

# 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.

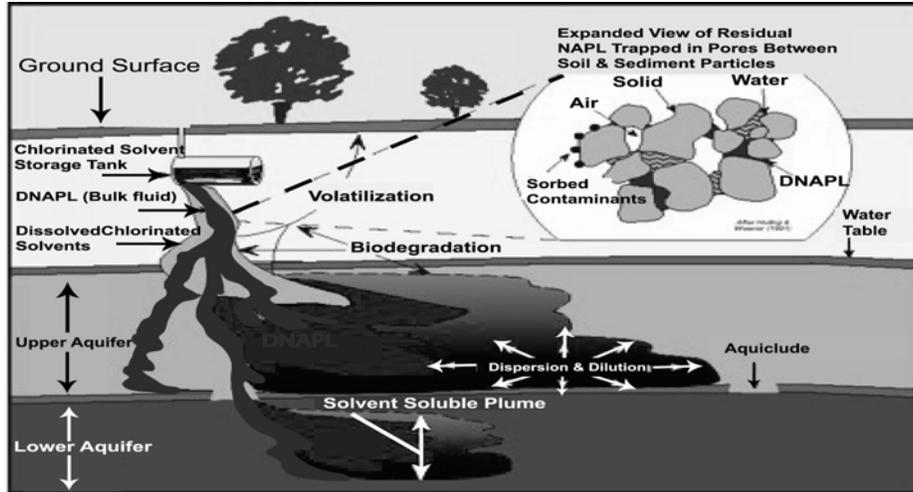
# The DNAPL Problem

- 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

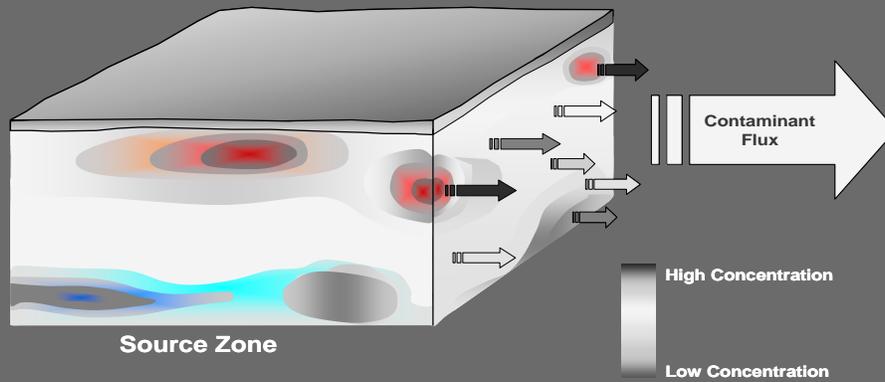


Schematic of Chlorinated solvent pollution as dense non-aqueous phase liquids migrating downward in an aquifer and serving as a source for a solvent soluble plume. Also shown are natural attenuation processes (Modified USEPA 1999).

# Source-zone Mass Flux

Input for dissolved-phase groundwater plume

(Which is usually primary risk driver for site)

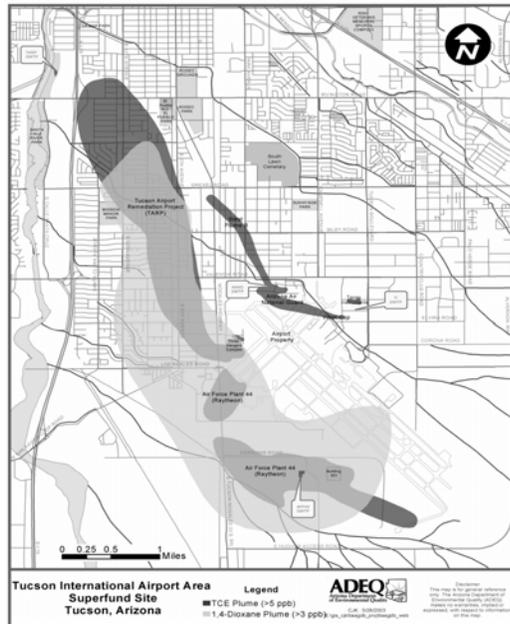


(Figure adapted from EPA)

