Use of a Biostimulatory Solution to Enhance Petroleum Hydrocarbon Degradation Rates in Cold-Region Soils: A Bench-Scale Microcosm Study

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*** Presenting Author**

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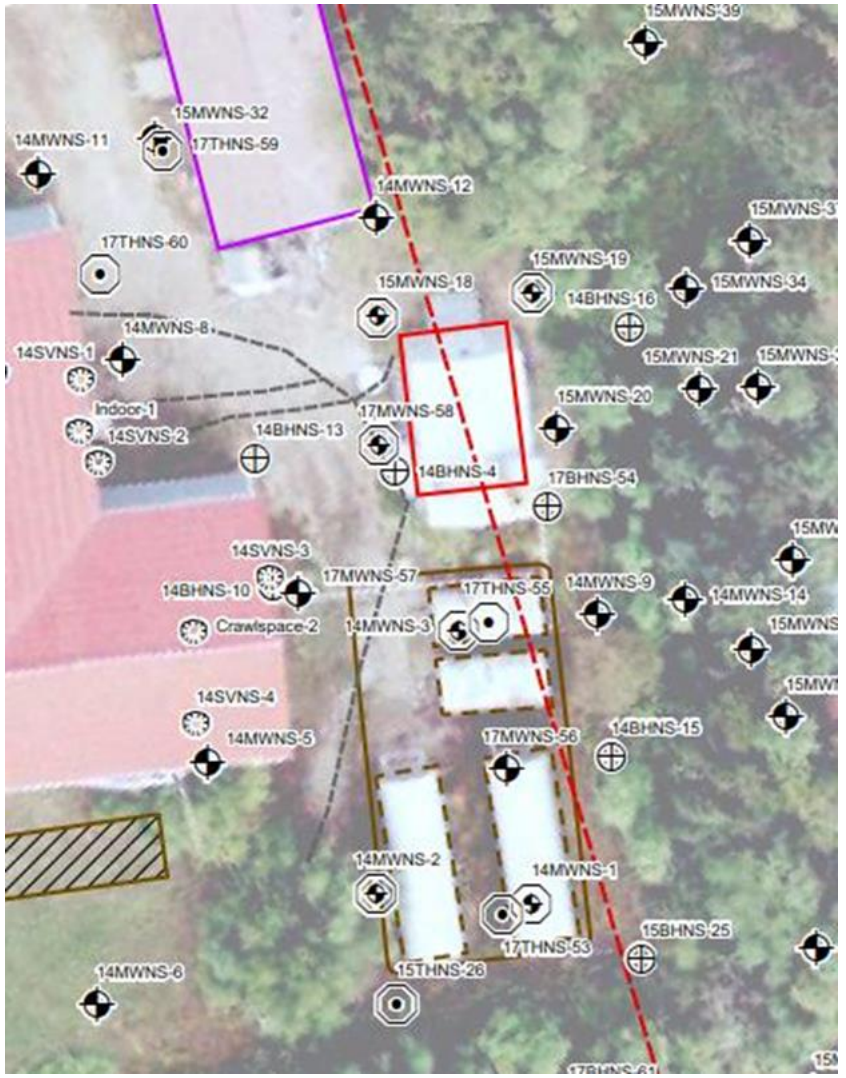
Site Background

- Remote, fly-in only community

- Five ASTs were removed in 2008
- Berm, liner and underground piping still present

- Contamination at the site linked to:
  - 50+ years of fuel handling
  - Spill during removal of ASTs
  - Berm known to be compromised



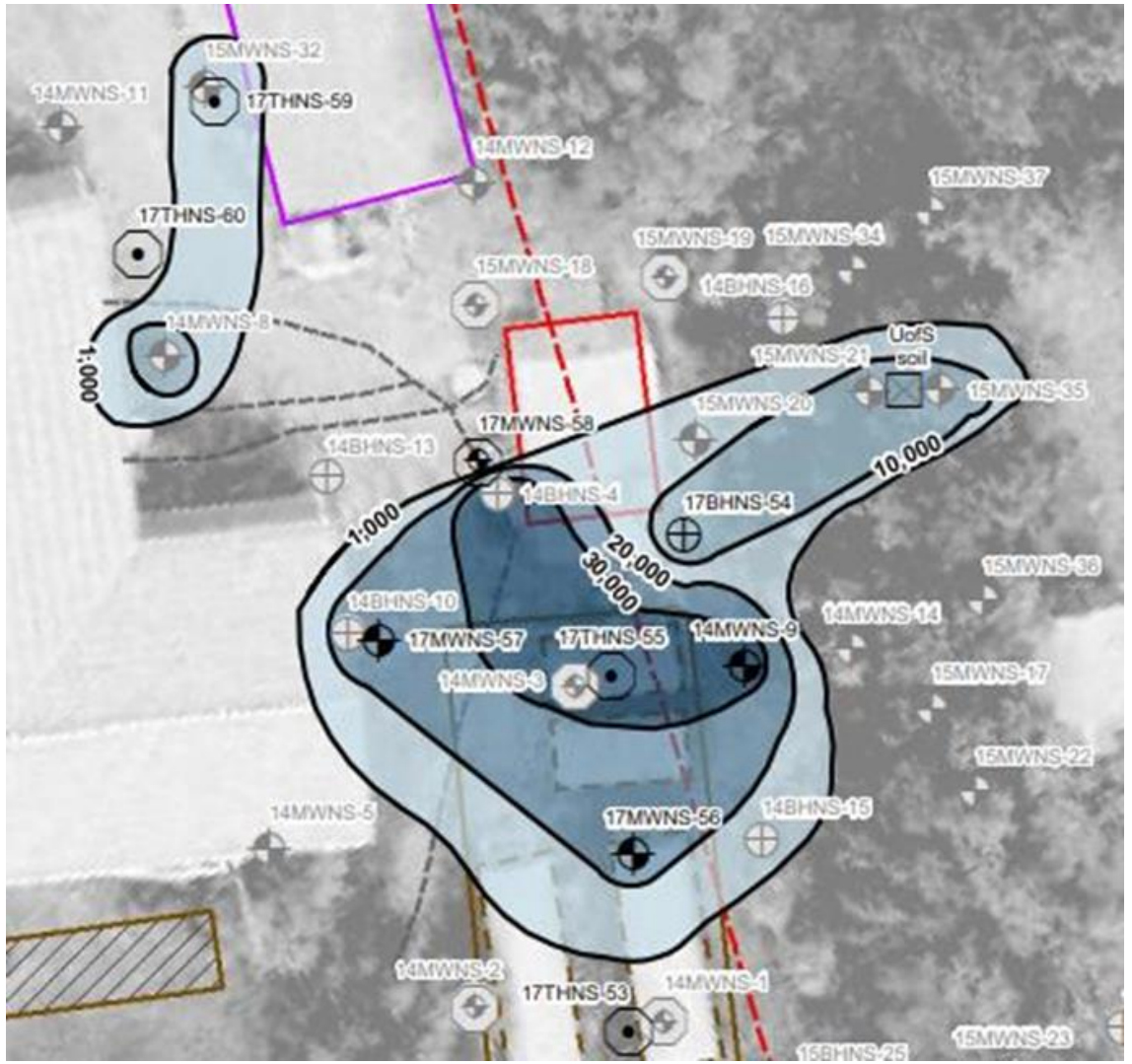
Challenges

Logistics

- Lack of local infrastructure
- Narrow implementation window
- Social influences
- Structural risks

Contaminant of Concern: Diesel

- F2 (>C10-16)



