DNAPL Source Zones

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Superfund Basic Research Program
University of Arizona

- Funded and administered by the National Institute of Environmental Health Sciences (NIEHS), an institute of the National Institutes of Health (NIH)

- Hazardous wastes investigated include: arsenic, chlorinated hydrocarbons, and mine tailings contamination

Recent Studies

- Interstate Technology and Regulatory Council. 2002. DNAPL Source Reduction: Facing the Challenge.
- Environmental Protection Agency. 2003. The DNAPL Remediation Challenge: Is There a Case for Source Depletion?
- National Research Council. 2004. Contaminants in the Subsurface: Source Zone Assessment and Remediation.
- Strategic Environmental Research & Development Program. 2006. Reducing the Uncertainty of DNAPL Source Zone Remediation.

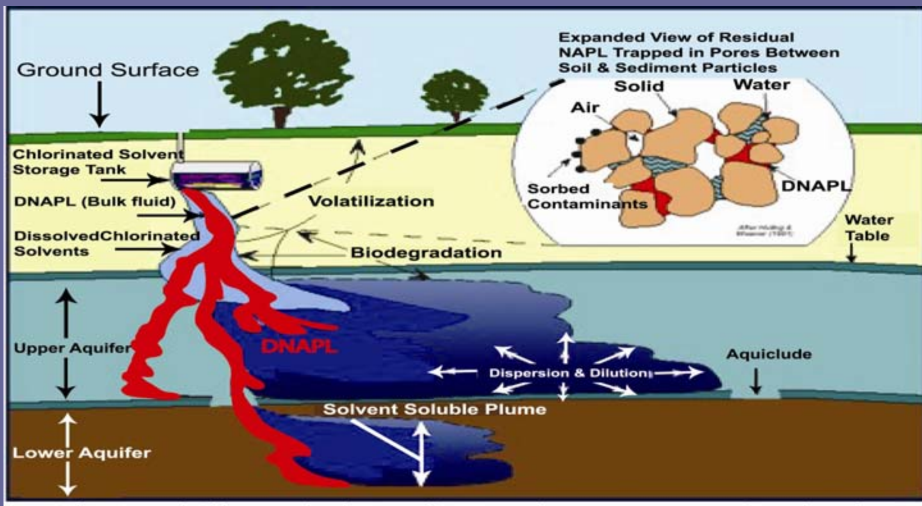
The DNAPL Problem

- Long-term Source of Contamination
- Accurate risk assessment and effective remediation of DNAPL sites requires understanding of source-zone architecture, mass-transfer dynamics, and mass-flux response
- Current Understanding is Insufficient

UA DNAPL Research

- Three Major Aspects:
  - Fundamentals of Source-zone Architectures and Mass-transfer Dynamics
  - Source-zone Characterization Technologies
  - Source-zone Remediation Methods

Source-zone Architecture & Mass-transfer Dynamics

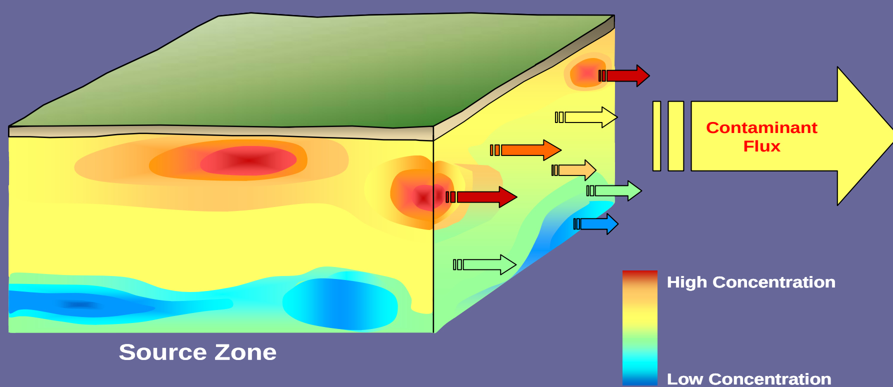


Schematic of Chlorinated solvent pollution as dense non-aqueous phase liquids migrating downward in an aquifer and serving as a source for a solvent soluble plume. Also shown are natural attenuation processes (Modified USEPA 1999).

