Field Remediation Trials for Sulfolane Impacted Soil and Groundwater: Aeration, Nutrient Amendments and/or Peroxide?


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Sulfolane

➢ Used in Sulfinol for sour gas sweetening since 1960s

➢ Human health related guidelines

➢ Poorly adsorbed to soil

➢ High solubility in water

➢ Microbial degradation slow in typical groundwater conditions

➢ Clear, colourless, no field indicators (visual or olefactory)

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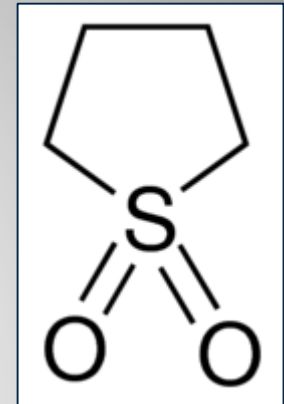
Sulfolane

- Microbial degradation rapid in aerobic environments and surface water (CCME, 2006)

  - $C_4H_8O_2S + 6.5O_2 \rightarrow 4CO_2 + 3H_2O + 2H^+ + SO4^{2-}$

  - Nutrients improve degradation times

  - Low pH conditions inhibit degradation

  - Typical degradation times: 2 to 4 days at 28°C

and 8 to 12 days at 8°C (Green et al., 1998), average air temperatures during trials ranged from 6.9 to 14.1°C

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Sulfolane: Previous Remediation Approaches

Groundwater and Soil

➢ Oxygen and nutrients (soil tilling, blowers) (Biogenie, 2006)

Groundwater

➢ Activated Sludge Treatment System (WorleyParsons Komex, 2008)

➢ Oxidants (e.g., hydrogen peroxide) and/or UV light

  ➢ Mixed success (Barr Engineering, 2013; Gallegos et al., 2013; EBA, 2015)

  ➢ Peroxide and iron catalyst shown to be more effective than peroxide (Gallegos, 2013)

  ➢ No sulphate as by-product

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Site Description

➢ Site is an operating gas plant located in southern Alberta

➢ Constructed in 1960s

➢ Sulfolane investigation and monitoring since 1994

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Landfill Area: History

- ➢ No active facilities
- ➢ Downgradient of active facilities
- ➢ Majority of plant waste stored here before the 1980s
- ➢ Potential materials disposed: alumina catalyst, filters (compressor, sulfinol, salt water, glycol, solvent receiver), zeolite, etc.
- ➢ Cells (but likely not soil) excavated in 1993

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Landfill Area

- ➢ Predominately sulfolane and EC (sulphate) issues
- ➢ Currently >10,000 tonnes of sulfolane impacted soil
- ➢ Impacts extend into groundwater and bedrock around former landfills

Soil Impacts	Water Impacts
Sulfolane	Sulfolane
Electrical Conductivity (EC) (predominately sulphate)	Sulphate
Minor DIPA, hydrocarbon, elemental sulphur impacts	DIPA

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Site Setting
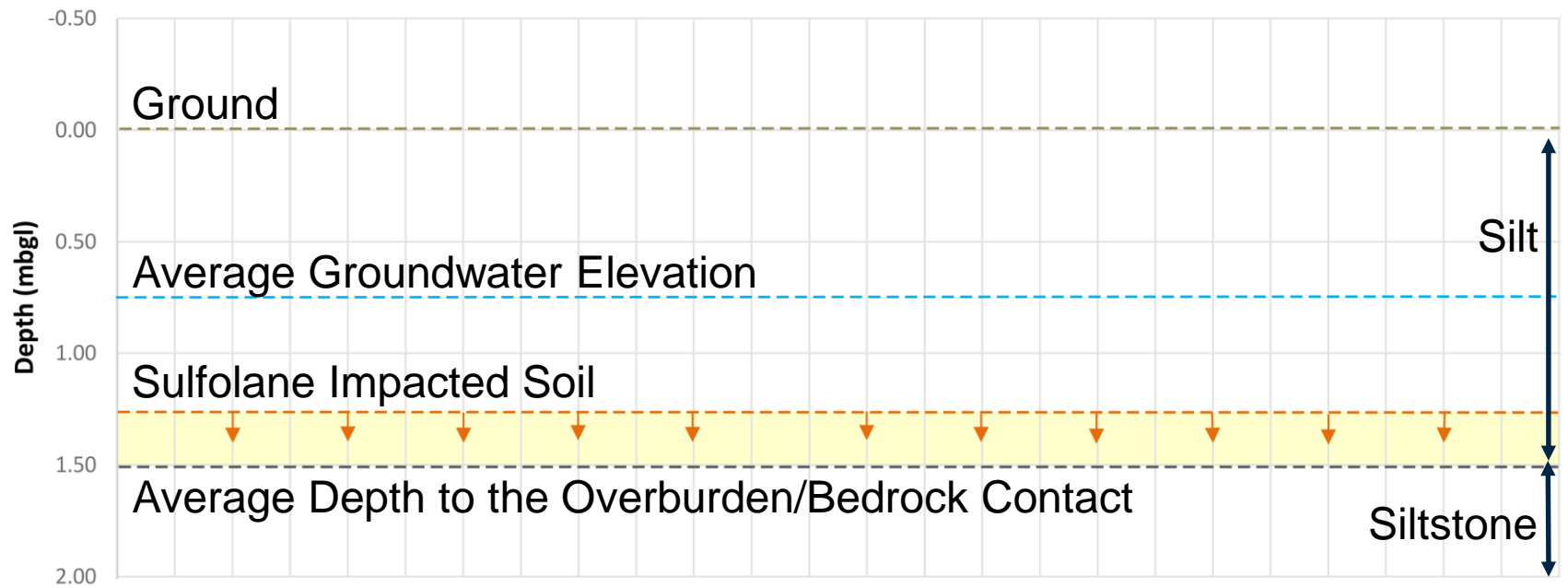
Soil Remediation: Trials