# 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

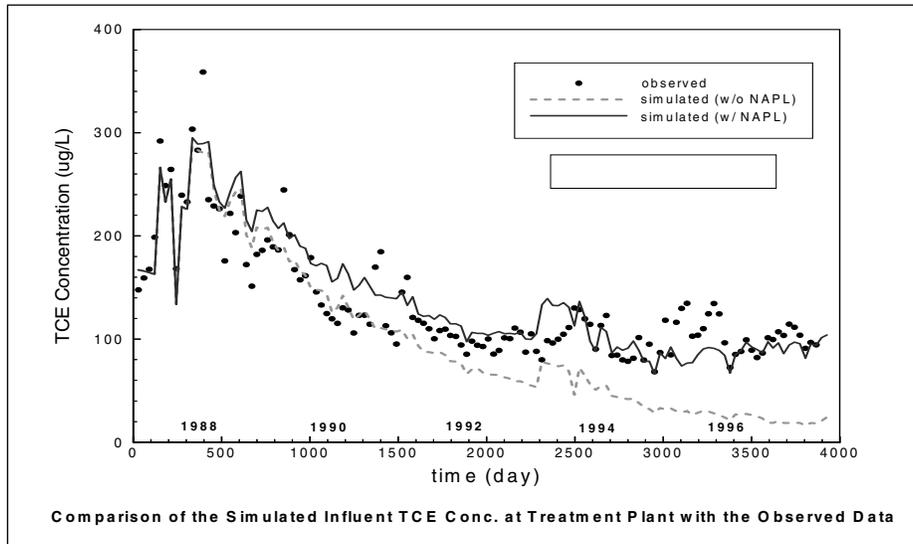


- Site Remediation under Superfund and DOD-IR

- Multiple source zones and PRPs

- 14 years of research at portions of the complex

# Contaminant Elution



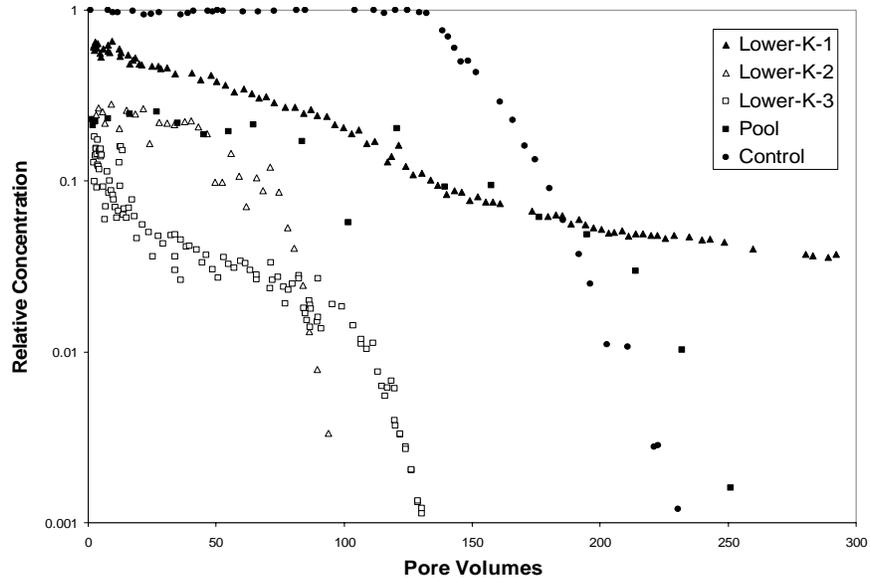
# Intermediate-scale Research

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

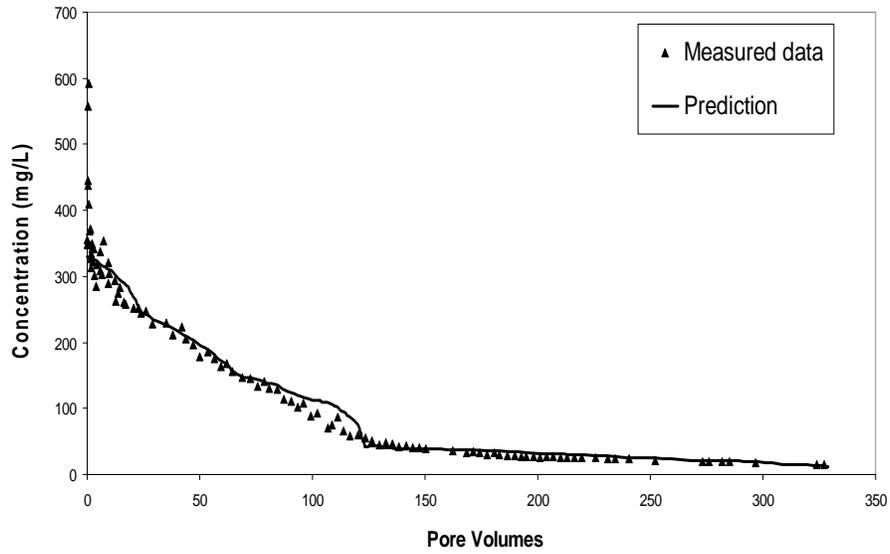


- **Develop DNAPL Source Zone**
- **Characterize Architecture**  
(Imaging; Tracer Tests)
- **Water Flush**  
(Monitor Q, C)
- **Simulate w/ Model**

