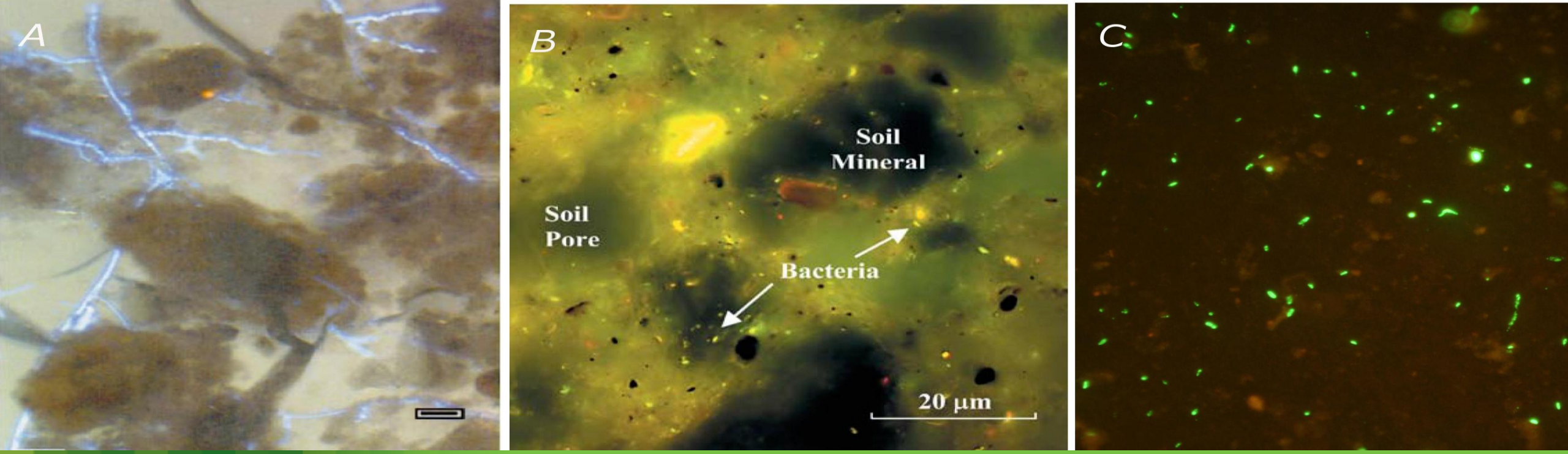


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Dissolved Organic Matter as a Booster for Hydrocarbon Bioremediation: Insights from Radiotracer Imaging and X-ray Spectroscopy

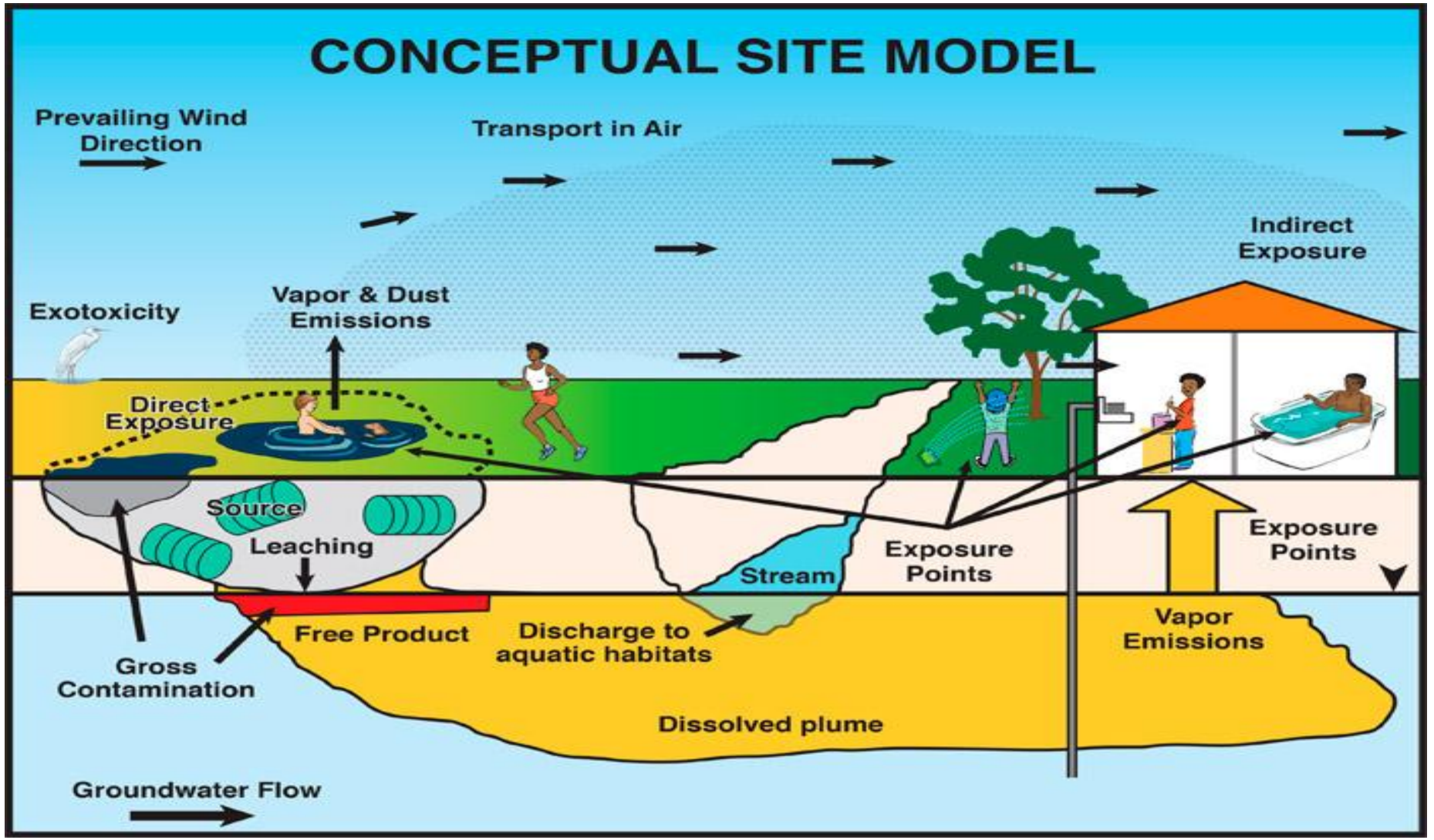
Tony Tian, Dr. Derek Peak, Dr. Steven Siciliano

October 17, 2025

Please feel free to reach me at tonytian349@gmail.com or connect with me on LinkedIn

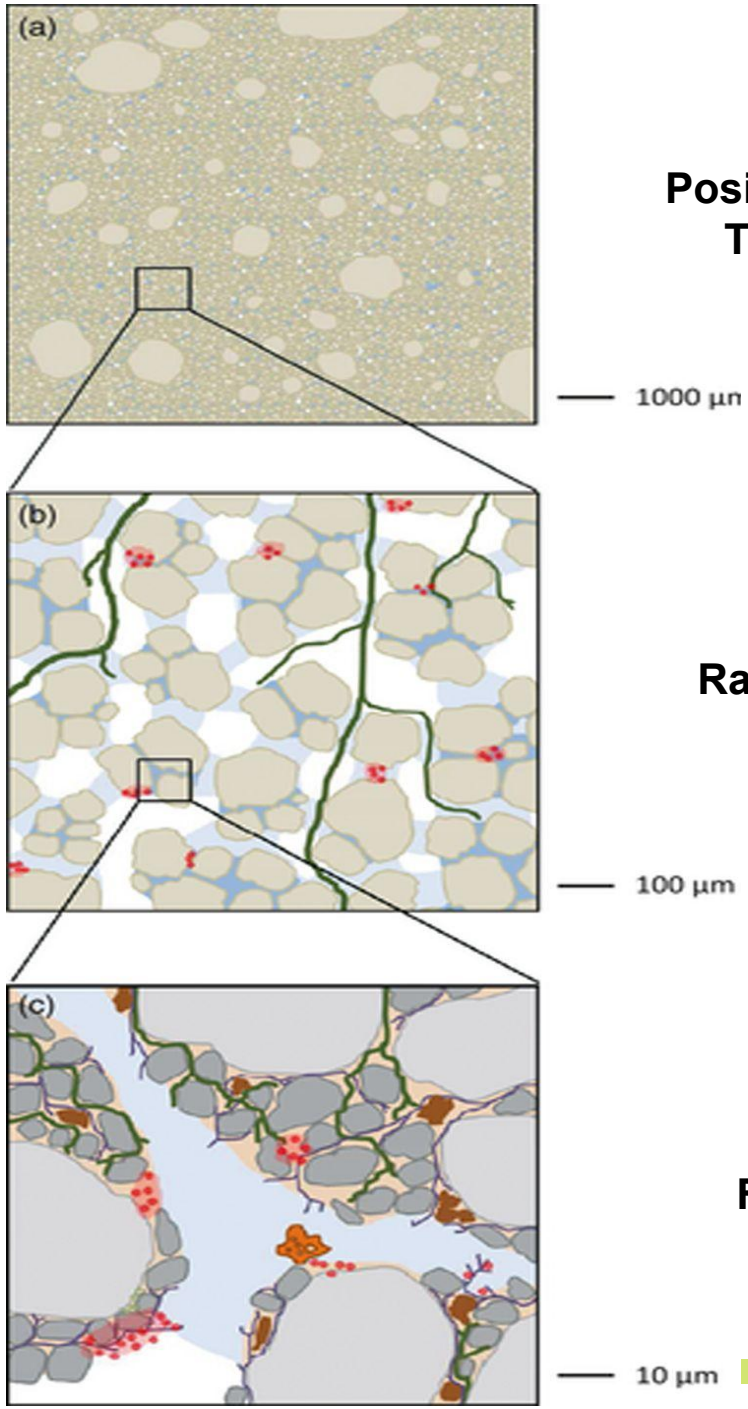
Cover image adapted from Baveye et al., 2018

The Problem: Persistent BTEX in Prairie Soils



Adapted from ITRC's *TPH Risk Evaluation at Petroleum-Contaminated Sites* (2018)

