

Klozur[®] Persulfate Chemistry Revisited

Soil & Groundwater
Remediation

Webinar | December 4, 2024



Welcome to Today's Webinar

Running Time: 60 minutes

- Presentation – 50+ min
- Q&A after



Today's Webinar is being recorded

- Email communication once available online
- www.evonik.com/remediation



Certificate of Attendance

- Present for the entire duration of the webinar
- remediation@evonik.com



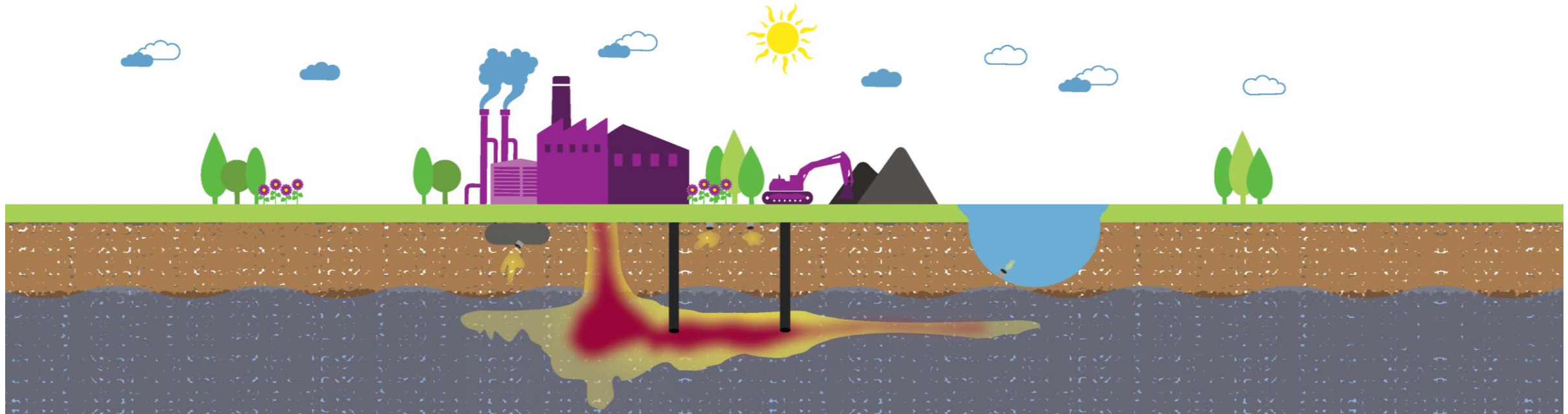
Questions

- GoToWebinar “Questions” box
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Evonik Soil & Groundwater Remediation

Field-Proven Portfolio of Remediation Technologies



Chemical Oxidation

- Klozur® Persulfate Portfolio
 - Klozur® SP
 - Klozur® KP
 - Klozur® One
 - Klozur® CR
- Hydrogen Peroxide

Aerobic Bioremediation

- Terramend® Reagent
- PermeOx® Ultra
- PermeOx® Ultra Granular

Enhanced Reductive Dechlorination

- ELS® Microemulsion
- ELS® Liquid Concentrate

Chemical Reduction

- EHC® ISCR Portfolio
 - EHC® Reagent
 - EHC® Liquid
 - EHC® Plus
- Daramend® Reagent

Metals Remediation

- MetaFix® Reagents

BioGeoChemical

- GeoForm® Reagents

NAPL Stabilization

- ISGS® Technology

Our Presenter



Brant Smith, P.E., Ph.D.

Director of Technology
Soil & Groundwater Remediation
Persulfates

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Klozur® Persulfate Chemistry Revisited

Brant Smith, P.E., Ph.D.
Director of Technology

Soil & Groundwater Remediation

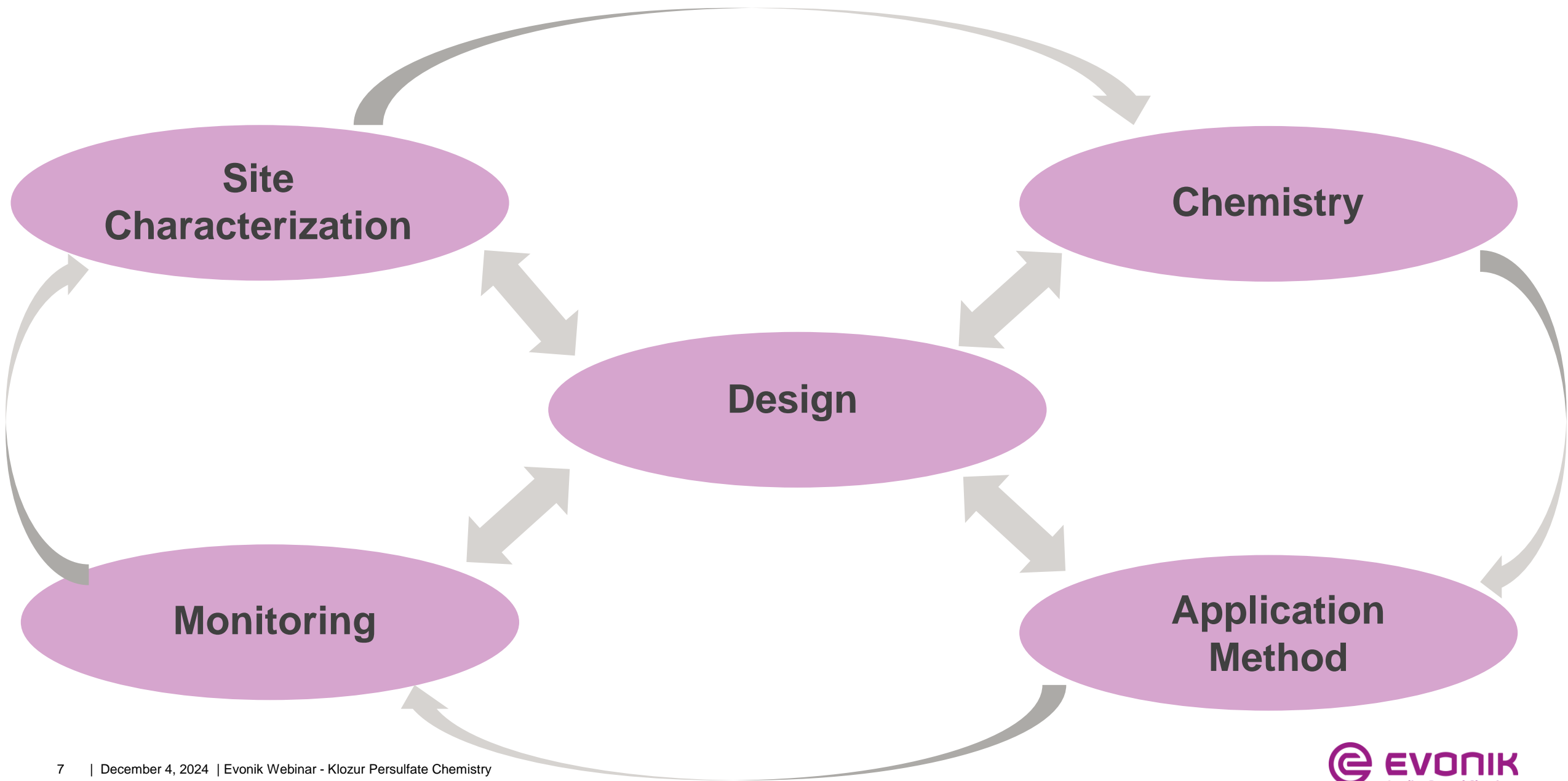
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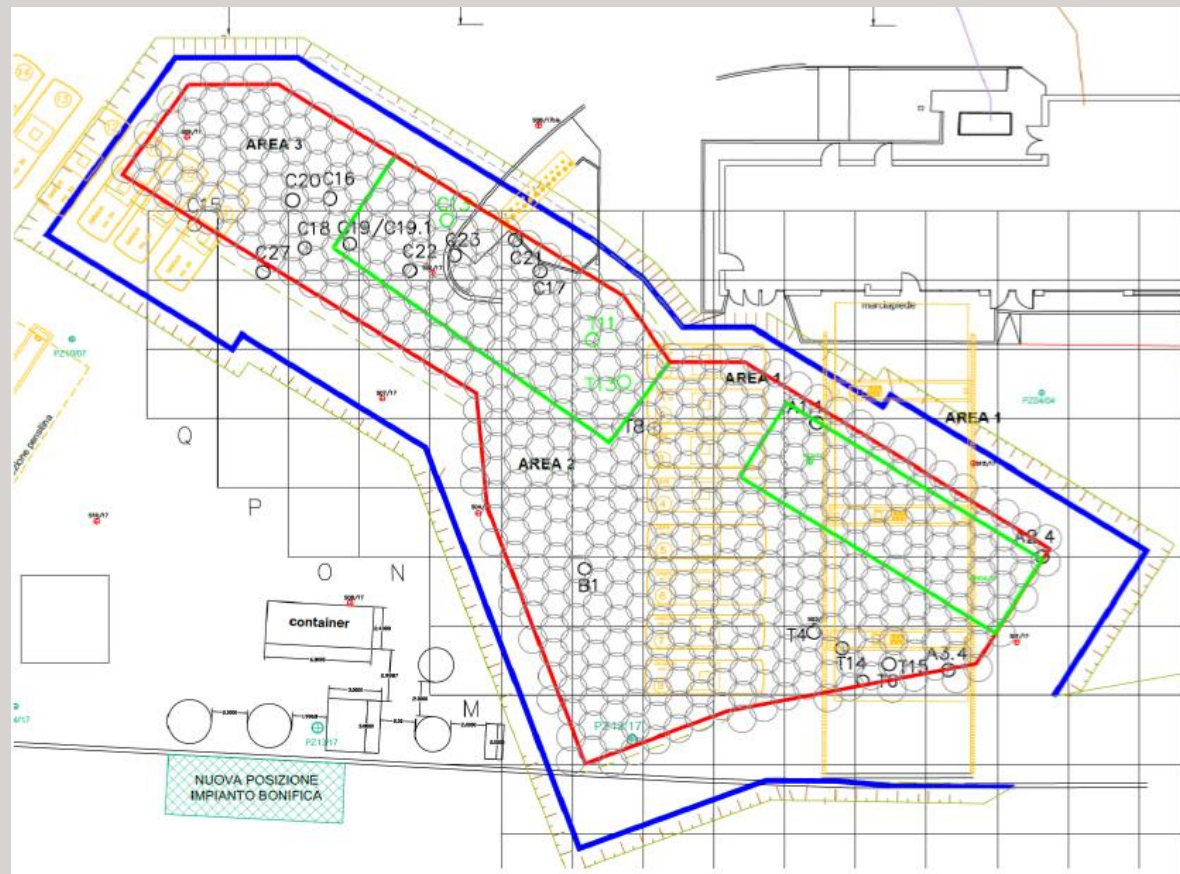
Webinar Overview