Source-zone Mass Flux

Input for dissolved-phase groundwater plume

(Which is usually primary risk driver for site)

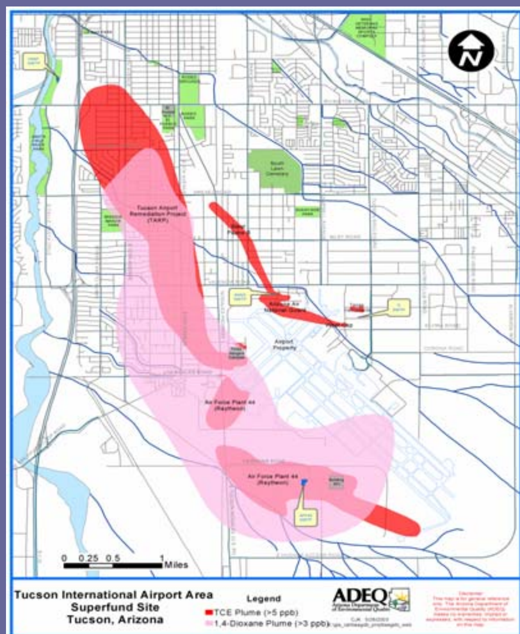


(Figure adapted from EPA)

Field-scale Research: TIAA Study

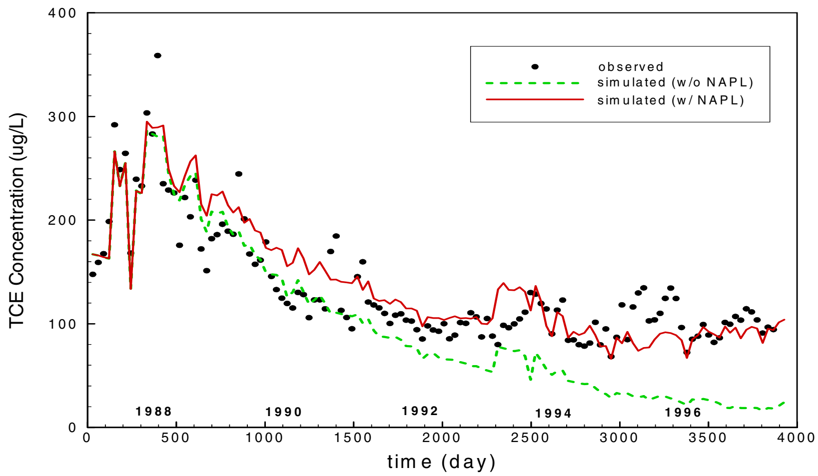
- Site Characterization
  - Source-Zone TCE Mass Flux
  - TCE Spatial Distribution (areal, vertical)
  - DNAPL presence
  - Advective, Diffusive, Dispersive Transport
- Laboratory Experiments--- Mass Transfer Processes
- Mathematical Modeling--- Plume Behavior
- Pilot Source-zone Remediation Projects

TIAA Site



- Site Remediation under Superfund and DOD-IR
- Multiple source zones and PRPs
- 14 years of research at portions of the complex

Contaminant Elution



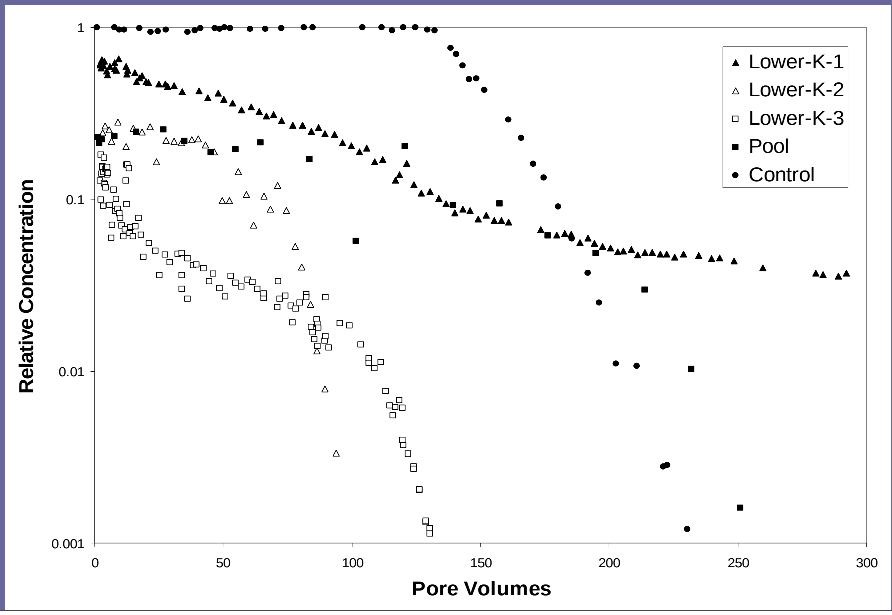
Comparison of the Simulated Influent TCE Conc. at Treatment Plant with the Observed Data