Spatial scales of various imaging techniques



Positron Emission Tomography

Radiographic Imaging

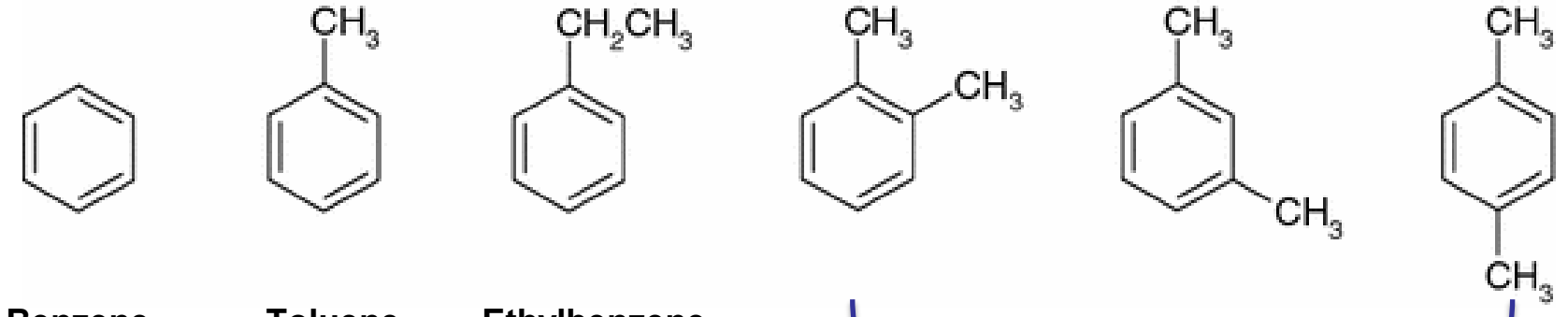
X-ray Fluorescence Imaging

<u>Overall Goal</u> is to decipher how microbial activity in soil is linked to physicochemical properties in its **microenvironments that are relevant to bacteria, i.e. µm - mm**

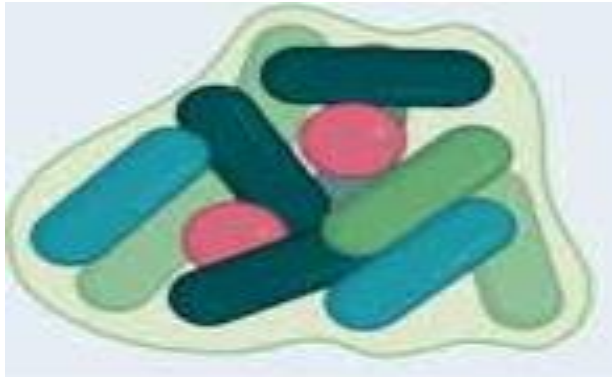
Adapted from Vos et al., 2013

Key Players in Anaerobic BTEX Biodegradation

Pollutants



Benzene **Toluene** **Ethylbenzene** **Xylene**



Electron acceptors (EAs)

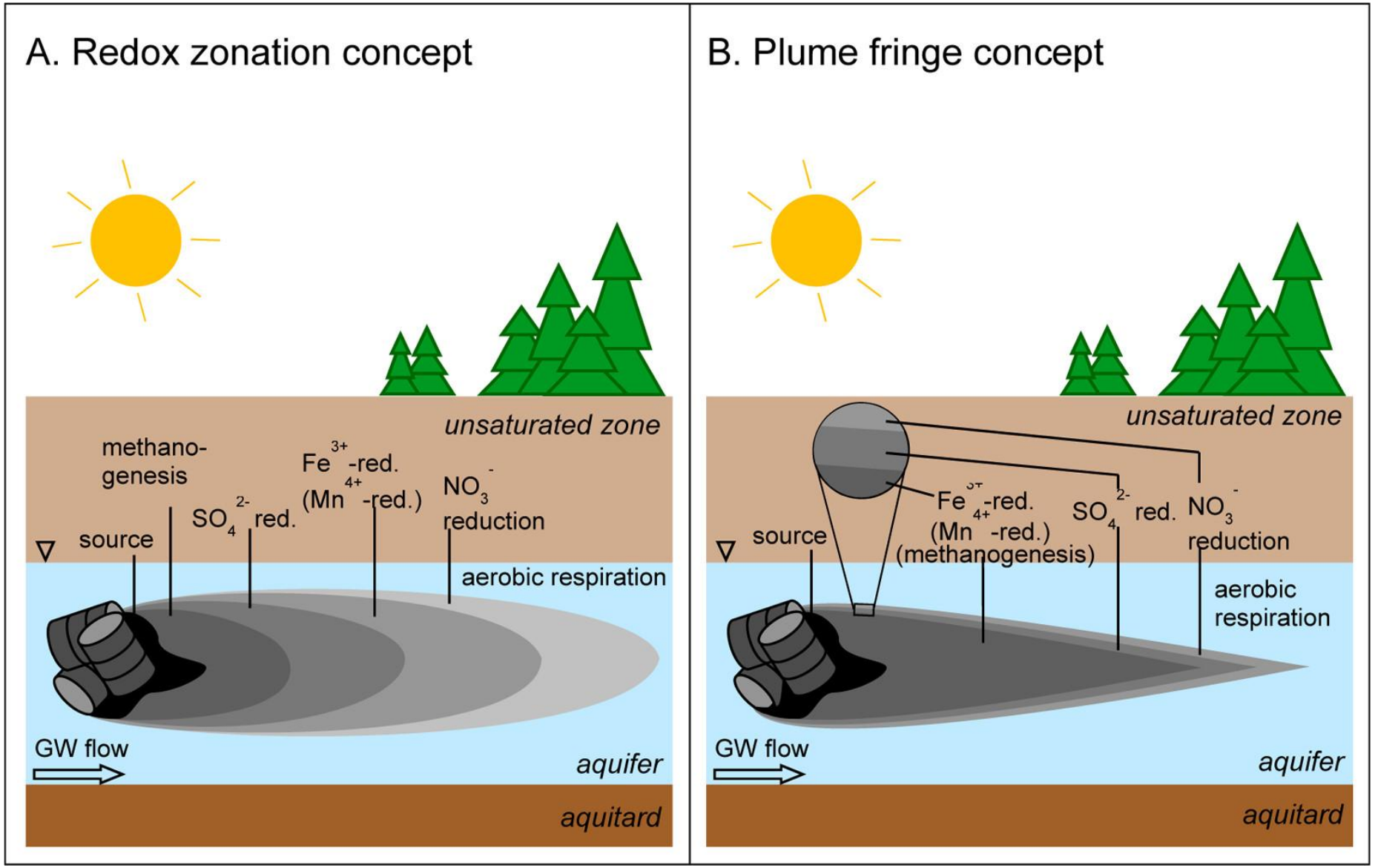
NO_3^-

Fe(III) / Mn (IV)

SO_4^{2-}

CO_2

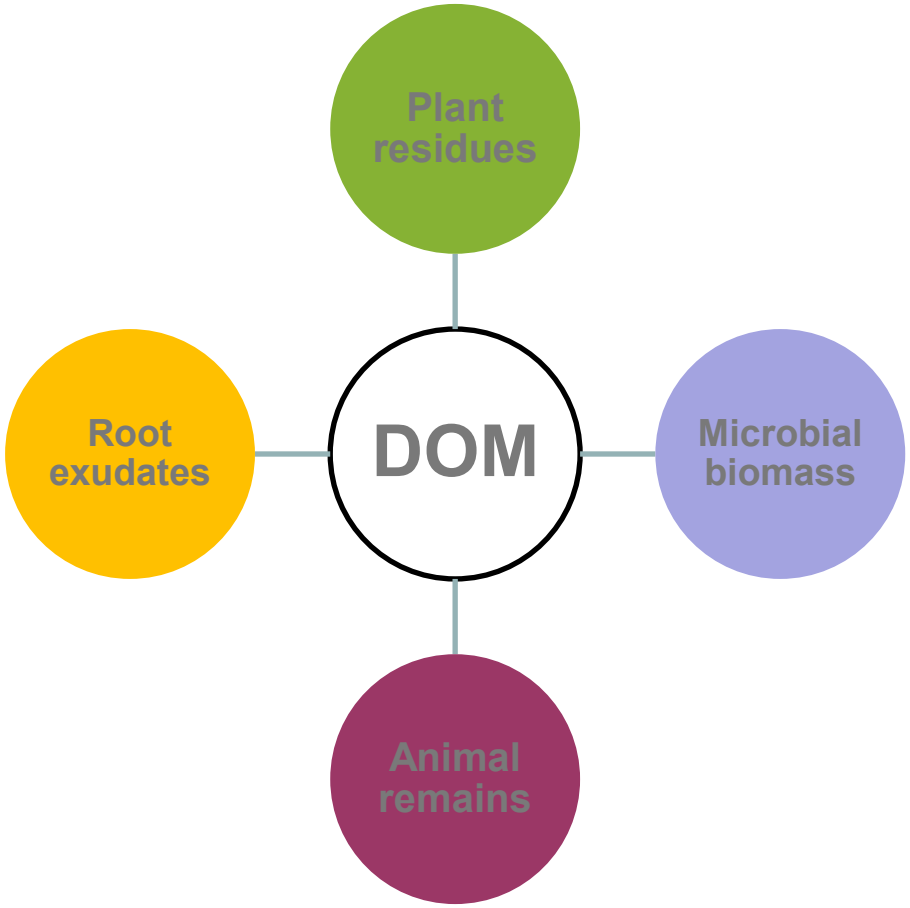
The Problem: Persistent BTEX in Prairie Soils