# Contaminant Elution: Data

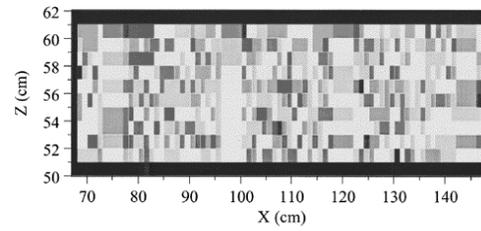


# Contaminant Elution: Modeling

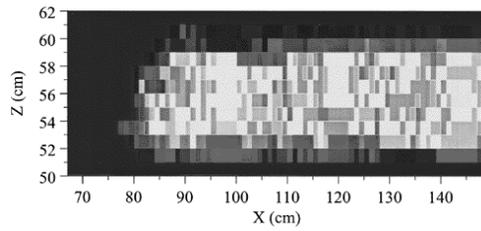


# NAPL Distribution

**In-situ Measurement of  
NAPL Saturation**  
[dual-energy gamma]

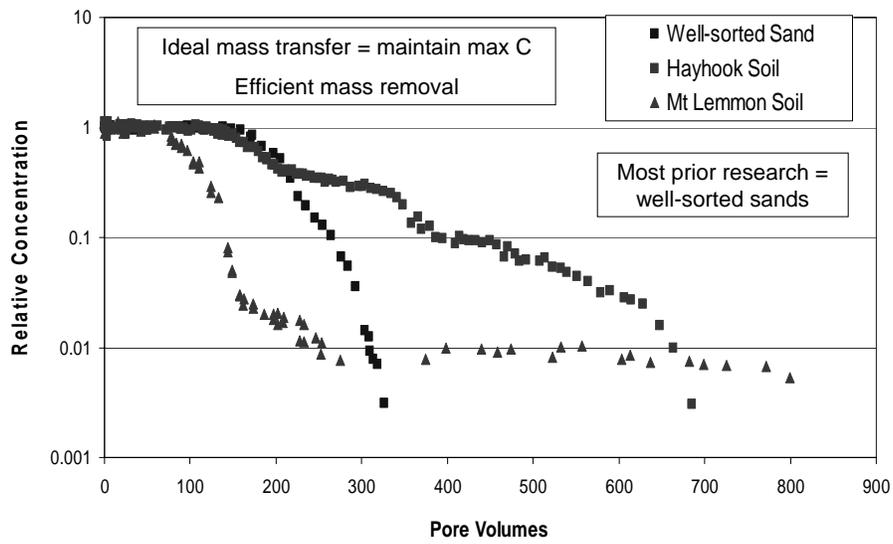


0.00 0.02 0.04 0.06 0.08 0.10 0.12  
