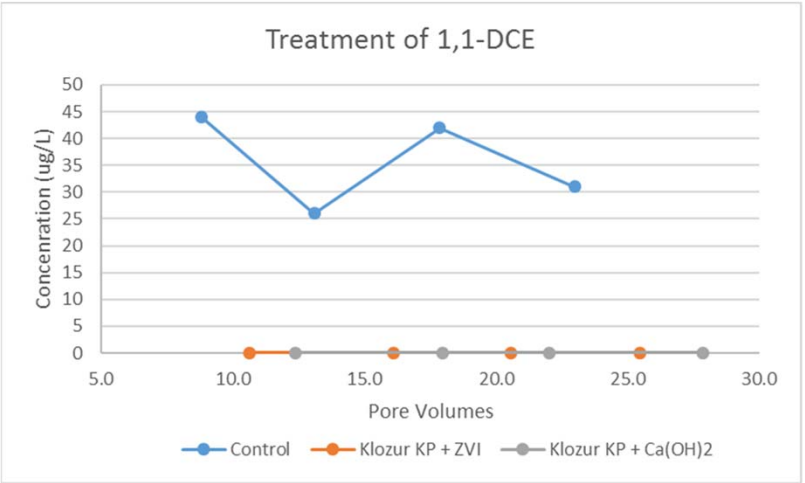


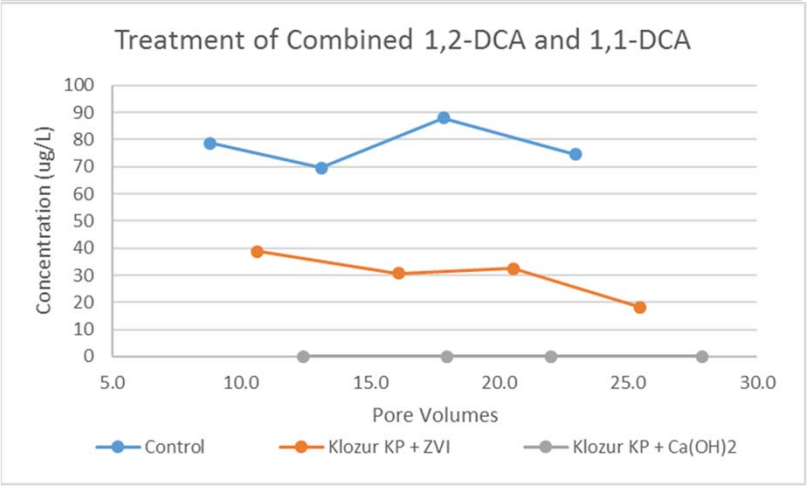
1,4-Dioxane treated by oxidative pathway