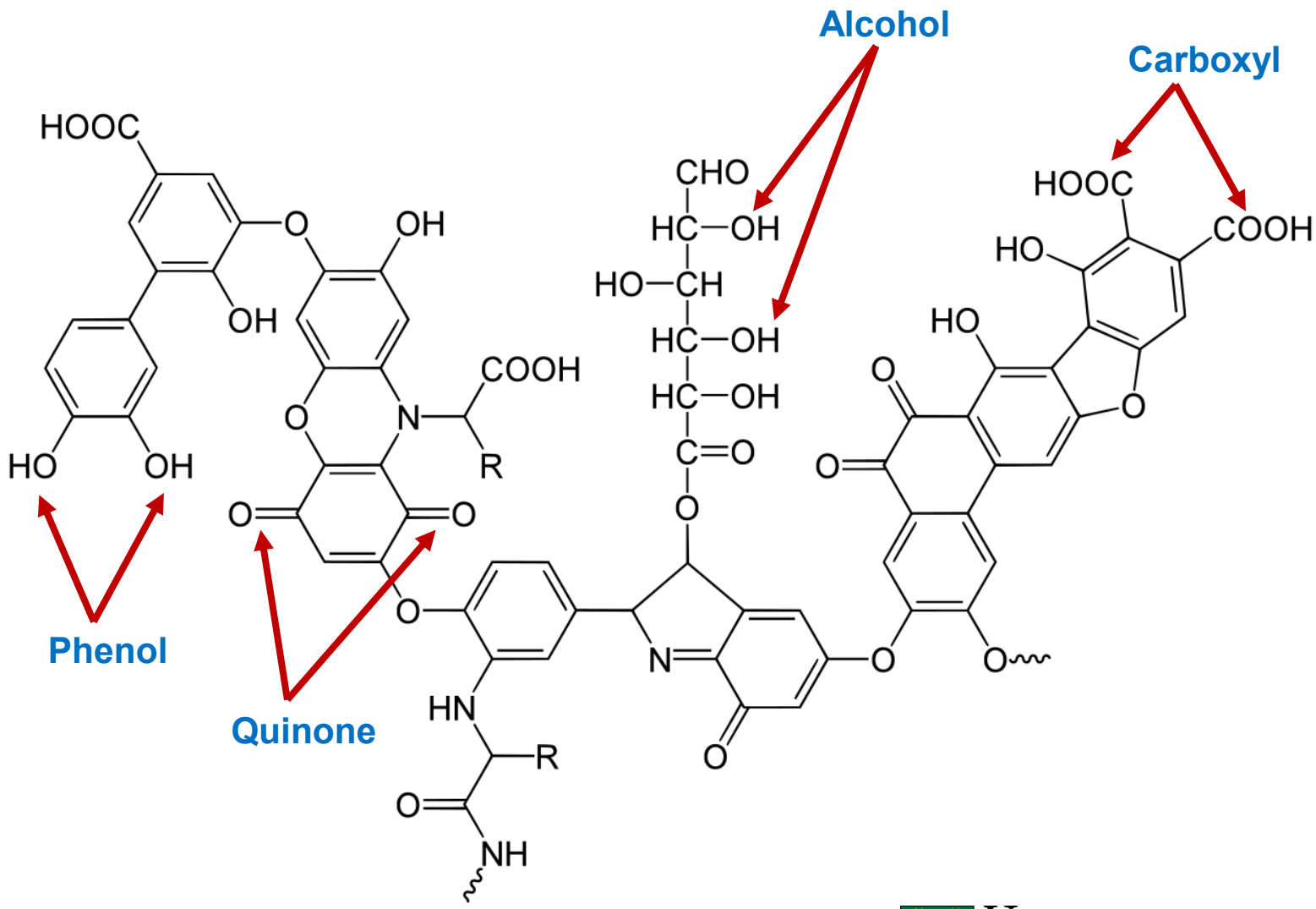


- **Traditional redox zonation concept only considers thermodynamics, whereas plume fringe concept takes kinetics into account too**
- **Soluble EAs are depleted in plume core, in which degradation relies on insoluble EAs, e.g. Fe(III)**

Adapted from Meckenstock et al., 2015

What is Dissolved Organic Matter (DOM)