- Chemistry Considerations
 - Contaminant
 - Site
- Background Chemistry
- Persulfate Chemistry
- Health & Safety





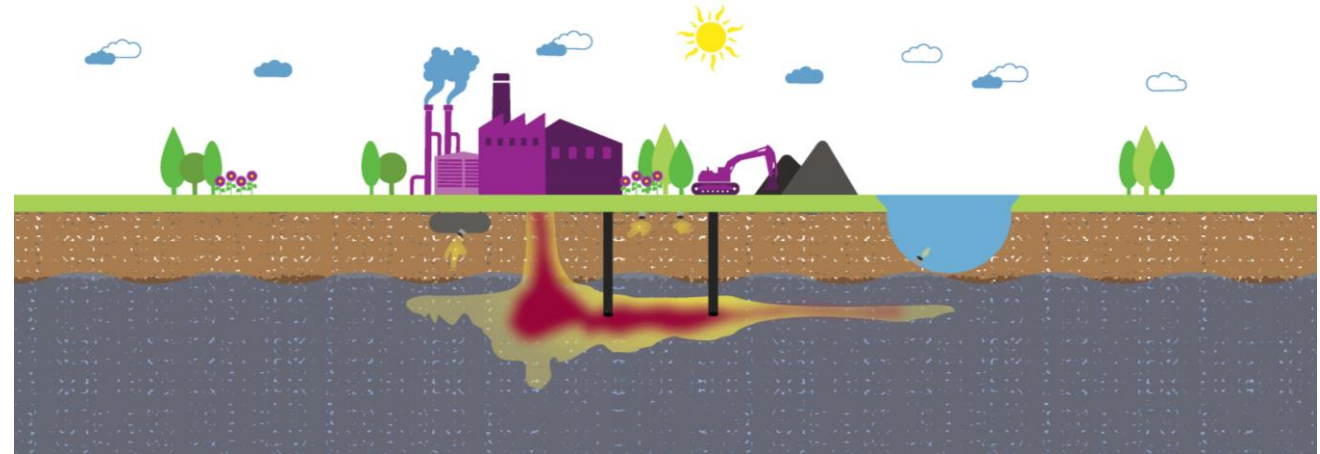
Chemistry Considerations: Contaminant and Site Characteristics



Courtesy of Ladurner

Contaminant Chemistry

- Key Common Characteristics of the Contaminant:
 - Oxidized vs reduced contaminants
 - Solubility
 - Partitioning onto soil (K_{oc})
 - Phase
 - Soil
 - Aqueous
 - Non-Aqueous Phase Liquid (NAPL)



Common Oxidized and Reduced Compounds

Oxidized Compounds

- Carbon Tetrachloride
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- Chlorobenzenes/Chlorophenols
- Many pesticides
- Energetics (trinitrotoluene-TNT; RDX, etc)
- PFAS

Commonly, if you hear of chloro-, nitro-, fluoro-, hydroxide, keto-/oxygen etc added to a carbon, it is oxidized.

Reduced Compounds

- Benzene, Toluene, Ethylbenzene and Xylenes (BTEX)
- Petroleum hydrocarbons (F1, F2, GRO/DRO)
- Methyl Tert-Butyl Ether (MTBE)
- Polyaromatic hydrocarbons (PAHs)
- MGP Residuals

Commonly, if you see H- only, no others, or hear petroleum hydrocarbon, it is a reduced compound

Understanding Contaminants: Solubility

- Highly Soluble (>~2,000 mg/L)

- 1,4-Dioxane
- Dichloroethane(s)
- Ethylene bromide
- Methylene chloride
- Many ketones

Often not persistent unless a source is present as the mass will have migrated with GW flow

- Moderately Soluble (~100 mg/L to ~2,000 mg/L)

- Chloroethenes (TCE, PCE, etc)
- BTEX
- 1,1,1-Trichloroethane
- Trichlorophenol(s)

Most Common Contaminants of Concern
Moderate solubility helps with treatment

- Low Solubility (<1 mg/L)

- Most PAHs
- DDT
- PCBs
- Many pesticides

Low solubility becomes an important dynamic, benefiting from extended oxidant persistence

Understanding the Contaminants: Partitioning

- Organic contaminants have unique characteristics that factor into treatment
 - Variation in partitioning coefficient (K_{oc}) with fraction of organic carbon on soil (F_{oc})
 - Lower K_{oc} results in higher proportion of contaminant being in aqueous phase
 - F_{oc} can change with treatment by ISCO technologies
 - Monitoring should focus on total contaminant mass reduction (soil + GW)
 - Remediation primarily occurs in aqueous phase

$$K_d = K_{oc} * f_{oc} = \frac{\text{Soil } (\frac{g}{Kg})}{\text{GW } (\frac{g}{L})}$$

Contaminant	EPA* K_{oc}	F_{oc}	Contaminant Distribution (%)	
			GW	Soil
1,4-Dioxane	17	0.005	70%	30%
1,1,1-TCA	110		27%	73%
1,2-DCA	38		51%	49%
1,1-DCA	53		43%	57%
DCE	38		51%	49%
Benzene	59		40%	60%
Toluene	182		18%	82%
Ethylbenzene	363		10%	90%
Xylene	386		9%	91%
TCE	166		19%	81%
Carbon Tetrachloride	174		19%	81%
1,2-Dichlorobenzene	617		6%	94%
Dieldrin	21,380		0%	100%