➢ Control
➢ Aeration
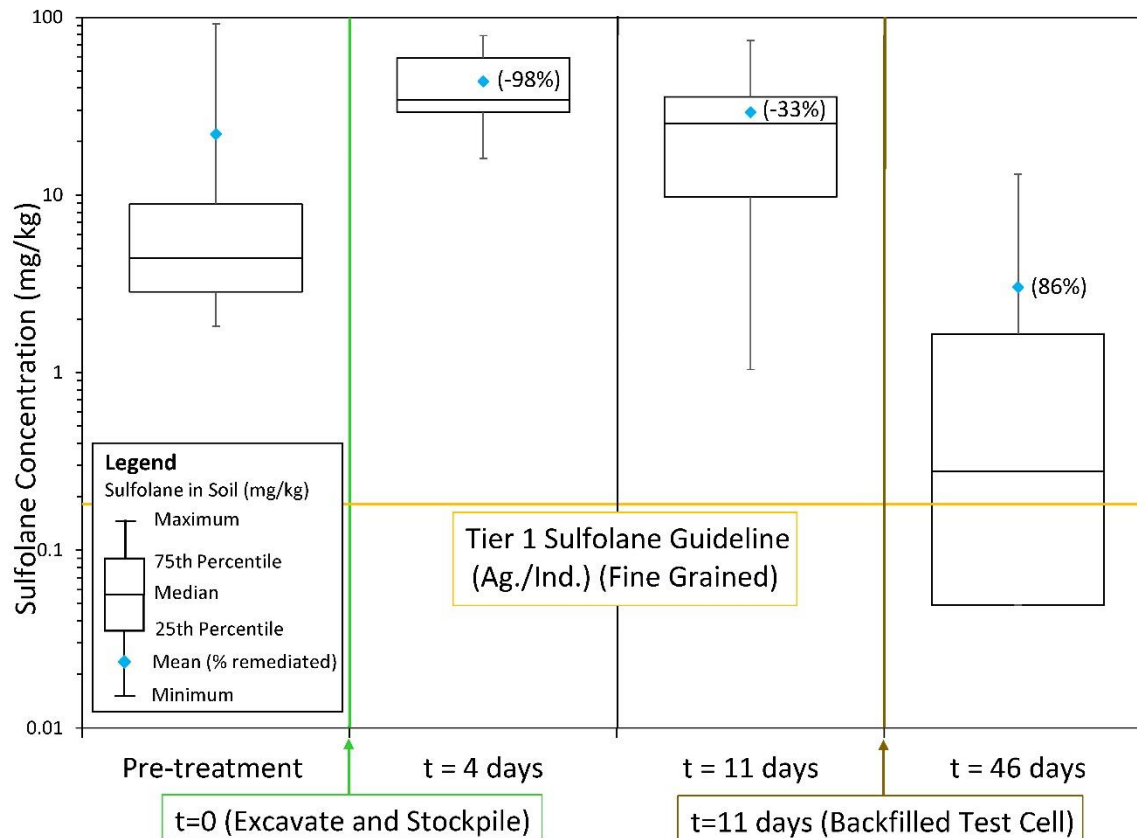➢ Aeration and Nutrient Amendment
➢ Hydrogen Peroxide