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

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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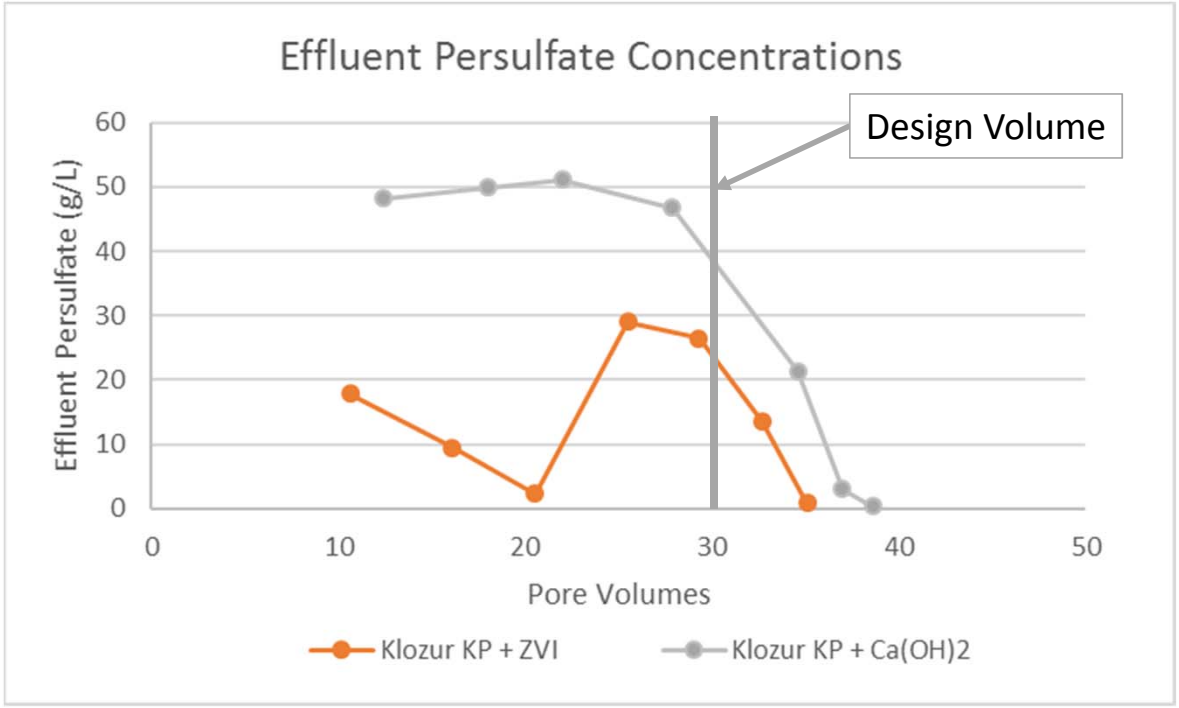
Site 1: Extended Release of Klozur® KP

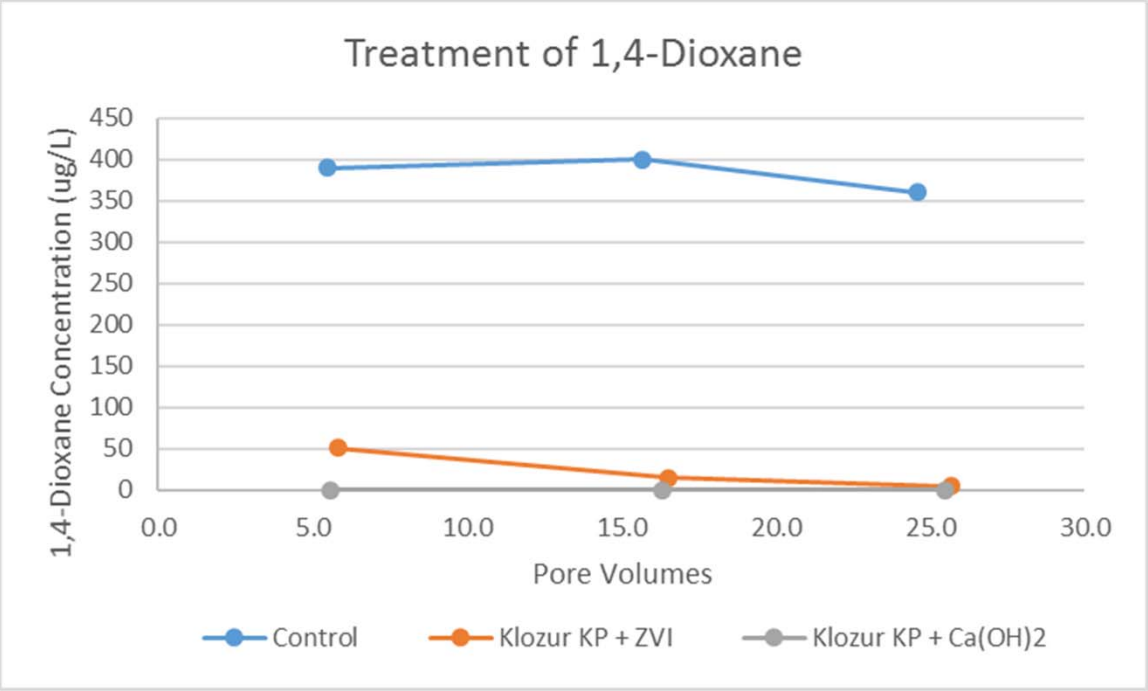
- Klozur® KP persisted in both reactors for longer than the design period
  - Hydrated lime lasted longest
  - ZVI activation showed more consumption of persulfate, but effective treatment for design life