Intermediate-scale Research

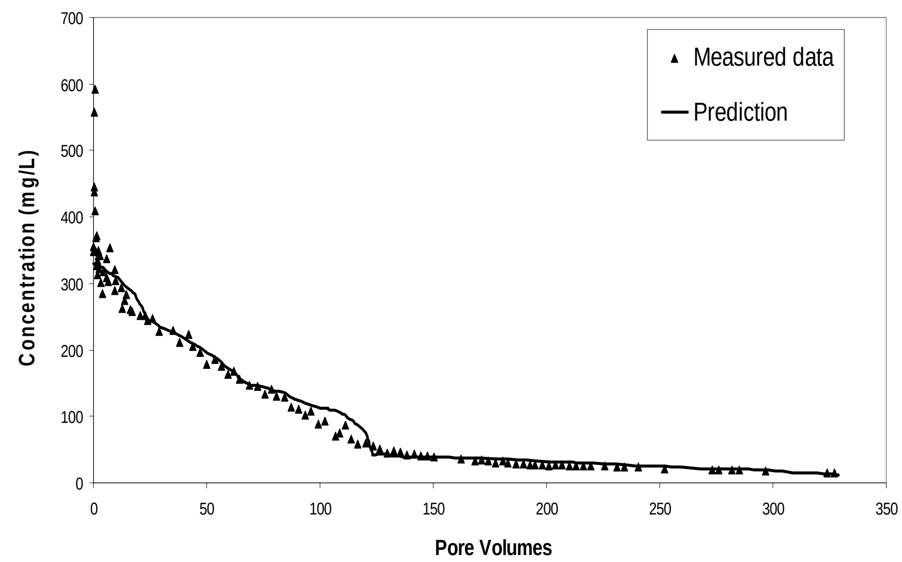
- **Conducted with Flow Cells**
  - Well-defined conditions

- **Develop DNAPL Source Zone**
- **Characterize Architecture**
  (Imaging; Tracer Tests)
- **Water Flush**
  (Monitor Q, C)
- **Simulate w/ Model**