Note: 1. Assuming 1.5 g/cm³ soil bulk density and effective pore volume of 0.15

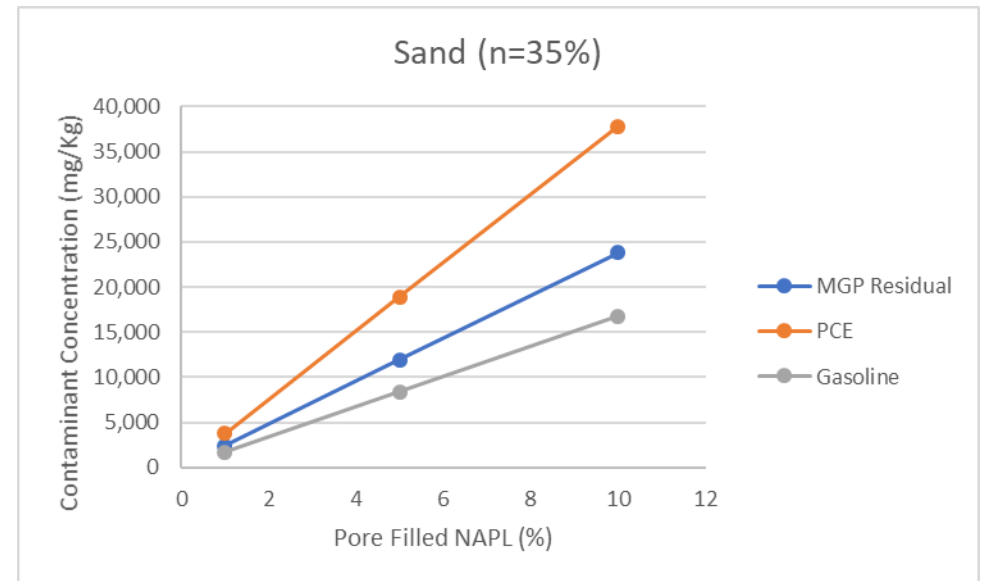
Understanding Your Site: NAPL from Soil Concentrations

- When might we start seeing NAPL?
 - Lab reports phase separation as low as 500 mg/Kg
 - Concentrations exceed typical F_{oc}

- Percent of pore space filled with NAPL
 - Varies with contaminant type (Specific Gravity/density)
 - ~17,000 mg/Kg GRO is ~10% of pore space in a sand (n=35%)

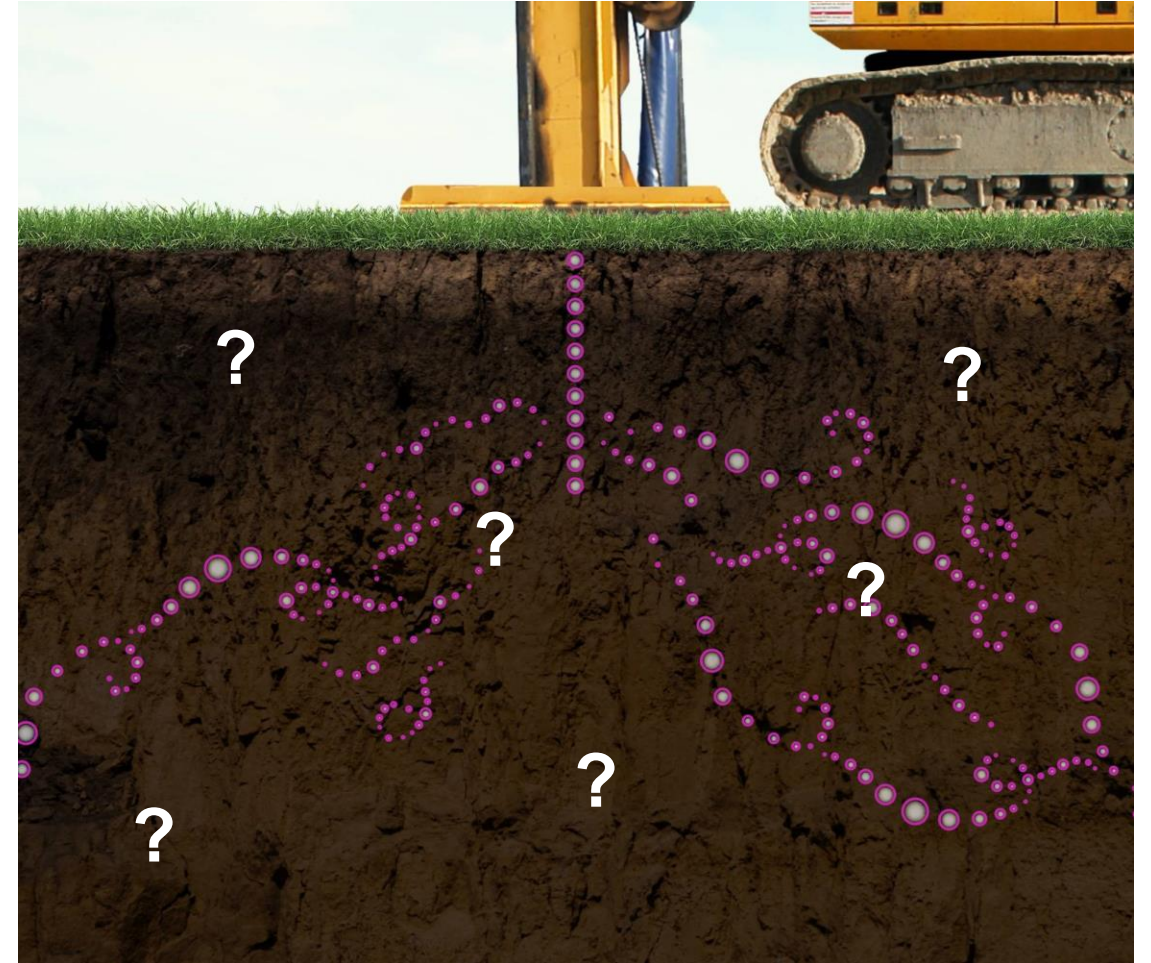
- Mobility of NAPL will be a function of viscosity and percent pore volume

Foc	TOC (mg/Kg)	Contaminant Sorption Capacity (mg/Kg)			
		5%	10%	15%	40%
0.01%	100	5	10	15	40
0.10%	1,000	50	100	150	400
0.50%	5,000	250	500	750	2,000
1.00%	10,000	500	1,000	1,500	4,000



Key Site Characteristics

- Many Site Characteristics are Critical to Design
 - Site access: Impact application strategy
 - Soil/Matrix type: Impact application strategy
- Site Characteristics that Pertain to Persulfate Chemistry:
 - Groundwater Velocity
 - Contact time with NAPL or contaminant on soil
 - Recontamination from upgradient sources
 - Soil permeability
 - Longevity/persistence of remedy
 - Non-target demand (Soil Oxidant Demand-SOD)
 - Naturally occurring transition metals



Establishing Contact

- Many factors go into establishing and maintaining contact
- Contact is on the microlevel
 - Contaminant dissolved in aqueous phase contacting radicals

ISCO Works by Establishing and Maintaining Contact between a sufficient mass of activated oxidant for the contaminant mass in the subsurface

Summary: Key Factors

- Contaminant
 - Oxidized or reduced? Comingled?
 - Solubility
 - Partitioning coefficient
 - Phase (Soil, Groundwater, or NAPL)
- Site
 - Groundwater velocity: Affects contact time
 - Soil permeability: Affects ability to establish contact

Conventional Approaches are effective with significant number of sites and situations

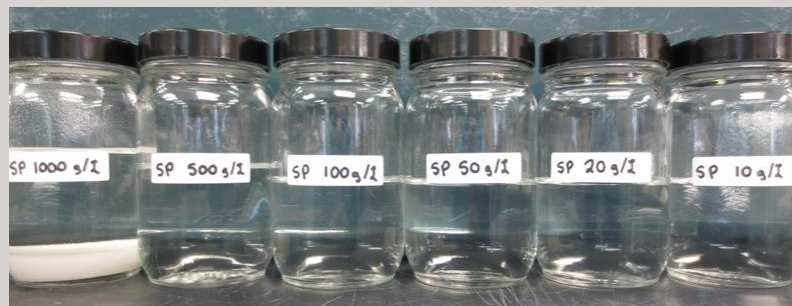
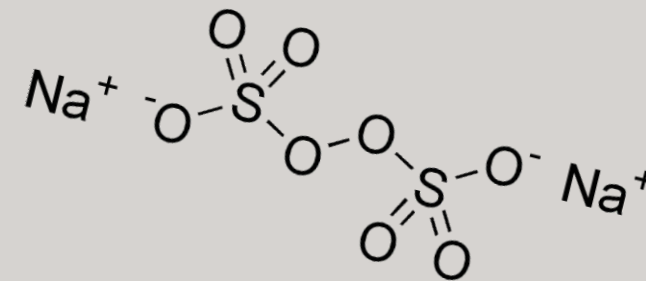
Look for when your situation is atypical

Look for Factors that may limit treatment at Each Site

Contact will not be established if reagents are consumed or flushed down gradient before contaminant can dissolve into aqueous phase from NAPL or Soil

NAPL, High K_{oc} or Low Solubility Contaminants can have
Dissolution Limited Treatment

Necessary Background Chemistry



Oxidation and Reduction Overview

Definition:

“a type of chemical reaction in which the **oxidation states** of atoms are changed”

This occurs by transfer of electrons between chemicals

Oxidation is the *loss* of electrons or an *increase* in the oxidation state of an atom, an ion, or of certain atoms in a molecule.

