

# Activated Persulfate and Its Impact on Microbial Populations



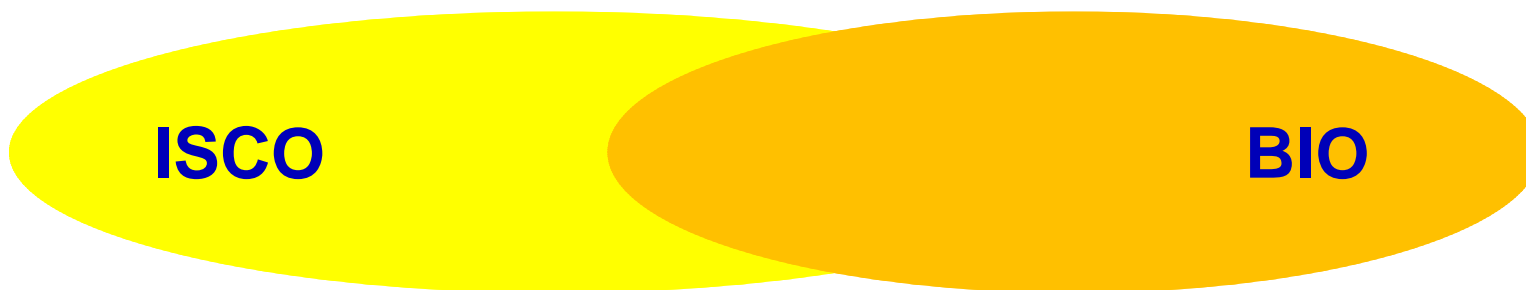
**KLOZUR®**

Solutions for a cleaner earth.

