



SOIL STERILANTS PROGRAM (SSP) –

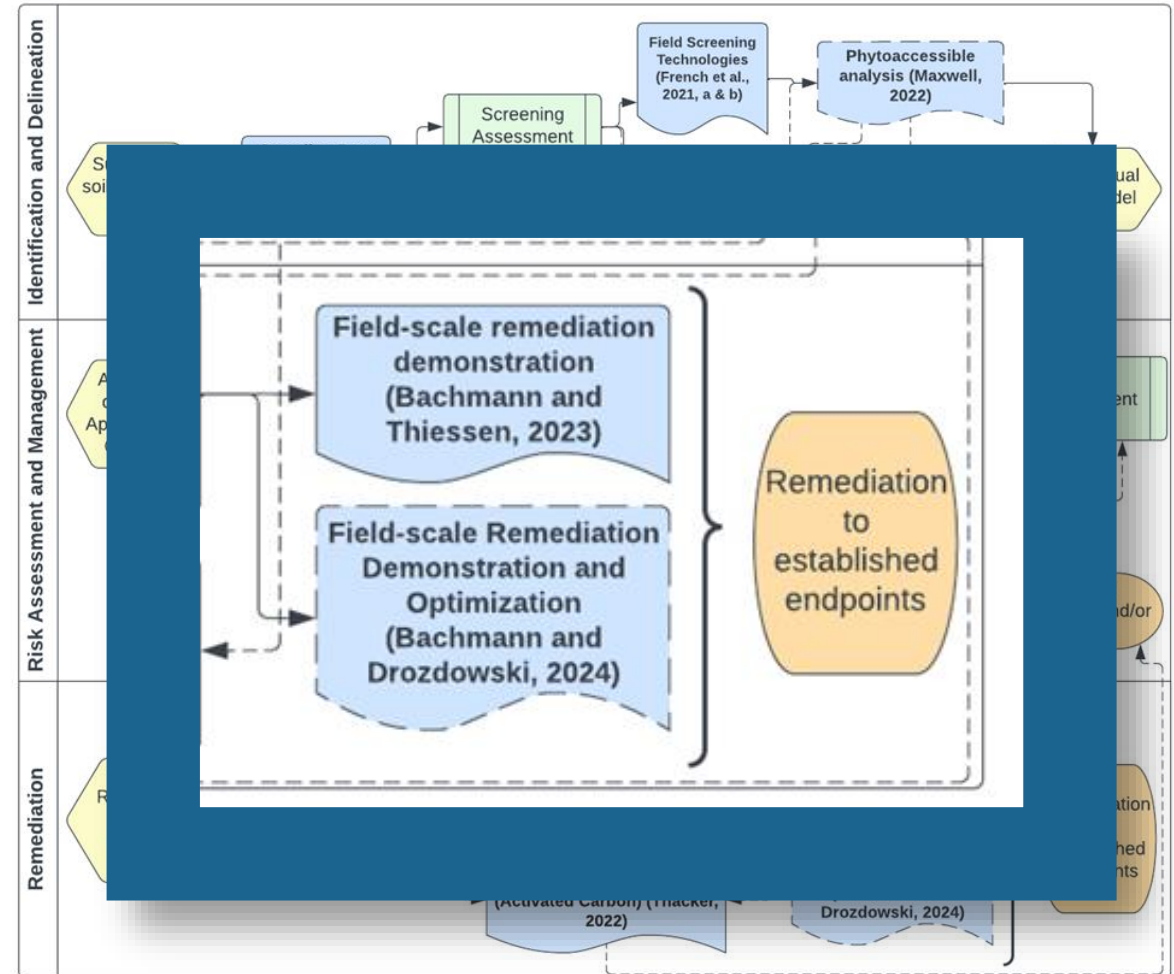
FIELD DEMONSTRATION OF REMEDIATION TECHNOLOGIES