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Soil Remediation: Methods

- ➤ Treated ~10 m^3 impacted soil/test cell
- ➤ Excavated and stockpiled treated soil for 11 days
- ➤ Lined and backfilled test cells after 11 days
- ➤ Sets of 5 soil samples collected ~3 to 45 days after remediation activities
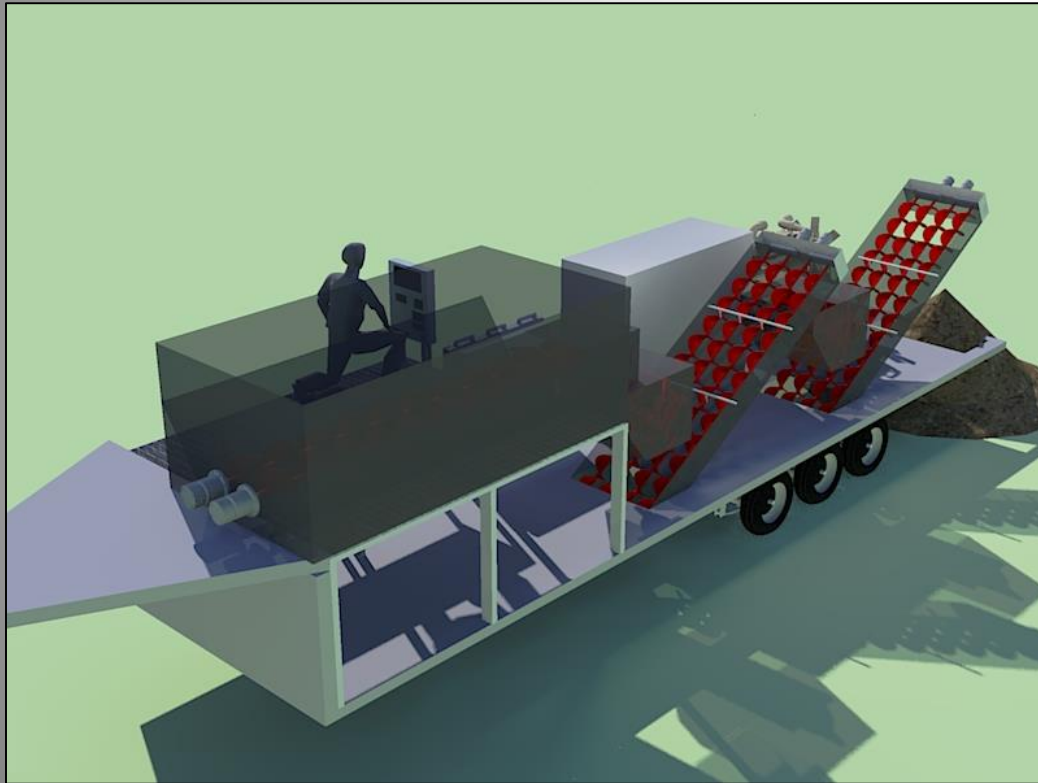

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Soil Remediation: Control

➢ Heterogeneous sulfolane concentrations

➢ Potential outliers

Soil Remediation: Soil Oxidative Blender

➢ Two hammer mills and rotating augers to homogenize soil
➢ Timeline: Hours to complete, issues with wet silt during trials not typically encountered with clay
➢ Trials included:
   ➢ Aeration
   ➢ Aeration/nutrient amendment
   ➢ Hydrogen peroxide/UV