Reduction is the *gain* of electrons or a *decrease* in the oxidation state of an atom, an ion, or of certain atoms in a molecule. (a reduction in oxidation state).

Pathways: Oxidative vs Reductive Pathways

- Oxidative Pathway:
 - Typically add an oxidant to oxidize a reduced contaminant
- Reductive Pathway:
 - Typically add a reductant to reduce an oxidized contaminant

Electron Tower	
Compound	Standard Reduction Potential (V)
Persulfate anion	2.01
Carbon Tetrachloride	0.67
Tetrachloroethene (PCE)	0.58
ZVI	-0.45
Benzene	-3.4

Notes: 1. Siegrist et al. (2011), 2. CRC (76th Edition), 3. Watts (1999)

**Need to consider factors such as:
Both half reactions, energy gained in
biotic processes, and Gibbs Free
Energy for abiotic processes**

Common Radicals In ISCO

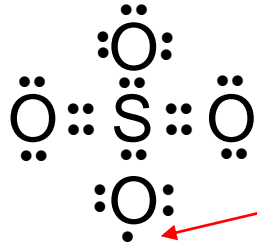
- Oxidants:
 - Hydroxyl radical (OH•): Longevity in water is typically <2 nanoseconds
 - Sulfate radical (SO₄•): ~30-40 microseconds
- Reductant:
 - Superoxide radical anion (O₂^{-•}): Half-life typically measured in milliseconds
- Non-radical Oxidant:
 - Persulfate anion:
 - Longevity in groundwater and soils is typically weeks to months
 - Longevity in pure water can be months to years

Radical Definition

A compound is a radical when it has an unpaired electron. If it needs an electron to stabilize, it is typically an oxidant. If it has an excess electron that can be donated, it is typically a reductant.

Common Radicals: Lewis Structures

Sulfate Radical (SO₄•⁻)

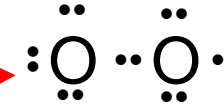


Missing
electron

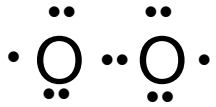


Superoxide Radical (O₂•⁻)

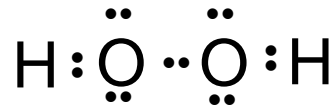
Excess
electron



Oxygen (O₂)



Hydrogen Peroxide



Water (H₂O)

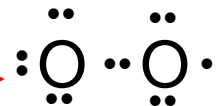


e⁻

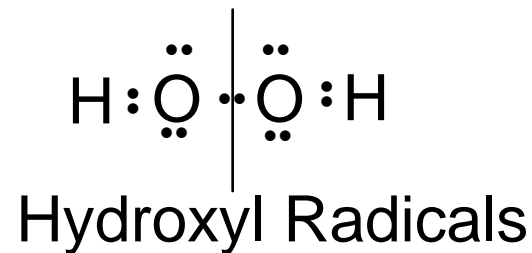
e⁻

2e⁻

Excess
electron

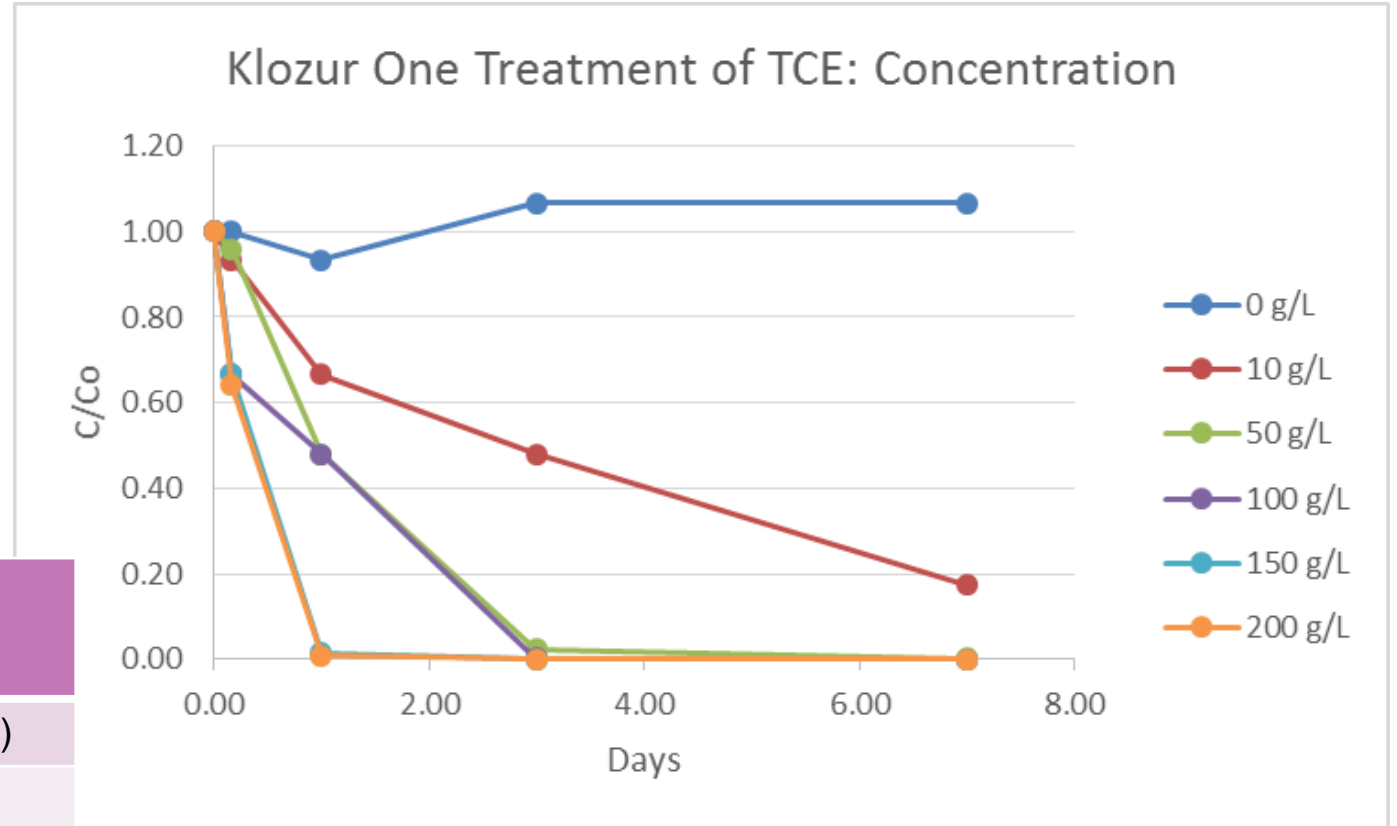


Superoxide (O₂•⁻)



Concentration Based Kinetics: Persulfate Concentration

- Increasing concentration of persulfate results in more rapid treatment of the contaminant
- On a micro-level
 - More persulfate = more collisions with the contaminant



Treatment of 1,4-Dioxane in 25°C Persulfate Solution		
(g/L)	$K \times 10^4 \text{ (s}^{-1}\text{)}$	Half-life (min)
3	0.95	122
6	1.8	64
12	2.23	52
24	3.08	38