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SOIL STERILANTS PROGRAM

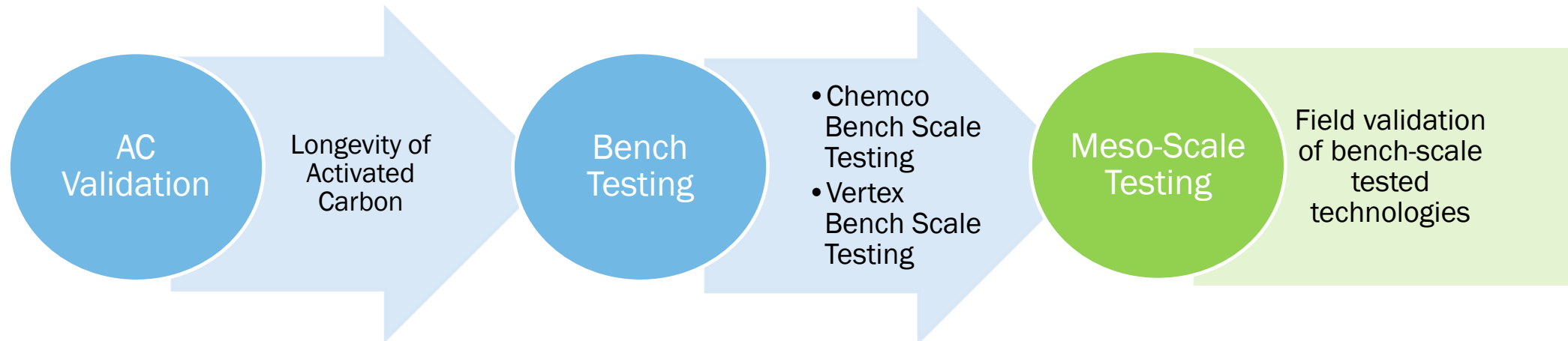


- Objective was to establish **proven, technical** and **cost-effective** strategies and best practices for management of sites impacted by residual soil sterilants, with the goal of supporting regulatory site closure.
- 5 year program
 - Completed 2019-2024
- Scope
 - Address challenges specific to AB
 - Applied research
 - Focus on Bromacil and Tebuthiuron
- Executed through a series of projects in:
 - Identification and Delineation
 - Risk Assessment and Management
 - Remediation



REMEDIATION PROJECTS GOALS AND OBJECTIVES

- Are the remediation technologies identified in **Longevity of Activated Carbon** and **Bench Scale Testing of Remediation** projects effective in treating bromacil from field-affected soils at larger scales?
 - Stage 1: Field demonstration of remediation technologies
 - Stage 2: Optimization of technology from Stage 1



TECHNOLOGIES SELECTED

- Criteria
 - Currently available
 - On-site application
 - Destructive remediation
 - Effective in SSP bench scale studies
 - Effective on bromacil
- Technologies selected
 - Hydrogen peroxide with VTX catalyst and Tween 80[®] surfactant (PVT)
 - Daramend[®]
 - Activated Carbon



Bench testing of various remediation technologies

TECHNOLOGIES SELECTED

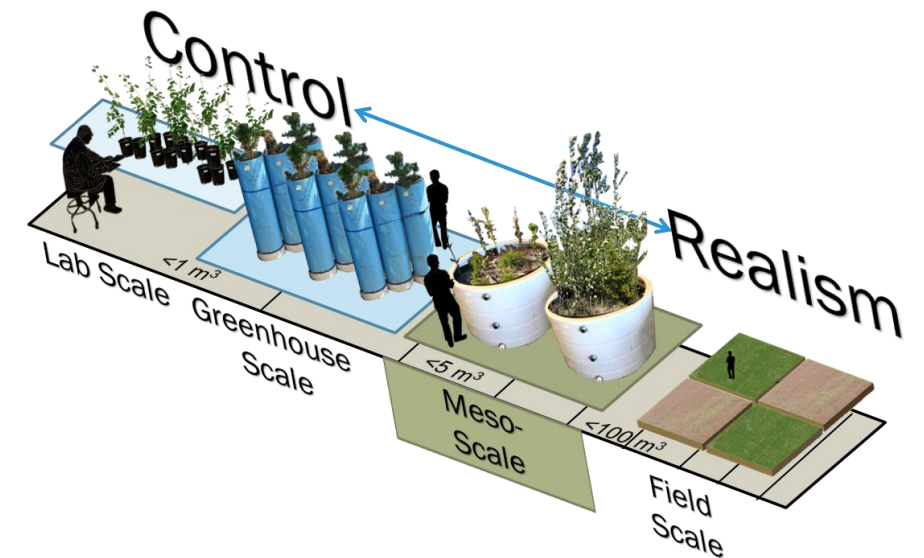
- Hydrogen peroxide with VTX catalyst and Tween 80® (PVT)
 - In-situ chemical oxidation
 - Surfactant to solubilize bromacil
 - Catalyst to produce reactive free-radicals
- Daramend®
 - In-situ chemical/biological reduction
 - Organic substrate to promote biodegradation
 - Zero valent iron (ZVI) as electron donor
- Activated Carbon
 - Adsorbent
 - Non-destructive
 - Support longevity and bioaccessibility studies



