Environmental Solutions

PeroxyChem

Introducing

Klozur® One

Brant Smith/PeroxyChem

PeroxyChem Webinar Series

June 14, 2017

Field-Proven Portfolio of Remediation Technologies Based on Sound Science

***In Situ* Chemical Oxidation**
- Klozur® SP
- Klozur® One
- Klozur® KP
- Klozur® CR

In Situ Chemical Reduction
- EHC® Reagent
- EHC® Liquid
- Daramend® Reagent

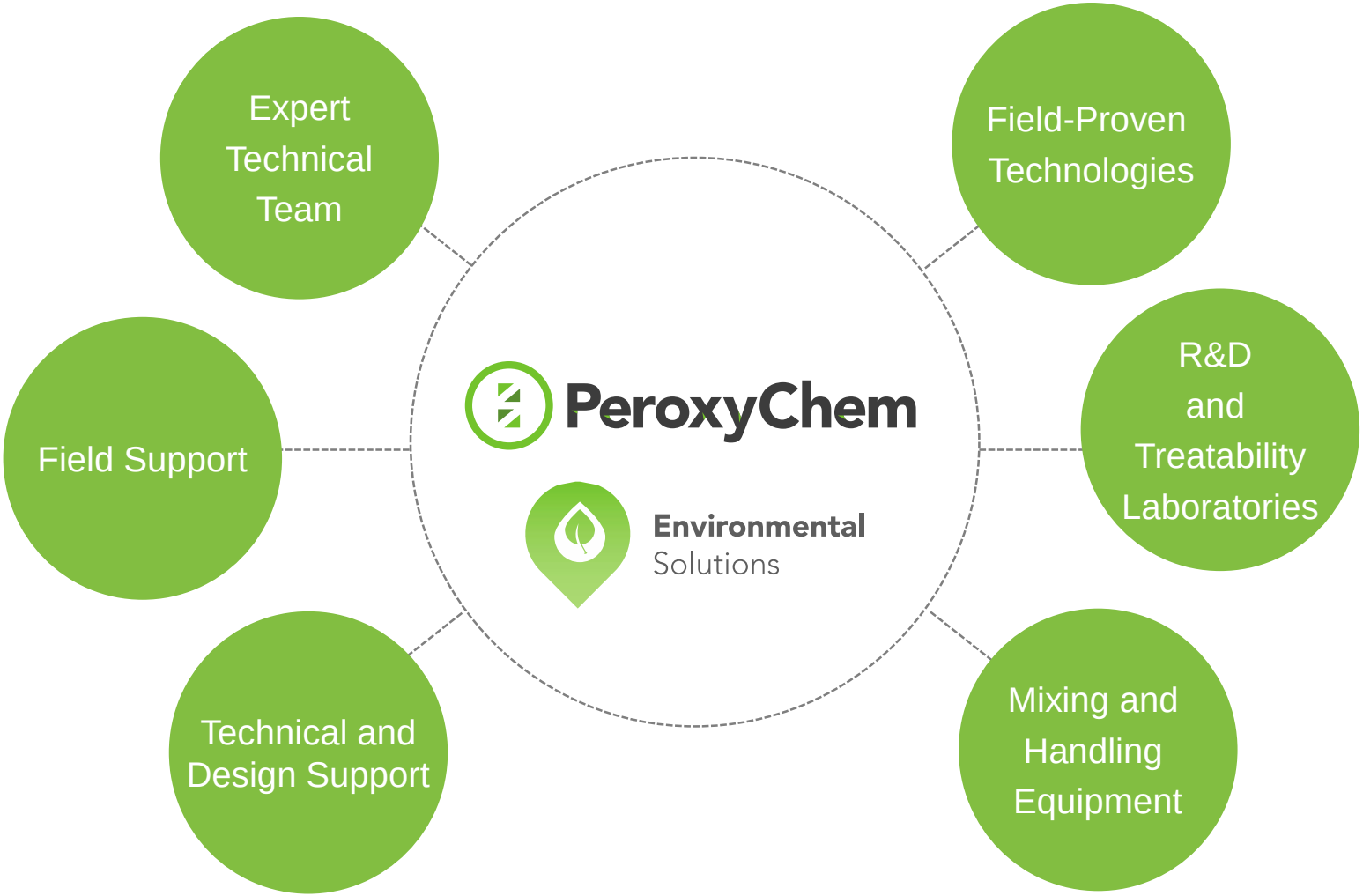
Aerobic Bioremediation
- Terramend® Reagent
- PermeOx® Ultra & PermeOx® Ultra Granular

Metals Remediation
- MetaFix® Reagent

Enhanced Reductive Dechlorination
- ELS® Microemulsion & ELS® Concentrate

NAPL Stabilization/Mass Flux Reduction
- ISGS® Technology

Support We Provide



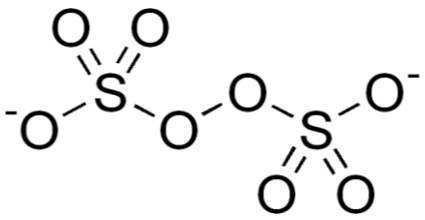
Presentation Outline

- Klozur Overview
- Klozur One
  - Introduction
  - Technical Data
  - Recommendations
- Klozur Portfolio
- Summary and Conclusions