a) Initial TCE Saturation Distribution



0.00 0.02 0.04 0.06 0.08 0.10  
b) Final TCE Saturation Distribution

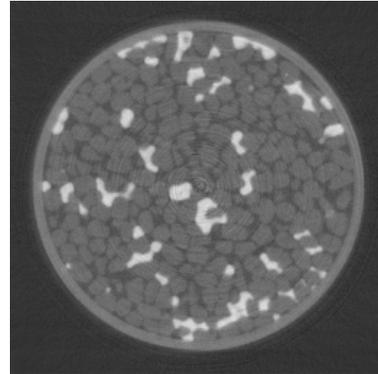
# Column-scale Experiments



# Pore Scale Research: Synchrotron X-ray microtomography

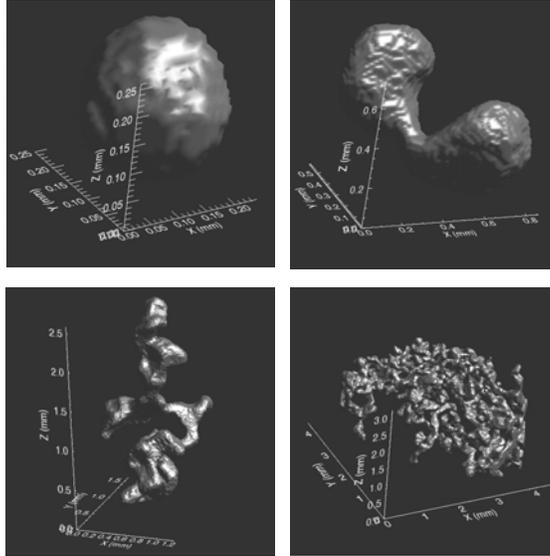


**DOE APS facility**

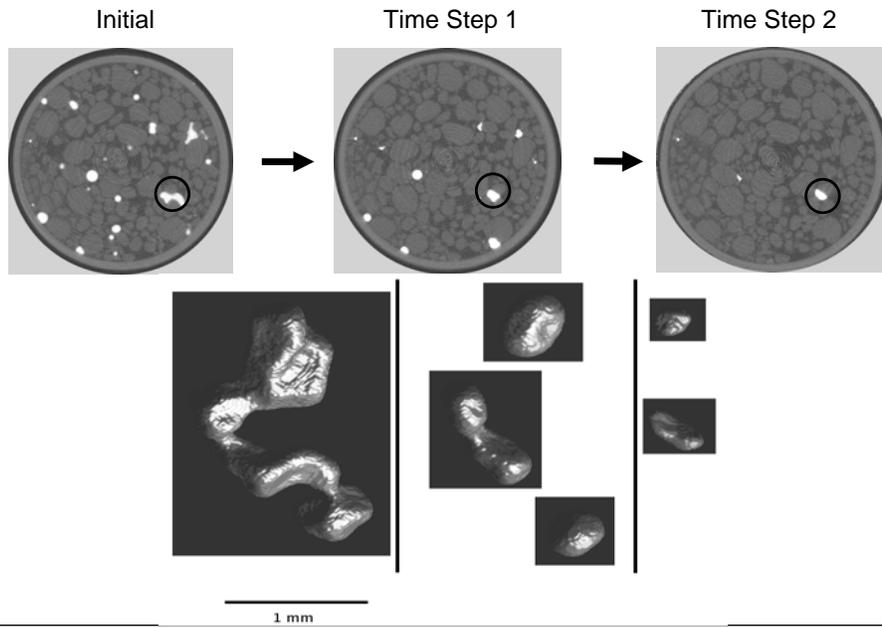