Bench testing of various remediation technologies

METHODS

- Stage 1: Field Demonstration
 - 5.4 m³ soil treatment cells, 3 replicates for each treatment and controls
 - 12-week demonstration trial
 - Remediation technologies:
 - Hydrogen peroxide with VTX[®] catalyst and Tween[®]-80 surfactant (PVT)
 - Powdered Activated Carbon
 - Daramend[®]
- Stage 2: Optimization of Daramend[®]
 - 4 m³ soil treatment cells, 3-4 replications for each treatment
 - 1-year demonstration trial
 - Daramend[®] dosage levels: 0% (control), 0.5% and 2%
 - Application frequencies:
 - Initial application of Daramend[®] and water only
 - Daramend[®] (0 and 10 months) and water (0, 4 weeks, 10 months) applications

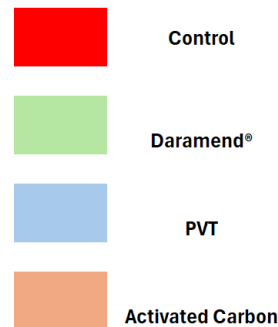
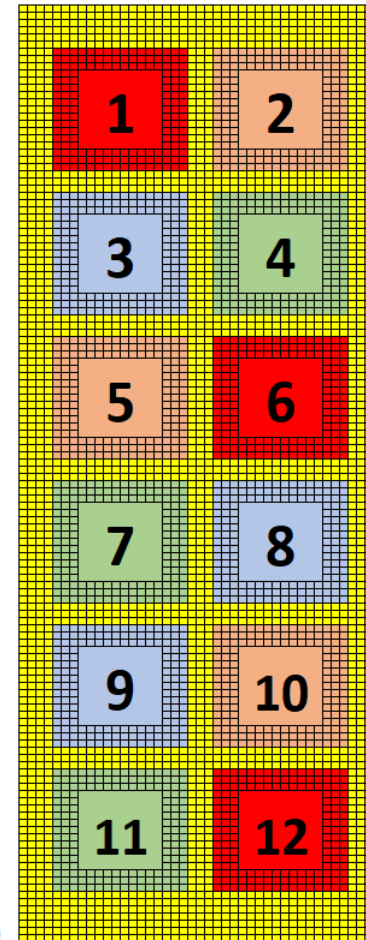