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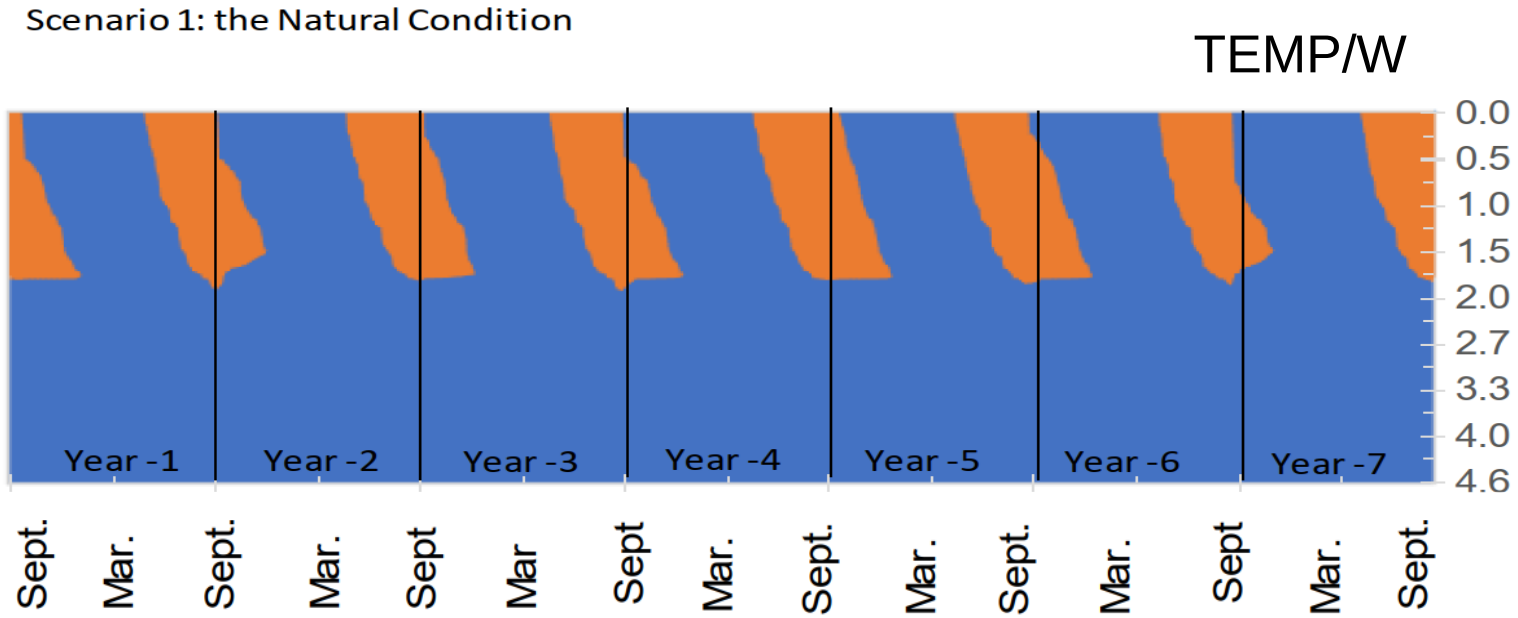
Site Geology

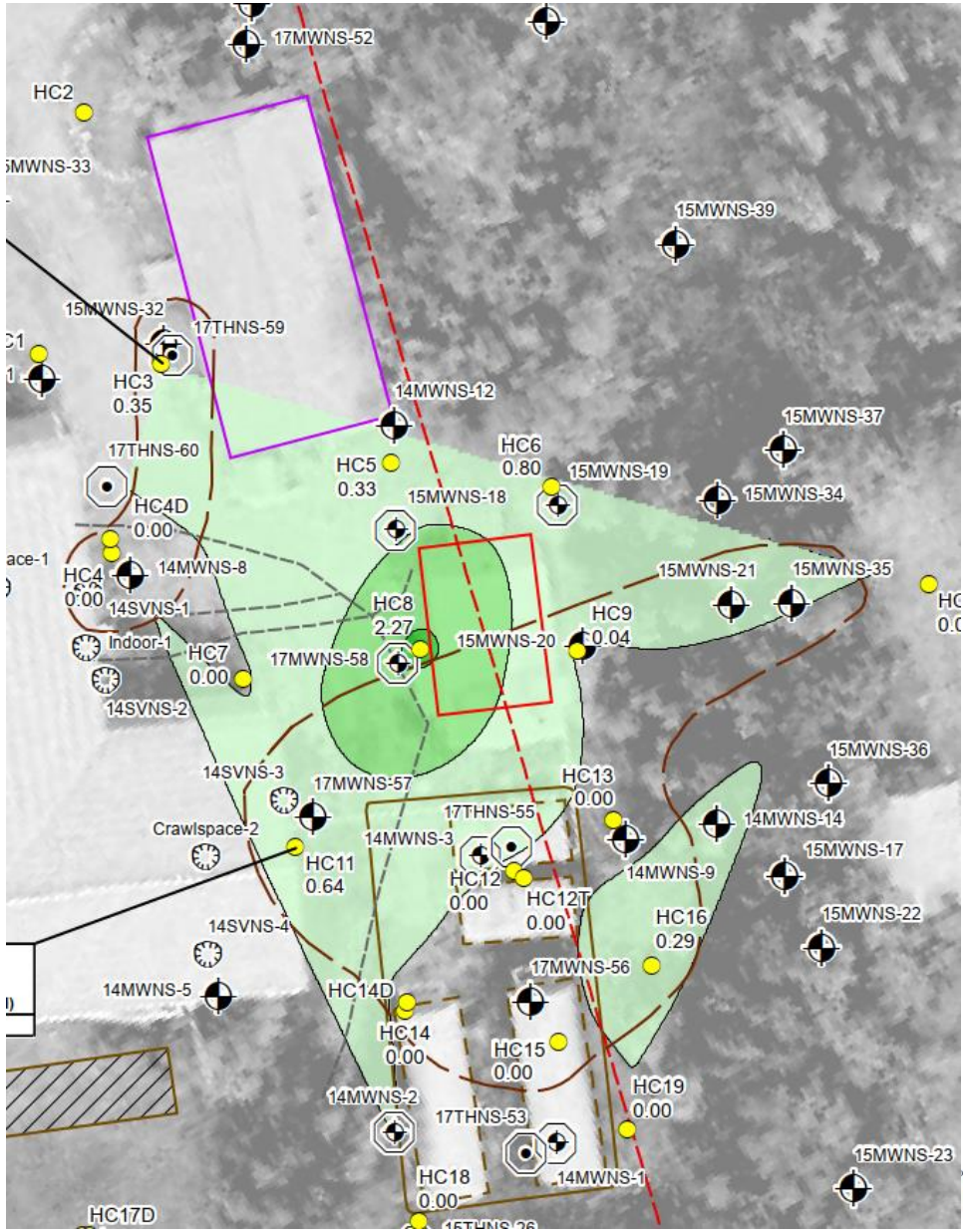
- Cryosolic Soils
- Organic Silt
- Cryoturbation
- Seasonally fluctuating active layer



Frozen soil (blue)
Active Layer Thaw Predictions (orange)

Natural Source Zone Depletion

- Degradation rates:
  - 23 – 49 kg/yr
  - 91-96% Aerobic



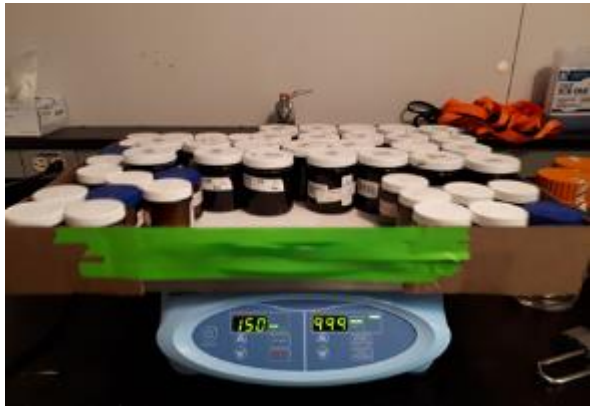
Objectives and Scope

- Develop an in situ remediation approach appropriate for Cryosols
- Determine if a biostimulatory solution can enhance the growth of indigenous microorganisms to more effectively degrade PHC F2
- Bench-scale Microcosm Study
  - Test 1: Proof of Concept
  - Test 2: Preliminary Microcosm
  - Test 3: Final Microcosm

Experimental Design: Soil Collection

- 20 Intact Soil Cores

Experimental Design: Microcosms



Experimental Design: Biostimulatory Solutions

- Orthophosphate / Sodium triphosphate
- Nitric acid
- Magnesium sulphate / potassium sulphate
- Ammonium iron citrate

Preliminary Microcosm

- Determine if optimized biostimulatory solutions out performs base solution
- Key Points:
  - Intact soil cores (4 cores)
  - Optimized solution with DI control