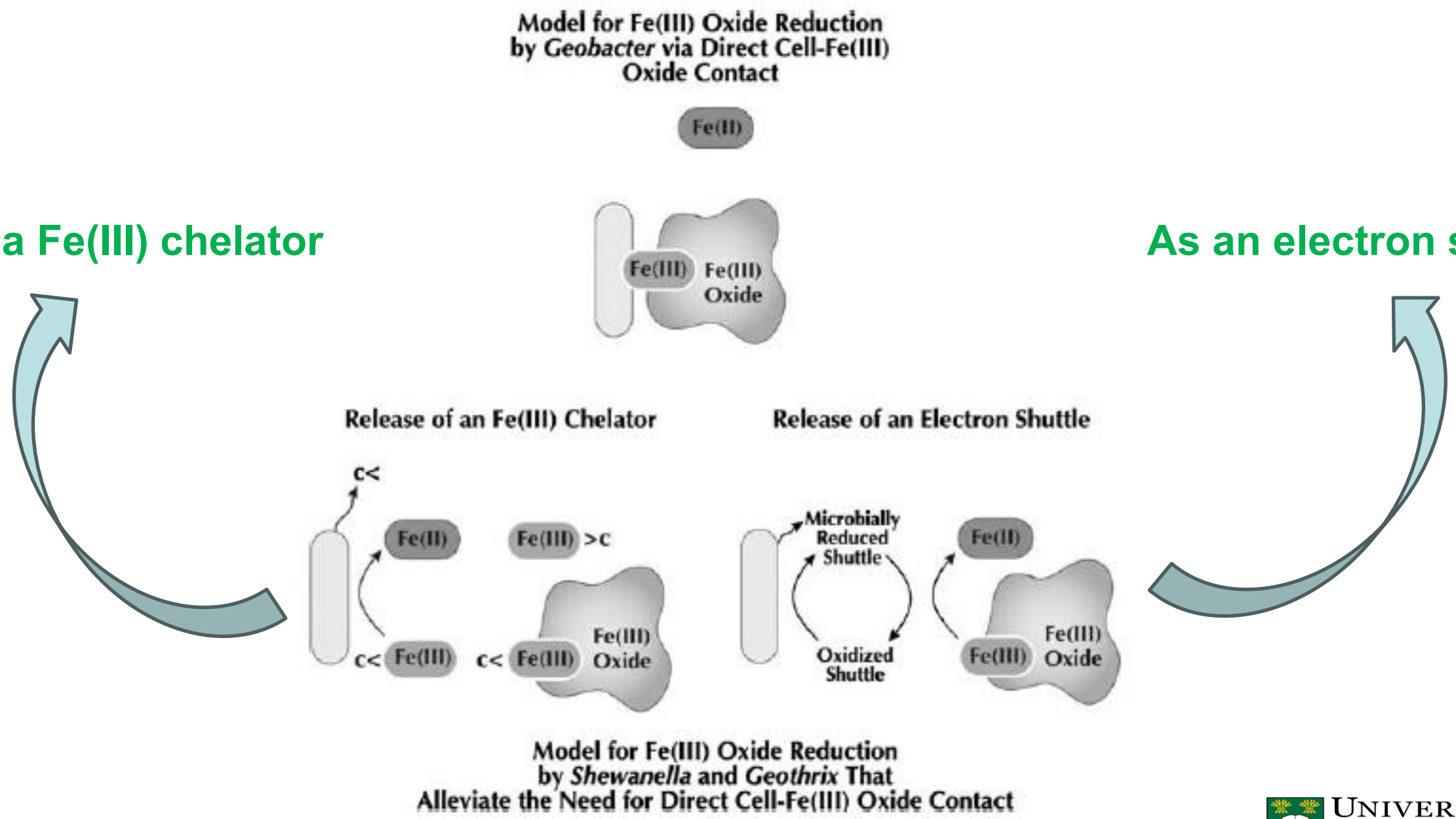




How Can DOM Help BTEX Biodegradation? Potentially Dual Roles

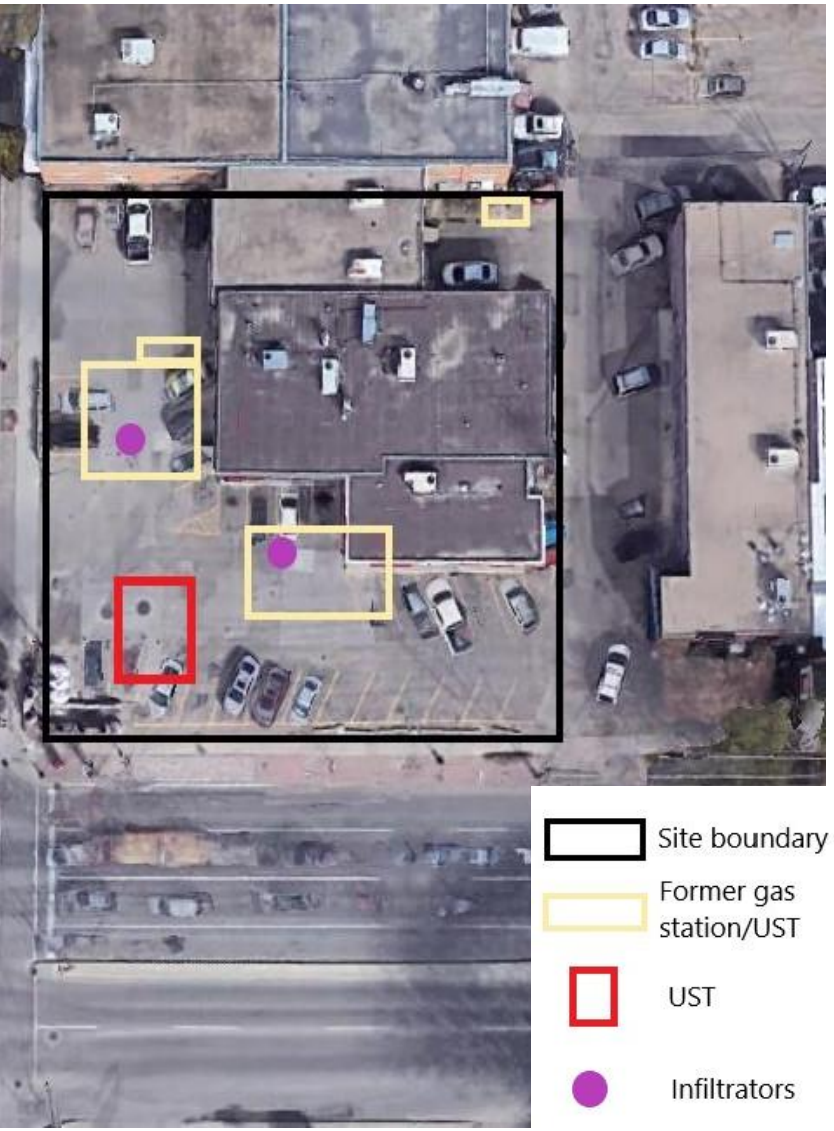
As a Fe(III) chelator

As an electron shuttle



Adapted from Tabak et al., 2005

Field Soil Sampling & Lab Studies Setup

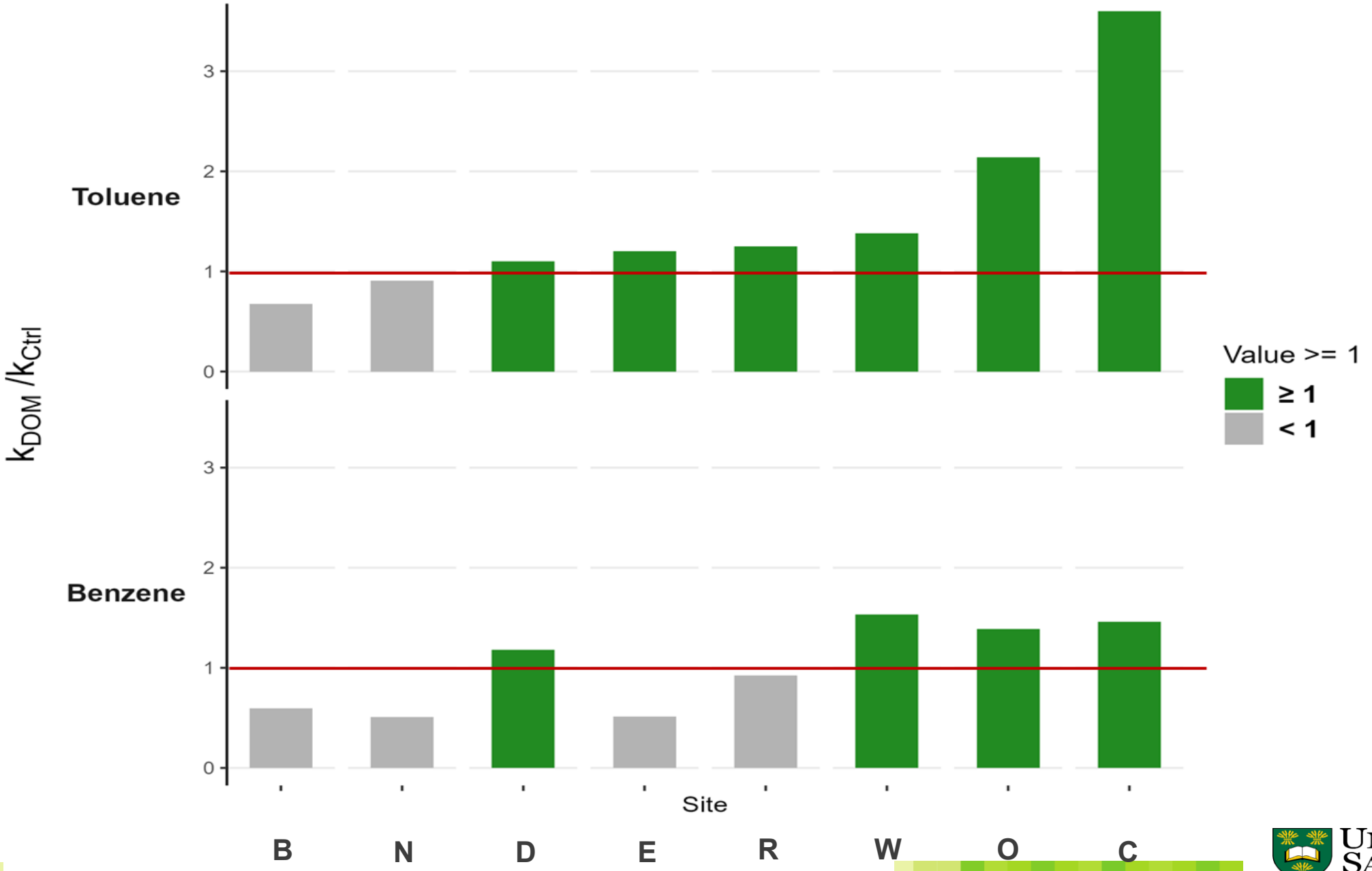






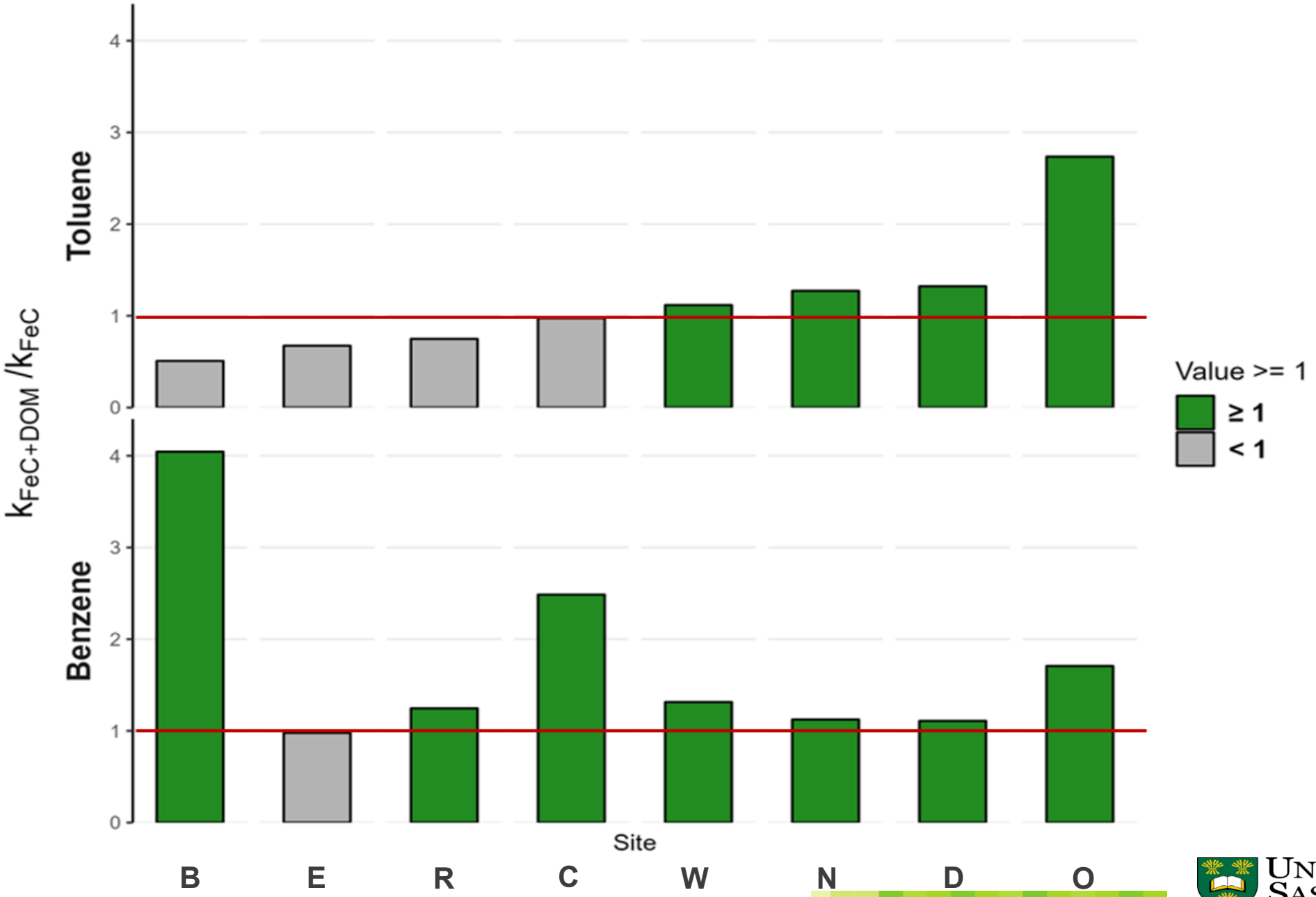


DOM Accelerates Toluene and Benzene Degradation



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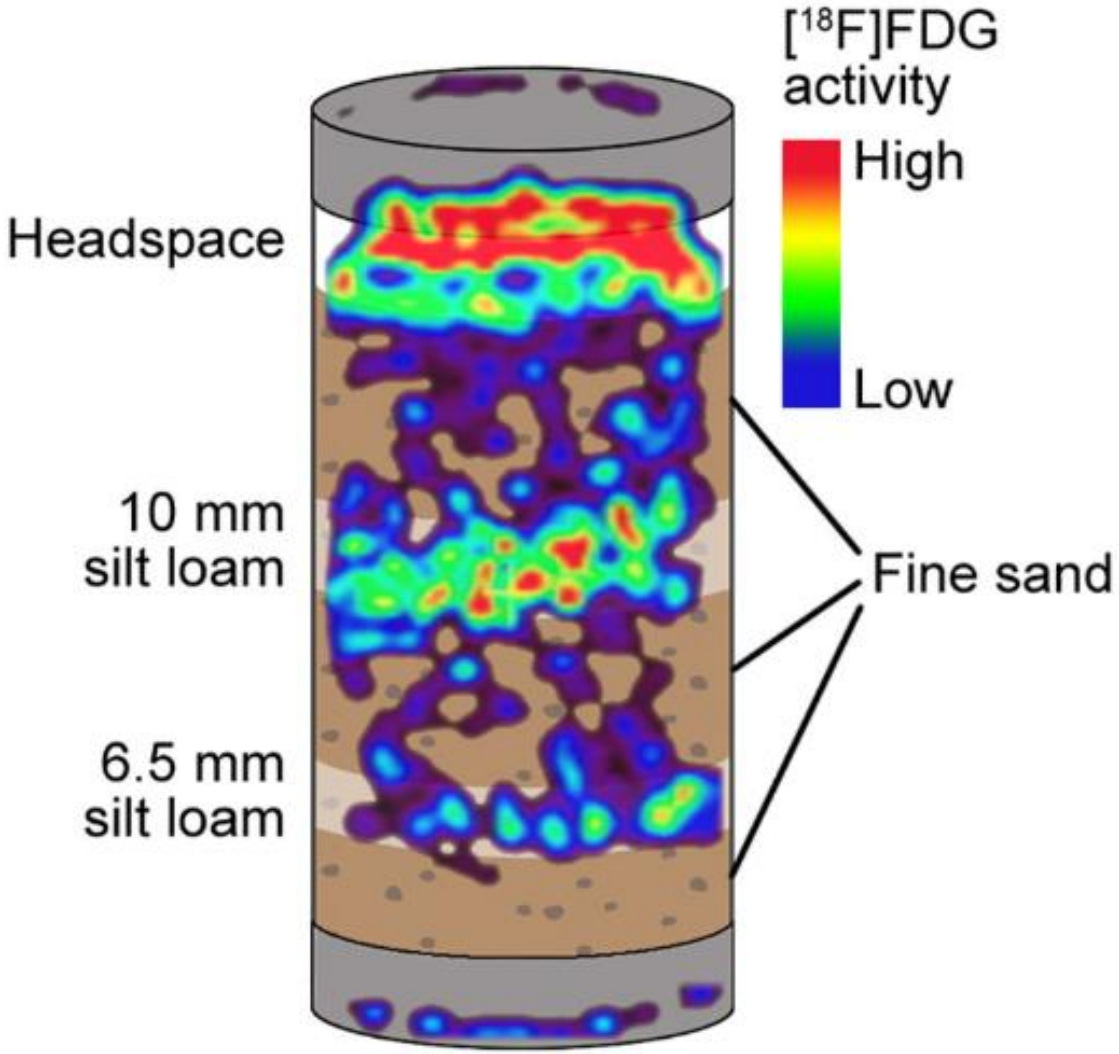
DOM + Fe(III) Citrate better than Fe(III) Citrate Only

