SOIL & GROUNDWATER
REMEDIATION

Addressing Residual LNAPL Using Klozur Persulfate

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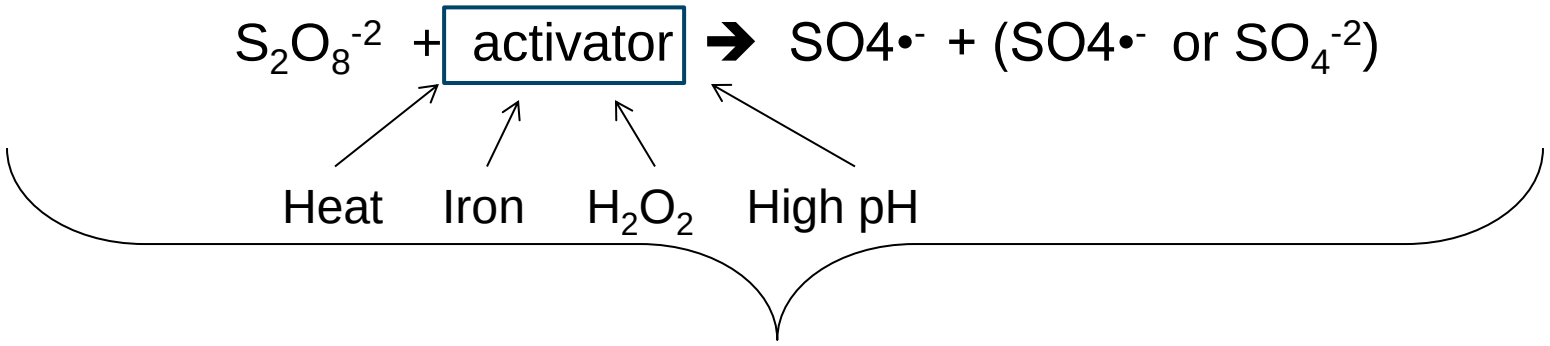
Klozur® Persulfate Chemistry

Klozur® Activated Persulfate

- produces a radical which is more powerful and kinetically fast
- **FMC always recommends using an activator**
- proper activation method is based on contaminant, site lithology, and hydrogeology



Purchase of FMC's Klozur® Persulfate includes rights to practice the inventions covered by the patents in the purchase price of the product.

Sustainable Solution: Utilizes Hydroelectric Power

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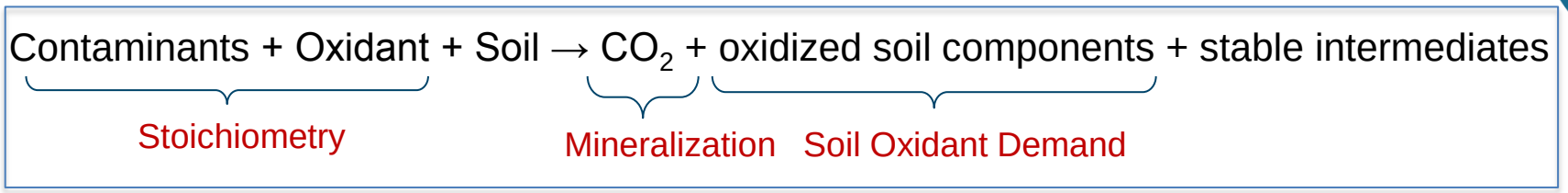
Determination of Klozur® Persulfate Demand



Stoichiometric Demand

- Contaminant demand is based on 2-electron transfer of persulfate anion
  - 45 lbs of persulfate per lb of Benzene
  - 3 lbs of persulfate per lb of PCE

Natural Decomposition Demand

- Demand can be dependent upon activation chemistry

Soil Oxidant Demand (SOD)

- SOD arises from reactions with naturally occurring soil organics and reduced metals
- Average SOD = 1 g persulfate / kg soil, but will be site dependent
- FMC's Klozur Demand Test ($600 / soil & gw sample)

Note: It is important to account for SOD, or the oxidant will be under-dosed and will not meet the contaminant demand

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Residual LNAPL Considerations

Physical Removal Typically Used First

- ISCO is best for thin, recalcitrant LNAPL Layers ('Residual NAPL')