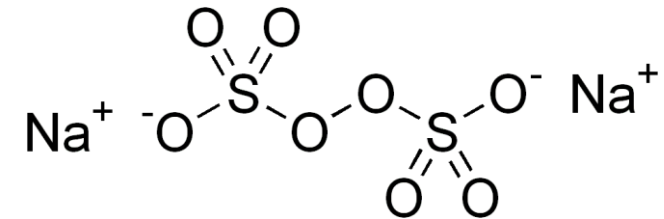
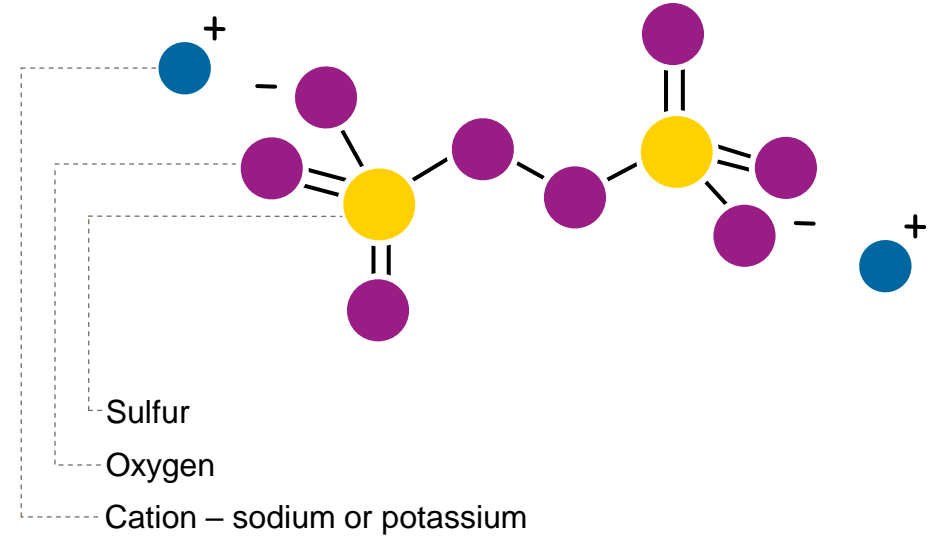
Felix-Navarro et al (2007)

Persulfate Chemistry



Persulfate

- Persulfate is a peroxygen
 - Oxygen-oxygen bond
 - Similar to hydrogen peroxide
- Persulfate salts
 - Persulfate available as sodium, potassium and ammonium salts
 - Oxidative potential resides with the persulfate anion
 - Not the salt
- Persulfate anion, once dissolved, is relatively stable and can persist for weeks to months
 - pH and reactant dependent



Klozur® Portfolio: What they are

KLOZUR® SP

Environmental grade, high purity (>99%) sodium persulfate (SP)

KLOZUR® KP

Environmental grade, high purity (>98%) potassium persulfate (KP)

KLOZUR® ONE

95% Klozur® SP and 5% built in activator

- Iron-chelate and organic acid activated persulfate

KLOZUR® CR

A 50/50 blend of Klozur® SP and PermeOx® Ultra engineered calcium peroxide.

- Alkaline and hydrogen peroxide activated persulfate

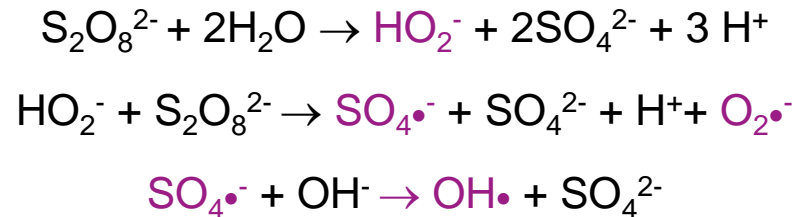
Persulfate is Typically Activated

- Persulfate anion tends to be slow reacting
- Radicals formed from activation tend to be:
 - More thermodynamically powerful oxidants
 - Reductants
- All activation methods generate oxidative pathway
- Only certain activation methods generate reductive pathway

- Alkaline Activation
 - More Compatible with carbon steel
 - Oxidants and reductants
- Klozur[®] One / Iron-Chelate Activated Persulfate
 - Chlorinated ethenes and petroleum hydrocarbons
 - Oxidative pathway
- Heat
 - Polishing step after thermal treatment
 - Oxidants and reductants
- Hydrogen Peroxide
 - Sites that benefit from rapid and vigorous reaction with both hydrogen peroxide and sodium persulfate
 - Oxidants and reductants

Alkaline Activation

- Target for Alkaline Activation: pH >10.5
 - Maintained throughout reaction
 - Typically accomplished by adding enough alkali to neutralize acid formed from persulfate decomposition and buffer capacity of soil
- Reaction (Furman et al., 2010):



(note: $\text{H}_2\text{O}_2 \leftrightarrow \text{HO}_2^- + \text{H}^+$ $\text{pK}_a = 11.7$)

- Creates oxidative and reductive radicals in single system
- Increasing alkalinity increases rate of decomposition

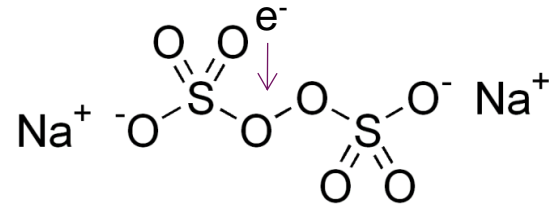
ISCO-ISS: Built in Alkaline Activator

- Remedy in a single application combining:
 - Alkaline activated Klozur[®] persulfate
 - In situ Solidification and Stabilization (ISS)
 - Portland cement
 - Blast Furnace Slag
- Alkali Source
- In single soil mixing application
 - Degrades contamination (ISCO)
 - Solidifies remaining contamination (ISS)
 - Lowers leachate concentrations (ISCO and ISS)
 - Provides competent soils for future site activities and redevelopment



One Electron Transfer: Metal/Iron/Organic Activation

- Similar to Fenton's Reagent:



- Activation methods based on one electron transfer:
 - Reduced metals: Fe (II)
 - Organics
 - Hydrogen peroxide

Klozur® One

An all-in-one product that is 95% sodium persulfate and 5% activator. Built in activator include iron and organic activation methods

Hydrogen Peroxide Activation

- Hydrogen peroxide activation, combination of both alkaline and electron transfer activation methods:

- Second step of alkaline activation:



- At pH < 11.7 HO_2^- is increasingly H_2O_2 and the equation becomes:



- Oxidizing hydrogen peroxide gives you superoxide which becomes oxygen

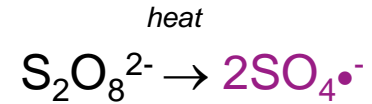
- Transition metals in the subsurface tend to make it proceed much quicker

- In clean tank/water, hydrogen peroxide and persulfate reaction proceeds relatively slow. Increases once injected into soil.

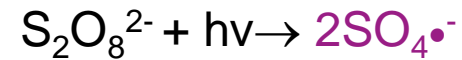
- Increased decomposition of hydrogen peroxide may result in copious gas/heat evolution and it may not persist/distribute with the persulfate anion which is more stable

Other Activation Methods

- Heat:



- UV Light:



- Activated Carbon:



Example Review Articles

Matzek, L.W. and Carter, K.E., (2016) *Chemosphere*, 151, 178-188

Zhou, Z. et al (2019) *Chemical Engineering Journal*, 372, 836-851

Santos, A. et al (2021) Chapter in *Electrochemically Assisted Remediation of Contaminated Soils*

Thermodynamics vs Kinetics

- Thermodynamics (Equilibrium Thermodynamics)
 - Gibbs Free Energy Equations used to predict if a reaction will proceed or not
 - Half reactions
 - **Thermodynamics: Will a reaction proceed? Yes or no. Binary: 0 or a 1.**
- Kinetics (Chemical Kinetics)
 - Rate of chemical reactions
 - **Kinetics: How quickly will something occur?**
 - **How quickly will the reaction take place?**

Bucket Analogy

A bucket filled with water.

Will the water drain?

Thermodynamics: Is there a hole in the bucket below the water line

How quickly will the bucket drain?
Kinetics: Size of hole, pressure, etc.