Courtesy of XDD and NAVFAC

Klozur® Persulfate Portfolio

All Klozur products release the persulfate anion:



Key Characteristics:

- **A strong oxidant**
- **Activation results in the formation of radicals**
- **Applicable across a broad range of organic contaminants**
- **Extended subsurface lifetime (weeks to months)**
- **Little to no heat or gas evolution**

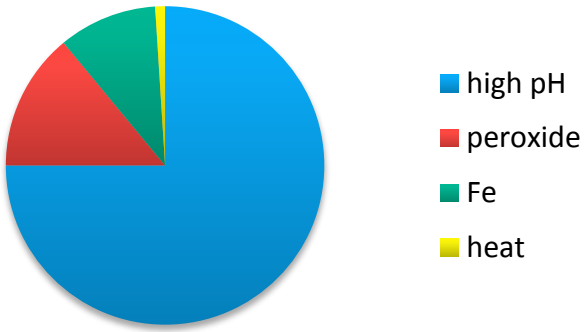
Radical Formation Upon Activation

- Kinetically faster reacting radicals that are:
  - More powerful oxidants (SO_4• and OH•) than persulfate itself
  - Reductants (O_2•$^-$)
  - Nucleophiles (O_2•$^-$ and HO_2^-)

Oxidant	Standard Reduction Potential (V)	Reference
Hydroxyl radical (OH•)	2.59	Siegrist et al.
Sulfate radical (SO_4•$^-$)	2.43	Siegrist et al.
Ozone	2.07	Siegrist et al.
Persulfate anion	2.01	Siegrist et al.
Hydrogen Peroxide	1.78	Siegrist et al.
Permanganate	1.68	Siegrist et al.
Chlorine (HOCl)	1.48	CRC (76th Ed)
Oxygen	1.23	CRC (76th Ed)
Oxygen	0.82	Eweis (1998)
Fe (III) reduction	0.77	CRC (76th Ed)
Nitrate reduction	0.36	Eweis (1998)
Sulfate reduction	-0.22	Eweis (1998)
Superoxide (O_2•$^-$)	-0.33	Siegrist et al.
ZVI	-0.45	CRC (76th Ed)

PeroxyChem Activation Technologies

Estimated Activator Usage



- Zero Valent Iron
  - Solid state activator
  - Oxidative pathway

Purchase of Klozur persulfate includes with it the grant of a limited license under PeroxyChem's patents covering the use of Klozur persulfate for environmental applications at no additional cost to the buyer

- Alkaline Activated Persulfate
  - Well suited for most applications
  - More compatible with carbon steel
  - Reductants, oxidants and nucleophiles
- Iron-Chelate Activated Persulfate
  - Chlorinated ethenes and hydrocarbons
  - Oxidative pathway
- Heat
  - Complex sites
  - Polishing step after thermal treatment
  - Reductants, oxidants and nucleophiles
- Hydrogen Peroxide
  - Sites that benefit from vigorous reaction with both hydrogen peroxide and sodium persulfate
  - Reductants, oxidants and nucleophiles

Compounds Degraded

Example Contaminants Treated by Klozur Persulfate

(not all ISCO reagents treat all compounds listed)

Chlorinated Solvents
PCE, TCE, DCE
TCA, DCA
Vinyl chloride
Carbon tetrachloride
Chloroform
Chloroethane
Chloromethane
Dichloropropane
Trichloropropane
Methylene chloride

Others
Carbon disulfide
Aniline
1,4-Dioxane

TPH
BTEX
GRO
DRO
ORO
creosote

Oxygenates
MTBE
TBA

Perfluorinated
Freon
PFOA, PFBA

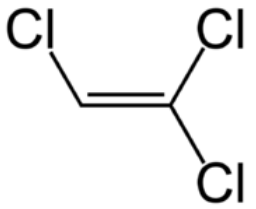
Chlorobenzenes
Chlorobenzene
Dichlorobenzene
Trichlorobenzene

Phenols
Phenol
Chlorophenols
Nitrophenols

PAHs
Anthracene
Benzopyrene
Styrene
Naphthalene
Pyrene
Chrysene
Trimethylbenzene

Pesticides
DDT
Chlordane
Heptachlor
Lindane
Toxaphene
MCPA
Bromoxynil

Energetics
Trinitrotoluene (TNT)
Dinitrotoluene (DNT)
RDX



KLOZUR ONE

ONE Product

ONE Tank

ONE Injection System

ONE Design

KLOZUR® ONE

KLOZUR® ONE

- Activator and Klozur® SP in a single product
  - 95% Klozur SP
  - 5% Activator Blend
- Convenience and ease of use Klozur SP

KLOZUR® ONE

- Soluble all-in-one product
- Key Characteristics
  - Stable in the bag
  - Soluble once batched
  - Aggressive treatment of contaminants
- Other Characteristics
  - pH buffer
  - Multiple activation methods

What is Klozur One?

- 5% Activator Blend
  - Includes trace potassium permanganate (less than 1%) that gives Klozur One its distinct initial color once dissolved
  - Dry phase is off-white color with purple/black and brown specks

What Activates Klozur One?

