

Development of Klozur SP with a Built in Activator

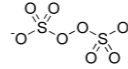
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Persulfate

All Klozur products release the persulfate anion:

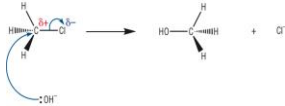


Key Characteristics:

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

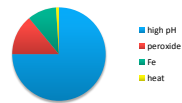
Reaction Pathways

- Oxidative
 - Electrons are taken from contaminants → CO₂
- Reductive
 - Electrons are donated to the contaminants → CH₄
- Nucleophilic
 - Substitution reaction (electron neutral)



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

Fluorinated

Freons
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



All-In-One Products

- Definition:
 - Activator and persulfate combined into a single product
- Klozur CR was first to market with this concept
 - Others have since been released
 - Klozur CR is injected as a solid-slurry

Development Objectives

- Soluble: Injected through well screens
- Stable in the bag: Large package
- Stable once dissolved
- Aggressive treatment of contaminants
- Other Characteristics
 - pH buffer



KLOZUR[®] ONE

- 95 Percent Klozur SP (sodium persulfate)
- 5 Percent Chelated Metal Activation blend:
 - Iron-chelate
 - Manganese (permanganate)
 - pH buffer



Stability in Bag

- Klozur One Blend:
 - UN 1505
 - Same oxidizer classification as Klozur SP and Klozur KP (UN Class 5.1 Packing Group III)
- Bag Type
 - 55.1 lb (25 Kg)
 - 2,204 lb super sack (1,000 Kg)



Original challenge of organic activation

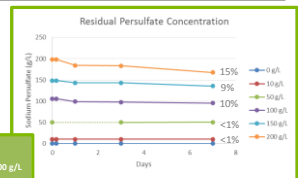


Klozur One



Dissolved Stability

- Residual sodium persulfate
- Temperature (°C)



| 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 |

- Klozur One stable once dissolved
 - Temperature
 - Residual concentration
 - Higher concentrations



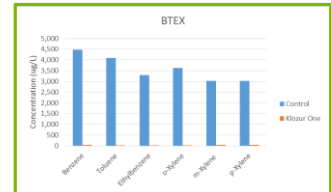
Compounds Treated

- 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



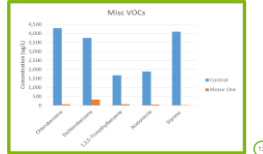
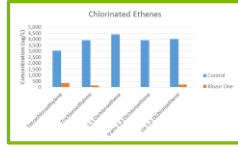
Treatment of BTEX

- 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 %



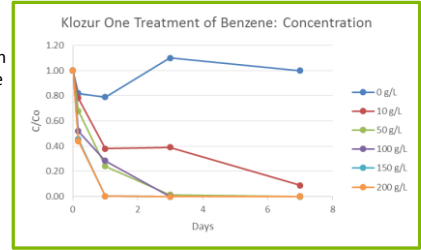
Chlorinated Ethenes and Others

- Chloroethene reductions:
 - PCE: 88.3%
 - TCE: 96.2%
 - 1,1-DCE: 99.8%
 - Trans-DCE: 99.6%
 - cis-DCE: 94.6%
- Misc. VOC reductions:
 - Chlorobenzene: 98.5%
 - Dichlorobenzene: 91.5%
 - Trimethylbenzene: 96.2%
 - Acetonitrile: 97.2%
 - Styrene: 99.9%



Concentration Based Kinetics

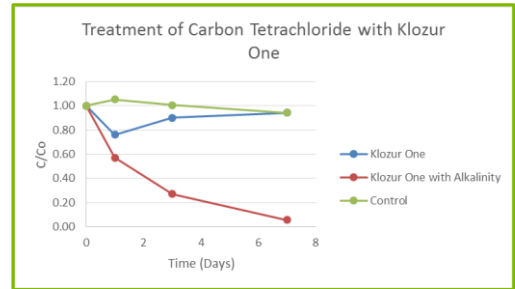
- Varied the concentration of Klozur One
- 20°C
- 10 mg/L Benzene



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



Summary

- Klozur One is a new All-in-One product
 - Stable in bag
 - Stable in solution
 - Completely soluble activator system
 - Treatment of contaminants of concern via oxidative pathway

Questions

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