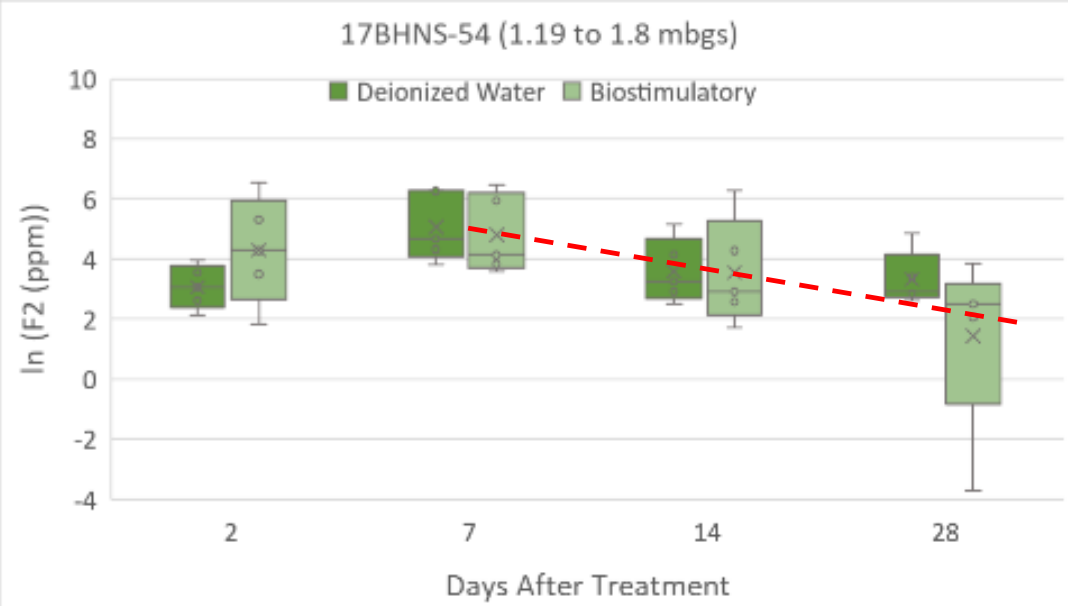
Optimized Solution

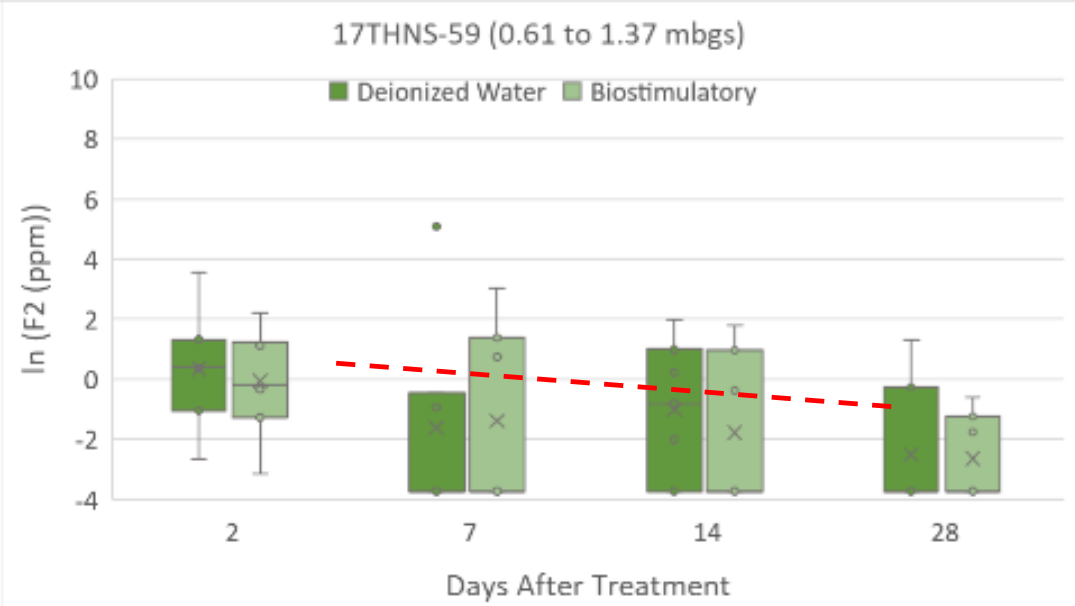
	Location ID	17BHNS-54	17THNS-59	14 MWNS 9	17MWNS-57
	Depth (m)	1.2 - 1.8	0.61 - 1.37	1.04 - 1.65	1.22 - 1.83
Parameter	**Units**				
Sulphate (as $MgSO_4 \cdot 7H_2O$)	mM	0.41	0.41	0.41	0.41
Phosphate (as Orthophosphate)	mM	25.52	2.83	53.75	31.56
Nitric Acid (HNO_3)	mM	0.65	0.76	0.68	0.9
Ammonium Iron Citrate	mM	0.24	0.24	0.24	0.24

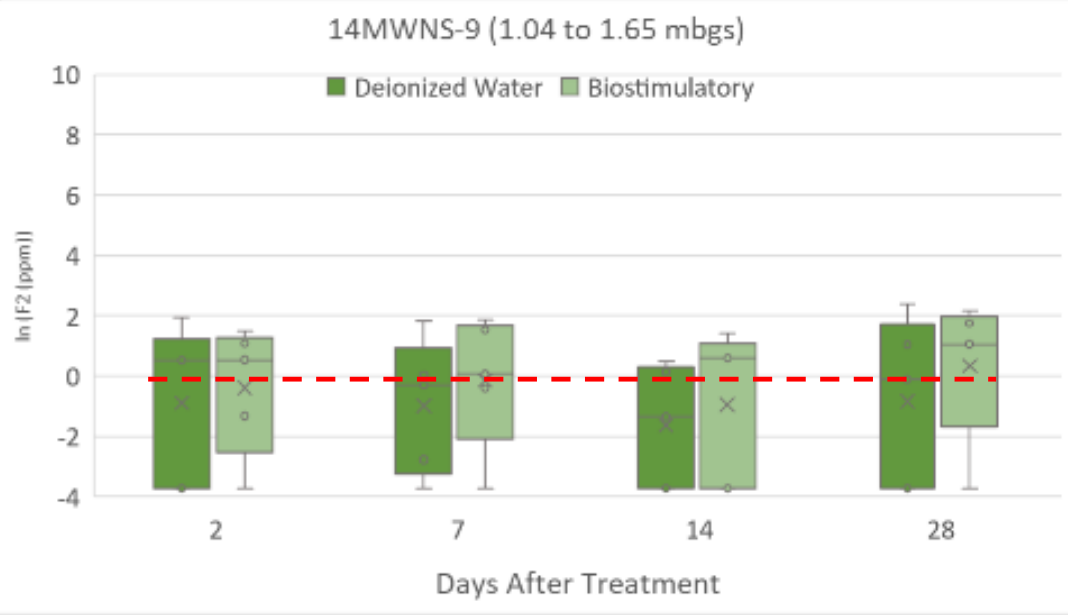
Notes:

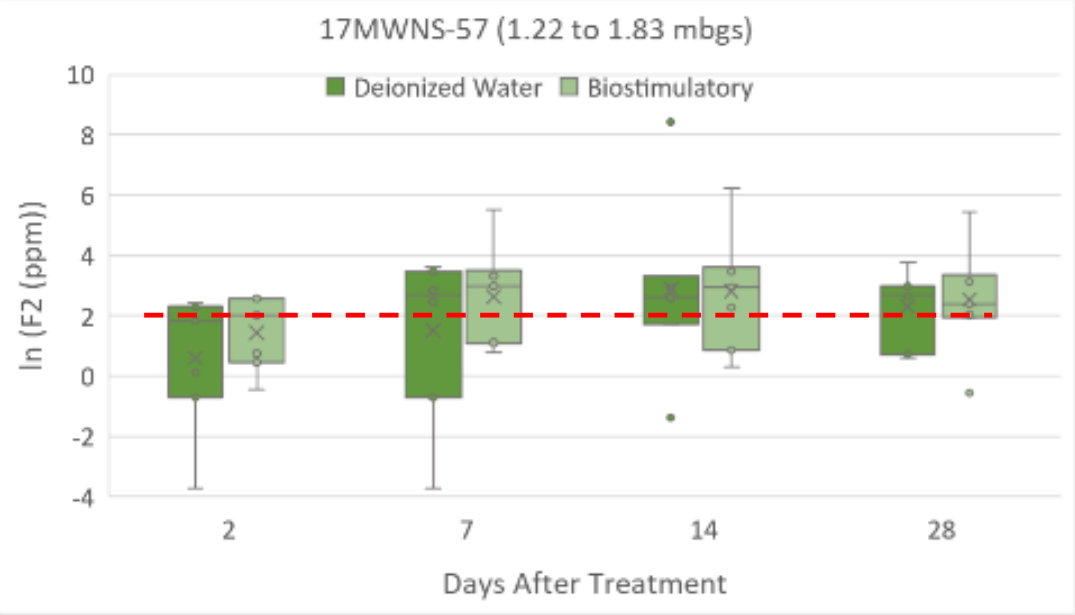
ID = identification

Preliminary Microcosm Results









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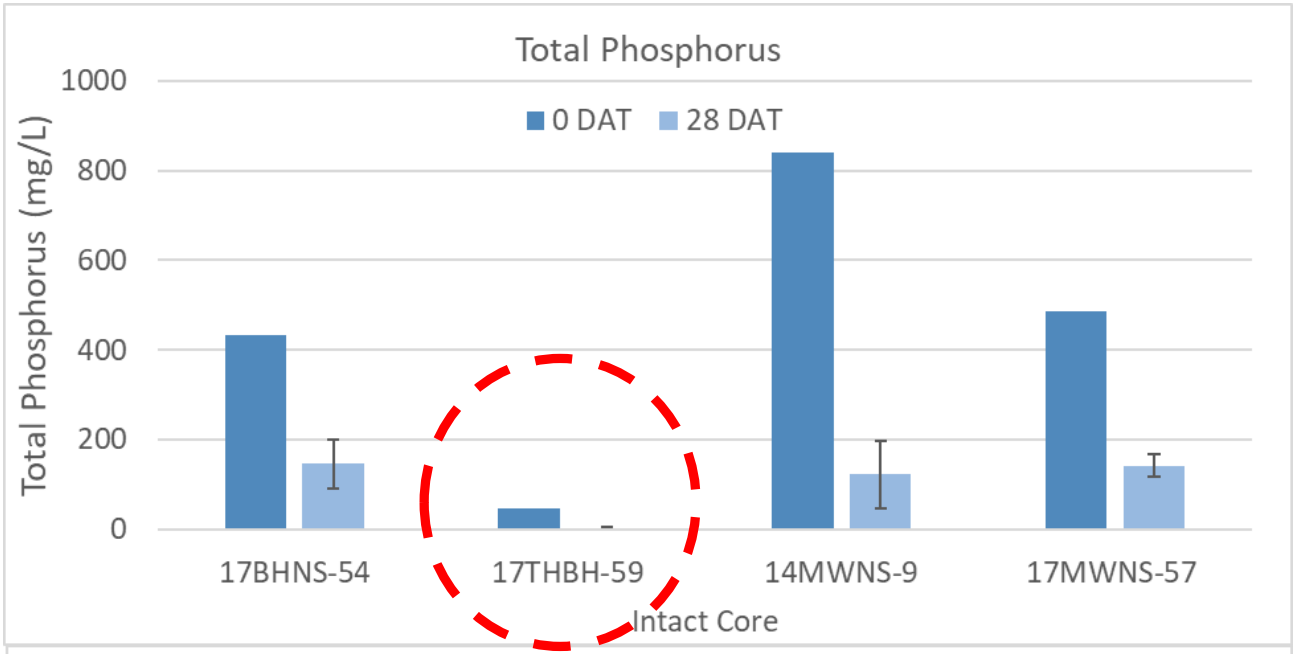

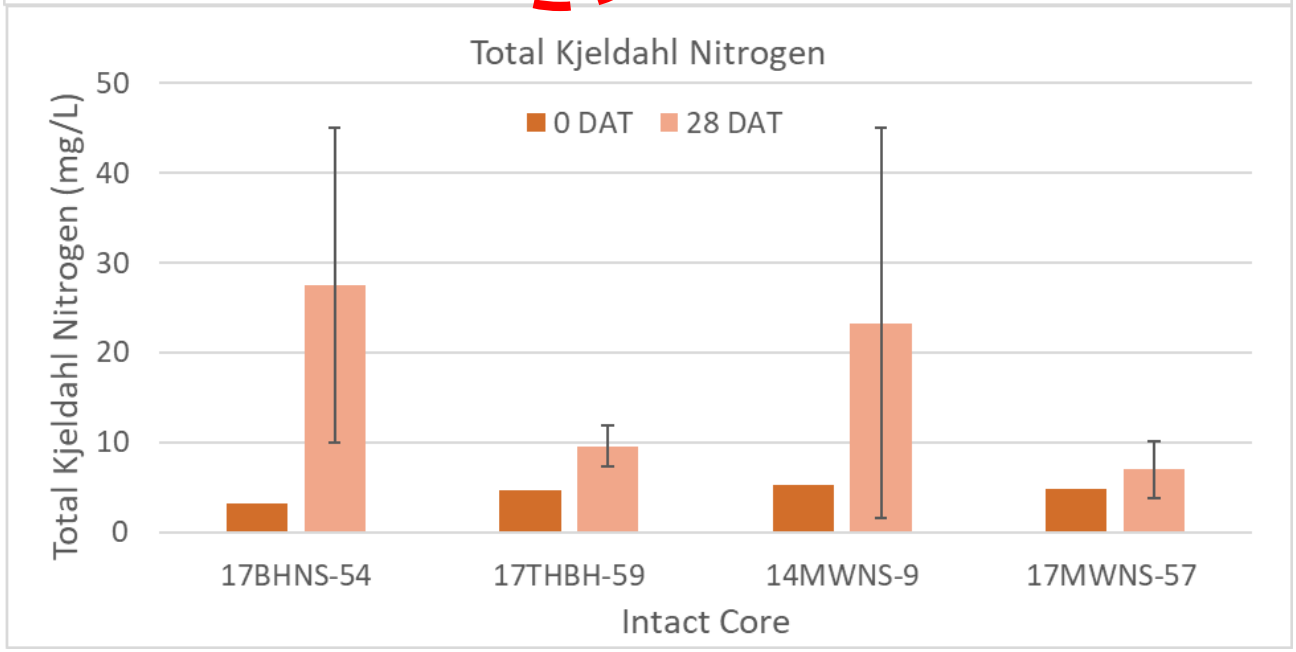

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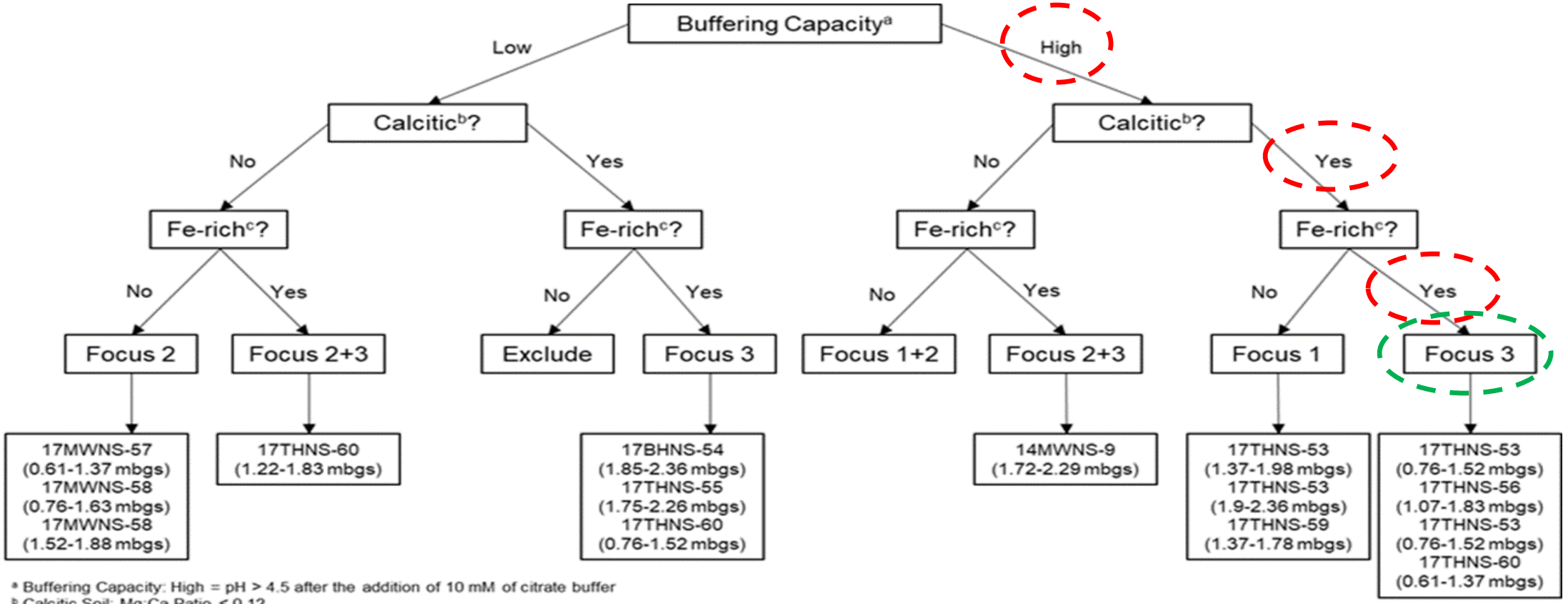
Final Microcosm

- Further optimizing the biostimulatory solutions based on location-specific soil properties
- Produce results that would enable design of an in situ pilot test