# Chemical Oxidation vs Bioremediation

## Contaminant Concentration

> 50 ppm    10 ppm    1 ppm    500 ppb    200 ppb    100 ppb    < 50 ppb



source

down gradient →

plume

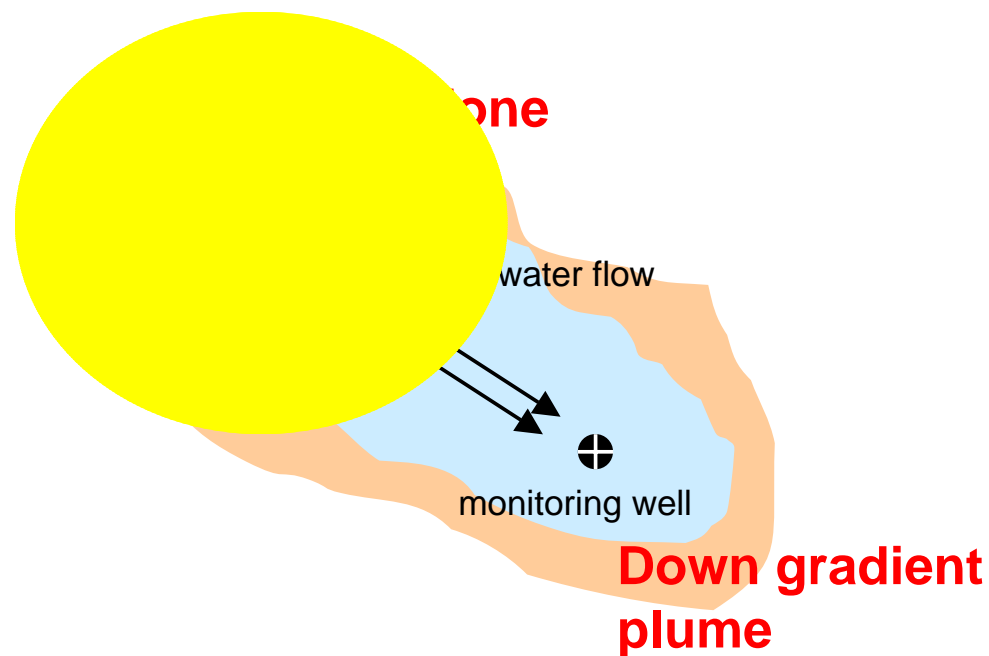
Contaminant Source

# Chemical Oxidation vs Bioremediation

## Possible Treatment Train Approach

- spatially
- temporally

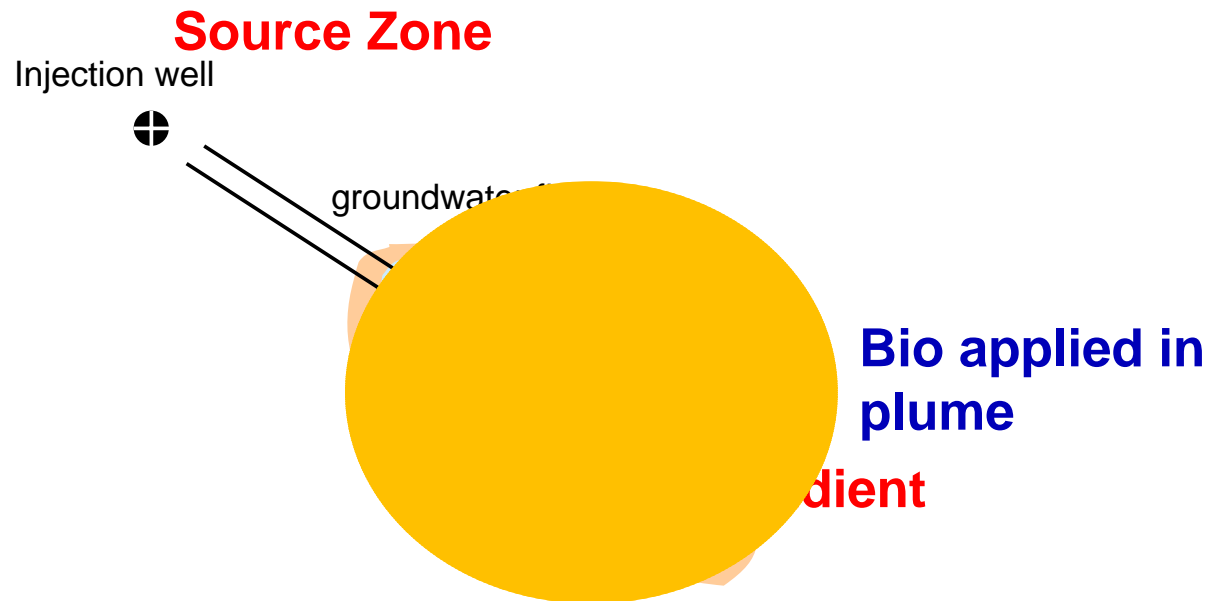
**ISCO applied first  
in source zone**



# Chemical Oxidation vs Bioremediation

## Possible Treatment Train Approach

- spatially
- temporally



- will ISCO interfere with BIO?

# Persulfate ISCO impact on microbial populations



## Questions:

**Can you stimulate bioremediation process post *in situ* chemical oxidation with activated persulfate?**

- does persulfate ISCO sterilize soil?
- does persulfate ISCO impede bioprocesses?
- can persulfate ISCO be beneficial?