- Activation mechanisms:
  - Iron-chelate
  - Manganese

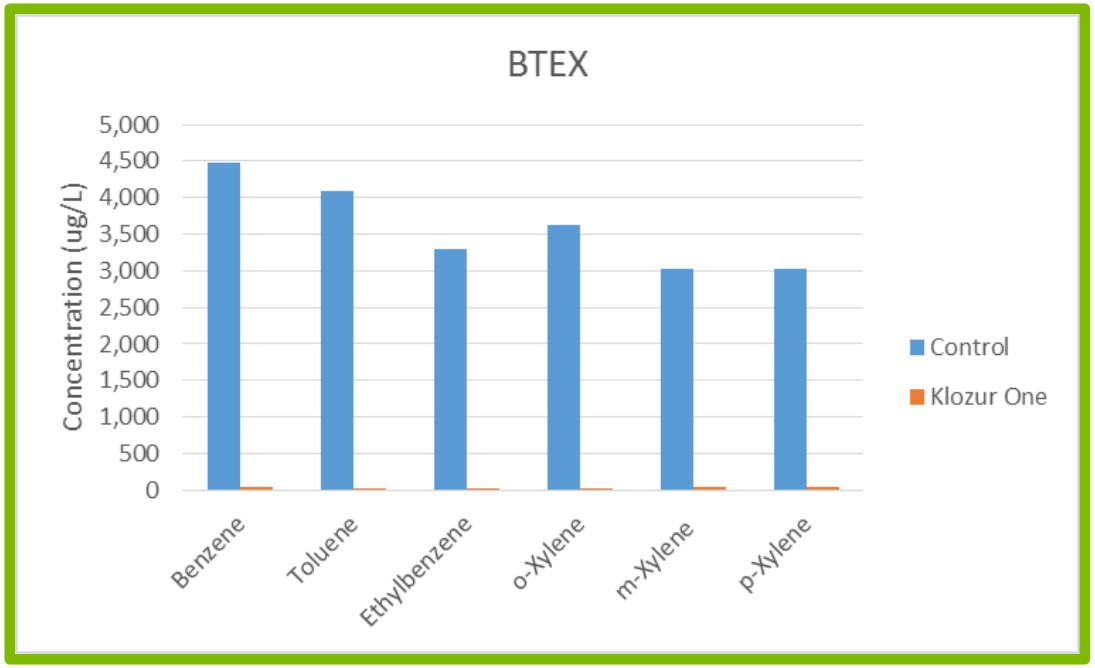
- Built in redundancy to account for natural site variability

Compounds Treated

- Klozur One primarily benefits from the **oxidative pathway**
  - Total petroleum hydrocarbons (BTEX, PAHs, GRO and DRO)
  - Chlorinated ethenes (PCE, TCE, DCE, and VC)
  - Chlorobenzenes
  - 1,4-Dioxane

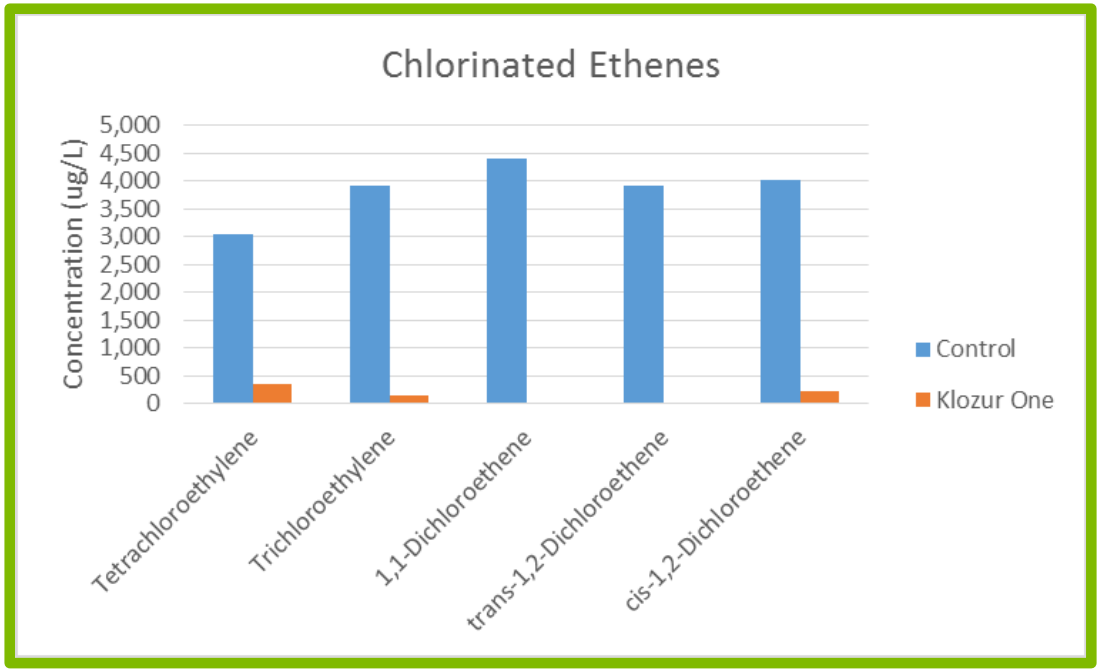
Treatment of BTEX

- Conditions:
  - 21 Days
  - 20° C
  - 50 g/L Klozur One
    - 45 g/L remaining
- Reductions:
  - Benzene: 99.1%
  - Toluene: 99.9%
  - Ethylbenzene: 99.7%
  - Xylenes: 98.4 %