PROJECT SETUP

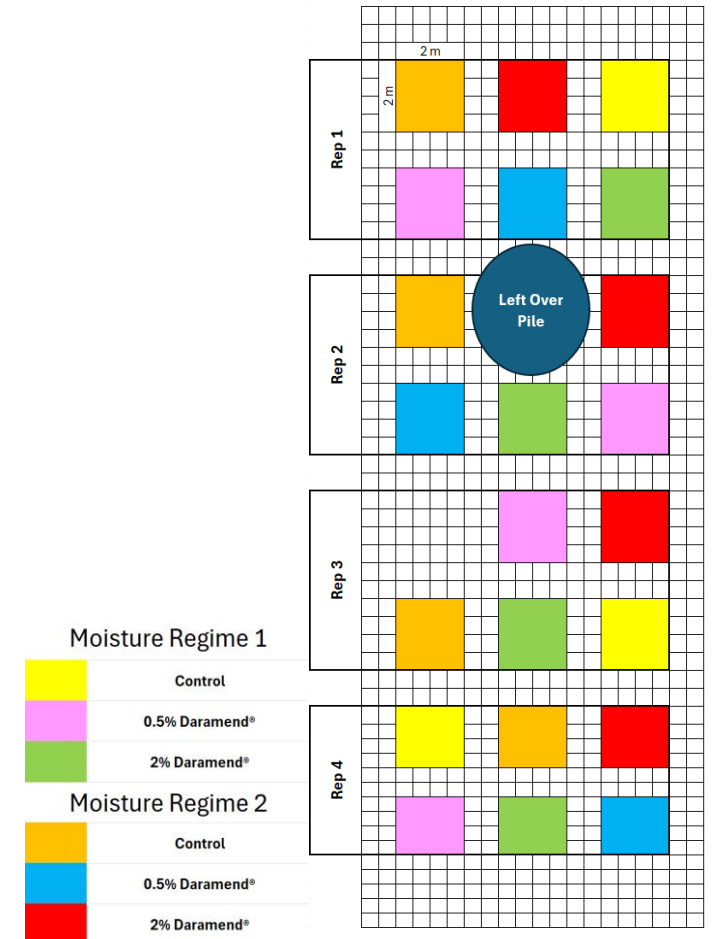
- 10m x 30m double-lined containment pad at InnoTech Alberta's Vegreville location
- Individual treatment cells within a small berm
- Each treatment cell lined with poly tarp on the bottom and covered
- Entire area covered for 7-months



Stage 1 layout



Stage 2 layout



STAGE 1: DEMONSTRATION OF REMEDIATION TECHNOLOGIES - APPLICATION



PVT

- PVT
 - All components mixed prior to application
 - Applied directly to the soil making a slurry
- Activated Carbon
 - Activated carbon mixed into water on-site
 - Soil spread in layers
 - Each soil layer sprayed with AC as a slurry until saturated
- Daramend®
 - Spread over soil in layers
 - Each Daramend® layer watered until saturated
 - Soil mixed with excavator after treatment