Contaminant Elution: Data



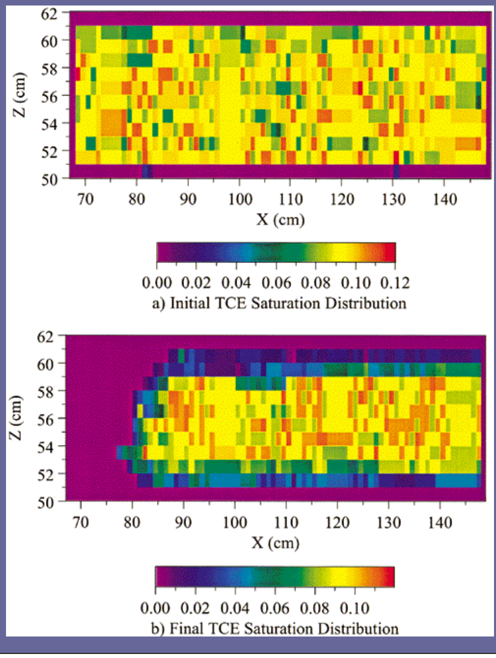
Contaminant Elution: Modeling



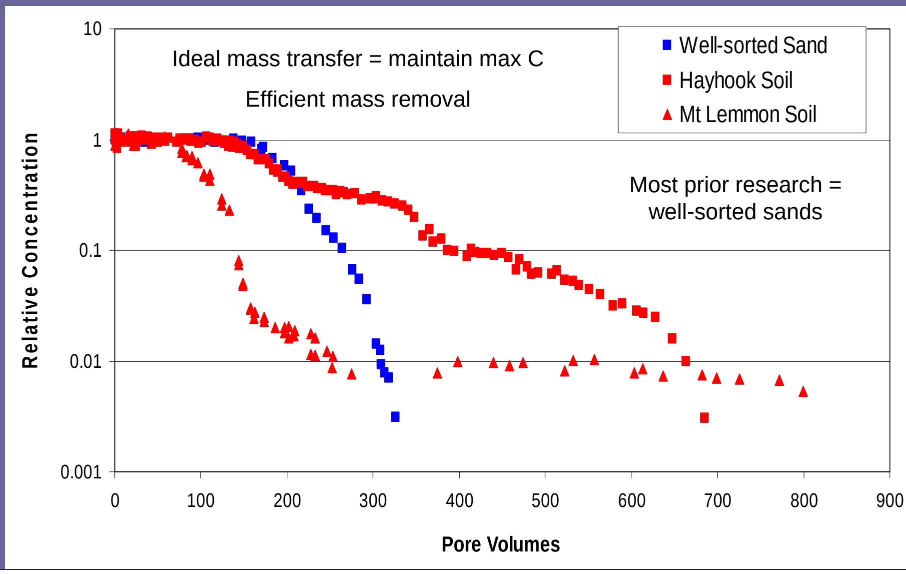
NAPL Distribution

In-situ Measurement of NAPL Saturation

[dual-energy gamma]

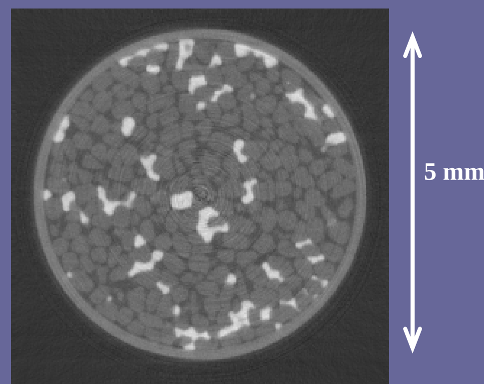


Column-scale Experiments



Pore Scale Research: Synchrotron X-ray microtomography

DOE APS facility

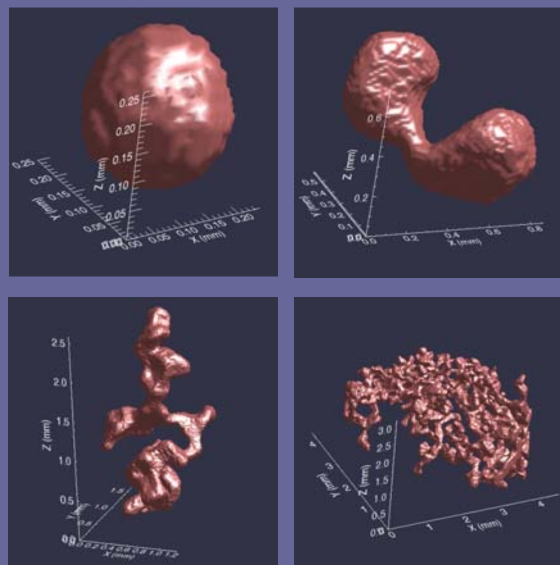


NAPL = white

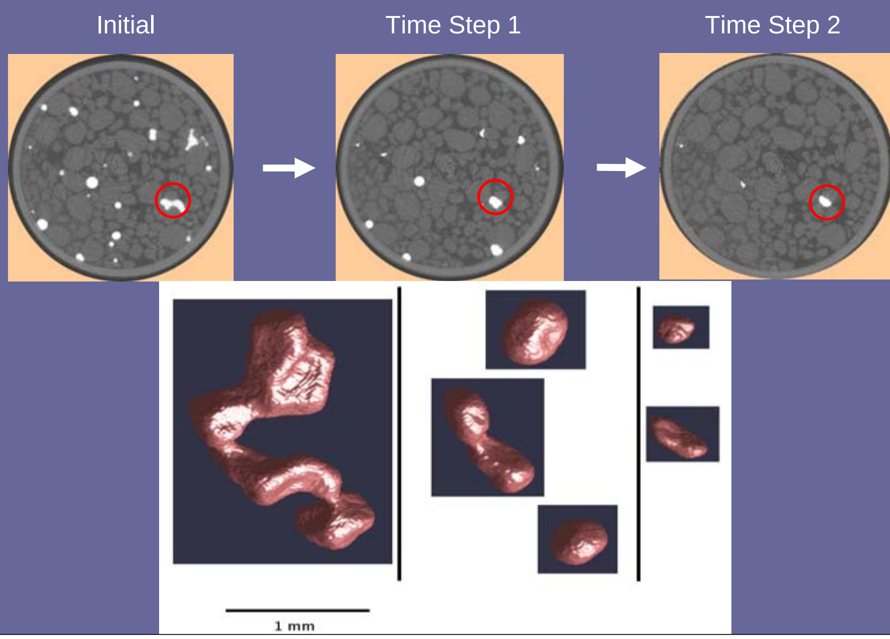
Water = Black

Solid = Gray

NAPL Blob Morphology



NAPL Dissolution Dynamics



Summary: Part 1

- NAPL configuration and flow-field dynamics are key
  - Hydraulic Accessibility of NAPL
- Constraints to full characterization at the field scale
- Need methods for profiling general behavior
  - Up-scaled Modeling
  - MFR-MR Assessment