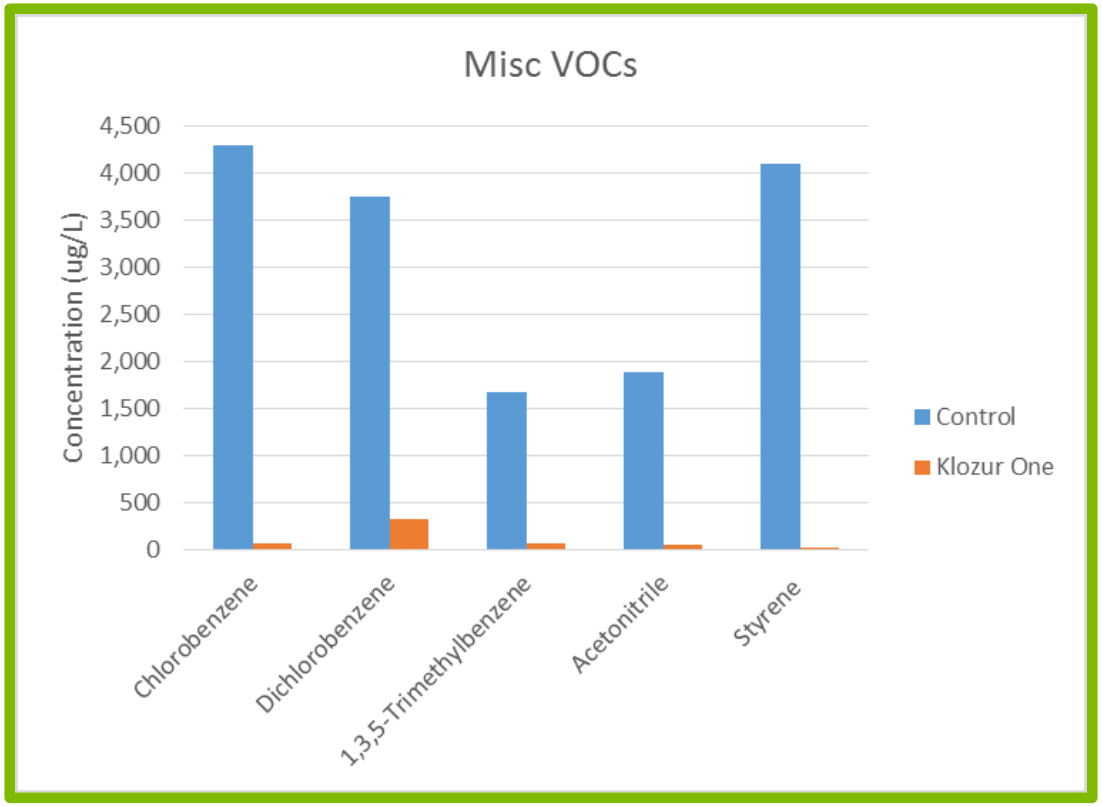
Treatment of Chlorinated Ethenes

- Conditions:
  - 21 Days
  - 20° C
  - 50 g/L Klozur One
    - 45 g/L remaining
- Reductions:
  - PCE: 88.3%
  - TCE: 96.2%
  - 1,1-DCE: 99.8%
  - Trans-DCE: 99.6%
  - cis-DCE: 94.6%