Daramend®



Activated Carbon

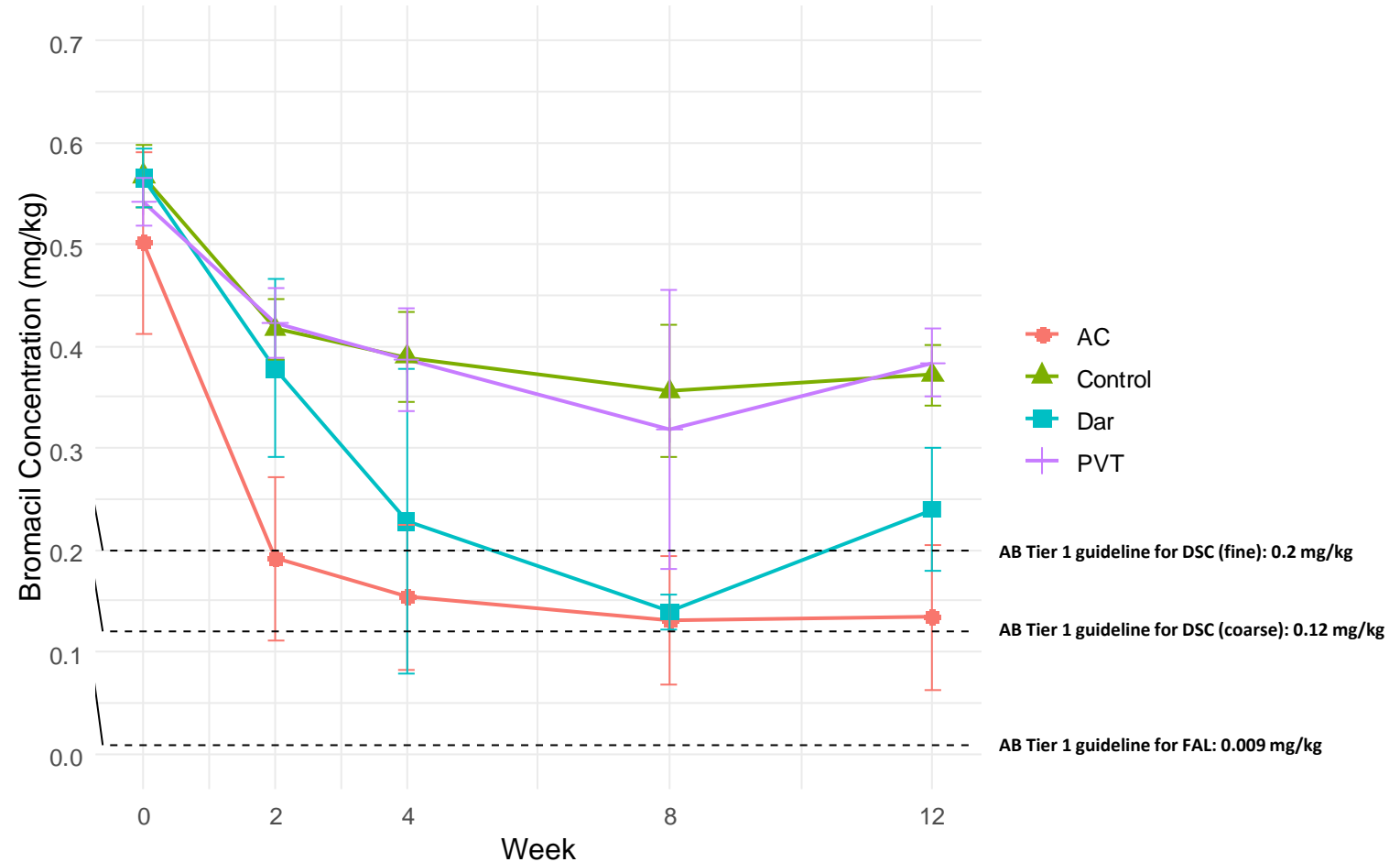
STAGE 2: OPTIMIZATION OF DARAMEND® - APPLICATION

- Initial Daramend® and water application
 - Daramend® added to soil in Allu® bucket
 - Amended soil deposited in layers
 - Each soil layer watered until saturated
- Subsequent applications (Moisture Regime 2)
 - Soil excavated and shifted to one half of cell
 - Daramend® and water added to soil in layers
 - Repeated Daramend® dosage at 10 moths
 - 160L to 220L of water added on 2nd (8 weeks) and 3rd application (10 months)