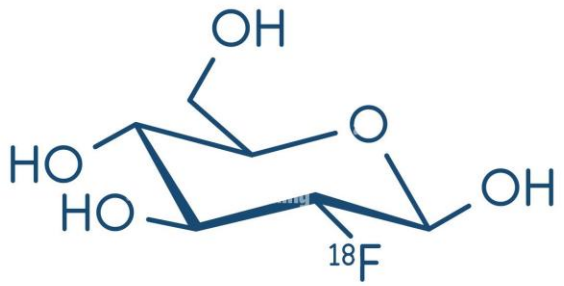


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Allows Us to See Inside Out

A model soil column dosed with [^{18}F]FDG and imaged with Positron Emission Tomography (PET)

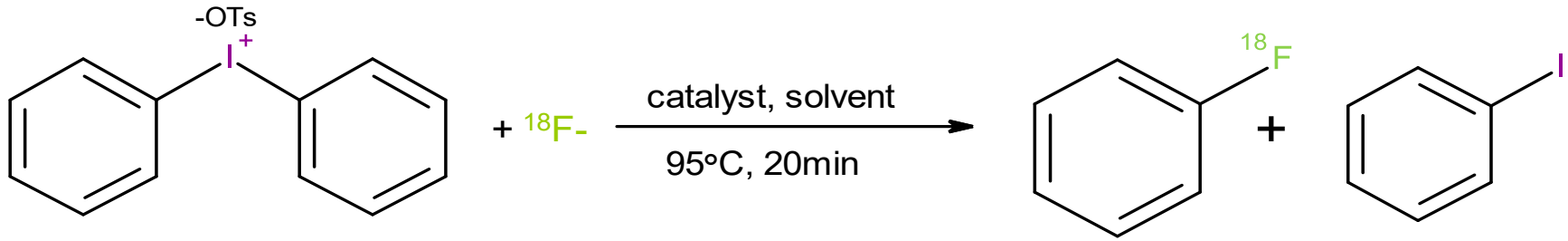




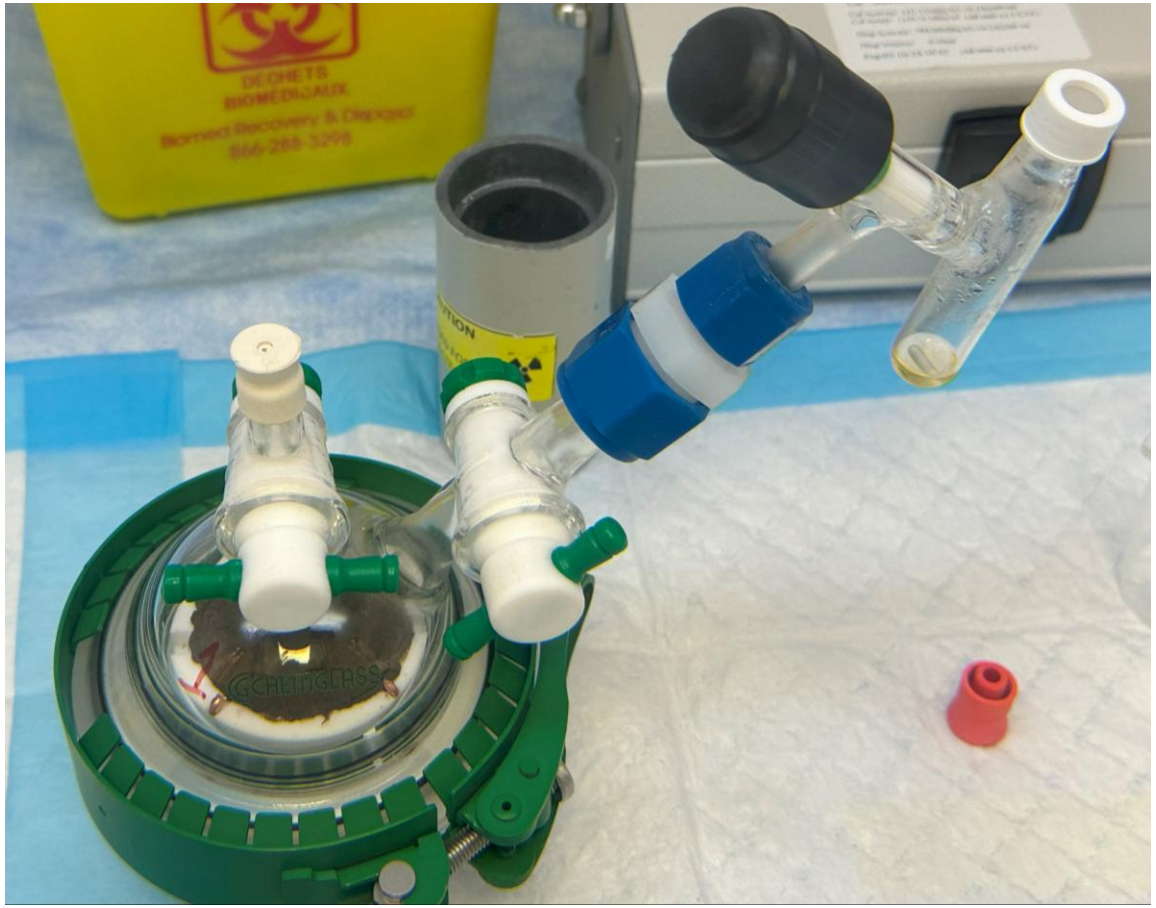
fludeoxyglucose (^{18}F)

Adapted from Kinsella et al., 2012

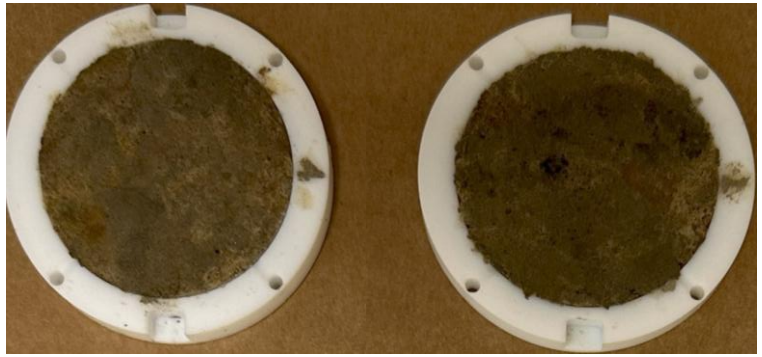
Radiosynthesis of [^{18}F]fluorobenzene → Soil Dosing → Autoradiography