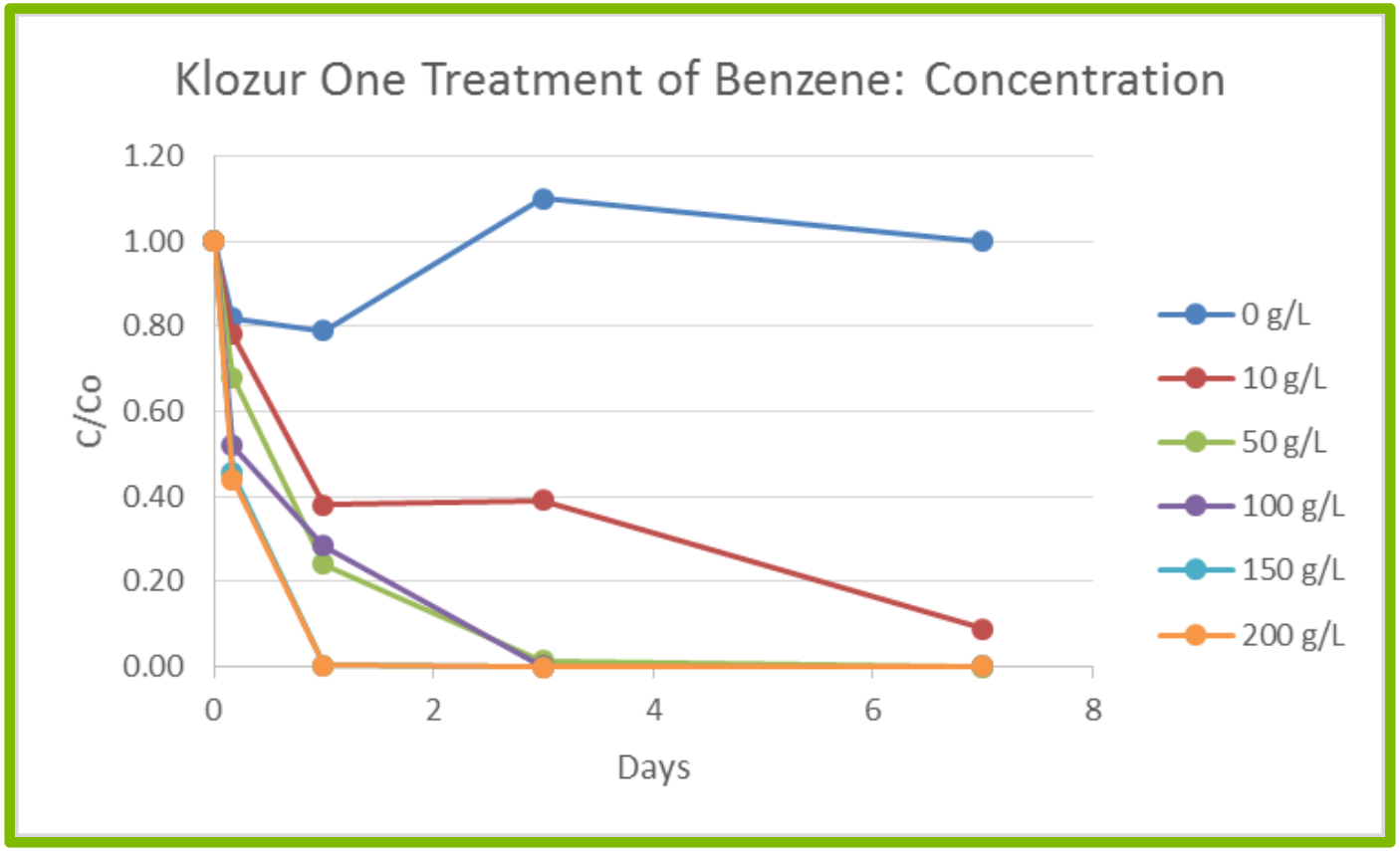
Treatment of Miscellaneous VOCs

- Conditions:
  - 21 Days
  - 20° C
  - 50 g/L Klozur One
    - 45 g/L remaining
- Reductions:
  - Chlorobenzene: 98.5%
  - Dichlorobenzene: 91.5%
  - Trimethylbenzene: 96.2%
  - Acetonitrile: 97.2%
  - Styrene: 99.9%