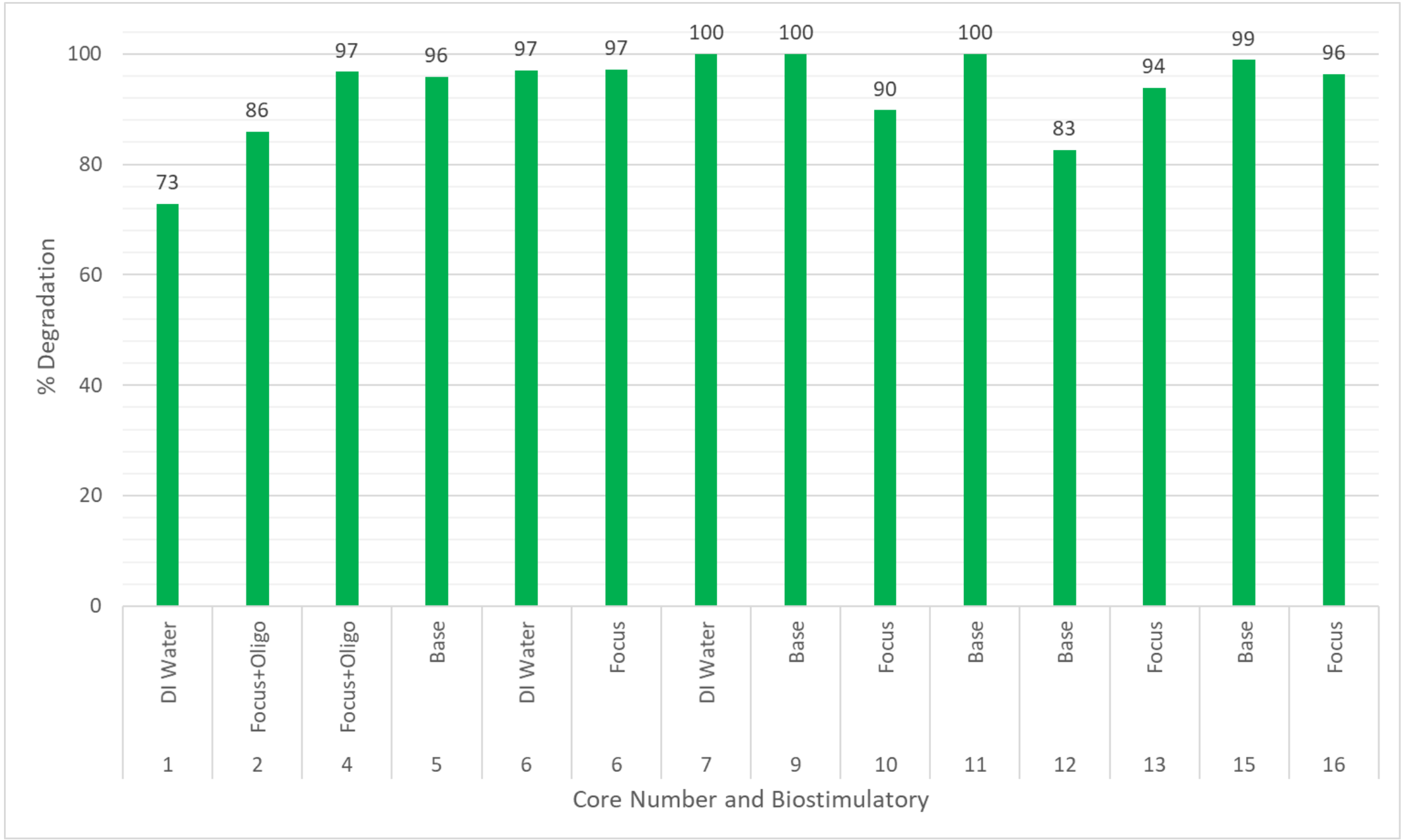


[a] Buffering Capacity: High = pH > 4.5 after the addition of 10 mM of citrate buffer
[b] Calcitic Soil: Mg:Ca Ratio < 0.12
[c] Fe-rich soil: $Fe_{solution}$ > 30 mg/L

Notes:

17THNS-53 (1.9-2.36 mbgs) was not used for the final microcosm test because it did not follow the same flow as the other cores (unusual place on decision tree)
> = greater than
< = less than
Ca = calcium
Mg = magnesium

Final Microcosm Results



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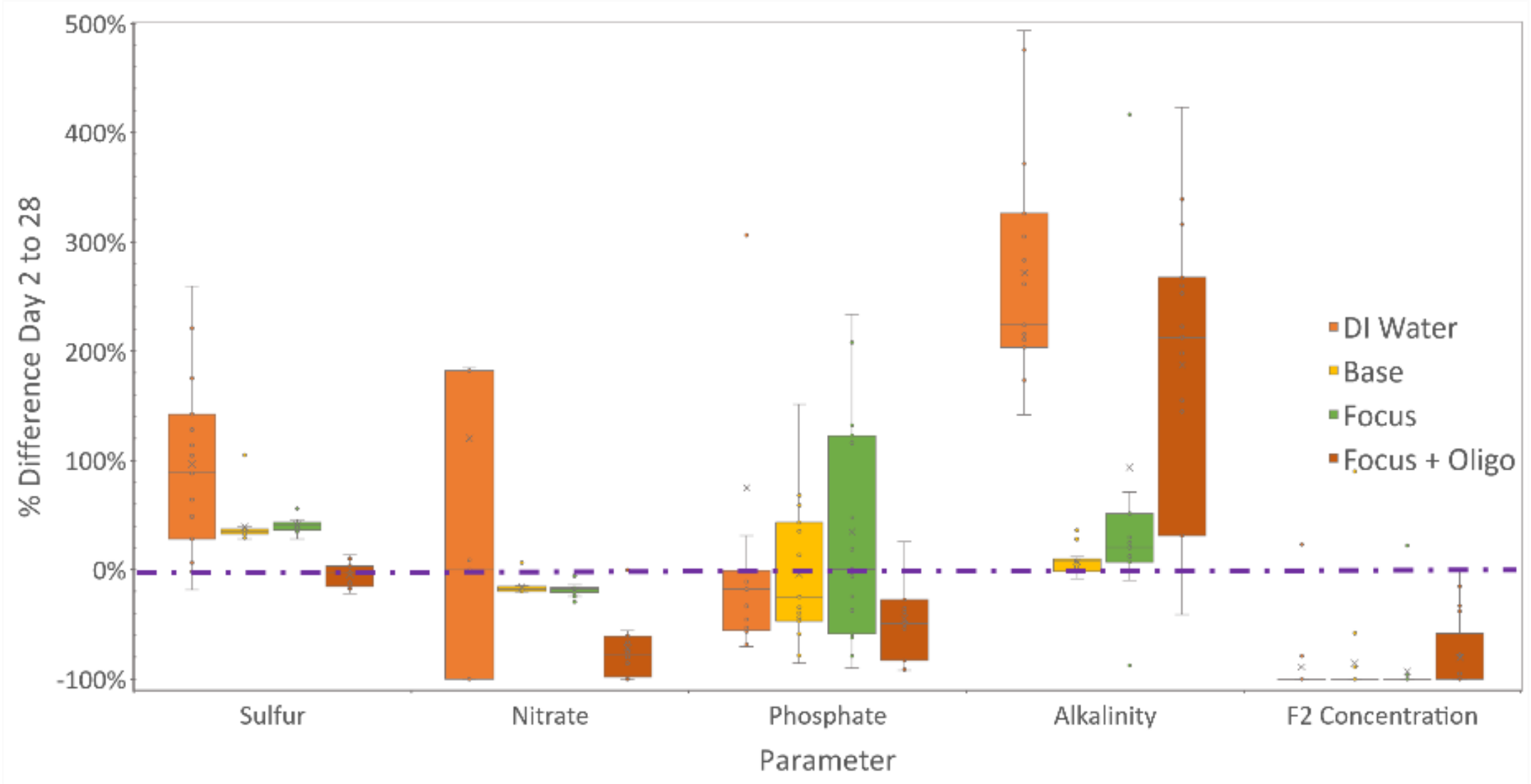
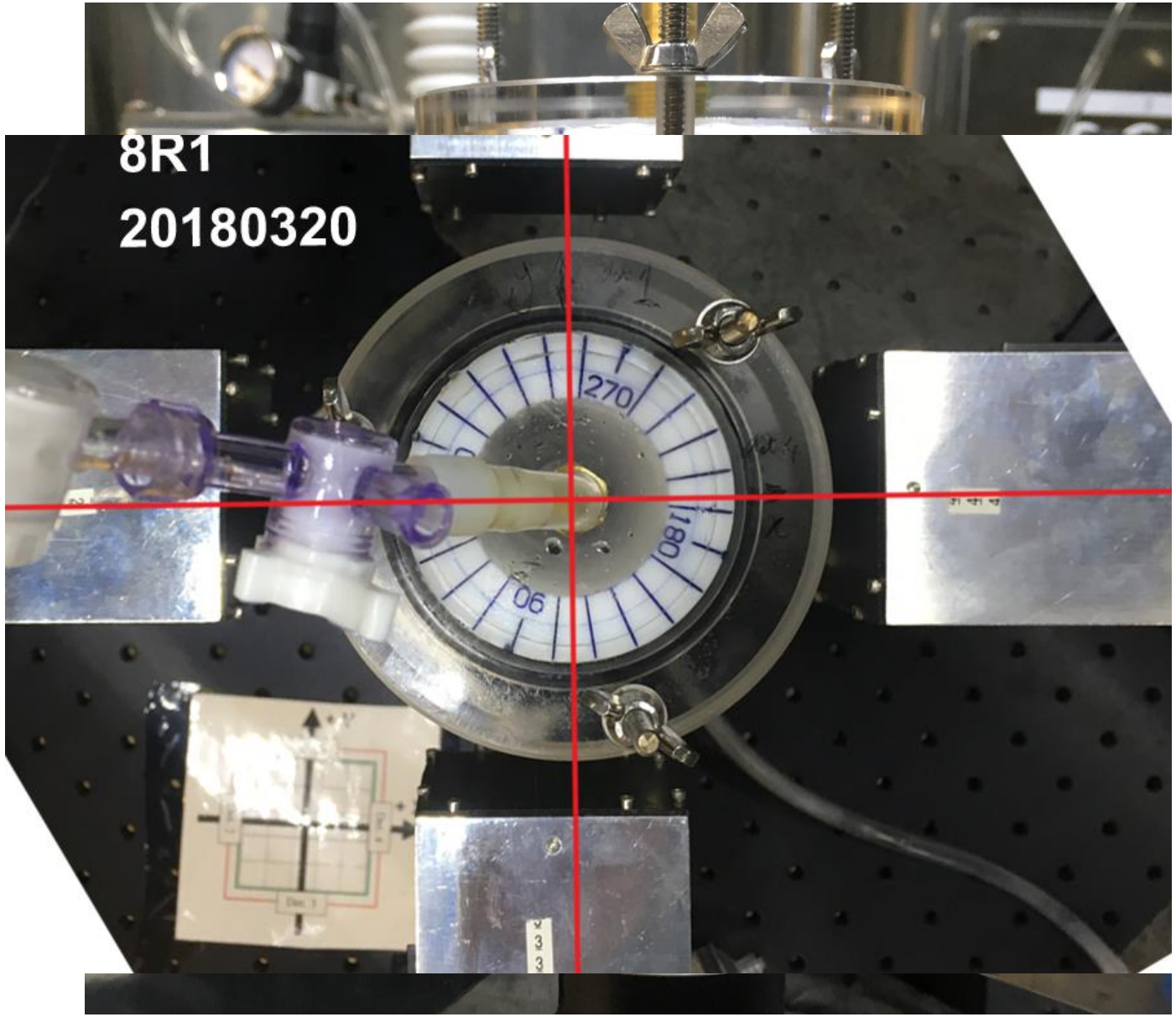
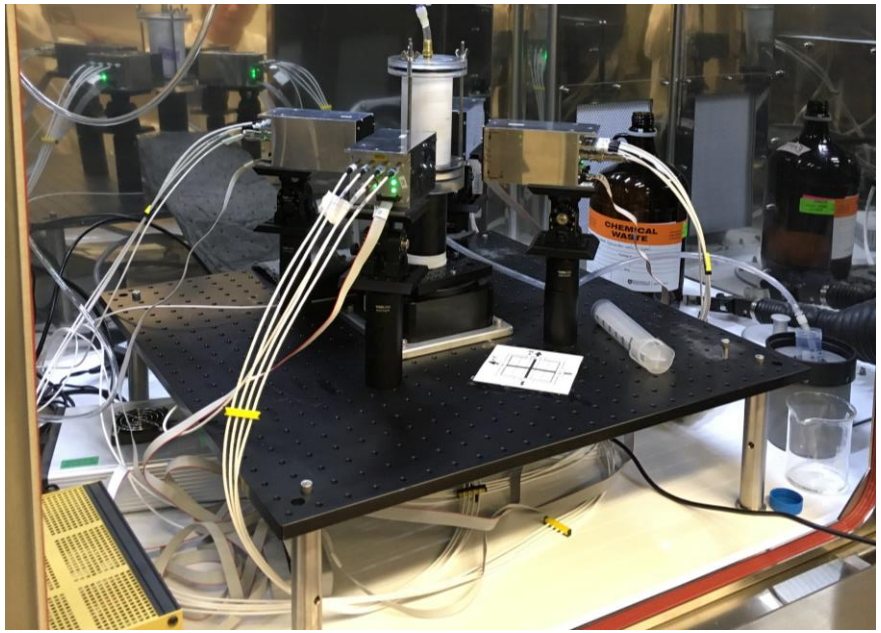