**NAPL = white**  
**Water = Black**  
**Solid = Gray**

# 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...

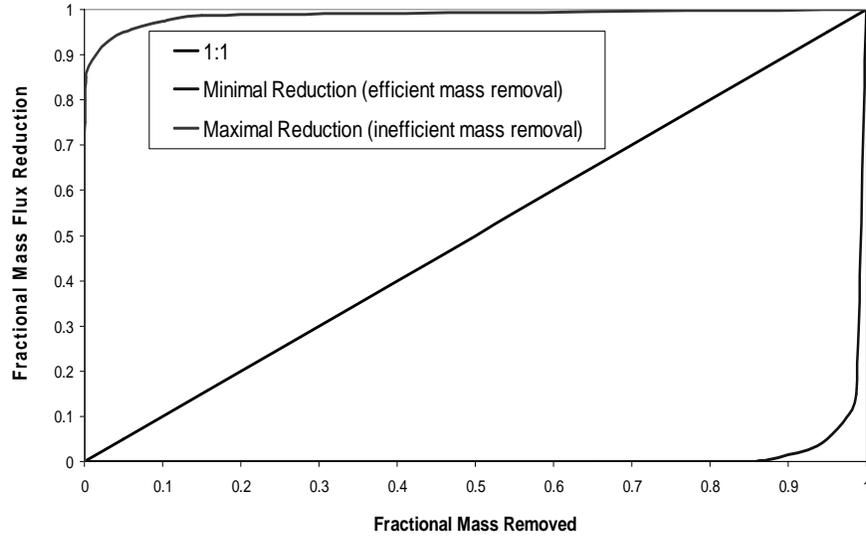
## Source-zone Remediation

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

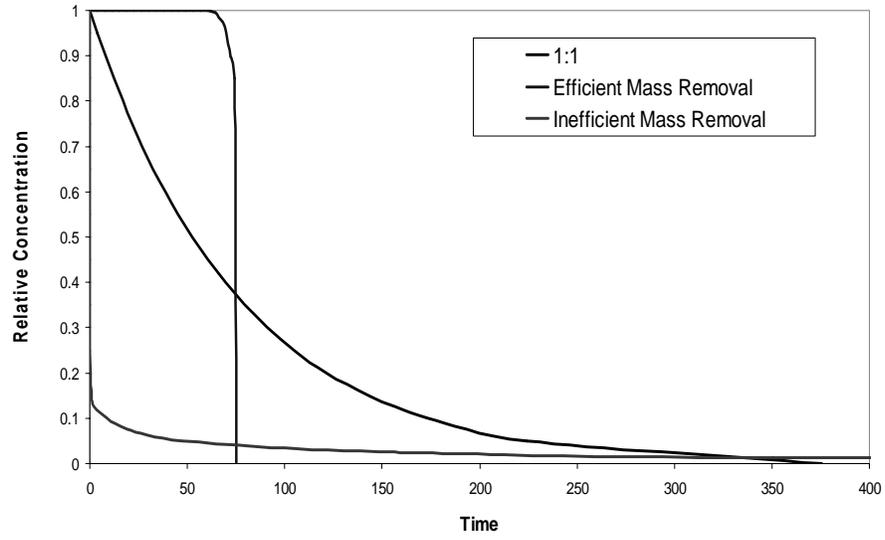
## **Mass Flux Reduction vs Mass Removal**