Site 2: 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 2: Treatment of 1,4-Dioxane

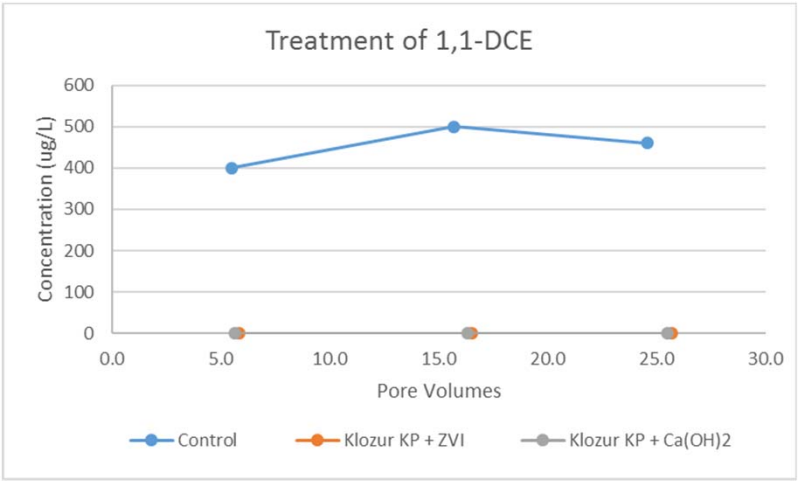


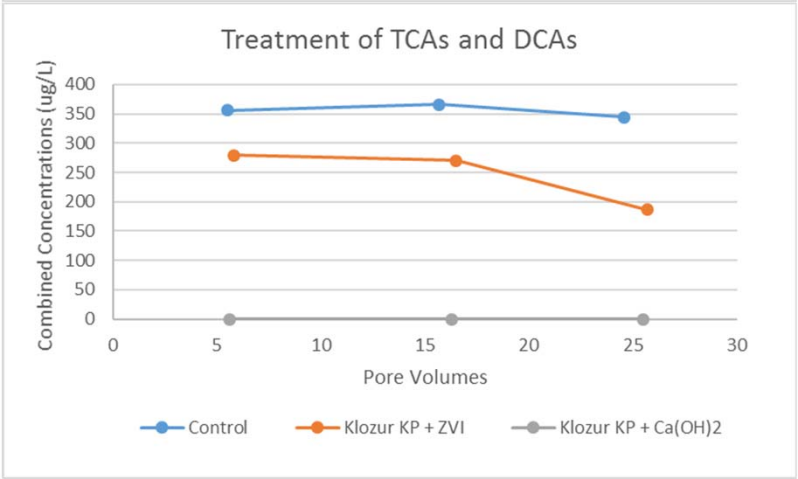
1,4-Dioxane treated by oxidative pathway

- Treated to below the detection limit by hydrated lime activated persulfate
- Up to 98.7% reduction in column activated with ZVI