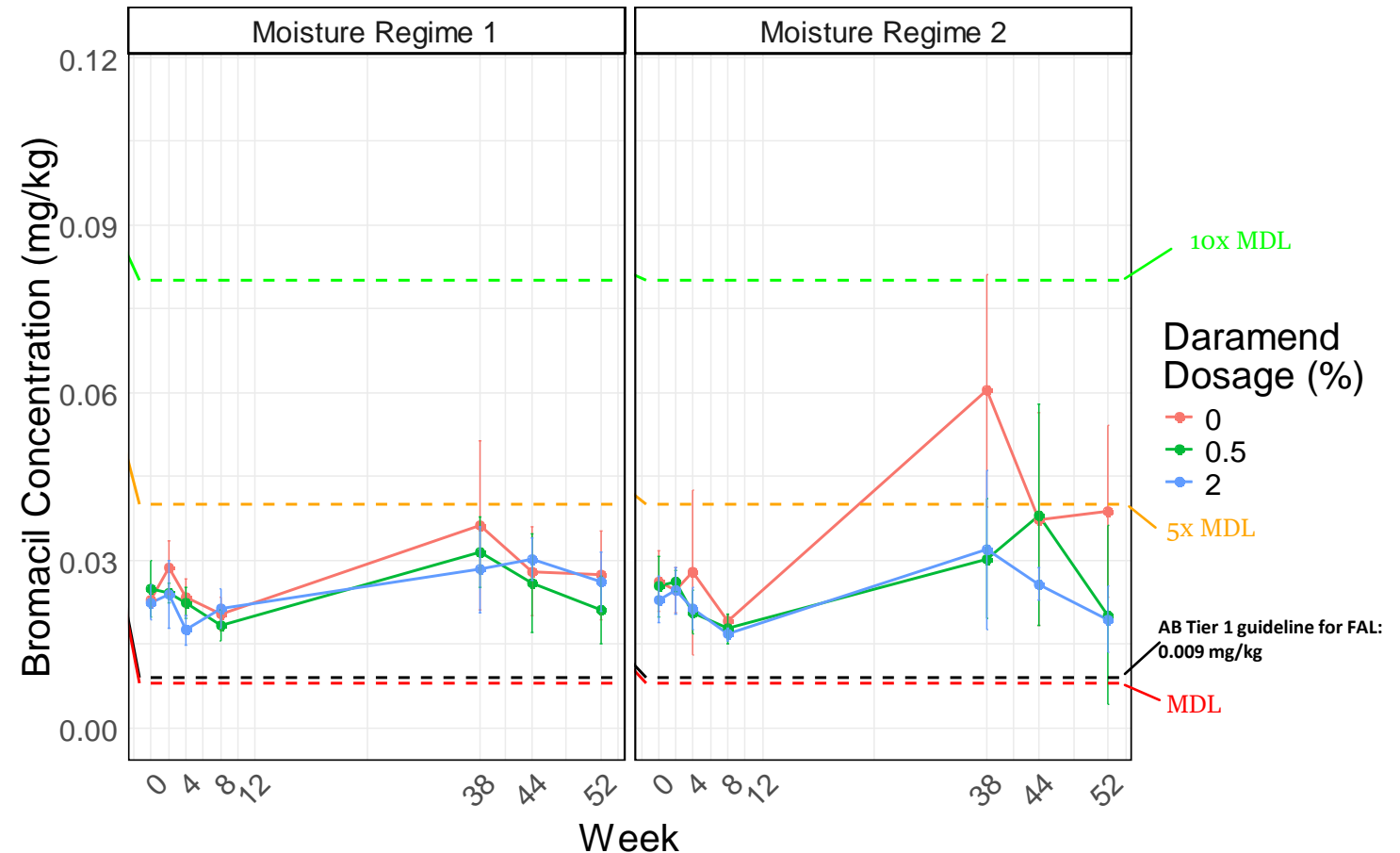
STAGE 1: RESULTS

- Control
 - 34% reduction in bromacil
 - Reduction occurred in the first 2 weeks
- Hydrogen peroxide with VTX[®] catalyst and Tween[®]-80 surfactant (PVT)
 - Bromacil reduction same as control (29%)
 - Peroxide likely consumed by catalyst prior to contact with soil
- Activated Carbon (AC)
 - 74% reduction in bromacil
 - Majority of reduction in the first 4 weeks
 - No further bromacil reduction after week 4
- Daramend[®]
 - 58% reduction in bromacil
 - Partial rebound in bromacil concentrations after week 8



STAGE 2: RESULTS

- Bromacil concentrations stable over first 8 weeks
- Rebound in bromacil concentrations in the spring
- Moisture regime 1 - bromacil some decrease in during summer
- Moisture regime 2 - bromacil decreasing after 2nd Daramend[®] application



STAGE 2: RESULTS

- No net decrease in bromacil concentrations
- Control treatments had an overall increase in bromacil concentrations
- Comparing treatments to controls on the final week:
 - Moisture regime 1 Daramend[®] treatments same as control
 - Moisture regime 2 Daramend[®] treatments significantly lower than control ($p < 0.05$)

Daramend Applications	Water applications	Daramend Dosage (%)	Bromacil Concentration		% of Initial	% of Control (final)
			Initial (mg/kg)	Final (mg/kg)		
1	1	0	0.023	0.027	119%	100%
		0.5	0.025	0.021	85%	77%
		2	0.023	0.026	116%	96%
2	3	0	0.026	0.039	148%	100%
		0.5	0.025	0.015	80%	38%
		2	0.023	0.020	85%	50%