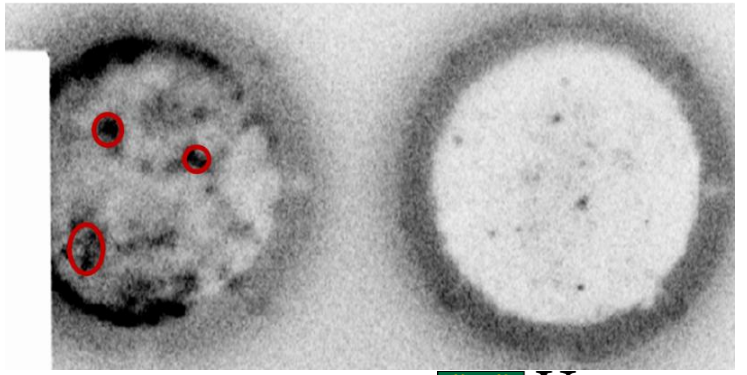
Diphenyliodonium tosylate



Live Autoclaved

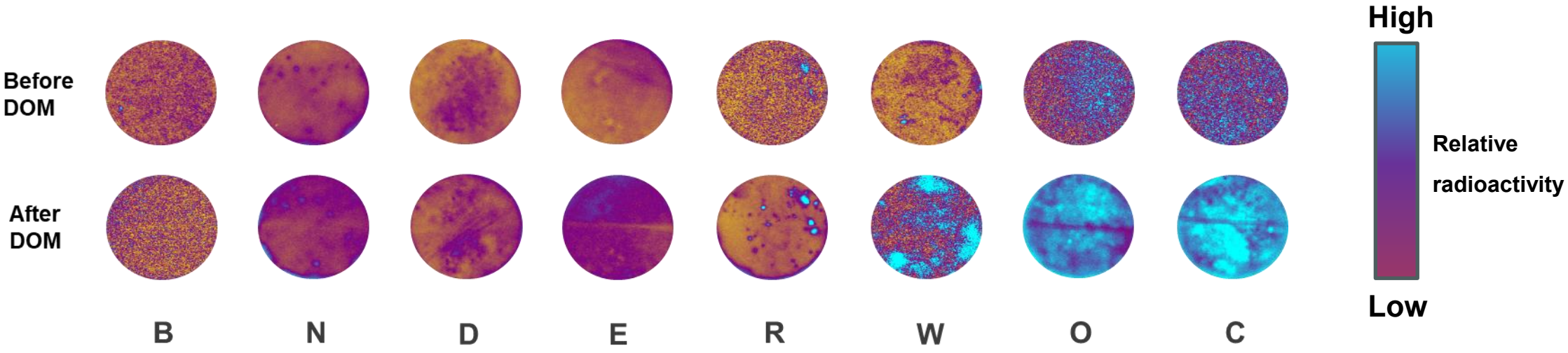


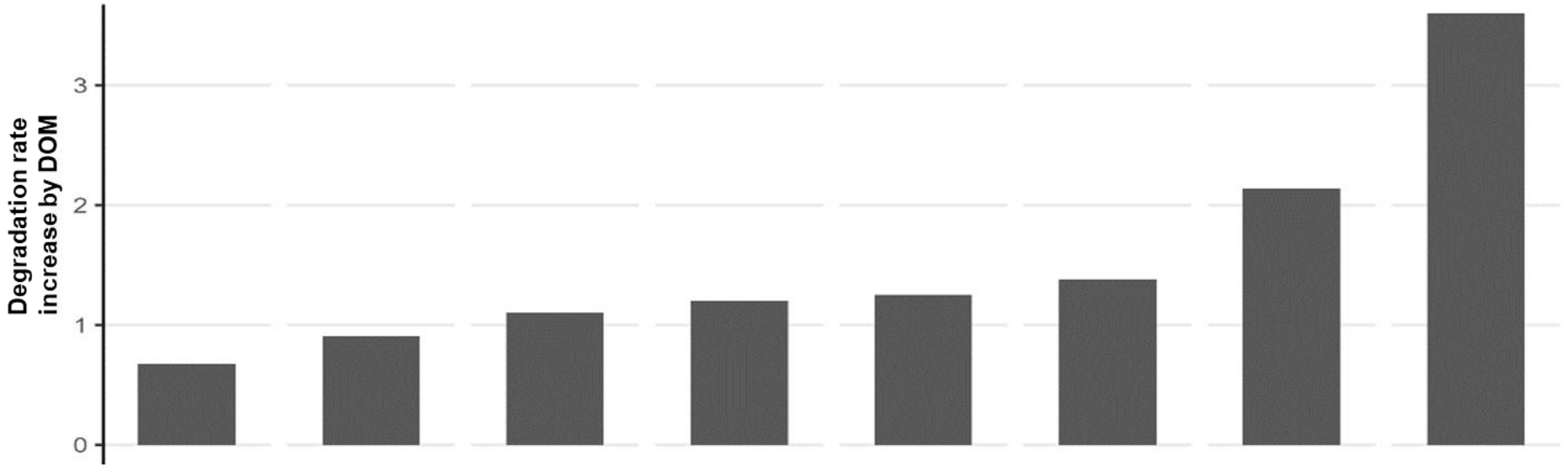
High [^{18}F]fluorobenzene uptake 10 mm



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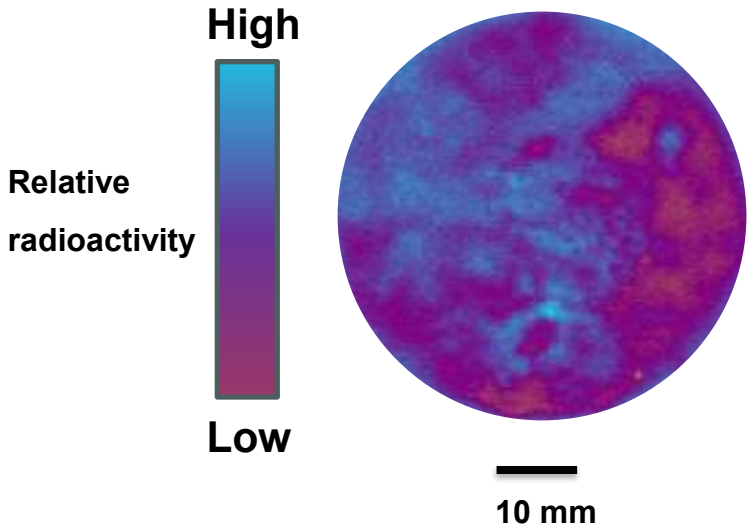
Radio-imaging of soils incubated with DOM vs Biodegradation impact by DOM





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Radio-image of Soil



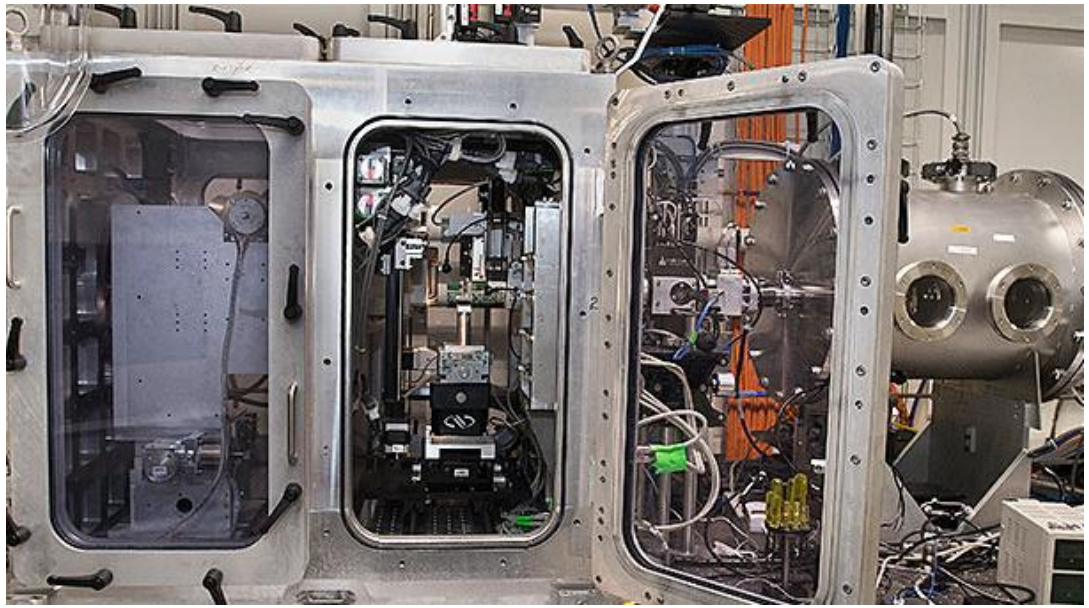
Why some spots "hotter" than others?

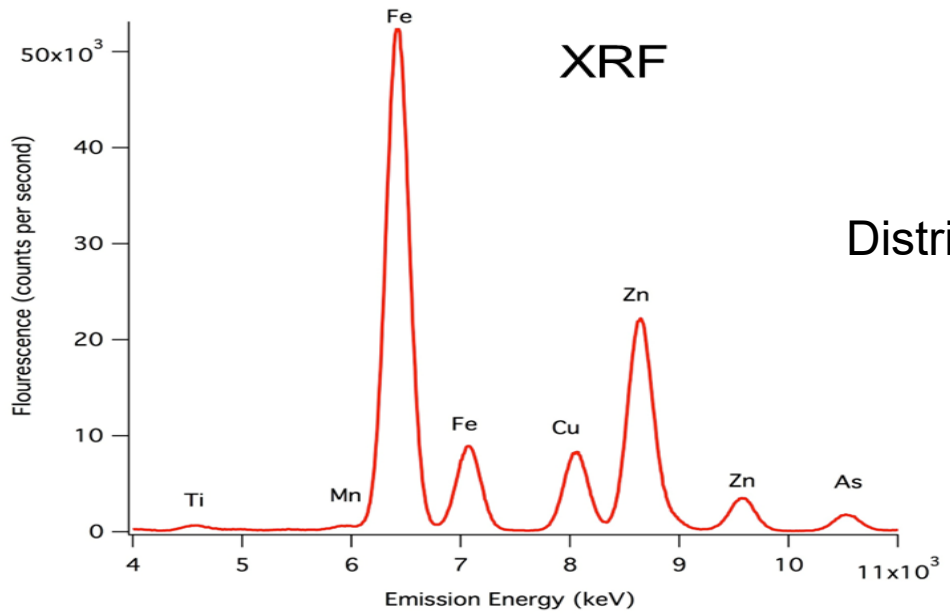
- More electron acceptors: Fe(III), nitrate, sulfate?
- More soil organic matter: C, N?
- More nutrients: N, P?

X-ray spectroscopy!