Source-Zone Remediation

To Remediate or Not To Remediate---
that is the question…

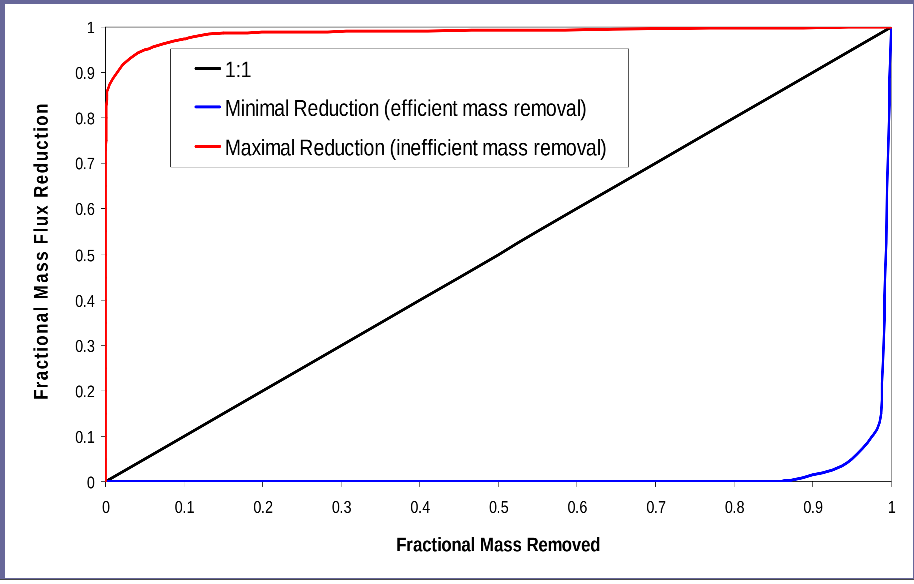
Source-zone Remediation

- Complete Mass Removal Not Possible
- Is Partial Removal [Mass Reduction] Beneficial?
- Need To Define Objectives
- Cost/Benefit Analysis
- Need Metrics