Poor Characterization Often a Problem

- Good understanding of nature and extent needed
- Long term contaminant rebound

High Dissolved Concentrations May Indicate Residual NAPL

Contaminant	Solubility (20 – 25 C) ppm	1% of solubility ppm	10% of solubility ppm
Benzene	1,790	17.9	179
Toluene	530	5.3	53
Naphthalene	30	0.3	3
TCE	1,000	10	100
PCE	150	1.5	15
Carbon Tetrachloride	8	0.08	0.8
Chlorobenzene	472	4.72	47.2

Table 1: Several chemical compounds and their solubilties in water, and the concentrations indicative of their presence of NAPLs.

Residual LNAPL & Klozur® Persulfate

Contact is Essential

- Klozur is hydrophyllic, aqueous-phase reactions

Klozur Solution Densities

Klozur Persulfate Solution Properties					
Solution wt%	5	10	15	20	25
Specific Gravity	1.031	1.066	1.104	1.145	1.189

Methods that Enhance Contact

- Heat activation (improves solubility and increases reactivity)
- H_2O_2 activation (localized heat)
- High pH activation (surface tension, charge)
- Klozur persulfate with surfactants (used by several implementation firms)

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Klozur® Persulfate Residual LNAPL Cases

Customer & Site	Product & Activation Method	Target	Result
Earth Tech, Edwards AFB, CA (Pilot)	Alkaline activated Klozur with A/S	CVOCs and JP-4 LNAPL	CVOCs and LNAPL oxidized
WSP, Coastal Plains of Florida	Klozur CR and PermeOx Plus	Petroleum LNAPL and dissolved phase plume	LNAPL reduced from 1-3 to < 1 cm, 70% dissolved plume area decrease
MECx, Trento, Italy (Pilot)	Klozur and CHP with recirculation	PAH LNAPL	LNAPL eliminated, dissolved PAHs to < 50 µg/L
MECx, Kentwood, LA	Klozur with low dose H2O2 and ferrous iron	Refined petroleum products (pipeline) LNAPL	0.1 to 1 foot LNAPL eliminated, 70% dissolved TPH decrease
MECx, Dallas/Fort Worth, TX	Klozur with low dose H2O2 and ferrous iron	LNAPL and light HC dissolved phase	LNAPL eliminated, BTEX reduced 95%, MTBE reduced 66%

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Residual LNAPL Treatment - Key Data

Distribution

- GW and Soil, horizontal and vertical

Compounds

- Much more than just BTEX & SOD

What's the driver?

- LNAPL itself?
- GW concentrations?
- Both or something else?

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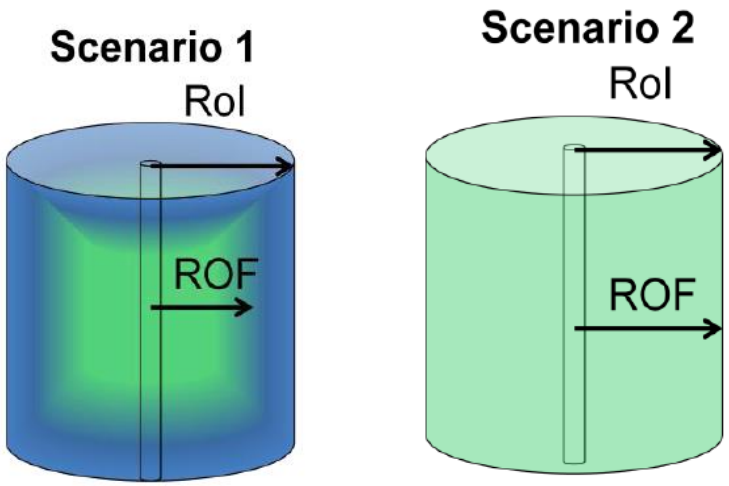
Klozur® Persulfate Dosing Considerations

Target Suitable Fraction of Residual LNAPL Mass

- % Reduction Needed » Goal (Csat or other technical basis)

Identify Injection Approach

- Scenario 1 – high concentration injection (20 – 30 wt%)
- Scenario 2 – low concentration injection (< 5 wt%)



Consider Multiple Injections if Required

- More dilute solutions and high concentrations may require

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Any Questions?

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