APPLICATIONS ON BROMACIL-IMPACTED SITES

- Hydrogen Peroxide with VTX catalyst (PVT)
 - No effect on bromacil concentrations
 - Mixing of components prior to application likely consumed oxidant
 - Additional pilot testing required to evaluate technology
 - Hazardous chemicals require specialized handling
 - Not typically applied at surface
 - Reagent cost \$135 m⁻³ (\$257 m⁻³ with earthworks)



APPLICATIONS ON BROMACIL-IMPACTED SITES

- Activated Carbon
 - No further bromacil reduction after 4 weeks
 - Bromacil not removed or destroyed - risk management
 - Achieving 74% reduction required excavation of soil and application of activated carbon to the entire soil mass
 - Other application methods
 - Surface broadcasting and tilling
 - Surface slurry application
 - Injection
 - Permeable Reactive Barrier
 - Widely available with many service providers
 - \$53 m⁻³ (\$206 with earthworks)



APPLICATIONS ON BROMACIL-IMPACTED SITES

- Daramend®
 - Field testing not consistent with bench scale
 - Application rates and methods need further optimization
 - Achieving & maintaining required moisture logistically challenging
 - May not be effective on sites approaching Tier 1 levels
 - Further optimization and piloting required using different application methods
 - Daramend® cost \$99 m⁻³ 2% dosage rate (\$185 m⁻³ with earthworks), \$25 m⁻³ at 0.5% (\$111 m⁻³ with earthworks)



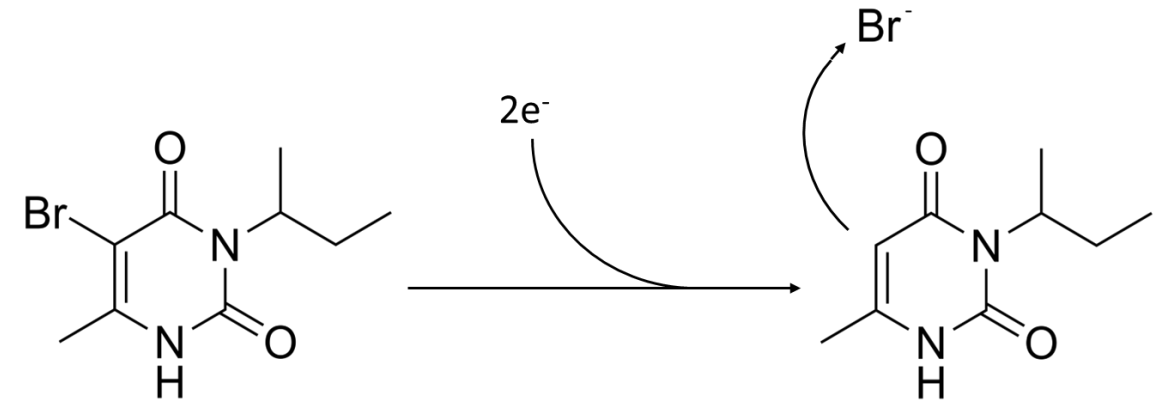
PROJECT CONCLUSIONS

- Bromacil remains difficult to remediate
- No technologies tested in the program achieved AB Tier 1 of 0.009 mg/kg
- Activated Carbon effective as a risk management practice
- Daramend® performance inconsistent with varying bromacil concentrations and soil types
- Emerging technologies need further testing
 - BOS 200+
 - CAT 100
 - ZVI



PROJECT CONCLUSIONS

- Bromacil degrades anaerobically
- Bench testing of Daramend[®], CAT 100, BOS 200+, ZVI in saturated microcosms
- Piloting on saturated soil required
- May not be suitable for surface soil application



Source: InnoTech
Alberta Mesocosm
Facility



Source: Daramend[®] Reagent
Application, United States. Evonik
Corporation.

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