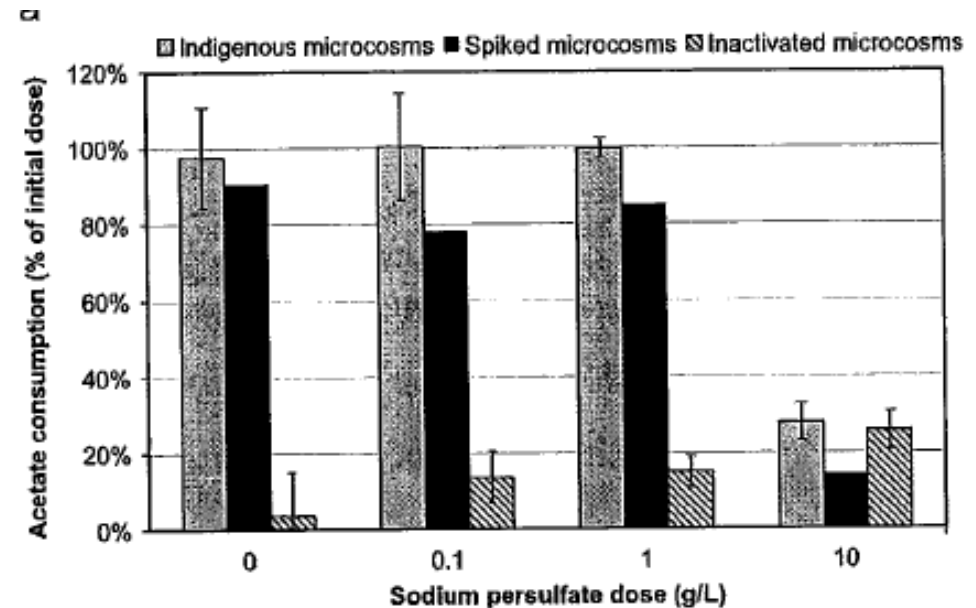
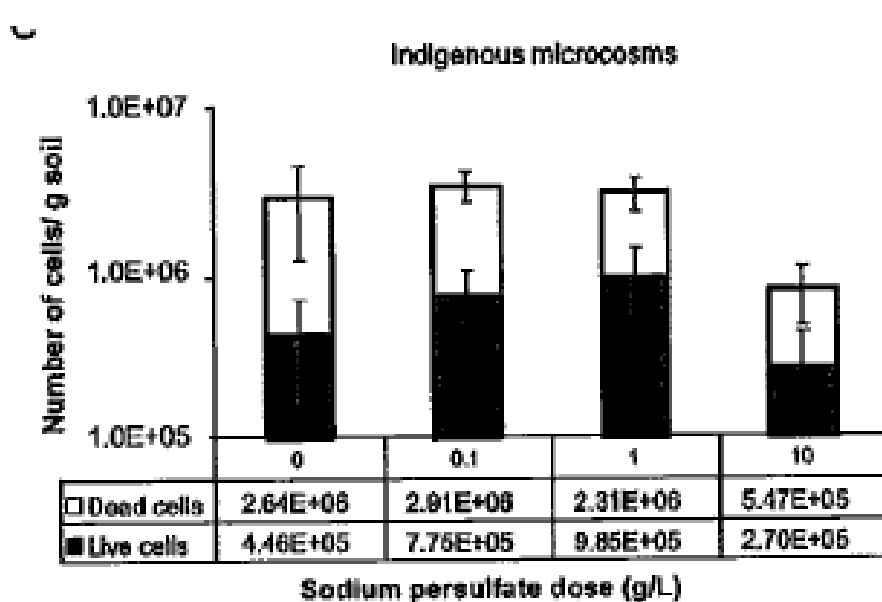
**Can you have a successful treatment train of ISCO with bioremediation?**

- can ISCO and bioremediation be part of an overall treatment approach?

# Background

## Impact on Microbial Population

- Historical research
  - Indigenous microbial populations in soil showed a high degree of resistance in terms of cellular integrity to heat (40 C) activated persulfate
    - Tsitonaki et al (**Water Research** 42, 2008)



Impact on microbial population

Impact on acetone consumption

# Background

## Impact on Microbial Population



Little impact on indigenous cell concentrations when exposed to iron activated persulfate

Bou-Nasr et al (5<sup>th</sup> Battelle Conf on Chlorinated / Recalcitrant Compounds, 2006)

Biomass not significantly altered and sulfate reducing bacteria (SRB) remain present and active when soil is treated with persulfate, activated by FeEDTA, FeCitrate or high pH

Crimi et al (5<sup>th</sup> ORTs Conference, 2007)

Enhancement of reductive dechlorination of TCE observed in the field post application of persulfate

Droste et al (3<sup>rd</sup> Battelle Conf on Chlorinated / Recalcitrant Compounds, 2002)