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# Soil Remediation: Soil Oxidative Blender Aeration
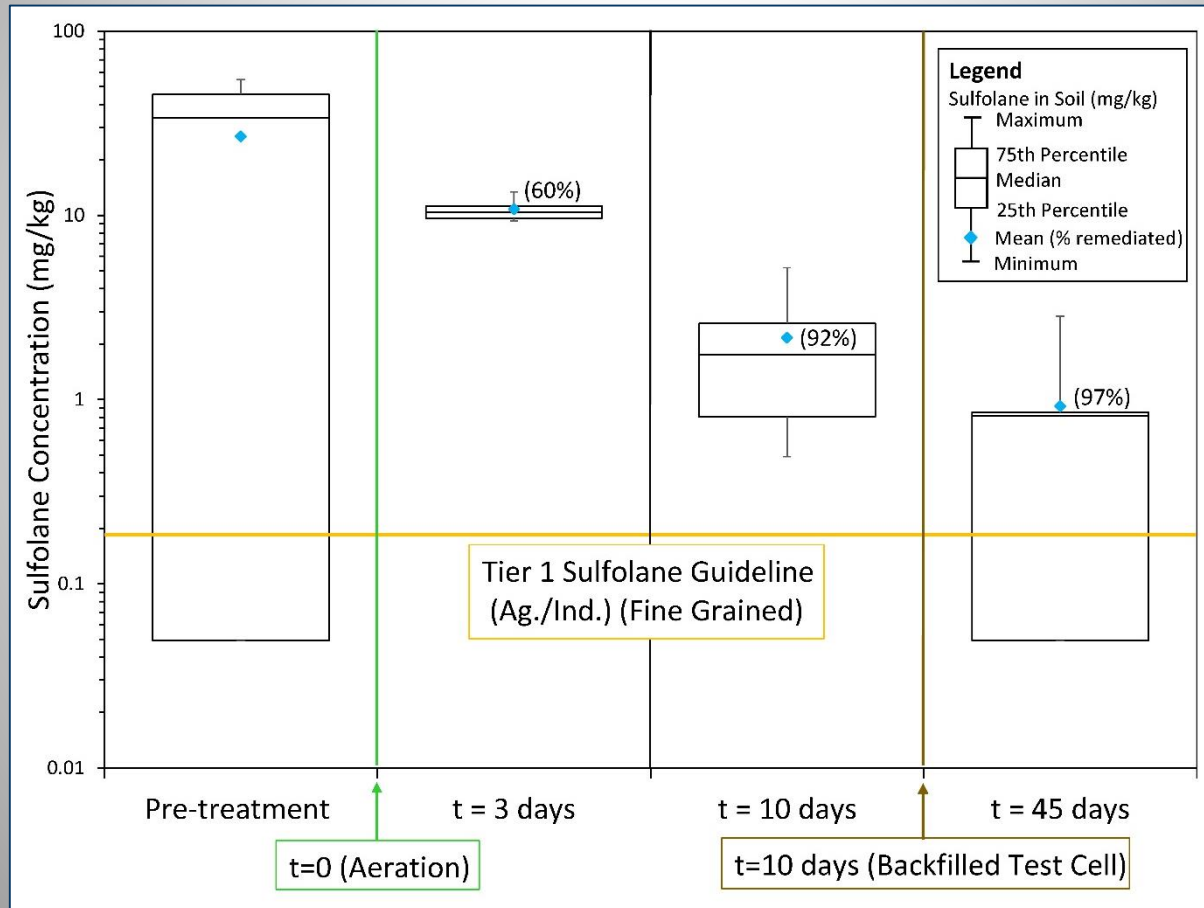
Soil Remediation: Soil Oxidative Blender Aeration and Nutrient Amendment
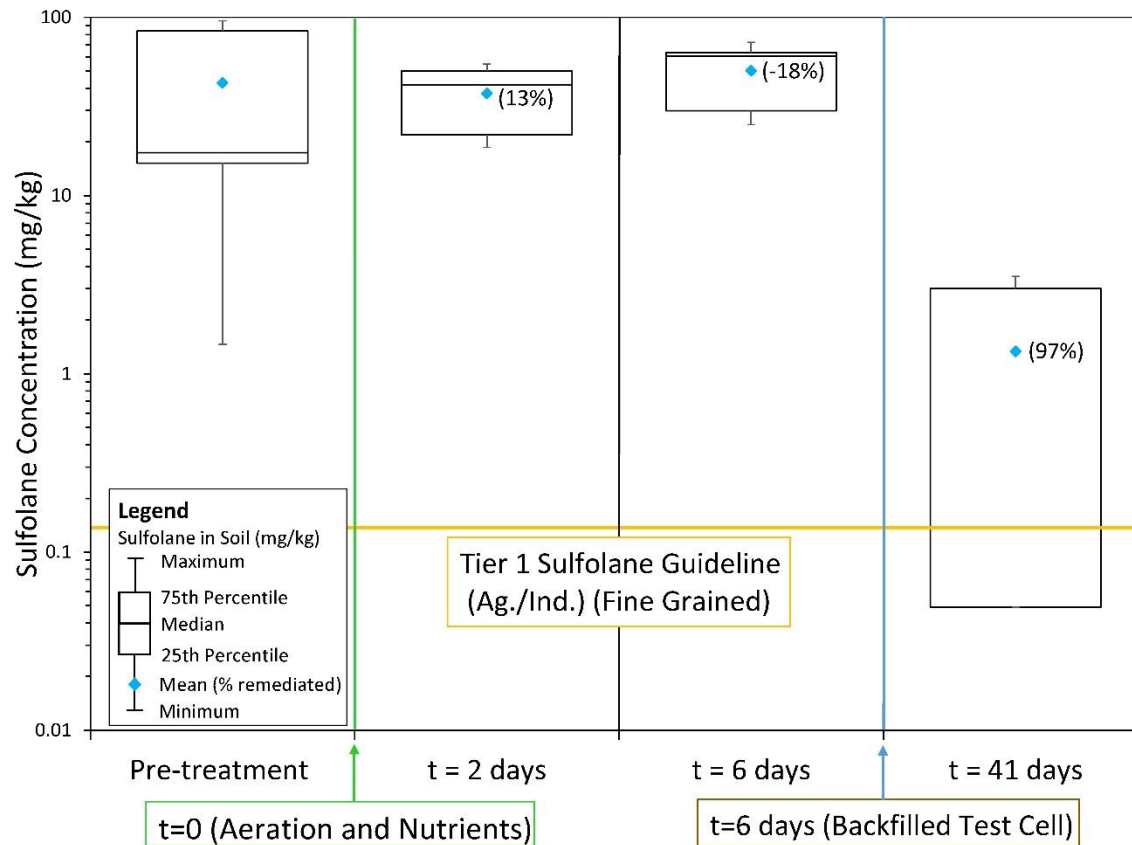
➢ N:P:K ratio 28:14:14, 200 mg/kg dose

➢ Identical results to aeration only indicate that the fertilizer application did not have a measurable influence