Positron Emission Tomography



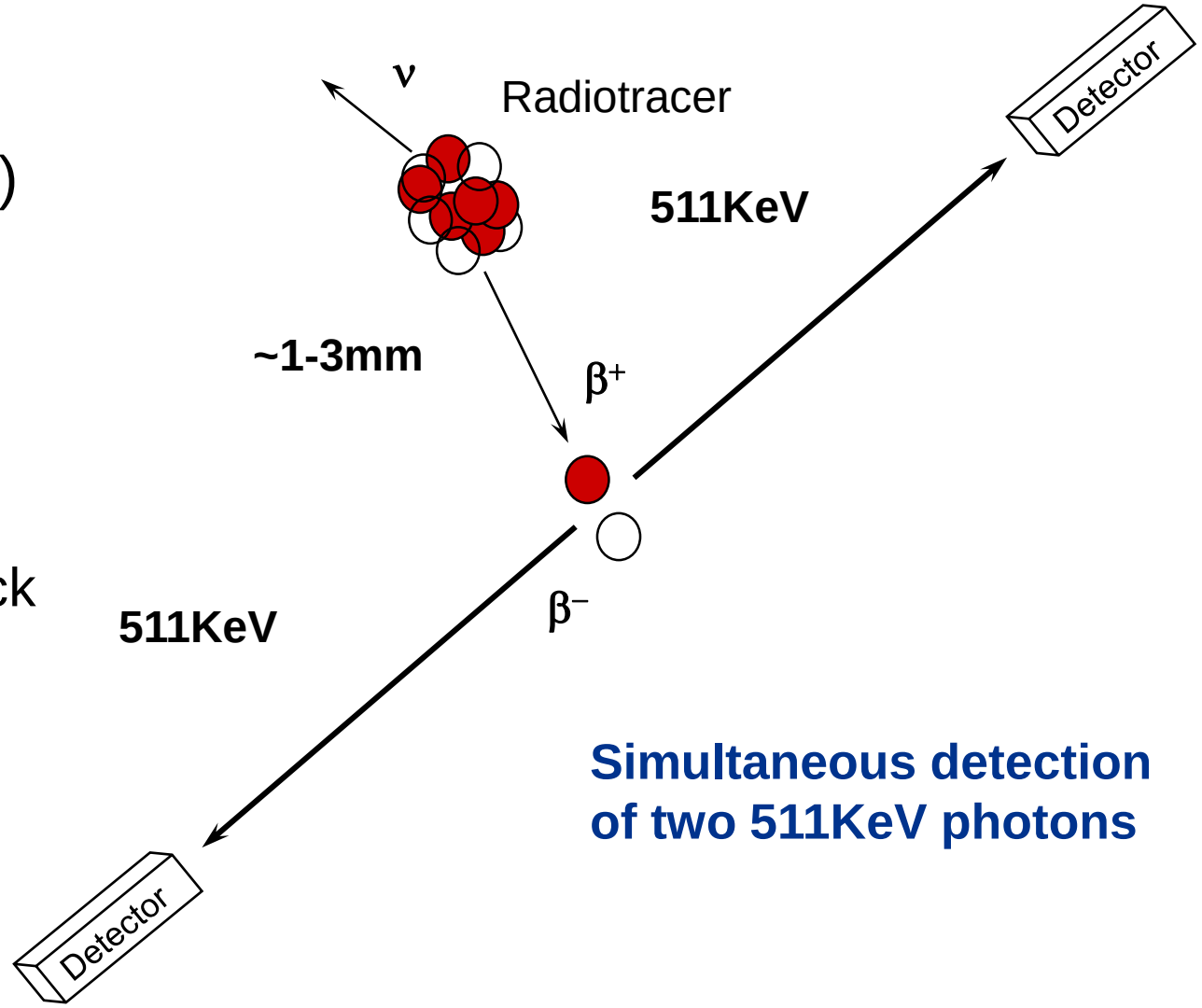
You measure what stays in the system, not what you add!



How do we trace PET Isotopes?