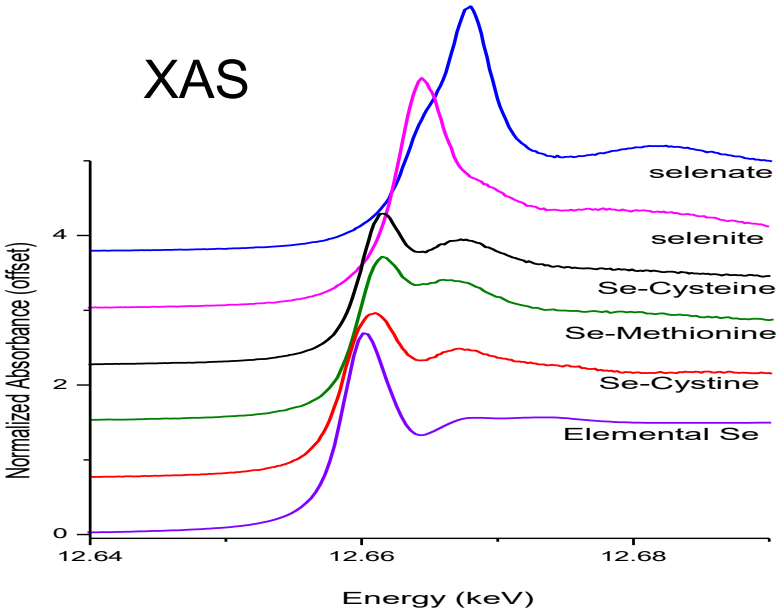
Synchrotron-based X-ray Spectroscopy





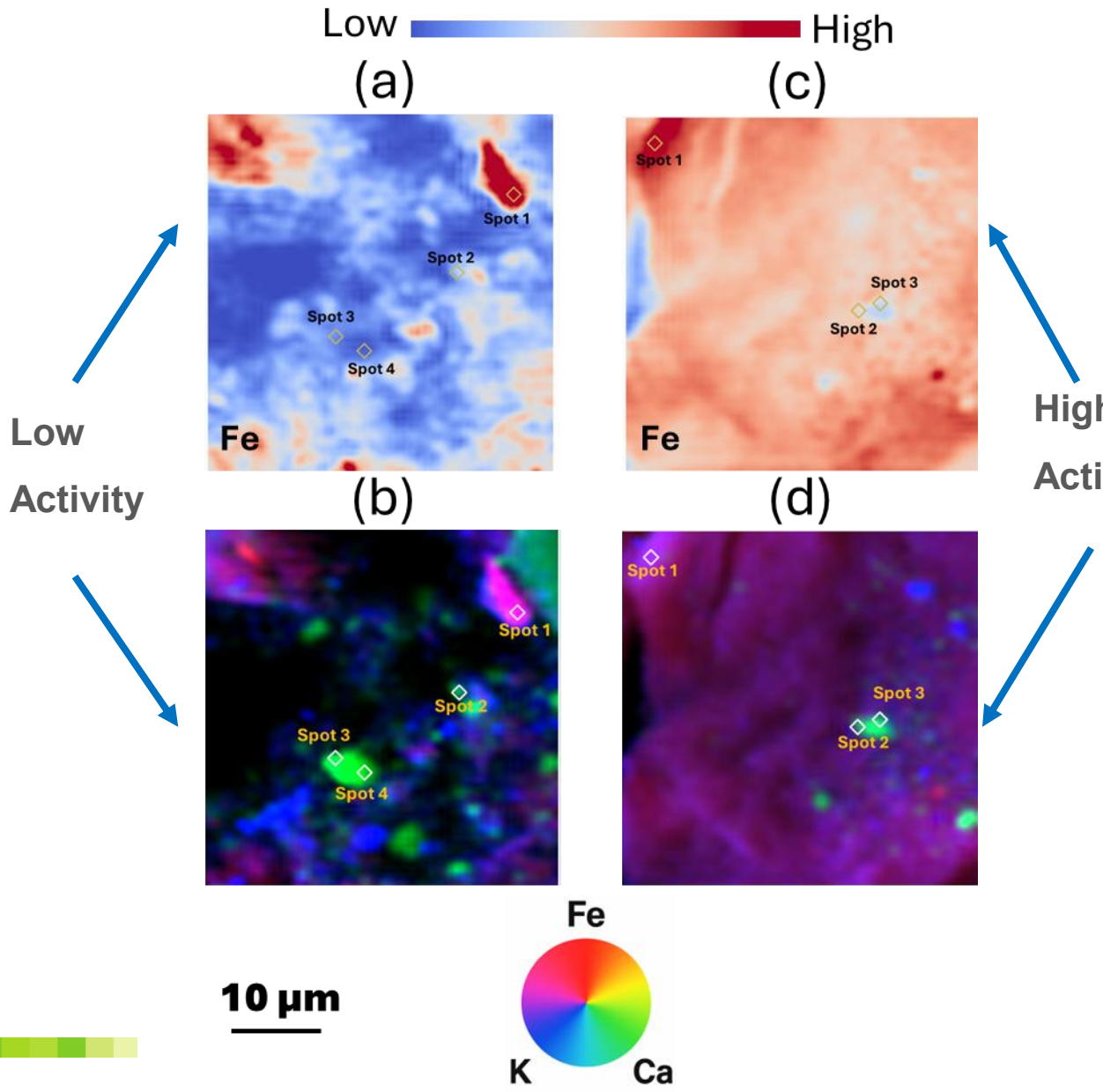


Distribution mapping

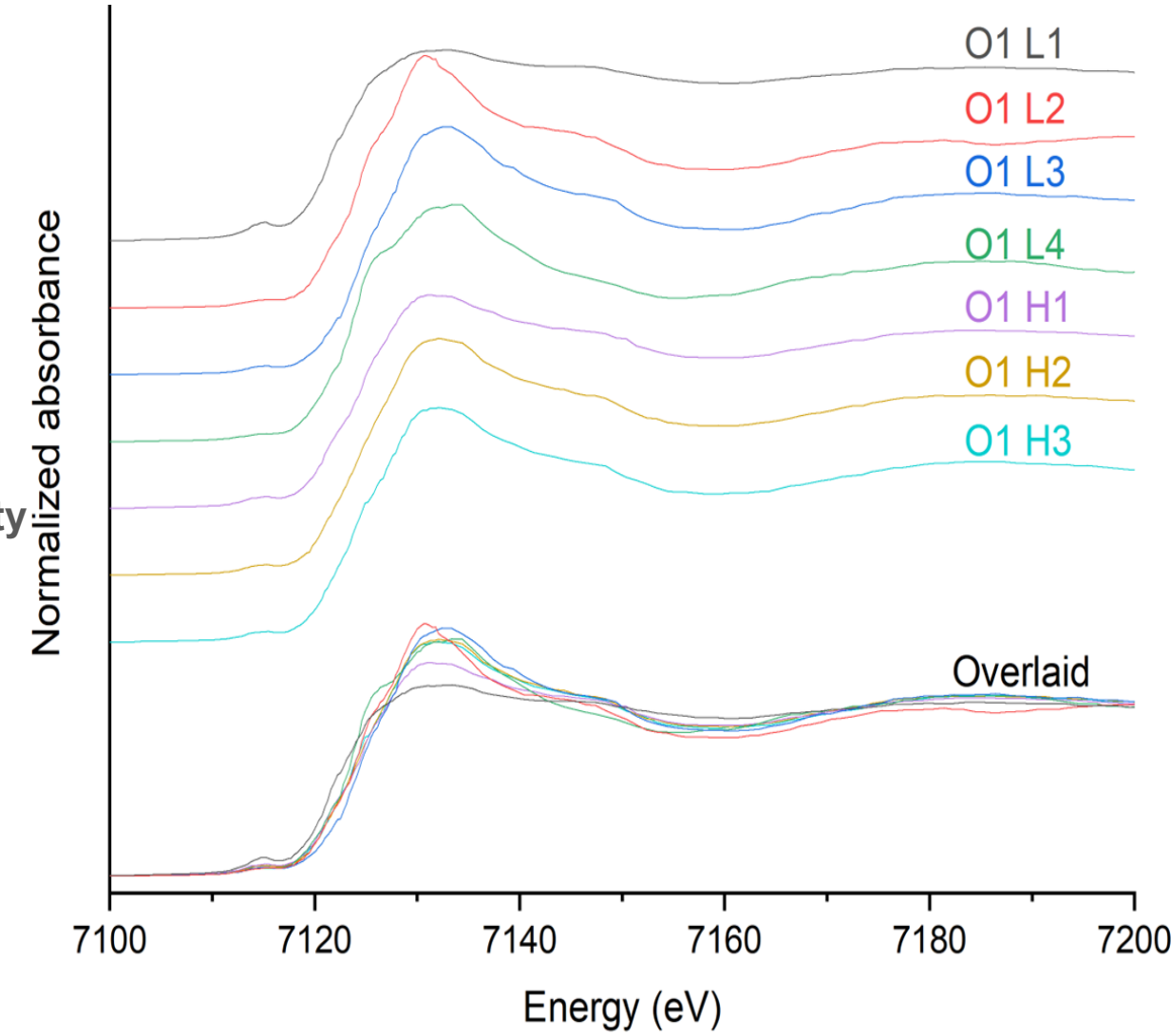


Elemental speciation

Micro-XRF Mapping

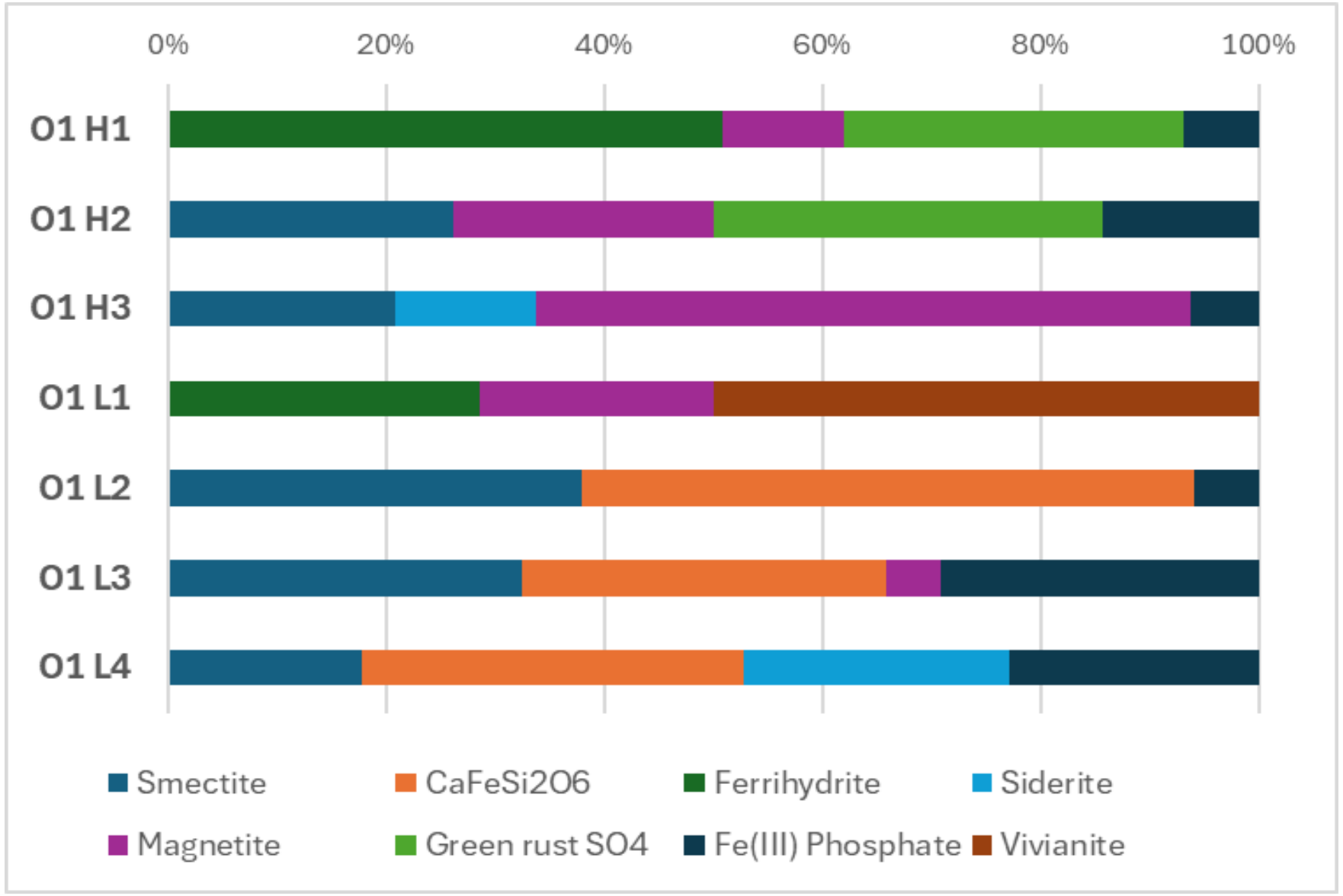


Micro-XANES



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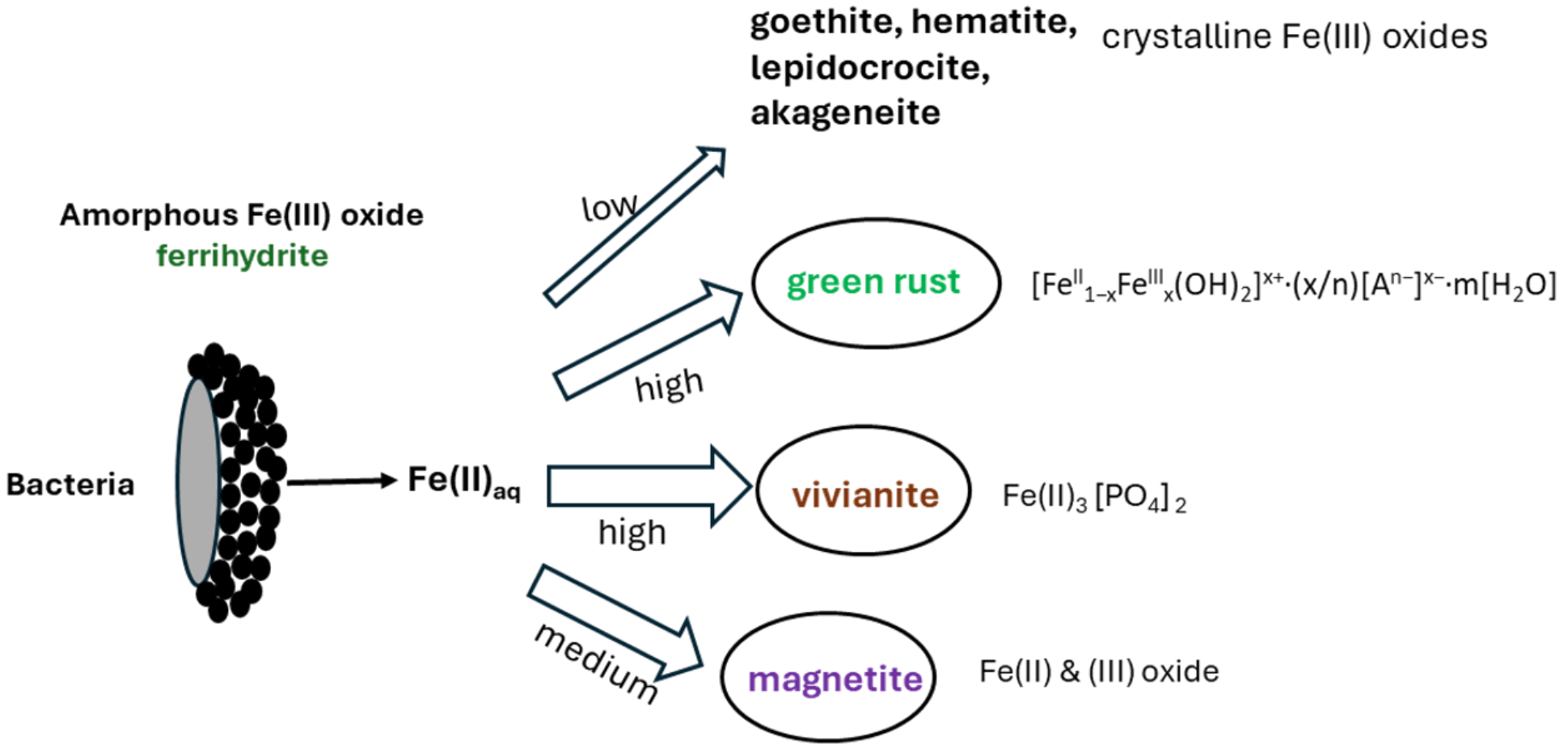
Linear Combination Fitting of Micro-XANES



Active zones have much higher redox-active Fe species,

- **ferrihydrite**
- **green rust**
- **magnetite**