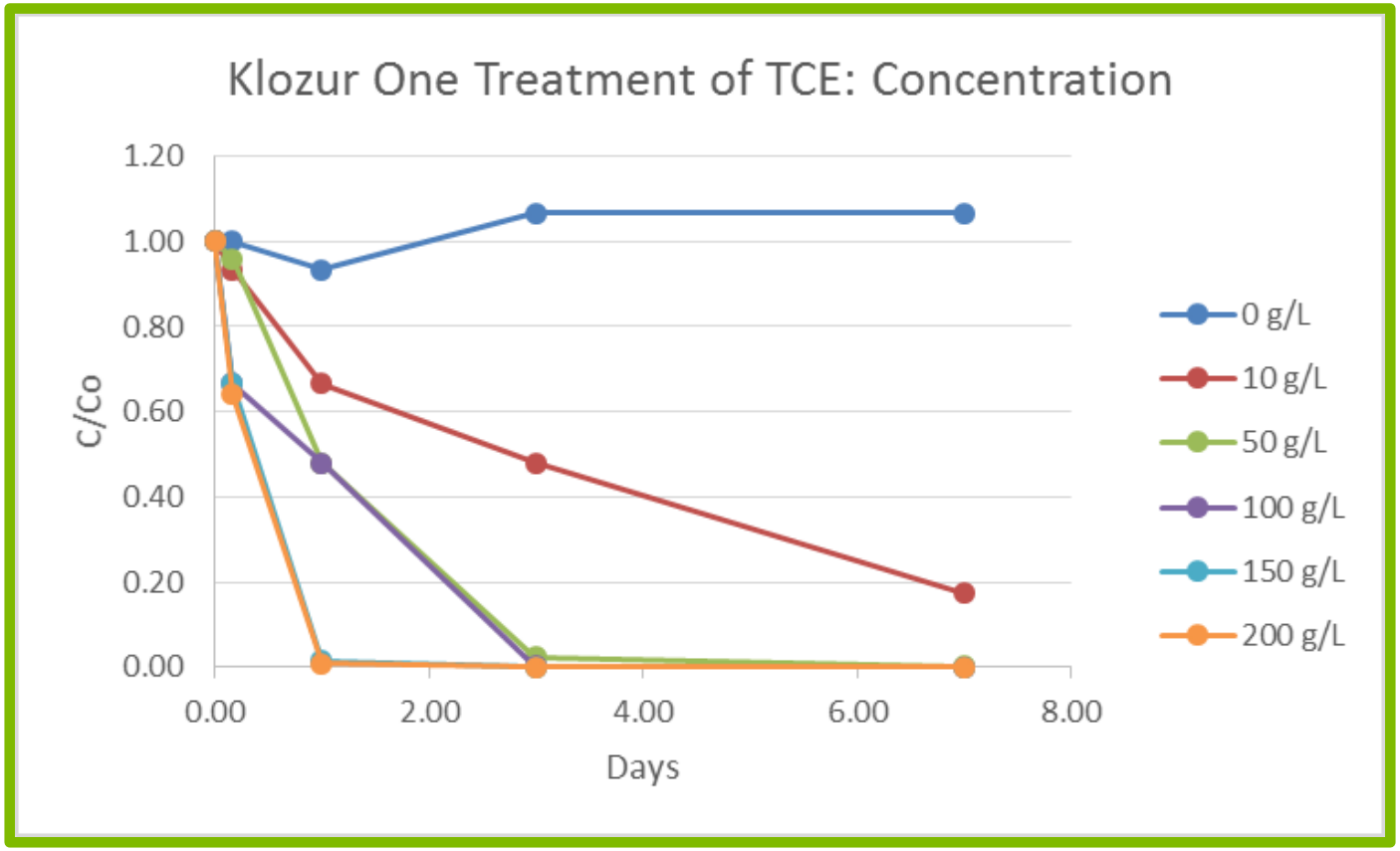
Concentration Based Kinetics

- Varied conc of Klozur One
- 20°C
- 10 mg/L Benzene



Concentration Based Kinetics

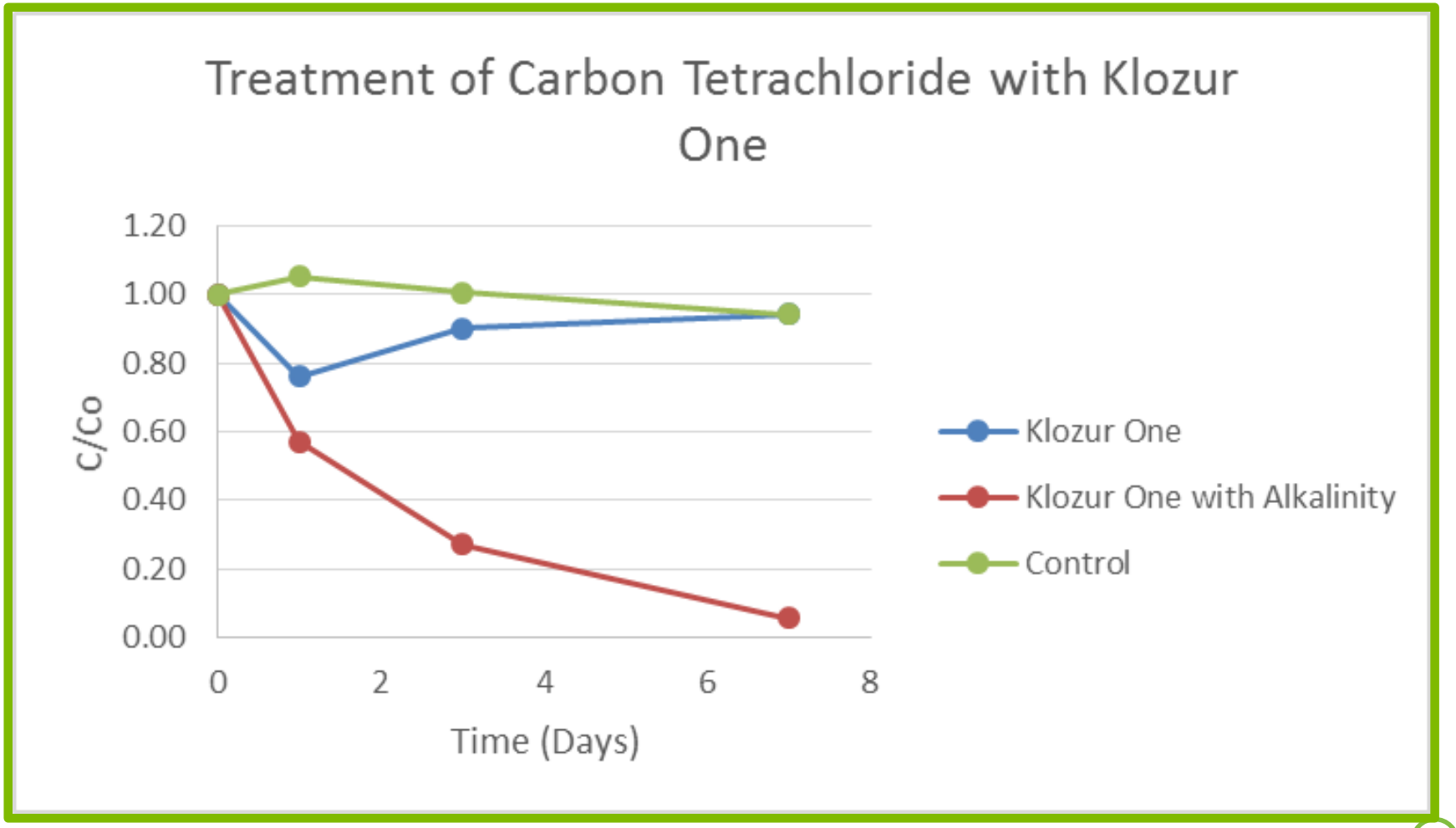
- Varied conc of Klozur One
- 20°C
- 15 mg/L TCE



Reductive Pathway

- Klozur One can generate a reductive pathway with the addition of alkali materials
  - Carbon Tetrachloride, 1,1,1-TCA, etc
- Kinetically more aggressive than Alkaline Activated Persulfate
- Strong alkali
  - NaOH and hydrated lime
    - Heat evolution
    - Will precipitate Fe and Mn
  - Soil mixing