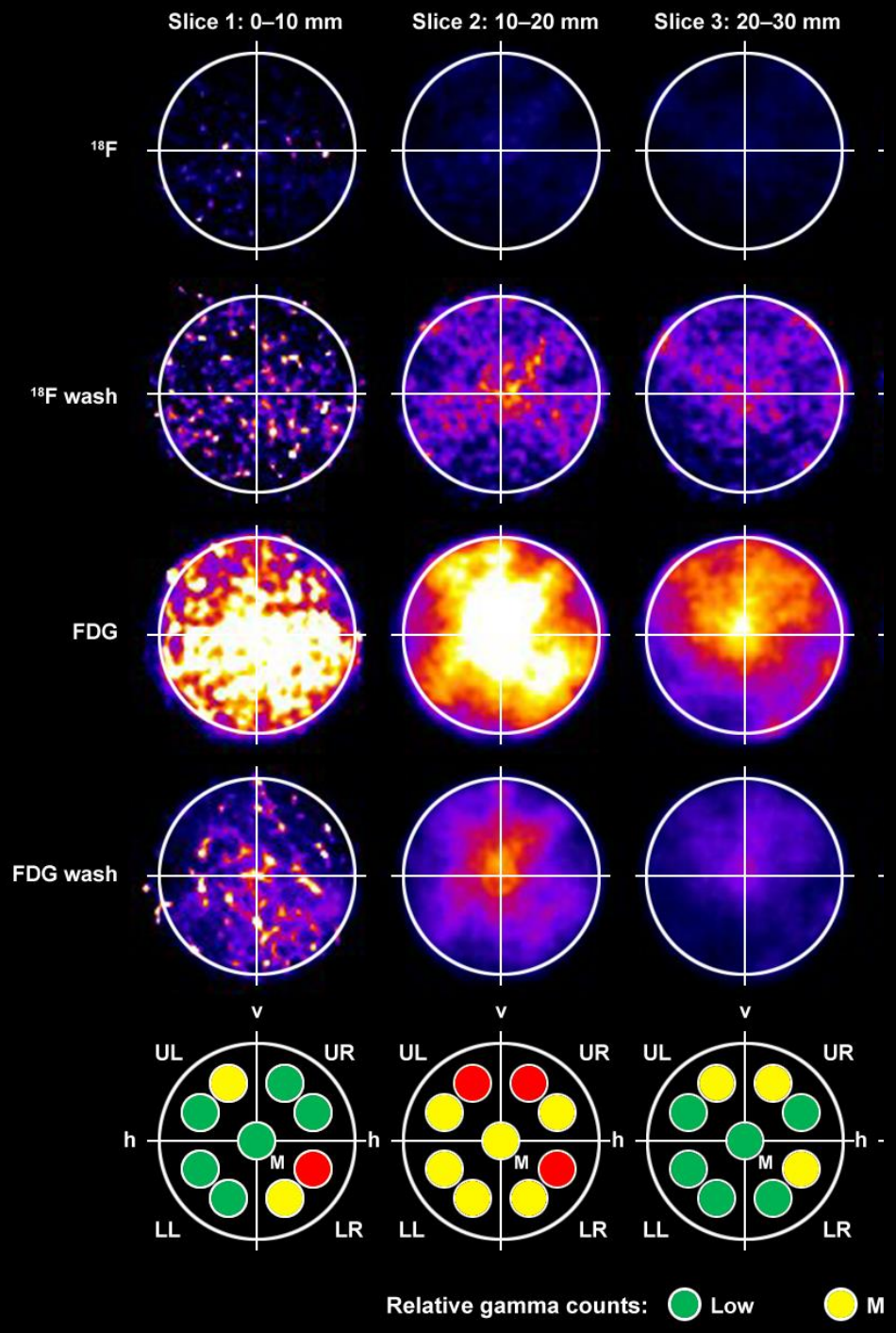
Positron travels 1-3 mm before annihilation (depending on energy)

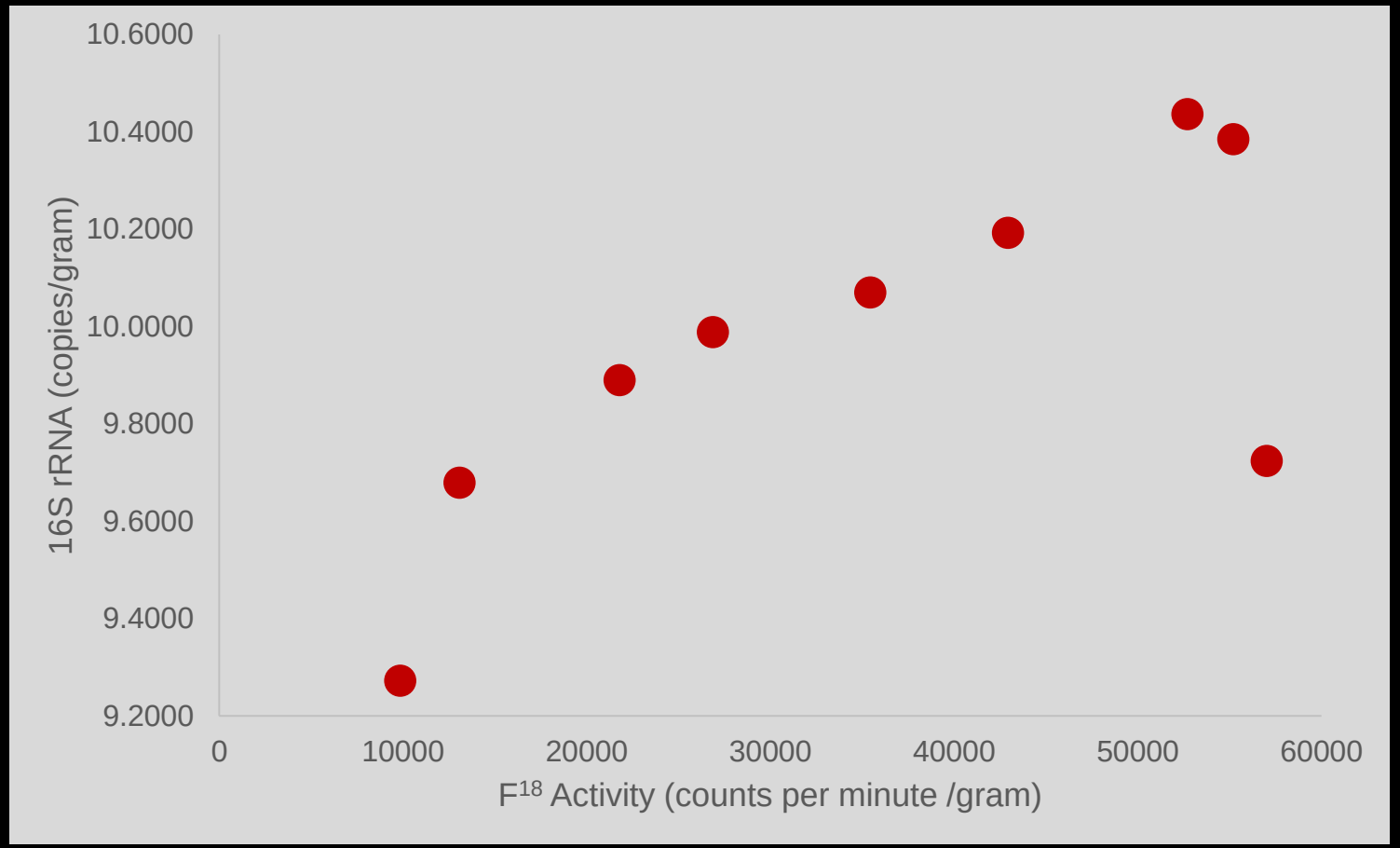
Energy and Momentum conservation
- 511 keV Photons and back-to-back