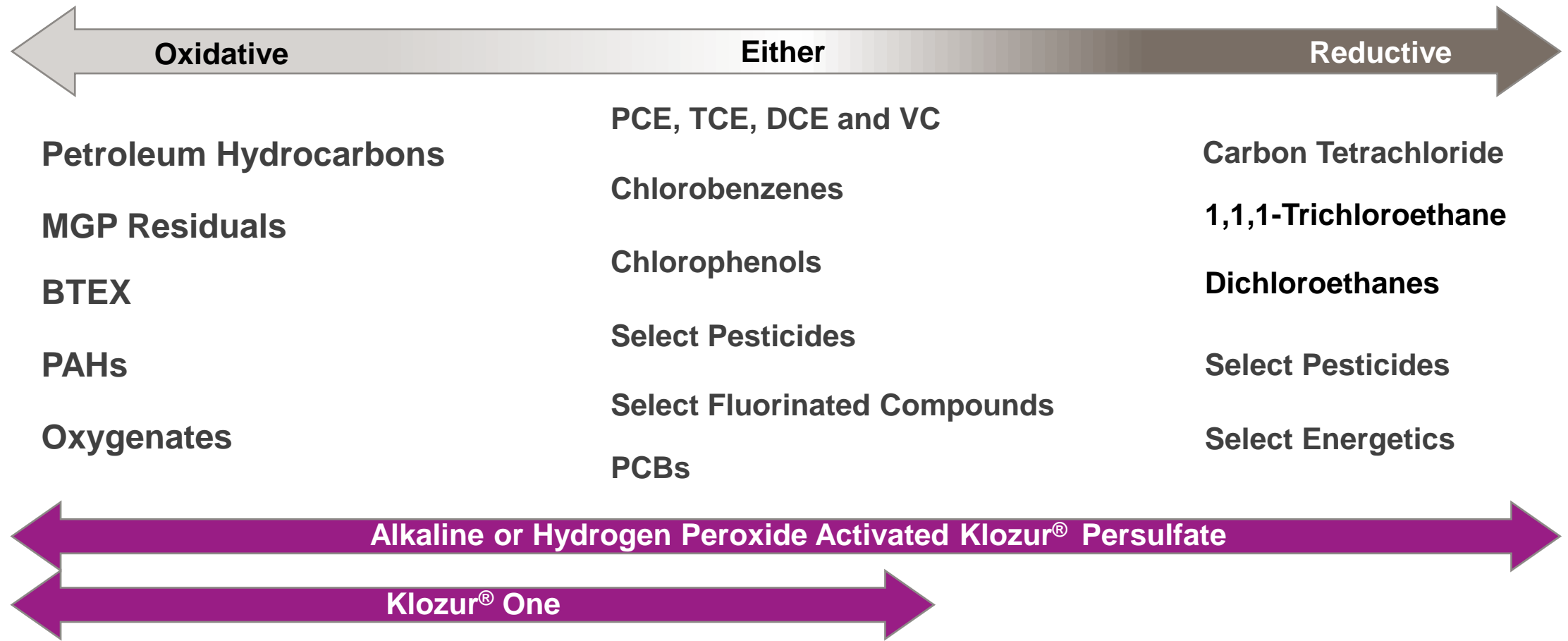
Thermodynamics: Electron Tower

- Hydroxyl and sulfate radicals are two of the most powerful oxidants known
- Superoxide radical is a reductant approaching the reduction potential of ZVI

Electron Tower	
Compound	Standard Reduction Potential (V)
Hydroxyl radical (OH·)	2.59
Sulfate radical (SO ₄ · ⁻)	2.43
Ozone	2.07
Persulfate anion	2.01
Hydrogen Peroxide	1.78
Permanganate	1.68
Oxygen	1.23/0.82
Hydrogen (H ₂)	0.0
Sulfate (Sulfide to)	-0.22
Superoxide (O ₂ · ⁻) (O ₂ to)	-0.33
ZVI [Fe (II) to]	-0.45

Notes: 1. Siegrist et al. (2011), 2. CRC (76th Edition), 3. Watts (1999)

Contaminants Treated with Klozur® Persulfates



Kinetic Consideration: Klozur[®] Persulfate During Treatment

- **Kinetics: How quickly will something occur?**
- Distribution during injection events is about persulfate longevity in the subsurface.
- Persulfate longevity in the subsurface is about:
 1. Persistence of persulfate salt
 2. Once dissolved, longevity of the persulfate anion

Key Kinetic Steps

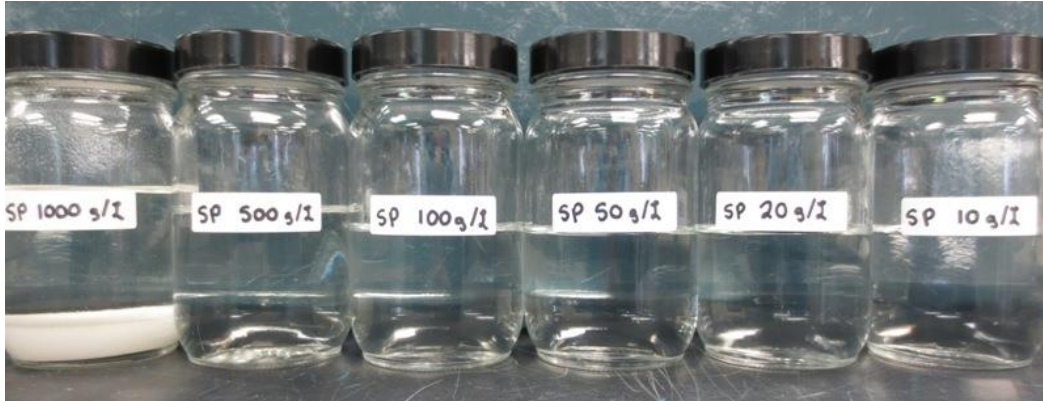
1. Release of reactive reagent (persulfate anion)
2. Activation of persulfate anion to form radicals
3. Rate of reaction of reactants with contamination

Understanding Fundamental Mechanisms can be used to address potential issues at complex sites

Kinetics Step 1: Two Types of Salts

KLOZUR® SP

Solubility =
570 g/L at ~20°C



KLOZUR® KP

Solubility =
47 g/L at ~20°C



Temperature (°C)	Klozur® SP $\text{Na}_2\text{S}_2\text{O}_8$		Klozur® KP $\text{K}_2\text{S}_2\text{O}_8$	
	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

Key Differences:

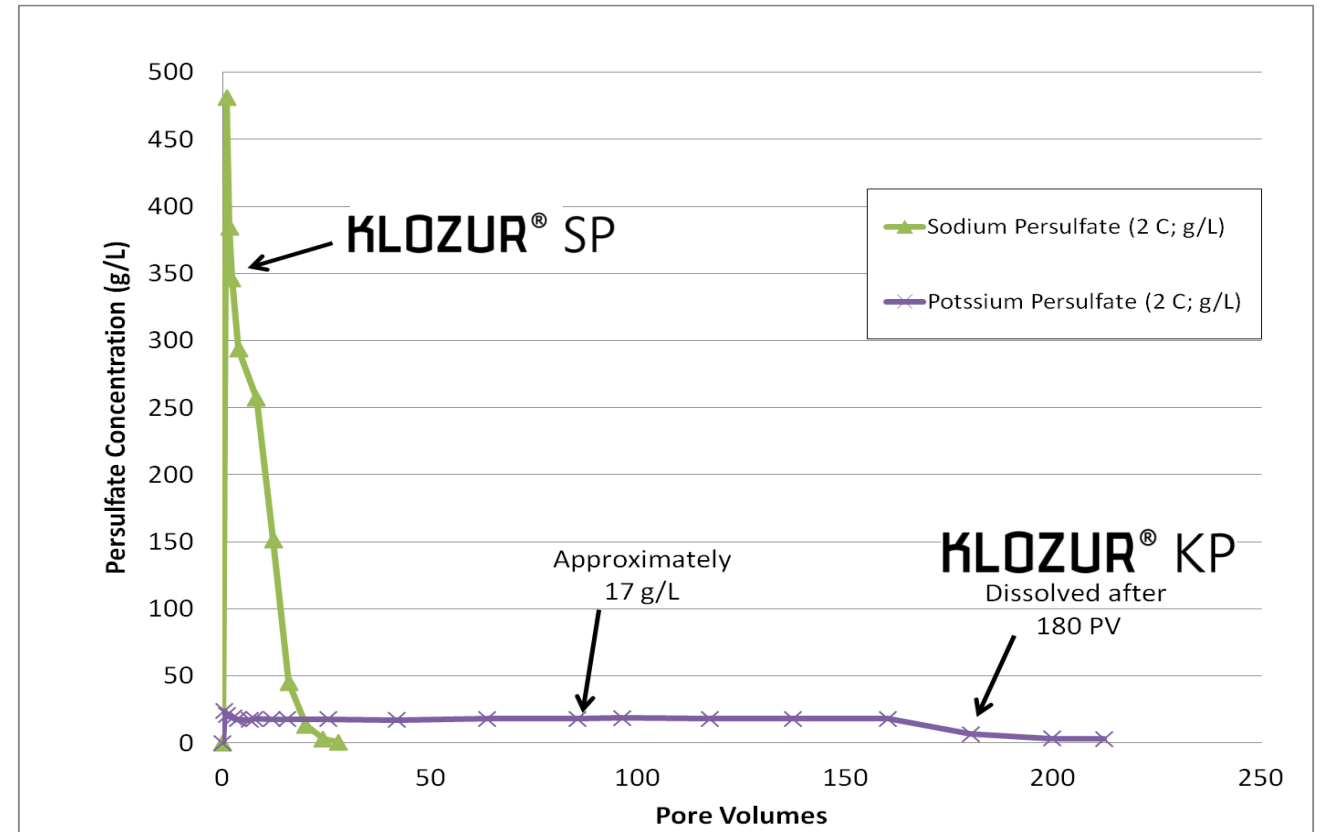
- Solubility
- Na^+ vs K^+ residual

Types of Persulfate

Key Kinetic Steps

1. Release of reactive reagent (persulfate anion)

- Characteristics create options for Step 1:
 - Klozur[®] SP is highly soluble and dissolved into the persulfate anion at the time of application
 - Klozur[®] KP has a much lower solubility and slowly dissolves over time releasing the persulfate anion gradually
 - Klozur[®] CR is ISCO at the start, but then the PermeOx[®] Ultra slowly releases oxygen over time



When to Use Lower Solubility/Solid Slurry Oxidants?