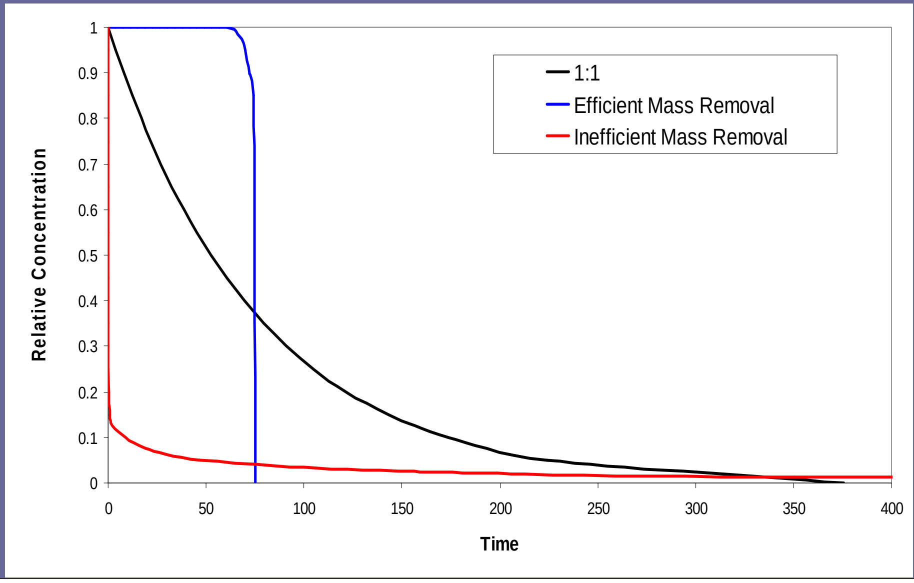
Mass Flux Reduction vs Mass Removal

A key metric for assessing remediation-system effectiveness

MFR-MR Relationship



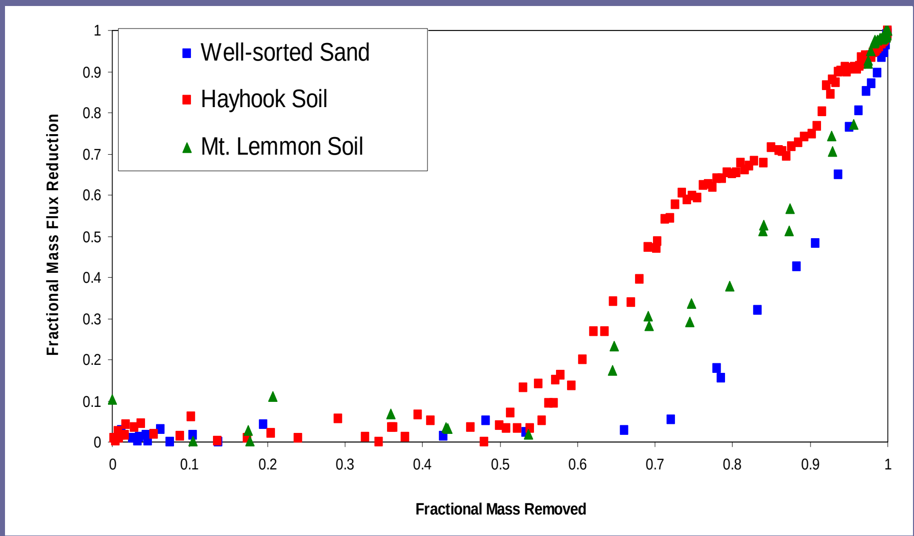
Mass Removal Behavior



Key Questions

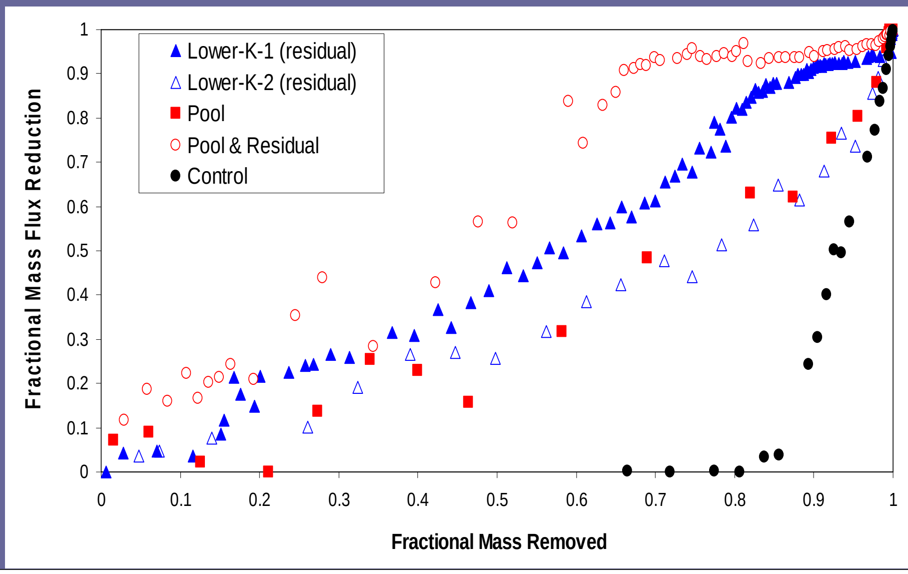
- Expected Degree of Mass Removal?
- Impact of Specified MR on Mass Flux?
- Impact of Mass Flux Reduction on Risk?