# Impact on Aerobes Field Study

## West Central Alberta diesel and gasoline plume site

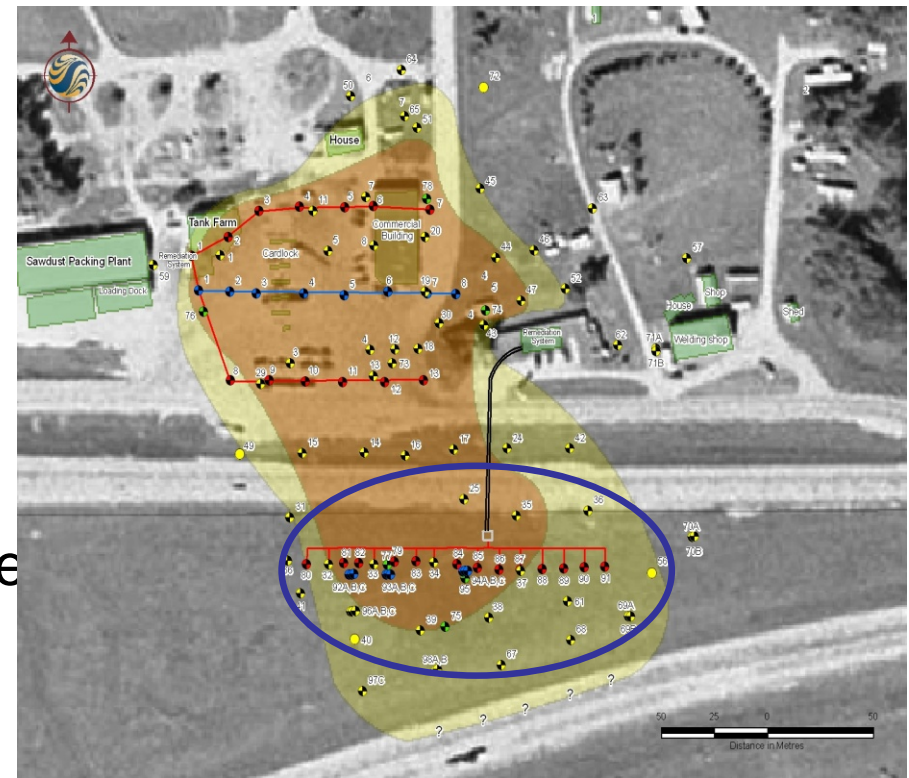
### Contaminants:

BTEX, fuel constituents F1 and F2



**Lithology:** alternating layers of siltstone / mudstone and sandstone

**Application:** 1600 lbs of Klozur CR

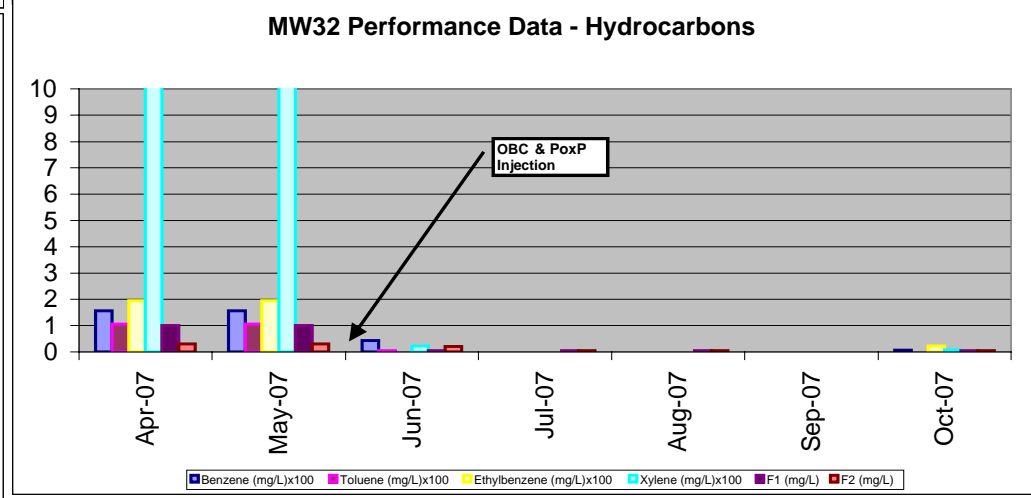
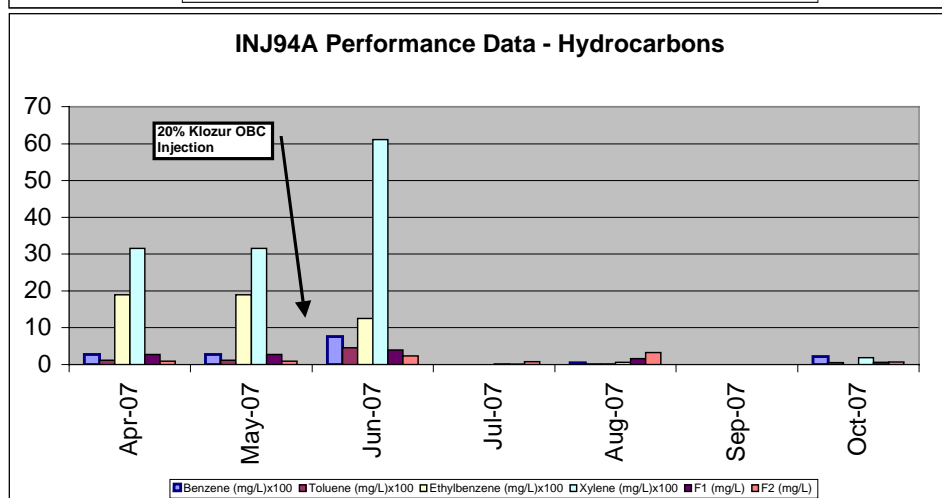
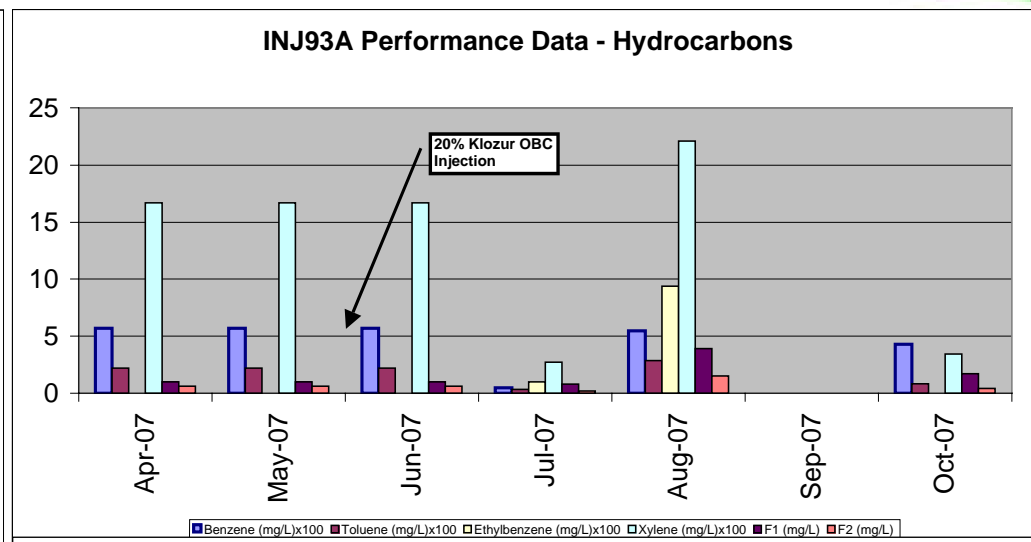
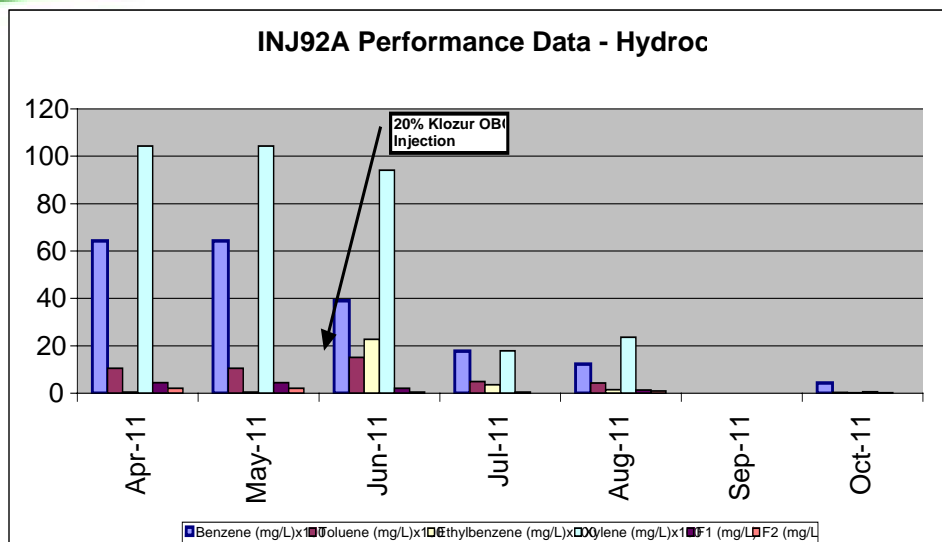
- combination of persulfate and calcium peroxide