Treatment of Carbon Tetrachloride



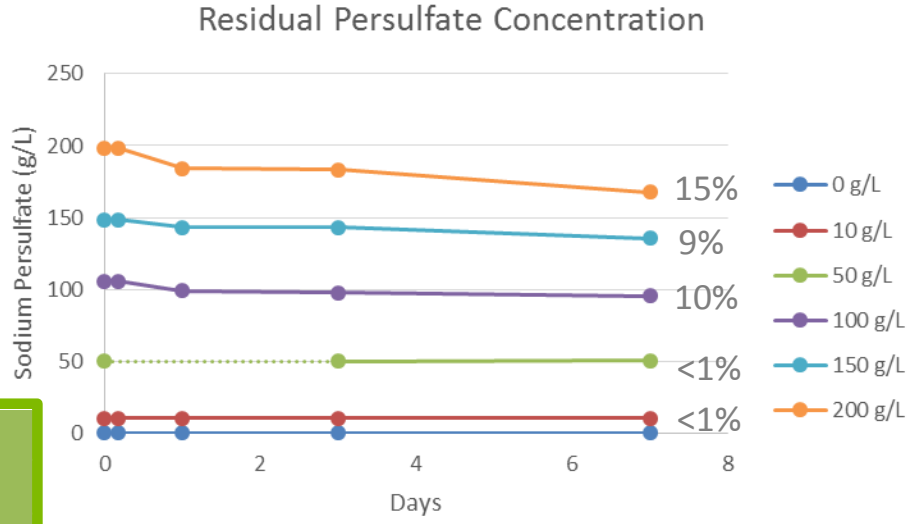
OTHER CHARACTERISTICS

Transportation

- Availability
  - 55.1 lb bags (25 Kg)
  - 2,204 lb supersacks (1,000 Kg)
- UN 1505
- Same oxidizer classification as Klozur SP and Klozur KP (UN Class 5.1 Packing Group III)

Dissolved Stability

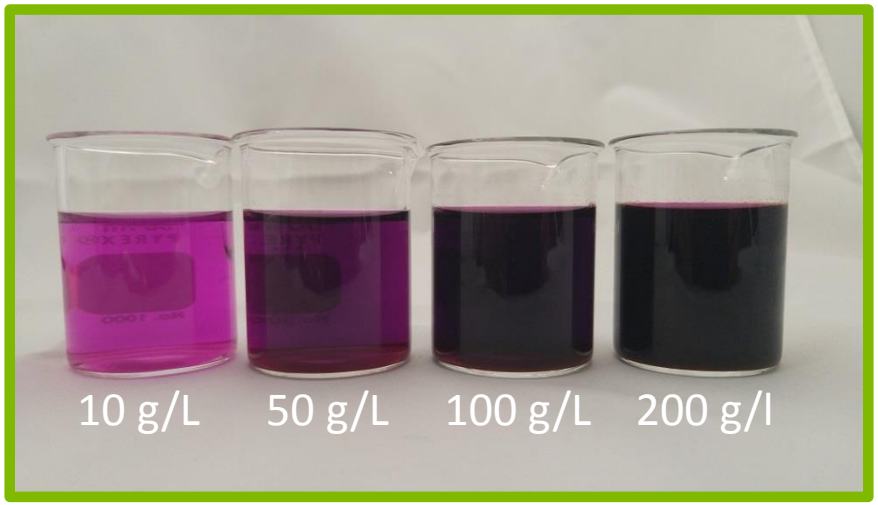
- Residual sodium persulfate
- Temperature (°C)



Temperature in Klozur One Reactors Over Time

Time (hrs)	0 g/L	10 g/L	50 g/L	100 g/L	200 g/L
0	24.0	23.0	22.0	21.0	19.5
1	23.5	23.0	22.0	21.5	21.0
2	23.2	22.9	22.5	22.2	22.2
3	23.0	23.0	23.0	22.9	23.1
4	23.0	22.0	22.9	22.5	23.0
5	22.5	22.0	22.0	22.2	22.5
24	22.0	21.5	20.5	20.0	20.5

Dissolved Klozur One



- Pink to purple depending upon concentration due to the permanganate
- Very low amounts of permanganate (<1%)
  - Not anticipated to stay purple in the subsurface
  - Even after batched, can lose color as permanganate reacts

Compatibility

- Corrosive with carbon steel
  - Similar to iron-chelate activated persulfate
  - Special precautions
    - DPT rods
    - Soil mixing equipment

Alkaline activated persulfate is recommended when using carbon steel

KLOZUR ONE: RECOMMENDATIONS

Recommendations: Injection

- Injection concentrations of between 50 g/L and 200 g/L
- Inject through constructed wells
  - Stainless steel or PVC
  - Corrosive nature will require precautions with carbon steel
- Contaminants:
  - Chlorinated ethenes
  - BTEX
  - PAHs
  - DRO/GRO
  - Chlorobenzenes

Recommendations: Batching

- Batch Concentration = Injection Concentration
- Inject batched solution within 2 to 4 hours
- Batch time increases with concentration
  - 5 to 10 min, or less, is expected given an adequate mixing system
- Chemically compatible tanks, wetted parts or parts that may become wetted.

