Agenda

Introduction
Background
Pilot Test Design
Field Results
Ongoing Efforts
Conclusions
Background
Sulfolane Use Onsite

- $\text{C}_4\text{H}_8\text{SO}_2$
- Industrial solvent used as a sweetening agent in sour gas processes
- Historically used onsite from the 1960s to the 1980s
- Biodegradation Pathways:

1) $\text{C}_4\text{H}_8\text{O}_2\text{S} + 6.5\text{O}_2 \rightarrow 4\text{CO}_2 + 3\text{H}_2\text{O} + 2\text{H}^+ + \text{SO}_4^{2-}$ (Greene et al., 2000)
2) $5\text{C}_4\text{H}_8\text{O}_2\text{S} + 18\text{NO}_3^- \rightarrow 20\text{HCO}_3^- + 9\text{N}_2 + 5\text{HS}^- + 7\text{H}^+ + 4\text{H}_2\text{O}$ (Greene et al., 1998)
3) $\text{C}_4\text{H}_8\text{O}_2\text{S} + 9\text{MnO}_2 + 5\text{HCO}_3^- \rightarrow 9\text{MnCO}_3 + 4\text{H}_2\text{O} + \text{HS}^- + 4\text{OH}^-$ (Greene, 1998)
4) $\text{C}_4\text{H}_8\text{O}_2\text{S} + 10\text{H}_2\text{O} + 18\text{Fe}^{3+} \rightarrow \text{S}^{2-} + 18\text{Fe}^{2+} + 4\text{HCO}_3^- + 24\text{H}^+$ (Greene, 1999)
5) $4\text{C}_4\text{H}_8\text{O}_2\text{S} + 4\text{H}_2\text{O} + 9\text{SO}_4^{2-} \rightarrow 13\text{HS}^- + 16\text{HCO}_3^- + 11\text{H}^+$ (Greene, 1999)
6) $\text{C}_4\text{H}_8\text{O}_2\text{S} + 1.5\text{H}_2\text{O} \rightarrow 1.75\text{CO}_2 + 2.25\text{CH}_4 + \text{H}_2\text{S}$ (Greene et al., 1998)
Complex Fracture Bedrock
Pilot Test Design
Objectives

- What is the goal?
- How do we measure the success of the pilot?
  1. Increase dissolved oxygen concentrations
  2. Decrease dissolved plume sulfolane concentrations
  3. Provide evidence to support \textit{in situ} biodegradation is the dominant mechanism of decreased sulfolane concentrations
Biosparging and Monitoring Well Network

- **Biosparging Wells**
  - 12m Interval - 3 wells
  - 17m Interval – 3 wells

- **Monitoring Network**
  - 7m Interval – 8 wells
  - 12m Interval – 14 wells
  - 17m Interval – 14 wells
Biosparging and Monitoring Well Network

Injection Depths

Monitoring Depths

4m to 7m
9m to 12m
14m to 17m

14m to 17m
10m to 13m
4m to 7m
Groundwater Monitoring Program

- Sulfolane and Dissolved Oxygen
- Traditional Geochemistry
- Microbial Testing
Field Results
Dissolved Oxygen Concentrations – 17m Interval
Sulfolane Concentrations – 17m Interval

Baseline August 2017

December 2017
January 2018
February 2018
March 2018

April 2018
May 2018
June 2018
July 2018
August 2018
Biodegradation – Total Bacteria via qPCR (16S rRNA)
Biodegradation – Sulfolane Degrading Bacteria Plate Counts
Biodegradation of Sulfolane – Colony Identification
Ongoing Efforts
Sulfolane Treatability Study #2

- Three treatments – groundwater inoculated, *Acidovorax* isolate inoculated, uninoculated killed controls (negative controls)
- 6 time steps per treatment
- Incubated at room temperature at 100 rpm
- Sterile foam stoppers used to allow gas headspace exchange and avoid oxygen limitation
- Samples analyzed for sulfate as a proxy for sulfolane degradation (analytical cost)

\[ C_4H_8O_2S + 6.5O_2 \rightarrow 4CO_2 + 3H_2O + 2H^+ + SO_4^{2-} \] (Greene et al., 2000)
Aerobic Treatability Study – Groundwater Inoculum

\[ C_4H_8O_2S + 6.5O_2 \rightarrow 4CO_2 + 3H_2O + 2H^+ + SO_4^{2-} \] (Greene et al., 2000)
Microbial Community Analysis

• Quarterly samples collected for community analysis (16s rRNA gene)
• Coupled to culture-based isolation effort
• **Goal:**
  - Track increases/decreases of key sulfolane degraders in count and abundance over space and time
• Key sulfolane-degrading genera being tracked
  • *Acidovorax*
  • *Acinetobacter*
  • *Pseudomonas/Stenotrophomonas*
  • *Rhodoferax*
  • *Shinella*
Conclusions
Conclusions

• Objectives:
  1. Increase dissolved oxygen concentration✓
  2. Decrease dissolved plume sulfolane concentration✓
  3. Provide supporting evidence that *in situ* biodegradation is occurring due to biostimulation with oxygen✓

• Further work needed to identify and track dominant sulfolane degraders to show enhancement of *in situ* biodegradation
Questions?
Extra Slides