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# Soil Remediation: Soil Oxidative Blender Aeration, Hydrogen Peroxide and Natural UV Exposure
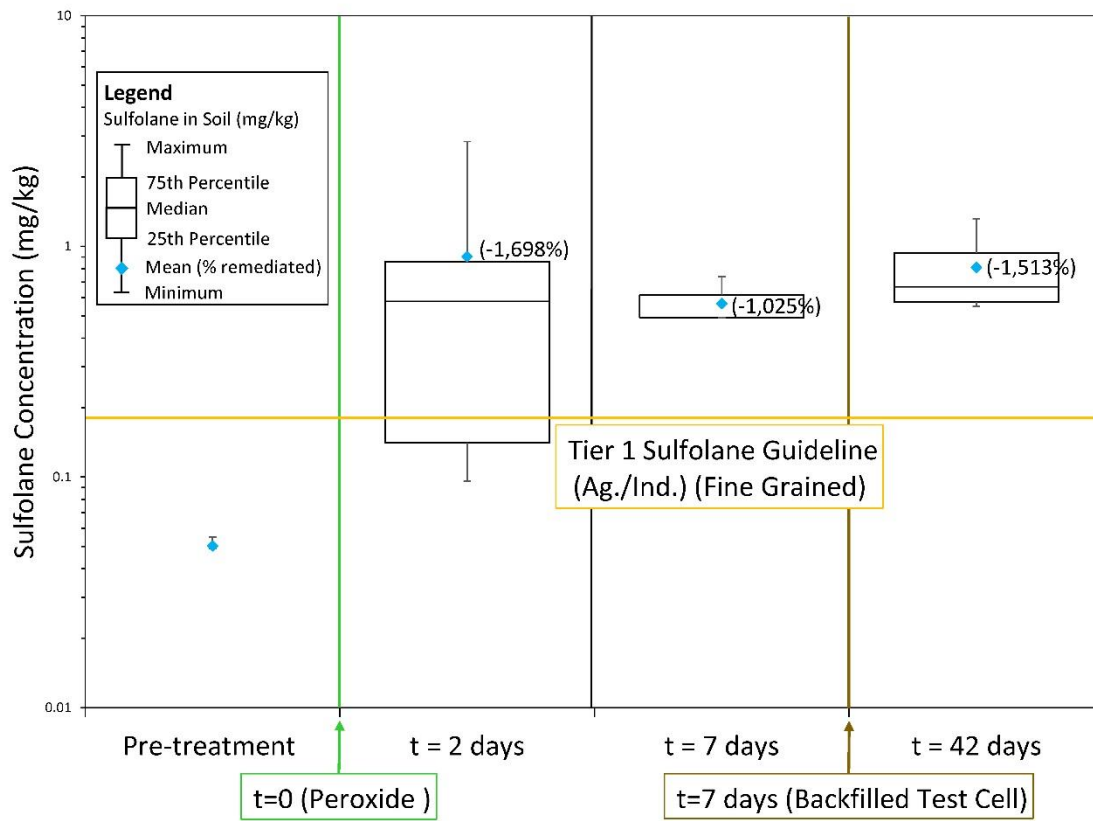
➢ 11% hydrogen peroxide with citric acid stabilizer, 1,000 L applied to ~10 m³ soil

➢ Hydrogen peroxide is a disinfectant in other applications, possibly reduced naturally occurring microbe population

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Soil Remediation: ALLU Bucket/Nutrient Amendment

- ➢ Aerated twice with Allu bucket
- ➢ N:P:K ratio 28:14:14, 200 mg/kg dose
- ➢ 20 minutes to complete remediation

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Soil Remediation: ALLU Bucket/Nutrient Amendment
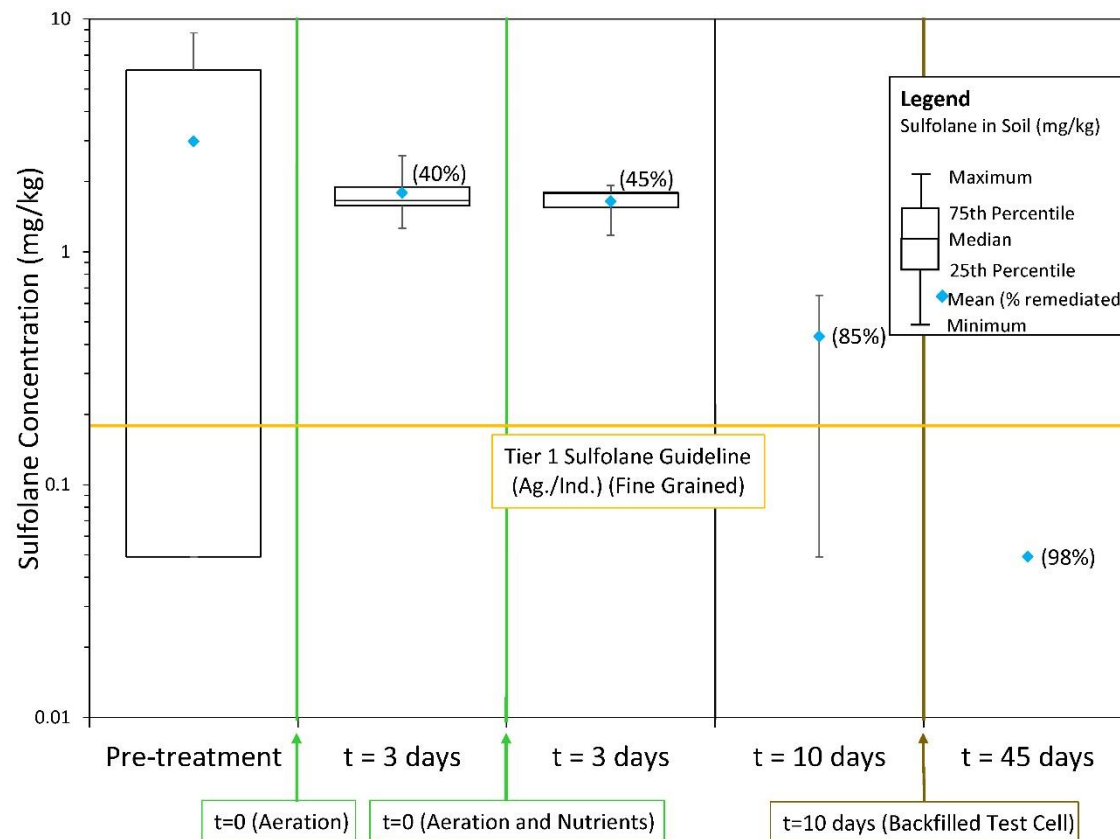
Soil Remediation: Summary