A key metric for assessing remediation-system effectiveness

# MFR-MR Relationship



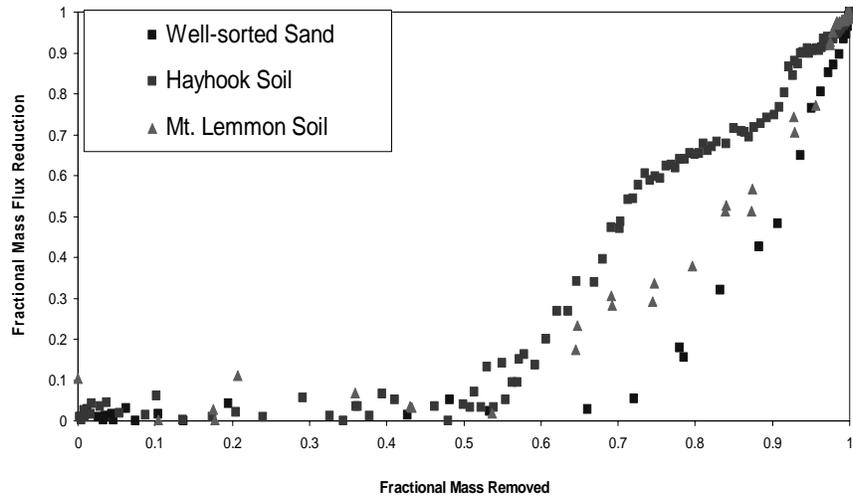
# Mass Removal Behavior



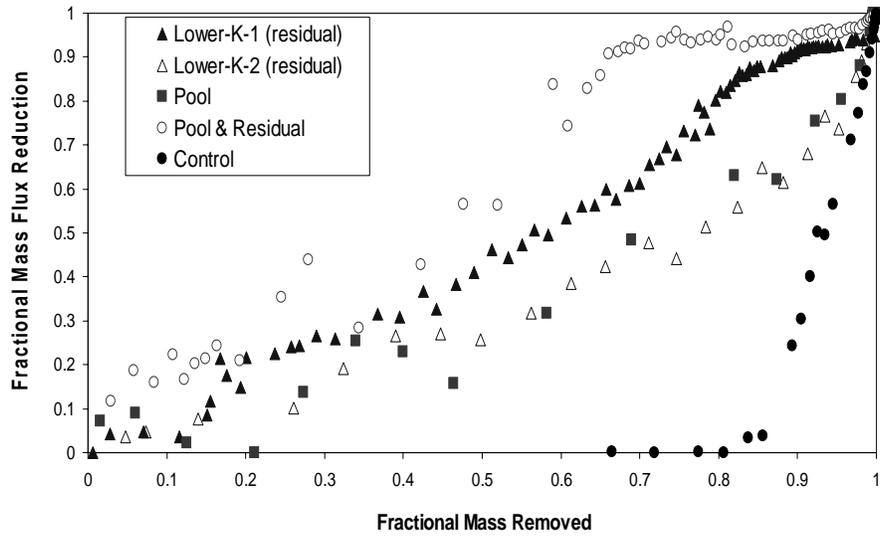
## Key Questions

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

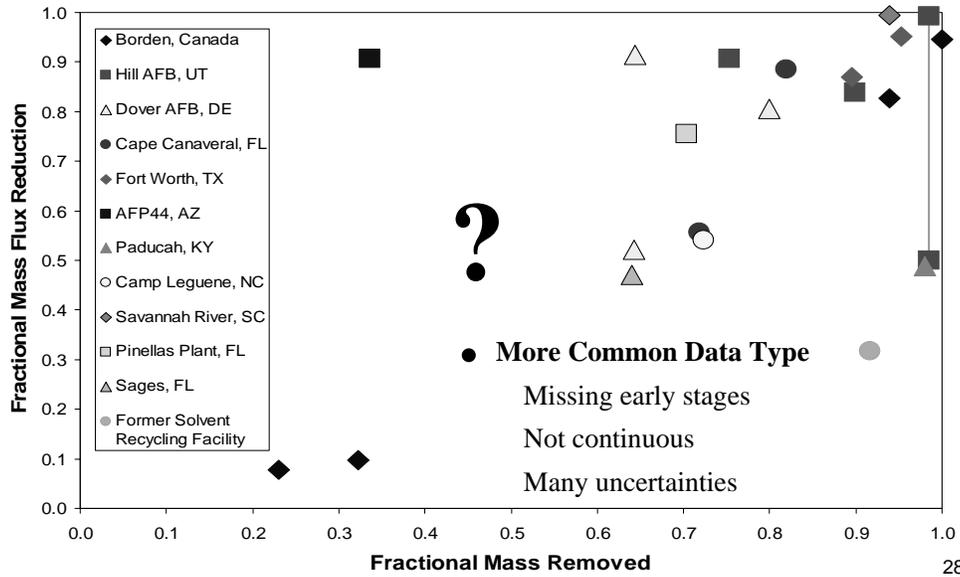
# Column Data



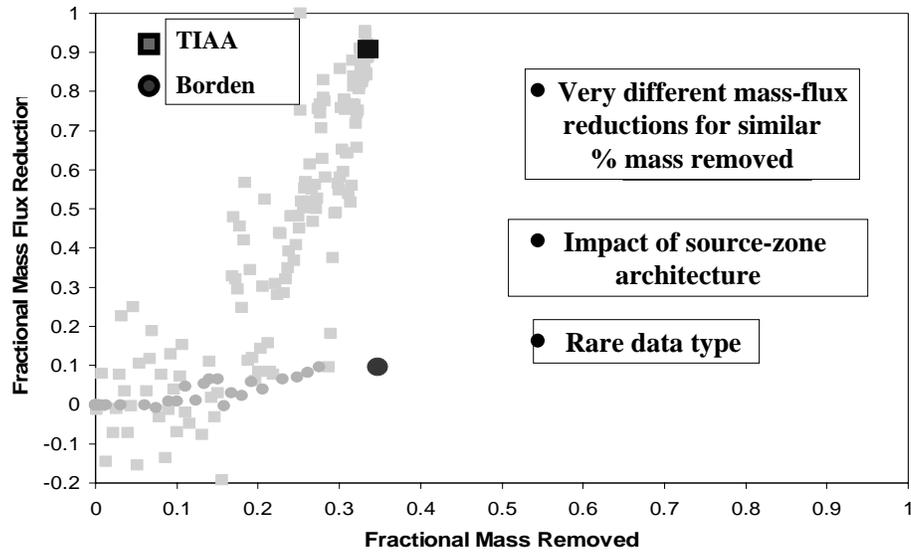