Column Data

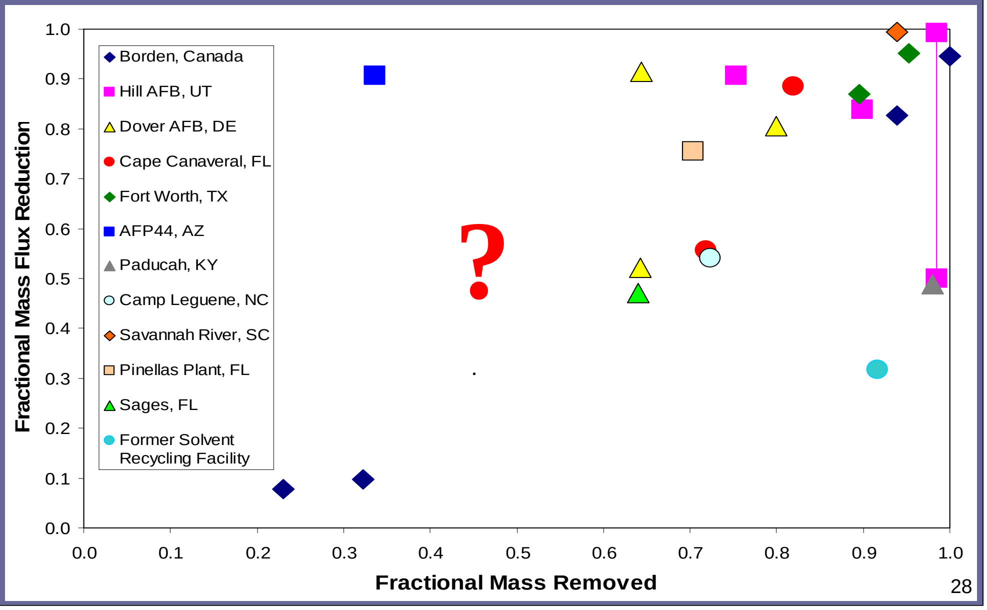


Well-sorted Sand
Hayhook Soil
Mt. Lemmon Soil
Fractional Mass Flux Reduction
Fractional Mass Removed
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

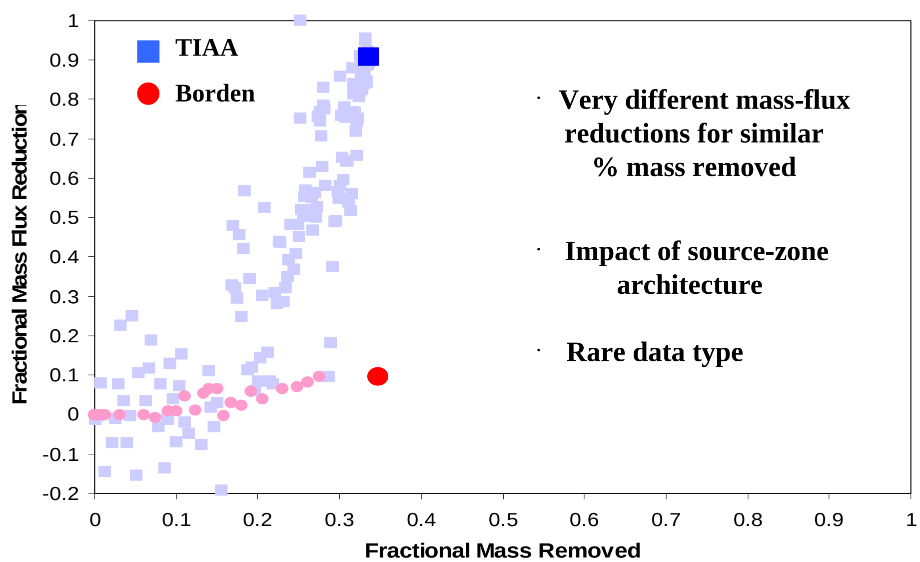
Flow-cell Data



Field Data: End-Point Analysis of MFR-MR



Field Data: Time-Continuous Analysis of MFR-MR



- **Very different mass-flux reductions for similar % mass removed**
- **Impact of source-zone architecture**
- **Rare data type**

Answer

- Need to Understand the Impact of Source-zone Architecture and Mass-transfer Dynamics on Mass Flux Behavior