➢ 97 to 98% reduction in sulfolane concentrations using aeration and/or nutrient application

➢ ALLU Bucket trial concentrations after treatment <Tier 1 guidelines

➢ Peroxide application: No apparent remedial benefit

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Groundwater Remediation

➢ Groundwater trials completed opportunistically
➢ Test cells excavated into shallow bedrock
➢ Test cells left open for ~1 week while completing soil trials
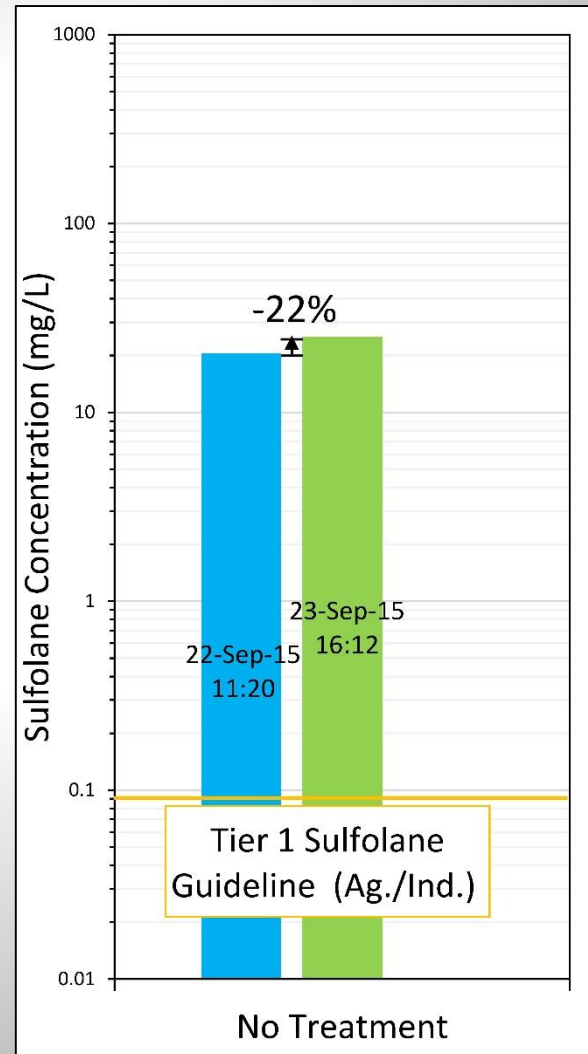➢ <24 hour duration groundwater trials

➢ Approaches:
  ➢ No treatment (Control)
  ➢ Aeration with trash pump
  ➢ Sparging
  ➢ Hydrogen peroxide

➢ Pumping test completed and test pit went dry after storage within test pit was pumped off
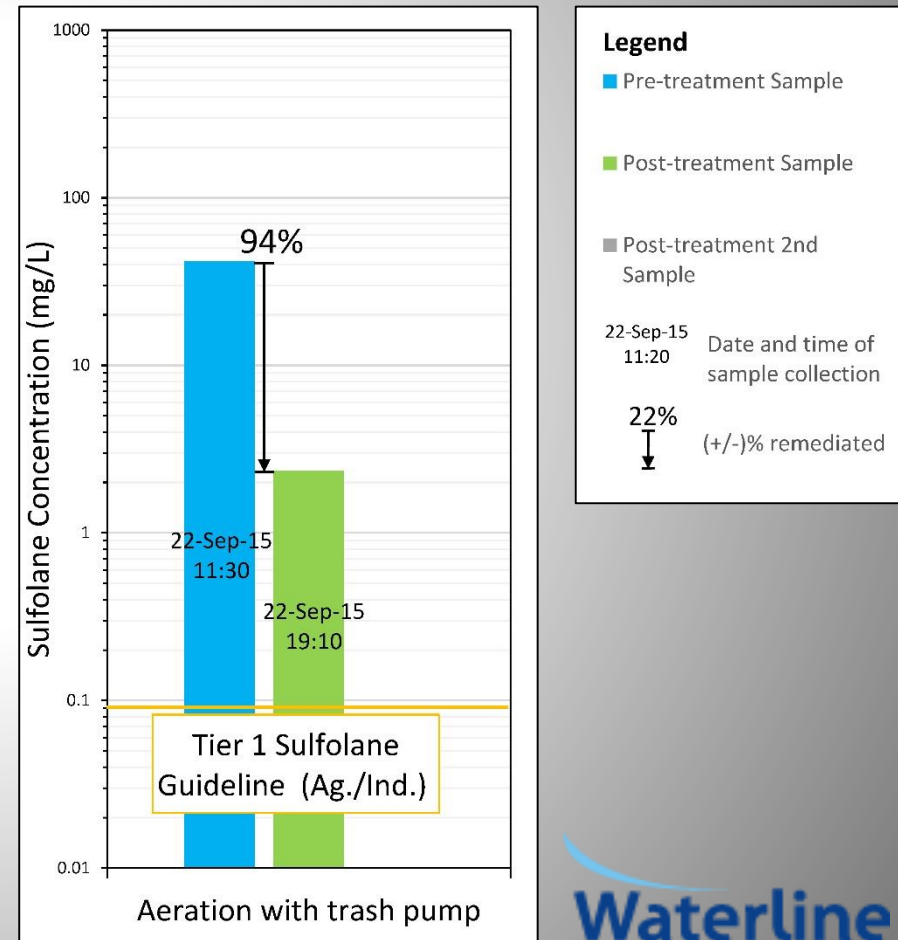
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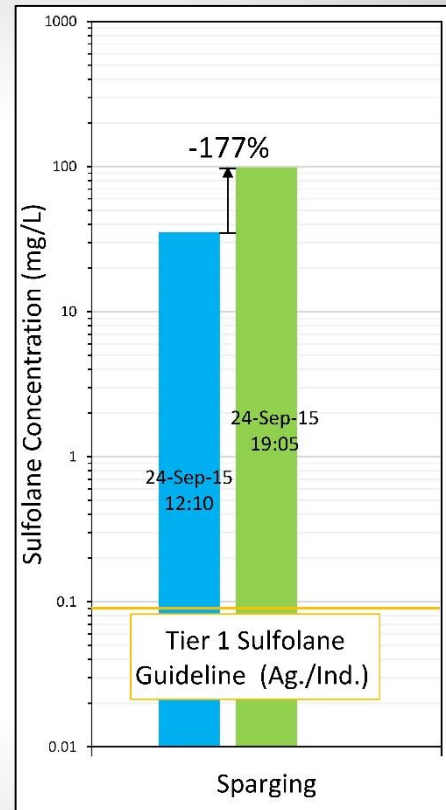# Groundwater Remediation: No Treatment