# Flow-cell Data



# Field Data: End-Point Analysis of MFR-MR



## Field Data: Time-Continuous Analysis of MFR-MR



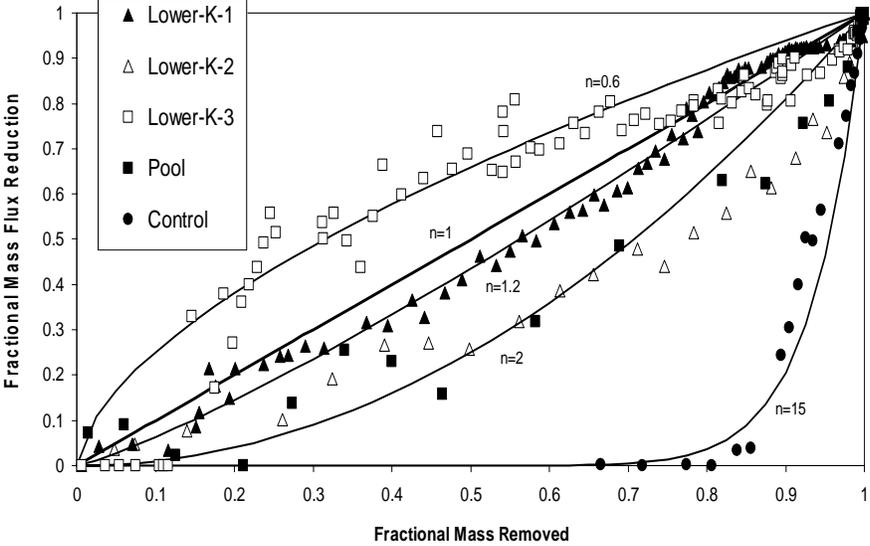
# Answer

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

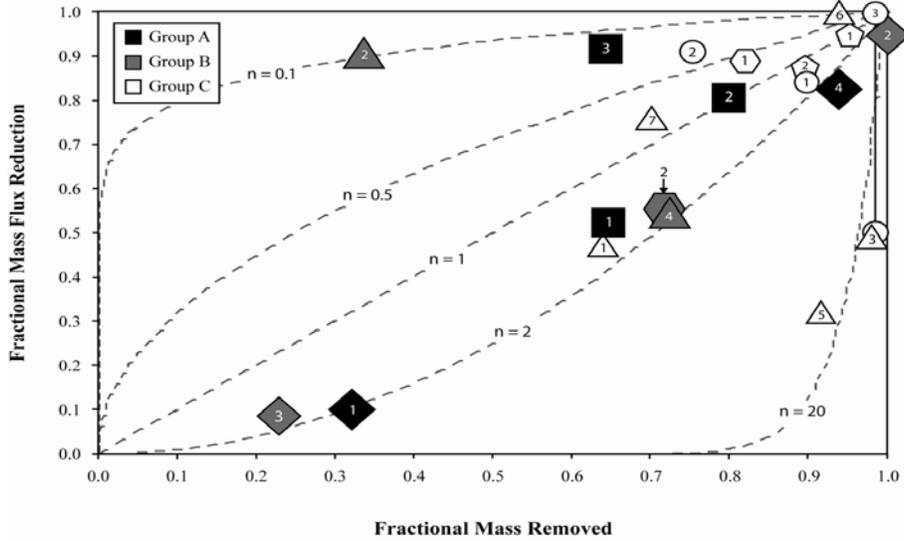
## Predicting MFR-MR Relationships

- Simplified Mathematical Modeling
- Systems Indicator Parameters