**Data courtesy of:  
Jim Studer, InfraSUR**

-  Portion of plume with dissolved phase
-  Portion of plume with diesel / gas NAPL

# Impact on Aerobes Field Study



**Significant chemical oxidation of BTEX, F1 and F2 occurred**

# Impact on Aerobes Field Study



## Biological Assay

- **Bio-Traps<sup>®</sup> deployed with C<sup>13</sup>-labelled benzene substrate**
  - **capture and enumerate native microbial populations**
  - **determine carbon utilization rate (measure of microbial life functions)**



**Bio-Trap from  
Microbial Insights**

## Results

- **Near complete reductions of contaminants in all pilot monitoring wells**
- **microorganism populations reduced initially, but rebounded quickly (both aerobic and anaerobic)**
- **benzene utilization observed post ISCO application (0.023 – 0.043 mg / day)**

# Impact on Anaerobes Sulfate Reducing Bacteria (SRBs)



**KLOZUR®**  
Solutions for a cleaner earth.

## W. Michigan Lab Study Prof. Dan Cassidy

- contaminated sediments from Kalamazoo River
- study incorporated 3 dosages of Klozur CR
  - 4 g / kg sediment
  - 10 g / kg sediment
  - 20 g / kg sediment



Stirred tank reactor

### % reductions from control

Dose	MeHg <sup>1</sup> (%)	PCB <sup>2</sup> (%)	PAH <sup>2</sup> (%)	NOM (%)
Dose 1	>99.96	31	27	22
Dose 2	>99.96	59	61	37
Dose 3	>99.96	91	88	43