Site 2: Treatment of CVOCs

- DCE can be treated by both oxidative and reductive pathway
- TCA/DCA 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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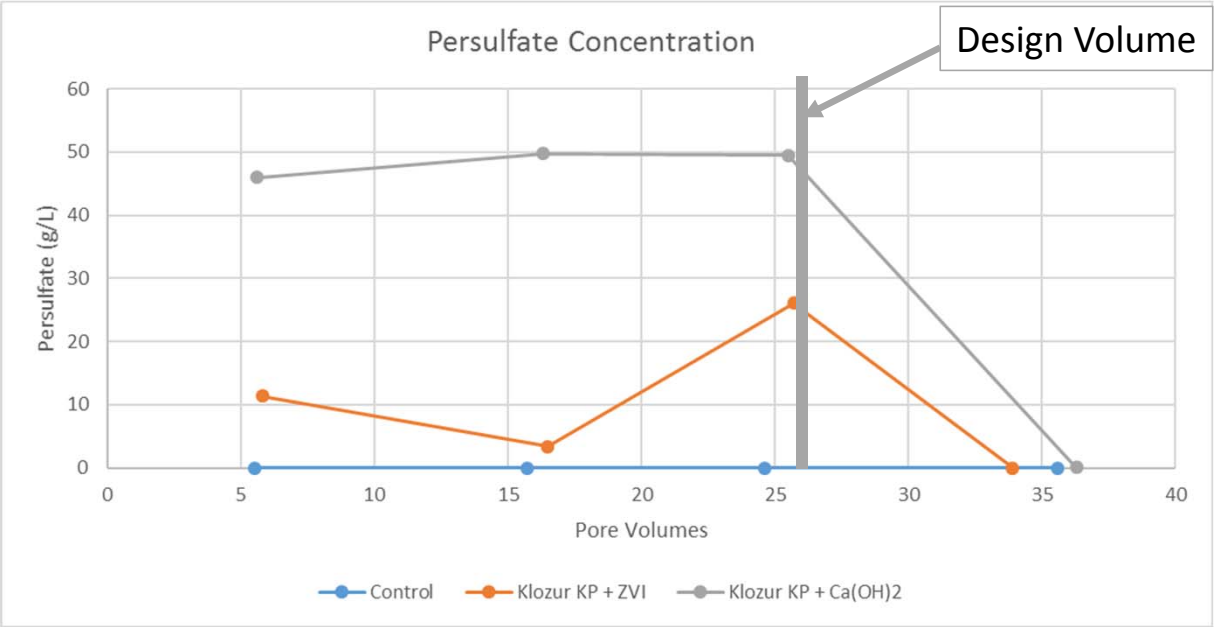
Site 2: Extended Release of Klozur® KP

- Klozur® KP is thought to have persisted in both reactors for longer than the design period



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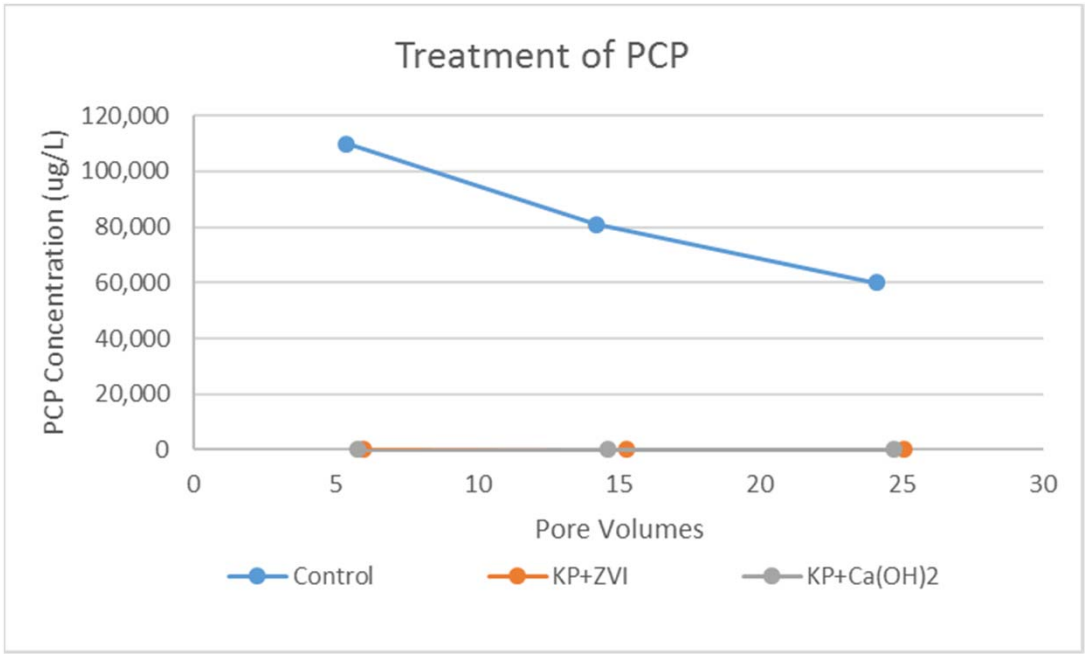
Site 3: Pacific Northwest Site