Simultaneous detection of two 511KeV photons

Gene Expression and Glucose Use





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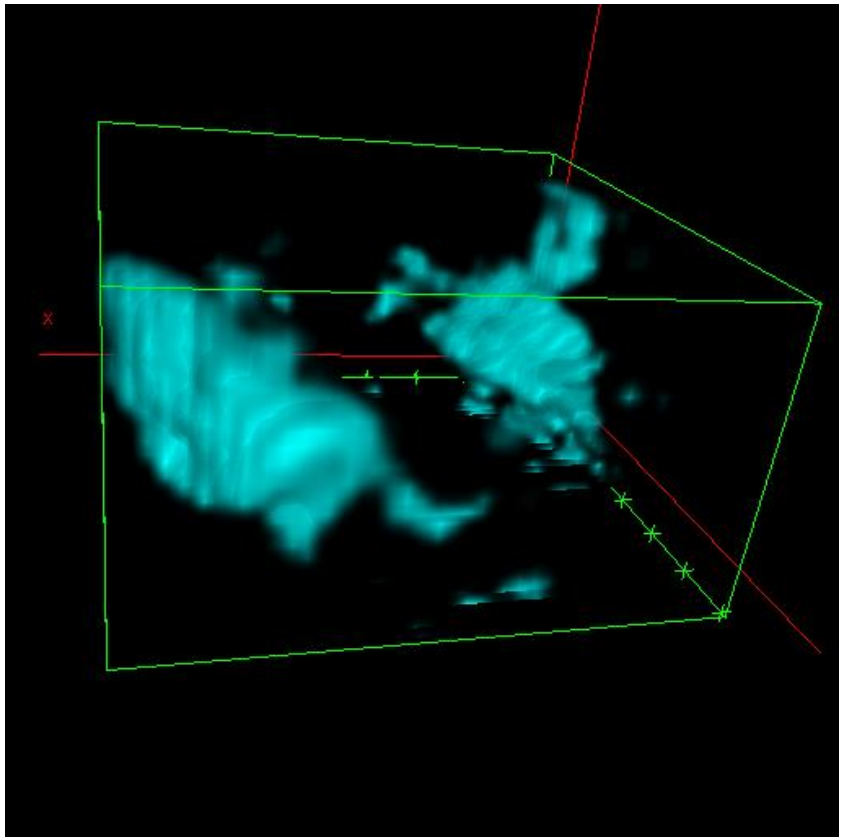
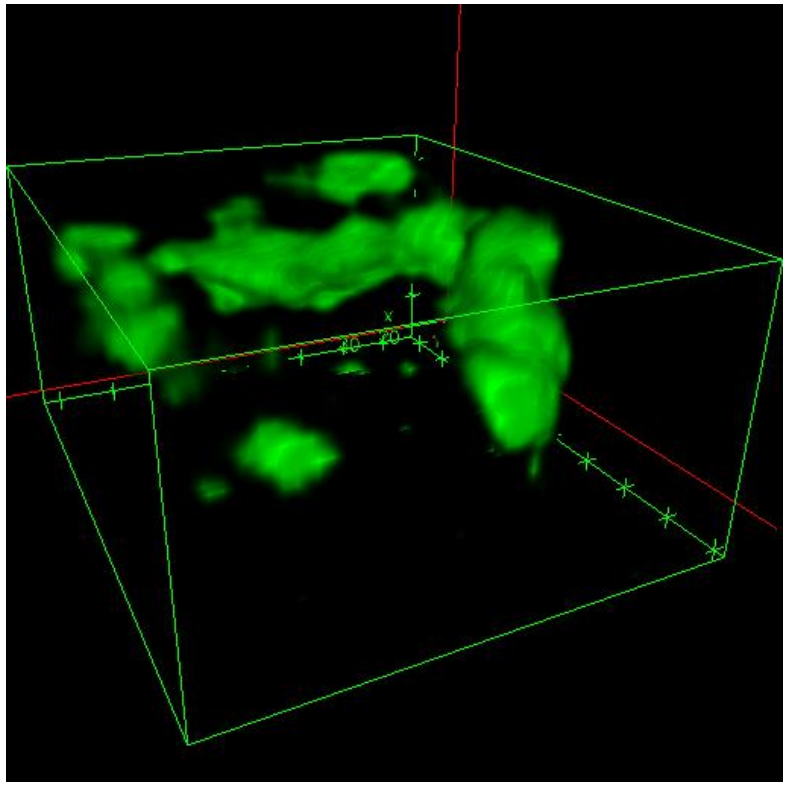
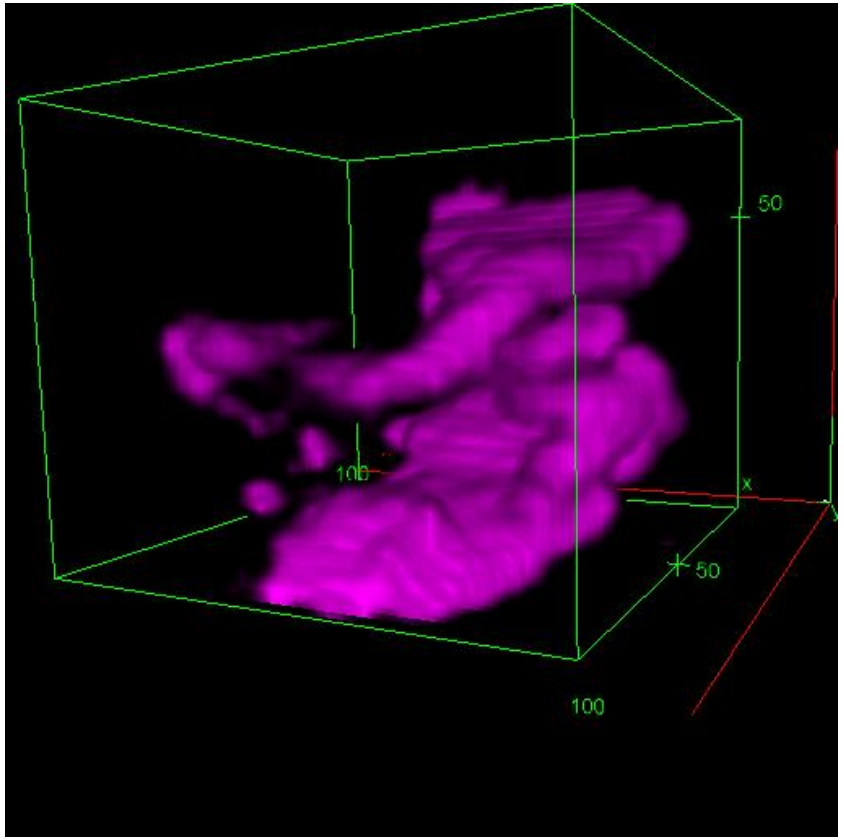
Comparing DI Water to Base Solution to Focused Solution



Medium



Fast



Faster!

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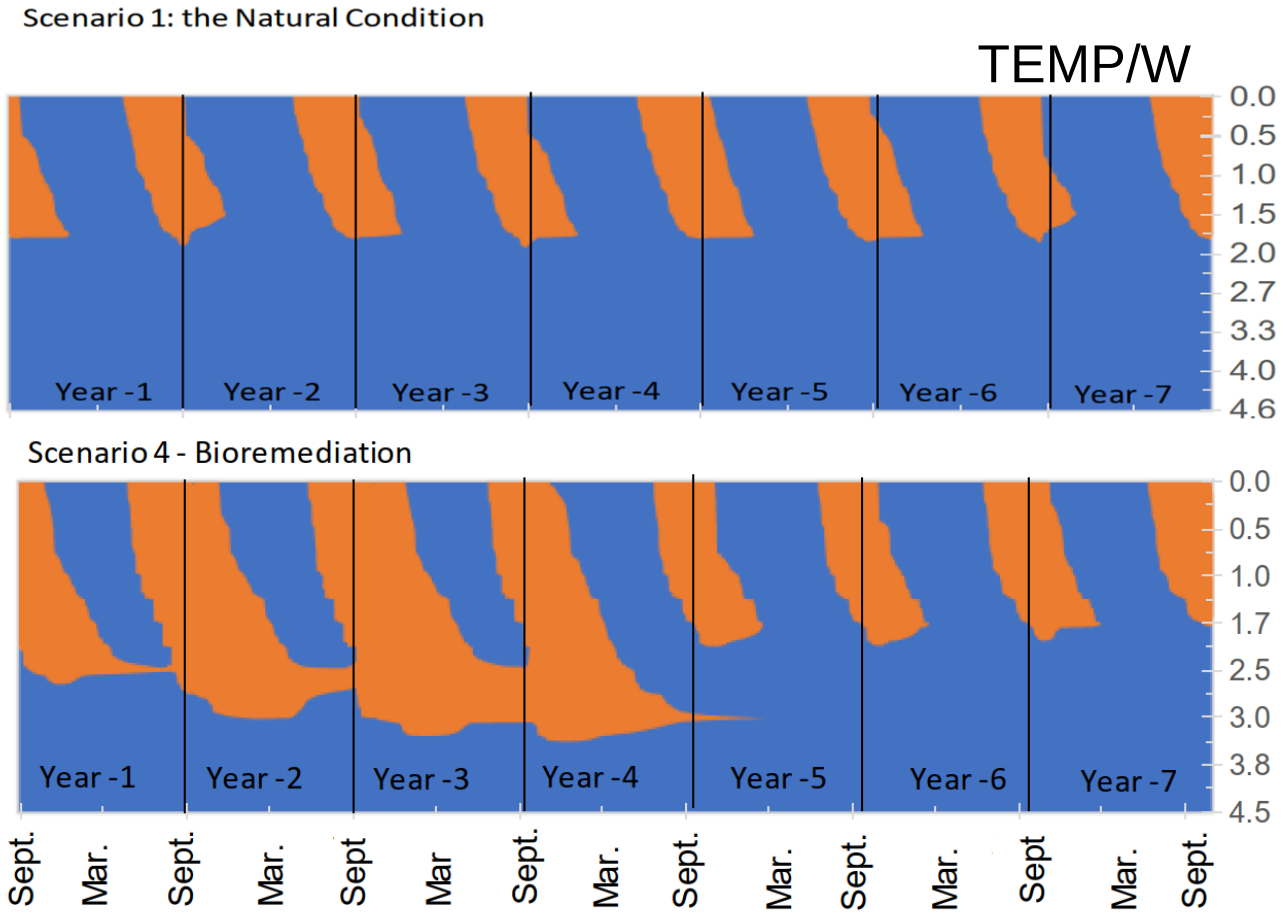
Conclusions

- General trends were evident
  - Interference/Dilution effects due to microcosm design
- Further development of the focus solutions is warranted
- Implement additional testing to further understand the variability in the soil nutrient concentration
- Refine the decision tree and associated biostimulatory solutions to enhance degradation in cold-region soils

Conclusions

- Design and implement an in situ treatability pilot test at the site using focused biostimulatory solutions



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Acknowledgements

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Questions?

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