  - (e.g., Ganglia:Pool Ratio)
- Mass-removal Functions
  - $MFR = MR^n$

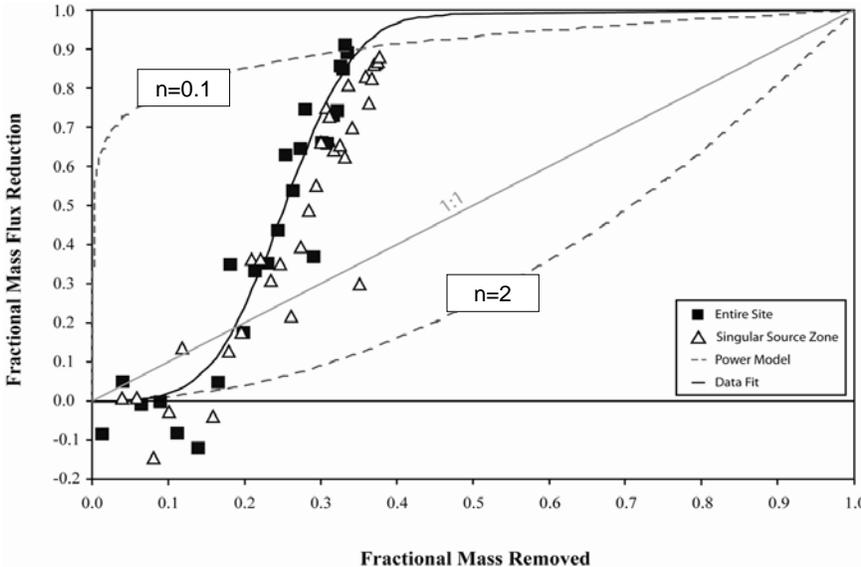
# Example: Flow-cell Data



# 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

- NIEHS SBRP, US Air Force, EPA
- Erica DiFilippo, Justin Marble, Ann Russo, Greg Schnaar, Nicole Nelson, Mart Oostrom

# Thank You

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