Dissimilatory Iron Reducing Bacteria (DIRB) Induced Iron Transformation

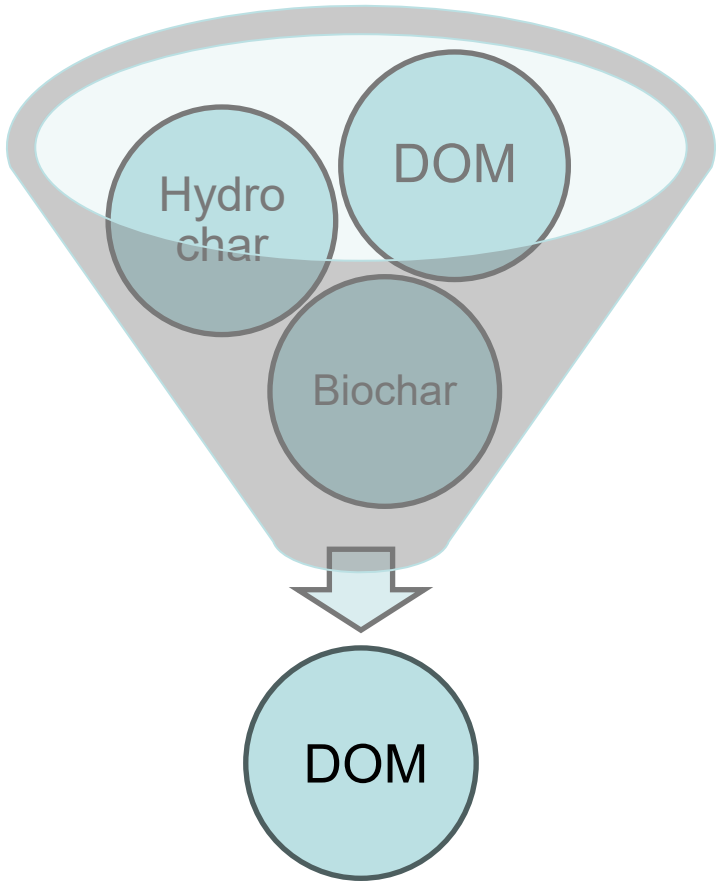


Adapted from Hansel et al., 2004

Future Applications

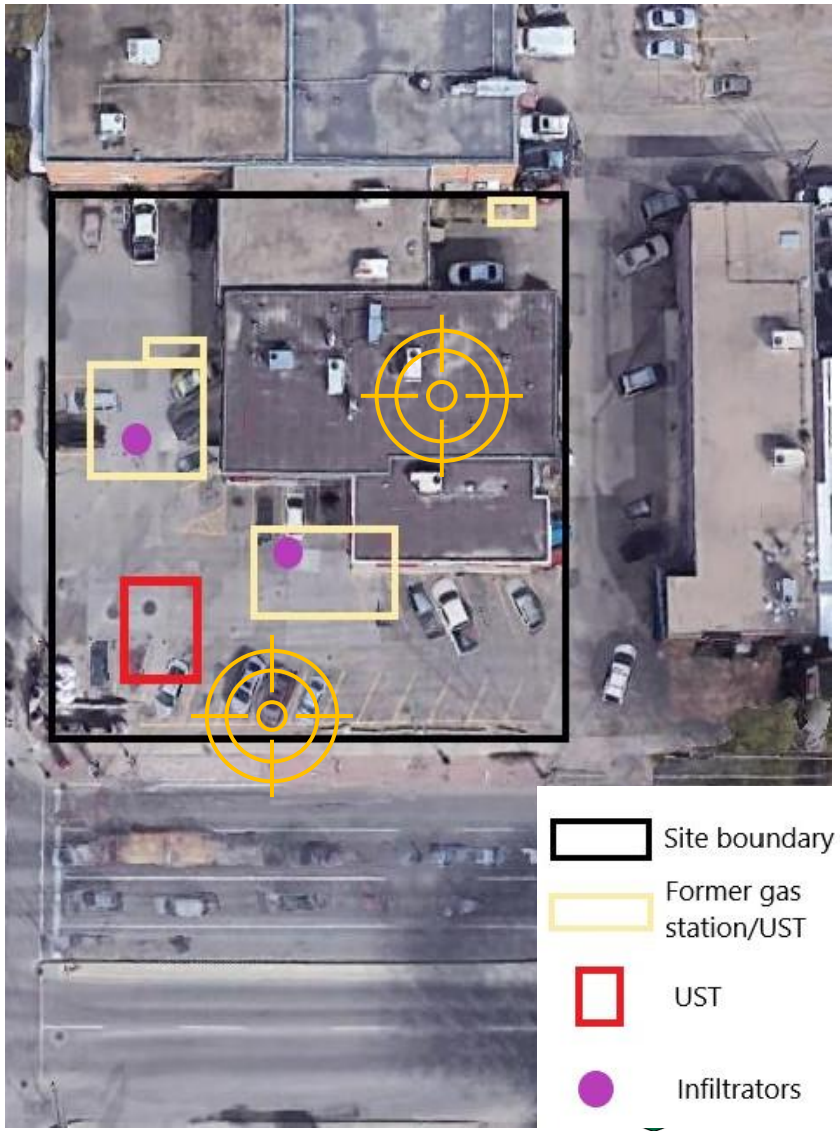
- ✓ **Screen biostimulants before field trials**

WHAT?



- ✓ **Targeted delivery of amendments**

WHERE?



Acknowledgement

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Levi Lundell

Dr. Placid Orji

Dominique Rwizinkindi

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THANKS
Questions & Comments



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