- High Solubility: When you want all oxidant available at injection. Source zones, high oxidant demands, etc.
- Lower Solubility:
 - Treating Aqueous Phase Contaminants
 - Permeable Reactive Barriers (PRBs)
 - Source zones
 - Longer Contact Time
 - Low permeable soils
 - Low solubility contaminants
 - Low contaminant concentrations
 - High groundwater velocity

PCB	Day 56 PCB % Reduction			
	Klozur [®] SP		Klozur [®] KP	
	Low	High	Low	High
Arochlor 1254	12%	26%	53%	53%

Klozur KP
Solid Slurry
Fracture



Courtesy of FRx/Brown & Caldwell

Kinetics: Second Primary Consideration

- Rate of activation of persulfate is important:
 - Evonik Guidance is intended for a reasonable rate of activation
 - Alkaline activation:
 - Rate increases with increasing pH
 - Significantly increases pH>12
 - Iron-Chelate Activation
 - Concentration based kinetics (increasing concentration, more rapid activation)
 - Heat Activation
 - Higher temperatures more rapid activation of persulfate
- Critical balance of rate of activation and persistence of persulfate
 - Greater persistence allows for better distribution and treatment less available contamination

Key Kinetic Steps

2. Activation of persulfate anion to form radicals

Kinetics: Third Primary Consideration

- Rate of reaction with radicals is very rapid: <1 sec
 - Radicals need to be formed in close proximity to contaminants
 - No practical distribution of radicals
- Issue with “Natural Activation” / “Unactivated Persulfate”
 - Rate of reaction of persulfate anion and contaminants is typically very slow (can be days to weeks)

Key Kinetic Steps

3. Rate of reaction of reactants with contamination

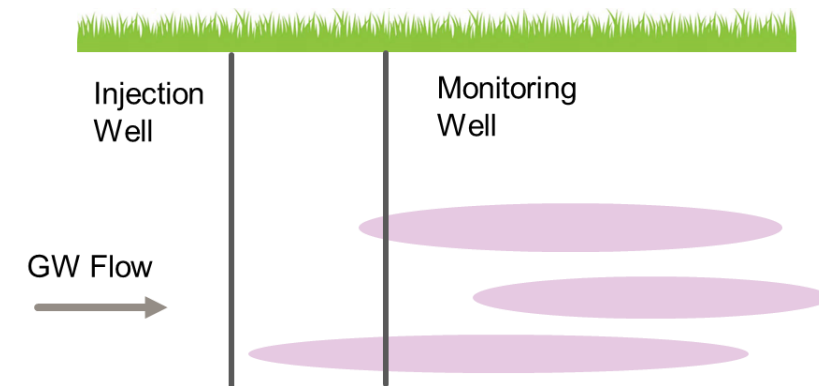
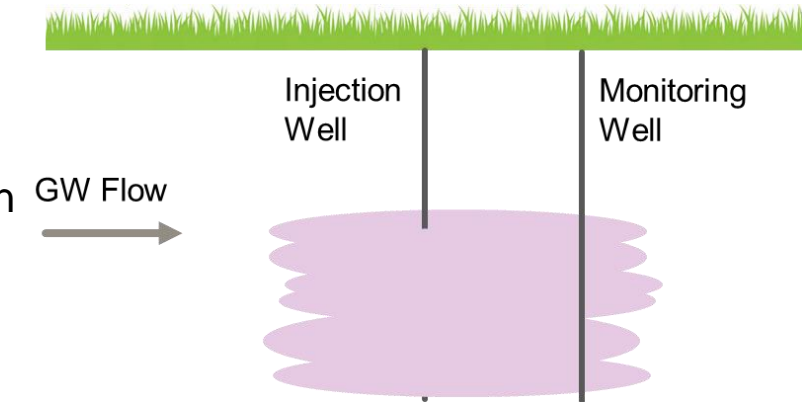
Rate Constants

Compound	Sulfate Radical (M ⁻¹ S ⁻¹)	Hydroxyl Radical (M ⁻¹ S ⁻¹)
Tetrachloroethene (PCE)	1 x 10 ⁹	2.8 x 10 ⁹
1,4-Dioxane	~5 x 10 ⁷	~3 x 10 ⁹
Benzene	3 x 10 ⁹	7.8 x 10 ⁹
Toluene	3.1 x 10 ⁹	3 x 10 ⁹
Carbon Tetrachloride	<1 x 10 ⁴	2 x 10 ⁶

Notes: 1. Watts (1999), 2. Neta (1977) 3. Wojnarovits (2019)

Persulfate Chemistry Summary

- Thermodynamics: Tend to be well understood
 - Sulfate and hydroxyl radical are powerful oxidants
 - Superoxide is a reductant that is formed by alkaline or hydrogen peroxide activation
- Kinetics: Can have rate limiting steps
 - Contaminant & Site
 - Contaminant dissolution from NAPL or off soil can be rate limiting step to treatment
 - Contact time of reagent with contaminated soils can be limited by GW velocity
 - Potential mechanism issues can be addressed. Persulfate:
 - Extended Release vs Highly Soluble
 - Activation
 - Radicals vs non-radicals



Combining Key Characteristics

- Site Characteristics

- Groundwater velocity
- Soil/Formation/Matrix type
- Access
- Remedial goals
- Remediation timeline

- Contaminant Characteristics

- Phase
- Solubility
- Partitioning (K_{oc})
- Distribution/Concentration
- Mass

- ISCO Chemistry

- Oxidative and Reductive Pathway
- All oxidant available at once vs Extended Release
- Contaminant K_{oc}
- Mass to be applied
- Cost
- Aerobic bio after ISCO
 - Klozur CR
- Anaerobic bio after ISCO
 - Sulfate reduction after persulfate
- DOC

- Application Methods/Establishing Contact
- Monitoring Programs
- Case Studies

Pragmatic and Health & Safety Considerations



Understanding the Oxidants: Oxidant dose per Application

Characteristic	Klozur® SP	Klozur® One	Klozur® KP	Klozur® CR
Liquid Injection	50 to 250 g/L	50 to 200 g/L		
Solid Slurry Injection	Can be blended with KP		~1 to 1.5% w/w with soil	~1 to 1.5% w/w with soil
Soil Mixing	Typical: 1-5% w/w soil Max: 5 to 10% w/w soil	Compatibility Issues with Carbon Steel	Usually SP or CR If KP selected, similar to SP	Typically 0.5 to 4% w/w soil
Permeable Reactive Barrier	Continuous Injection	Continuous Injection	Solid Slurry Injection or Trenched Application	Solid Slurry Injection or Trenched Application

Lessons Learned: Materials Compatibility

- Compatible materials/Corrosion of carbon steel
 - Persulfate can corrode carbon steel at low-neutral pH
- Corrosion at high pH is minimal
- See Evonik's Materials Compatibility Guide



Persulfates are Salts

- Persulfate is a salt that can form clumps. Some clumps should be anticipated. Key factors include:
 - Time
 - Humidity
 - Temperature
- While this can occur in any environment, it is recommended that special precautions be taken if a persulfate will be stored:
 - Humidity > 60%
 - Temperatures > 30°C or 85°F
 - Persulfate is not to be stored at >45°C or 110°F
- Consult an Evonik Representative for Storage Guidance



Persulfate is an Oxidizer

- Persulfate is an Oxidizer and should be properly labeled and handled
 - SP and K1 are UN 1505 Class 5.1 PG III
 - KP is UN 1492 Class 5.1 PG III
 - CR is UN 1479 Class 5.1 PG II
 - PermeOx Ultra (Calcium Peroxide) can decompose to form oxygen
 - Self Accelerating Decomposition Temperature (SADT) of persulfate is
 - >100°C
 - All members of team working with persulfate should be aware of hazards and be familiar with the Safety Data Sheet (SDS)
 - **Safely applied at 1,000s of sites over decades**