Initial mg/kg

6400

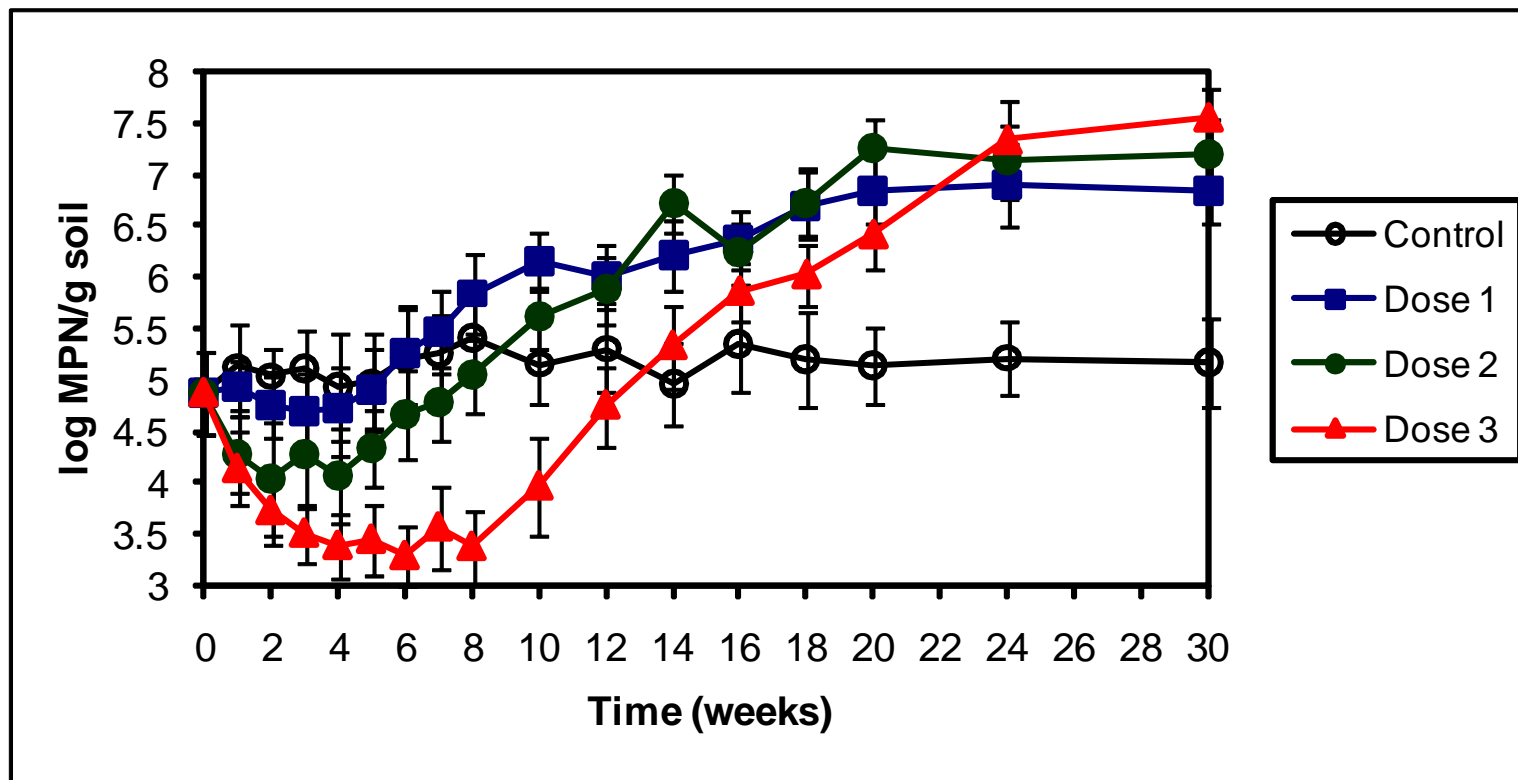
8300

<sup>1</sup> time= 5-10 days

<sup>2</sup> time= 4-8 weeks

# Impact on Anaerobes SRBs

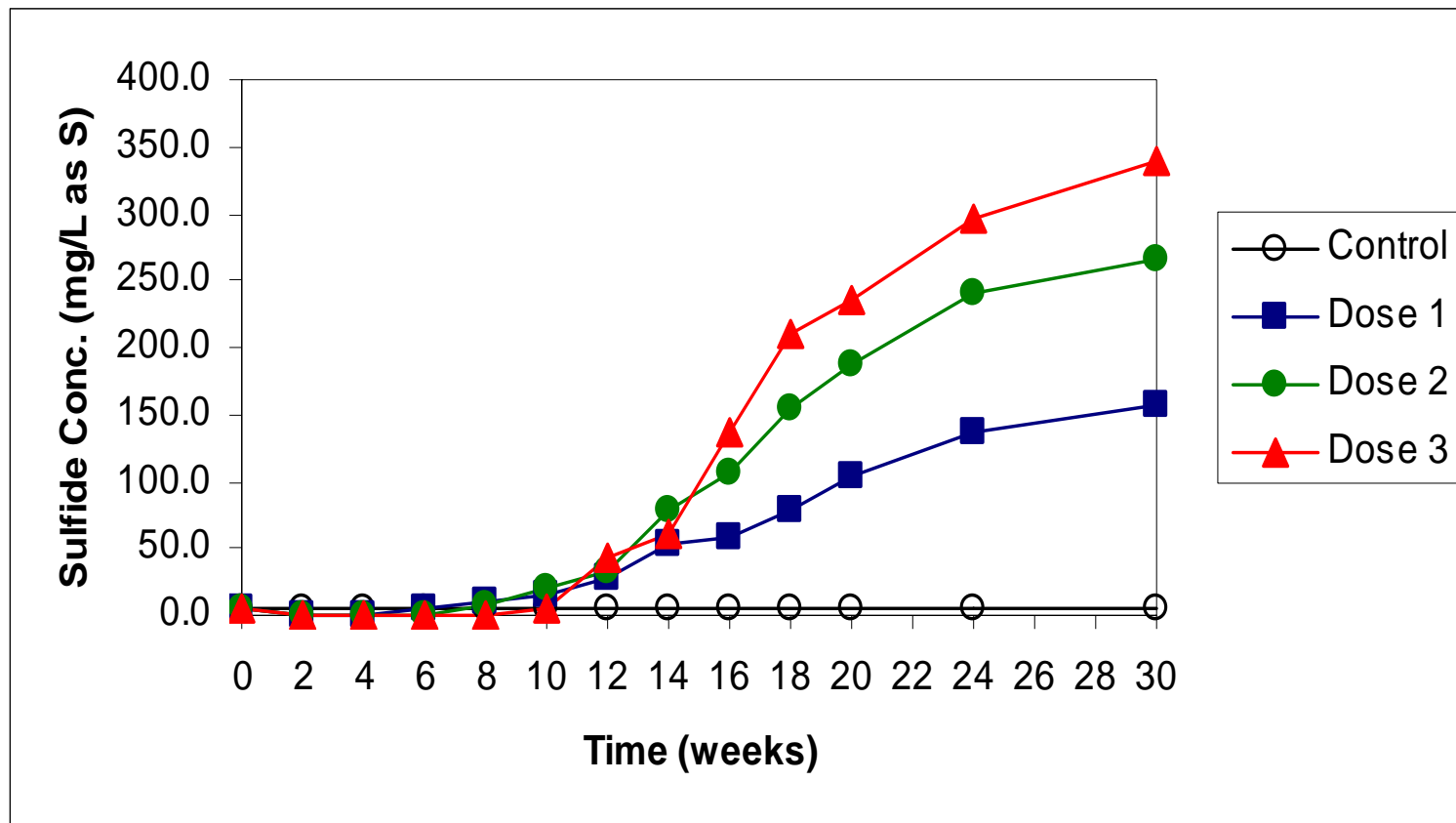
## MPN of Sulfate Reducing Bacteria (SRB)



SRB survive high doses of persulfate

# Impact on Anaerobes SRBs

## Sulfide Production



Biological function remains intact

# Impact on Anaerobes SRBs



## HgS formation after 30 weeks

Dose	[HgS] ( $\mu\text{g}/\text{kg}$ )*	% total Hg
Control	22.5	11.1
Dose 1	104.7	51.6
Dose 2	135.2	66.6
Dose 3	169.7	83.5

\*[HgS]=203  $\mu\text{g}/\text{kg}$  if all Hg precipitated as cinnabar.

# Impact on Anaerobes SRBs



## Conclusions from the W. Michigan Study:

- Klozur® CR oxidized all contaminants in a sediment high in NOM (>14%)
- Native SRB survived the highest dose (20 g/kg) and thrived soon afterwards
- SRB produced sulfide within weeks
- >80% of Hg precipitated as HgS after 30 weeks
- No MeHg produced

# General Conclusions



- Activated persulfate will negatively impact aerobic and anaerobic populations in the short term (1 – 2 months)
- Aerobic and anaerobic populations will rebound (potentially in excess of original concentrations)
- Microbial bio-processes are not inhibited
- Activated persulfate /ISCO can be couple with subsequent bioremediation approaches

# Questions?



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