Recommendations: Onsite Storage

- Store materials as needed for injection
- NFPA 400 guidelines (www.nfpa.org)
  - Code for the Storage of Liquid or Solid Oxidizers
- Storage Guidelines:
  - Store in a cool and dry area
    - Less than 45°C (113°F)
    - Low humidity
  - Store in a manner that is secure from unauthorized personnel
  - Do not store:
    - Near acids, bases, reducing agents, or other oxidizers
    - Near potential sources of fuel
    - Near sources of heat
  - Storage areas have proper egress

KLOZUR PORTFOLIO

Klozur® Portfolio

KLOZUR® SP

- Based on environmental grade sodium persulfate

KLOZUR® ONE

- "All-in-One" product where activator (5%) and Klozur SP (95%) are in the same product

KLOZUR® KP

- Based on environmental grade potassium persulfate

KLOZUR® CR

- "Combined Remedy" with ISCO and ISB from a blend of Klozur SP and PermeOx® Ultra

Portfolio Overview

- KLOZUR® SP
  - Source zone treatment
    - Highly soluble
  - Oxidative and reductive pathways
  - Alkaline activation best for DPT rods/soil mixing
- KLOZUR® ONE
  - Source zone treatment
    - Highly soluble
  - Primarily oxidative pathway
  - Ease of Use
- KLOZUR® KP
  - Permeable Reactive Barriers and low permeable soil treatment
  - Solid/slurry
  - Oxidative and reductive pathways
- KLOZUR® CR
  - Combined remedy of ISCO followed by bioremediation
  - Solid/slurry

Activator Selection Guide

- Klozur One
  - Ease of use
  - Simplicity
  - Convenience
- Alkaline
  - Reductive pathway
  - High concentration sites
  - When contacting carbon steel (DPT, soil mixing, etc)
- Hydrogen Peroxide
  - Reductive pathway
  - Highly contaminated sites
  - Residual oxygen
- Heat
  - Following a thermal application

Activator Selection Guide

KLOZUR® ONE

Activator combined with Klozur SP

KLOZUR® SP

With customizable activators:

- Alkaline
- Fe-Chelate
- Hydrogen Peroxide
- Heat
- ZVI

Site Complexity
(soil mixing, elevated contaminant concentrations, needing reductive pathway, etc)

SUMMARY

Klozur One Summary

- Activation methods with Klozur SP:
  STILL WORK!!!

- Klozur One is a new All-in-One product
  - Combining activator in the same product as Klozur SP
  - Ease of use and convenience

- Transported and handled UN Class 5.1 Oxidizer

- Reacts with most common oxidizable contaminants of concern

Klozur One Resources

- PeroxyChem Technical Managers
- Documents
  - Safety Data Sheet (multiple languages)
  - Product Sheet
  - Application Guide
  - Technical Overview (coming soon)

More information on all Klozur Products: www.klozur.com

Availability

- 55.1 lb (25 kg) bags
- 2,204 lb (1,000 kg) supersacks

- **Late June in North America**

- **Early August in Europe**

ONE Product

ONE Tank

ONE Injection System

ONE Design

KLOZUR® ONE

Environmental Solutions

North American Environmental Solutions Commercial Team

PeroxyChem

Technical Sales Managers

Regionally focused

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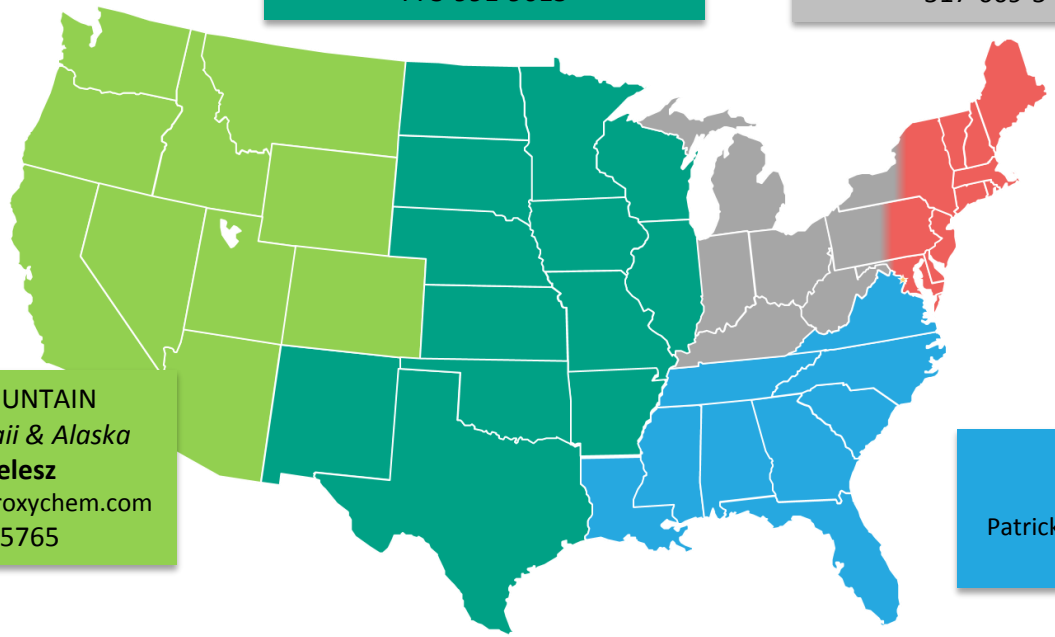

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