- 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

Treatment of Pentachlorophenol

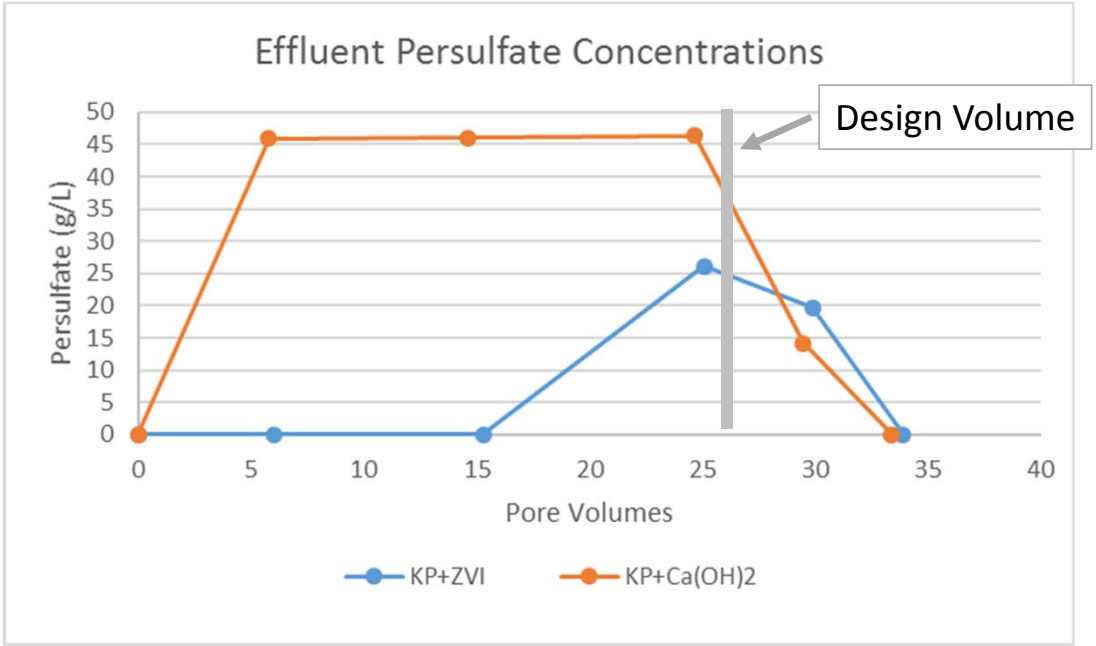


PCP treated by oxidative or reductive pathway

- 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

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 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 (Northeast-AECOM)
  - Pilot tested in December 2017. KP still persisting. Initial data successful.
  - Full scale design underway.
- Site 3 (Pacific Northwest-ERM)
  - Pilot test scheduled for summer 2018.

Conclusions

- Klozur® KP was successfully used in column studies emulating a permeable reactive barrier
- Extended persistence over multiple pore volumes complied with theoretical estimates
  - Permeable reactive barriers, low permeable soils, low solubility contaminants, and/or low remedial goals
- Klozur® KP can be activated with:
  - Hydrated lime to provide both an oxidative and reductive pathway
  - ZVI to provide primarily an oxidative pathway
- Many complex sites with comingled contaminants require treatment with both an oxidative and reductive pathway

Questions

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