Groundwater Remediation: Aeration with Trash Pump

➤ Re-circulated pit water ~9 times
➤ Nitrate in groundwater present before and after trial (8 to 9 mg/L)

Legend

- Pre-treatment Sample
- Post-treatment Sample
- Post-treatment 2nd Sample

22-Sep-15 11:20 — Date and time of sample collection

22% — (+/-)% remediated

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Groundwater Remediation: Sparging

- Regenerative blower with slotted pipe, 6 hours
- Non-detectable nitrate in groundwater not favourable for microbial degradation of sulfolane?
- Trial too short or the entire water column not aerated?

Groundwater Remediation: Hydrogen Peroxide
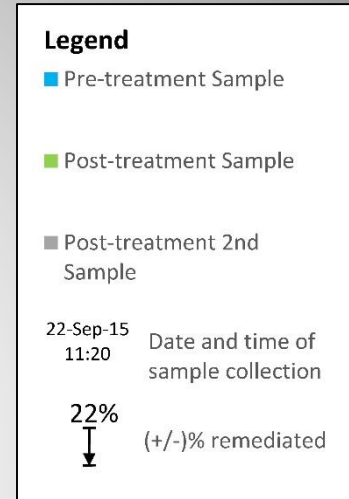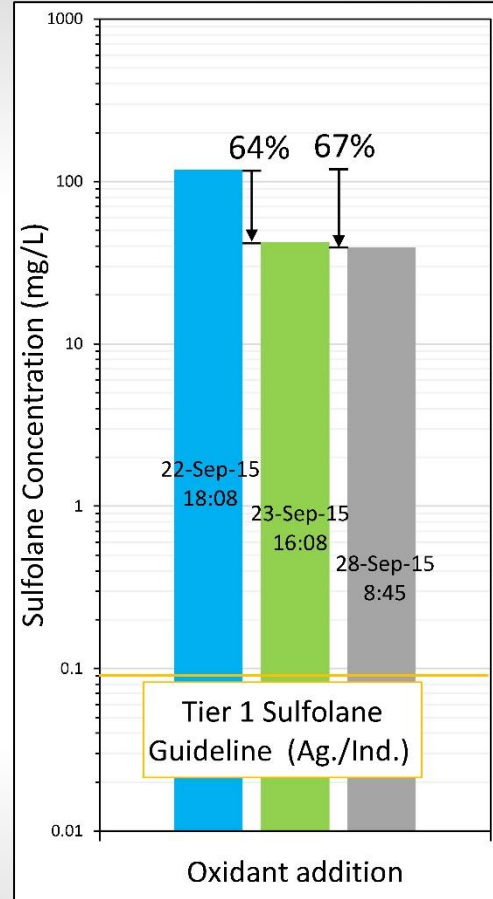
- ➢ 11% hydrogen peroxide with citric acid stabilizer, 1,000 L hydrogen peroxide added to 1,000 L of groundwater
- ➢ Groundwater diluted by half initially, excluding dilution=minor remedial benefit