Klozur® CR adds:



Summary

- Classic Approaches using Klozur® Persulfate have been used with a great deal of success at thousands of sites around the world
 - Keys are to achieve and maintain contact with a sufficient mass of activated oxidant for the contaminant mass
- Consider potential rate limiting steps such as desorption, diffusion and dissolution especially when evaluating sites with:
 - NAPL
 - High Koc contaminants
 - Low solubility contaminants
 - Low permeable soils
- Can address these types of sites with application strategies and/or extended release oxidants such as Klozur® KP or Klozur® CR

20 Year Anniversary of Klozur® Persulfate

- Decades of Experience
- Thousands of Successful Applications
- Well established technology
- Oxidative and reductive pathways
- Treats great number of different types of contaminants

Please see webinars on

- Design
- Monitoring
- ISCO-ISS

Many others at:

www.Evonik.com/remediation

Best Practices for Designing and Applying In Situ Chemical Oxidation (ISCO)

- **Site**: Understanding details of each site.
- **Chemistry**: Is the contaminant degraded by activated the oxidant?
- **Design**: Is there sufficient oxidant mass to react with non-target demand and the contaminant mass?
 - Safety factors
- **Application**: How will the persulfate chemistry establish contact with the contamination in the subsurface?
- **Monitoring Program**: Designed to answer key questions regarding the ISCO application

Current Best Practices

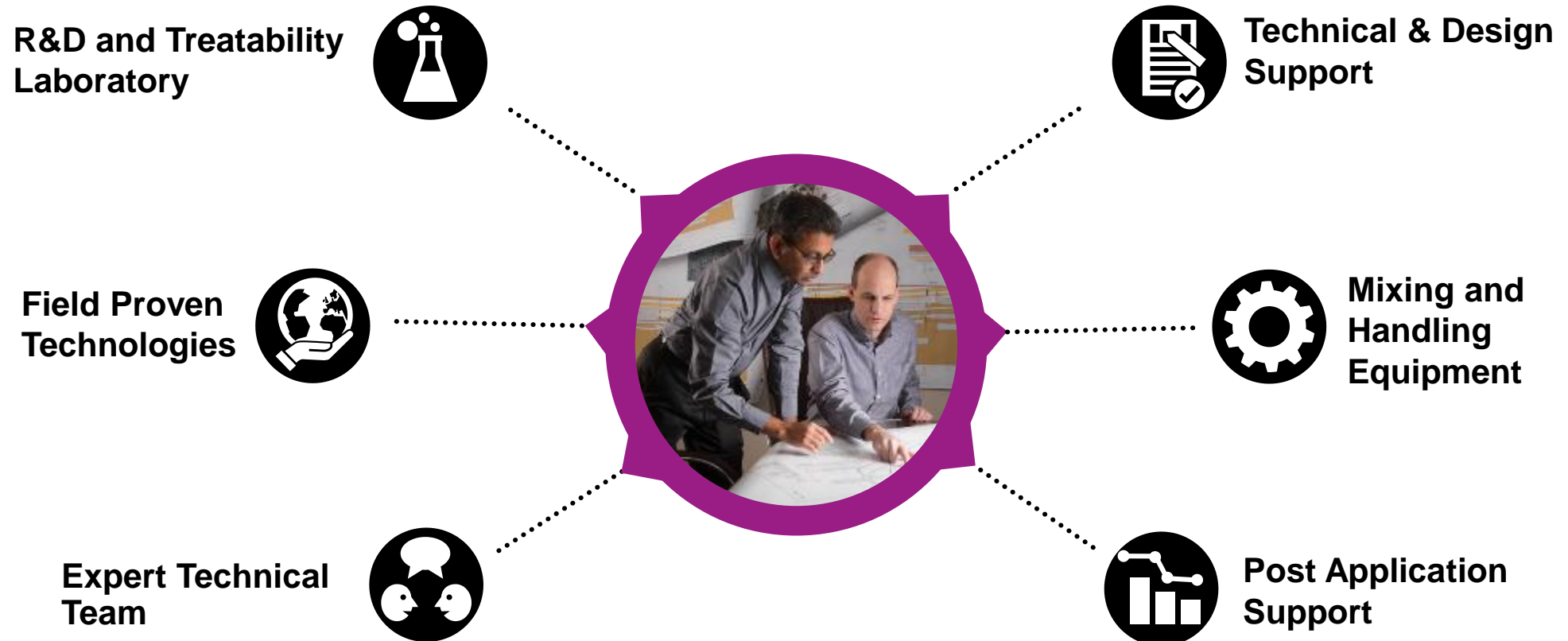
Understanding Key Characteristics of Each Facet of a Remedy and Combining them in the Most Advantageous Way for Your Site

- Chemistry
- Site
- Contaminant
- Application Method

Use Monitoring Program to Inform the Design, Understand the Application, and Confirm Progress toward Remedial goals.

Evonik Soil & Groundwater Remediation

Technical Support Overview



Evonik Soil & Groundwater Global Commercial Team

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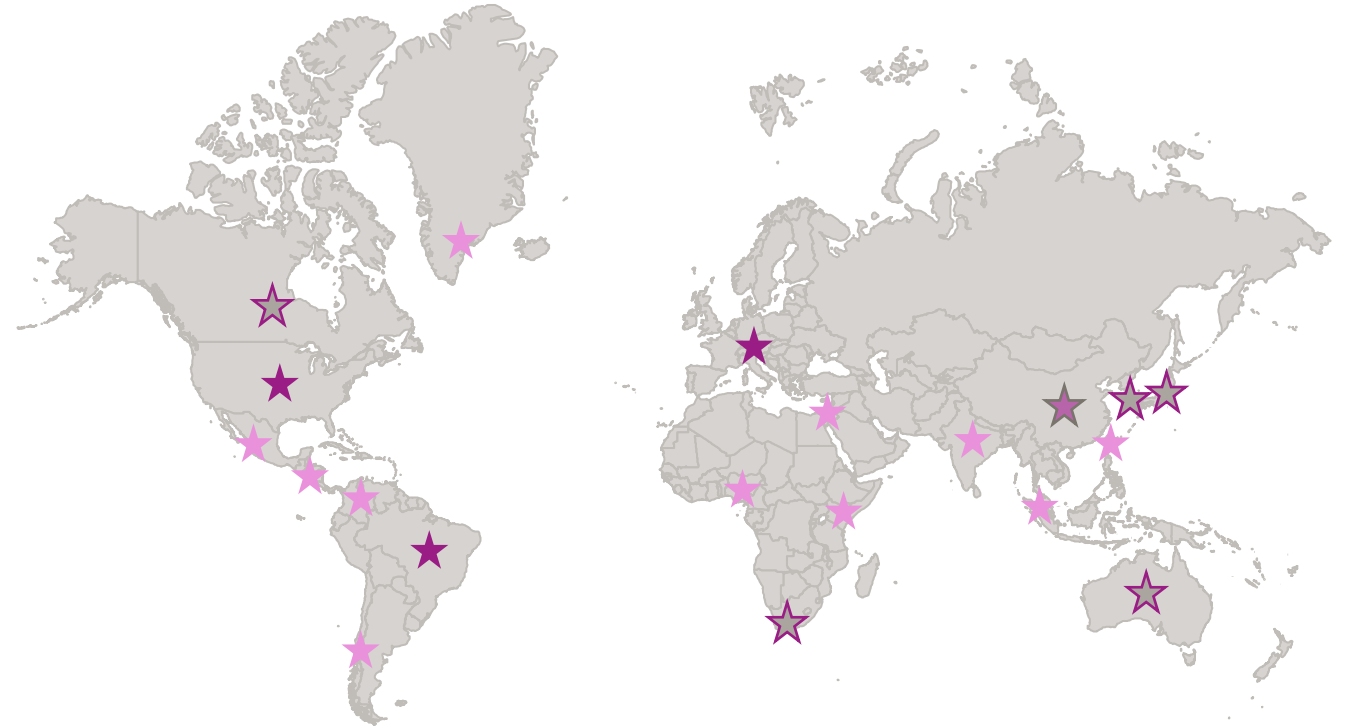
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- ★ Evonik S&GW Staff
- ★ Representatives
- ★ International Site Locations
- ★ Joint Venture

Questions?



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