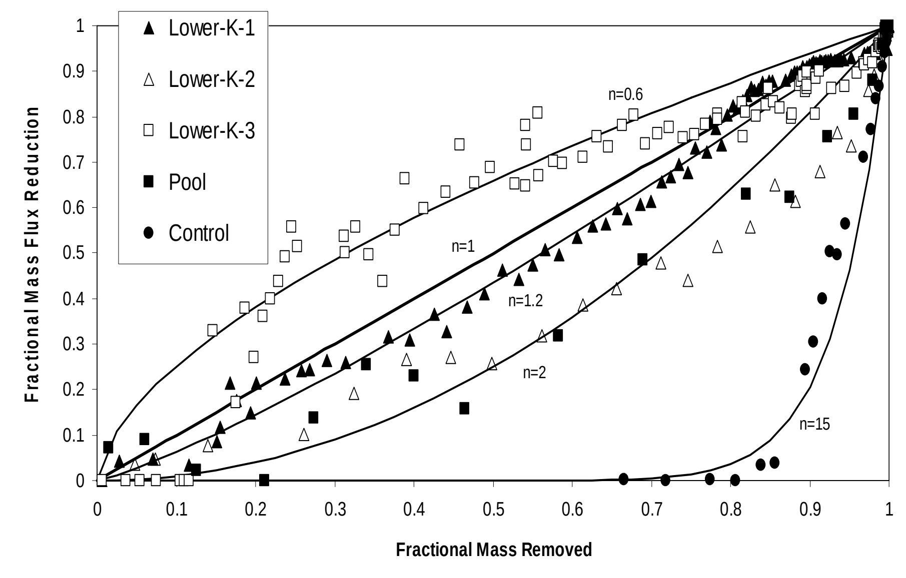
Predicting MFR-MR Relationships

- Simplified Mathematical Modeling

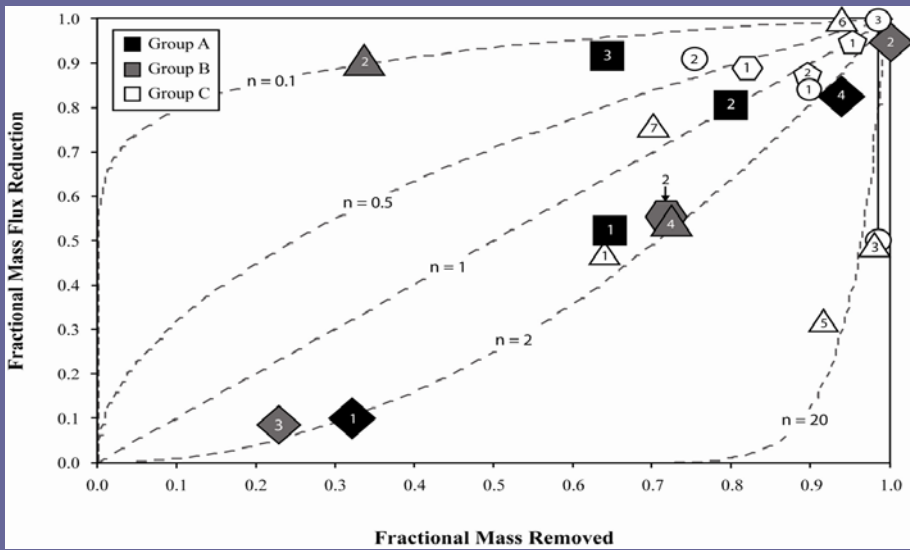
- Systems Indicator Parameters
  - (e.g., Ganglia:Pool Ratio)

- Mass-removal Functions
  - $MFR = MR^n$

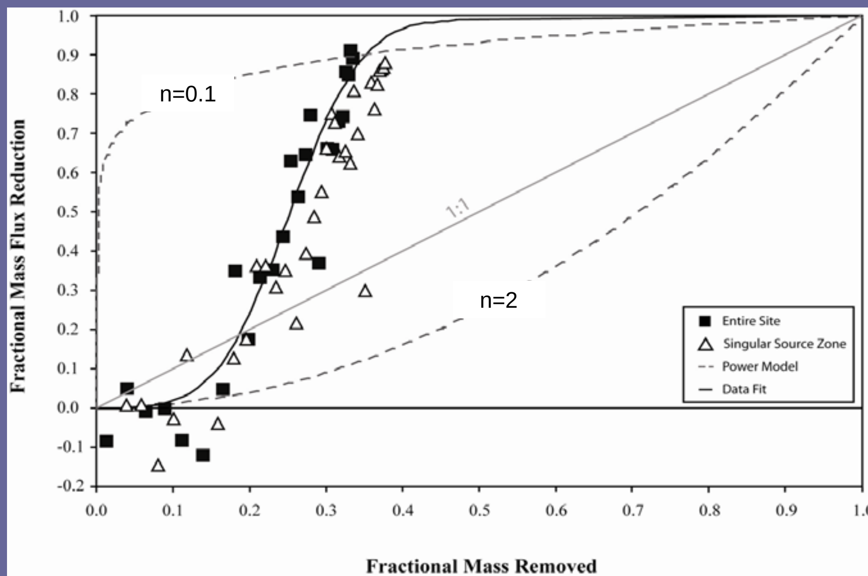
Example: Flow-cell Data



Example: Field Data



Example: TIAA Data



Summary: Part 2

- MFR-MR Relationship Useful for Evaluating Behavior
- How to Predict– need more data
- What Site Information can Support Application

Acknowledgements

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Thank You

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