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Groundwater Remediation
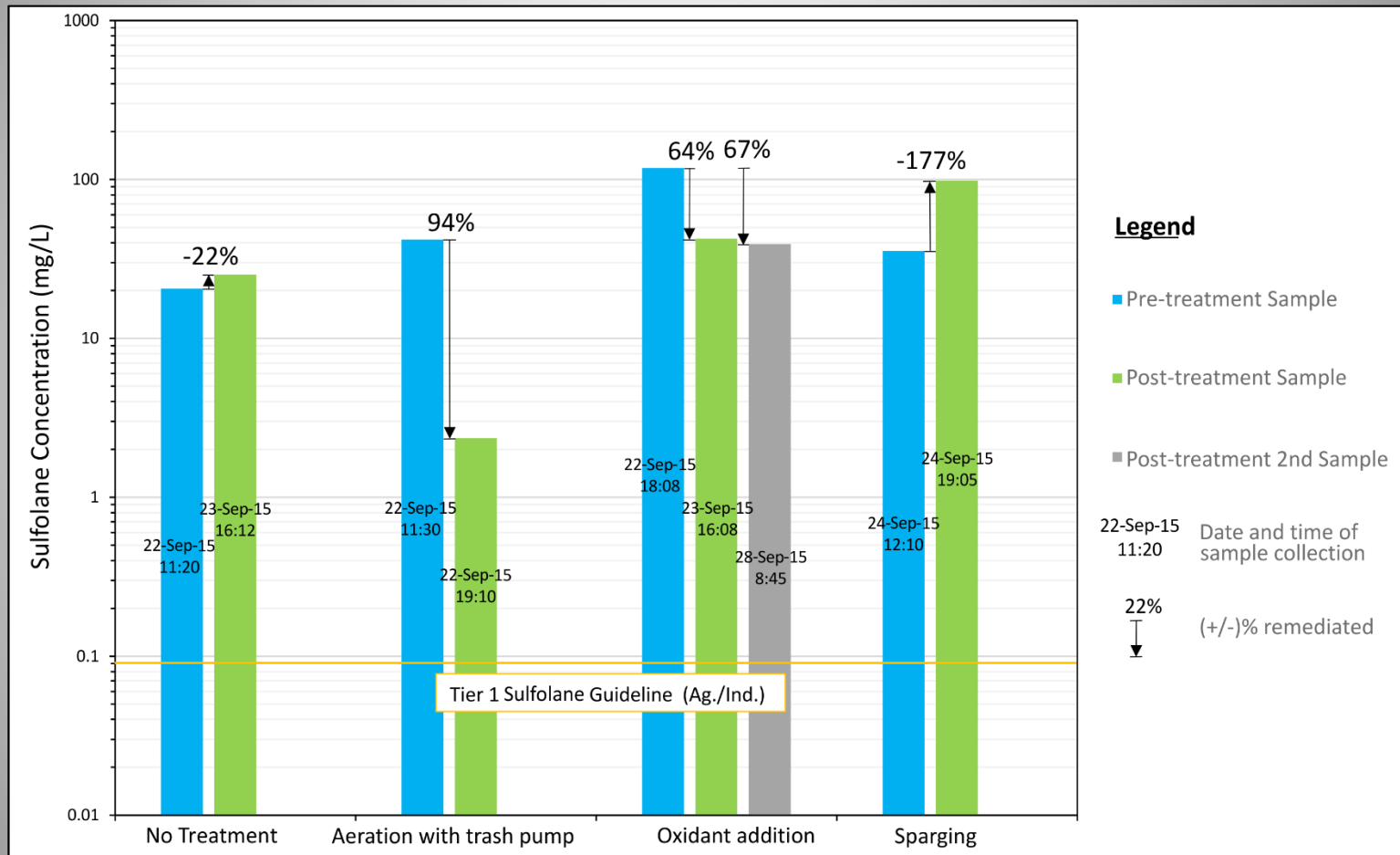
Findings

➢ Peroxide/exposure to natural UV light generally not as effective as aeration/nutrient amendment approaches

➢ Simple, practical, and cost effective approaches can be taken to remediate sulfolane in soil and groundwater

  ➢ Soil: aeration/nutrient amendment

  ➢ Groundwater: water re-circulation/aeration

➢ Due to the site setting and potential for groundwater re-contamination, a groundwater remediation approach should be applied

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Questions?

Thank You

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http://www.waterlineresources.com

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References

➢ Barr Engineering, July 31, 2013. Revised point-of-entry treatment system feasibility study and design report.

➢ Biogenie, 2006. Large Scale Sulfolane-Impacted Soil Remediation at a Gas Plant. Remediation Technologies Symposium Presentation, Banff, AB.

➢ CCME, 2006. Canadian Environmental Quality Guidelines for Sulfolane: Water and Soil. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

➢ EBA Engineering Consultants Ltd., 2015. Sulfolane Impacted Soil and Groundwater Treatability Study. Remediation Technologies Symposium Paper, Banff, AB.

➢ Gallegos, P.G., Fitzhenry, T., Moody, W., November 12 to 14, 2013. Successful Chemical Oxidation Treatment of Sulfolane. IPEC Presentation.

➢ Greene, E.A., Gieg, L.M., Coy, D.L., Fedorak, P.M., 1998. Sulfolane Biodegradation Potential in Aquifer Sediments at Sour Natural Gas Plant Sites. Water Resources, 32: 3680-3688.

➢ WorleyParsons Komex, 2008. Remediation of Sulfolane Impacted Groundwater – Characterization, Treatment and Disposal. Remediation Technologies Symposium Presentation.

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